AGE AND PALAEOENVIRONMENT OF PLIOCENE SEDIMENTS, CAMERON INLET FORMATION, EASTERN FLINDERS ISLAND, TASMANIA: IMPLICATIONS FOR SOUTHEASTERN AUSTRALIAN BIOSTRATIGRAPHY

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(with seven text-figures, four plates, one appendix and one appendix table)

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A previously unrecorded thin unit of very Early Pliocene calcareous sediments of the Cameron Inlet Formation from two auger holes in central Flinders Island, Tasmania, has yielded a very diverse fauna of benthic Foraminifera and enough planktonic forms to allow fine cor-relation with international biostratigraphic standards (N19, approximately 5.3–4.4 Ma, or Lower Opoitian in New Zealand terminology). Ostracods are also recorded. It is older than an earlier recorded sample from North Patriarch Drain a few kilometres away. It lies within the Kalimnan of southeastern Australian stage nomenclature and probably equivalent to 1985 Molluscan Assemblage XVI. The sediments and faunas accumulated in very shallow, fully marine conditions, initially with some possible estuarine aspect that faded with time. The fauna is of well-known species, dominated by *Parredicta kalimnensis* (Parr, 1939). Other abundant and diverse forms are elphidiids and cibicidids. Agglutinated forms are almost absent and miliolids are diverse but minor components. The fauna includes a new polymorphinid genus and species that will be described elsewhere. The samples contain a bewildering array of unilocular forms. Water temperature appears to have been about 12°C. The Kalimnan Stage may encompass the entire Pliocene and two substages may be identifiable.

Key Words: Pliocene, Flinders Island, Foraminifera, ostracods, Cameron Inlet Formation, Kalimnan.

INTRODUCTION

The Pliocene was a very significant time in global history resulting in major re-organisation of the world's oceanographic circulation and its consequences. The emergence of the Isthmus of Panama halted the flow of marine waters from the Atlantic Ocean to the Pacific Ocean (Haug *et al.* 2001, Schmidt 2007, Sarnthein *et al.* 2009), in turn strengthening the flow of the Gulf Stream to the north and causing initiation of the sequence of oscillating northern hemisphere ice sheets controlled in detail by orbital forcing – the Milankovich cycles. There is evidence of major extinctions and radiations in the marine environment at some time approximately in the Late Miocene to mid-Pliocene (Berkman & Prentice 1996, Bargelloni *et al.* 1997, Fordyce & de Muizon 2001, Fordyce *et al.* 2002, Fulton & Strobeck 2010, Chen *et al.* 2011), and subsequent effects worldwide, typified by the hypothesis of an impact on aridification in east Africa (Cane & Molnar 2001) but there is scope for considerable improvement in the understanding of the scale and timing of these changes. It is not clear how directly these changes affected oceanography in southeastern Australia. Much of this change occurred during the time of deposition of sedimentary successions recorded in this paper.

Flinders Island (fig. 1A–C) contains as yet poorly understood marine Pliocene sediments that contribute to our knowledge of the evolution of biostratigraphy and palaeoenvionment of southeastern Australia during this critical time. The island is 65 km long (N–S), 40 km wide (E–W) and 1333 km^2 in surface area, in eastern Bass Strait on the shallow continental shelf between southeastern Australia and the mainland of Tasmania (fig. 1A). It is the largest island of the Furneaux Group in Bass Strait, the exposed part of the Bassian Rise between Bass Basin to the west and Gippsland Basin to the east (e.g., Thompson 1986). On the western half of the island, Ordovician-Devonian sedimentary rocks of the Mathinna Supergroup (fig. 1B) are intruded by Devonian granitic rocks and form an elevated ridge ≤ 756 m in altitude. On the eastern half of the island are granitic hills (Patriarchs), isolated from the main western ridge and surrounded by coastal plain that consists of marine sediments of Pliocene and Pleistocene age, largely overlain by Quaternary lagoon sediments, alluvium and soils. Early Miocene basalt outcrops (20 ± 2.7 Ma; Zwingmann *et al.* 2004) in the south of the island and marks the southwestern extent of Cenozoic sediments. Magnetic data suggest that basalt underlies much of the Pliocene and younger sedimentary sequence on the eastern part of the island (J. Everard pers. comm. 29 May 2013). The Pliocene sediments belong to the Dutchman Coquinoid Limestone, and the Cameron Inlet Formation (CIF) that occur up to 32 m altitude and are presumed to cover an area of ~150 km^2. There is little or no sub-aerial outcrop and the formations are normally exposed in farm dams, agricultural drainage trenches, and in underwater outcrops to the east of the island. It is perhaps convenient to consider the marine Neogene sequence of eastern Flinders Island, studied here, as marking the southwestern onshore margin of the marine Cenozoic section of the Gippsland Basin (Maung & Nicholas 1990).

This study revises the sedimentology, lithostratigraphy and foraminiferal biostratigraphy of the CIF based on a recently sampled section of age older than recorded previously. The sections studied are rich in microfossils and the Foraminifera and ostracods provide ample evidence for the age and environment of deposition of this material using quantitative foraminiferal and ostracod data.

PREVIOUS STUDIES

The earliest records of Pliocene sediments on the island were probably by Johnston (1879), who referred to deposits on several islands in the area, and Singleton (1941) who listed them from ?Wingaroo Bore (fig. 1B).

R.W.T. Wilkins (quoted p. 235 in Spry & Banks 1962, and Sutherland & Kershaw 1971) stated that: "On the eastern side of Flinders Island are two formations of probably post-Kalimnan, pre-Maretimo age. Kalimnan is Lower Pliocene and the Maretimo Member in Victoria is probably uppermost Pliocene. The formations contain suites of mollusca [sic], and appear to be approximate lateral equivalents. … The Cameron Inlet Marl is a green, glauconitic, shelly marl outcropping in the floor of the Nelson Lagoon drain". The two formations are the Cameron Inlet Marl and the Dutchman Coquinoid Limestone. Wilkins further suggested a mid to Late Pliocene age on the basis of the molluscan fauna and thus probably post-Kalimnan, pre-Maretimo age, while noting that the molluscs "have a very strong Kalimnan aspect". That report can be interpreted as allowing the possibility of two distinct units with different molluscan (and, by extension, foraminiferal) faunas. Darragh 1971 (in Sutherland & Kershaw 1971) listed molluscs from strata that belong to the two formations and the faunas are different, consistent with the foraminiferal data generated here. The Pliocene units are overlain by various other, younger, stratigraphic units. In the North Patriarch Drain section, they are the Memana Formation and Petibela Sand (Dimmock 1957) (fig. 2). The Memana Formation is marine and possibly of Lower Pleistocene (Werrikooian) age on the basis of its mollusc fauna, and the widespread Petibela Sand is non-marine.

The Cenozoic geology of the island was reviewed by Sutherland & Kershaw (1971) who showed that the late Cenozoic stratigraphy is complex, marking a variety of advances and retreats of the sea generating a series of thin units both marine and non-marine, and leading to recycling of molluscs and possibly Foraminifera from marine into non-marine sediments. There is, to date, no record of Cenozoic marine sediments older than the Pliocene on the island but Sutherland & Kershaw (1971) referred to possible records of recycled older Foraminifera and Miocene faunas recorded from nearby Preservation Island (Quilty 1972). Sutherland & Kershaw (1971) discussed each of the known stratigraphic units and provided the understanding of the geology of the island as then, and now, known with a comprehensive list of the molluscs from various units including the CIF. They also noted a few species of Foraminifera and commented

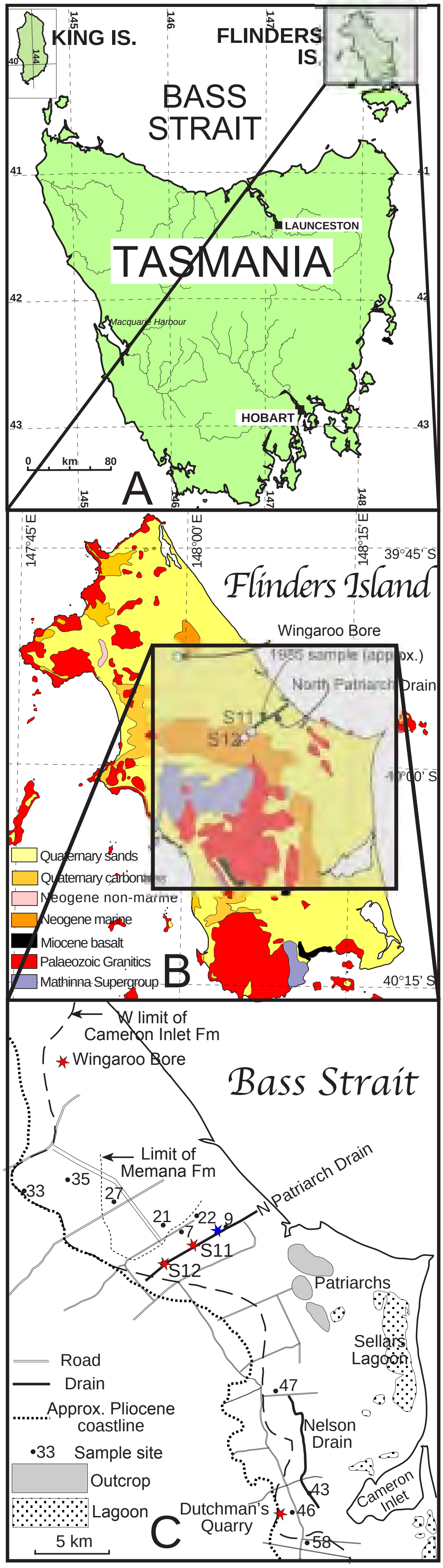

FIG. 1 — *Locality map. Sections studied in detail are from North Patriarch Drain (1985), S11 and S12. (A) General locality map. (B, C) Details of sample sites mentioned in text. Red stars indicate important sites. Blue star – North Patriarch Drain (1985).*

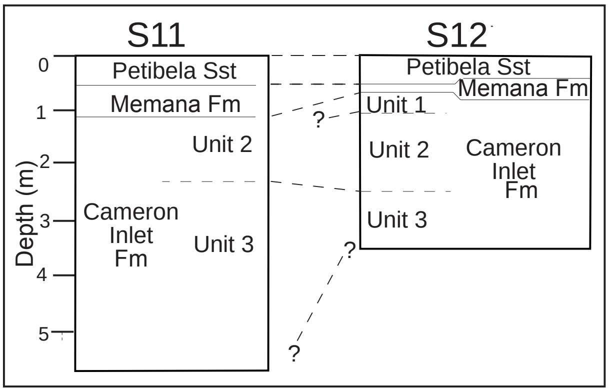

FIG. 2.— Lithostratigraphy of sections S11 and S12

that it accumulated in a shallow-water, nearshore but open ocean environment. They showed that the thickness may exceed 7.5 m.

Quilty (1985) recorded a fauna from a single sample from the North Patriarch Drain on Flinders Island (fig. 1C), about 2 km from the location of the sections studied here. It is referred to here as NPD1985. The presence of *Globorotalia inflata* (d'Orbigny, 1839), *G. crassaformis* (Galloway & Wissler, 1927), *Globigerina bulloides* d'Orbigny, 1826 and *G. rubescens decoraperta* Takayanagi & Saito, 1962 allowed correlation with the Blow (1969) N20 or N21 planktonic foraminiferal zones indicating a mid- to Late Pliocene age. However, the mollusc biostratigraphy was revised and the age constrained to the Late Pliocene (Darragh 1985). Amino acid racemisation dating of molluscs provided relative age results younger than anticipated for the Pliocene. This is thought to be due to *in situ* leaching of the molluscs (Murray-Wallace & Goede 1995). While many of the major species of Foraminifera are in common with the sections studied here, the lesser species, while diverse, are very different, reflecting marked environmentally controlled differences. In the sample recorded by Quilty (1985), using the concepts introduced by Walton (1964), dominance was much lower (7.5%), diversity higher (60) and planktonic percentage much higher at 29% than in samples of this study, all suggestive of significantly deeper water deposition (approximately inner-mid-continental shelf) in marked contrast with the very shallow water indications of the present study.

Palaeotemperature reconstructions from isotope measurements of *Ostrea* sp. shells from Dutchman's Quarry (fig. 1C) imply that the Pliocene annual mean sea surface temperature around Flinders Island was 16.5°C (Dorman 1966), one degree warmer than current (15.6°C). The Dutchman's Quarry and Nelson Drain outcrops were correlated through similarities in mollusc faunas and the strata renamed the Cameron Inlet Formation (Darragh & Kendrick 1971).

STRATIGRAPHIC SETTING

The CIF was described initially from outcrops in the Dutchman's Quarry (i.e., Dutchman Coquinoid Limestone) and Nelson Drain (i.e., Cameron Inlet Marl), where its lithology varies from glauconitic calcareous sand, silt, gravel, shell coquina and marl (Wilkins 1962) (fig. 2). Sutherland & Kershaw (1971) mapped the extent of the Formation and described a 0.6-m-thick type section at Nelson Drain (fig. 1C) consisting of green glauconitic shelly marl that contains different mollusc horizons. Other sections include 0.8 km north of East River (0.52 m thick), Dutchman's Quarry (1.2 m), and Wingaroo Bore (~7 m; 17–24 m below ground surface). North of East River, the exposed portion of the formation consists of a lowermost 15 cm shelly sand bed (Unit d), overlain by 30 cm sand bed (Unit e), and a 7.5-cm-thick fossiliferous green glauconitic marl (Unit f) (Sutherland & Kershaw 1971). Similar units were also identified at the Dutchman's Quarry, but contained more silt, and were thought to be deeper water deposits. The Cameron Inlet Marl (Unit f) appears to correlate laterally throughout the above outcrops. At the Wingaroo Bore location the CIF consists of fossiliferous sand and muddy sand deposited in a semi-sheltered bay. A mid- to Late Pliocene age was assigned to the formation based upon the presence of the fossil echinoid *Lovenia* sp. and the bivalve *Cucullaea* sp. The mollusc fauna suggests that some facies have been deposited in a lagoon or nearshore marine environment. Some sediment horizons contain broken mollusc fossils, suggesting some re-working in shallow water, and eroded and bored shells, indicating some aerial exposure. However, the moderate percentage of planktonic to benthic Foraminifera in NPD1985 relates to a period of deposition in a deeper, inner continental shelf environment (Taylor 1971 in Sutherland & Kershaw 1971). Other fossils found in the CIF include corals, whale vertebrae, a whale skull of a form of the genus *Ziphius*, and fish teeth including those of the large shark *Carcharodon megalodon* Agassiz, 1843 (Sutherland & Kershaw 1971, Fordyce 1982).

Early Pleistocene marine sediments of the Memana Formation overlie the CIF in the northeastern region of the coastal plain (Sutherland & Kershaw 1971). The Memana Formation was distinguished from the CIF by the presence of the mollusc *Zenatiopsis ultima* (Darragh & Kendrick, 1971). Some reworked Pliocene shells from the CIF also occur in the basal member of the Memana Formation. Pleistocene fossiliferous marine sediments of the East River Coquina (Sutherland & Kershaw 1971) overlie the eastern extent of the CIF. The few natural exposures of these marine sediments of different age are due to an overlying cover of Pleistocene sands (Nala and Petibela Sands), aeolian limestones (Palana Limestone) and Quaternary to Recent lagoon deposits.

The Petibela Sand has been documented previously as aeolian in origin (Sutherland & Kershaw 1971); however, at Site S12 (fig. 1), what could perhaps be interpreted as the Petibela Sand overlying of the CIF, contains a bed of molluscs (*Katelysia* sp.) that were deposited during a marine incursion in the Pleistocene. The mollusc valves have been separated and oriented with their concave inner surfaces facing downward, as a result of past water current or wave action. The molluscs indicate that this may belong to the Upper Pleistocene East River Coquina, which outcrops in Nelson Drain area ~12 km farther south (fig. 1C). A sand bed beneath the *Katelysia* sp. bed overlies the CIF to the northwest. The Petibela Sand may in turn overly the East River Coquina.

Three units (3, 2 and 1) are recognisable within the CIF (figs 2, 5). Lithology coarsens upwards from Unit 3 to Unit 2 (which may represent a regressive sea level sequence or a change to shallower basin conditions due to sediment infilling) but these units are overlain by Unit 1 of marl representing deposition in quiet waters. This facies succession corresponds with a transition from a shallow open marine (Unit 3) through shallower conditions or sand bar development (Unit 2) to quiet coastal lagoon or deeper water conditions (Unit 1). There is virtually no change in planktonic Foraminifera from Unit 3 to shallow Units 2 and 1. Whale fossil remains appear to be more prevalent within Unit 3. Sutherland & Kershaw (1971) described a coarser facies variation within Unit 1 to the northwest and have interpreted this as representing a littoral inshore environment in contrast to deeper depositional conditions to the east.

New fieldwork shows that the CIF contains abundant *Ostrea* sp. (at Sites 33, 32 and 27; fig. 1C), and *Glycymeris* sp. (Sites 35, 30A, 30B, 30C and 16A). *In situ* and articulated *Ostrea* sp. occurs at Site 33 (elevation 32 m). Sites 35 and 32 appear more diverse in mollusc species than other sites from the northwestern extent of the formation. This region of the formation typically lacks *Eucrassatella* sp. and *Cucullaea* sp. that are abundant elsewhere on the island within fossiliferous marl exposures. Only an individual reworked *Eucrassatella* sp. hinge was found at Site 27. Augers were attempted at other sites but were unsuccessful due to the presence of impenetrable coarse shell horizons (Sites 32, 30B and 15) or lithified coarse sand layers (Sites 27 and 16a). The occurrence of *Amoria undulata* (Lamarck, 1804) and *Polinices* aff. *cunninghamensis* at these sites suggests that these strata belong to the CIF and are not part of the nearby Pleistocene Memana Formation. The Memana Formation is absent at Site 9 due to a disconformity but is typically overlain by Petibela Sand (Sutherland & Kershaw 1971). The northwestern region of the CIF is generally overlain by a grey sand unit which, in turn, is overlain by Lower Pleistocene Palana Limestone.

MATERIAL AND METHODS

Post-1970 pastoral expansion with dam and drain construction, has increased the exposed extent of the CIF a few kilometres farther north of that mapped by Sutherland & Kershaw (1971). Field identification of the formation in this region was possible from the presence of *in situ* and articulated, or abundant, Pliocene mollusc fossils, as in Sutherland & Kershaw (1971).

Lithological data were collected in a west to east transect over the northern extent of the CIF at Sites 11, 12 and 22, from which three lithological units can be identified (fig. 2).

Unit 1 (upper unit): Calcareous glauconitic green to grey sandy marl. This lithified to semi-lithified unit typically contains *in situ* articulated molluscs. The unit is ~50 cm thick.

Unit 2 (middle unit): A grey, tan or brown unlithified, dominantly of shell fragments, and crystal quartz sand. The unit is ~120 cm thick.

Unit 3 (lower unit): Grey sandy silt with occasional shell fragments or shell layers. The unit is ~290 cm thick.

Samples were taken in 5 cm bulk intervals through the exposed sections for microfossil analysis. At several locations sub-surface sediments were also obtained using a hand auger to obtain samples from a depth of ~4 m. Exposure and auger samples were collected from Sites 12, 11 and 9, in an east–west transect across the formation. The outer edge of the auger samples was removed to avoid any microfossil re-working during the augering process. The lithology was logged and again the samples divided into 5-cm-long intervals for microfossil analysis.

Foraminifera and ostracod data were collected from 32 samples from sites S11 and S12. Samples were prepared for microfossil analysis through sediment drying and sieving on an EFL 2mk3 Test Sieve Shaker for ~30 seconds, then gently sieved by hand. Microfossils were analysed from two sieve size fractions: 500–1000 μ and 500–150 μ. Approximately 400 Foraminifera were collected from the 150–500 μ fractions while all Foraminifera were collected from the 500–1000 μ fraction. The age of the Formation was revised using the foraminiferal zonations of Blow (1969), Kennett & Srinivasan (1983), Hornibrook (1982), Hornibrook *et al.* 1989) and Berggren *et al.* (1985). Benthic Foraminifera dominate and were identified dominantly by reference to Carter (1964), Hayward *et al.* (1997, 1999), Yassini & Jones (1995), Jones (1994) and Parr (1932, 1939, 1950). Ostracods were collected in conjunction with the Foraminifera, and constitute the first investigation of these in the formation. The quantitative data were standardised to represent total of microfossil abundance per gram of original unsieved sediment.

Samples were collected by augering by JW and termed Sections S11 and S12.

Locality:

S11 – 39°5.5'S; 148°00.9'E – (ER9276 on Universal Grid Reference, Grid Zone 55G)

S12 – 39°57'S; 148°01.1'E – (ER9474)

NPD1985 – 39°58'S; 148°07'E (ER93750)

JW picked the samples which were then passed to DL and PQ for identification of the ostracods and Foraminifera respectively. Because of the apparent difference in detail between the sample studied by Quilty (1985) and the more numerous and better-controlled samples studied here, the earlier sample was re-processed and the results refined and modernised. The fauna from the 1985 sample consists of those species resting on a 125-micron sieve. The ostracods from that sample were not studied.

Preservation varies markedly for specimens of many species even within the one sample. Agglutinated species are rare. The dominant larger forms of *Elphidium* and *Parredicta* commonly include highly damaged specimens although most are very well preserved. Nodosariid species are well preserved and show no evidence of high-energy damage. A striking feature is the abundance and diversity of unilocular species (pl. 1), and the variation in unilocular fauna from section to section. Miliolids generally are well preserved, and preservation of planktonic species is adequate. Preservation is better in samples from Section S12 and this is evident in the lower proportion of unidentified specimens.

Almost all species were subject to SEM imaging at the Central Science Laboratory (CSL), University of Tasmania.

Figured species (pls 1–4) are the planktonic forms, those benthics that are the major components or new or unusual records, and the unilocular forms because of their bewildering diversity. Figured specimens are held at the School of Earth Sciences, University of Tasmania, and the number following the inital UTGD on plate explanations is the accession number in that collection.

AGE AND CORRELATION

In Australian stage terms, the faunas from the NPD1985, and those recorded here, based on composition of the molluscan and benthic foraminiferid fauna, are Kalimnan (fig. 7), but there are questions about exactly how the Kalimnan equates to international schemes.

Blow (1969) introduced his zonation employing the now commonly accepted P (Palaeogene) and N (Neogene) zones but many authors have experienced difficulty in applying consistently zones N18 (bridging the Miocene/Pliocene boundary), and N19-21, those of the Pliocene (Berggren *et al.* 1995). Recently the Pliocene/Pleistocene boundary has been reconsidered and is now taken as being at 2.59 Ma (Gibbard *et al.* 2009, ICS Subcommission on Quaternary Stratigraphy 2009), including much of N21, and thus some faunas earlier considered Late Pliocene may now be Pleistocene.

There is no satisfactory comprehensive local southeastern Australian zonation using planktonic species because few well-studied continuous sequences through this interval in the region have been published. Hornibrook (1982) provided a useful description of the sequence of *Globorotalia* in Deep Sea Drilling Project (DSDP) Site 284 at a similar latitude to the material studied here and lying in the Tasman Sea between Flinders Island and New Zealand, and Hornibrook *et al.* (1989) published the most useful regional review. This allows application of New Zealand stage terminology to the Flinders Island material. Otherwise, it has been necessary to identify species from a variety of authorities, including Blow (1969) and Kennett & Srinivasan (1983).

While planktonic species constitute only a small percentage of the foraminiferal faunas in S11 and S12, typically approximately 2%, the diversity represented probably contains the full range that inhabited the region at the time. The planktonic species are dominated by simple globigerinid forms such as *Globigerina bulloides* d'Orbigny, 1826 with a few *G. apertura* Cushman, 1918 and *G. woodi* Jenkins, 1960. Keeled *Globorotalia* are rare and restricted to *Globorotalia pliozea* Hornibrook, 1982 and *G. mons* Hornibrook, 1982 Most globorotalids are simple turborotalids (very dominantly *G. crassaformis* (Galloway & Wissler, 1927)—"rounded" in Hornibrook's (1982) terms and always sinistrally coiled) and *G. puncticulata* (Deshayes, 1832). No large heavily thickened keeled *Globorotalia* were identified and *Globoquadrina*, *Pulleniatina*, *Sphaeroidinella* (and related genera) are absent, consistent with other cool water indications of the fauna.

The S11/S12 sections appear to allow correlation with a very narrow interval at DSDP Site 284, particularly Cores 14 and 15 that lie on the Kapitean/Opoitian boundary, very early Pliocene. Hornibrook *et al.* (1989) reviewed New Zealand foraminiferal biostratigraphy with comprehensive range charts. The fauna here relates (Hornibrook *et al.* 1989, Table 5) to a narrow interval in the older half of the Opoitian, early to mid-N19, approximately 5.3–4.4.Ma, or early to mid-Zanclean in European terms. The older limit is imposed by the First Appearance Datum (FAD) of unkeeled *G. crassaformis* and *G. puncticulata* and the younger limit by the Last Appearance Datum (LAD) of *G. mons*.

Carter (1964) described the foraminiferal faunas of comparable age from the Gippsland Basin and included those from both Tambo River and Jemmys Point Formations. It is a moot point about correlation but from the foraminiferal species listed, it seems that sections S11 and S12 are correlates of the Jemmys Point Formation. The relationship with the Tambo River Formation is unclear.

