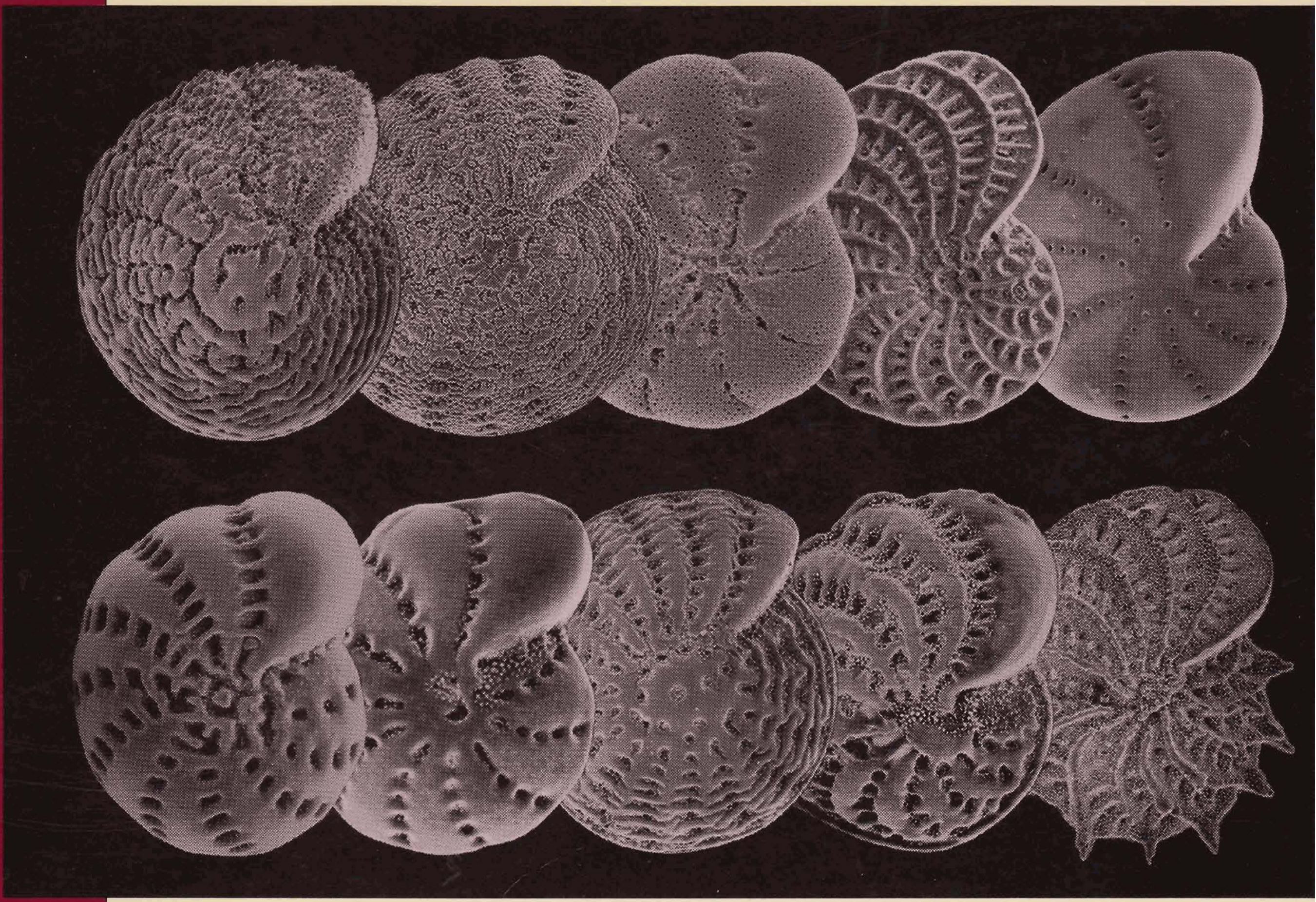
monograph 16

RECENT ELPHIDIIDAE (FORAMINIFERIDA) OF THE SOUTH-WEST PACIFIC AND FOSSIL ELPHIDIIDAE OF NEW ZEALAND



BRUCE W. HAYWARD
CHRIS J. HOLLIS
HUGH R. GRENFELL

Institute of
GEOLOGICAL
& NUCLEAR
SCIENCES
Limited

RECENT ELPHIDIIDAE (FORAMINIFERIDA) OF THE SOUTH-WEST PACIFIC AND FOSSIL ELPHIDIIDAE OF NEW ZEALAND

BRUCE W. HAYWARD
CHRIS J. HOLLIS
HUGH R. GRENFELL

Institute of Geological & Nuclear Sciences monograph 16
(New Zealand Geological Survey paleontological bulletin 72)

Institute of Geological & Nuclear Sciences Limited
Lower Hutt, New Zealand

1997

BIBLIOGRAPHIC REFERENCE

Hayward, Bruce W., Hollis, Chris J. and Grenfell, Hugh R., 1997. Recent Elphidiidae (Foraminiferida) of the South-west Pacific and fossil Elphidiidae of New Zealand. Institute of Geological & Nuclear Sciences monograph 16. 170 p. Lower Hutt, New Zealand: Institute of Geological & Nuclear Sciences Limited.

Bruce W. Hayward[1], Chris J. Hollis[1,2] and Hugh R. Grenfell[1]
[1] Auckland Institute and Museum, Private Bag 92-018,
Auckland, New Zealand
[2] present address: Institute of Geological & Nuclear Sciences Limited,
Lower Hutt, New Zealand

Editing and layout by Geoff Gregory, Word Therapy, Paraparaumu
Printed by Graphic Press & Packaging Ltd, Levin

ISBN 0-478-09562-7
ISSN 1172-028X

Front cover: Recent *Elphidium* species from the southwest Pacific.
Top row, left to right:
Elphidium hispidulum Cushman, *E. collinsi* Hayward n.sp., *E. vellai* Hayward n.sp., *E. novozealandicum* Cushman, *E. albanii* Hayward n.sp.
Bottom row, left to right:
Elphidium advenum maorium Hayward n.ssp., *E. excavatum oirgi* Hayward n.ssp., *E. craticulatum* (Fichtel & Moll), *E. advenum botaniense* Albani, *E. silvestrii* Hayward.

CONTENTS

ABSTRACT

Elphidiidae is a family of mostly shallow-water benthic foraminifera that occur throughout the world at present and in sedimentary rocks of Cenozoic age. Two subfamilies (Elphidiinae and Notorotaliinae) and four genera (*Elphidium, Cristatavultatus, Parrellina, Notorotalia)* occur in the South-west Pacific region today and two further genera (*Cribrorotalia, Discorotalia)* are present in the New Zealand fossil record.

All 39 species and subspecies of *Elphidium, Cristatavultatus* and *Parrellina* in the South-west Pacific today and all 26 fossil species and subspecies of *Elphidium* and *Discorotalia* in the New Zealand Cenozoic are described and illustrated, including 12 new taxa: ***E. aculeatum norcotti*** (Miocene, New Zealand), ***E. advenum maorium*** (Recent, east Australia, New Zealand, South-west Pacific islands), ***E. albanii*** (Recent, east Australia, Lord Howe Island), ***E. carteri*** (Recent, east Australia; Miocene, New Zealand), ***E. collinsi*** (Recent, east Australia), ***E. crispum waiwiriense*** (Miocene, New Zealand), ***E. excavatum oirgi*** (Recent, New Zealand), ***E. fijiense*** (Recent, tropical South-west Pacific islands), ***E. matanginuiense*** (Eocene, New Zealand), ***E. matauraense*** (Miocene, New Zealand), ***E. vavauense*** (Recent, Tonga) and ***E. vellai*** (Recent, New Zealand). *E. phillipense* (Recent, southeast Australia) and *E. silvestrii* (Recent, east Australia) are proposed as replacement names for *E. granulosum* Collins and *E. macellum aculeatum* Silvestri.

Forty-three percent of these elphidiid taxa in the South-west Pacific today are cosmopolitan, 19% are endemic to the region as a whole, 27% endemic just to eastern Australia, 7% to New Zealand and 2% to Tonga. New Zealand has received a sporadic flow of immigrant elphidiids throughout most of the Cenozoic and its fossil record only contains parts of some of the branches of the elphidiid phylogenetic tree. Many of the branches that became established evolved endemic New Zealand taxa, with 48% of New Zealand's fossil and Recent elphidiids endemic.

New Zealand time ranges are documented for all species of *Elphidium, Discorotalia* and *Haynesina.* Most of the more common species are long-ranging. The biostratigraphically most useful taxa appear to be *E. hampdenense* (middle Eocene, Heretaungan, Dh), *E. saginatum* (middle Eocene, Porangan, Dp), *E. wadeae* (Oligocene-early Miocene, Whaingaroan-Otaian, Lwh-Po), *E. kanoum* (late Oligocene-middle Miocene, Duntroonian-Waiauan, Ld-Sw), *E. aculeatum subrotatum* (early-middle Miocene, Altonian-Waiauan, Pl-Sw), *E. novozealandicum* (late Miocene-Recent, Kapitean-Recent, Tk-Rec) and *D. aranea* (early-middle Miocene, Otaian-Waiauan, Po-Sw).

Elphidium appears in New Zealand in the early Eocene. Diversity and endemism increases to a peak of 18 taxa and 50% endemism in the early Miocene, declining through a late Miocene low to the present 13 taxa and 23% endemism. Mean species durations for all *Elphidium* and *Discorotalia* in New Zealand is 14.5 million years. Endemic taxa are generally shorter-lived (mean 10 m.yr) than cosmopolitan taxa (mean 19 m.yr). Application of modern biogeographic and diversity patterns to the fossil record imply warm subtropical water temperatures around central New Zealand in the early Miocene, some 5–8°C warmer than today.

Recent *Elphidium* and *Haynesina* live in their greatest abundances (20% or more of total benthic foraminifera) in intertidal and shallow subtidal environments. As herbivores, reliant to some extent on husbanded chloroplasts, they live in the photic zone. They are common members of most benthic foraminiferal faunas in normal marine salinity at inner shelf depths down to about 40 m and in the middle and outer, slightly brackish parts of inlets and estuaries. Taxa living almost exclusively in brackish environments are *E. excavatum excavatum, E. excavatum clavatum, E. gunteri* and *E. phillipense.* Those tolerating slightly brackish, as well as normal salinity, conditions include *E. advenum botaniense, E. advenum limbatum, E. excavatum sydneyense, E. excavatum williamsoni, E. fijiense, E. lene* and *H. depressula.*

All except the early and middle Eocene fossil *Elphidium* in New Zealand appear to have lived in paralic and shelf environments. Most lived at inner shelf depths, but several species may have lived in lower abundances at middle and outer shelf depths. The early Eocene *E. matanginuiense* and middle Eocene *E. hampdenense* and *E. saginatum* appear to have lived much deeper than subsequent members of the genus, being common in outer shelf and bathyal assemblages. It appears that there was a major ecological shift from deep to shallow water in the middle to late Eocene which possibly accompanied the adoption of a herbivorous feeding strategy and the husbandry of functioning chloroplasts.

Keywords. Foraminifera; Elphidiidae; *Elphidium; Parrellina; Haynesina; Cristatavultatus; Discorotalia;* systematics; biogeography; phylogeny; biology; ecology; paleoecology; biostratigraphy; Eocene; Oligocene; Miocene; Pliocene; Pleistocene; Recent; New Zealand; Australia; Cook Islands; Fiji; New Caledonia; Samoa; Solomon Islands; Tonga; Vanuatu.

INTRODUCTION

RATIONALE

Members of the family Elphidiidae are the most abundant foraminifera in inner shelf environments throughout most temperate and subtropical parts of the world. They have been dominant members of shallow water assemblages in New Zealand since the Oligocene. Despite this abundance, it has long been recognised, at least in New Zealand, that their taxonomy is confused and in need of a thorough review.

This study was conceived to address the taxonomic confusion of New Zealand's fossil and Recent *Elphidium* taxa, so that they may be useful in interpreting paleoenvironments and potentially also assist in dating shallow-water fossil assemblages that usually lack the more stratigraphically useful planktic foraminifera.

New Zealand seas have been considerably warmer throughout much of the Cenozoic than the present day. Thus many of New Zealand's fossil elphidiids have closer taxonomic and ecological similarities to species currently living in subtropical and tropical areas. As a consequence this study has been extended to include Recent *Elphidium* taxa from throughout the South-west Pacific and east Australia.

SCOPE OF STUDY

This monograph contains the results of a study of the foraminiferal genus *Elphidium* and morphologically similar genera of the family Elphidiidae and Nonionidae living in the South-west Pacific (*Cristatavultatus, Parrellina, Haynesina*) and found fossil in New Zealand (*Discorotalia, Haynesina*). Many of the remaining elphidiids of New Zealand (Paleogene *Cribrorotalia* and *Notorotalia*) have been treated elsewhere (Hornibrook 1996). A fully revised taxonomy of 58 Recent and fossil species and subspecies is presented, together with details of the biogeographic and ecologic distribution of Recent taxa and the stratigraphic range, paleobiogeography and paleoecology of fossil taxa. A speculative phylogeny of New Zealand elphidiids is presented.

The geological timescale used is shown in Figure 1. For the purposes of this study, the South-west Pacific has been taken to include (Figure 2): the east coast states of Australia (Queensland, New South Wales, Victoria, Tasmania, including Lord Howe and Norfolk islands), New Zealand (including Kermadec, Chatham, Auckland, Campbell, Antipodes and Snares islands), and the islands lying between 10°S and 30°S and 150°E and 160°W (Solomon, Vanuatu, New Caledonia, Fiji, Samoa, Tonga, Cook islands).

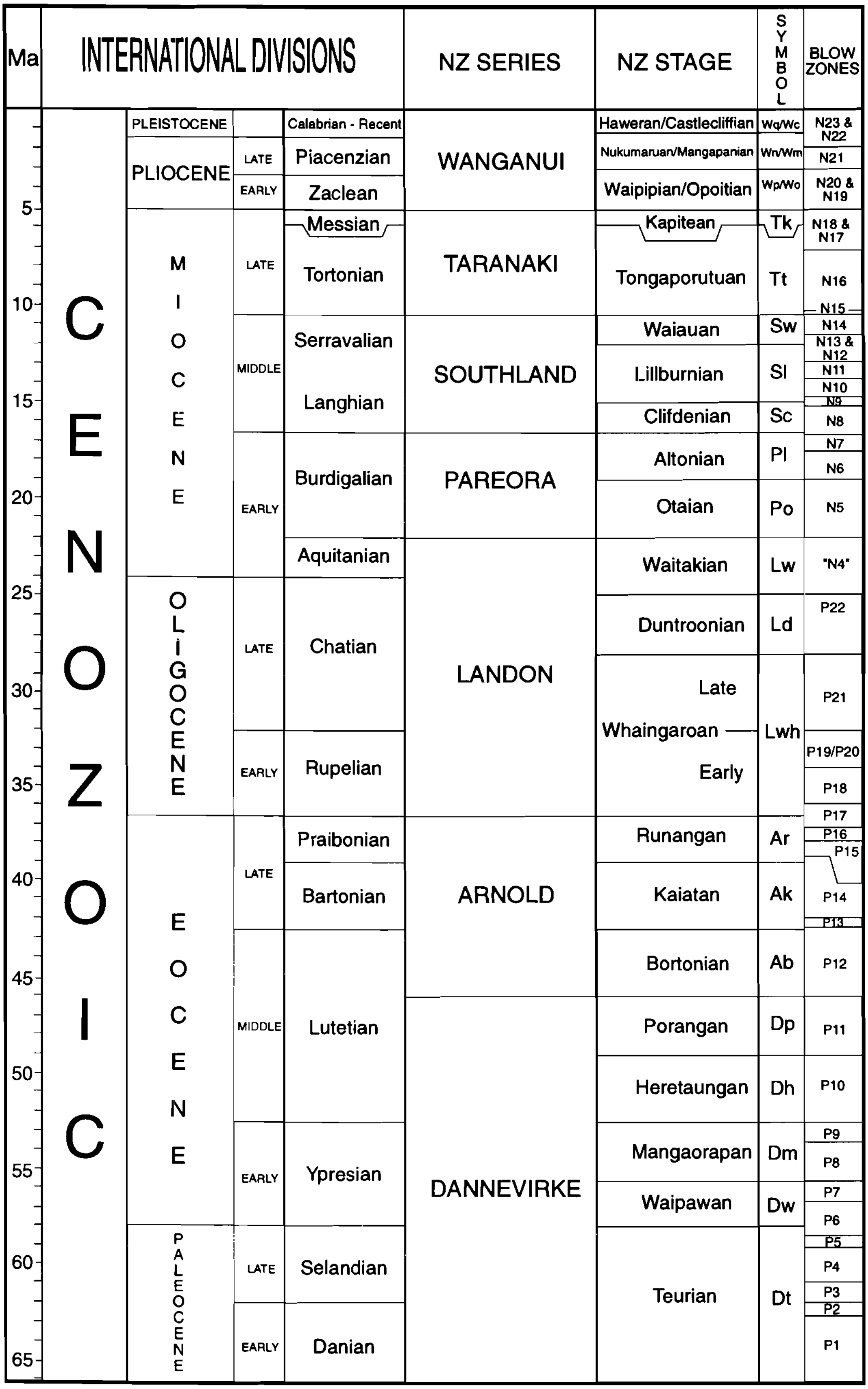
PREVIOUS WORK

The family Elphidiidae was proposed by Galloway (1933), replacing the infrequently used family Polystomellidae (Reuss & Fritsch, 1861), once it was realised (Cushman 1927) that *Elphidium* Montfort (1808) was a senior synonym for *Polystomella* Lamarck (1822). Even then the family Elphidiidae was not universally accepted or used for many years. For a long time *Elphidium* was still placed by many in the family Nonionidae (e.g. Cushman 1939). Loeblich & Tappan (1964) firmly established the widespread use of Elphidiidae. At that stage they recognised two subfamilies - Elphidiinae and Faujasininae Bermudez (1952), but they later (Loeblich & Tappan, 1988) added the subfamily Notorotaliinae Hornibrook (1961). Hornibrook (1996) proposed elevating the Notorotaliinae to family status, but that recent suggestion has not been adopted here.

Many genera have been proposed for taxa within the Elphidiidae, but *Elphidium* is often the main or only genus used by many workers for planispiral forms. Loeblich & Tappan (1988) accepted eight valid genera in the Elphidiinae: *Elphidium, Cribroelphidium, Cribrononion, Elphidiella, Ozawaia, Pellatispirella, Rectoelphidiella* and *Stomoloculina.* Forms referrable to the last three genera have not been found in the study area. *Ozawaia* is synonymised to *Elphidium* in this work. The recognition and use of *Cribroelphidium, Cribrononion* and *Elphidiella* as genera distinct from *Elphidium* is not universal and is indeed quite sporadic and in many instances inconsistent. We recognise that in the South-west Pacific there are a number of recognisable groups of species within our present use of the genus *Elphidium,* but they do not correspond well with this existing subdivision. We believe a full world review of the species of Elphidiidae is preferable before proposing a new generic subdivision.