Sutherland & Kershaw (1971) listed a few Foraminifera identified by A.C. Collins from the top of the CIF in the Dutchman's Quarry and included *Glandulina kalimnensis* Parr, 1939 *Rotalia* (as *Rotalina*) *hamiltonensis* Parr, 1939, *Nonion victoriensis* Cushman, 1936 and *Massilina lapidigera* (Howchin & Parr, 1938). This is a typical Kalimnan fauna. Of these, only *Pseudononion victoriensis* has been recorded in this study and is abundant in both NPD1985 and S11 and S12 sections. *Flintina intermedia* (Howchin, 1889) another Kalimnan species, is present in NPD1985 but has not been seen in the S11 and S12 sections. Other generic comments by Collins on the fauna at the Dutchman's Quarry are consistent with the general comments that can be made about the fauna in the NPD1985 sample.

Darragh (1985) described the sequence of 18 Mollusc Assemblage faunas in southeastern Australia and his Molluscan Faunas XV, XVI, XVII and XVIII are relevant to the timescale of the Flinders Island sections. Fauna XV is Cheltenhamian (Late Miocene, possibly Early Pliocene) and thus probably pre-dates the Flinders Island material. Fauna XVI is defined from the Jemmys Point Formation which is Early Pliocene (Kalimnan). Fauna XVII is defined from the CIF on Flinders Island and taken to be Late Pliocene. No southeastern Australian stage name is applicable. Fauna XVIII is regarded as Late Pliocene (now probably Early Pleistocene) Werrikooian. Unfortunately, the S11 and S12 sections have not been subject to mollusc study and at the time of writing, Darragh's CIF material had not had the foraminiferal data published (Quilty 1985), but that now seems also to be Late Pliocene in modern terms. It is likely that a mollusc fauna from S11/S12 would be equivalent to Assemblage XVI of the Jemmys Point Formation.

Abele *et al.* (1988) have provided the most comprehensive review of the stratigraphy of the Cenozoic of Victoria and the stage terminology employed on figure 7 is based on that summary.

It seems clear that the foraminiferal faunas from both NPD1985 and S11 and S12 sections, while of different ages in foraminiferal terms, can be referred to the Kalimnan. It perhaps follows that the CIF contains within it products of more than one episode of sedimentation covering much of the Pliocene (5.3–2.6 Ma). Another emerging possibility is that the Kalimnan may be divisible into early (characterised by Darragh's 1985 Mollusc Assemblage XVI) and late (characterised by Darragh's 1985 Mollusc Assemblage XVII) substages, both within the Pliocene.

The time of deposition of S11 and S12 corresponds very closely with Supercycle TB3, Cycle 3.4 of Haq *et al.* (1987) and the thinness of the unit suggests that it occurred at the peak of a transgression marked by that curve.

COMPARISON OF S11 AND S12 SECTIONS

As illustrated in figure 3, there is a clear contrast between dominance and diversity trends between the two sections, using dominance and diversity as defined by Walton (1964) and in change in planktonic foraminiferal content (fig. 4A, B). Section S11 has a higher variability in both dominance and diversity than is the case for section S12. Both sections were deposited in less than 10 fathoms (~20 m), using the criterion of dominance/diversity developed by Walton.

Although the sections are relatively close (2 km apart), and while species composition is very similar, there are marked differences in proportions of Foraminifera present, and there are changes that, while differing in detail, are interpreted as part of a consistent trend of increasing water

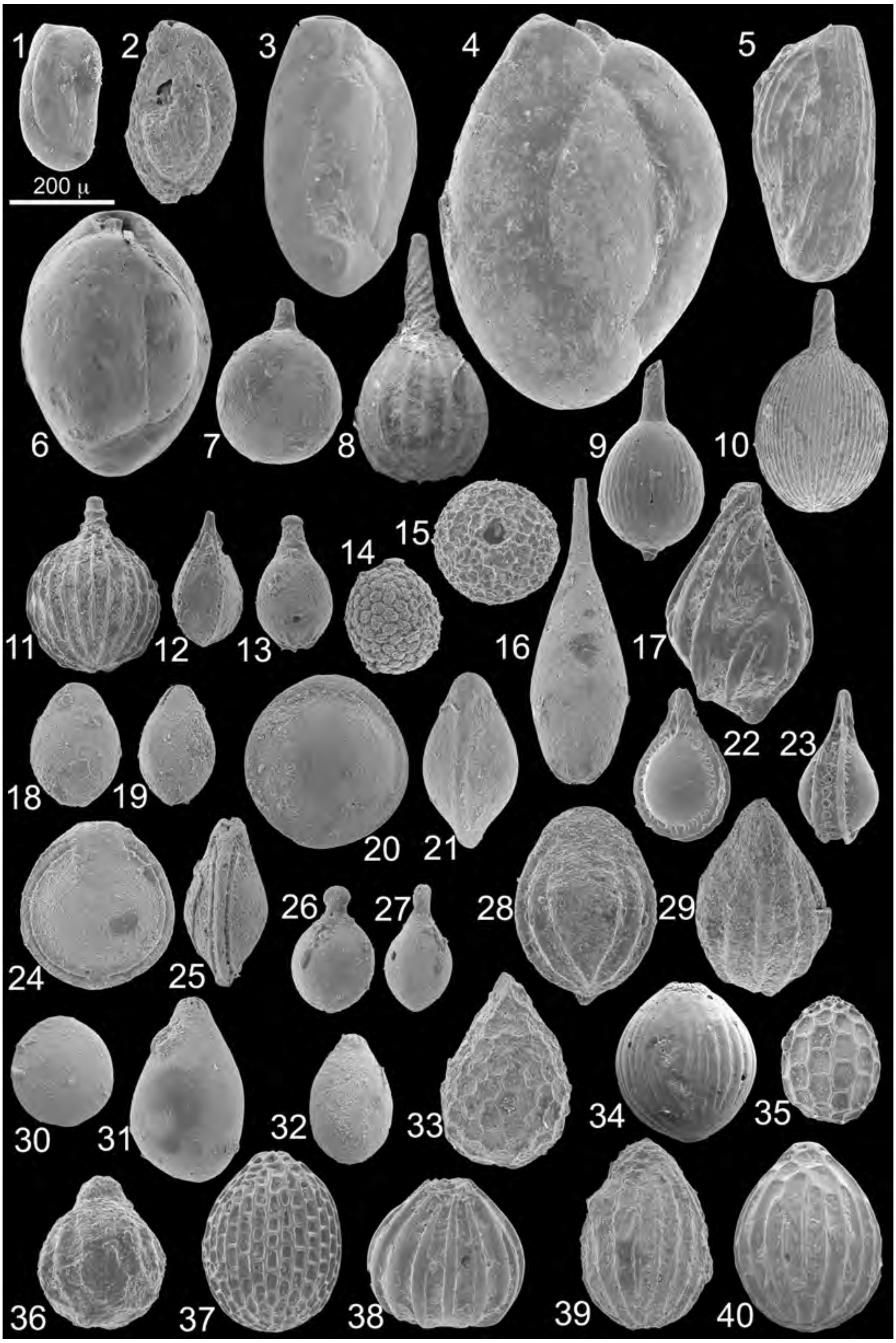

PLATE 1

Pliocene benthic Foraminifera, Flinders Island. 1. *Gordiospira* sp., UTGD128852. 2. *Quinqueloculina asperula* Seguenza 1862, UTGD128853. 3. *Q. oblonga* (Montagu 1803), UTGD128854. 4. *Q. seminulum* (Linné 1758), UTGD128855. 5. ?*Q. poeyana victoriensis* Collins 1974, UTGD128856. 6. *Triloculina trigonula* (Lamarck 1804), UTGD128857. 7. *Lagena flatulenta* Loeblich & Tappan 1953, UTGD128858. 8. *L. perlucida* (Montagu 1803), UTGD128859. 9. *L. striata paucistriata* Yassini & Jones 1995, UTGD128860. 10. *L. striatospirolata* Albani & Yassini 1989, UTGD128861. 11. *L. sulcata* (Walker & Jacob 1798), UTGD128862. 12. *L* sp. 1, UTGD128863. 13. *L*. sp. 2, UTGD128864. 14. *L*. sp. 3, UTGD128865. 15. ?*Lagena* sp., UTGD128866. 16. *Procerolagena clavata* (d'Orbigny 1846), UTGD128867. 17. *Cushmanina spiralis* (Brady 1884), UTGD128868. 18, 19. *Fissurina lucida* (Williamson 1848), UTGD128869. 20, 21. *F. marginata* (Montagu 1803), UTGD128870. 22, 23. *F. pacifica* Parr 1950, UTGD128871. 24, 25. *F*. sp. 1, UTGD128872. 26, 27. *F.* sp. 2, UTGD128873. 28, 29. *F*. sp. 3, UTGD128874. 30. *F*. sp. 4, UTGD128875. 31. *Oolina emaciata* (Reuss 1862), UTGD128876. 32. *O. globosa* (Montagu 1803), UTGD128877. 33. *O. hexagona* (Williamson 1848), UTGD128878 . 34. *O. lineata* (Williamson 1848), UTGD128879. 35. *O. melosquammosa* (McCulloch 1977), UTGD128880. 36. *O. ramulosa* (Chapman 1907), UTGD128881. 37. *O. squamosa* (Montagu 1803), UTGD128882. 38. *O. subacuticostiformis* Albani & Yassini 1989, UTGD128883. 39. *O. tasmanica* Parr 1950, UTGD128884. 40. *O.* sp. 1, UTGD128885.

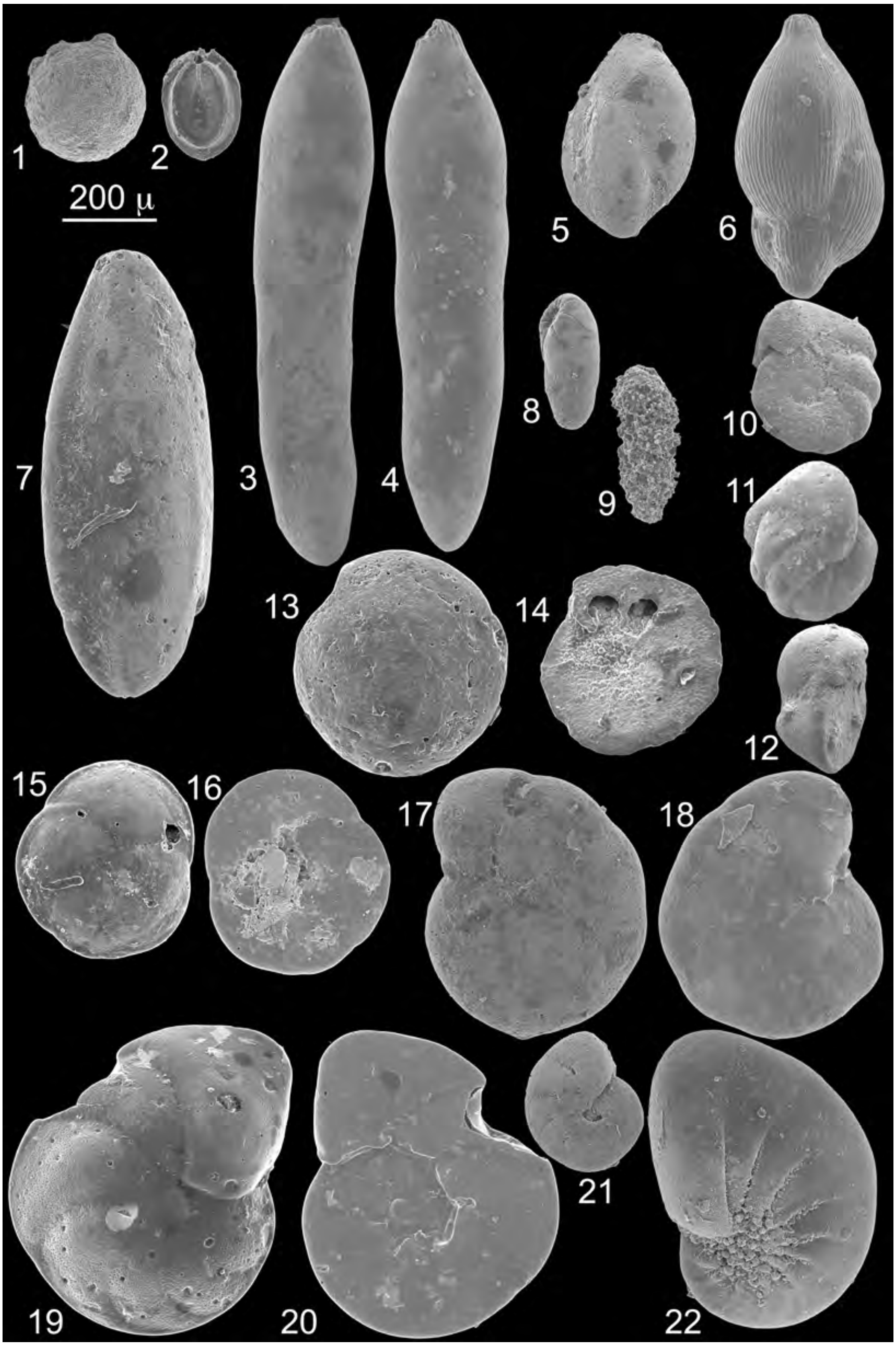

PLATE 2

Pliocene benthic Foraminifera, Flinders Island. 1. ?*Oolina* sp., UTGD128886. 2. *Pseudofissurina* sp., UTGD128887. 3, 4. *gen. et sp. nov.* Quilty, 2014. Holotype, UTGD128888. 5. *Guttulina communis* (d'Orbigny 1826), UTGD128891. 6. *G. regina* (Brady, Parker & Jones 1870), UTGD128892 . 7. *Sigmoidella kagaensis* Cushman & Ozawa 1928, UTGD128893. 8. *Elongobula arethusae* Revets 1993, UTGD128894. 9. *Virgulopsis* sp., UTGD128895. 10-12. *Discanomalina vermiculata* (d'Orbigny 1839), UTGD128896. 13. *Mesorotalia* sp., UTGD128897. 14. *Mesorotalia* sp., UTGD128898. 15, 16. *Discorbinella* cf *vitrevoluta* (Hornibrook 1961), UTGD128899. 17, 18. *Parredicta kalimnensis* (Parr 1939), UTGD128900. 19, 20. *Planodiscorbis* sp., UTGD128901. 21. *Astrononion novozelandicum* Cushman & Edwards 1937, UTGD128902. 22. *Pseudononion victoriensis* (Cushman 1936), UTGD128903.

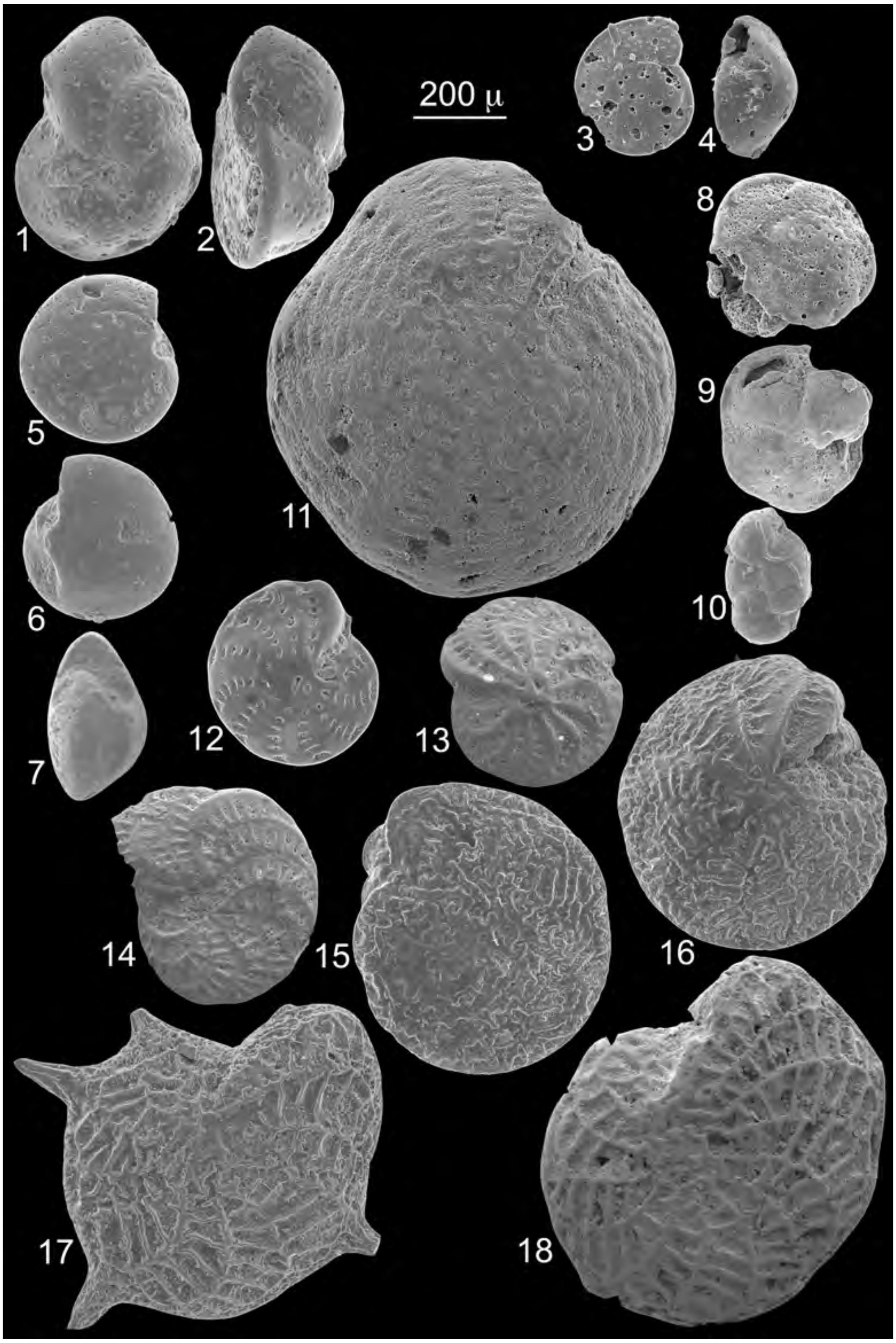

PLATE 3

Pliocene benthic Foraminifera, Flinders Island. 1, 2. *Cibicides ihungia* Finlay 1940, UTGD128904. 3, 4. *C. thiara* (Stache 1864), UTGD128905. 5-7. *C.* sp. 1, UTGD128906. 8, 9. *C.* sp. 2, UTGD128907. 10. *Dyocibicides biserialis* Cushman & Valentine 1930, UTGD128908. 11. *Elphidium craticulatum* (Fichtel & Moll 1798), UTGD128909. 12. *E. advenum advenum* (Cushman 1930), UTGD128910. 13. *E. crispum crispum* (Linné 1758), UTGD128911. 14. *E.* sp. 1, UTGD128912. 15, 16. *Notorotalia clathrata* (Brady 1884), UTGD128913. 17. *Parrellina imperatrix* (Brady 1881), UTGD128914. 18. *P. verriculata* (Brady 1881), UTGD128915.

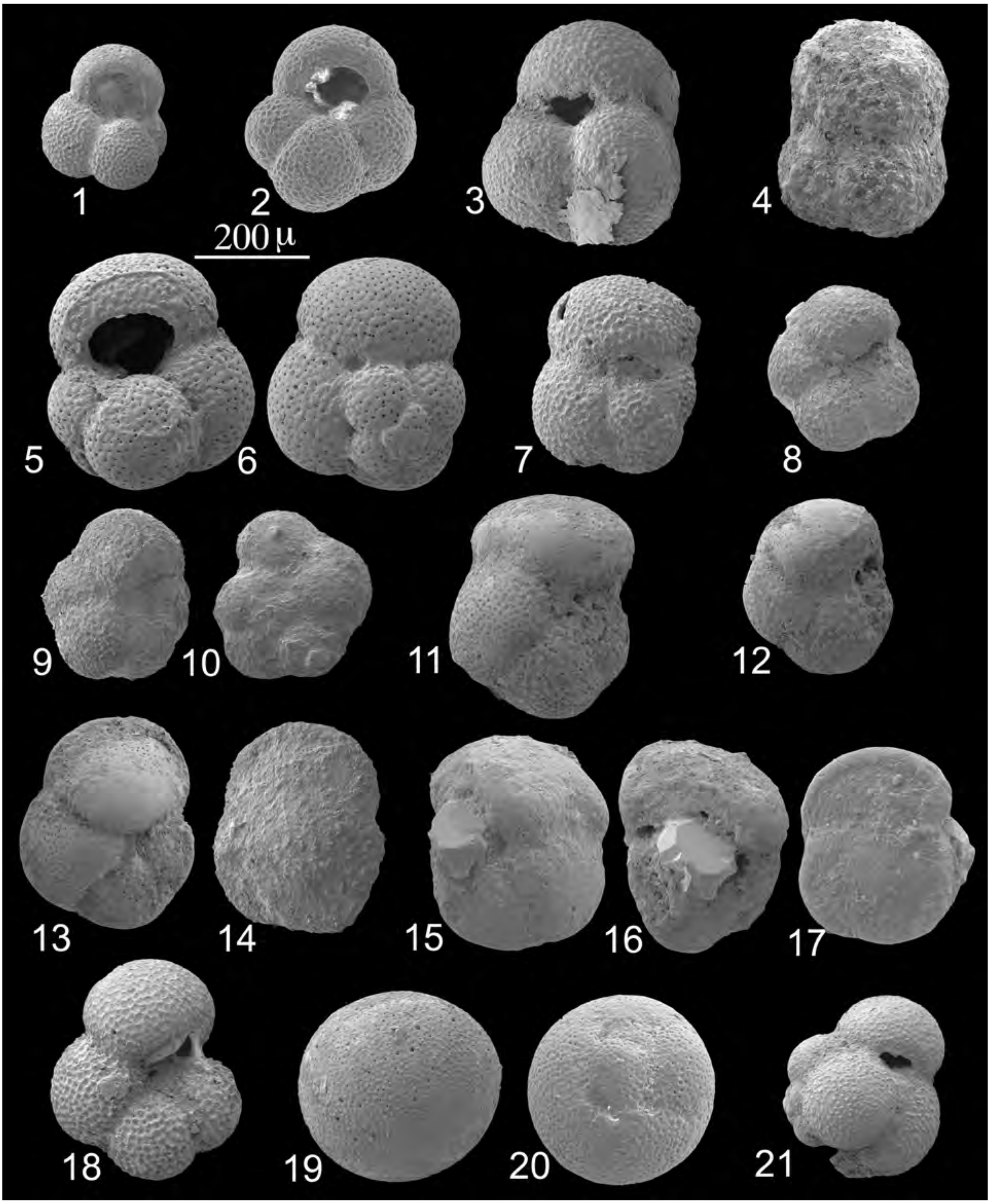

PLATE 4

Pliocene planktonic Foraminifera, Flinders Island. 1. *Globigerina apertura* Cushman 1918, UTGD128916. 2. *G. bulloides* d'Orbigny 1826, UTGD128917. 3. *G. falconensis* Blow 1959, UTGD128918 . 4. *G. woodi* Jenkins 1960, UTGD128919. 5, 6. *Globigerinoides obliquus* Bolli 1957, UTGD128920. 7. *G. quadrilobatus* (d'Orbigny 1846), UTGD12891. 8. *Neogloboquadrina pachyderma* (Ehrenberg 1861), UTGD128922. 9, 10. *N. humerosa* (Takayanagi & Saito 1962), UTGD128923. 11. *Globorotalia crassaformis* (Galloway & Wissler 1927), UTGD128924. 12. *G. puncticulata* (Deshayes 1882), UTGD128925. 13, 14. *G. pliozea* Hornibrook 1982, UTGD128926. 15-17. *G. mons* Hornibrook 1982, UTGD128927. 18. *G. 'obesa'* Bolli 1957, UTGD128928. 19. *Orbulina universa* d'Orbigny 1839, UTGD128929. 20. *O. suturalis* Brönnimann 1951, UTGD128930. 21. *Globigerinita uvula* (Ehrenberg 1861), UTGD128931.

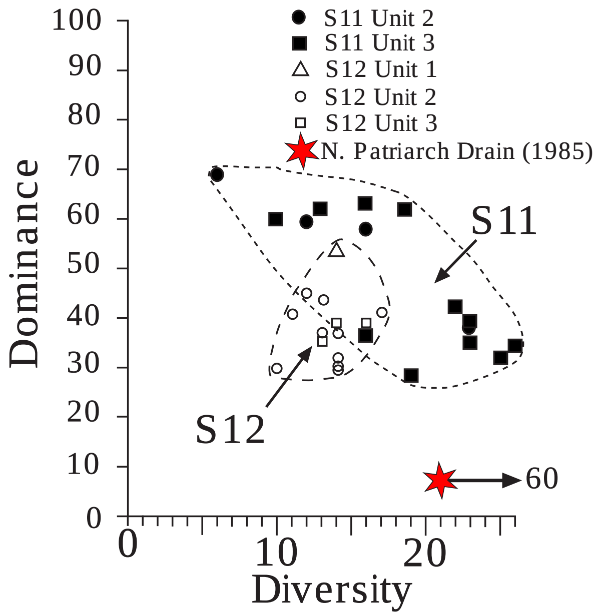

FIG. 3 — Dominance/diversity relationships between samples from sections S11 and S12. Those from North Patriarch Drain (1985) (red star) provided for comparison.

depth but quieter conditions with time, probably indicating deposition during a transgressive event (or local depression of a land surface).

Agglutinated species. Agglutinated forms occur in only two samples in trace quantities, both in S11. They appear to be virtually absent from the environments represented and are of little significance (other than absence) in interpretation of the environment at the time.

Miliolids. There is a very marked difference in the occurrence of simple miliolids between the two sections (fig. 5). In S11, species of *Quinqueloculina* and *Triloculina* occur throughout but in S12, these genera are rare and occur only in the lowest samples and then only in very low abundance. In S11, miliolids have an anitithetic relationship with *Parredicta kalimnensis* (Parr, 1939).