The only existing world review of the species of Elphidiinae was by Cushman (1936). Since then knowledge and confusion about *Elphidium* taxonomy have grown enormously.

Through biometric analysis, Buzas *et al.* (1985) clarified the identity of some of the more common north American *Elphidium* species. Murray (1971) and Albani and Yassini (1993) have provided useful illustrated guides to the species of Elphidiinae in the United Kingdom and Australia, respectively. The variable *Elphidium excavatum* group has had a chequered history, with many species names proposed for various ecologically and geographically separate forms. Feyling-Hanssen (1972) and Miller *et al.* (1982) studied some of the variability within this group in the northern hemisphere, and each recognised a number of named forms for ecologic variants.



INTERNATIONAL DIVISIONS				NZ SERIES	NZ STAGE	SYMBOL	BLOW ZONES
CENOZOIC	PLEISTOCENE		Calabrian - Recent	WANGANUI	Haweran/Castlecliffian	Wq/Wc	N23 & N22
	PLIOCENE	LATE	Piacenzian		Nukumaruan/Mangapanian	Wn/Wm	N21
		EARLY	Zaclean		Waipipian/Opoitian	Wp/Wo	N20 & N19
	MIOCENE	LATE	Messian	TARANAKI	Kapitean	Tk	N18 & N17
			Tortonian		Tongaporutuan	Tt	N16 N15
		MIDDLE	Serravalian	SOUTHLAND	Waiauan	Sw	N14 N13 & N12
			Langhian		Lillburnian	Sl	N11 N10
					Clifdenian	Sc	N9 N8
		EARLY	Burdigalian	PAREORA	Altonian	Pl	N7 N6
					Otaian	Po	N5
			Aquitanian	LANDON	Waitakian	Lw	"N4"
	OLIGOCENE	LATE	Chatian		Duntroonian	Ld	P22
					Whaingaroan — Late	Lwh	P21
		EARLY	Rupelian		Whaingaroan — Early		P19/P20 P18
	EOCENE	LATE	Praibonian	ARNOLD	Runangan	Ar	P17 P16 P15
			Bartonian		Kaiatan	Ak	P14 P13
		MIDDLE	Lutetian		Bortonian	Ab	P12
				DANNEVIRKE	Porangan	Dp	P11
					Heretaungan	Dh	P10
		EARLY	Ypresian		Mangaorapan	Dm	P9 P8
					Waipawan	Dw	P7 P6
	PALEOCENE	LATE	Selandian		Teurian	Dt	P5 P4 P3
		EARLY	Danian				P2 P1

Figure 1 Geological time scale for the Cenozoic, showing correlation of New Zealand stages with the international subdivisions and with Blow's (1979) planktic foraminiferal zones. Slightly modified after Edwards *et al.* (1988).

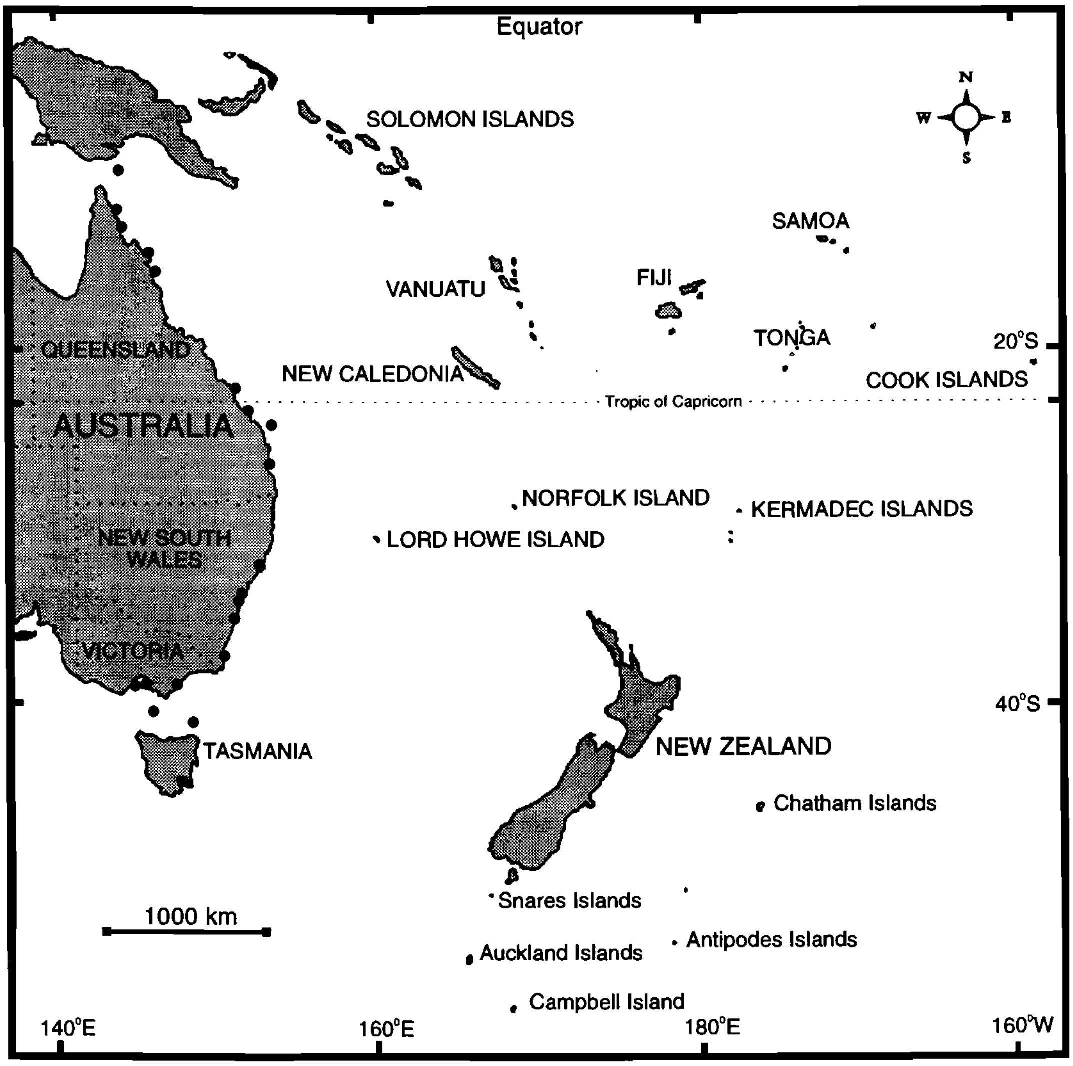


Figure 2 The South-west Pacific region as used in this study of Recent Elphidiidae. All islands and island groups that have been sampled are named, and sampling spread along the east coast of Australia is shown by dots.

Faujasininae is restricted to the northern hemisphere and Antarctica and is not present in the South-west Pacific. The Notorotaliinae is largely a southern hemisphere group, with its greatest diversity in New Zealand and secondarily in Australia. Loeblich and Tappan (1988) recognise five genera in this subfamily, four of which are present in the South-west Pacific. In this study we review the species of two of these genera - *Discorotalia* and *Parrellina,* because of their morphological similarity to *Elphidium.* Species of the diverse and fully trochospiral genera *Cribrorotalia* and *Notorotalia* have been largely covered in reviews and studies by Vella (1957), Hofker (1969) and Hornibrook (1996). The genus *Cristatavultatus*, proposed by Loeblich and Tappan (1994), is now included in this family and is also present in this study area.

South-west Pacific Recent elphidiid studies

Prior to the 1920s most species of Elphidiinae in the South-west Pacific were referred to by the names of similar northern hemisphere taxa. Only *Parrellina imperatrix* Brady (1881), *P. verriculata* Brady (1881) and *Elphidium macellum limbatum* Chapman (1907) had been recognised as new taxa from the area (all under the genus *Polystomella).* Subsequently Cushman (1924, 1931, 1933, 1936) obtained a number of samples of Recent foraminifera from Australia, the South-west Pacific islands and New Zealand and described a new genus *(Ozawaia)* and 7 new species from the islands, 3 new species from Australia and one from New Zealand. Since then there has been a steady progression of new species described from Australia, fewer from New Zealand and no more from the South-west Pacific islands. This reflects the level of attention the Recent foraminifera in each of these areas have received in the last 50 years. New species or subspecies from the east coast of Australia were described by: Parr (1945) - one, Collins (1958, 1974) - six, Albani (1974, 1978, 1981) - three, Albani and Yassini (1993) - two; and from New Zealand by: Vella (1957) - two. Albani and Yassini (1993) reviewed and illustrated 30 Recent elphidiid species from right around Australia (27 from eastern Australia), although they overlooked the species described by Chapman (1907), Collins (1958, 1974) and *E. sculpturatum* described by Cushman (1936). Eade (1967) and Dawson (1992) listed all the elphidiid names recorded from New Zealand in their checklists of Recent New Zealand foraminifera. Hayward and Hollis (1994) discussed and illustrated the brackish elphidiids found in New Zealand.

New Zealand fossil *Elphidium* and *Discorotalia* studies

Prior to the 1930s, virtually all fossil elphidiid taxa from New Zealand were referred to well known fossil species from Europe. The only exception was *Discorotalia tenuissima* (Karrer, 1864), which had been described as a *Polystomella* from the early Miocene of Auckland. The "father" of New Zealand fossil foraminiferal studies, Harold Finlay (1939), described two new early Eocene *Elphidium* species (*saginatum, hampdenense).* Subsequently, Dorreen (1948) described three new species (*ingressans, omotoense, nitidum)* from the late Eocene of the West Coast, Hornibrook (1958, 1961) described three species (*subrotatum, wadeae, D. aranea)* from the Oligocene and early Miocene of the South Island, Srinivasan (1966) described a species (*hornibrooki)* from the Oligocene of the West Coast, and Hayward and Buzas (1979) described two early Miocene species (*gibsoni, kanoum)* from the Auckland region. There has been no previous review of New Zealand's fossil *Elphidium* taxa.

INTRASPECIFIC VARIATION - FORM OR SUBSPECIES?

Studies (Schnitker 1974, Poag 1978, Miller *et al.* 1982) have demonstrated that several species of shallow water benthic foraminifera (e.g. *Ammonia beccarii, Elphidium excavatum*) consist of a number of ecologically or geographically restricted variants. Culturing experiments (Schnitker 1974) have shown that morphological variations mimicking some of the natural variants may be induced by changing environmental parameters such as temperature and light. Thus these variants are considered to be ecophenotypes (formae) rather than genetic varieties (subspecies).

Our own observations of the ecologic and geographic distributions of some of the variants within *Elphidium advenum, E. excavatum* and *Haynesina depressula* support this view and we would prefer to treat such intraspecific variants as formae (e.g. Hayward & Hollis 1994). However, there is at present no way of erecting new formae within the code of zoological nomenclature (ICZN 1964). In order to establish legitimate names with holotypes for new formae within *E. advenum* and *E. excavatum* we are therefore forced to first describe them as new subspecies. For consistency we treat all formae as subspecies in this monograph. We do not consider all the subspecies of *E. advenum* to be formae, however; some are geographically isolated genetic subspecies.

MATERIAL SOURCES

The majority of specimens used in this study come from the New Zealand national collection of foraminifera held by the Institute of Geological and Nuclear Sciences (IGNS), Lower Hutt, New Zealand. These have been augmented with many samples of Recent sediment taken by or for the authors in the 1990s, from around New Zealand (Figure 3), east Australia and the South-west Pacific islands (Figure 2). These are housed in the Auckland Museum.

The third largest source of material is the Recent Australian and South-west Pacific island collections held by the Smithsonian Institution, Washington DC, which was studied by BWH during visits in 1983 and 1994. Other Recent specimens from Australia and the South-west Pacific islands were borrowed from the National Museum of Victoria, Melbourne, and New Zealand Oceanographic Institute, Wellington, respectively.

Additional fossil New Zealand material was studied at Victoria University, Wellington, and the Smithsonian Institution, Washington DC, and borrowed from Canterbury University, Christchurch. As part of this study, types of a number of "classic" species were examined by BWH in 1983 in the collections of the British Museum of Natural History, London, and the Musée National d'Histoire Naturelle, Paris.

Abbreviations and prefixes indicative of specimen and sample repositories for Recent and fossil material are listed in Appendices I and III, respectively.

ACKNOWLEDGMENTS

This study owes a great deal to the inspiration and encouragement of the late Norcott de B. Hornibrook.

Research was commenced in the 1980s by BWH at the New Zealand Geological Survey, and completed by all three authors in the 1990s at Auckland Institute and Museum, with funding assistance from the Foundation for Research, Science and Technology.

For the generous loan of sediment or specimens, or for providing curatorial assistance during our study, we are grateful to C.G. Adams (British Museum of Natural History, London), M.A. Buzas (Smithsonian Institution, Washington DC), A.H. Cameron (University of Canterbury, Christchurch), S.H. Eagar (Victoria University, Wellington), R.L. Hodgkinson (British Museum of Natural History, London), T. Stranks (National Museum of Victoria, Melbourne), K.B. Lewis (National Institute of Water and Atmospheric Research, Wellington), H.E.G. Morgans (IGNS, Lower Hutt), C.P. Strong (IGNS, Lower Hutt), M. Venec-Peyre (Musée National d'Histoire Naturelle, Paris), K. Wetmore (University of California, Berkeley, San Francisco) and I. Yassini (Wollongong City Council, New South

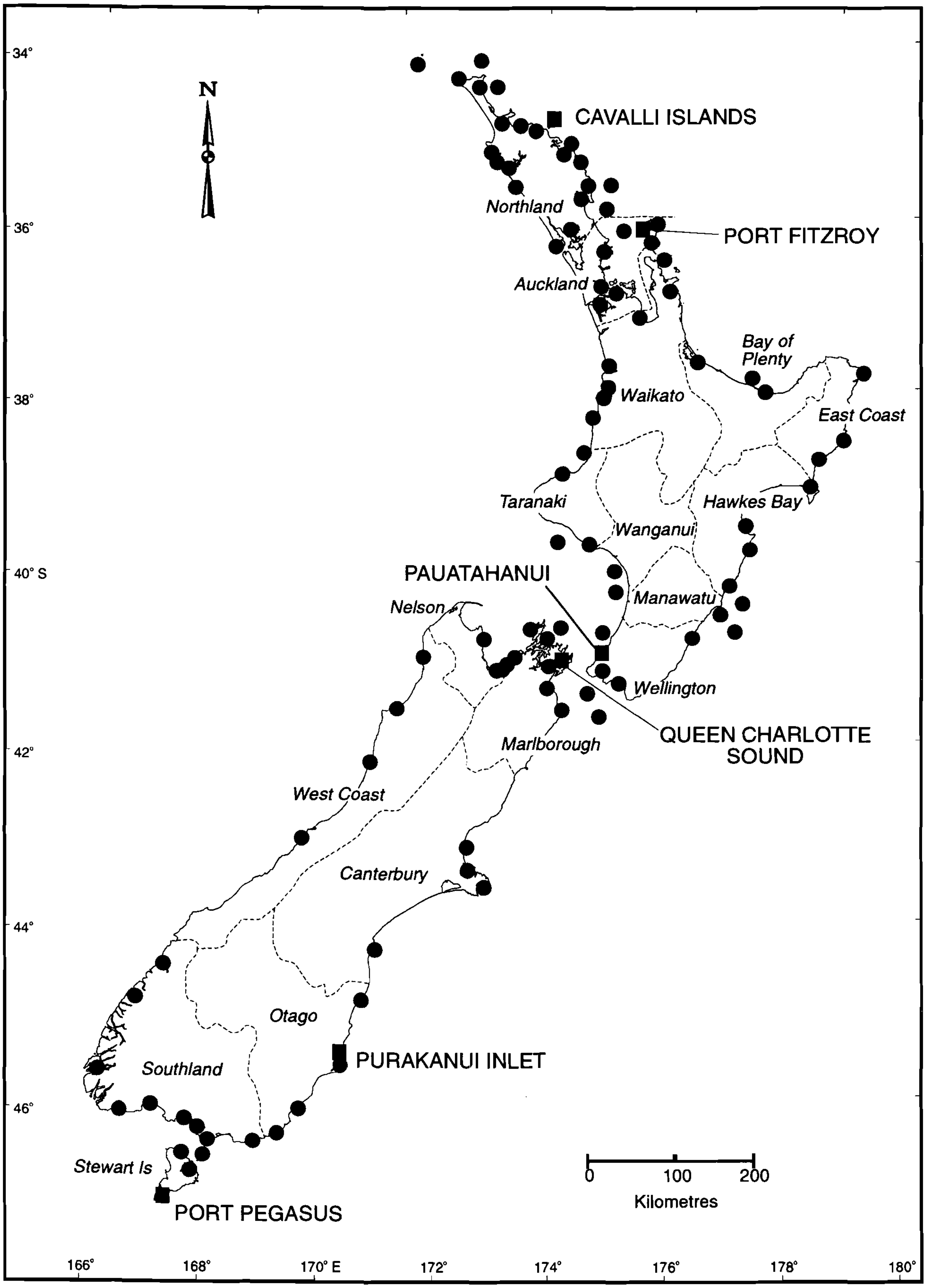


Figure 3 Location of sediment samples (dots) studied for Recent Elphidiidae around the coast of the three main islands of New Zealand. New Zealand regions are identified in lower case, and six quantitative ecologic study sites are identified in capitals and squares.

Wales). We are grateful to Fred Brook, Nick de Carteret, Michael Eagle and Norm Gardner for collecting Recent sediment samples from around the South-west Pacific for us for this study.

We also thank Barry Burt, Sue Bishop and Wendy St George (New Zealand Geological Survey, Lower Hutt) who took many of the scanning electron microscope photographs during the 1980s; Annette Pullin and Jenny Riley (Auckland Museum) for technical assistance during preparation of the manuscript; the Surface Materials Laboratory, School of Engineering, University of Auckland for the use of their SEM for photomicrographs in the 1990s. Ian Raine (Institute of Geological and Nuclear Sciences) assisted with searches of the computerised database of foraminiferal identifications in the NZ Fossil Record File made by IGNS micropaleontologists over many decades.

We are especially grateful to our colleagues Percy Strong, George Scott, Hugh Morgans and Marty Buzas for their helpful advice and assistance over the last 15 years. The manuscript has benefited greatly from the critical reading of George Scott and Marty Buzas.

MORPHOLOGY

The terminology used in describing the test and its ornament is shown in Figure 4.

Chamber arrangement

All Elphidiidae are planispiral or low trochospiral. The genera dealt with in this study are mostly planispiral (*Elphidium, Parrellina, Haynesina)* or partly involute trochospiral (*Cristatavultatus, Discorotalia).*

Chamber shape

Chamber shape is the basic character which determines test form. Short, inflated chambers produce broadly rounded subspherical tests (e.g. *E. saginatum),* whereas elongate, flattened chambers produce flat discoidal tests (e.g. *E. fichtellianum).* Some species have chambers that radiate out almost symmetrically from the umbilicus, whereas others have the chambers swept back strongly towards the periphery.