Bolivinids. The term is used to include the elongate, normally infaunal species. Their virtual absence supports the indications from rarity of cassidulinids, that the environment was a low nutrient one.

Cassidulinids. This group is rare and the significance lies in absence. As cassidulinids are infaunal, this may indicate a low nutrient, or more turbulent environment.

Elphidium. This genus is very diverse and a higher component in S11 (c. 7%) than in S12 (5%) but little consistent trend of change with time is evident (fig. 5). *Elphidium pseudonodosum* Cushman appears to be absent and Parr (1939) stated that it occurred only in Kalimnan strata at Hamilton in western Victoria. If present, it may be included in counts of other species such as *E. crispum*.

Parrellina. This genus is generally more abundant in S12 than in S11 (fig. 5). It has two species – *P. verriculata* and *P. imperatrix*. The difference is only in the presence or absence of prominent, robust marginal spines and it is likely that the difference is of little biological significance. *P. verriculata* dominates throughout. The genus is consistently more abundant in S12 than in S11.

Notorotalia. *Notorotalia* is generally relatively more important in S12 than in S11 (fig. 5).

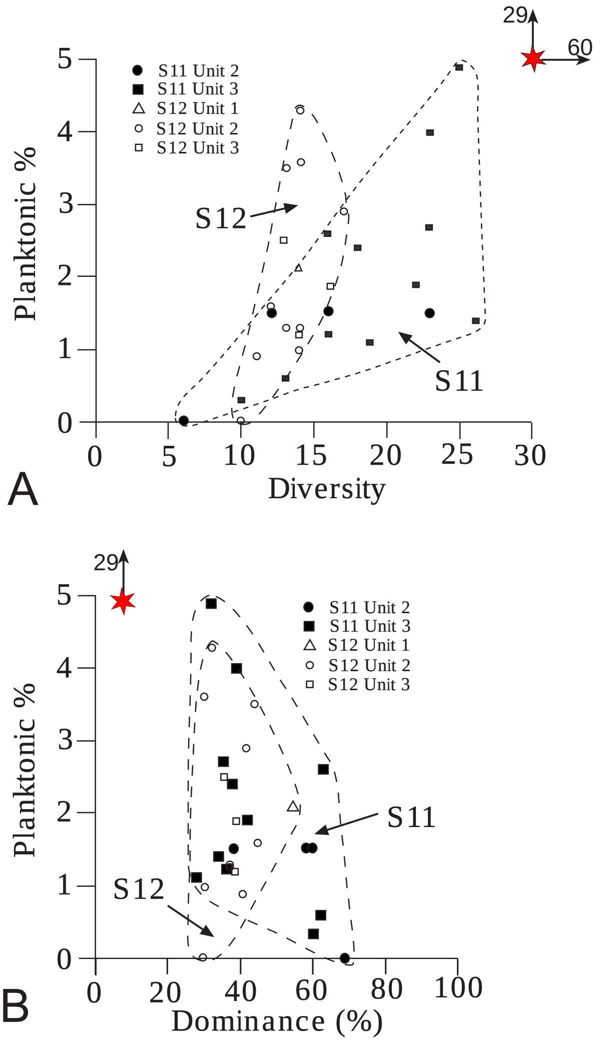

FIG. 4 — (A) Diversity vs planktonic foraminiferal content in sections S11 and S12. That from North Patriarch Drain (1985) (red star) provided for comparison. (B) Dominance vs planktonic percentage in Sections S11 and S12. That from North Patriarch Drain (1985) provided for comparison.

Parredicta kalimnensis. This genus and species, without any obvious modern equivalent, is the dominant form in all samples studied and is consistently more abundant in S11 than in S12 but there is a marked trend towards higher content in S11 with time (fig. 5).

Cibicides. Each section has a trend towards decreasing *Cibicides* content with time but the content in S12 is generally higher than in S11 (fig. 5).

Planktonic species. Planktonic forms make up only a very small proportion of samples, approximately 2% in both sections, but the diversity combined between sections is high.

CONTRASTS BETWEEN NORTH PATRIARCH DRAIN (1985) AND S11/S12

A major departure between Sections S11/12 and NPD1985 lies in the planktonic foraminiferal faunas and age implications. NPD1985 contains sinistral *Neogloboquadrina*

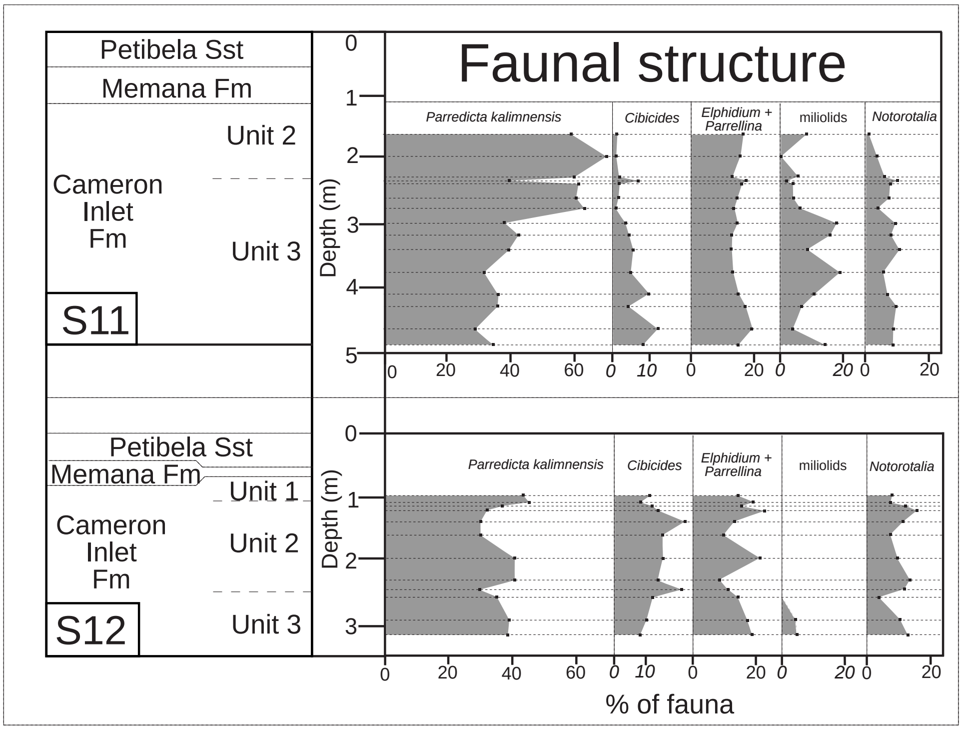

FIG. 5 — *Comparison of faunal structure in sections S11 and S12.*

pachyderma (Ehrenberg, 1861) that are fully developed kummerforms. *Orbulina universa* d'Orbigny, 1839 is rarer than expected compared with S11/12 samples. The sample lacks *Globigerinoides, Globorotalia mons, G. inflata* and *G. puncticulata.* It is a cool climate fauna deposited in an inner-mid-continental shelf setting and thus contains the full diversity of planktonic species, in contrast with the other sections which are shallower water samples perhaps excluding some of the species that live in a deeper water environment. The age determination for S11/S12 is discretely older than that of NPD1985 that now appears to belong to the interval 4.40–3.45 Ma. The absence of *G. mons* supports this conclusion.

Both the NPD1985 and S11/S12 sections, even if different in age within the Pliocene, are typically Kalimnan in age and fauna, partly equivalent to the Jemmys Point Formation of eastern Victoria. Parr (1939) listed those species that he took to be characteristic of the Kalimnan and both sections have faunas that clearly are Kalimnan, marked especially by the dominance of *Parredicta kalimnensis* although much more dominant (40–60%) in S11/S12 than in NPD1985 (8%). Many of these species have disjunct distributions within the southeastern Australian Neogene but the combination seems to occur only in the Kalimnan. Carter (1964) reviewed the faunas of this age from the onshore Gippsland Basin and several of the species listed by Parr (1939) were not discussed, suggesting absence from the samples he studied. This, in turn, indicates that there was some environmental differentiation at the time and that the faunas responded to these differences. NPD1985 has *F. intermedia* although extremely rare. *Nororotalia clathrata, Guttulina regina, G. seguenziana, Pseudononion victoriensis* and *Uvigerina miozea* are present in each section. *Parrellina imperatrix* and *P. verriculata* are restricted to the S11/S12 sections. *Pseudopolymorphina victoriensis* Parr, 1939 has not been identified but a new genus and species in S11 and S12 may be an analogue species in both size and abundance terms. *Ammonia beccarii* has not been seen.

NPD1985 lacks the earliest Pliocene species and also contains a mollusc fauna that Darragh (1985) referred to his Molluscan Assemblage XVII of Late Pliocene age and thus younger than his Molluscan Assemblage XVI which comes from the type Kalimnan, apparently the correlate of the S11/12 sections. The single specimen of *O. universa* recovered from NPD1985 is 0.32 mm in diameter, consistent with those from Sections S11 and S12, and indicating similar water temperature.

The implications of this age difference are that the CIF represents the entire Pliocene, and either that it consists of the products of more than one discrete depositional event, or that the sections studied are from different, as yet undifferentiated, formations.

PALAEOENVIRONMENT

Orbulina universa occurs sporadically throughout the sections and the specimens are thin-walled and very small, usually approximately only 0.35 mm (0.27–0.37 mm, all <0.40 mm). In extrapolating the results of the classic study by Bé *et al.* (1973) of *O. universa* in the Indian Ocean (fig. 6), it seems that the specimens found here lived at the lowest end of the species' temperature tolerance, probably several degrees lower than 15°C, in normal marine salinity. Water depths were very shallow (see dominance/diversity data) and thus the data of Bé *et al.* most likely to be applicable are those of their Text-figure 11 in which diameters ranged from 0.4–0.85 mm. Extrapolating the trend in that figure indicates that water temperature was approximately 12°C. The few specimens are not well enough preserved to allow study of the other features – pore density and pore diameter – examined by Bé *et al.* (1973). The interpreted temperature is several degrees cooler than in modern times.

Dominance/diversity relationships (figs 3, 4A, B) suggest that the environment at S12 was more stable than that at S11. The higher miliolid and *Elphidium* content in S11

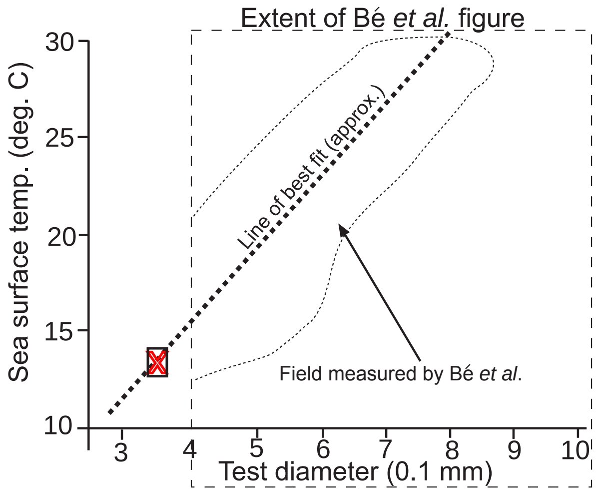

FIG. 6 — Size of Orbulina universa *from Flinders Island compared with those of Bé* et al. *(1973). X marks the Flinders Island sample.*

indicates some outer estuarine influence, and both localities were in very shallow, fully marine water. The high proportion of attached forms, (*Dyocibicides/Cibicides/Discorbinella*), more so in S12, suggests a seagrass environment well within the photic zone. The low planktonic percentage (0–3.5%, normally <2%) is consistent with this interpretation.

Section S12, while generally depauperate in miliolids, did commence with a few species but these abandoned the environment soon after deposition began suggesting a lessening of any estuarine influence and a transition to a more open or protected marine environment, consistent with generally deeper waters, in turn suggesting that deposition occurred during a transgressive phase. There is little trend in section S12.

Parredicta kalimnensis content is antithetic to attached forms but its higher abundance in S11 coincides generally with diminished miliolid abundance, indicating that it was a close inshore form, perhaps with some ability to survive outer estuarine conditions. The trends in *P. kalimnensis* seem to correlate with the implications of the ostracod data. The lower abundance in NPD1985 with its higher planktonic percentage seems to indicate that *P. kalimnensis* favoured shallower, closer inshore waters.

The presence of a significant component of poorly preserved eroded robust species amongst otherwise well-preserved delicate forms suggests that the generally quiet, shallow water environment was occasionally subject to more turbulent conditions, during storms with an easterly source. Such storm conditions allowed the wave base to be deepened.

The CIF in S11/S12 contains a diverse ostracod fauna, the majority of which have been identified previously from Recent coastal environments on southeastern Australia (Yassini & Jones 1995). The fauna comprises 39 species from a total of 24 genera and is typical of a generally shallow, consistently marine environment. Dominant species include *Malabaricythere oceanica* Yassini & Jones, 1995, *Trachyleberis ("Ponticocythereis") jervisbayensis* Yassini & Jones, 1995, *Bradleya bassbasinensis* Yassini & Jones, 1995, *Cytheropteron wrighti* Yassini & Jones, 1987, *Phlyctenophora zealandica* Brady, 1880 and *Cytherella dromedaria* Brady, 1880. The majority of species are stenohaline, but euryhaline species, common in marine environments, are also present.

The spectrum of species remained relatively constant during deposition of the Formation; however, some subtle changes in the abundance of species between samples suggest a gradual shallowing and increasing protection of the marine environment over time. The major shifts in these changes correlate loosely with the stratigraphic units of the Formation. The abundance of species typical of open marine conditions decreases from Unit 3 to Units and 1. The abundance of *P. zealandica*, a euryhaline species usually found in quiet protected coastal environments (Hartmann 1978, 1979, 1980, 1981), is greatest within Unit 1, suggesting that the unit may represent an enclosed, quiet protected shallow marine embayment or bay as implied from the lithology of the unit.

CONTRIBUTIONS TO UNDERSTANDING OF EVOLUTION OF THE PLIOCENE OF SOUTHERN AUSTRALIA

Much of the study of the later Neogene of southern Australian Foraminifera has concentrated on the Miocene and treated the Pliocene rather cursorily, even though changes in the southern Australian environment during the Pliocene have been profound, with details yet to be fully elucidated. To date, the prime source of biostratigraphic control has been on molluscs. Parr (1939) listed those forms of Foraminifera that he took to be characteristic of the Pliocene of southeastern Australia and his approach has stood the test of time. Li *et al.* (1996), in reviewing endemism in southern Australian foraminiferal faunas, could make only brief comments on the issue as it related to the Pliocene, indicating that southern Australian foraminiferal faunas were essentially modern in aspect with *Parredicta* as the genus most apt to be regarded as the endemic one. This study reinforces the view expressed by Li *et al.* (1996) because, while considerable diversity is encountered, very few new species are recorded.

Better understanding will need local biostratigraphic resolution at higher level than exists at present. The material studied here is a little unusual in that the New Zealand biostratigraphic scheme, which has been well studied, seems to be highly applicable.

Carter (1964) reviewed the foraminiferal biostratigraphy of the Gippsland Basin. The Flinders Island sections relate to the Jemmys Point and Tambo River Formations but the faunas on Flinders Island, while having many species in common with the Gippsland Basin formations, are much more diverse while still not allowing correlation on an individual formation basis with those of the Gippsland Basin. *Parredicta kalimnensis* and *Pseudononion victoriense* are characteristic of all. Carter (1964) quoted a diameter for *O. universa* of 0.59 mm, which is much larger than the Flinders Island specimens although it is clear from Carter, that specimens are as rare in his sections as in Flinders Island sections. In terms of Bé *et al.* (1973), Carter's specimens reflect a temperature closer to 20°C or even higher, indicating that northern Gippsland Basin was bathed in warmer water of the East Australian Current while farther south was subject to much cooler waters as indicated in Warne & Soutar (2012). The apparent anomaly between high sea level and cool local temperature is perhaps best explained by a scenario in which the East Australian Current (EAC) at the time flowed east (as it does now) from a position well north of Flinders Island, leaving Flinders Island bathed in cooler water.

Mallett (1982) documented the planktonic foraminiferal fauna of the Jandakot Beds in the Perth (Western Australia) area, recording a Late Pliocene age on the basis of primitive forms of *Globorotalia truncatuloides* (d'Orbigny, 1839). Examination of his figures suggests that his specimens could be compared with *G. tosaensis* Takayanagi & Saito, 1962 the immediate predecessor to *G. truncatulinoides.* He noted that it was a transitional form. The transition took place at the traditional (1.85 Ma) Pleistocene/Pliocene boundary. He estimated the temperature at the time to be comparable with the modern. He made no mention of the presence/absence of *O. universa*.

James *et al.* (2006) studied the Late Pliocene Roe Calcarenite of the Eucla Basin and recorded an age of 2.0–3.4 Ma. The age was not given in terms of either the Blow (1969) or Hornibrook *et al.* (1989) biostratigraphic schemes based on planktonic organisms. The environment of deposition of that unit was considerably warmer than at present as judged by the presence of abundance of tropical [mollusc] taxa. The Roe Calcarenite, like the CIF, is thin, very shallow water and characterised by very diverse mollusc fauna suggesting that it represents the peak incursion of the sea at the time. Deposition of the Roe Calcarenite perhaps equates with Haq *et al.'s* (1987) Cycle 3.6, in contrast to the CIF which may equate to Cycle 3.4.

It has long been recognised that a major unconformity exists between the well-studied Miocene sections in southeastern Australia and the Pliocene, and its extent and possible origin were reviewed and discussed in detail by Dickinson *et al.* (2002). It includes largely the time span of the Mitchellian and Cheltenhamian Australian stages (Wilkins 1963). The Miocene strata have been folded and faulted in places and eroded to various levels and overlain by the earliest Pliocene such as the Grange Burn Formation and Whalers Bluff Formations (Otway Basin), Brighton Group (Torquay sub-basin and Port Phillip Basin) and Haunted Hill Fomation (non-marine) or Jemmys Point Formation (Gippsland Basin). The Grange Burn Formation in the Hamilton area has been dated by Sr techniques to 5–4.0 Ma (Dickinson *et al.* (2002), an exact equivalent to the material studied here. The Moorabool Viaduct Formation has yielded an Sr based age of 4.5 Ma. Dickinson *et al.* (2002) noted that, in the Torquay sub-basin, folding continued into the Pliocene sedimentary section. In the Gippsland Basin, erosion of the folded Miocene sequence was Late Miocene-Early Pliocene (8–4 Ma; Dickinson *et al.* 2002) and the Jemmys Point Formation is younger, correlating with N20 planktonic foraminiferal zone. Holdgate *et al.* (2003) postulated that folding in the Gippsland Basin continued until approximately 1 Ma.

The Whalers Bluff Formation of southern Victoria has been the subject of considerable research (Singleton *et al.* 1976, Warne & Soutar 2012) and the history correlates closely with that on Flinders Island. Warne & Soutar (2012) showed that it was formed by two depositional events – one of Kalimnan/Zanclean age recorded at one metre, overlain disconformably at 5 m by one dated as Late Pliocene/Piacenzian, the boundary between the two units being placed at 3.81 m. This appears to be the same sequence, timing and sea level highstand history as is represented on Flinders Island.

CONCLUSIONS

The presence of *in situ*, articulated Pliocene molluscs enabled identification of the Cameron Inlet Formation over ~10 km^2 of previously unmapped outcrop. This is the northwesternmost extent of the CIF of fossiliferous marl, sand and silt. Here the formation is higher in altitude (23–32 m) than elsewhere (4–19 m). The southern extent of the CIF on Flinders Island was constrained topographically to a lower elevation (4–19 m) and blocked by Early Miocene basalt which is now largely eroded to a similar elevation as the surrounding coastal plain (Sutherland & Kershaw 1971). *In situ* weathered granitic soils also occur near the southern limit of the CIF (fig. 1C) indicating that granitic outcrops may also have created a physical barrier to Pliocene marine deposition in the area.

Foraminifera and ostracods from new sections S11/S12 of the CIF are very Early Pliocene in age and represent an age not previously recorded on Flinders Island. The sections are characterised by benthic foraminiferal faunas that are typically Kalimnan in southeastern Australian stage terms. The molluscan fauna from this section has not been studied to date. The sections can be correlated by planktonic Foraminifera with a very narrow interval at DSDP Site 284 (central Tasman Sea), particularly Cores 14 and 15 that lie on the Kapitean/Opoitian boundary, very early Pliocene in New Zealand terms. The fauna relates to a narrow interval in the older half of the Opoitian, early to mid-N19 in international planktonic foraminiferal zone terms, approximately 5.3–4.4.Ma, or early to mid-Zanclean in European nomenclature. This age correlates closely with Haq *et al.'s* (1987) Eustatic Cycle 3.4 of Supercycle TB3, the major onlap and close to the highest sea level of the last 10 million years (Miller *et al.* 2005).

The fauna is distinctly older than that recorded by Quilty (1985) from supposed CIF from North Patriarch Drain that is Late Pliocene but still Kalimnan in aspect. The Kalimnan therefore may represent the entire Pliocene (5.3–2.6 Ma). It is then possible that the Kalimnan may be divisible into early (characterised by Darragh's 1985 Mollusc Assemblage XVI) and late (characterised by Darragh's 1985 Mollusc Assemblage XVII) substages, both within the Pliocene. Probable correlation of the various faunas is depicted on figure 7.

The implications of this age difference are either that the CIF consists of the products of more than one discrete depositional event, or that the sections studied are from different, as yet undifferentiated, Kalimnan formations.

The Dutchman Coquinoid Limestone may best be considered a facies variant or member of the CIF rather than a formation in its own right.

The Pliocene sediments on Flinders Island correlate very closely with the history recorded in the Whalers Bluff Formation of southern Victoria that also consists of the products of two depositional events, contemporaneous with those on Flinders Island.

Deposition occurred in marine waters less than 20 m deep in sea surface temperatures cooler than today, perhaps some 12–13°C.

The sections on Flinders Island can be regarded as the southwesternmost onshore margin of the marine Cenozoic of the Gippsland Basin

Precise correlation of southeastern Australian stages with international zonal schemes is, as yet, not possible but the very Early Pliocene determination for the S11/S12 sections

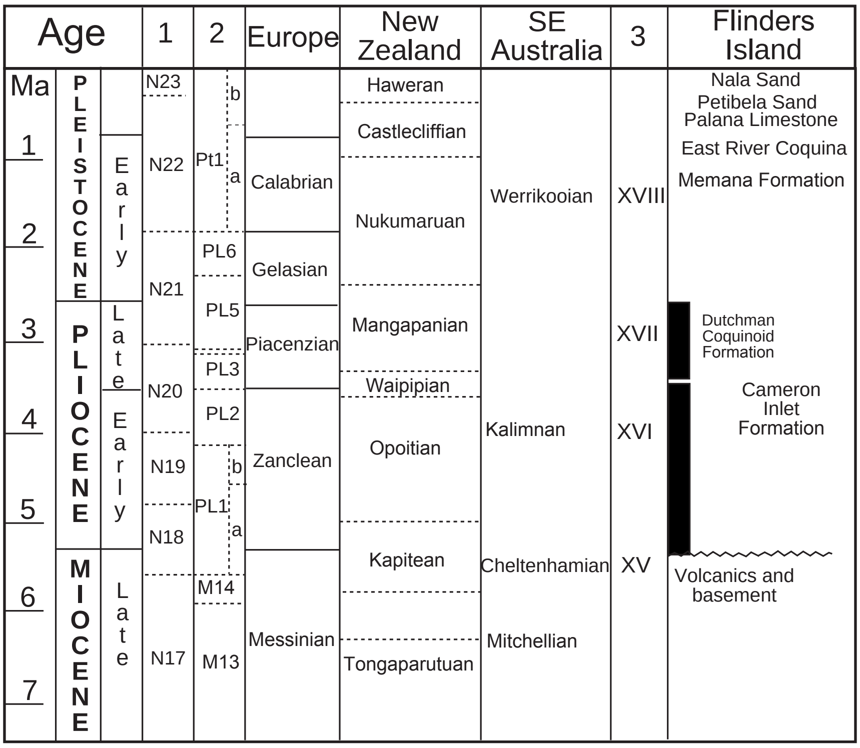

FIG.7 — Stratigraphy of Flinders Island Pliocene and younger, placed in southeastern Australian, New Zealand and European stage terms. 1, Blow (1969) planktonic foraminiferal zones. 2, Planktonic foraminiferal zones for Atlantic Ocean from Berggren et al. *(1995). 3, Mollusc Assemblages of Darragh (1985).*

helps tie this sequence to the New Zealand sequence and, via that, to the international schemes.

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REFERENCES

Abele, C. Gloe, C.S., Hocking, J.B., Holdgate, G., Kenley, P.R., Lawrence, C.R., Ripper, D., Threlfall, W.F. & Bolger, P.F. 1988: Tertiary. *In* Douglas, J.B. & Ferguson, J.A. (eds). *Geology of Victoria.* Geological Society of Australia, Victorian Division: 251–350.

Albani, A.D. & Yassini, I. 1989: Taxonomy and distribution of shallow-water lagenid Foraminifera from the south-eastern coast of Australia. *Australian Journal of Marine and Freshwater Research* **40**: 369–401.

Banner, F.T. & Blow, W.H. 1960: Some primary types of species belonging to the Superfamily Globigerinacea. *Contributions from the Cushman Foundation for Foraminiferal Research* **11**: 1–41.

Bargelloni, L., Patarnello, T., Ritchie, P.A., Battaglia, B. & Meyer, A. 1997: Molecular phylogeny and evolution of notothenioid fish based on partial sequences of 12S and 16S ribosomal RNA mitochondrial genes. *In* Battaglia, B., Valencia, J. & Walton, D.W.H. (eds) *Antarctic Communities: Species, Structure and Survival.* Cambridge University Press, Cambridge: 45–50.