Test outline

The test outline is the two dimensional shape of the test when viewed from the side (along the coiling axis). Some species have a nearly circular outline, produced by chambers with a low rate of size increase (e.g. *E. oceanicum).* Other species, having a rapid rate of chamber increase, develop a more oval outline (e.g. *E. advenum tongaense, E. lene).* Dependent upon the inflation of the chambers, some taxa have lobulate outlines, especially in the latter part of the test (e.g. *Haynesina, E. phillipense).*

Test profile and peripheral angle (Figure 5)

The test profile is the peripheral view of the test, perpendicular to the axis of coiling. It may range from strongly compressed (e.g. *E. fichtellianum),* through biconvex (e.g. *E. charlottense)* to strongly inflated (e.g. *E. ingressans).* Tests may have convex, concave or flat, parallel sides. For each taxon, a range of width/thickness ratios is quoted giving an objective measure of test inflation. In this instance the width is the greatest diameter of the test perpendicular to the axis of coiling, and the thickness is measured parallel to the axis.

In profile the periphery may be broadly (obtuse angle) or acutely rounded or have a sharp acute angle.

Keel and peripheral spines

Species with a broadly rounded periphery seldom have a peripheral keel; those that are sharply angled or acutely rounded often have a keel. Keels vary in strength and width. A few taxa (e.g. *E. excavatum maorium)* have rudimentary rounded keels or merely a thickened (limbate)

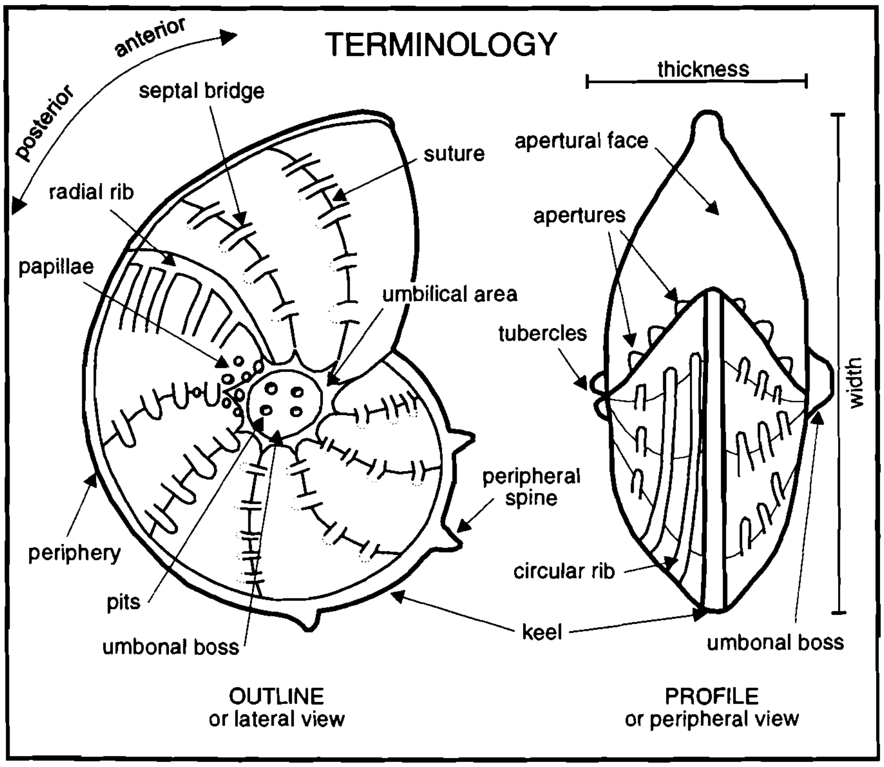


Figure 4 Terminology used for the planispiral elphidiid test and its ornament.

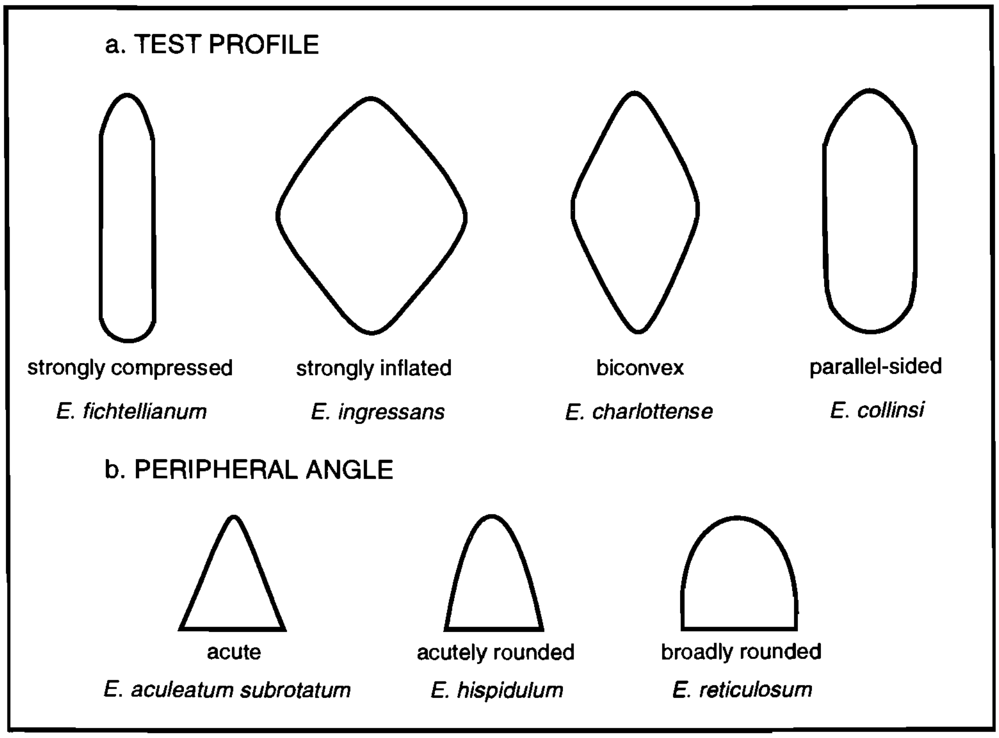


Figure 5 a Basic types of test profile in the Elphidiidae. **b** Types of peripheral angle in Elphidiidae in profile.

peripheral band that is only just discernable through a light microscope. Taxa with distinctive broad and strong keels (e.g. *E. advenum botaniense)* or weak, narrow keels (e.g. *E. collinsi*) are uncommon.

A few taxa possess peripheral spines on their keel. These vary in strength, length and number per whorl. Most taxa have one spine per chamber; some are extremely short and small (e.g. *E. aculeatum norcotti),* whereas others are slightly longer and pointed (e.g. *E. silvestrii).* The strongest and longest spines, with longitudinal costae, are present on *Parrellina imperatrix,* which only has 3–4 per whorl.

Chamber number

The number of chambers per whorl is another character of taxonomic significance. Although the number of chambers per whorl increases with the size and age of the test, the number in the final whorl of adult tests is relatively stable and is quoted for each taxon. Chambers per whorl range from 8 to 9 (e.g. *E. sandiegoense, Cristatavultatus pacificus)* up to a maximum of about 40 (e.g. large *E. craticulatum* and *E. crispum).*

Sutural incision and ornament

The sutures between chambers vary in their prominence. Some are wide and deeply incised (e.g. *E. advenum botaniense),* whereas others are narrow and shallow (e.g. *E. schencki, E. matauraense).* In some taxa the sutures are almost completely obscured by strong spiral ornament and septal bridges (e.g. *E. fichtellianum*). Many, but not all, species with wide sutures have them lined with fine papillae (e.g. *E. excavatum*, Pl. 1, Fig. 12).

Septal bridges

Solid or hollow chamber projections (septal bridges) that extend over the preceding suture are diagnostic of the family Elphidiidae. In some taxa (e.g. *Notorotalia, Parrellina)* these take the form of spiral ribs that are joined to a series of radial ribs. In *Elphidium,* the septal bridges are quite variable in their number per chamber. Some taxa have few (e.g. *E. sandiegoense)* whereas others characteristically have many (e.g. *E. crispum).* Septal bridges vary in their strength and length. They may be short and obscure (e.g. *E. excavatum excavatum*, Pl. 1, Fig. 12) or long and prominent (e.g. *E. novozealandicum*, Pl. 1, Fig. 9).

Spiral ornament

Spiral ornament mainly comprises the septal bridges, which in some species are strengthened on the earlier part of the whorl to form prominent circular ribs (e.g. *E. craticulatum, E. hispidulum)* or may combine with equally strong radial ribs to form a reticulate network (e.g. *E. kanoum, E. reticulosum*, *E. hampdenense,* Pl. 1, Fig. 11).

Radial ornament

Many species lack radial ornament (e.g. *E. vellai, Haynesina depressula).* Other taxa have pseudoradial ribs produced by inflation of the anterior portion of each chamber (e.g. *E. advenum limbatum),* or have narrow ribs extending part way (e.g. *E. carteri*, Pl. 1, Fig. 15) or all the way (e.g. *E. novozealandicum, Discorotalia tenuissima)* along the anterior edge of each chamber.

Umbilical ornament

Umbilical ornament is generally consistent within each taxon. A depressed umbilicus may be lined with fine papillae (e.g. *E. excavatum, E. hampdenense*, Pl. 1, Fig. 11), have numerous coarse papillae (e.g. *E. oceanicum, E. fichtellianum, Haynesina depressula*, Pl. 1, Fig. 10) or have a network of small ribs (e.g. *E. novozealandicum*, Pl. 1, Fig. 9). The umbilicus may be partly or fully filled with several strong tubercles (e.g. *E. matanginuiense, E. wadeae)* or a single large boss (e.g. *E. crispum*). Another useful taxonomic character is the form of the umbonal boss, which may be completely flat (e.g. *E. albanii)*, strongly raised (e.g. *E. subrotatum, E. vavauense)*, small and surrounded by a circular suture (e.g. *E. advenum maorium*, Pl. 1, Fig. 7), exceptionally wide (*E. craticulatum, E. mortonbayense)* or filling only the lower part of the umbilicus (e.g. *E. advenum botaniense).*

Additional chamber ornament

In a few species, ornament additional to the spiral and radial ribs may be developed on the chambers. *E. hispidulum* has short hispid spines on its early chambers (Pl. 1, Fig. 14); *E. phillipense* has coarse granules over most of the chamber walls; *E. collinsi* and *P. papillosa* have an irregular pattern of coarse papillae and wavy, short costae (Pl. 1, Fig. 16).

Apertural face ornament

The apertural face is the face of the last-formed chamber in profile. In most instances the apertures are a row of circular pores along the base of the apertural face (Pl. 1, Figs 3, 6). Occasionally supplementary apertures may be present higher on the face (Pl. 1, Fig. 4).

The apertural face is commonly unornamented in the genera *Haynesina* and *Elphidium,* but some strongly ornamented species have an apertural face with small papillae or occasionally granules covering some or all of it (e.g. *E. argenteum, E. collinsi, E. oceanicum).* In the genera *Parrellina, Discorotalia* and *Notorotalia* the apertural face is always strongly ornamented with narrow, often wavy riblets (Pl. 1, Fig. 5).

Surface wall texture

Most elphidiid species treated here have finely perforate wall texture, but a few (e.g. *E. gunteri, E. vellai*) have more coarsely perforate texture. Under a light microscope *E. argenteum* appears to be coarsely perforate, but scanning electron microscope study shows that it is actually covered with numerous fine papillae.

Internal canal systems

The Elphidiidae have a complex internal structure of sutural and umbilical canals which open to the surface through pores. These have been studied in detail by a number of workers (e.g. Hansen & Lykke-Anderson 1976, Hottinger & Leutenegger 1980) and require special techniques beyond the scope of this study. The internal structure is not helpful for routine identification of elphidiids using standard light or scanning electron microscope techniques, and its study and documentation is not essential for the purposes of this work.

BIOLOGY

Although this study has not involved any direct biological observations, it is appropriate to summarise what is known about elphidiid biology from overseas work.

Life history and life span

Lister's (1895) study of *Elphidium crispum* established what we now recognise as the "classical life-cycle" of foraminifera (Lee *et al.* 1991). This involves a regular alternation of generations between a haploid, uninucleate, gamont stage and a diploid, multinucleate, agamont stage. Free-swimming gametes are produced by the gamont and undergo syngamy in the open sea.

Most studies have shown that intertidal and subtidal species of *Elphidium* reproduce once or twice a year (e.g. *E. crispum* - Myers 1942; *E. excavatum* group - Haake 1967, Wefer 1976, Lutze 1968; *E. macellum* - Boltovskoy 1964). In most foraminifera the gamont or agamont dies upon reproduction, and hence in *Elphidium* each stage survives 6 months to a year and the whole life cycle is annual or biennial.

Life spans are longest where species live close to their limits of tolerance and reproduction is only possible in one season per year. Life spans are shorter where conditions are more favourable and reproduction can occur twice a year or more often (Murray 1991a). Hence *E. crispum* reproduces once a year in temperate areas but twice a year in the tropics (Jepps 1942).

Haynesina depressula is an opportunistic species (r-strategist) that thrives at times of high food availability, with an average life span for a stage of 3 to 4 months, but in optimal conditions of 6 weeks (Murray 1983).

Mode of life

Studies on a number of northern hemisphere species of *Elphidium* indicate that this largely opportunistic genus can have a number of modes of life (Murray 1991a, 1991b). It is mostly free-living in sediment, but sometimes adopts a clinging life-style. *Elphidium* may be an epifaunal or infaunal dweller. Its partial reliance on photosynthetic processes for food probably inhibit it from living terribly deep in the surface sediments. Specimens of *E. excavatum* have been recorded as living at depths of 0.5 to 6 cm in sand (Richter 1964), whereas *E. crispum* has been shown to live in the upper 1 cm (Myers 1943). *Haynesina depressula* is also an infaunal, free-living species (Murray 1983).

Nutrition

Studies on *E. crispum, E. excavatum clavatum, E. excavatum williamsoni, E. gunteri* and *Haynesina depressula* suggest that they are all primarily herbivores grazing mostly on pinnate diatoms (Lee 1980, Murray 1991b). When required they may sometimes also be detritivorous.

As herbivores, the growth and reproduction of elphidiids and *Haynesina* is related to algal blooms (Myers 1943) and hence there is a marked seasonal cyclicity in their biomass (Murray 1983, 1991a). In tidal flats, densities of *Elphidium* or *Haynesina* range up to several hundred per cm^2 depending upon food availability (Murray 1991a).

Many elphidiids (e.g. *E. crispum, E. excavatum, E. excavatum williamsoni)* and nonionids *(Haynesina)* retain and husband chloroplasts of some of the diatom algae they partially consume (Lopez 1979, Lee *et al.* 1988). Numbers of husbanded chloroplasts range between 100 and 5000 per individual (Lee and Lee 1990). Primary production studies have shown that the chloroplasts are functional and contribute to the foraminifer's nutrition (Lopez 1979, Lee *et al.* 1988). It has been suggested that the complex canal systems of elphidiids and *Haynesina* may have functions in terms of chloroplast husbandry but this has not yet been confirmed (Lee and Anderson 1991).

In shallow, tropical, oligotrophic waters elphidiids probably rely more on husbanded chloroplasts for food than they do in temperate waters. In these tropical environments some of the larger elphidiids (e.g. *E. craticulatum, E. mortonbayense)* may be longer-lived k-strategists like the associated larger foraminifera (Murray 1991a).

ECOLOGY

NEW ZEALAND SPECIES (Figures 6-13)

Eleven species or subspecies of *Elphidium* and one of *Haynesina* live around the coast of New Zealand today. Their ecologic distribution has been documented as part of quantitative studies on the distribution patterns of all benthic foraminifera in a number of areas: Northland - off North Cape (Hoskins 1978), Cavalli Islands (Hayward 1982a), Bay of Islands (Hayward 1981), Helena Bay (Hayward & Hollis 1994), Chickens Islands (Hayward *et al.* 1984); Auckland - Great Barrier Island (Hayward & Grenfell 1994); upper Waitemata Harbour (Hayward & Hollis 1994); Hawkes Bay - offshore east coast (Lewis 1979); Wellington - Pauatahanui Inlet (Hayward & Triggs 1994); Marlborough - Queen Charlotte Sound (Hayward *et al.* in prep); West Coast - Oparara Lagoon (Hayward & Hollis 1994); Otago - Purakanui Inlet (Hayward *et al.* 1996); Stewart Island - Port Pegasus (Hayward *et al.* 1994).

These studies show that *Elphidium* and *Haynesina* live in their greatest abundances (numbers greater than 20% of total benthic foraminifera) in intertidal and shallow subtidal environments shallower than 2 m depth. They are common members of most benthic foraminiferal faunas in normal marine salinity at inner shelf depths down to about 30–40 m and in the middle and outer, slightly brackish parts of inlets and estuaries. *Elphidium* tests are recorded from all depths down to the CCD (Hoskins 1978, Lewis 1979), but their abundance decreases rapidly below inner shelf depths. Several species may be able to live in low numbers at mid-outer shelf depths (Lewis 1979) but it is probable that all bathyal records are of tests that have been transported there by bottom currents.

Table 1. New Zealand's present-day *Elphidium* and *Haynesina* taxa grouped according to the salinity of the habitats in which they live.

Taxa living exclusively in slightly brackish conditions:
- *E. excavatum excavatum*
- *E. excavatum clavatum*
- *E. gunteri*

Taxa living in both slightly brackish and normal salinity conditions:
- *E. excavatum williamsoni*
- *E. advenum limbatum*
- *Haynesina depressula*

Taxa living exclusively in normal marine salinity conditions:
- *E. advenum maorium*
- *E. charlottense*
- *E. crispum crispum*
- *E. excavatum oirgi*
- *E. novozealandicum*
- *E. vellai*

The herbivorous nature of elphidiids and *Haynesina* and the prevalence of chloroplast husbandry presumably require these foraminifera to live in the photic zone and generally limit their depth distribution to the inner shelf.

In New Zealand, the different *Elphidium* and *Haynesina* taxa exhibit distinct environmental preferences (Figure 6). For a number of taxa, salinity appears to be a key ecological determinant. Other important influences include factors related to increasing water depth and the degree of exposure to high wave and current energy. With respect to salinity, three groups of taxa are distinguishable (Table 1).

Brackish group

Within the brackish group of taxa, there is a strong tendency for *E. excavatum excavatum* to live in lower salinity environments (*Haplophragmoides, Miliammina, Ammonia-Miliammina, Elphidium* associations of Hayward & Hollis 1994) than *E. excavatum clavatum* (*Ammonia-Miliammina, Elphidium, Ammonia* associations of Hayward & Hollis 1994). These two subspecies of *E. excavatum* often are the dominant foraminifera, on their own or in association with *Ammonia beccarii,* on the intertidal mud or sand flats of sheltered inlets and the outer parts of estuaries (Figure 7), where they may constitute up to 100% of the total foraminiferal fauna.

The other exclusively brackish species, *E. gunteri,* is nowhere common, reaching maximum abundances of about 5% in intertidal flats in the middle parts of sheltered inlets (*Miliammina, Ammonia-Miliammina* associations of Hayward & Hollis 1994).