Barker, R.W. 1960: Taxonomic notes on the species figured by H.B. Brady in his Report on the foraminifera dredged by H.M.S. Challenger during the years 1873–1876. *Special Publication of the Society of Economic Paleontologists and Mineralogists* **9**: 1–238.

Bé, A.W.H., Harrison, S.M. & Lott, L. 1973: *Orbulina universa* d'Orbigny in the Indian Ocean. *Micropaleontology* **19**: 150–192.

Beck, R.S. 1943: Eocene foraminifera from Cowlitz River, Lewis County Washington. *Journal of Paleontology* **17**: 584–614.

Berkman, P.A. & Prentice, M.L. 1996: Pliocene extinction of Antarctic pectinid mollusks. *Science* **271**: 1606–1607.

Bermudez, P.J. 1949: Tertiary smaller foraminifera of the Dominican Republic. *Special Publication, Cushman Laboratory for Foraminiferal Research* **25**: 1–322.

Bermudez, P.J. 1952: Estudio sistematico de los Forminiferos rotaliformes. Venezuela Ministerio Minas e Hidrocarburos, boletin geology **2**(4): 1–230.

Berggren, W.A., Kent, D.V., Swisher, C.C. Jr & Aubry, M.-P. 1995: A revised Cenozoic geochronology and chronstratigraphy. *In* Berrgren. W.A. (ed.) *Geochronology Time Scales and Global Stratigraphic Correlation. Society for Sedimentary Geology, Special Publication* **54**: 131–212 .

Blow, W.H. 1959: Age, correlation and biostratigraphy of the upper Tocuyo (San Lorenzo) and Pozon Formations, eastern Falcon, Venezuela. *Bulletins of American Paleontology* **39**(178): 67–251.

Blow, W.H. 1969: Late Middle Eocene to Recent planktonic foraminiferal biostratigaraphy. *In* Brönnimann, P. & Renz, H.H. (eds) *Proceedings of the First International Conference on Planktonic Microfossils, Geneva* **1**: 199 –421.

Bolli, H.M. 1957: Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I.. *Bulletin of the United States National Museum* **215**: 97–123.

Bolli, H.M. & Bermudez, P.J. 1965: Zonation based on planktonic foraminifera of Middle Miocene to Pliocene warm-water sediments. *Asociacion Venezolana de Geologia, Mineria y Petroleo Boletin Informativo* **8**: 119–149.

Brady, H.B. 1881: Notes on some of the reticularian Rhizopoda of the Challenger Expedition; part 3. *Quarterly Journal of the Microscopical Society*, new series, **21**: 31–71.

Brady, H.B. 1884: Report on the foraminifera dredged by H.M.S. Challenger, during the years 1873–1876. *Zoology* **9**: 1–814.

Brady, H.B., Parker, W.K. & Jones, T.R. 1870: A monograph of the genus Polymorphina. *Transactions of the Linnaean Society of London* **27**(1870): 197–253.

Brönnimann, P. 1951: The genus *Orbulina* d'Orbigny in the Oligo-Miocene of Trinidad, B.W.I.. *Contributions from the Cushman Foundation for Foraminiferal Research* **2**: 132–138.

Brotzen, F. 1936: Foraminiferen aus dem schwedischen untersten Senon von Eriksdal *Schonen. Sverige Geologiska Undersokning Serie C. Avhandligar och Uppatser* **396**: 1–206.

Burdett, I.D.J, Hedley, R.H., Hornibrook, N. de B. & Hurdle, C.M. 1963: *Gaudryina convexa* (Karrer) 1865 – Upper Eocene to Recent; an example of variation and synonymy among foraminifera. *New Zealand Journal of Science* **6**: 513–530.

Burrows, H.W. & Holland, R. 1895: *In* Jones, T.R., Parker, W.K & Brady, H.B.A (eds) *Monograph of the Foraminifera of the Crag, part 2. Monograph of the Palaeontographical Society, London*: 73–210.

Cane, M.A. & Molnar, P. 2001: Closing of the Indonesian seaway as a precursor to east African aridification around 3–4 million years ago. *Nature* **411**: 157–162.

Carpenter, W.B., Parker, W.K. & Jones, T.R. 1862: Introduction to the study of the Foraminifera. Ray Society, London: 319 p.

Carter, A.N. 1958: Tertiary Foraminifera from the Aire District, Victoria. *Bulletin of the Geological Survey of Victoria* **55**: 1–76.

Carter, A.N. 1964: Tertiary foraminifera from Gippsland, Victoria and their stratigraphical significance. *Memoir of the Geological Survey of Victoria* **23**: 1–154.

Chapman, F. 1907: Recent foraminifera of Victoria: some littoral gatherings. *Journal of the Queckett Microscopical Club* **10**(61): 117–147.

Chapman, F., Parr, W.J. & Collins, A.C. 1934: Tertiary foraminifera of Victoria, Australia – the Balcombian deposits of Port Phillip, Part III. *Journal of the Linnaean Society of London* **38**: 553–557.

Chen, Z., Xu, S., Zhou, K. & Yang, G. 2011: Whale phylogeny and rapid radiation events revealed using novel retroposed elements and their flanking sequences. *BMC Evolutionary Biology* **11**: 314–339.

Collins, A.C. 1958: Foraminifera. *In* Scientific Reports, Great Barrier Reef Expedition, 1928–1929, 6(6). British Museum Natural History: 335–437.

Collins, A.C. 1974: Port Phillip Survey 1957–63 Foraminiferida. *Memoirs of the National Museum of Victoria* **35**: 1–62.

Cushman, J.A. 1915: A monograph of the foraminifera of the North Pacific Ocean. Part 5. *Bulletins of the United States National Museum* **71**(5): 1–108.

Cushman, J.A. 1918: Some Pliocene and Miocene foraminifera of the coastal plain of the United States. *Bulletin of the U.S. Geological Survey* **676**: 1–100.

Cushman, J.A. 1921: Foraminifera of the Philippines and adjacent seas. *Bulletins of the United States National Museum* **100**(4): 1–608.

Cushman, J.A. 1922: Shallow-water foraminifera of the Tortugas region. Publication of the Carnegie Institution 311. *Department of Marine Biology Papers* **17**: 1–85.

Cushman, J.A. 1923: The Foraminifera of the Atlantic Ocean. Part 4. Lagenidae. *Bulletins of the United States National Museum* **104**(4): 1–228.

Cushman, J.A. 1924: Samoan foraminifera. Publication of the Carnegie Institution Washington 342, *Department of Marine Biology Papers* **21**: 1–75.

Cushman, J.A. 1930: The foraminifera of the Atlantic Ocean, Part 7: Nonionidae, Camerinidae, Peneroplidae and Alveolinellidae. *United States National Museum Bulletin* **104**: 79 pp.

Cushman, J.A. 1931: Two new foraminiferal genera from the South Pacific. *Contributions from the Cushman Laboratory for Foraminiferal Research* **7**: 78–82.

Cushman, J.A. 1933: The foraminifera of the tropical Pacific collections of the "Albatross", 1899–1900. *Bulletin of the Smithsonian Institution, United States National Museum* **161**(2): 1–79.

Cushman, J.A. 1936: Some new species of *Elphidium* and related genera. *Contributions from the Cushman Laboratory for Foraminiferal Research* **12**: 78–89.

Cushman, J.A. & Edwards, P.G. 1937. *Astrononion*, a new genus of the Foraminifera, and its new species. *Contributions from the Cushman Laboratory for Foraminiferal Research* **13**: 29–36.

Cushman, J.A. & Ozawa, Y. 1928: An outline of a revision of the Polymorphinidae. *Contributions from the Cushman Laboratory for Foraminiferal Research* **4**: 13–21.

Cushman, J.A. & Ozawa, Y. 1930: A monograph of the foraminiferal Family Polymorphinidae, recent and fossil. *Proceedings of the United States National Museum* **77**: 1–195.

Cushman, J.A., Todd, R. & Post, R.J. 1954: Recent foraminifera of the Marshall Islands. *In* "Bikini and nearby atolls; Part 2, Oceanography (biologic)". *United States Geological Survey, Professional Paper* **260-H**: 319–384.

Cushman, J.A. & Valentine, W.W. 1930: Shallow-water foraminifera of the Channel Islands of southern California. *Contributions from the Department of Geology of Stanford University* **1**(1): 5–51.

Darragh, T.A. 1985: Molluscan biogeography and biostratigraphy of the Tertiary of southeastern Australia. *Alcheringa* **9**: 83–116.

Darragh, T.A. 1971. *In* Sutherland, F.L & Kershaw, R.C. 1971: The Cainozoic geology of Flinders Island. *Papers and Proceedings of the Royal Society of Tasmania* **105**: 157. 158.

Darragh, T.A. & Kendrick, G.W. 1971: *Zenatiopsis ultima* sp. nov., terminal species of the *Zenatiopsis* lineage (Bivalvia: Mactridae). *Proceedings of the Royal Society of Victoria* **84**: 87–92.

Deshayes, G.P. 1832: Encyclopédie méthodique: Histoire naturelle des Vers. 2(2), Mme V. Agasse, Paris, 145–594.

Dickinson, J.A., Wallace, M.W., Holdgate, G.R., Gallagher, S.J. & Thomas, L. 2002: Origin and timing of the Miocene-Pliocene unconformity in southeast Australia. *Journal of Sedimentary Research* **72**: 288–303.

Dimmock, G.M. 1957: Soils of Flinders Island. CSIRO Division of Soils Report 85/86. *Soils and land use series* **23**: 1–68.

Dorman, F.H. 1966: Australian Tertiary paleotemperatures. *Journal of Geology* **74**: 49–61.

Egger, J.G. 1857: Die Foraminiferen der Miocän-Schichten bei Ortenburg in Nieder -Bayern. Neues Jahrbuch für Mineralogie, Geognosie, Geologie, und Petrefakten-Kunde: 266–311.

Ehrenberg, C.G. 1861: Elemente des tiefen Meeresgrundes im Mexikanischen Goldstrome bei Florida: über die Tiefgrund-Verhältnisse des Oceans am Eingange der Davisstrasse und bei Island. Monatsbericht der Königlichen *Preussischen Akademie der Wissenschaften zu Berlin* (1861): 275–315.

Ehrenberg, C.G. 1873: Mikrogeologische Studien über das kleinste Leben der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss. *Physikalische Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin* (1872): 131–397.

Fichtel, L., von & Moll, J.P.C., von, 1798: *Testacea microscopica*, aliaque minuta ex generibus *Argonauta* et *Nautilus*, ad naturam picta et descripta: Camesina, Vienna.

Finlay, H.J. 1940: New Zealand foraminifera: key species in stratigraphy – No. 4. *Transactions of the Royal Society of New Zealand* **69**: 448–472.

Fordyce, R.E. 1982: A review of Australian fossil Cetacea. *Memoirs of the National Museum of Victoria* **43**: 43–58.

Fordyce, R.E. & de Muizon, C. 2001: Evolutionary history of cetaceans: a review. *In* Mazin, J.-M. & de Buffrénil, V.(eds). *Secondary adaptations of tetrapods to life in water*. Verlag Dr Friedrich Pfeil, Munich: 169–33.

Fordyce, R.E., Quilty, P.G. & Daniels, J. 2002: *Australodelphis mirus*, a bizarre new toothless ziphiid-like fossil dolphin (Cetacea: Delphinidae) from the Pliocene of Vestfold Hills, East Antarctica. *Antarctic Science* **14**: 37–54.

Fornasini, C. 1886: Foraminiferi illustrati da Soldani e citati dagli autori: contribuzione allo studio dei Foraminiferi fossili negli strati Neogenici d'Italia e viventi nel Mediterraneo. *Bollettino della Società Geologica Italiana e del Servizio Geologico d'Italia* **1**:132–254.

Fornasini, C. 1887: Varieta di Lagena fossile negli strati a Pecten hystriz del Bolognese. *Bollettino della Società Geologica Italiana e del Servizio Geologico d'Italia* (1886): 350–353.

Fulton, T.L. & Strobeck, C. 2010: Multiple markers and multiple individuals refine true seal phylogeny and bring molecules and morphology back in line. *Proceedings of the Royal Society* B **277**: 1065–1070.

Gallagher, S.J., Greenwood, D.R., Taylor, D., Smith, A.J., Wallace, M.W. & Holdgate, G.R. 2003: The Pliocene climatic and environmental evolution of southeastern Australia: evidence from the marine and terrestrial realm. *Palaeogeography, Palaeoclimatology, Palaeoecology* **193:** 349–382.

Galloway, J.J. & Wissler, S.G. 1927: Pleistocene foraminifera from the Lomita Quarry, Palos Verdes Hills, California. *Journal of Paleontology* **1**: 35–87.

Germain, L. 1930: Mollusques terrestres et fluviatiles (première partie). *Faune de France* **21**: 1–477.

Gibbard, P.L., Head, M.J., Walker, M.J.C. and the Subcommission on Quaternary Stratigraphy 2009: Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with a base at 2.58 Ma. *Jounal of Quaternary Science* **25**: 96–102.

Haig, D.E. 1997: Foraminifera from Exmouth Gulf, Western Australia. *Journal of the Royal Society of Western Australia* **80**: 263–280.

Hansen, H.J. & Revets, S. 1992: A revision and reclassification of the Discorbidae, Rosalinidae, and Rotaliidae. *Journal of Foraminiferal Research* **22**: 166–180.

Hantken, M. von 1875: Die fauna der Clavulina szaboi schichten. I. Foraminiferen. *Mittheilungen Jahrbuche Königlichen Ungarischen Geolischen Anstalt* (1881) **4**: 1–93.

Haq, B.U., Hardenbol, J. & Vail, P.R. 1987: The new chronostratigraphic basis of Cenozoic and Mesozoic sea level cycles. *Special Publication of the Cushman Foundation for Foraminiferal Research* **24**: 7–13.

Hartmann, G. 1978: Zur Kenntnis des Eulitorals der australischen Kusten unter besonderer Berucksichtigung der Polychaeten und Ostracoden. Teil 1. Die Ostracode n Ordnung Podocopida G.W. Muller, 1894 der tropisch- subtropischen Westkust e Australiens (zwischen Derby im Norden und Perth im Suden). *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* **75**: 63–219.

Hartmann, G. 1979: Zur Kenntnis des Eulitorals der australischen Kusten unter besonderer Berucksichtigung der Polychaeten und Ostracoden. Teil 3. Die Ostracoden der Ordnung G.W. Muller, 1894 der warm-temperierten (antiborealen) West-und Sudwestkuste Australiens (zwischen Perth im Norden und Eucla im Suden). *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* **76**: 219–301.

Hartmann, G. 1980: Zur Kenntnis des Eulitorals der australischen Kusten unter besonderer Berucksichtigung der Polychaeten und Ostracoden. Teil 5. Die Ostracoden der Ordnung G.W. Muller, 1894 der warm-temperierten und subtropisch –tropischen Kustenabschnitte der Sud und Sudostkuste Australiens (zwischen Ceduna im Westen und Lake Entrance im Osten). *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* **77**: 11–204.

Hartmann, G. 1981: Zur Kenntnis des Eulitorals der australischen Kusten unter besonderer Berucksichtigung der Polychaeten und Ostracoden. Teil 7. Die Ostracoden der Ordnung G.W. Muller, 1894 der subtropisch –tropischen Ostkuste Australiens (zwischen Eden im Suden und Lake Heron Island im Norden). *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* **78**: 97–149.

Haug, G.H., Tiedemann, R., Zahn, R. & Ravelo, A.C. 2001: Role of Panama uplift on oceanic freshwater balance. *Geology* **29**: 207–210.

Haynes, J.R. 1973: Cardigan Bay Recent foraminifera (Cruises of the R. V. Antur, 1962-1964). *Bulletin of the British Museum (Natural History), Zoology,* Supplement **4**: 1–245.

Hayward, B.W., Grenfell, H. R., Reid, C. M. & Hayward, K. A. 1999: Recent New Zealand shallow-water benthic foraminifera: taxonomy, ecologic distribution, biogeography, and use in paleoenvironmental assessment. *Institute of Geological and Nuclear Sciences, Monograph* **21**: 1–258.

Hayward, B.W., Hollis, C.J. & Grenfell, H.R. 1997: Recent Elphidiidae (Foraminiferida) of the south-west Pacific and fossil Elphidiidae of New Zealand. *Institute of Geological and Nuclear Sciences Monograph* **16**: 1–166.

Hayward, B.W., Tendal, O.S., Carter, R., Grenfell, H.R., Morgans, H.E.G., Scott, G.H., Strong, C.P. & Hayward, J.J. 2012: Phylum Foraminifera. Foraminifera and Xenophyophores. *In* Gordon, D.P. (ed.) *New Zealand Inventory of Biodiversity: A Species 2000 Symposium Review 3*. Canterbury University Press, Christchurch: 242–287.

Heron-Allen, E. & Earland, A. 1922: Protozoa. Part 2. Foraminifera. British Antarctic (Terra Nova) Expedition, 1910. *Zoology* **6**(2): 25–268.

Heron-Allen, E. & Earland, A. 1930: The foraminifera of the Plymouth District. Part 1. *Journal of the Royal Microscopical Society*, ser. 3, **50**: 46–84.

Heron-Allen, E. & Earland, A. 1932: Foraminifera. Part 1. The ice-free area of the Falkland Islands and adjacent seas. *Discovery Reports* **4**: 291–460.

Hofker, J. 1951: The foraminifera of the Siboga Expedition. Part 3, Siboga Expeditie, Monographie IVa. E.J. Brill, Leiden: 1–513.

Hofker, J. 1969: Recent foraminifera from Barbados. *Studies on the fauna of Curaçao and other Caribbean islands* **31**: 1–158.

Holdgate, G.R., Wallace, M.W., Gallagher, S.J., Smith, A.J., Keene, J.B., Moore, D. & Shafik, S. 2003: Plio/Pleistocene tectonics and eustasy in the Gippsland Basin, southeast Australia: Evidence from magnetic imagery and marine geological data. *Australian Journal of Earth Sciences* **50**: 403–426.

Hornibrook, N. de B. 1958: New Zealand foraminifera: Key species in stratigraphy – no. 6. *New Zealand Journal of Geology and Geophysics* **1**: 653–676.

Hornibrook, N. de B. 1961: Tertiary foraminifera from Oamaru District (N.Z). Part 1 systematics and distribution. *New Zealand Geological Survey Paleontological Bulletin, Wellington* **34**: 1–192.

Hornibrook, N. de B. 1982: Late Miocene to Pleistocene Globorotalia (Foraminiferida) from DSDP Leg 29, Site 284, southwest Pacific. *New Zealand Journal of Geology and Geophysics* **25**: 83–99.

Hornibrook, N. de B., Brazier, R.C. & Strong, C.P. 1989: Manual of New Zealand Permian to Pleistocene foraminiferal biostratigraphy. *New Zealand Geological Survey Paleontological Bulletin* **56:** 175pp.

Howchin, W.J. 1889: The Foraminifera of the older Tertiary of

Australia (No. 1, Muddy Creek, Victoria). *Transactions of the Royal Society of South Australia* **12**: 1–20.

ICS Subcommission on Quaternary Stratigraphy 2009: Formal subdivision of the Pleistocene Series/Epoch. . http/www.quaternary.stratigraphy.org.uk/definitions/pleistocenesubdivision/ 3pp.

James, N.P., Bone, Y., Carter, R.M. & Murray-Wallace, C.V. 2006: Origin of the Late Neogene Roe Plains and their calcarenite veneer: implications for sedimentology and tectonics in the Great Australian Bight. *Australian Journal of Earth Sciences* **53**: 407–419.

Jenkins, D.J. 1960: Planktonic foraminifera from the Lakes Entrance oil shaft, Victoria, Australia. *Micropaleontology* **6**: 345–371.

Johnston, R.M. 1879: Notes on certain Tertiary and Post-Tertiary deposits on Flinders, Barren, Badger, and other islands in Bass Straits. *Papers and Proceedings of the Royal Society of Tasmania* (1878): 48, 49.

Jones, R.W. 1994: *The Challenger foraminifera*. Oxford Science publications, Oxford: 149 pp.

Jones, T.R. 1895: A monograph of the foraminifera of the Crag. Part 2. *Monograph of the Palaeontographical Society, London*: 73–210.

Karrer, F. 1865: Die Foraminiferen-fauna des Tertiär Gründsandsteines der Orakei - Bay bei Auckland. *Novara Expedition 1857-1859, Geologische Theil* **1**(2): 69–86.

Karrer, F. 1877: Geologie der Kaiser Franz-Josefs Hochquellen-Wasserleitung, eine Studie in den Tertiär-Bildungen am Westrande des alpinen Theiles der Niederung von Wien. *Abhandlungen der kaiserlich - königlichen Geologischen Reichsanstalt* **9**: 1–420.

Kennett, J.P. & Srinivasan, M.S. 1980: Surface ultrastructural variation in Neogloboquadrina pachyderma (Ehrenberg): phenotypic variation and phylogeny in the late Cenozoic. *In* Sliter, W.V. (ed.) Studies in marine micropaleontology. *Special Publication, Cushman Foundation for Foraminiferal Research* **19**: 134–162.

Kennett, J.P. & Srinivasan, M.S. 1983: *Neogene Planktonic foraminifera: A Phylogenetic Atlas*. Hutchinson Ross Publishing Co., Stroudsburg: 263 p.

Lamarck, J.B. 1804: Suite des Mémoires sur les fossiles des environs de Paris. *Annales du Muséum National d'Histoire Naturella Paris* **5**: 349–357.

Lankford, R.R. 1973: *In* Lankford, R.R. & Phleger, F. Foraminifera from the nearshore turbulent zone, western North America. *Journal of Foraminiferal Research* **3**: 101–132.

Li, Q. & McGowran, B. 1995: Comments on some southern Australian foraminifera and description of the new genus *Parredicta*. *Transactions of the Royal Society of South Australia* **119**: 99–112.

Li, Q. & McGowran, B. 2000: Miocene foraminifera from Lakes Entrance Oil Shaft, Gippsland, southeastern Australia. *Memoir of the Association of Australasian Palaeontologists* **22**: 1–142.

Li, Q., Quilty, P.G., Moss, G. & McGowran, B. 1996: Southern Australian endemic and semi-endemic foraminifera: a preliminary report. *Journal of Micropaleontology* **15**(2): 169–185.

Linné, C. 1758: Systema Naturae per regna tria naturae, secundun classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis: 10th ed., G. Engelman, Lipsiae 1: 824 pp.

Loeblich, A.R. Jr & Tappan, H. 1953: Studies of Arctic Foraminifera. *Smithsonian Miscellaneous Collections* **121**(7): 1–150.

Loeblich, A.R. Jr & Tappan, H. 1987: Foraminiferal genera and their classification. Van Nostrand Reinhold Company, New York: 2 vol., 970 pp, 847 pls.

Loeblich, A.R. Jr & Tappan, H. 1994: Foraminifera of the Sahul Shelf and Timor Sea. *Special Publication of the Cushman Foundation for Foraminiferal Research* **31**: 661 pp

Ludbrook, N.H. 1961: Stratigraphy of the Murray Basin in South Australia. *Bulletin of the Geological Survey of South Australia* **36**: 1–96.

McCulloch, I. 1977: Qualitative observations on Recent foraminiferal tests with emphasis on the Eastern Pacific. Parts I–III. University of Southern California, Los Angeles: 1079 pp.

Mallett, C.W. 1982: Late Pliocene planktonic foraminifera from subsurface shell beds, Jandakot, near Perth. *Search* **13**: 35, 36.

Maung, T.U. & Nicholas, E. 1990: A regional review of the offshore Gippsland Basin. Bureau of Mineral Resources, Australia, Report 297.

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, N. & Pekar, S.F. 2005: The Phanerozoic record of global sea-level change. *Science* **310**: 1293–1298.

Montagu, G. 1803: Testacea Brittanica, or Natural history of British shells, land and fresh water, including the most minute. J.S. Hollis, Romsey.

Murray, J.W. 1971: *An Atlas of British Recent foraminiferids*. Heinemann Educational Books, London: 244 pp.

Murray-Wallace, C.W. & Goede, A. 1995: Aminostratigraphy and electron-spin -resonance dating of Quaternary coastal neotectonism in Tasmania and the Bass Strait islands. *Australian Journal of Earth Sciences* **42**: 51–67.

Natland, M.L. 1938: New species of foraminifera from off the west coast of North America and from the late Tertiary of the Los Angeles Basin. *Bulletin of Scripps Institution of Oceanography, technical series* **4**(5): 137–164.

Orbigny, A. d' 1826: Tableau méthodique de la classe des Céphalopodes. *Annales des Sciences Naturelles, Paris*, ser. 1 **7**: 245–314.

Orbigny, A. d' 1839: Voyage dans l'Amerique meridionale; Foraminiferes. *Levrault, Strasbourg* **5**(5): 1–86.

Orbigny, A. d' 1846: Foraminiféres fossiles du Bassin Tertiaire de Vienne (Autriche). Gide et Compe. Paris: 312 pp.

Parker, W.K. & Jones, T.R. 1865: On some foraminifera from the North Atlantic and Arctic Oceans, including Davis Straits and Baffin's Bay. *Philosophical Transactions of the Royal Society* **155**: 325–441.

Parr, W.J. 1932: Victorian and South Australian shallow-water foraminifera. *Proceedings of the Royal Society of Victoria* **44**: 1–14; 218–234.

Parr, W.J. 1939: Foraminifera of the Pliocene of south-eastern Australia. *Mining and Geological Journal* **1**(4): 65–71.

Parr, W.J. 1950: Foraminifera. Reports of the B.A.N.Z. *Antarctic Research Expedition 1929-1931. ser. B (Zoology, Botany)* **5**(6): 232–392.

Quilty, P.G. 1969: On two recorded species of Tertiary foraminifera from Fossil Bluff, Wynyard. *Papers and Proceedings of the Royal Society of Tasmania* **103**: 97–98.

Quilty, P.G. 1972: The biostratigraphy of the Tasmanian Tertiary marine. *Papers and Proceedings of the Royal Society of Tasmania* **106**: 25–44.

Quilty, P.G. 1974: Tasmanian Tertiary Foraminifera. Part 1. Textulariina, Miliolina, Nodosariacea. *Papers and Proceedings of the Royal Society of Tasmania* **108**: 1–106.

Quilty, P.G. 1977: Tasmanian Tertiary Foraminifera. Part 2, chiefly Spirillinacea to Glabratellidae. *Papers and Proceedings of the Royal Society of Tasmania* **111**: 69–109.

Quilty, P.G. 1982: Tasmanian Tertiary Foraminifera. Part 3, Discorbacea (Eponididae) to Nonionacea. *Papers and Proceedings of the Royal Society of Tasmania* **116**: 5–52.

Quilty, P.G. 1985: A Pliocene foraminiferid fauna from Flinders Island. *Papers and Proceedings of the Royal Society of Tasmania* **119**: 89–91.

Quilty, P.G. & Whitehead, J. (in press): ----------- n. gen. (Polymorphinidae) from the earliest Pliocene of Flinders Island, Tasmania. *Journal of Foraminiferal Research*

Reuss, A.E. 1848: Die fossilen Polyparien des Wiener Tertiärbeckens. *Naturwissenschaftliche Abhandlungen* **2**(1): 1–109.

Reuss, A.E. 1851: Über die fossilen Foraminiferen und Entomostraceen der Septarienthone der Umgegend von Berlin. *Zeitschrift der Deutschen Geologischen Gesellschaft Berlin* **3**: 49–91.

Reuss, A.E. 1862: Paläontologische Beitrage. 1. Über eine neue Oligocäne Scalpellum-Art. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Classe* (1861) **44**(1): 301–342.

Revets, S. 1993: The revision of the genus *Elongobula* Finlay, 1939. *Journal of Foraminiferal Research* **23**: 254–266.

Revets, S. 2000: Foraminifera of Leschenault Inlet. *Journal of the Royal Society of Western Australia* **83**: 365–375.

Roemer, F.A. 1838: Cephalopoden des Nord-Deutschen tertiären Meersandes. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefakten-Kunde (1838): 381–394.

Sarnthein, M., Bartoli, G., Prange, M, Schmittner, A., Schneider, B., Weinelt, W., Andersen, N. & Garbe-Schönberg, D. 2009: Mid-Pliocene shifts in ocean overturning circulation and the onset of Quaternary-style climates. *Climate of the Past* **5**: 269–283.

Schmidt, D. 2007: The closure history of the Central American Seaway: evidence from isotopes and fossils to models and molecules. *In* Williams, M., Haywood, A.M., Gregory, F.J. & Schmidt, D.N. (eds) Deep time perspectives in climate change: marrying the signal from computer models and biological proxies. *Special Publications of the Micropalaeontological Society, The Geological Society, London*: 427–442.

Schwager, C. 1866: Fossile Foraminiferen von Kar Nikobar, Reise der Österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859. 2(2) Paläontologische Mitteilungen (2): 187–268.

Seguenza, G. 1862: Die terreni Terziarii del distretto di Messina. Parte II. Descrizione dei Foraminiferi Monotalamici delle marne Mioceniche del distretto di Messina. Capra, Messina: 84 pp.

Seguenza, G. 1862: Prime ricerche intorno al rizopodi fossili delle argille Pleistocenichedei dintorni di Catania. *Atti Accademia Gioenia Scienze Naturali ser* 2, **18**: 85–126.

Sellier de Civrieux, J.M. 1977: Las Discorbidae del Mar Caribe, frente a Venezuela. *Cuardenos Oceanograficos, Universidad de Oriente, Cumana* **6**: 1–44.

Singleton, F.A. 1941: The Tertiary geology of Australia. *Proceedings of the Royal Society of Victoria* **53**: 1–119.

Singleton, O.P., McDougall, I. & Mallett, C.W. 1976: The Pliocene/Pleistocene boundary in Southeastern Australia. *Journal of the Geological Society of Australia* **23**: 299-311.

Spry, A. & Banks, M.R. 1962: The geology of Tasmania. *Journal of the Geological Society of Australia* **9**: 107–362.

Stache, G. 1864: Die Foraminiferen die tertiären Mergel des Whaingoroa-Hafens (Prov. Auckland). *Novara Expedition, 1857–1859, 1, Geologische Theil* 159–304.

Sutherland, F.L. & Kershaw, R.C. 1971: The Cainozoic geology of Flinders Island, Bass Strait. *Papers and Proceedings of the Royal Society of Tasmania* **105**: 151–176.

Takayanagi, Y. & Saito, T. 1962: Planktonic foraminifera from the Nobori Formation, Shikoku, Japan. *Tohoku University Scientific Reports, ser. 2 (Geology)* **5**: 67–106.

Taylor, D.J. 1971: *In* Sutherland, F.L & Kershaw, R.C. 1971: The Cainozoic geology of Flinders Island. *Papers and Proceedings of the Royal Society of Tasmania* **105**: 164.

Terquem, O. 1875: Essai sur le classement des animaux qui vivent sur le plage et dans les environs de Dunkerque. *Paris* **1**: 1–54.

Terquem, O. 1878: Les Foraminiféres du Pliocène Supérieur de lîle de Rhodes. *Mémoires de la Société Géologique de France*, ser. 3, **1**: 1–135.

Thalmann, H.E. 1933: Nachtrag zum Nomenclator zu Brady's Tafelband der Foraminiferen der "Challenger"-Expedition. *Eclogae Geologicae Helveticae* **26**: 251–255.

Thalmann, H.E. 1951: Mitteilungen über Foraminiferen XI. *Eclogae Geologicae Helveticae* (1950) **43**: 221–225.

Thompson, B.R. 1986: The Gippsland Basin – development and stratigraphy. *In* Glenie, R.C. (ed.) *Second south-eastern Australia oil exploration symposium*. The Petroleum Exploration Society of Australia Symposium: 57–64.

Van Morkhoven, F.P.C.M., Berggren, W.A. & Edwards, A.S. 1986: Cenozoic cosmopolitan deep-water benthic foraminifera. *Bulletin des Centres de Recherches Exploration-Production ELF-Aquitaine, Memoir 11*, Pau: 419 pp.

Vella, P. 1957: Studies in New Zealand foraminifera; part I. Foraminifera from Cook Strait. Part II. Upper Miocene to Recent species of the genus Notorotalia. *Paleontological Bulletin of the New Zealand Geological Survey* **28**: 64 pp.

Vella, P. 1963: Some foraminifera from the upper Miocene and Pliocene of Wairarapa New Zealand. *Transactions of the Royal Society of New Zealand, (Geology)* **2**: 1–14.

Vilks, G. 1975: Comparison of *Globorotalia pachyderma* (Ehrenberg) in the water column and sediments of the Canadian Arctic. *Journal of Foraminiferal Research* **5**: 313–325.

Walker, G. & Boys, W. 1784: Testacea minuta rariora nuperrime detecta in arena littoris Sandvicensis. J. March, London: 25 pp.

Walker, G. & Jacob, E. 1798: *In* Adams, G. *Esssays on the Microscope, containing a practical description of the most improved microscopes; a general history of insects*. Second edition, Dillon & Keating, London: 629–645.

Walton, W.R. 1964: Recent foraminiferal ecology and paleoecology. *In* Imbrie, J. & Newell, N. (eds) *Approaches to Paleoecology*. John Wiley and Sons, New York: 151–237.

Warne, M.T. & Soutar, B. 2012: Pliocene coastal palaeomorphy and ostracod faunas of the Bass Strait hinterland, southeast Australia. *Hydrobiologia* **688**: 93–112.

Wilkins, R.W.T. 1962: Cainozoic marine succession *In* Spry, A. & Banks, M.R. (eds) *The Geology of Tasmania*. *Journal of the Geological Society of Australia* **9**(2): 35.

Wilkins, R.W.T. 1963: Relationships between the Mitchellian, Cheltenhamian and Kalimnan stages in the Australian Tertiary. *Proceedings of the Royal Society of Victoria* **76**: 39–59.

Williamson, W.C. 1848: On the Recent British species of the genus Lagena. *Annals and Magazine of Natural History* ser. 2, **1**: 1–20.

Yassini, I. & Jones, B.J. 1995: Recent Foraminifera and Ostracoda from estuarine and shelf environments on the southeastern coast of Australia: University of Wollongong Press, Wollongong: 484 pp.

Zwingmann, H., Sutherland, F.L., Graham, I., Forsyth, S.M., Everard, J.L. & Wartho, J.-A. 2004: New K-Ar and Ar-Ar ages for Tasmanian basalts: implications for volcanic evolution following Tasman rifting. Abstracts, *Geological Society of Australia, 17th Convention, Hobart 2004* **73**: 141.

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APPENDIX 1. SYSTEMATIC PALAEONTOLOGY

Species allocated to the genera *Elphidium* and *Parrellina* have been identified, where possible, using the taxonomy employed by Hayward *et al.* (1997).

Unilocular species. There have been many attempts in recent decades to develop a classification that make sense of the extreme diversity of unilocular forms. Most criteria depend on minor variation on gross shape or "ornamentation" but few schemes seem to be based on any concept of genetic limits. One element in this argument is the role of details of the pattern on the neck – spiral, with horizontal striae, a bare neck or flared apertural margin. Here, a conservative approach recognises few genera.

The faunas are rich in unilocular forms and the identity and synonymy of many is confused. It is the "lumpers" vs "splitters" argument. For example, in *Lagena* some species are interpreted very broadly, others narrowly. Yassini & Jones (1995) discussed and illustrated many "species" that in other works would be taken as one. Their figures 309–316, while taken as four species, in other concepts could all be taken as variants of *L. sulcata.* The approach taken here is to compare forms with published figures, whatever the approach of the authors but to accept a limited number of genera.

Fissurina and related genera are present in many samples but usually as one or two specimens of a bewildering array of possible names even for the one form. Many species occur in very few samples. Identification is based on comparison with forms recorded in the synonymy.

The category of unidentifiable species consists dominantly of fragments of robust species, commonly eroded and rounded, and indicates that the environment at some stage was highly turbulent, apparently in conflict with the evidence of good preservation of many otherwise delicate species. It may suggest some re-cycling from earlier units, althoughy none are known.

The supraordinal classification of Foraminifera has been in a state of flux over recent decades but that below class has been comparatively settled. For this study, I use the hierarchy summarised by Hayward *et al.* (2012) but use the termination *–acea* for superfamily. While all species listed on appendix table 1 are included below, remarks are given for very few. The synonymy is not exhaustive but intended to outline the taxonomy employed with the original description, some Australian references from nearby sites, particularly Quilty (1974, 1977, 1982), and Li & McGowran (2000) as the authority.

An asterix indicates that the species is figured on the plates.

PHYLUM FORAMINIFERA d'Orbigny, 1826
CLASS ATHALAMEA Haeckel, 1862
ORDER LITUOLIDA Lankester, 1885
Superfamily VERNEUILINACEA Cushman, 1911
Family VERNEUILINIDAE Cushman, 1911

Gaudryina convexa **(Karrer, 1865)**
Textilaria convexa Karrer 1865, 78, pl. 16, fig. 8.
Gaudryina convexa (Karrer): Burdett *et al.* 1963, 513–530; Quilty 1974, 39, pl. 1 figs 14, 15; Li & McGowran 2000, 53, figs 24S, U, V.
Remarks: A single poorly preserved specimen in NPD1985. It is not recorded from Sections 11 or 12.

ORDER TEXTULARIIDA Lankester, 1885
Superfamily TEXTULARIACEA Ehrenberg, 1838
Family TEXTULARIIDAE Ehrenberg, 1838

Siphotextularia saulcyana **(d'Orbigny, 1839)**
Textularia saulcyana d'Orbigny 1839, 146, pl. 1, figs 21, 22.
Siphotextularia saulcyana (d'Orbigny, 1839); Li & McGowran 2000, 50, figs 24I, J.

Siphotextularia **cf** ***saulcyana*** **(d'Orbigny, 1839)**
cf. *Siphotextularia saulcyana* (d'Orbigny): Li & McGowran 2000, 50, fig. 241J.
Remarks: A fragment of the juvenile end of a specimen. Apertural details not visible.

Textularia candeiana **d'Orbigny, 1839**
Textularia candeiana d'Orbigny 1839, 143, pl. 1, figs 25-27; Hayward *et al.* 1999, 90, pl. 2, figs 24-26.
Textularia conica d'Orbigny: Yassini & Jones 1995, 75, figs 101, 109.

ORDER MILIOLIDA Lankester, 1885
Superfamily HEMIGORDIOPSACEA Nikitina, 1969
Family HEMIGORDIOPSIDAE Nikitina, 1969

*** *Gordiospira* sp.** **Pl. 1, fig. 1**
?*Quinqueloculina culebriana* McCulloch, 1977: Yassini & Jones 1995, 83, fig. 193.
Remarks: Initially taken to be *Quinqueloculina,* the specimen appears to be a single post-prolocular chamber. Coiling is a little oblique and thus not in one plane. Yassini & Jones illustrated a specimen that seems identical to the specimen figured here. Chamber boundaries are invisible suggesting they do not exist. This species seems to be an analogue of the Late Palaeozoic *Agathammina.*

Superfamily MILIOLACEA Ehrenberg, 1839
Family HAUERINIDAE Schwager, 1876

Adelosina **sp.**
Remarks: A compressed quinqueloculine form with regular angular periphery and slightly extended neck, narrow aperture and single plate-like tooth. It is akin to *A. bicornis* but has a more angular periphery.

Flintina intermedia **(Howchin, 1889)**
Hauerina intermedia Howchin 1889, 4, pl. 1, figs 6a,b.
Flintina intermedia (Howchin, 1889); Parr 1939, 70, figs 24a, b; Carter 1964, 63, pl. 1, figs 18, 19.
Remarks: This species was taken by Parr (1939) as a foraminiferal index for the Kalimnan on southeastern Australia. It is known here as a single specimen from NPD1985.

Miliolinella subrotundum **(Montagu, 1803)**
Vermiculum subrotundum Montagu 1803, 521.
Miliolinella subrotunda (Montagu): Yassini & Jones 1995, 88, figs 1984, 195
Miliolinella subrotundata (Montagu): Hayward *et al.* 1999, 96, pl. 3, fig. 24.
Remarks: The few specimens are poorly preserved, partly through diagenesis and partly through breakage.

Pseudoflintina crassatina **(Brady, 1884)**
Miliolina crassatina Brady 1884, 16, pl. 8, figs 5a, b.
Pseudoflintina crassatina (Brady, 1884). Yassini & Jones 1995, 86, fig. 213.

Pyrgo **spp.**
Remarks: *Pyrgo* occurs rarely throughout the sections. All are characterised by a marked expanded chamber on one side and by T-shaped teeth, in contrast to most species of this type. One (*P.* sp. 1) has a thick adapical spine.

Pyrgo **sp. 1**
Remarks: A single inflated specimen with thick, marked adapical spine and slightly angular periphery.

****Quinqueloculina asperula*** **Seguenza, 1862** **Pl. 1, fig. 2**
Quinqueloculina asperula Seguenza 1862, 120, pl. 2, figs 6-6b.
Remarks: While grossly similar to *Q. anguina arenata* Said, 1949 (Yassini & Jones 1995, 83, figs. 180–182), it lacks an extended neck and this also distinguishes it from *Siphonaperta.*

Quinqueloculina lamarckiana **d'Orbigny, 1839**

Quinqueloculina lamarckiana d'Orbigny, 1839, 189, pl. 11, figs 14, 15: Yassini & Jones, 1995, 84, figs 203–205, 208.

*Quinqueloculina oblonga (Montagu, 1803) Pl. 1, fig. 3

Vermiculum oblongum Montagu 1803, 179, pl.10, figs 15-17.
Triloculina oblonga (Montagu): Yassini & Jones, 1995, 92, figs 188–192, 196, 197. *Quinqueloculina oblonga* (Montagu): Hayward *et al.* 1999, 102, pl. 4, figs 27, 28. *Quinqueloculina* sp. 6: Haig, 1997, figs 4, 14, 15.

Remarks: A survey of the synonymy of this form shows that it is variously placed in *Triloculina, Quinqueloculina* or *Miliolinella*, perhaps depending on the ability of the aperture to reveal its features. Specimens examined in detail have a quinqueloculine tooth. Here, Hayward *et al.* (1999) are followed even though some specimens could legitimately be placed in *Miliolinella.*

*Quinqueloculina seminulum (Linné, 1758) Pl. 1, fig. 4

Serpula seminulum Linné 1758, 786.
Quinqueloculina seminulum (Linné): Quilty 1974, 52, pl. 2, figs 52, 53; Yassini & Jones, 1995, 85, figs 198, 199; Hayward *et al.* 1999, 103, pl. 5, figs 9, 10.

Remarks: The most widespread of the miliolids. Several specimens have walls that are pitted.

*?Quinqueloculina poeyana victoriensis Collins, 1974 Pl. 1, fig. 5

?*Quinqueloculina poeyana victoriensis* Collins 1974, 16, pl. 1, figs 6, b.

Remarks: The identification is tentative as the characteristic apertural details are not preserved. Collins (*op. cit.*) noted that the form he described has been found in older sediments of Victoria.

***Quinqueloculina* sp. A**

Remarks: This form occurs in the NPD1985 and appears to have apertures at each extremity. The most similar form appears to be *Quinqueloculina quinquecarinata* Collins, 1958, which has striae or narrow costae particularly along early chambers.

***Siphonaperta ammophila* (Parr, 1932)**

Quinqueloculina ammophila Parr 1932, 8, pl. 1, fig. 10.
Siphonaperta ammophila (Parr, 1932). Ludbrook, 1961, 71, pl. 6, fig. 2; Quilty 1974, 56, pl. 2, figs 67, 68.

***Triloculina earlandi* Cushman, 1954**

Triloculina earlandi Cushman *et al.* 1954, 338, pl. 85, fig. 3.

Remarks: Specimens of this form commonly are poorly preserved but integrating of the characters supports the identification.

***Triloculina gilboei* Beck, 1943**

Triloculina gilboei Beck 1943, 594, pl. 101, figs 1–3: Li & McGowran 2000, 55, fig. 22S.

Remarks: This species occurs uniformly with *T. trigonula* and may be an extreme variant.

***Triloculina laevigata* d'Orbigny, 1826**

Triloculina laevigata d'Orbigny 1826, 134 (figures Terquem 1878, 57, pl. 5, figs 20, 21); Quilty 1974, 58, pl. 2, figs 76, 77.

Remarks: Three names could be used for this species and I have chosen d'Orbigny's. Other names are *T. laevigata* but attributed to Terquem, or *T. inflata* d'Orbigny, 1826. It seems all are available and for the same species.

***Triloculina tricarinata* d'Orbigny, 1826**

Triloculina tricarinata d'Orbigny 1826, 299, modeles no 94: Hayward *et al.* 1999, 106, pl. 5, figs 29, 30.

Remarks: Most specimens, while clearly distinct from *T. trigonula* by virtue of sharper periphery to all chambers, are not as sharp as in many identifications and it almost intergrades with *T. trigonula.*

*Triloculina trigonula (Lamarck, 1804) Pl. 1, fig. 6

Miliolites trigonula Lamarck 1804, 351, pl. 17, figs 4a-c.
Triloculina trigonula (Lamarck): Quilty 1974, 59, pl. 2, figs 80, 81; Li & McGowran 2000, 55, fig. 25T; Hayward *et al.* 1999, 106, pl. 5, figs 31, 32.

Remarks: Occurs almost routinely with *T. tricarinata* but always is very dominant.

Family SPIROLOCULINIDAE Wiesner, 1920

***Spiroloculina canaliculata* d'Orbigny, 1846**

Spiroloculina canaliculata d'Orbigny 1946, 269, pl. 16, figs 10-12: Li & McGowran 2000, 56, fig. 25L.

ORDER LAGENIDA Lankester, 1885
Superfamily NODOSARIACEA Ehrenberg. 1838
Family NODOSARIIDAE Ehrenberg. 1838

***Dentalina godjeni* Quilty, 1969**

Dentalina godjeni Quilty 1969, 97, fig. 2; Quilty, 1974, 63, pl. 3, fig. 91.

Remarks: The test is generally smooth and lacks any basal spine. The only 'ornament' is weakly developed longitudinal costae in the final intercameral sutures and/or a few weak surface ribs on the early chambers. Intercameral sutures flush or weakly depressed.

Dentalina subemaciata Parr, 1950

Dentalina subemaciata Parr 1950, 329, pl. 12, fig. 1; Jones 1994, 74, pl. 62, figs 25, 26.

Remarks: A large smooth form over 2 mm long but incomplete.

Dentalina spp. indet.

A few unidentifiable fragments in three samples.

***Frondicularia* juv. sp. indet.**

Remarks: The juvenile of a palmate species lacking a basal spine. It consists of the spherical proloculus and a single frondicularine chamber with a few weakly developed ribs at the base.

Family VAGINULINIDAE Reuss, 1860

*Lagena flatulenta Loeblich & Tappan, 1953 Pl. 1, fig. 7

Lagena flatulenta Loeblich & Tappan 1953, 60, pl. 11, fig. 10; Yassini & Jones 1995, 104, fig. 302.

Remarks: The simplest of forms consisting of a spherical smooth body with simple tubular neck and open aperture. It may be the form recorded by Jones (1994, pl. 56, fig. 14) as *Lagena* sp. nov.

*Lagena perlucida (Montagu, 1803) Pl. 1, fig. 8

Vermiculum perlucida Montagu 1803, 525, pl. 14, fig. 3
Lagena perlucida (Montagu, 1803). Cushman 1923, 46, pl. 8, figs 12, 13; Li & McGowran 2000, 73, fig. 31A

Remarks: Differs from that illustrated by Li & McGowran in having a spiral neck. The costae extend from the base to the apertural end but do not meet at the flat base.

*Lagena striata paucistriata Yassini & Jones, 1995 Pl. 1, fig. 9

Lagena striata paucistriata Yassini & Jones 1995, 106, figs 323–325.

Remarks: This form consists of a simple spherical body with clearly differentiated tubular neck with simple aperture; short basal spine. Surface marked by weakly developed costae.

*Lagena striatospiralata Albani & Yassini, 1989 Pl. 1, fig. 10

Lagena striatospiralata Albani & Yassini 1989, 380, figs 2x, y; Yassini & Jones 1995, 107, figs 314, 315.

Remarks:A simple form with spherical body and well differentiated, long narrow neck with spiral pattern. Surface with numerous fine costae extending from apical end to base. The species has much in common with *L. sulcata* (Walker & Jacob, 1798) and is differentiated on the basis of the multitude of costae and a spiral neck.

*Lagena sulcata (Walker & Jacob, 1798) Pl. 1, fig. 11

Serpula (*Lagena*) *sulcata* Walker & Jacob 1798, 634, pl. 14, fig. 5.
Lagena sulcata (Walker & Jacob): Quilty 1974, 69, pl. 3, fig. 106; Jones 1994, 64, pl. 57, figs 23, 25-27, 33, 34; Li & McGowran 2000, 74, fig. 30W.

Remarks: This is a classic case of "splitters" vs "lumpers" but I have followed Jones (1994) in treating this group of intergradational forms as one species. An abundant form. There does seem to be a differentiation of forms with much more abundant, finer striae that are here placed in *L. striatospiralata*.

*Lagena sp. 1 Pl. 1, fig. 12

Remarks: Elongate, broadest approximately 1/3 of length from base with tapering neck. Surface with 5 narrow, low punctate costae from base, where they join, to the neck. A single specimen in NPD1985. The most similar species appears to be *L. quinquelaterata* Brady, 1881, as figured by Jones (1994, p. 72, pl. 61, figs 15, 16) but *L.* sp. 1 is relatively shorter, has punctae along each costa and lacks a basal spine.

***Lagena* sp. 2** **Pl. 1, fig. 13**
Remarks: A slightly elongate species characterised by dominantly smooth ovoid body tapering gently to neck with single raised ring and flared simple aperture. Lower test with about six radiating short costae that do not join at the base. Haynes (1973) described a similar but more elongate form as *L. doveyensis* but it has an unadorned neck and more costae (he termed them striae) at the base. *L. doveyensis* is only questionably differentiated from *L. semistriata* (Williamson, 1848) (see Jones 1994, pl. 57, figs 13, 14).

***Lagena* sp. 3** **Pl. 1, fig. 14**
Remarks: It is not certain that this is a foraminiferid but body shape and apparent apertural end suggest it is. The surface is marked by very many irregularly circular "outgrowths" with roughened flat tops and deep clefts between.

***?*Lagena* sp.** **Pl. 1, fig. 15**
Remarks: Two specimens in NPD1985. Unilocular, spherical, with finely irregular polygonal surface pattern. It has no neck and the aperture is a simple hole. It is unclear whether or not it is a foraminiferid but it is very similar to many lagenids but lacks a neck. This form is akin to *O. favosopunctata* (Brady, 1881) as figured by Jones (1994, pl. 58, fig. 35) but broken or without a neck.

***Lenticulina foliata* (Stache, 1864)**
Robulina foliata Stache 1864, 245, pl. 23, fig. 24.
Lenticulina foliata (Stache): Li & McGowran 2000, 61, figs 28H, I.
Remarks: The identification is based on general features as the details of the aperture are not clear.