Brackish/normal marine salinity group

In this group of taxa, *E. excavatum williamsoni,* occurs mostly at intertidal depths in the outer parts of estuaries and sheltered inlets in normal or periodically slightly lowered salinity (*Elphidium, Ammonia, Haynesina, Elphidium charlottense* associations of Hayward & Hollis 1994, Hayward & Grenfell 1994). *Haynesina depressula,* too, is most abundant (up to 40% of faunas) in sheltered intertidal or shallow subtidal environments with periodic very slightly lowered salinity (Figure 8, *Ammonia, Haynesina* associations). *Haynesina* also lives quite commonly (up to 10% of faunas) in a wide range of inner shelf, normal salinity environments.

E. advenum limbatum lives in a similar range of environ-

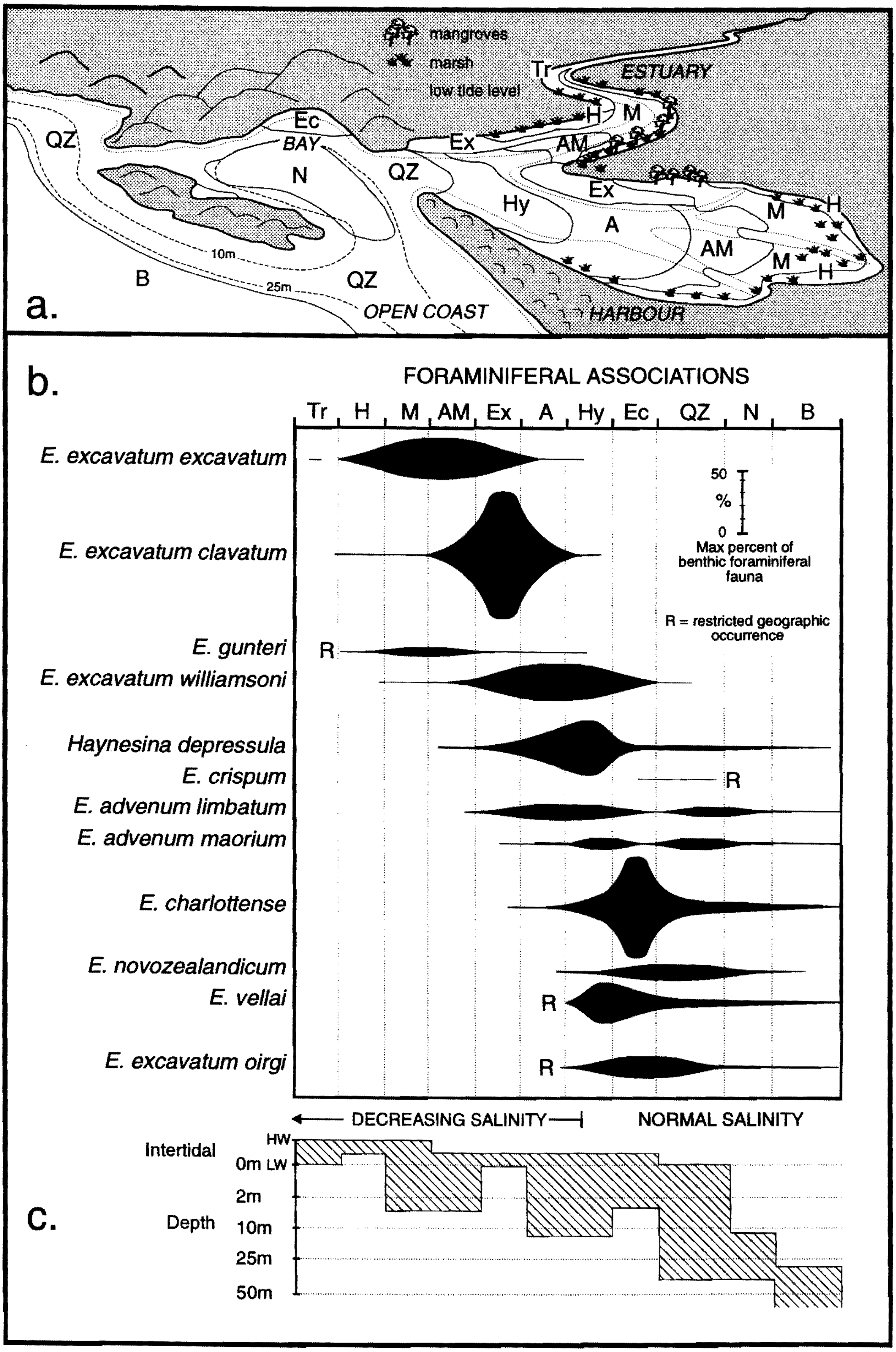

a.
mangroves
marsh
low tide level
Tr
ESTUARY
H
M
Ec
BAY
QZ
N
QZ
Ex
AM
Hy
Ex
A
M
H
AM
M
H
10m
25m
B
QZ
OPEN COAST
HARBOUR
b.
FORAMINIFERAL ASSOCIATIONS
Tr H M AM Ex A Hy Ec QZ N B
E. excavatum excavatum
E. excavatum clavatum
E. gunteri
E. excavatum williamsoni
Haynesina depressula
E. crispum
E. advenum limbatum
E. advenum maorium
E. charlottense
E. novozealandicum
E. vellai
E. excavatum oirgi
R
R
R
R
50
%
0
Max percent of benthic foraminiferal fauna
R = restricted geographic occurrence
DECREASING SALINITY
NORMAL SALINITY
c.
Intertidal
Depth
HW
0m LW
2m
10m
25m
50m

Figure 6 ***(opposite)*** Schematic diagram and charts summarising the ecologic distribution of New Zealand Recent species and subspecies of *Elphidium* and *Haynesina.*

a Paralic and coastal foraminiferal associations (slightly modified after Hayward and Hollis 1994, Hayward *et al.* 1994, 1996) are: Tr - *Trochamminita;* H - *Haplophragmoides wilberti;* M - *Miliammina;* AM - *Ammonia-Miliammina;* Ex - *Elphidium excavatum;* A - *Ammonia;* Hy - *Haynesina-Elphidium advenum;* Ec - *Elphidium charlottense;* QZ - *Quinqueloculina-Zeaflorilus;* N - *Nonionella flemingi;* B - *Bulimina.*

b Relative abundance chart with respect to foraminiferal associations.

c Salinity and depth ranges of the foraminiferal associations.

ments to *Haynesina* but in considerably lower abundance (mostly less than 5% of faunas). It is most abundant (up to 15%) in intertidal and shallow subtidal flats in the middle and outer parts of sheltered inlets (Figure 9; *Ammonia, Haynesina* associations).

Normal marine salinity group

In this group, *E. charlottense* is the most abundant and widespread species. It is a codominant member of inner shelf sand faunas in many parts of the country (Figure 10; *Quinqueloculina-Zeaflorilus* association), but is most abundant (up to 70% of faunas) in beach and shallow subtidal sand (up to 3 m depth) in moderately sheltered bays (Figure 10; *Elphidium charlottense* association of Hayward 1982a). It often occurs in the current-swept entrances to estuaries and inlets, but has probably been swept in, together with other members of the *Quinqueloculina-Zeaflorilus* association, from normal salinity environments.

The next most common and widespread species in this group is *E. novozealandicum,* which occurs through all inner shelf associations and is most abundant (up to 10% of faunas) in moderately exposed, high energy subtidal environments in sand and gravel (Figure 11; *Quinqueloculina-Zeaflorilus* association).

E. advenum maorium is relatively uncommon and is largely restricted to normal salinity, subtidal, sheltered to moderately sheltered inner shelf environments. It is most abundant (up to 5% of faunas) usually in the outer parts and entrances of sheltered inlets and harbours (*Haynesina, Quinqueloculina-Zeaflorilus* associations).

Of the three geographically restricted species, *E. crispum crispum* is the rarest, constituting up to 2% of faunas in relatively sheltered subtidal sand. Where it occurs, *E. excavatum oirgi* has a similar distribution pattern to *E. charlottense,* and is most abundant (up to 10% of faunas) in beach and shallow subtidal sand in sheltered bays (Figure 12; *Elphidium charlottense, Quinqueloculina* associations). *E. vellai* has a local distribution, but consti-

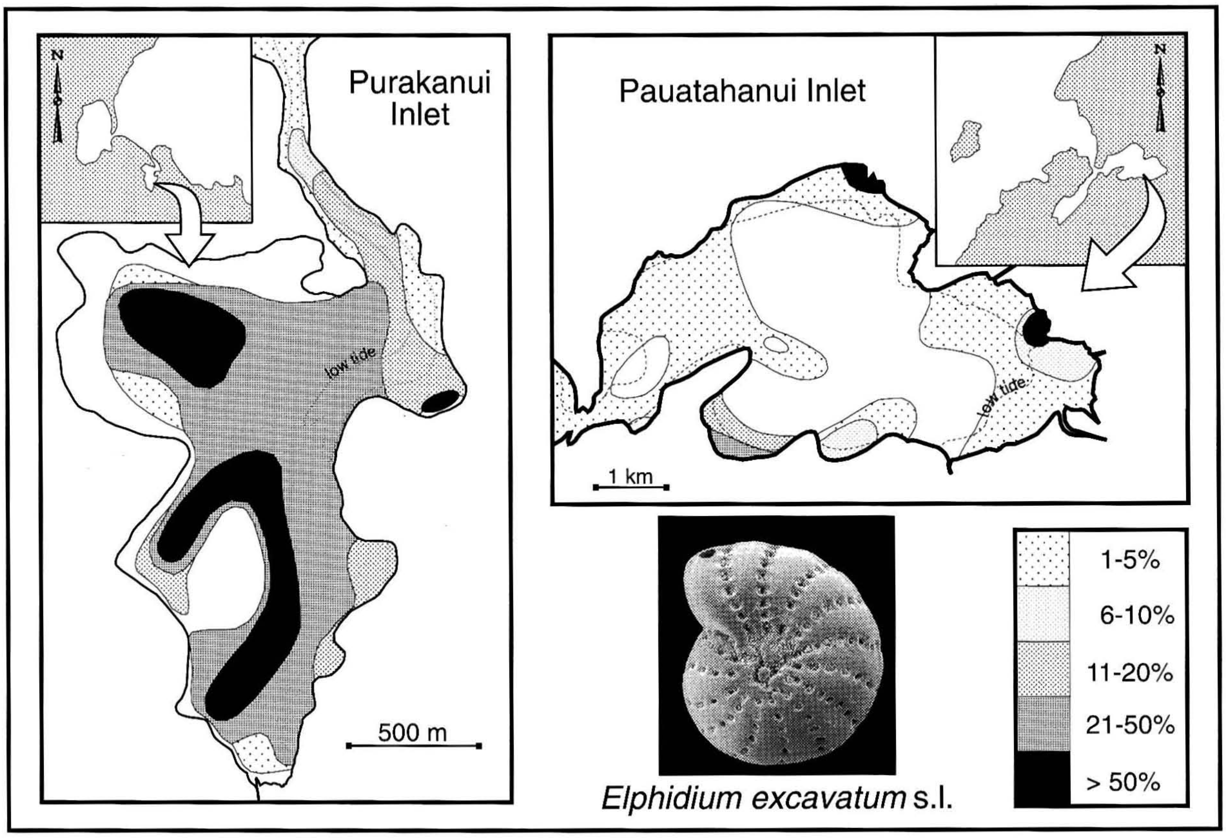


Figure 7 Contoured abundance distribution maps of *Elphidium excavatum clavatum* plus *E. excavatum excavatum* in Pauatahanui Inlet (Wellington) and Purakanui Inlet (Otago), New Zealand. Based on data from Hayward and Triggs (1994) and Hayward *et al.* (1996).

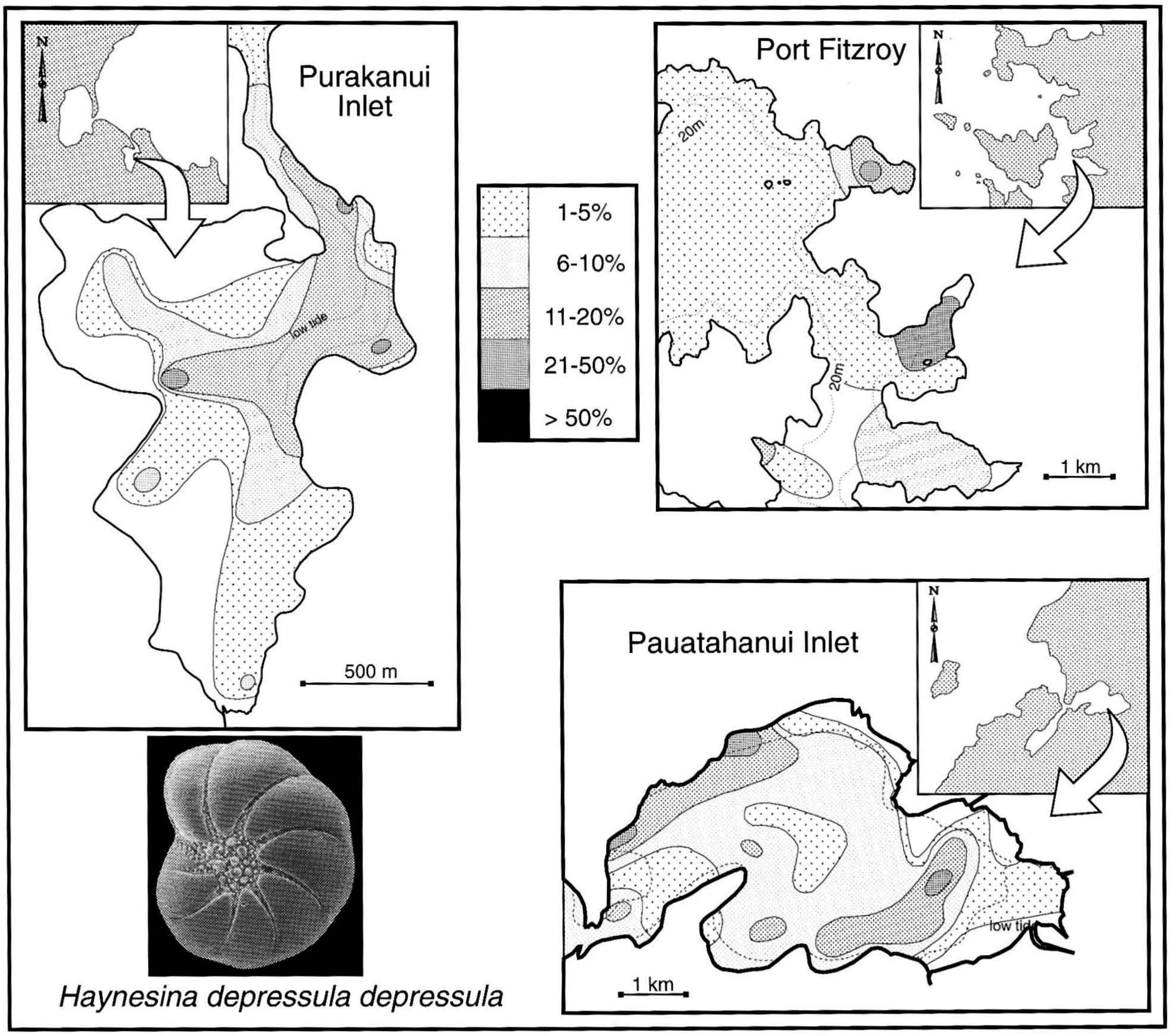


Figure 8 Contoured abundance distribution maps of *Haynesina depressula depressula* in Port Fitzroy (Great Barrier Island) Pauatahanui Inlet (Wellington) and Purakanui Inlet (Otago), New Zealand. Based on data from Hayward and Grenfell (1994), Hayward and Triggs (1994) and Hayward *et al.* (1996).

tutes up to 40% of faunas in muddy sand in 10–20 m depth in moderately exposed bays (Figure 13; *Haynesina* association, Hayward *et al.* in prep).

EAST AUSTRALIAN SPECIES

Over 30 species or subspecies of *Elphidium*, *Haynesina*, *Parrellina* and *Cristatavultatus* live around the coast of eastern Australia today. Their ecologic distribution has been documented as part of quantitative and qualitative studies on the distribution patterns of all benthic foraminifera in a few areas: Queensland - Moreton Bay (Palmieri 1976a), central Queensland continental shelf (Palmieri 1976b); New South Wales - Broken Bay (Albani 1978), Port Hacking (Albani 1968a), Lake Illawarra (Yassini & Jones 1988); Victoria - Gippsland Lakes system (Apthorpe 1980), Port Phillip (Collins 1974).

As in New Zealand, these studies show that *Elphidium* is most abundant (numbers greater than 20% of total benthic foraminifera) in intertidal and shallow subtidal environments shallower than 2 m depth. In addition *Elphidium*, *Haynesina* and *Parrellina* are common members of east Australian benthic foraminiferal faunas in normal marine salinity at inner shelf depths down to about 30–40 m. These genera are recorded from all depths down to the CCD, but their abundance decreases rapidly below inner shelf depths and it is doubtful that any individuals actually live at depths greater than 100 m or so.