***Palmula longiformis* Bermudez, 1949**
Palmula longiformis Bermudez 1949, 158, pl. 10, figs 14, 15.

***Procerolagena clavata* (d'Orbigny, 1846)** **Pl. 1, fig. 16**
Oolina clavata d'Orbigny 1846, 24, pl. 1, figs 2, 3
Procerolagena clavata (d'Orbigny, 1846). Jones 1994, 62, pl. 56, figs 8, 9.

***Vaginulina vertebralis* Parr, 1932**
Vaginulina vertebralis Parr 1932, 221, pl. 22, fig. 42; Hayward *et al.* 1999, 115, pl. 6, fig. 24.

Family ELLIPSOLAGENIDAE A. Silvestri, 1923

***Cushmanina spiralis* (Brady, 1884)** **Pl. 1, fig. 17**
Lagena spiralis Brady 1884, 468, pl. 114, fig. 9; Loeblich & Tappan 1994, 78, pl. 139, figs 3–9.
Cushmanina tasmaniae (Quilty, 1974): Li & McGowran 2000, 75, fig. 31E.
Remarks: This is the species recorded by Li & McGowran (2000) but has a more elongate body than the holotype of *C. tasmaniae.* The form figured is less regular in growth than other specimens figured to date. The ribs on this species and the specimens figured by Loeblich & Tappan (1994) are robust and lack the perforations obvious on the figures of *Cushmanina* by Quilty (1974), Jones (1994) and Li & McGowran (2000).

***Fissurina lucida* (Williamson, 1848)** **Pl. 1, figs 18, 19**
Fissurina marginata (Montagu) var. *lucida* Williamson 1848, 17, pl. 2, fig. 7
Fissurina lucida (Williamson, 1848); Loeblich & Tappan 1994, 90, pl. 156, figs 1–3; Hayward *et al.* 1999, 119, pl. 7, figs 20, 21.
Fissurina annectens (Burrows & Holland, 1895). Li & McGowran 2000, 79, fig. 32F.
Remarks: This is the form illustrated by Li & McGowran (2000) as *F. annectens* (Burrow & Holland, 1895) but it differs from *F. annectens* in lacking a basal spine and also a narrow fissure around the lower part of the test. The test surface lacks ornamentation of any kind. The forms recorded here vary from inflated (as illustrated by Hayward *et al., op cit.*) to less so.

***Fissurina marginata* (Montagu, 1803)** **Pl. 1, figs 20, 21**
Vermiculum marginatum Montagu 1803, p. 524
Fissurina crassiannulata Collins, 1974; Li & McGowran 2000, 80, figs 32B, C.
Fissurina marginata (Montagu, 1803); Hayward *et al.* 1999, 119, pl. 7, figs 22, 23.
Remarks: This is the form illustrated by Li & McGowran (2000) as *F. crassiannulata* but the form discussed by Li & McGowran and recorded here lacks the characteristic thick solid keel, which is almost as thick as the main body of the test in Collins' species. Li & McGowran (2000) figured a species as *F. marginata* but their specimen has a clear flange developed around the base of the test and is not the species recorded here.

***Fissurina pacifica* Parr, 1950** **Pl. 1, figs 22, 23**
Fissurina pacifica Parr 1950, 314, pl. 9, fig. 10a, b; Collins 1974, 27; Jones 1994, 69, pl. 60, fig. 8.
Remarks: A slightly elongate form with smooth surface; marked by two keels on either side of a prominent punctate zone around the entire chamber, but not joining at the base. Neck short and broadening near the chamber. Two specimens were recovered from the NPD1985 originally included by Quilty (1985) in *Fissurina* spp. It was described originally from modern sediments of nearby Bass Strait.

***Fissurina* sp.** **1 Pl. 1, figs 24, 25**
Remarks: This species is characterised by an almost circular test with clearly defined groove immediately in from the margin around the body but absent from just below the aperture which is very slightly extended. In profile, the test is only slightly inflated and there is a single clear simple keel separated from the rest of the test by the groove. Surface of test smooth. Li & McGowran (2000) figured a very similar form as *Fissurina* cf. *densifasciataformis* Albani & Yassini, 1989. The form recorded here has a slightly less pronounced neck with aperture, and the marginal groove is complete around the base of the test.

***Fissurina* sp. 2** **Pl. 1, figs 26, 27**
Remarks: A single specimen in NPD. A simple form with smooth circular, slightly compressed chamber, and well-developed neck, distinctly flared at the aperture. It is very similar to species illustrated by Jones (1994, pl. 59, fig. 1) as *Fissurina seguenziana* (Fornasini, 1886) but lacks the distinct keel of that species.

***Fissurina* sp. 3** **Pl. 1, figs 28, 29**
Remarks: A single, well-preserved, unidentifiable specimen of a small, inflated, robust-ribbed species. Body highly inflated, with strong keel around most of test but weakening towards aperture. Body with two strong ribs on each side; ribs converge adapically but die out about 2/3 of way towards apical end of test leaving a ribless apical part. Centre of body with raised triangular platform that also converges on ribs.

***Fissurina* sp. 4** **Pl. 1, fig. 30**
Remarks: A simple almost circular, compressed form, lacking keel or any 'ornament' and with a hint of an adapical spine.

***Oolina emaciata* (Reuss, 1862)** **Pl. 1, fig. 31**
Lagena emaciata Reuss 1862, 319, pl. 1, fig. 9.
Oolina emaciata (Reuss): Li & McGowran 2000, 77, fig. 31T.
Remarks: This is a simple, slightly asymmetrical, smooth tear-shaped species.

***Oolina globosa* (Montagu, 1803)** **Pl. 1, fig. 32**
Vermiculum globosum Montagu 1803, 523.
Oolina globosa (Montagu): Quilty 1974, 92, pl. 4, fig. 158; Li & McGowran 2000, 77, fig. 31U.
Remarks: Various authors have recorded this seemingly simple species as *Lagena.* Yassini & Jones (1995) interpreted it to include more elongate forms such as illustrated on their Figs 369, 370 and that practice is followed here. Elongate forms are rare.

__*_Oolina hexagona_ (Williamson, 1848)__ **Pl. 1, fig. 33**
Entosolenia squamosa var. *hexagona* Williamson 1848, 20, pl. 2, fig. 23.
Lagena hexagona (Williamson): Howchin 1889, 8; Quilty 1974, 66, pl. 3, fig. 98; Jones 1994, 66, pl. 58, fig. 33; Li & McGowran 2000, 75, figs 31K, L.
Remarks: This species contains two populations, one of coarse and one of fine hexagons, the latter perhaps comparable with *F. digitale* (Heron-Allen & Earland, 1932). Li & McGowran (2000), while not commenting on this feature, did illustrate both forms. The figured specimen agrees with the form figured by Jones.

__*_Oolina lineata_ (Williamson, 1848)__ **Pl. 1, fig. 34**
Entosolenia lineata Williamson 1848, 18, pl. 2, fig. 18; Jones 1994, 63, pl. 57, fig. 13
Oolina lineata (Williamson, 1848); Albani & Yassini 1989, 387, figs 4C, D
Remarks: A common species. Modern interpretation of this species may be of a form a little more globular than Willamson's concept which is distinctly elongate.

__*_Oolina melosquammosa_ (McCulloch, 1977)__ **Pl 1, fig. 35**
Oolina melosquammosa McCulloch 1977, 82, pl. 54, figs 26-28.
Favulina melosquammosa (McCulloch, 1977); Loeblich & Tappan 1994, 86, pl. 151, figs 13–17.

__*_Oolina ramulosa_ (Chapman, 1907)__ **Pl. 1, fig. 36**
Lagena acuticosta Reuss var. *ramulosa* Chapman 1907, 129, pl. 9, fig. 9
Oolina ramulosa (Chapman, 1907); Yassini & Jones 1995, figs 363, 364, 366

__*_Oolina squamosa_ (Montagu, 1803)__ **Pl. 1, fig. 37**
Vermiculum squamosa Montagu 1803, 526, pl. 14, fig. 2.
Oolina squamosa (Montagu, 1803). Jones 1994, pl. 58, figs 28–32 (especially fig. 32); *Favulina squamosa* (Montagu, 1803); Li & McGowran 2000, 77, pl. 31, figs 31M-O (*partim*).
Remarks: I have followed Jones (1994) who outlined the range of names used for this form. It is a common species with little variation.

__*_Oolina subacuticostiformis_ Albani & Yassini, 1989__ **Pl.1, fig. 38**
Oolina subacuticostiformis Albani & Yassini 1989, 389, fig. 4M
Remarks: Test robust, broadest below its equator and a little attenuated at the apertural end, with about 18 strong, flat-topped longitudinal costae from adapical to apical end; costae narrow towards each end. Costae terminate immediately before the aperture that may be the inner part of an ooline apertural collar with the surrounding rim lost.

__*_Oolina tasmanica_ Parr, 1950__ **Pl. 1, fig. 39**
Oolina tasmanica Parr 1950, 303, pl. 8, fig. 4; Hayward *et al.* 1999, 123, pl. 8, fig. 4.
Remarks: The figured specimen, while slightly affected by diagnesis, is typical of the form described by Parr (1950). Hayward *et al.* (1999) described *O. tasmanica* as having transverse costae that form a ring at the base. That is not obvious in Parr's description or illustration. The specimens recorded here have no evidence of the ring of transverse costae at the adapical end and thus conform closely with Parr's original illustration.

__*_Oolina_ sp.1__ **Pl. 1, fig. 40**
Oolina melo d'Orbigny, 1839. Yassini & Jones 1995, 113, figs 355 (not 353/354);
Remarks: A species with transverse costae at either apical or adapical end, but none with transverse costae over the entire test. It is intermediate between *O. melo* and *O. tasmanica*. Yassini & Jones (1995) recorded *O.melo* as a form dominated by longitudinal costae with transverse costae at the apical and adapical ends but essentially absent from the centre of the test. D'Orbigny's original specimen clearly has transverse costae throughout, more in keeping with the concept of the species of Hayward *et al.* (1999) and Albani & Yassini (1989). The specimens recorded here are of the same form as Yassini & Jones' (1995) figure 355, but not 353 or 354. Parr (1950) and Hayward *et al.* (1999) both refer to a ring of transverse costae at the adapical end but that must be very small as neither Parr nor Hayward *et al.* figure it.

__*?_Oolina_ sp.__ **Pl. 2, fig. 1**
Remarks: The form figured here is unusual in having a spherical body and two apertures, each on a short tube with simple opening. Similar forms in the same sample have a single aperture.

__*_Pseudofissurina_ sp. 1__ **Pl. 2, fig. 2**
Pseudofissurina sp. 1. Li & McGowran 2000, 82, pl. 32, fig. S
Remarks: This name is used in the same sense as by Li & McGowran (*op. cit.*). Apertural details are not available.

Family POLYMORPHINIDAE d'Orbigny, 1839

__*New genus and species__ **Pl. 2, figs 3, 4**
Remarks: A new widespread, large and prominent species, absent from the NPD1985 and other Flinders Island material seen to date, and relatively more common in section S12 where it makes up several percent of many faunas. It is a polymorphinid characterised by a short, simple polymorphinid initial section followed by a rectilinear uniserial series of chevron shaped chambers with terminal radiate aperture. It will be described formally elsewhere (Quilty & Whitehead in press).

Globulina gibba **(d'Orbigny, 1826)**
Polymorphina (*Globuline*) *gibba* d'Orbigny 1826, 266.
Globulina gibba (d'Orbigny); Quilty 1974, 79, pl. 4, fig. 127; Li & McGowran 2000, 71, fig. 29W.

Guttulina austriaca **d'Orbigny, 1846**
Guttulina austriaca d'Orbigny 1846, 223, pl. 12, figs 23-25: Cushman & Ozawa 1930, pl. 4, figs 3–5.
Remarks: Most specimens are typical of those with smaller numbers of chambers. Those in S12/4 are identified only tentatively because the chambers are more elongate than normal. The figured specimen from sample S12/1 is unusual in having a radiate aperture at each end.

__*_Guttulina communis_ (d'Orbigny, 1826)__ **Pl.2, fig. 5**
Polymorphina (*Guttuline*) *communis* d'Orbigny 1826, 266.
Guttulina communis (d'Orbigny): Quilty 1974, 79, pl. 4, figs 128, 129; Li & McGowran 2000, 69, figs 29M, N.
Guttulina problema d'Orbigny 1826, 266; Li & McGowran 2000, 70, fig. 29L
Remarks: Quilty (1974) could not differentiate *G. communis* from *G. problema* and that approach is followed here.

Guttulina lactea **(Walker & Jacob, 1798)**
Serpula lactea Walker & Jacob 1798, 634, pl. 14, fig. 4.
Guttulina lactea (Walker & Jacob): Cushman & Ozawa 1930, 43, pl. 10, figs 1–4; Quilty 1974, 80, pl. 4, fig. 131.

__*_Guttulina regina_ (Brady, Parker & Jones, 1870)__ **Pl. 2, fig. 6**
Polymorphina regina Brady, Parker & Jones 1870, 241, pl. 41, figs 32a, b.
Guttulina regina (Brady, Parker & Jones): Quilty 1974, 81, pl. 4, figs 132–134; Li & McGowran 2000, 70, fig. 29P.

Guttulina seguenzana **(Brady, 1884)**
Polymorphina seguenzana Brady 1884, 567, pl. 72, figs 16, 17.
Guttulina (*Sigmoidina*) *seguenzana* (Brady): Cushman & Ozawa 1930, 50, pl. 37, figs 8, 9.

Pseudopolymorphina ligua **(Roemer, 1838)**
Polymorphina (*Polymorphinen*) *ligua* Roemer 1838, 385, pl. 3, figs 25a, b.
Pseudopolymorphina ligua (Roemer): Barker 1960, pl. 72, figs 9–11.

Pseudopolymorphina subcylindrica **(Hantken, 1875)**
Polymorphina subcylindrica Hantken 1875, 51, pl. 14, fig. 14.
Pseudopolymorphina subcylindrica (Hantken): Cushman & Ozawa 1930, 107, pl. 28, fig. 2; Quilty 1974, 83, pl. 4, fig. 138; Li & McGowran 2000, 69, fig. 29J.
Remarks: The usage follows that of Li & McGowran (2000). The differences from *P. ligua* seem minor.

***Pyrulina angusta* (Egger, 1857)**

Polymorphina (*Globulina*) *angusta* Egger 1857, 290, pl. 13, figs 13–15.

Pyrulina angusta (Egger): Li & McGowran 2000, 71, fig. 29F.

***Pyrulina fusiformis* (Roemer, 1838)**

Polymorphina (*Globulinen*) *fusiformis* Roemer 1838, 386, pl. 3, fig. 37.

Pyrulina fusiformis (Roemer): Quilty 1974, 84, pl. 4, fig. 140; Li & McGowran 2000, 71, figs 29H, I.

***Pyrulina gutta* (d'Orbigny, 1826)**

Polymorphina (*Pyruline*) *gutta* d'Orbigny 1826, 267.

Pyrulina gutta (d'Orbigny): Quilty 1974, 84, pl. 4, fig. 141; Li & McGowran 2000, 71, fig. 29E.

***Sigmoidella elegantissima* (Parker & Jones, 1865)**

Polymorphina elegantissima Parker & Jones 1865, 438.

Sigmoidella elegantissima (Parker & Jones): Cushman & Ozawa 1930, 140, pl. 39, figs 1a–c; Quilty 1974, 85, pl. 4, fig. 142; Li & McGowran 2000, 70, fig. 29T.

***Sigmoidella kagaensis* Cushman & Ozawa, 1928**

Pl. 2, fig. 7

Sigmoidella kagaensis Cushman & Ozawa 1928, 19, pl. 2, fig. 14; Cushman & Ozawa 1930, pl. 39, figs 2, 5.

Remarks: The species recovered here and an element of most samples, is large, with quadrate outline, and a strongly angled periphery on the ultimate chamber. It is relatively more elongate than the species figured under this name by Hayward *et al.* (1999, pl. 7, figs 13, 14). While numbers per sample may appear low, because of it size, it is a prominent species.

***Sigmomorphina* cf. *schwageri* (Karrer, 1877)**

Polymorphina schwageri Karrer 1877, 384, pl. 166, fig. 43.

Sigmomorphina schwageri (Karrer): Cushman & Ozawa 1930, 130, pl. 34, figs 1a, b.

Remarks: A single, large robust specimen that agrees well with the figures of Cushman & Ozawa (1930).

ORDER BULIMINIDA Fursenko, 1958
Superfamily BOLIVINACEAGlaessner, 1937
Family BOLIVINIDAE Glaessner, 1937

***Bolivina pseudoplicata* Heron-Allen & Earland, 1930**

Bolivina pseudoplicata Heron-Allen & Earland 1930, 81, pl. 3, figs 36–40; Quilty 1977, 76, pl. 1, fig. 26; Yassini & Jones 1999, 130, figs 549, 550, 554; Li & McGowran 2000, 89, figs 34 T, U.

Family BULIMINELLIDAE Hofker, 1951

*** *Elongobula arethusae* Revets, 1993** **Pl. 2, fig. 8**

Elongobula arethusae Revets 1993, 256, pl. 1. figs 6, 7; Jones 1994, 55, pl. 50, figs 24a, b.

Remarks: The presence of fine, roughly longitudinal striae on the surface of all but the last 20% of the test is characteristic. Revets (1993) illustrated *Elongobula arethusae* with striate test and Jones (1994) followed with a specimen with more finely striate test. This form has finer striae again.

Family BULIMINIDAE Jones, 1875

***Bulimina* cf. *aculeata* d'Orbigny, 1826**

Bulimina aculeata d'Orbigny 1826, 269; Li & McGowran 2000, 93, fig. 34C.

Remarks: The surface of most of the final whorl is smooth but the early part of the test is pustulose, this feature concentrated at the lower margin of each chamber showing a similarity with *B. aculeata* as illustrated by Li & McGowran (2000). There is a progression in concept from the apparently spineless form of Li & McGowran, through a weakly spined form of Hayward *et al.* (1999), to the highly spinose version of Jones (1994). The latter is truer to the original concept of *B. aculeata.* The spines typical of *B. aculeata* are not obvious.

Family SIPHOGENERINOIDIDAE Saidova, 1981

***Rectobolivina* sp.**

Remarks: This form, occurring only in NPD1985 is similar to *Rectobolivina striatula* (Cushman, 1922) but is compressed rather than circular in section.

Family UVIGERINIDAE Haeckel, 1894

***Trifarina* cf. *bradyi* Cushman, 1923**

cf. *Trifarina bradyi* Cushman 1923, 99, pl. 22, figs 3–9; Quilty 1977, 81, pl. 2, fig. 18; Li & McGowran 2000, 95, fig. 33BB.

Remarks: A tentative identification because of poor material, partly recrystallised and possibly with some fine costae.

***Uvigerina pliozea* (Vella, 1963)**

Hofkeruva (*Trigonouva*) *pliozea* Vella 1963, 8, pl. 2, figs 28, 29.

Uvigerina pliozea (Vella, 1963); Hornibrook *et al.* 1989, 158, fig. 37, 10.

***Uvigerina rodleyi* (Vella, 1963)**

Uvigerina sp. cf. *pigmaea* d'Orbigny: Parr 1939, 8, fig. 14

Hofkeruva (*Laminiuva*) *rodleyi* Vella 1963, 9, pl. 2, figs 28, 29.

Uvigerina (*Euuvigerina) rodleyi* (Vella, 1963): Hornibrook *et al.* 1989, 158, fig. 37:9

Remarks: An elongate, completely striate form but with striae discontinuous across sutures. It occurs only in Section S11, perhaps reflecting a difference in nutrient supply to the infauna. It is likely to be the form identified by Parr (1939, fig. 14) as *U.* sp. cf. *pigmaea* d'Orbigny).

Superfamily CASSIDULINACEA d'Orbigny, 1839
Family CASSIDULINIDAE d'Orbigny, 1839

***Globocassidulina subglobosa* (Brady, 1881)**

Cassidulina subglobosa Brady 1881, 60 (figures in Brady 1884, pl. 54, fig. 17).

Globocassidulina subglobosa (Brady): Quilty 1982, 29, pl. 4, figs 23, 24; Li & McGowran 2000, 97, figs 35DD, EE.

Remarks: A few specimens in NPD1985, including one with thinner wall and depressed sutures, that may belong to a different species.

Superfamily TURRILINACEA Cushman, 1927
Family STAINFORTHIIDAE Reiss, 1963

*** *Virgulopsis* sp.** **Pl. 2, fig. 9**

Remarks: A single well-preserved specimen in NPD1985. It has the same degree of hispid surface and body form as *Uvigerina auberiana* d'Orbigny (Jones 1994, 86, pl. 75, fig. 9) but lacks the elongate tubular aperture, instead having a *Virgulopsis* aperture.

ORDER ROTALIIDA Lankester, 1885
Superfamily ACERVULINACEA Schultze, 1854
Family ACERVULINIDAE Schultze, 1854

***Sphaerogypsina globulus* (Reuss, 1848)**

Ceriopora globulus Reuss 1848, 33, pl. 5, fig. 7.

Gypsina globulus (Reuss): Loeblich & Tappan 1994, 154, pl. 334, figs 4-6; Quilty 1982, 15, pl. 2, fig. 15.

Sphaerogypsina globula (Reuss): Li & McGowran 2000, 127, figs 45E, F.

Superfamily CHILOSTOMELLACEA Brady, 1881
Family ALABAMINIDAE Hofker, 1951

***Alabamina tenuimarginata* (Chapman, Parr & Collins, 1934)**

Pulvinulinella tenuimarginata Chapman, Parr & Collins 1934, 565, pl. 9, figs 19a-c.

Alabamina tenuimarginata (Chapman, Parr & Collins): Carter 1964, 114, pl. 11, figs 220–222; Quilty 1982, 33, pl. 5, figs 11, 12; Li & McGowran 2000, 107, figs 39M–O.

Family GAVELLINELLIDAE Hofker, 1956

*__*Discanomalina vermiculata*__ __(d'Orbigny, 1839) Pl. 2, figs 10-12__
Truncatulina vermiculata d'Orbigny 1839, 39, pl. 6, figs 1-3.
Discanomalina vermiculata (d'Orbigny): Jones 1994, 101, pl. 97, fig. 7; Li & McGowran 2000, 116, figs 42D–F.
Remarks: The identification is tentative as comparison figures are not ideal. The material consists of specimens closest to Li & McGowran's (2000) fig. 41D with regular *Cibicides*-like dorsal surface and with final few chambers extending well over the periphery. Ventral surface completely involute.

Gyroidina neosoldanii **Brotzen, 1936**
Rotalia soldanii (d'Orbigny): Brady 1884, pl. 107, figs 6, 7.
Gyroidina neosoldanii Brotzen 1936, 158: Quilty 1982, 34, pl. 5, figs 21–23: Li & McGowran 2000, 116, fig. 39R
Remarks: A single specimen in S11/43

Family HETEROLEPIDAE Gonzalez-Donoso, 1969

Anomalinoides fasciatus **(Stache, 1864)**
Rotalia fasciata Stache 1864, 281, pl. 24, fig. 31.
Anomalinoides fasciatus (Stache): Hornibrook *et al.* 1989, 85, figs 18.7a, b: Li & McGowran 2000, 115, figs 42L–N.
Remarks: The ventral aspect is appropriate but the dorsal surface is too poor for positive identiication.

Anomalinoides nonionoides **Parr, 1939**
Anomalina nonionoides Parr 1939, 231, pl. 22, figs 38a–c.
Anomalinoides nonionoides Parr 1939; Carter 1964, 100, pl. 8, figs 154–156; Quilty, 1982, 37, pl. 6, figs 11–13; Li & McGowran, 2000, 115, figs 42Q, R.
Remarks: The form is similar to that figured by Carter (1964) as *A. nonionoides* (Parr) but has more deeply impressed umbilici.

Heterolepa brevoralis **(Carter, 1958)**
Cibicides brevoralis Carter 1958, 47, pl. 6, figs 54–56.
Cibicidoides brevoralis (Carter): Quilty 1982, 11, pl. 1, figs 26, 27.
Heterolepa brevoralis (Carter): Li & McGowran 2000, 115, figs 40A–C.
Remarks: A very tentative identification based on general shape and profile, number of chambers and lobulate periphery. Characteristic apertural details not visible.

Family ORIDORSALIDAE Loeblich & Tappan, 1984

*__*Mesorotalia*__ __sp. Pl. 2, figs 13, 14__
Remarks: This unidentified (perhaps new) species has a very low domed dorsal and flat ventral surface. Rate of increase of chamber height is very low. Smooth dorsal surface has small slitlike apertures along the intercameral sutures for the entire final whorl but not earlier. Some of the apertures are accompanied by small circular openings. The primary aperture is interiomarginal on the ultimate chamber on the ventral surface; chamber surface immediately below the aperture is papillate.
Yassini & Jones (1995, figs 844–845, 850–851) described *M. rara* from Recent sediments of the south coast of New South Wales. It differs from this form in that the entire ventral surface is papillate.

Superfamily DISCORBINELLACEA Sigal, 1952
Family DISCORBINELLIDAE Sigal, 1952

Discorbinella araucana **(d'Orbigny, 1839)**
Rosalina araucana d'Orbigny 1839, 44, pl. 6, figs 10, 11.
Discorbinella araucana (d'Orbigny): Quilty, 1977, 82, pl. 2, figs 23–25; Jones 1994, 93, pl. 86, figs 10, 11.
Remarks: This species is rare and it may also equate to what Li & McGowran (2000) referred to as *D. scopos* (Finlay 1940).

Discorbinella bertheloti **Cushman, 1924**
Discorbinella bertheloti Cushman 1924, 33, pl. 10, fig. 1: Jones 1994, 95, pl. 89, figs 10–12; Li & McGowran 2000, 103, pl. 38, N, O.

Discorbinella papillata **(Chapman, Parr & Collins, 1934)**
Discorbis bertheloti var. *papillata* Chapman, Parr & Collins 1934, 561, pl. 9, figs 14a–c.
Discorbinella papillata (Chapman, Parr & Collins, 1934): Carter 1964, 87, pl. 5, figs. 105–107.
Planulina papillata (Chapman, Parr & Collins, 1934): Li & McGowran 2000, 111, pl. 38T, U
Remarks: On some specimens, the papillae are only weakly developed and the dorsal surface is a little more highly vaulted than is typical as illustrated by Carter (1964).
The species is characterised by flat ventral and dorsal surfaces, the former with markedly raised ridge-like intercameral sutures that break into nodes proximally, more so on earlier chambers. Ventral surface smooth with subtle straight intercameral sutures and a central, slitlike aperture with low simple rim.

Discorbinella timida **Hornibrook, 1961**
Discorbinella timida Hornibrook 1961, 116, pl. 14, figs 288, 293, 297; Hayward *et al.* 1999, 152, pl. 14, figs 13–15.
Remarks: It seems possible that forms described by Yassini & Jones (1995) as *Milesina differens* McCulloch, 1977 and *M. splendida* Yassini & Jones, 1995 refer to this species.

*__*Discorbinella*__ __cf.__ __*vitrevoluta*__ __(Hornibrook, 1961)__
Pl. 2, figs 15, 16
? *Discorbis williamsoni* Chapman & Parr, Parr 1932, 226, l. 21, fig. 25. cf. *Rosalina vitrevoluta* Hornibrook 1961, 102, pl. 13, figs 275–277.
cf. *Discorbinella vitrevoluta* (Hornibrook, 1961); Hayward *et al.* 1999, 153, pl. 14, figs 16–18.
?*Orbitina carinata* Sellier de Civrieux 1977, 29, pl. 18, figs 3-10; Loeblich & Tappan 1994, 137, pl. 275, figs 7–12; Revets 2000, pl. 4, figs 35, 36.
Remarks: Hayward *et al.* (1999) illustrated a specimen as *Discorbinella vitrevoluta* (Hornibrook) and it is arguably conspecific with this species. It is not so clear that it is the form decribed by Hornibrook (1961) as *Rosalina vitrevoluta.* This species is represented by many specimens, often well-preserved, and seems to be the first record as a fossil. It is very similar to what Loeblich & Tappan (1994) and Yassini & Jones (1995) figured as *Orbitina carinata* Sellier de Civreux, 1977. A characteristic of the species figured by Hayward *et al.* (1999) and Yassini & Jones (1995) but not by Hornibrook (1961) is that the dorsal intercameral sutures are distinctly raised near the periphery, as a continuation of the peripheral thickening, but gently depressed proximally. It may also be the form discussed and illustrated by Parr (1932) as *Discorbis williamsoni* and foreshadowed for publication in Parr (1950), although it was not so described in Parr (1950). The name *Orbitina* may be a junior homonym of the European Decollate Snail described by Linné (1758) as *Rumina decollata* and later re-described as *Orbitina incomparabilis* and *O. truncatella* by Germain (1930).

Discorbinella **sp. 1**
Remarks: A single specimen with distinctly limbate dorsal sutures, and strongly recurved ventral sutures. It is very similar in gross appearance to *Planulina wuellerstorfi* (Schwager, 1866) but is smaller, more compressed, has gently pustulose chamber walls and a discorbinellid ventral surface.

Laticarinina altocamerata **(Heron-Allen & Earland, 1922)**
Truncatulina tenuimargo Brady var. *alto-camerata* Heron-Allen & Earland 1922, 209, pl. 7, figs 24–27.
Parvicarinina altocamerata (Heron-Allen & Earland): Hornibrook 1961, 118, pl. 14, figs 296, 299, 301, 302, 305; Jones 1994, 97, pl. 93, figs 2a–c.
Laticarinina alatocamerata (Heron-Allen & Earland): Yassini & Jones 1995, 165, figs 981–983.
Remarks: The single specimen recovered is very well-preserved and lacks a broad marginal flange but has the pronounced tubercles on the extreme ventral aspect of chambers.

Family PSEUDOPARRELLIDAE Voloshinova, 1952

***Planulinoides biconcavus* (Jones & Parker, 1862)**

Discorbina biconcava Jones & Parker 1862 in Carpenter, Parker & Jones 1862, 201, pl. 32g.

Discorbinella biconcava (Jones & Parker): Carter 1964, 86, pl. 5, figs 97–100.

Planulinoides biconcava (Jones & Parker): Quilty 1977, 87, pl. 3, fig. 28.

Planulina biconcava (Jones & Parker): Li & McGowran 2000, 111, figs 38V–X.

Remarks: A pervasive but never major component of the faunas. Placed by Quilty (1977) and Loeblich & Tappan (1987) in *Planulinoides*.

Superfamily DISCORBACEA Ehrenberg, 1838

Family BAGGINIDAE Cushman, 1927

***Baggina phillipinensis* (Cushman, 1921)**

Pulvinulina philippinensis Cushman 1921, 331, pl. 58, fig. 2.

Baggina philippinensis (Cushman): Carter 1964, 85, pl. 5, figs 94–96: Quilty 1977, 89, pl. 4, figs 15, 16: Li & McGowran 2000, 99, fig. 37A.

***Parredicta kalimnensis* (Parr, 1939) Pl. 2, figs 17, 18**

Planulina kalimnensis Parr 1939, 69, pl. 1, figs. 19a–c.

Valvulineria kalimnensis (Parr): Carter 1964, 101, pl. 8, figs. 157–167: Quilty 1982, 9, pl. 1, figs 15–18.

Parredicta kalimnensis (Parr). Li & McGowran 1995, 101, figs. 37 B–D.

Remarks: This is by far the dominant species in the Flinders Island material. Preservation varies from excellent (normal) to very fragmentary (less commonly) indicating that the environment in the Pliocene was, at times, high energy, but not such that all material was damaged. A significant proportion of species include as "unidentified" probably represents this species.

Parr (1939) stated that this is the typical species of the Kalimnan.

Family EPONIDIDAE Hofker, 1951

***Eponides repandus* (Fichtel & Moll, 1798)**

Nautilus repandus Fichtel & Moll 1798, 35, pl. 3, figs a-d.

Eponides repandus (Fichtel & Moll): Quilty 1982, 7, pl. 1, figs 3, 4.

Eponides rapandus (Fichtel & Moll): Li & McGowran 2000, 103, fig. 36Y.

Remarks: A single broken, poorly preserved unfigured specimen in S12/1, identified tentatively.

Family DISCORBIDAE Ehrenberg, 1838

***Discorbis balcombensis* Chapman, Parr & Collins, 1934**

Discorbis balcombensis Chapman, Parr & Collins 1934, 562, pl. 8, figs 10a–c: Carter 1964, 77, pl. 3, figs 64–66; Quilty 1977, 84, pl. 3, figs 5–8, 11-13; Li & McGowran 2000, 104, figs 37T–V.

***Lamellodiscorbis dimidiatus* (Jones & Parker, 1862)**

Discorbina dimidiatus Jones & Parker, in Carpenter, Parker & Jones 1862, 201, fig. 32B

Lamellodiscorbis dimidiata (Jones & Parker): Bermudez 1952, 39; Hansen & Revets 1992, 176, pl. 4, figs. 1–3, 7, 8.

Trochulina dimidiata (Jones & Parker): Yassini & Jones 1995, 158, figs. 916, 917; Hayward *et al.* 1999, 139, pl. 10, figs. 9–11.

Remarks: Occurs in only one sample and is poorly preserved.

***Neoeponides procerus* (Brady, 1881)**

Pulvinulina procera Brady, 1881, 16 (figures Brady 1884, pl. 105, figs 7a–c)

"Eponides ?" procera (Brady): Barker 1960, pl. 105, figs 7a–c.

Family ROSALINIDAE Reiss, 1963

***Neoconorbina* cf *pacifica* Hofker, 1951**

cf. *Neoconorbina pacifica* Hofker 1951, 438, figs 302, 303; Hayward *et al.* 1999, 141, pl. 10, figs 21–23.

Remarks. The name applied tentatively to a specimen with hemispherical dorsal surface with flush sutures and non-lobulate periphery; apertural details not clear.

***Planodiscorbis* sp. Pl. 2, figs 19, 20**

Remarks: This species, occurring as a single specimen, is marked by a gently domed, finely perforate involute dorsal surface of eight chambers in the final whorl and depressed intercameral sutures that are gently recurved distally. No later thickening. Coarse pores on ealier chambers may be due to later boring. A marked keel. Ventral surface flat or gently concave, apparently imperforate with small isolated central boss. Aperture with slightly flared rim continues from dorsal surface across the periphery to continue along the base of the final chamber and link with those of earlier four or five chambers, but with a re-entrant at each ventral intercameral suture. The most distinguishing feature is the projecting anteroperipheral margin of the final whorl. This form belongs to the same genus as *Cibicidina walli* Bandy, 1949 as figured by van Morkhoven *et al.* (1986, pl. 60) but has eight chambers in the final whorl. *C. walli* is very reminiscent of *Planodiscorbis* sp. nov. of Jones (1994 pl. 90, figs 1a–c) and is likely to be the same species. It differs from *P. rarescens* in having a distinctly projecting anteroperipheral aspect of the final whorl.

***Rosalina australis* (Parr, 1932)**

Discorbis australis Parr, 1932, 227, pl. 22, fig. 31.

Rosalina australis (Parr, 1932): Jones 1994, 94, pl. 87, figs 5–7; Yassini & Jones, 1995, 159, fig. 768.

Remarks: This robust species is uncommon and the specimen in NPD1985 is distorted.

***Rosalina bradyi* (Cushman, 1915)**

Discorbis globularis (d'Orbigny) var. *bradyi* Cushman 1915, 12, pl. 8, figs 1a–c.

Rosalina bradyi (Cushman): Jones 1994, 93, pl. 86, figs 8a–c; Yassini & Jones, 1995, 159, fig. 767: Hayward *et al.* 1999, 142, pl. 11, figs 1–3: Li & McGowran 2000, 104, figs 38F, G.

***Rosalina mitchelli* Carter, 1964**

Rosalina mitchelli Carter 1964, 73, pl. 3, figs 54–56; Quilty 1977, 88, pl. 4, figs 9, 10.

***Rosalina vilardeboana* d'Orbigny, 1839**

Rosalina vilardeboana d'Orbigny 1839, 44, pl. 6, figs 13–15; Quilty 1977, 89, pl. 4, figs 11, 12; Jones 1994, 93, pl. 86, figs 9a–c; Li & McGowran 2000, 105, figs 38J, K.

***Rosalina* sp. 1**

Remarks: A low domed form normally revealing little detail. Preservation is poor. The ventral surface seems to be depressed to a plane generally below a very thick periphery. A similar form may be *Neoconorbina pacifica* Hofker (Hayward *et al.* 1999, pl. 10, figs 21–23.

***Rosalina* sp. 3**

Remarks: This form occurs in only one sample. It lacks the imperforate zone on the apertural face typical of *Cancris auriculus* (Fichtel & Moll, 1798), which it resembles initially, and the ventral surface is esentially flat. The high rate of increase of chamber height is unusual for *Rosalina.*

Superfamily GLABRATELLACEA Loeblich & Tappan, 1964

Family GLABRATELLIDAE Loeblich & Tappan, 1964

***Pileolina australensis* (Heron-Allen & Earland, 1932)**

Discorbis australensis Heron-Allen & Earland 1932, 416.

Pileolina (?) *australensis* (Heron-Allen & Earland): Barker 1960, 184, pl. 89, figs 2–4.

Pileolina australensis (Heron-Allen & Earland): Quilty 1977, 94, pl. 5, fig. 17.

Glabratella australensis (Heron-Allen & Earland): Jones 1994, 95, pl. 89, figs 2–4; Yassini & Jones 1995, 160, figs 731–734.

Remarks: A single plastogamic pair. Hayward *et al.* (1999) gave a good justification for the retention of the generic name of *Pileolina* for this group of species. They used widespread use in New Zealand as a justification but the genus also is well-known in Australia.

Planoglabratella opercularis **(d'Orbigny, 1826)**

Rosalina opercularis d'Orbigny 1826, 271, modeles no. 7

Pileolina (?) *opercularis* (d'Orbigny): Barker 1960, pl. 89, figs 8, 9.

Planoglabratella opercularis (d'Orbigny): Hayward *et al.* 1999, 148, pl. 13, figs 1–3.

Remarks: A few poor specimens, partly recrystallised.

Family HERONALLENIIDAE Loeblich & Tappan, 1986

Heronallenia lingulata **(Burrows & Holland, 1895)**

Discorbina lingulata Burrows & Holland, 1895, in Jones 1895, pl. 7, figs 33a–c.

Heronallenia lingulata (Burrows & Holland): Chapman, Parr & Collins 1934, 564, pl. 8, figs 11a–c; Carter 1964, 92, pl. 6, figs 124–126; Quilty 1977, 93, pl. 5, figs 13, 14; Hayward *et al.* 1999, 148, pl. 13, figs 4–6; Li & McGowran 2000, 106, figs 37O, P.

Remarks: Apertures on chamber wall are open in last few chambers but closed on earlier chambers**.**

Heronallenia parri **Carter, 1958**

Heronallenia parri Carter 1958, 43, pl. 5, figs 43–45; Carter 1964, 92; Quilty 1977, 93, pl. 5, figs 15, 16; Li & McGowran 2000, 106, fig. 37Q.

Remarks: This small species has a disjunct distribution and I question whether it is distinct from *H. lingulata* which may be the mature larger form.

Superfamily NONIONACEA Schultze, 1854
Family NONIONIDAE Schultze, 1854

****Astrononion novozealandicum*** **Cushman & Edwards, 1937** **Pl. 2, fig. 21**

Astrononion novozealandicum Cushman & Edwards 1937, 35, pl. 3, figs 18a,b

Astrononion novozealandicum Cushman & Edwards, 1937; Hayward *et al.* 1999, 157, pl. 15, figs 8, 9

Remarks: This is the most common species of *Astrononion* but still is rare, with about 10–11 chambers in the final whorl and sutural apertures less distinct on earlier chambers. The zone between the apertural sutures and the umbilicus is smooth and apparently imperforate, in contrast with the periphery. Umbilicus is closed. The characteristic pit is seldom as well developed as illustrated by Hayward *et al.* (1999).

Astrononion obesum **Carter, 1964**

Astrononion obesum Carter 1964, 112, pl. 10, figs 205, 206.

Remarks: Specimens are uncommon and only tentatively placed here. They have inflated chambers, depressed sutures and about eight chambers in the final whorl.

Astrononion tasmaniensis **Carter, 1964**

Astrononion tasmaniensis Carter 1964, 111, pl. 10, figs 203, 204: Quilty 1982, 31, pl. 5, figs 4, 5.

****Pseudononion victoriense*** **(Cushman, 1936)** **Pl. 2, fig. 22**

Nonion victoriense Cushman 1936, 67, pl. 12, figs 10a, b; Carter 1964, 109, pl. 10 figs 201, 202; Li & McGowran 2000, 122, figs 43M, N.

Florilus victoriensis (Cushman): Quilty 1982, 31, pl. 5, fig. 6.

Remarks: Quilty (1982) placed this species in *Florilus* but that is an invalid genus and Loeblich & Tappan (1987) noted that submission had been made to the ICZN to suppress the name; thus *Pseudononion* now seems more appropriate. This is one of the dominant species throughout the sections studied and, with *Parredicta kalimnensis* is the characteristic of the faunas.

Superfamily PLANORBULINACEA Schwager, 1877
Family CIBICIDIDAE Cushman, 1927

Cibicides cygnorum **Carter, 1964**

Cibicides cygnorum Carter 1964, 98, pl. 7, figs 139–144: Li & McGowran 2000, 113, figs 41O, P.

****Cibicides ihungia*** **Finlay, 1940** **Pl. 3, figs 1, 2**

Cibicides ihungia Finlay 1940, 465, pl. 67, figs 201–206; Hornibrook 1961, 162, pl. 24, figs 488, 189; Li & McGowran 2000, 113, figs 41E, F.

****Cibicides thiara*** **(Stache, 1864)** **Pl. 3, figs 3, 4**

Remarks: A few poor specimens in NPD.

****Cibicides*** **sp. 1** **Pl. 3, figs 5–7**

Remarks: This is one of the most abundant species, making up to 19% of faunas. It is characterised by a robust, regular, thick test with up to 12 chambers in the final whorl. Finely perforate throughout. Dorsal surface flat to gently convex; sutures flush early and slightly depressed later; recurved little peripherally. Periphery varying from moderately to broadly rounded, not keeled. Ventral surface a high dome with marked central boss; sutures initially flush, slightly depressed later, recurved distally; boss merging with chamber walls. Aperture interiomarginal on the ventral side.

It is distinguished by thick test, number of chambers per whorl, ventral boss and rounded periphery.

?*Cibicides **sp. 2** **Pl. 3, figs 8, 9**

Remarks: The dorsal surface is evolute with about five coarsely perforate chambers; intercameral sutures swept back and raised near the periphery. Periphery gently lobulate, with clear keel. Ventral surface completely involute with inflated chambers, straight radial slightly depressed intercameral sutures and high interiomarginal aperture. Shape very reminiscent of *Oridorsalis umbonatus* (Reuss, 1851) but with no hint of dorsal apertures. Van Morkhoven *et al.* (1986) figured *Cibicidoides* sp. 14 that is grossly similar but has the typical cibicidid small peripheral aperture. Yassini & Jones (1995) also figured *Cibicidoides* spp. but their specimens, while having the coarsely perforate dorsal surface, have too many chambers per whorl.

Genus DYOCIBICIDES Cushman & Valentine, 1930

Dyocibicides is a common element of most samples. While the generic name probably has no biological validity and species allocated to it are variants of various species of *Cibicides* such as *C. mediocris* Finlay, 1940, the three morphotypes described – *D. biserialis* Cushman & Valentine, 1930, *D. primitiva* Vella, 1957, and *D. uniserialis* Thalmann, 1933 – can be recognised in the Flinders Island samples. All were probably attached during life and this has had a significant influence on the form taken. Often, there is evidence of attachment to a straight, narrow cylindrical body, perhaps a small echinoid spine. Most were probably attached to something flat such as an algal thallus.

Dyocibicides primitiva **Vella, 1957**

Dyocibicides primitiva Vella 1957, 41, pl. 9, figs 198–200; Li & McGowran 2000, 114, figs 41T, V.

Remarks: The most common form seen and marked by irregular growth of a few chambers following an early regular *Cibicides* coil.

****Dyocibicides biserialis*** **Cushman & Valentine, 1930** **Pl. 3, fig. 10**

Dyocibicides biserialis Cushman & Valentine 1930, 30, pl. 10, figs 1, 2; Quilty 1982, 13, pl. 2, figs 7, 8; Li & McGowran 2000, 114, fig. 41U.

Remarks: Recognised by development of a short series of almost regular biserial chambers.

Dyocibicides uniserialis **Thalmann, 1933**

Dyocibicides uniserialis Thalmann 1933, 254; Li & McGowran 2000, 114, pl. 41W, Y.

Remarks: Uncommon in Flinders Island samples and the name is applied only when the final chamber has a circular terminal aperture with rim.

Superfamily PLANORBULINACEA
Family PLANORBULINIDAE Bermúdez, 1952

***Planorbulina mediterranensis* d'Orbigny, 1826**

Planorbulina mediterranensis d'Orbigny 1826, 280, pl. 14, figs 4-6; Quilty 1982, 14, pl. 2, fig. 9.

Remarks: Occurs as single specimens in only two samples, but attests to the existence of substrate for attachment.

Family PLANULINIDAE Bermúdez, 1952

***Planulina ariminensis* d'Orbigny, 1826**

Planulina ariminensis d'Orbigny 1826, 280, pl. 14, figs 1–3.

Remarks: A few poor specimens are placed here tentatively.

Superfamily ROTALIACEA Ehrenberg, 1839
Family ELPHIDIIDAE Galloway, 1933

***Discorotalia aranea* (Hornibrook, 1958)**

Notorotalia aranea Hornibrook 1958, 662, figs 12–14.

Discorotalia aranea (Hornibrook): Hayward *et al.* 1997, 95, pl. 18, figs 4–6.

Genus *Elphidium*

Elphidium is one of the most diverse species groups and commonly constitutes about 10% of any sample. Hayward *et al.* (1997) used a "lumpers" approach to the generic concept of *Elphidium* and that is the approach followed here. They then seem to have employed a "splitters" approach at species level. There are some anomalies, one of the most important of which involves the concept of *E. advenum advenum.* While noting that it is extant, it is listed as becoming extinct in the mid-Late Miocene in the New Zealand region but is an important part of the faunas recorded here. A problem palaeontologically lies in the value of the distribution of papillae which may be very fine and easily affected by diagenesis.

****Elphidium advenum advenum* (Cushman, 1930) Pl. 3, fig. 12**

Polystomella advena Cushman 1922, 56, pl. 9, figs 11, 12.

Elphidium advenum advenum (Cushman): Hayward *et al.* 1997, 65, pl. 2, figs. 9–18.

Remarks: This is an abundant form throughout both sections and in NPD1985. As noted by Hayward *et al.* (1997) it is quite variable and best identified as a population rather than on every specimen.

***Elphidium advenum limbatum* (Chapman, 1907)**

Polystomella macellum var. *limbatum* Chapman 1907, 142, pl. 10, figs 9a, b.

Elphidium limbatum (Chapman): Collins 1958, 421.

Elphidium advenum limbatum (Chapman): Hayward *et al.* 1997, 67, pl. 3, figs 9–17; pl. 4, figs 1–10.

***Elphidium advenum maorium* Hayward, 1997**

Elphidium advenum maorium Hayward 1997 in Hayward *et al.* 1997, 69, pl. 1, fig. 7, pl. 4, figs 11–16, pl. 5, figs 1–5.

****Elphidium craticulatum* (Fichtel & Moll, 1798) Pl. 3, fig. 11**

Nautilus craticulatus Fichtel & Moll 1798, 51, pl. 5, figs h, i, k.

Elphidium craticulatum (Fichtel & Moll): Cushman 1933, 48, pl. 11, figs 5a, b; Hayward *et al.* 1997, 73, pl. 7, figs 5–12.

****Elphidium crispum crispum* (Linné, 1758) Pl. 3, fig. 13**

Nautilus crispus Linné 1758, 709.

Elphidium crispum (Linné): Cushman 1933, 47, pl. 11, fig. 4.

Elphidium crispum crispum (Linné): Hayward *et al.* 1997, 74, pl. 7, figs 13–16; pl. 8, figs 1–9.

Remarks: This is a medium to large form and the specimens recorded, while in lateral view identical to Hayward *et al.*'s (1997) figures, are generally more compressed than their figures would indicate. It is marked by a distinct rhomboidal profile and high number of chambers that are narrow, almost ridge-like on the surface. It has some similarities with *E. advenum tongaense* (Cushman).

Some specimens recorded as *E. crispum* have a rounded periphery (acutely rounded in the terms of Hayward *et al.*) rather than acute and keeled. Species counts may include specimens of *E. pseudonodosum* Cushman stated by Parr (1939) to be characteristic of the Kalimnan although he recorded it only from the Kalimnan of the Hamilton region of western Victoria.

The form identified earlier as *E.* cf. *hawkesburyense* (Albani) (Quilty 1985) is likely to be of this species but is poorly preserved. It has a stellar arrangement of incised proximal intercameral sutures as well illustrated by Hayward *et al.* (1997, especially pl. 9, fig. 12.). Some poorly preserved specimens with deeply incised sutures may approach *Elphidium sandiegoense* (Lankford, 1973).

***Elphidium excavatum excavatum* (Terquem, 1875)**

Polystomella excavata Terquem 1875, 25, pl. 2, figs 2a–f.

Elphidium excavatum (Terquem): Murray 1971, 159, pl. 66, figs 1–7.

Elphidium excavatum excavatum (Terquem): Hayward *et al.* 1997, 77, pl. 1, figs 3, 12, pl. 9, figs 9–18.

***Elphidium tongaense* (Cushman, 1931)**

Ozawaia tongaense Cushman 1931, 80, pl. 10, figs 7–10: Loeblich & Tappan 1987, 675, pl. 791, figs 1–4.

Elphidium advenum tongaense (Cushman): Hayward *et al* 1997, 71, pl. 5, figs 13–18.

Remarks: This rather unusual form has the same lateral aspect as *E. advenum limbatum* (Chapman) but is much more highly compressed. The degree of compression is such that forms intermediate between this and *E. a. limbatum* do not occur.

****Elphidium* sp. 1 Pl. 3, fig. 14**

Remarks: This very rare species, occurring only in NPD1985, is of the *E. novozealandicum* group. It is highly compressed and differs from *E. novozealandicum* and *E.* aff. *novozealandicum* as discussed by Hayward *et al.* (1997) in having too few (about 14) chambers in the final whorl and only some 10 septal bridges.

****Notorotalia clathrata* (Brady, 1884) Pl. 3, figs 15, 16**

Rotalia clathrata Brady 1884, 709, pl. 107, fig. 8.

Notorotalia clathrata (Brady): Carter 1964, 124, pl. 13, figs 256–259; Li & McGowran 2000, 125, figs 45A–C.