The various taxa exhibit distinct environmental preferences in their ecological distribution patterns (Figure 14). With respect to salinity, three groups of taxa are recognised:

Taxa living exclusively in slightly brackish conditions:
E. excavatum excavatum, *E. excavatum clavatum*, *E. gunteri*, *E. phillipense*

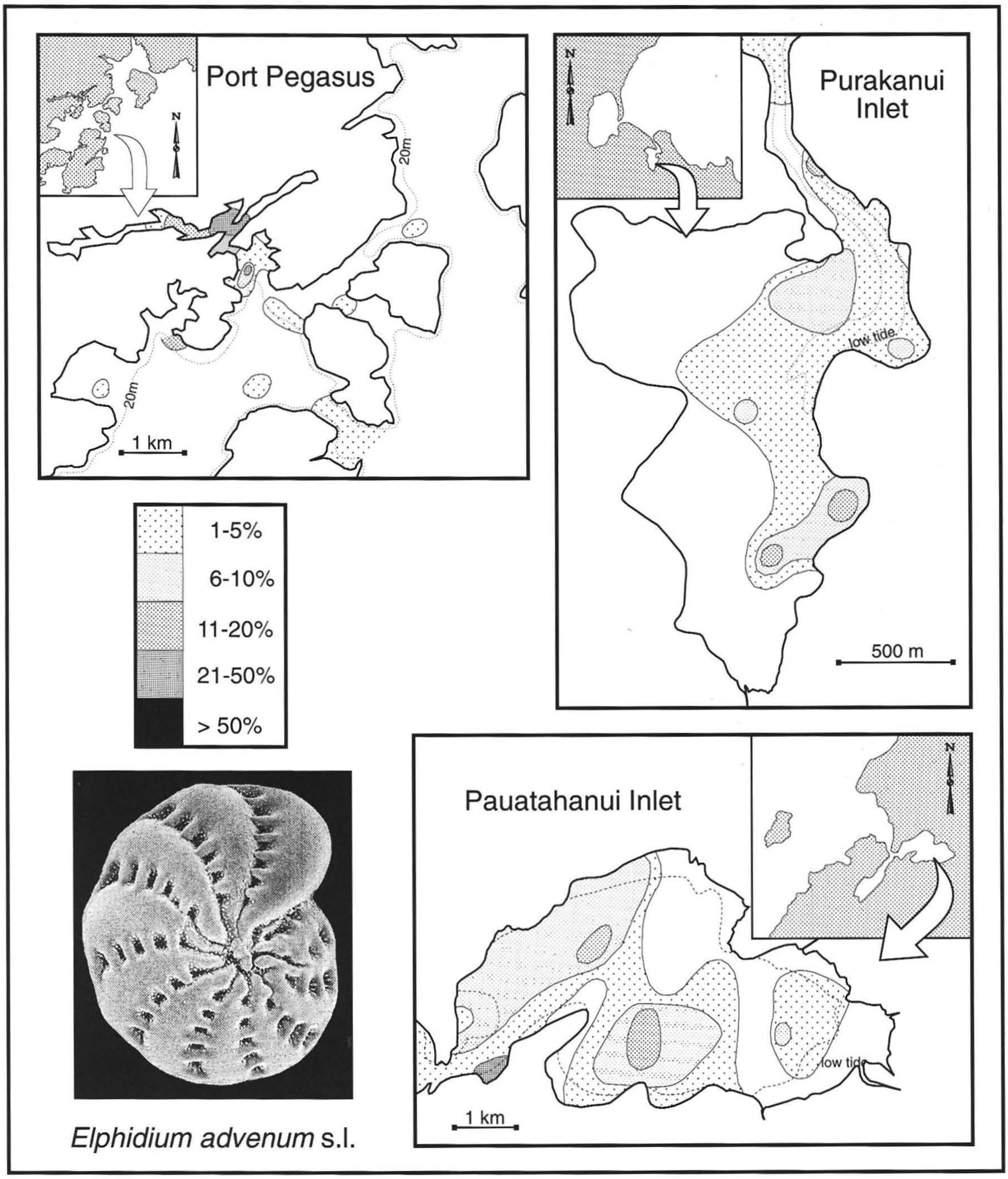


Figure 9 Contoured abundance distribution maps of *Elphidium advenum* s.l. in Pauatahanui Inlet (Wellington), Purakanui Inlet (Otago) and Port Pegasus (Stewart Island), New Zealand. Based on data from Hayward and Triggs (1994), Hayward *et al.* (1996) and Hayward *et al.* (1994).

Taxa living in both slightly brackish and normal salinity conditions:

E. excavatum williamsoni, E. excavatum sydneyense, E. advenum botaniense, E. advenum limbatum, E. lene, Haynesina depressula

Taxa living exclusively in normal marine salinity conditions:

E. macellum, E. craticulatum, E. mortonbayense, E. crispum crispum, E. hispidulum, E. fichtellianum, P. imperatrix, E. oceanicum and a number of rarer species.

Brackish group

E. excavatum excavatum appears to be the elphidiid most tolerant of low salinity conditions, occurring quite widely in upper and middle estuarine locations. *E. excavatum clavatum* is common and at times codominant with *Ammonia beccarii* in intertidal and shallow subtidal middle estuaries, bays and lagoons, especially in the south around the coasts of New South Wales and Victoria (e.g. Apthorpe 1980).

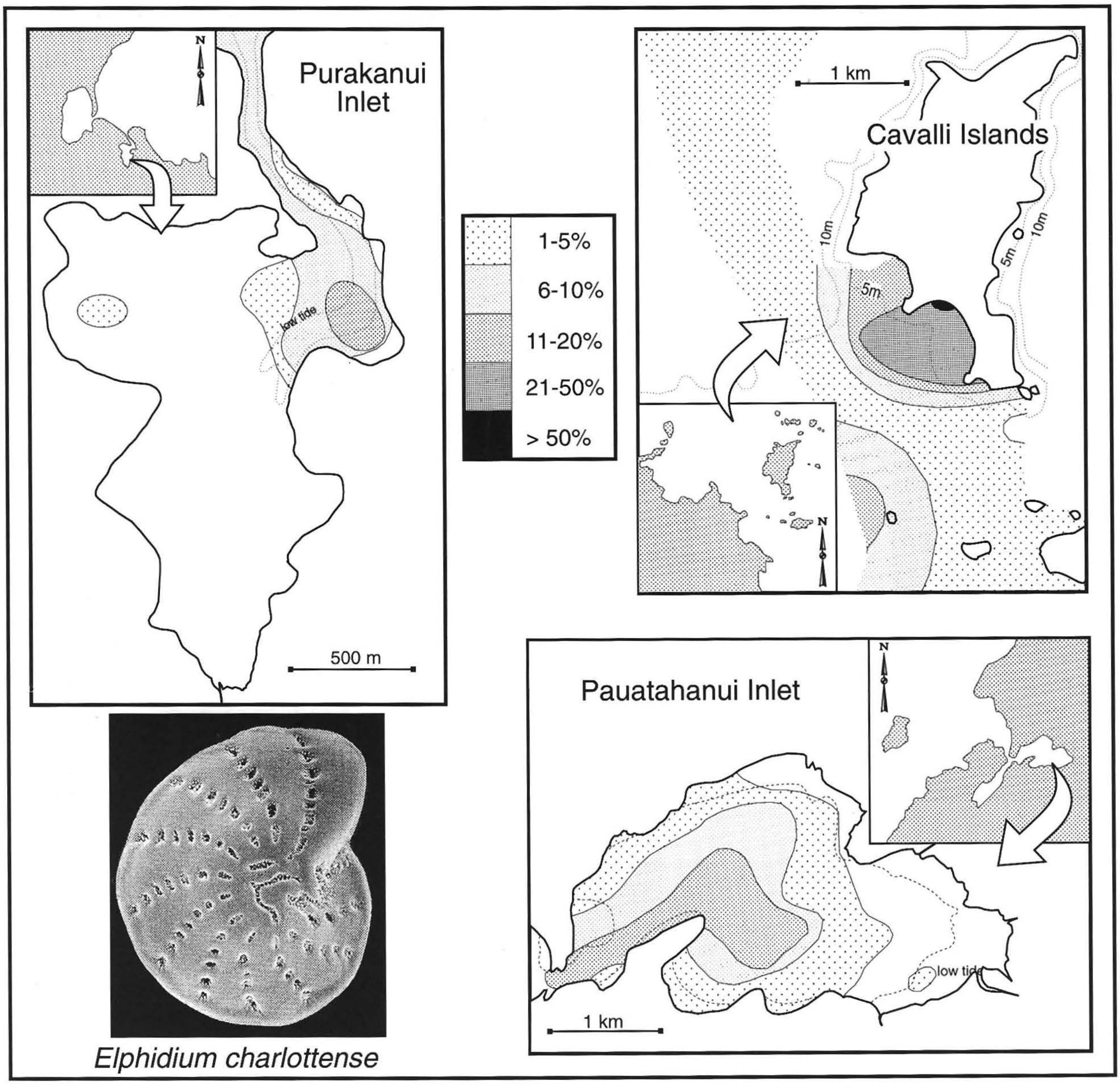


Figure 10 Contoured abundance distribution maps of *Elphidium charlottense* at the Cavalli Islands (Northland) and in Pauatahanui and Purakanui Inlets (Wellington and Otago), New Zealand. Based on data from Hayward (1982a), Hayward and Triggs (1994) and Hayward *et al.* (1996).

Brackish/normal marine salinity group

In this group, the southern taxon *E. excavatum williamsoni* occurs mostly at intertidal depths in the outer parts of estuaries and sheltered inlets in normal or periodically slightly lowered salinity (*Elphidium, Ammonia, Haynesina* associations). *Haynesina depressula* and *E. advenum botaniense* occur along most of the east coast of Australia and have their greatest relative abundances in intertidal or shallow subtidal environments in sheltered bays and harbours, outer estuaries or coastal lagoons (e.g. Albani 1968, Apthorpe 1980) with periodic very slightly lowered salinity (25–35 $‰$). *Haynesina* also lives quite commonly (up to 5% of faunas) in a wide range of inner shelf, normal salinity environments. *E. advenum limbatum* occurs in a similar range of environments to the two preceding taxa, but appears to be limited to the southern parts of the east coast of Australia.

Normal marine salinity group

E. macellum, E. crispum crispum and *P. imperatrix* are frequently major components of low tidal and shallow subtidal (0–20 m depth), normal salinity foraminiferal associations throughout the east coast of Australia, with faunas dominated by combinations of *Textularia, Quinqueloculina, Spiroloculina, Triloculina, Discorbis* and elphidiids.

In the north, along the coast of northern New South Wales

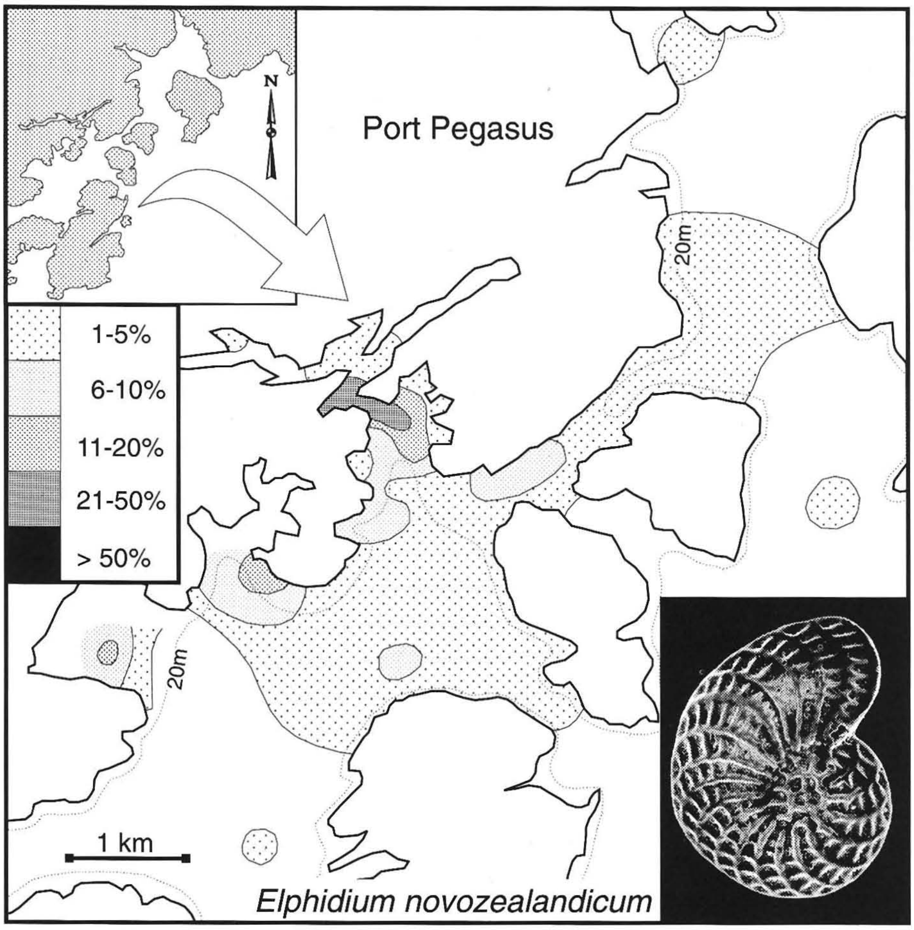


Figure 11 Contoured abundance distribution map of *Elphidium novozealandicum* in Port Pegasus (Stewart Island), New Zealand. Based on data from Hayward *et al.* (1994).

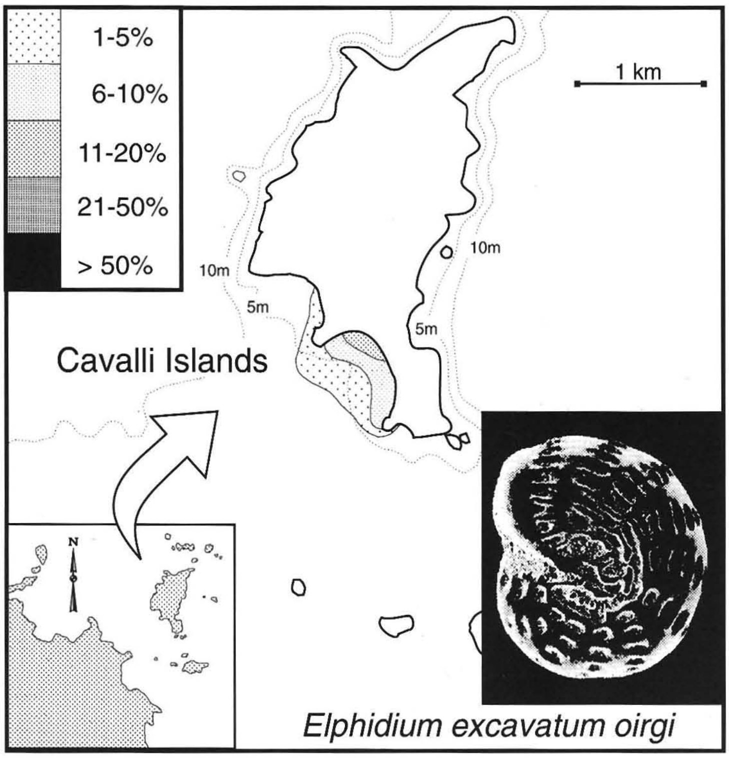


Figure 12 Contoured abundance distribution maps of *Elphidium excavatum oirgi* at the Cavalli Islands (Northland), New Zealand. Based on data from Hayward (1982a).

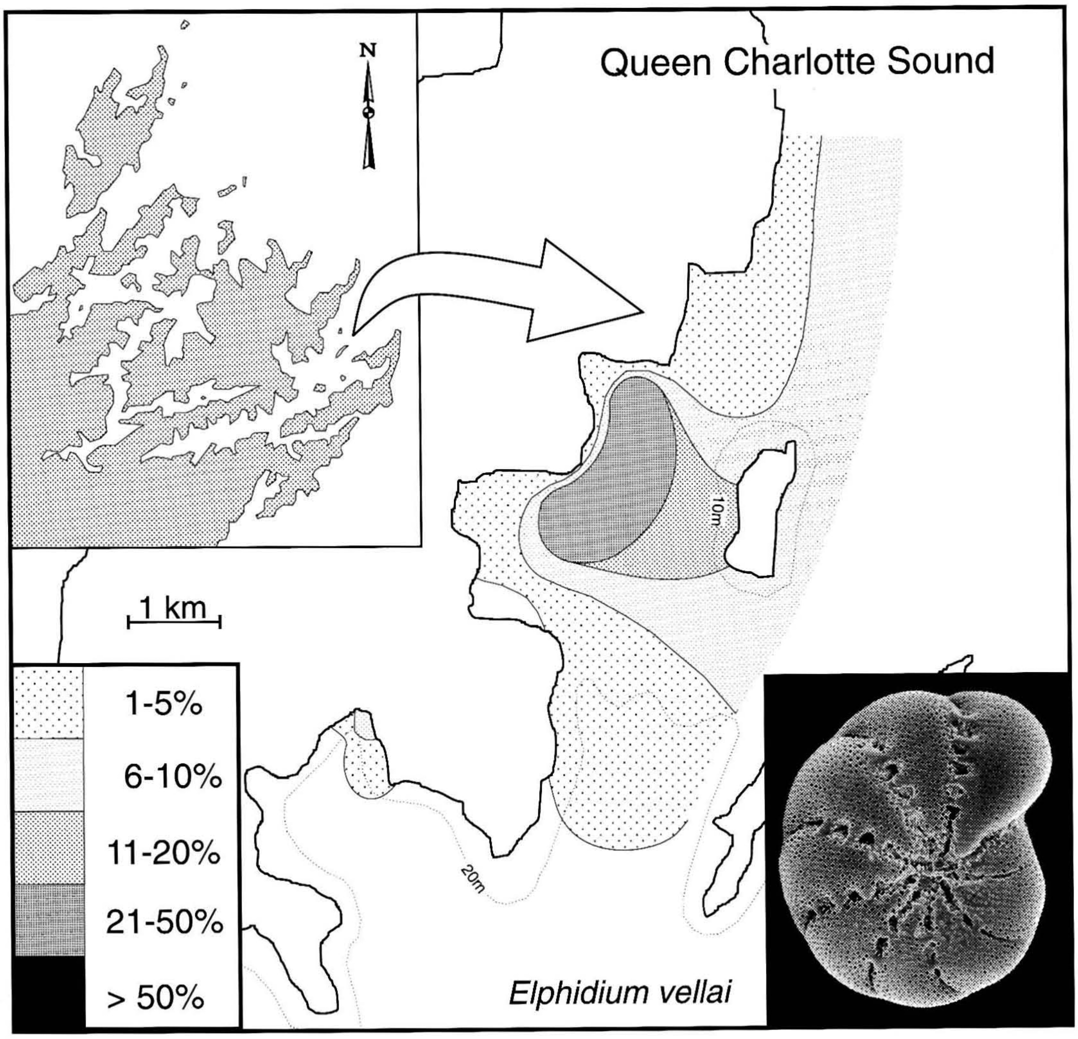


Figure 13 Contoured abundance distribution maps of *Elphidium vellai* in Queen Charlotte Sound (Marlborough), New Zealand. Based on data from Hayward *at al.* (in press).

and Queensland, *E. craticulatum*, *E. mortonbayense*, *E. albanii* and *E. hispidulum* are also often major components of these low tidal and shallow subtidal foraminiferal associations.

SOUTH-WEST PACIFIC ISLAND SPECIES

The ecologic distribution pattern of elphidiids around the South-west Pacific islands is largely based on the faunal samples of this study and is therefore limited in its extent. There have been no published accounts on the ecological distribution of foraminiferal faunas in that part of the South-west Pacific encompassed by this study.

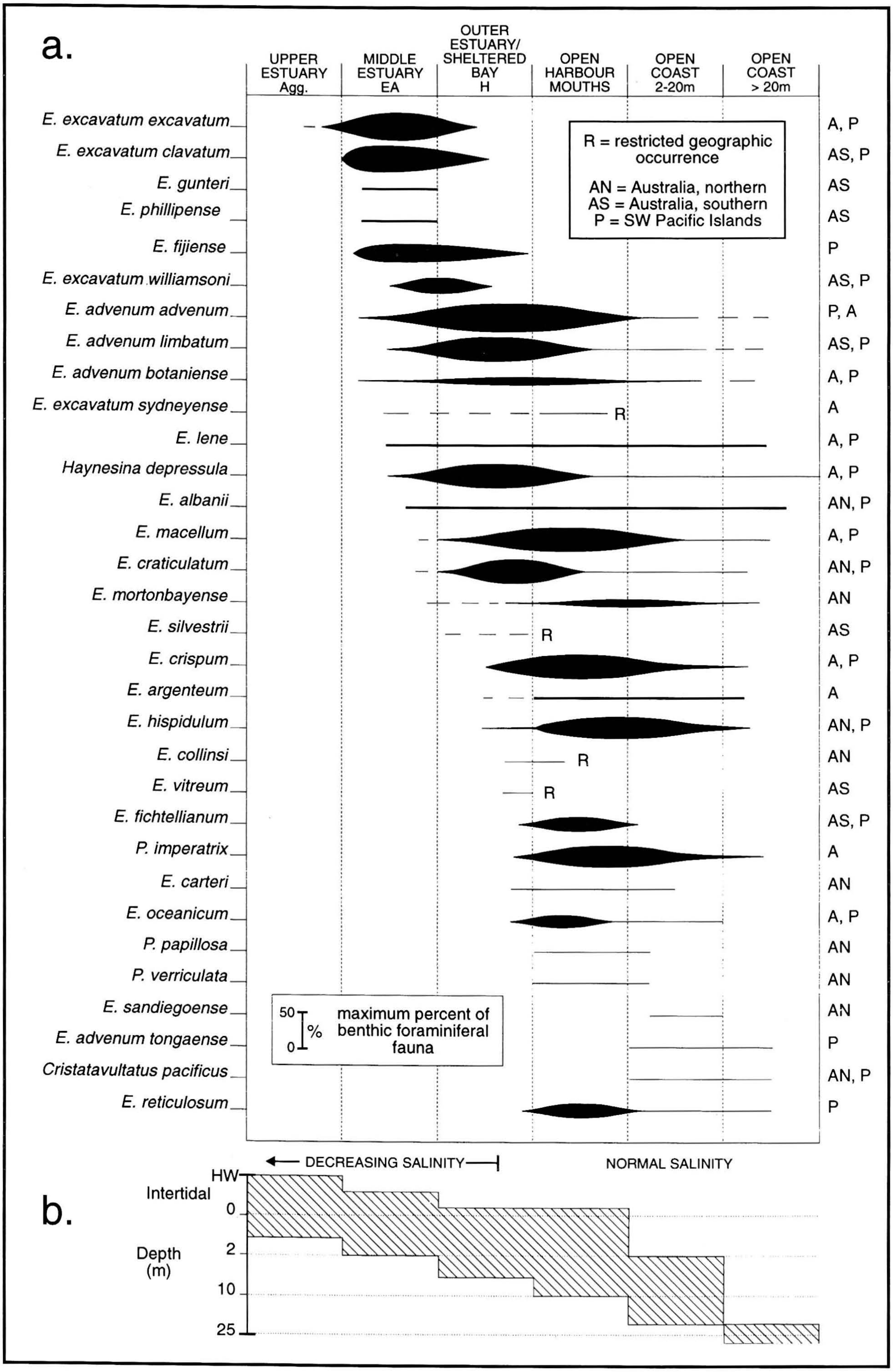
Only the larger islands in the region have sufficient fresh-water run-off to create brackish habitats (e.g. Fiji, New Caledonia, Solomon Islands). Like elsewhere in the world, *E. excavatum excavatum* and *E. excavatum clavatum* are the elphidiids tolerant of the lowest salinity conditions such as the middle reaches of estuaries. Species tolerant of slightly brackish to normal marine salinity from intertidal to shallow subtidal depths are *E. fijiense, E. advenum advenum, E. advenum limbatum, E. advenum botaniense, E. oceanicum* and *E. reticulosum* (Figure 14).

E. crispum crispum, E. craticulatum, E. macellum, E. hispidulum, E. fichtellianum and *E. reticulosum* are all common members of foraminiferal faunas living in clean sand in coral-enclosed lagoons, bays and outer reef slopes around the tropical islands in the South-west Pacific (possibly k-strategists), in diverse faunas dominated by combinations of *Textularia, Quinqueloculina, Spiroloculina, Triloculina, Elphidium, Peneroplis, Amphistegina, Baculogypsina, Tinoporus, Discorbis* and *Operculina.*

Figure 14 ***(opposite)*** Summary of the ecologic distribution of east Australian and South-west Pacific Island Recent species and subspecies of *Elphidium, Parrellina* and *Haynesina.*

a Relative abundance kite diagrams with respect to coastal habitats and foraminiferal associations: Agg = Agglutinated foraminiferal associations; EA = *Elphidium excavatum - Ammonia beccarii* association; H = *Haynesina depressula - Elphidium advenum* association.

b Salinity and depth ranges of the foraminiferal associations and habitats.


a.
UPPER ESTUARY Agg.
MIDDLE ESTUARY EA
OUTER ESTUARY/ SHELTERED BAY H
OPEN HARBOUR MOUTHS
OPEN COAST 2-20m
OPEN COAST > 20m
R = restricted geographic occurrence
AN = Australia, northern
AS = Australia, southern
P = SW Pacific Islands
E. excavatum excavatum A, P
E. excavatum clavatum AS, P
E. gunteri AS
E. phillipense AS
E. fijiense P
E. excavatum williamsoni AS, P
E. advenum advenum P, A
E. advenum limbatum AS, P
E. advenum botaniense A, P
E. excavatum sydneyense R A
E. lene A, P
Haynesina depressula A, P
E. albanii AN, P
E. macellum A, P
E. craticulatum AN, P
E. mortonbayense AN
E. silvestrii R AS
E. crispum A, P
E. argenteum A
E. hispidulum AN, P
E. collinsi R AN
E. vitreum R AS
E. fichtellianum AS, P
P. imperatrix A
E. carteri AN
E. oceanicum A, P
P. papillosa AN
P. verriculata AN
E. sandiegoense AN
E. advenum tongaense P
Cristatavultatus pacificus AN, P
E. reticulosum P
50 0 % maximum percent of benthic foraminiferal fauna
← DECREASING SALINITY
NORMAL SALINITY
b.
HW
Intertidal
0
Depth (m)
2
10
25

BIOGEOGRAPHY

Existing records (Appendix 1) give an overall but incomplete picture of the geographic distribution of Recent elphidiids in the South-west Pacific (Appendix 2). Our records are considered to be most complete for the three main islands of New Zealand and the Chatham Islands. Satisfactory coverage is available for eastern Australia, Tonga, Fiji, Lord Howe, Norfolk and the Kermadec islands, with poor coverage of the other island groups, especially of New Caledonia, Samoa and the Cook islands.

Elphidiids in the South-west Pacific exhibit a variety of distribution patterns (Table 2). Some taxa are widespread throughout the region (e.g. *E. advenum limbatum*), others have a tropical distribution (e.g. *Cristatavultatus pacificus, E. craticulatum)* or a cooler water distribution (e.g. *E. advenum maorium, E. charlottense)*, and some are restricted to a single island group or local area of coast (e.g. *E. phillipense, E. vavauense, E. vitreum)*. Several species appear to be restricted to the New Zealand area (e.g. *E. novozealandicum, E. vellai)* and a number to eastern Australia (e.g. *Parrellina* spp., *E. mortonbayense)*.

SOUTH-WEST PACIFIC SPECIES (Figures 15–21)

Of the forty-one species and subspecies of *Elphidium, Cristatavultatus, Parrellina* and *Haynesina* living in the South-west Pacific, nearly half (45%) have a cosmopolitan distribution extending well beyond the region. Some of these occur in a wide range of climate zones right around the world (e.g. *E. excavatum excavatum, Haynesina depressula)*, some live in warmer waters around many parts of the world (e.g. *E. crispum, E. macellum)*, some have a sporadic distribution around the world in several widely separated areas (e.g. *E. sandiegoense, E. silvestrii)* and some are widely distributed in the tropical Pacific (*E. advenum dispar, E. hispidulum, Cristatavultatus pacificus)*.

Approximately 50% of the Recent taxa are endemic to the South-west Pacific. Three appear to be restricted to the islands, being absent from east Australia and New Zealand (*E. advenum tongaense, E. fijiense, E. reticulosum)*, four occur around the islands and east Australia (*E. advenum botaniense, E. carteri, E. oceanicum, H. depressula simplex)*, one is present around the islands and New Zealand (*E. charlottense)* and one around the islands, east Australia and New Zealand (*E. advenum maorium)*.

Table 2. Biogeographic distribution pattern of the species and subspecies of *Elphidium, Cristatavultatus, Parrellina* and *Haynesina* living in the South-west Pacific.

	No of taxa	%
Cosmopolitan or widespread distribution	18	43
Endemic to wider South-west Pacific	8	19
Endemic to Australia	11	27
Endemic to New Zealand	3	7
Endemic to Tonga	1	2
TOTAL	41	100

One species (*E. vavauense)* appears to be endemic to a single tropical island group (Tonga).

AUSTRALIAN SPECIES

Almost 30% of the Recent taxa appear to be endemic to eastern Australia. Four of these species are common and extend most of the way along the coast from Queensland to Victoria or Tasmania (*E. argenteum, E. hawkesburiense, P. imperatrix, P. verriculata)*, three are restricted to the warmer coasts of Queensland and New South Wales - one as a common species (*E. mortonbayense)* and one less common with sporadic records (*E. collinsi)*. Two taxa are known only on the coast of New South Wales (*E. excavatum sydneyense, P. papillosa)* and two species are only known from the Port Phillip area of Victoria (*E. phillipense, E. vitreum)*. There are no species known to be endemic to Tasmania.

NEW ZEALAND SPECIES (Figures 22–24)

Three (25%) of the twelve species or subspecies of *Elphidium* and *Haynesina* living around New Zealand today are endemic. The coarsely perforate *E. vellai* has the most local distribution, in that it is only known in near normal marine salinity in two localities - one within and adjacent to the Marlborough Sounds at the northern end of the South Island, and the other in the Waitemata Harbour in the North Island (Figure 24). The glassy *E. excavatum oirgi* is restricted to a 500 km length of coast along the northeast of the North Island (Figure 23). The third endemic species, *E. novozealandicum,* lives around all the main islands of New Zealand as well as the Chatham Islands and most of the subantarctic islands (Figures 19, 24).

Two further species, *E. charlottense* and *E. advenum maorium,* appear to be endemic to the southern part of the South-west Pacific (Figures 15, 16, 22). Both occur around the three main islands of New Zealand, with *E. charlottense* also known from Lord Howe Island and *E. advenum maorium* known from Chatham, Lord Howe and Norfolk islands and Victoria in southeast Australia.

Five of the remaining seven cosmopolitan species occur right around New Zealand's three main islands with

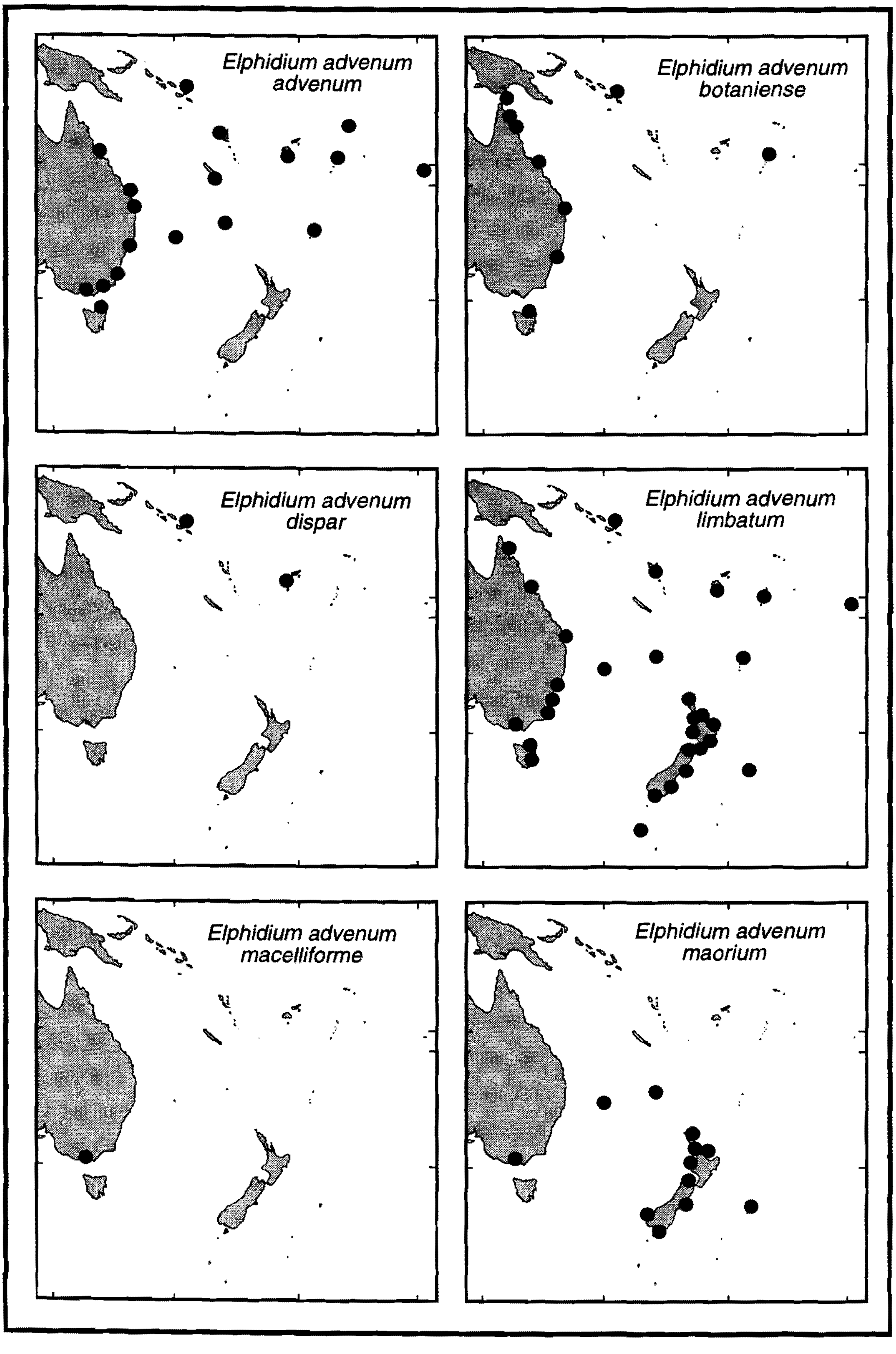


Figure 15 Summary of the recorded distribution of the six Recent subspecies of *Elphidium advenum* throughout the South-west Pacific.

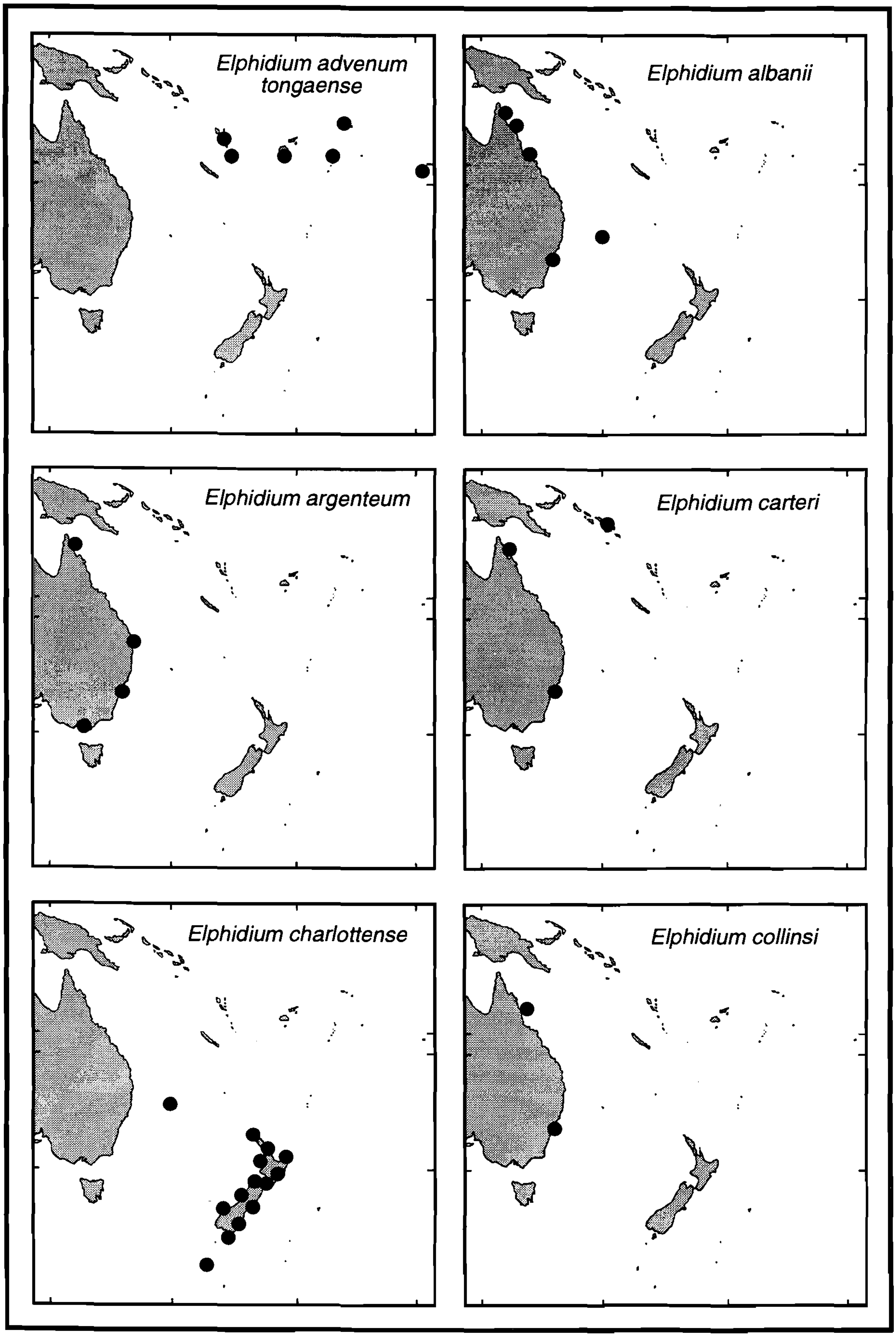


Figure 16 Summary of the recorded distribution of Recent *Elphidium advenum tongaense, E. albanii, E. argenteum, E. carteri, E. charlottense* and *E. collinsi* throughout the South-west Pacific.