Remarks: *Notorotalia* is common in most samples, one of the dominant species of the entire study. It is taken to be a single species but may be two. The difficulty in differentiation is due to the fact that some specimens have a smooth dorsal surface and a ventral plug while others have the typical *N. clathrata* surface. The smooth dorsal surface may arise from original condition or from abrasion. Chamber arrangement is typical of *N. clathrata.*

****Parrellina imperatrix* (Brady,1881) Pl. 3, fig. 17**

Polystomella imperatrix Brady 1881, 66: Brady 1884, pl. 110, figs. 13–15.

Parrellina imperatrix (Brady): Thalmann 1951, 224; Hayward *et al.* 1997, 96, pl. 18, figs. 10–12; Li & McGowran, 2000, 125, figs 44D, E.

Elphidium imperatrix (Brady): Carter 1964, 120, pl. 12, figs. 247–249.

Remarks. Hayward *et al.* (1997) regarded this as a modern species but Carter (1964) and Li & McGowran (2000) recorded it in older sections from southeastern Australia.

****Parrellina verriculata* (Brady, 1881) Pl. 3, fig.18**

Polystomella verriculata Brady 1881, 66 (figures Brady 1884, pl. 110, fig. 12).

Parrellina verriculata (Brady): Hofker 1969, 478, figs 74–76, 79–85; Hayward *et al.* 1997, 97, pl. 19, figs 1–3.

Remarks: This species varies from umbonate with pores, to involute, and from parallel-sided to lenticular. The differentiation from *P. imperatrix* on the basis of a few strong spines, while technically simple, would appear to be without biological foundation. Following tradition, they are differentiated herein.

***Parrellina* sp.**

Remarks: Two unidentifiable fragments in NPD1985.

ORDER GLOBIGERINIDA Lankester, 1885
Superfamily GLOBOROTALIACEA Cushman, 1927
Family GLOBOROTALIIDAE Cushman, 1927

***Globorotalia crassaformis* (Galloway & Wissler, 1927) Pl. 4, fig. 11**

Globigerina crassaformis Galloway & Wissler 1927, 41, pl. 7, fig. 12: Kennett & Srinivasan 1983, 146, pl. 34, figs 6–8; Hornibrook 1982, 93, fig. 6d–w; Hornibrook *et al.* 1989, 129, figs 29.10, 30.1a–c.

Remarks: Hornibrook *et al.* (1989) listed a FAD for non-keeled specimens of this species, and *G. puncticulata*, of 5 Ma, the basis for the oldest estimate of age of the samples.

***Globorotalia mons* Hornibrook, 1982 Pl. 4, figs 15–17**

Globorotalia conomiozea mons Hornibrook 1982, 91, figs 3a–g, 4a–i.

Globorotalia mons Hornibrook: Hornibrook *et al.* 1989, 132, figs 29.2a, b, 32.

Remarks: A very characteristic species that bridges the boundary between New Zealand Kapitean and Opoitian stages. The co-occurrence with *G. crassaformis* and *G. puncticulata* ensures that the age is Early Opoitian.

***Globorotalia 'obesa'* Bolli, 1957 Pl. 4, fig. 18**

Globorotalia obesa Bolli 1957, 119, pl. 29, figs 2a–3.

Globigerinella obesa (Bolli): Kennett & Srinivasan 1983, 234, pl. 59, figs 2–5

Remarks: This species is interpreted a little broadly to include common planktonic species in NPD1985. Specimens are small, thin-walled have 4½ chambers in the final whorl and the apertures vary from those that are moderate to high with no lip or rim (typical *G. obesa*), those that are moderately high with poorly developed rim and rarely even a small tooth (could be termed *Globigerina angustiumbilicata* Bolli), to those in which the aperture is large and merges with that of the previous chamber (*Globigerina bulloides concinna* Reuss of Blow 1969).

***Globorotalia pliozea* Hornibrook, 1982 Pl. 4, figs 13, 14**

Globorotalia pliozea Hornibrook 1982, 95, figs 7a–g; Hornibrook *et al.* 1989, 133, figs 29, 6a, b.

Remarks: This species forms (with *G. mons*) a convenient link with the New Zealand biostratigraphic subdivision of the Late Neogene.

***Globorotalia puncticulata* (Deshayes, 1832) Pl. 4, fig. 12**

Globigerina puncticulata Deshayes 1832, 170: Banner & Blow 1960, 15, pl. 5, figs 7a–c.

Globorotalia puncticulata (Deshayes): Kennett & Srinivasan 1983, 116, pl. 27, figs 4–6.

***Neogloboqudrina humerosa* (Takayanagi & Saito, 1962) Pl. 4, figs 9, 10**

Globorotalia humerosa Takayanagi & Saito 1960, 78, pl. 28, figs 1a–2b.

Neogloboquadrina humerosa (Takayanagi & Saito, 1962): Kennett & Srinivasan 1983, 196, pl. 48, figs 4–6.

***Neogloboquadrina pachyderma* (Ehrenberg, 1861) Pl. 4, fig. 8**

Aristospira pachyderma Ehrenberg 1861, 276.

Globorotalia pachyderma (Ehrenberg): Vilks, 1975, 321, pl. 1 figs. 1–3, pl. 2, figs. 1–3.

Neogloboquadrina pachyderma (Ehrenberg): Kennett & Srinivasan 1980, 148, pl. 3, figs 1–13: Kennett & Srinivasan 1983, 192, pl. 47, figs 6–8.

Remarks: This species is a common element of several samples and sinistral and dextral coiling patterns are approximately equally represented. In sections 11 and 12 the specimens are less heavily thickened than modern *N. pachyderma* specimens from the Antarctic, but other aspects of the species are typical; four sinistral specimens from NPD1985 are typical kummerforms.

Superfamily GLOBIGERINACEA Carpenter, Parker & Jones, 1862
Family GLOBIGERINIDAE Carpenter, Parker & Jones, 1862

***Globigerina apertura* Cushman, 1918 Pl. 4, fig. 1**

Globigerina apertura Cushman 1918, 57, pl. 12, figs 8a-c: Kennett & Srinivasan 1983, 44, pl. 8, figs 4–6.

***Globigerina bulloides* d'Orbigny, 1826 Pl. 4, fig. 2**

Globigerina bulloides d'Orbigny 1826, 277, list no. 1; Banner & Blow 1960, 3, pl. 1, figs. 1, 4; Kennett & Srinivasan 1983, 36, pl. 6, figs 4–6.

Remarks: The most common species among the planktonic component. Preservation varies considerably and it is possible that some specimens could be referred to *G. apertura.*

***Globigerina decoraperta* Takayanagi & Saito, 1962**

Globigerina druryi decoraperta Takayanagi & Saito 1962, 85, pl. 28, figs 10a–c.

Globigerina (*Zeaglobigerina*) *decoraperta* Takayanagi & Saito: Kennett & Srinivasan 1983. 48, pl. 9, figs 4–6.

***Globigerina falconensis* Blow, 1959 Pl. 4, fig. 3**

Globigerina falconensis Blow 1959, 177, pl. 9, figs 40a–c, 41: Kennett & Srinivasan 1983, 40, pl. 7, figs 1–3.

***Globigerina quinqueloba* Natland, 1938**

Globigerina quinqueloba Natland 1938, 149, pl. 6, figs 7a–c: Kennett & Srinivasan 1983, 32, pl. 5, figs 4–6.

Remarks: A few specimens from NPD1985 displaying a great diversity in character of the final chamber. The lip varies from non-existent to well developed, characteristic, according to Kennett & Srinivasan (1983), of the Pliocene. Some specimens have up to 5 ½ chambers in the final whorl.

***Globigerina woodi* Jenkins, 1960 Pl. 4, fig. 4**

cf. *Globigerina woodi* Jenkins 1960, 352, pl. 2, figs 2a–c: Kennett & Srinivasan 1983, 42, pl. 7, figs 4–6.

Remarks: A single specimen for which apertural details are a little obscured.

***Globigerinoides extremus* Bolli & Bermudez, 1965**

Globigerinoides obliquus extremus Bolli & Bermudez 1965, 139, pl. 1, figs 10–12.

Globigerinoides extremus Bolli: Kennett & Srinivasan 1983, 58, pl. 12, figs 1–3.

***Globigerinoides obliquus* Bolli, 1957 Pl. 4, figs 5, 6**

Globigerinoides obliqua Bolli 1957, 113, pl. 25, figs 10a–c.

Globigerinoides obliquus Bolli: Kennett & Srinivasan 1983, 56, pl. 11, figs 7–9.

***Globigerinoides quadrilobatus* (d'Orbigny, 1846) Pl. 4, fig. 7**

Globigerina quadrilobatus d'Orbigny 1846, 164, pl. 9, figs 7–10.

Globigerinoides quadrilobatus (d'Orbigny): Kennett & Srinivasan 1983, 66, pl. 14, figs 1–3.

***Orbulina suturalis* Brönnimann, 1951 Pl. 4, fig. 20**

Orbulina suturalis Brönnimann 1951, 135, text-fig. 4, figs 15, 16, 20: Kennett & Srinivasan 1983, 86, pl. 20, figs 1–3.

Remarks: A single specimen in NPD1985, 0.35 mm in diameter. As with *O. universa*, at this size it may be close to its lower temperature limit. Specimens figured by Kennett & Srinivasan (*op. cit.*) are 0.44 and 0.32 mm in diameter.

***Orbulina universa* d'Orbigny, 1839 Pl. 4, fig. 19**

Orbulina universa d'Orbigny 1839, 3, pl. 1, fig. 1; Kennett & Srinivasan 1983, 86, pl. 20, figs. 4–6; Hornibrook *et al.* 1989, 136, 148, figs 28.2, 31.

Remarks: The occurrence is sporadic and all specimens are very small (~0.35 mm) and at the temperature limit for the species. It thus forms a basis for estimating the palaeotemperature at the time of deposition using the results contained in Bé *et al.* (1973).

Family CANDEINIDAE Cushman, 1927

***Globigerinita uvula* (Ehrenberg, 1861)** **Pl. 4, fig. 21**

Pylodexia uvula Ehrenberg 1861, 206 (figs Ehrenberg 1873, pl. 2, figs 24, 25). *Globigerinita uvula* (Ehrenberg): Kennett & Srinivasan 1983, 224, pl. 56, figs 6–8.

APPENDIX TABLE 1

Distribution of Foraminifera in samples from North Patriarch Drain (1985), and sections S11 and S12. Figures are percentages of the faunas. tr=<1%.

Species/Sample	**NPD**	S11/1	S11/5	S11/13	S11/13A	S11/14	S11/17	S11/20	S11/22	S11/24	S11/29	S11/31	S11/37	S11/39	S11/40	S11/43	S12/1	S12/2	S12/3	S12/4	S12/7	S12/13	S12/22	S12/24	S12/28	S12.31	S12/32	S12/36	S12/38	S12/prox. Cast. Marl
BENTHIC SPECIES																														
Adelosina sp.												tr																		
Alabamina tenuimarginata																	tr													
Gen. et sp. nov.			tr		tr	tr	tr	tr		tr	tr	tr	tr	2	2	tr	2	2	2	3			2		3	tr	tr	1	1	1
Anomalinoides fasciatus											tr															tr				
Anomalinoides nonionoides	tr																													
Astrononion novozealandicum	tr							tr		tr	tr	tr		?tr		tr				tr	tr	tr	tr					tr	tr	tr
Astrononion obesum					tr		tr									tr												tr		tr
Astrononion tasmaniensis					tr		tr				tr		tr							tr		tr					tr			tr
Baggina philippinensis	tr						tr		tr	tr	tr	tr				tr										tr	tr	tr		
Bolivina pseudoplicata	1.4																													
Brizalina sp.	tr																													
Bulimina cf. *aculeata*	tr										tr					tr	tr							tr					tr	
Cibicides cygnorum						tr																								
Cibicides ihungia					tr				tr		tr	1		1	2	tr	tr		2		tr	1	tr	tr	tr		tr	tr	tr	tr
Cibicides sp. 1	7.5	1	tr	2	5	2	2	tr	3	4	3	3	9		9	8	4	4	7	11	19	10	10	11	11	13	13	10	6	9
Cibicides sp. 2				tr																			tr							
Cibicides thiara	2.2																													
Cushmanina spiralis																												tr		
Dentalina fragment indet.																														
Dentalina godjeni																		tr		tr										1
Dentalina subemaciata				tr														tr							tr					
Discanomalina vermiculata	tr				1																									
Discorbinella araucana																										tr				
Discorbinella bertheloti	tr						tr	tr	tr	tr	tr	tr		tr			tr			tr	tr			tr						tr
Discorbinella cf. *vitrevoluta*	2.8				tr	tr		tr	tr	tr	tr		tr	tr	tr		tr	tr			tr	tr		tr	tr		tr	tr		tr
Discorbinella papillata	1.2											tr		tr					tr					tr						
Discorbinella sp. 1	tr																				tr							tr		tr
Discorbinella timida	3.5	tr			tr	tr																								
Discorbis balcombensis										tr																				
Discorotalia aranea																														tr
Dyocibicdes uniserialis										tr							tr													
Dyocibicides biserialis	tr				tr		tr		tr	tr	tr	tr	tr		tr	tr	tr	tr			tr			tr		tr			tr	tr
Dyocibicides primitiva	1.9	tr			1	tr	tr	tr		tr	2	2	2	4	3	1	6	4	3	3	2	4		1	2	3	8	tr	3	1
Elongobula arethusae	tr																													
Elphidium advenum advenum	9.9		1		5	2	1	tr	1	1	tr	2	3	3	4	5	2	tr	4	5	2	4	3	6	2	2	3	tr	1	2
Elphidium advenum limbatum	tr	1		2	tr	tr	tr	tr	tr									tr	tr					1	tr		tr		tr	tr
Elphidium advenum maorium				tr	tr																									

APPENDIX TABLE 1 cont.

	NPD	S11/1	S11/5	S11/13	S11/13A	S11/14	S11/17	S11/20	S11/22	S11/24	S11/29	S11/31	S11/37	S11/39	S11/40	S11/43	S12/1	S12/2	S12/3	S12/4	S12/7	S12/13	S12/22	S12/24	S12/28	S12.31	S12/32	S12/36	S12/38	S12/prox. Cast. Marl
Elphidium craticulatum	2.8		5	3	tr	4	6	5	2	3	2	tr	1	2		tr	1	tr	tr	tr	tr	tr	tr	1	2	tr	tr	tr	tr	tr
Elphidium crispum crispum		3	8	2	4	1	tr	tr	2	3	tr	3	4	5	5	5	4	tr	3	1	3	2	2	4	2	3	4	2	1	1
Elphidium excavatum clavatum	5.8				tr							tr																		
Elphidium excavatum excavatum	tr	tr		tr				tr																						
Elphidium sp. 1	tr																													
Elphidium tongaense	tr			tr	tr			tr	tr	tr	tr	tr	tr	tr			tr		tr					tr		tr			tr	tr
Entosolenia cf. *lineata*																											1	tr	tr	
Eponides repandus																	tr													
Fissurina lucida	tr								tr						tr															
Fissurina marginata	1.5								tr																					
Fissurina pacifica	tr																													
Fissurina sp. 1	1.4																													
Fissurina sp. 2	tr																													
Fissurina sp. 3					tr																									
Fissurina sp. 4	tr																													
Flintina intermedia	tr																													
Frondicularia juv. sp. indet.																						tr								
Gaudryina convexa	tr																													
Globocassidulina subglobosa	tr																													
Globulina gibba				2	tr			tr	tr						tr				tr											
Gordiospira sp.	tr											tr																		
Guttulina austriaca								tr									tr	tr	tr	tr		tr					tr			tr
Guttulina communis	1.4	tr	tr		2	tr	tr	1	tr	tr	tr	1	tr	tr	tr	tr			tr	tr	tr	tr	tr	tr	tr	tr		tr	tr	
Guttulina lactea	tr																													
Guttulina regina	tr		tr		tr		tr	tr		tr	tr	tr	1	tr	tr	tr	tr		tr	tr	tr	tr	tr	tr	tr	tr	tr			
Guttulina seguenzana	tr			tr																										
Gyroidina neosoldanii																tr														
Heronallenia lingulata	tr	tr			tr		tr				tr			tr		tr	tr				tr	tr							tr	tr
Heronallenia parri										tr		tr																tr		
Heterolepa brevoralis					tr																									
Lagena cf. *maccullochae*																								tr						
Lagena flatulenta								tr										tr												
Lagena maccullochae																											tr			
Lagena perlucida																								tr			tr			
Lagena sp. 1	tr																													
Lagena sp. 2	tr																													
Lagena sp. 3	1																													
Lagena striaospiralata		1																				tr		tr			tr		tr	
Lagena striata paucistriata	1.2																		tr	tr										

APPENDIX TABLE 1 cont.

	NPD	S11/1	S11/5	S11/13	S11/13A	S11/14	S11/17	S11/20	S11/22	S11/24	S11/29	S11/31	S11/37	S11/39	S11/40	S11/43	S12/1	S12/2	S12/3	S12/4	S12/7	S12/13	S12/22	S12/24	S12/28	S12.31	S12/32	S12/36	S12/38	S12/prox. Cast. Marl
Lagena sulcata		tr	tr		1			tr			tr	tr	tr	tr	1	tr		tr	tr	tr	1	tr	tr	tr		1	tr	tr	1	
?*Lagena* sp.	tr																													
Lamellodiscorbis dimidiatus																													tr	
Laticarinina altocamerata																							tr							
Lenticulina foliata	tr												tr								tr									
Lenticulina indet.										tr																				
Mesorotalia sp.	tr																	tr												tr
Miliolinella subrotunda	2.8	tr					tr		tr	tr	tr																			
Neoconorbina cf.*pacifica*			tr																											
Neoeponides procerus	1.6		tr	tr	tr	tr	tr			tr	tr	tr	tr	tr	tr	tr	tr				tr		tr		tr	2	2	tr	tr	tr
Notorotalia clathrata	3.3	1	4	tr	10	8	8	4	10	8	11	6	7	10	9	9	8	7	12	16	11	7	16	10	13	12	4	10	13	9
Oolina emaciata								tr							tr	1														tr
Oolina globosa	1	1			1	tr		tr		tr		1	2	tr		tr	1		tr			tr		tr		tr	tr	tr	tr	
Oolina hexagona	2.5							tr	tr		tr		tr	tr	2	tr		tr		tr		tr	tr							
Oolina lineata						tr				tr	tr	tr	tr		tr	tr	tr					tr				tr	tr			
Oolina melosquammosa	2.6																													
Oolina ramulosa	tr													tr									tr							
Oolina sp. 1	2.5	tr	tr	tr	tr			tr	tr		tr	tr				1	tr		tr	tr	tr	tr						tr		
Oolina sp.																			tr	tr										
Oolina squamosa		tr							tr	tr	tr	tr	tr		4	1	tr	1	2	2	tr	2	tr	2	tr	1	3	tr	tr	tr
Oolina subacuticostiformis																														tr
Oolina tasmanica					tr												tr													
?*Oolina* sp.															1															
Palmula longiformis		tr		6																										
Parredicta kalimnensis	6.8	58	69	60	38	62	60	63	38	42	39	32	36	35	28	34	43	45	37	32	30	30	37	41	41	29	35	39	39	54
Parrellina imperatrix		2	tr		tr	tr	tr	tr	tr	tr		tr		1	tr	tr	3	3	tr		tr	tr	tr	1	1	tr	tr	1	tr	4
Parrellina sp.	tr																													
Parrellina verriculata		2	1		6	6	5	4	7	5	6	6	7	8	8		7	7	7	9	7	10		8	7	5	6	6	6	8
Pileolina australensis	tr															tr														
Planodiscorbis sp.								tr																						
Planoglabratella opercularis	tr																													
Planorbulina mediterranensis					tr										tr															
Planulina ariminensis					tr		tr										tr													
Planulinoides biconcavus	tr					tr	tr		tr		tr		tr	tr	tr	tr	tr	tr	tr	tr		tr		tr	tr				tr	tr
Procerolagena clavata	tr																													
Pseudofissurina sp. 1	tr																													
Pseudoflintina crassatina								tr																						
Pseudononion victoriensis	3	6	3		6	1	3	4	8	6	7	8	4	4	4	3	3	3	2	2	2	3	2	3	1	3	6	5	3	tr
Pseudopolymorphina ligua										tr				tr																
Pseudopolymorphina subcylindrica		tr			1	tr	tr	tr	1		2	1			tr	tr	tr	tr	tr	tr	tr	tr	tr	1	tr					tr

APPENDIX TABLE 1 cont.

	NPD	S11/1	S11/5	S11/13	S11/13A	S11/14	S11/17	S11/20	S11/22	S11/24	S11/29	S11/31	S11/37	S11/39	S11/40	S11/43	S12/1	S12/2	S12/3	S12/4	S12/7	S12/13	S12/22	S12/24	S12/28	S12.31	S12/32	S12/36	S12/38	S12/prox. Cast. Marl
Pyrgo sp. 1		tr																												
Pyrgo spp.		tr					tr					tr																		
Pyrulina angusta	tr											tr	2											tr						
Pyrulina fusiformis																tr														
Pyrulina gutta			tr	tr			tr	tr				tr		tr			tr	tr	tr		1	tr		tr		tr	tr		tr	
Quinqueloculina asperula	tr																													
Quinqueloculina lamarckiana									tr		tr	1				1														
Quinqueloculina oblonga								tr	1	3	1	tr			tr	1														
Quinqueloculina seminula	6.5	2	tr	1	1	2	1	1	7	3	3	7	6	3	2	5												1	tr	
Quinqueloculina sp. indet.									tr		tr*																			
Quinqueloculina sp.A	tr																													
?Quinqueloculina poey. victoriensis									tr																					
Rectobolivina sp.	tr																													
Rosalina australis	tr														tr								1							
Rosalina bradyi		tr		tr	tr		tr	tr	tr	tr	tr	tr	tr			tr	tr	tr	tr	tr	tr	tr			tr	tr	tr	tr	tr	tr
Rosalina mitchelli	3				tr																									
Rosalina sp. 1		tr	tr	tr	2	tr	tr		tr		1					tr	tr			tr	tr				tr	tr		1		tr
Rosalina sp. indet.										tr																				
Rosalina sp.3	tr								tr																					
Rosalina vilardeboana	1.6																													
Sigmoidella elegantissima							tr									tr										tr		tr		
Sigmoidella kagaensis		2	3	3	tr	tr	3	2	1	2	2	tr	tr	1		tr	1	2	1		1	2	tr	2	tr	tr	tr	2	1	tr
Sigmomorphina cf. *schwageri*													tr																	
Siphotextularia cf *saulcyana*	tr																													
Siphotextularia saulcyana	tr																													
Sphaerogypsina globulus														tr																
Spiroloculina canaliculata											tr																			
Textularia candeiana				tr																										
Trifarina cf. *bradyi*	tr																													
Triloculina earlandi	1.2				tr		tr		1	tr		tr	tr	tr		tr cf														
Triloculina gilboei		tr					tr			tr	1	tr		tr															tr	
Triloculina laevigata		2		1		tr		2	tr					tr																
Triloculina tricarinata		tr		tr		tr	tr	tr	tr	tr		tr				tr														
Triloculina trigonula	tr	4		3	tr	1	2	2	6	6	5	5	2	2	1	3												2	4	
Unident. nodosariids	tr																													
Unident. miliolids	1.6									3		1	2	tr		3														
Unidentified		tr		2	3	2	2	1	1	2	tr	4	5	7	7	1	11	9	12	9	11	15	8	15	7	15	7	8	10	4
Uvigerina pliozea	1.2										tr	tr	tr			1			tr		tr	tr	tr	tr	tr		tr	tr	tr	tr

APPENDIX TABLE 1 cont.

	NPD	S11/1	S11/5	S11/13	S11/13A	S11/14	S11/17	S11/20	S11/22	S11/24	S11/29	S11/31	S11/37	S11/39	S11/40	S11/43	S12/1	S12/2	S12/3	S12/4	S12/7	S12/13	S12/22	S12/24	S12/28	S12.31	S12/32	S12/36	S12/38	S12/prox. Cast. Marl
Uvigerina rodleyi		tr		tr	tr			tr	tr	tr																				
Vaginulina vertebralis	tr													tr				tr												
Virgulopsis sp.	tr																													
TOTAL BENTHICS	**429**	**459**	**569**	**476**	**484**	**842**	**732**	**574**	**416**	**792**	**627**	**494**	**252**	**338**	**261**	**295**	**518**	**310**	**528**	**420**	**449**	**576**	**378**	**518**	**335**	**249**	**472**	**466**	**598**	**625**
PLANKTONIC SPECIES																														
Globigerina apertura					1			2	1																1			1		1
Globigerina bulloides	83	2		2		2		4	4	7	10	8	1	4	1	1	14	4	4	14	7	5	2	12	1	1	9	7	5	10
Globigerina cf woodi					1																									
Globigerina decoraperta	2																													
Globigerina falconensis				1		1	1			1											1			1						
Globigerina quinqueloba	9																													
Globigerinita uvula	3			1																										
Globigerinoides extremus				1	1																									
Globigerinoides obliquus																	1													
Globigerinoides quadrilobatus								1																						
Globorotalia crassaformis	30				1			1	2		2			1			1		1			1	1	1						1
Neogloboquadrina humerosa	1				1									1		1														
Globorotalia intern. *inflata/ puncticulata*												1																		
Globorotalia mons																	1										1			
Globorotalia 'obesa'	44																													
Globorotalia pliozea	1							1						1			cf. 1		1	1			1							
Globorotalia puncticulata										2		3			1					3	2								1	1
Neogloboquadrina pachyderma	4s	cf. 1d		1s	1d			1s;2d	1s;1d	2d	2s;2d	5s	1s								3s		1s	1s						
Orbulina universa												3		2	1			1									1	1		
Orbulina suturalis	1																													
Unidentified		2		1	2	2	1	3		3	9	5	1			2					3								1	