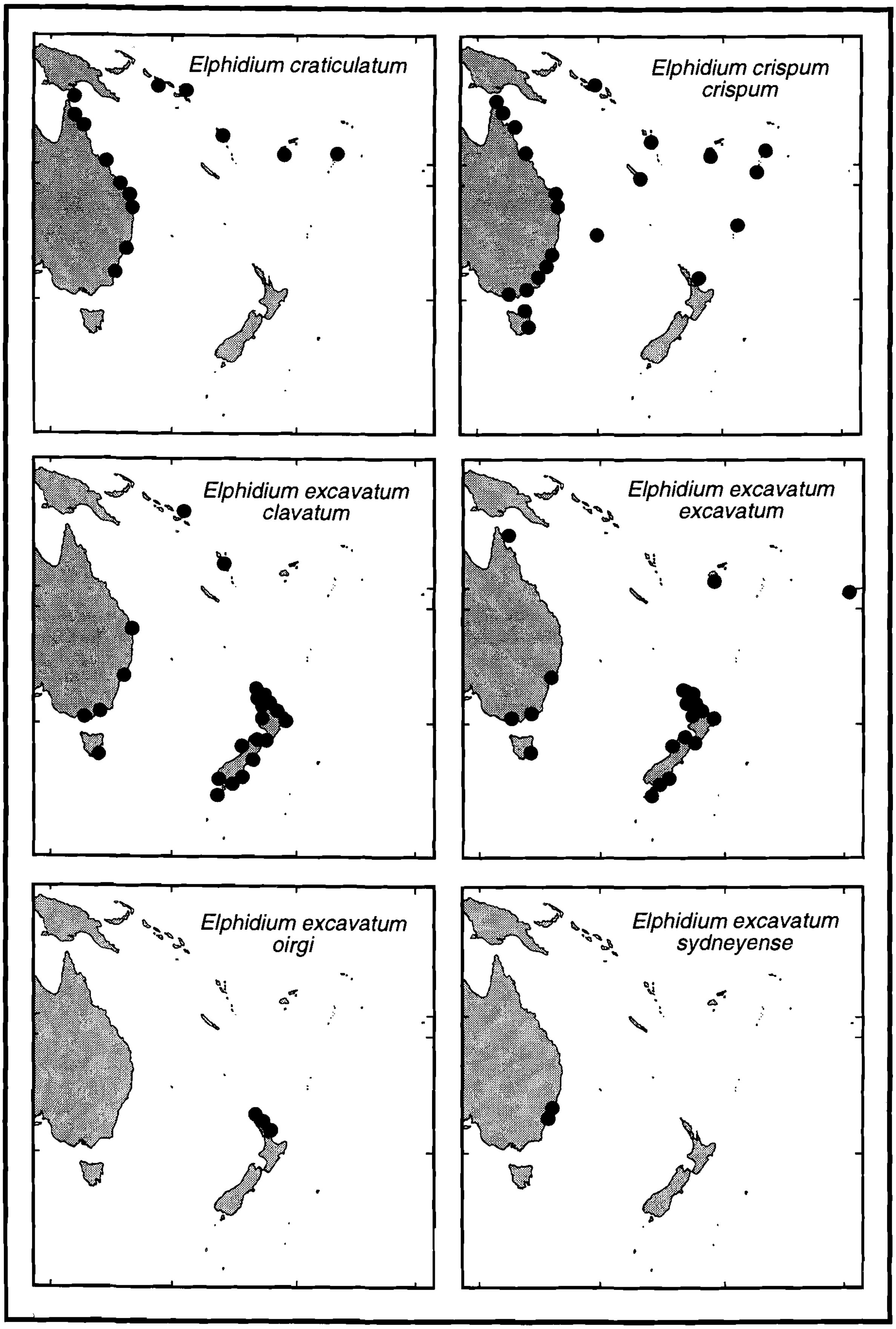


Figure 17 Summary of the recorded distribution of *Elphidium craticulatum, E. crispum crispum* and four Recent subspecies of *Elphidium excavatum* throughout the South-west Pacific.

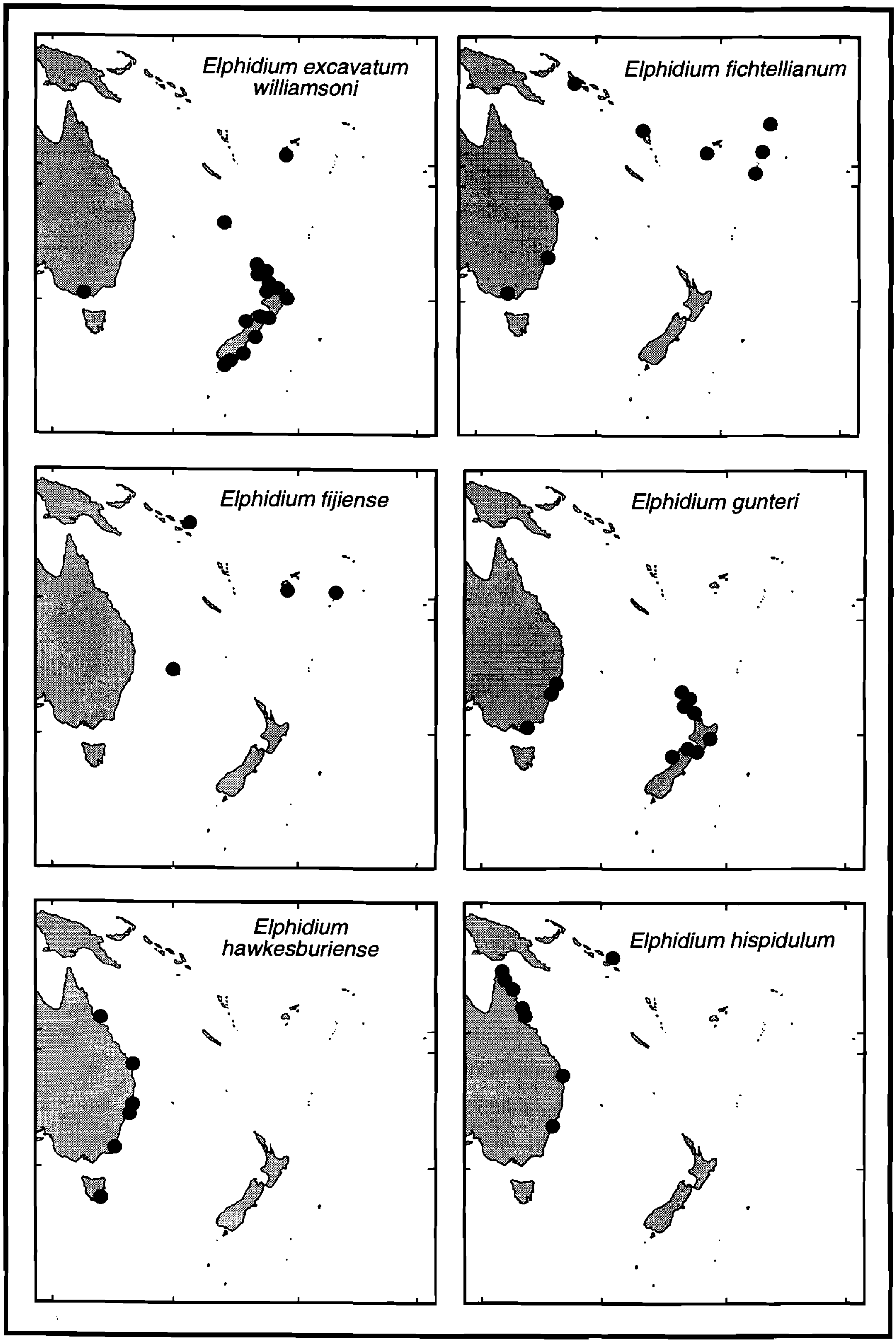


Figure 18 Summary of the recorded distribution of Recent *Elphidium excavatum williamsoni*, *E. fichtellianum*, *E. fijiense*, *E. gunteri*, *E. hawkesburiense*, and *E. hispidulum* throughout the South-west Pacific.

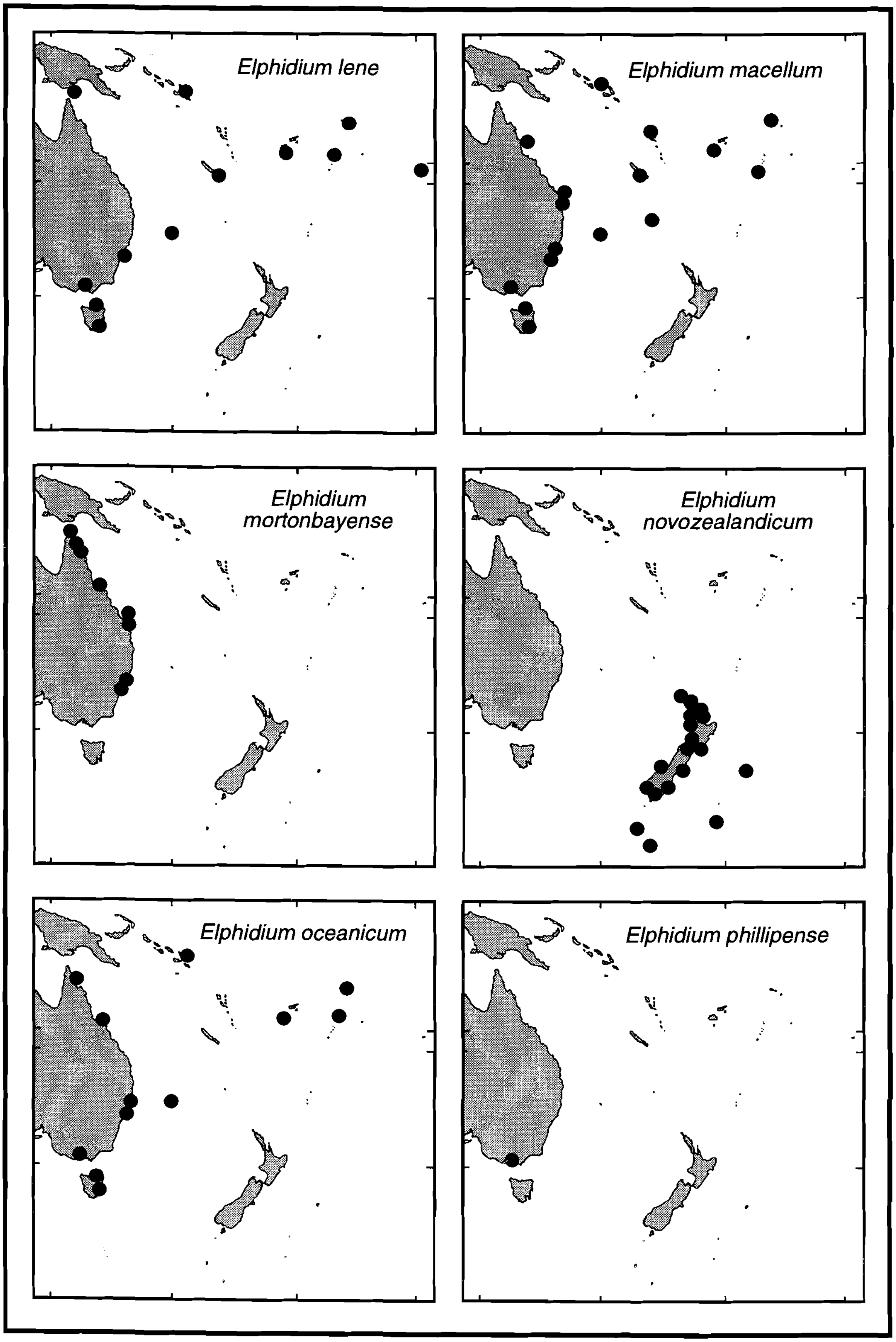


Figure 19 Summary of the recorded distribution of Recent *Elphidium lene, E. macellum, E. mortonbayense, E. novozealandicum, E. oceanicum* and *E. phillipense* throughout the South-west Pacific.

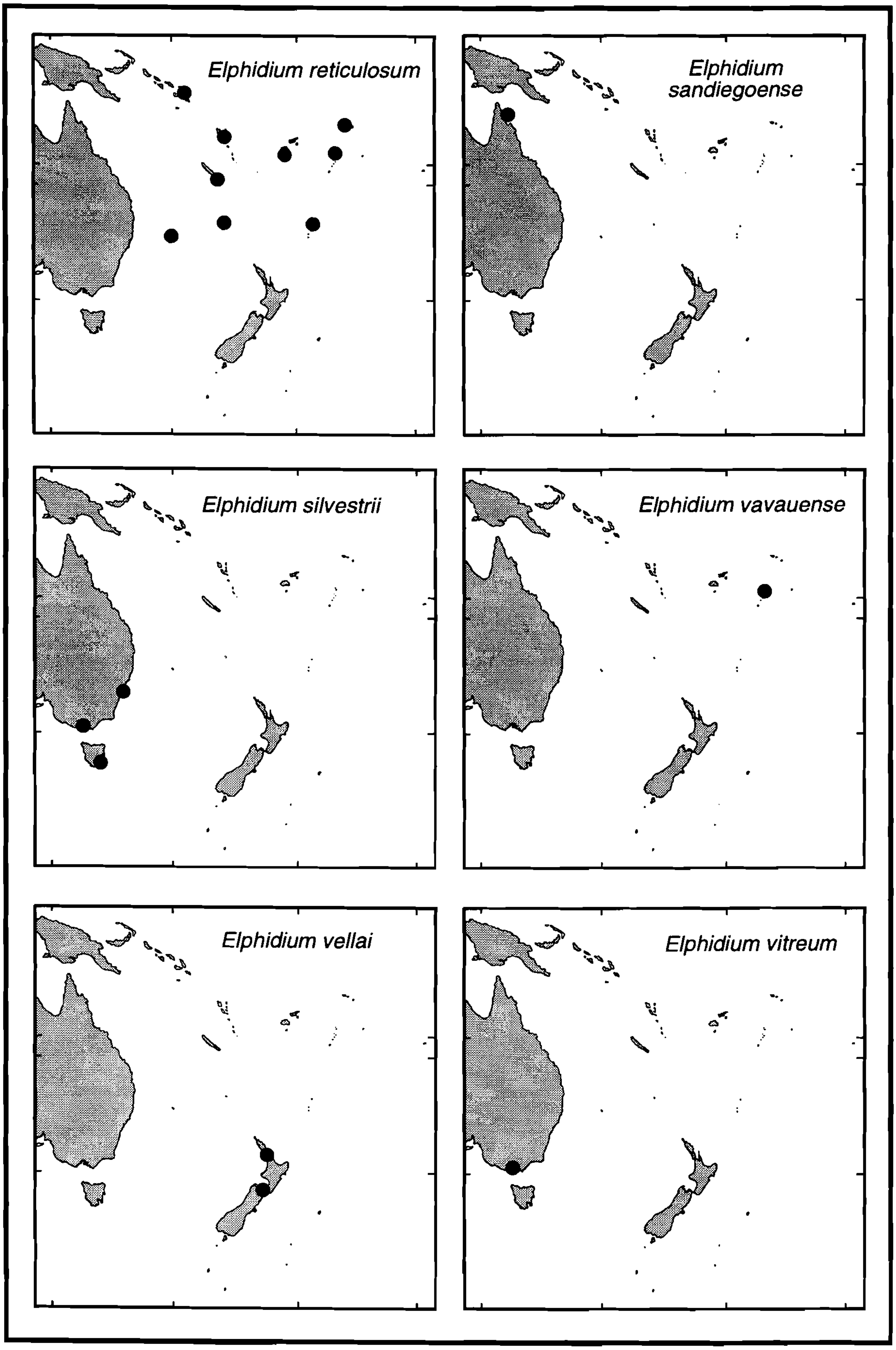


Figure 20 Summary of the recorded distribution of Recent *Elphidium reticulosum*, *E. sandiegoense*, *E. silvestrii*, *E. vavauense*, *E. vellai* and *E. vitreum* throughout the South-west Pacific.

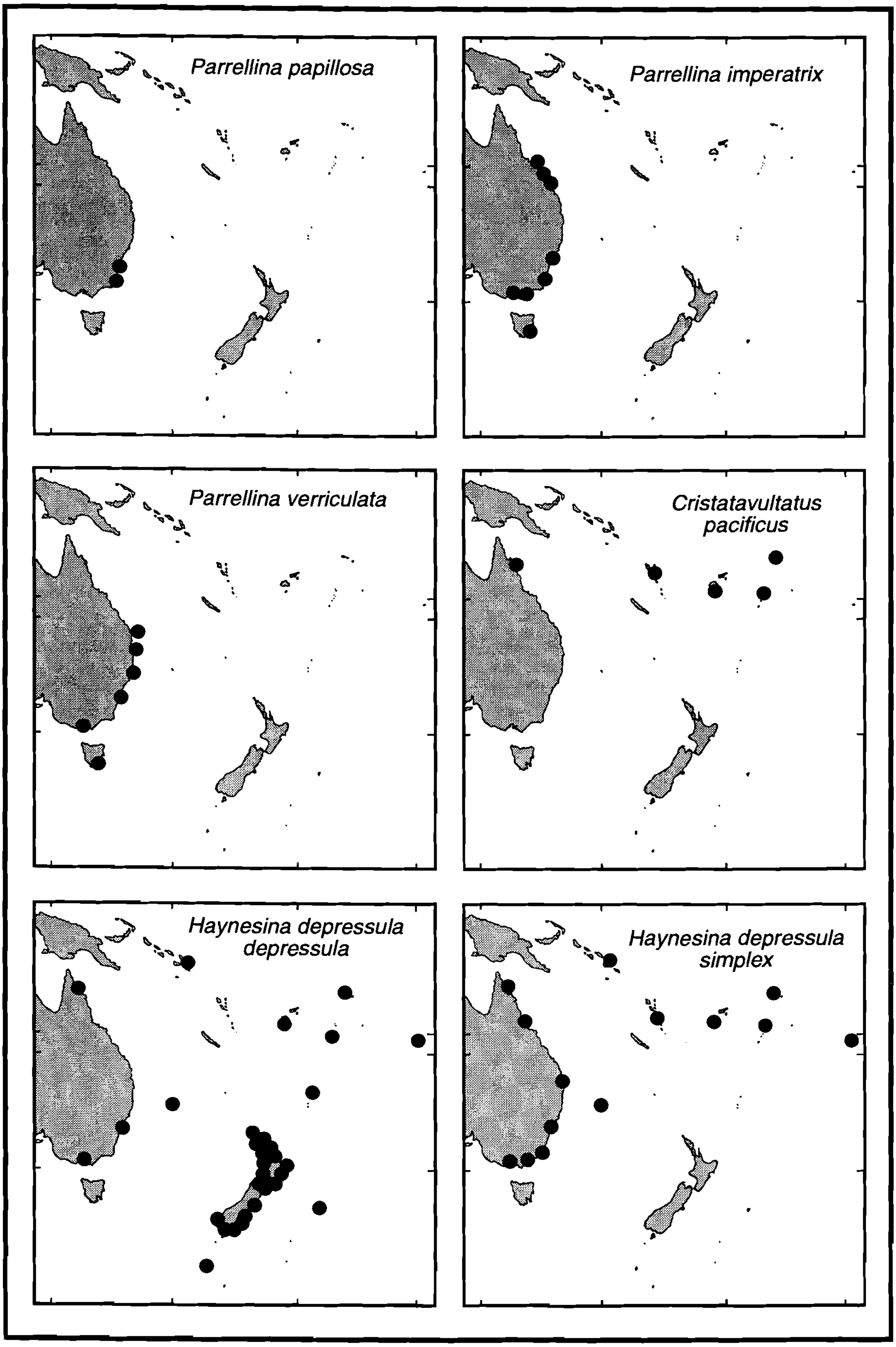


Figure 21 Summary of the recorded distribution of the Recent species of *Cristatavultatus*, *Parrellina* and *Haynesina* throughout the South-west Pacific.

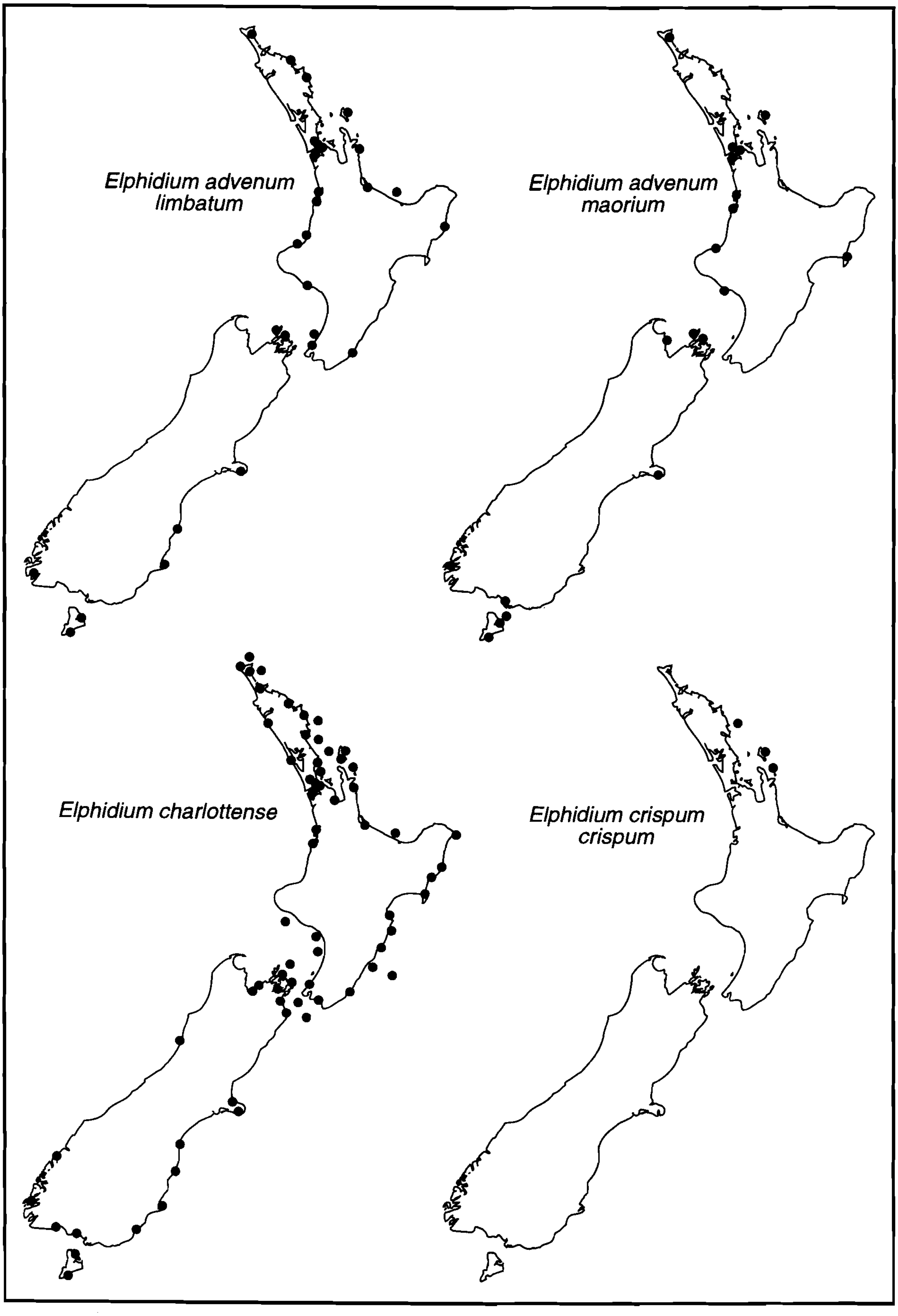


Figure 22 Recorded distribution of Recent *Elphidium advenum limbatum*, *E. advenum maorium*, *E. charlottense* and *E. crispum crispum* around the coast of New Zealand's three main islands.

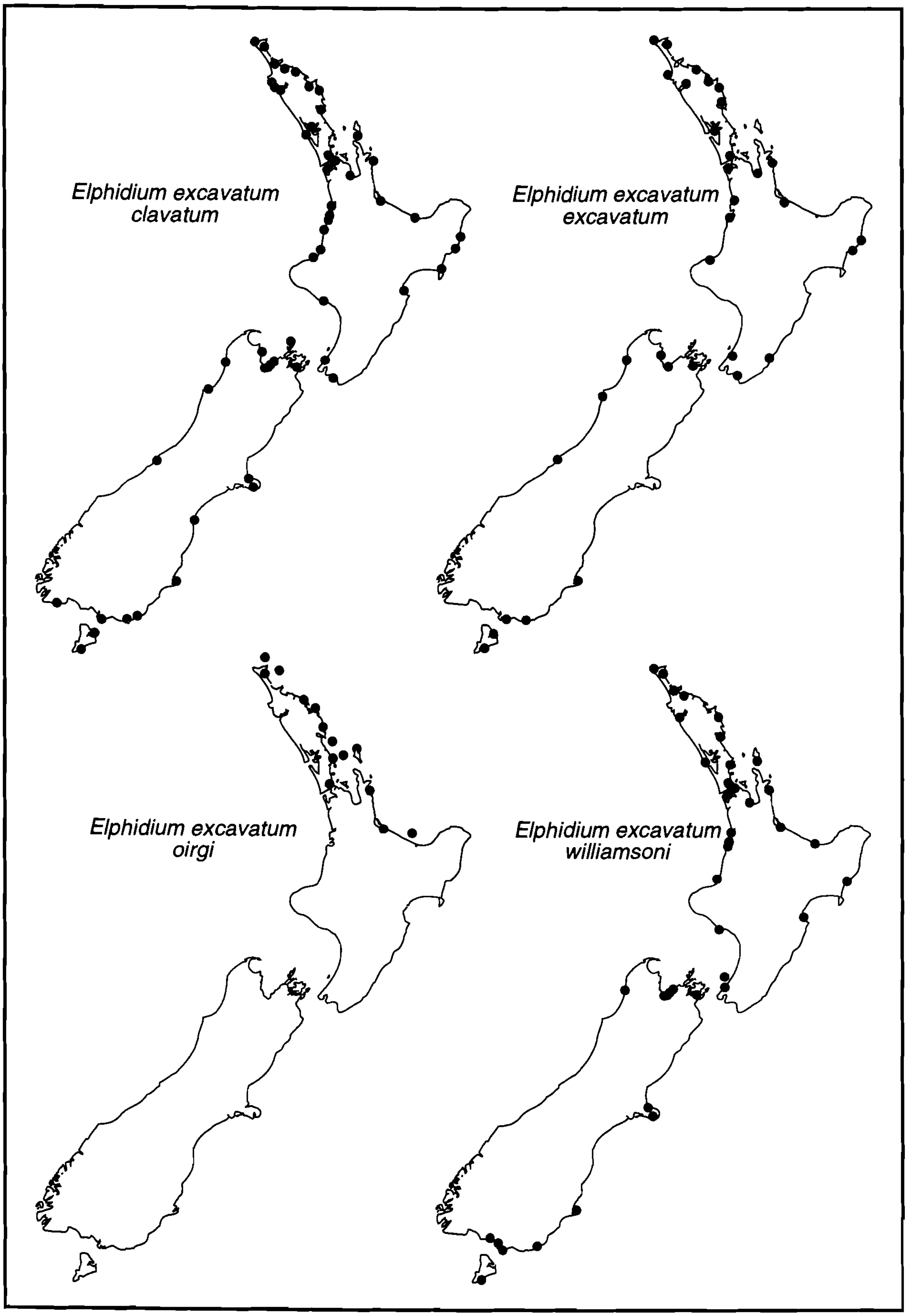


Figure 23 Recorded distribution of the Recent subspecies of *Elphidium excavatum* around the coast of New Zealand's three main islands.

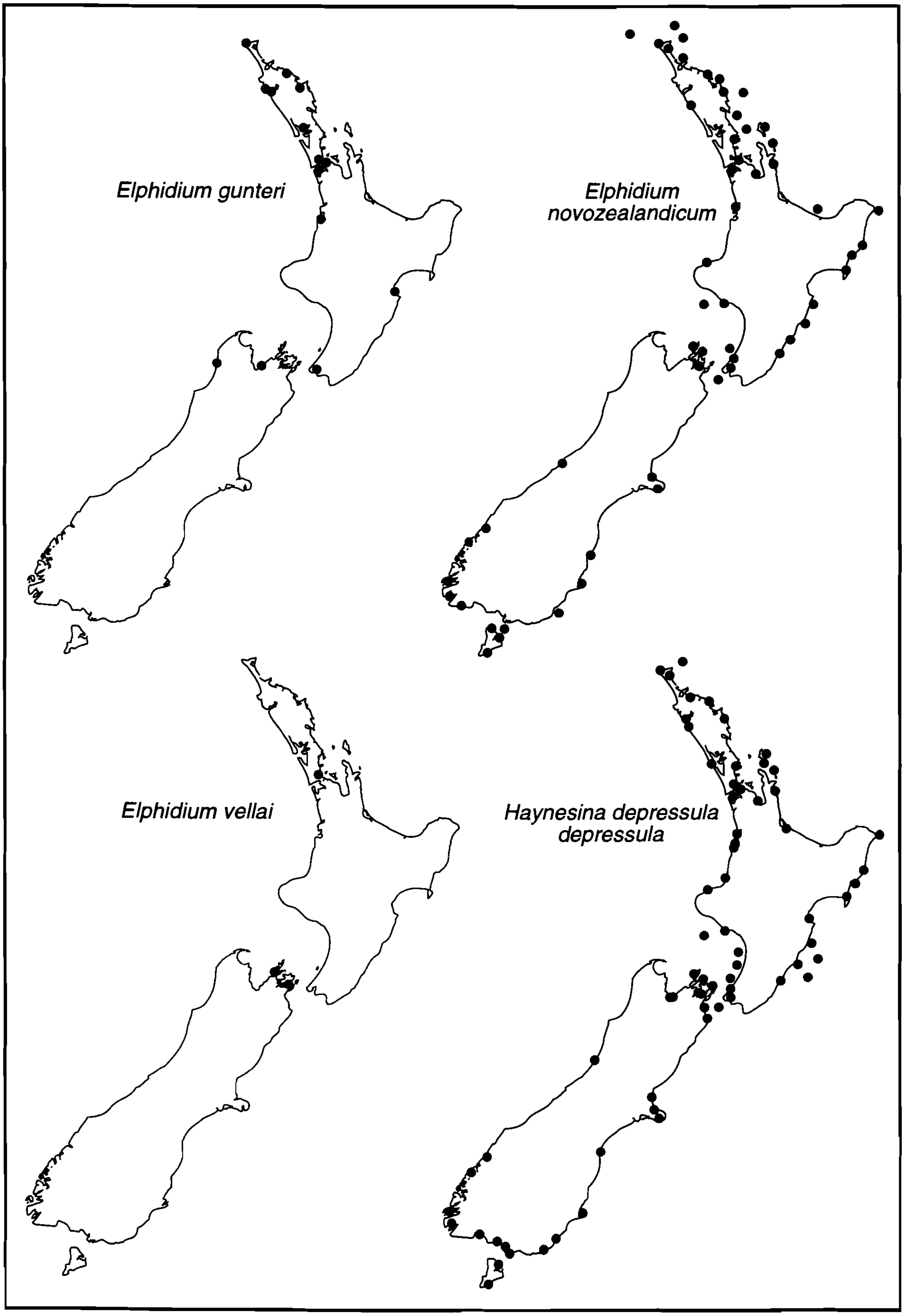


Figure 24 Recorded distribution of Recent *Elphidium gunteri*, *E. novozealandicum*, *E. vellai* and *Haynesina depressula depressula* around the coast of New Zealand's three main islands.

E. advenum limbatum and *H. depressula depressula* also present on the Chatham and Auckland islands. *E. excavatum clavatum, E. excavatum excavatum* and *E. excavatum williamsoni* are not present on the Chatham or subantarctic islands, despite the presence of suitable brackish environments at least on Chatham Island.

The two remaining cosmopolitan taxa are more restricted in their New Zealand distribution. *E. gunteri* occurs sporadically in slightly brackish habitats around all of the North Island and north end of the South Island (Figure 24), whereas *E. crispum crispum* is only known from four localities off the northeastern coast of the North Island.

In summary, most species live right around New Zealand's three main islands and some have extended ranges across to the Chatham and subantarctic islands. Of the four more restricted taxa, two live only off the northeast coast under the influence of the warm East Auckland Current and two live in the northern half of the country, one with a very local distribution.

DISPERSAL MECHANISMS

The biogeographic patterns show that many elphidiid taxa have managed to disperse widely around the world and the South-west Pacific. They are obviously capable at times of dispersing across oceanic barriers of up to 1500 km. The best examples are the cosmopolitan species, some of which (e.g. *E. advenum, E. excavatum, H. depressula)* live throughout the world.

In contrast to these cosmopolitan species, there are a number of taxa (e.g. *E. vavauense, E. vitreum)* that are endemic to relatively small areas and for some reason have not dispersed widely. This mixture of widespread and locally endemic taxa in shallow water benthic foraminifera is also found around the coast of North America (Buzas and Culver 1991) and in the shallow water Bolivinellidae (Hayward 1990a).

The question that arises is, how do shallow water benthic foraminifera like the elphidiids, which lack a pelagic stage in their life cycle, manage to be so widely dispersed at times? Elphidiids do not develop float chambers (unlike some *Rosalina-Tretomphalus),* which would facilitate trans-oceanic dispersal, nor do they live cemented to or clinging to seaweeds or seagrass, and thus dispersal on floating plant material ripped up by storms is also unlikely. The two most likely methods of trans-oceanic transport are on the feet or feathers of migratory seabirds and transport by ocean currents of individuals suspended in the water column.

For elphidiids that live in intertidal sand and mud flats (e.g. *E. excavatum* group, *E. advenum* group, *E. gunteri, Haynesina depressula)* transport in sediment clinging to the feet or feathers of migratory birds seems the most likely methods of dispersal (Resig 1974, Patterson 1987). Many hundreds of thousands of wading seabirds migrate every year between New Zealand and the northern hemisphere and between New Zealand and Australia. Many of them do not land on the sea en route but do stop off at various coastal and island resting places on the way. For the majority, their first and last landfalls on their journeys are intertidal mud and sand flats.

For elphidiids that do not appear to live intertidally and most commonly live in normal marine environments on the inner shelf (e.g. *E. crispum crispum, E. macellum, E. fichtellianum, E. oceanicum),* successful transport by birds would be unlikely. The most likely method is that proposed for bolivinellids (Hayward 1990a) - via oceanic current transport. Although this method is not well documented, several studies have shown that strong tidal and storm-generated bottom currents or upwellings can lift small benthic foraminifera into suspension to be carried away (Murray *et al.* 1982, Foster & Battaerd 1985). Benthic foraminifera are occasionally recorded from plankton tows in the oceans, but juvenile tests (1-3 chambers) would pass through many nets and be difficult to identify, even as benthic foraminifera, if caught. Thus transport of juvenile elphidiids in currents appears to be quite feasible. Because foraminifera reproduce assexually as well as sexually, the chance arrival of even a single schizont individual in a favourable habitat could be a successful colonising event.

Why some elphidiids are widely dispersed and others are not is difficult to explain, as many of the locally endemic species occur in equal abundance and in the same habitats as those that are cosmopolitan. Perhaps certain taxa are better adapted to survive a trans-oceanic journey in suspension.

PALEOECOLOGY OF NEW ZEALAND FOSSIL *ELPHIDIUM*, *DISCOROTALIA* AND *HAYNESINA*

Elphidiidae occur widely throughout the New Zealand fossil record from middle Eocene times onwards. Their occurrence is strongly dependent on the environment in which the sediment originally accumulated.

PALEODEPTH (Figure 25)

All taxa except those from the early and middle Eocene appear to have lived at shelf depths (shallower than c. 200 m) and almost all of these lived at their greatest abundances in paralic or inner shelf depths (shallower than 50 m). This suggests that elphidiids may have adopted a primarily herbivorous feeding strategy and begun husbanding chloroplasts in the late Eocene. There are occasional records of late Eocene to Pleistocene elphidiid tests occurring in bathyal foraminiferal faunas, but all of these are inferred to be a result of post-mortem downslope transport.

In all instances where an elphidiid taxon (e.g. *E. crispum crispum, E. crispum waiwiriense, E. advenum limbatum)* constitutes more than 40% of a foraminiferal fauna, the associated assemblage has extremely low abundances of planktic tests (usually 0%) and a low diversity benthic fauna. By comparison with modern assemblages, we infer these faunas to have lived in intertidal or shallow subtidal beaches or tidal flats. Although *E. kanoum* does not exceed 15% relative abundance it reaches its greatest abundances in these intertidal or shallow subtidal associations with either of the two *E. crispum* subspecies dominant (e.g. Hayward & Brook 1994).

Taxa that appear to have lived entirely at inner shelf depths, shallower than 50 m, and are unknown from fossil assemblages typical of greater depths, are: *E. advenum advenum, E. advenum limbatum, E. advenum macelliforme, E. carteri, E. crispum waiwiriense, E. excavatum excavatum, E. excavatum williamsoni, E. ingressans, E. matauraense, E. oceanicum* and *E. schencki.*

Taxa that appear to have lived in their greatest relative abundances (up to 10% of foraminiferal faunas) at inner shelf depths, but also frequently occur in lower abundances (less than 5%) in assemblages of mid or outer shelf character (50–200 m) and may have lived at these greater depths are: *E. aculeatum subrotatum, E. charlottense, E. crispum crispum, E. excavatum clavatum, E. kanoum, E. novozealandicum, E.* aff. *novozealandicum, E. pseudoinflatum, E. wadeae, Discorotalia tenuissima* and *Haynesina depressula.*

Taxa that appear from the associated fauna to have lived more commonly at sheltered, deep inner, mid or outer shelf depths (c. 30–150 m) are: *E. aculeatum norcotti, E. advenum maorium* and *Discorotalia aranea.*

The early Eocene, Chatham Island species *E. matanginuiense* occurs in assemblages that suggest that it lived at outer shelf to upper bathyal depths (c.100–400 m).

The widespread, biostratigraphically important, middle Eocene species *E. hampdenense* and *E. saginatum* have relative abundances up to 10% in a wide range of foraminiferal assemblages. Associated species indicate that *E. hampdenense* lived throughout most of the depth range between mid shelf and mid bathyal (c. 50–2000 m) and that *E. saginatum* lived throughout the upper and mid bathyal (c. 200–2000 m).

PALEOSALINITY

Because of New Zealand's tectonic instability and the transitory nature of brackish estuarine and paralic systems, very few brackish foraminiferal faunas have been identified in the New Zealand fossil record. All but one of the known fossil occurrences of Elphidiidae in the New Zealand fossil record appear to be in normal marine salinity assemblages.

From this we conclude that all the Elphidiidae taxa found fossil in New Zealand could live in normal marine salinity. One possible exception is *E. excavatum,* which has only been found in two fossil samples and is restricted to brackish environments around New Zealand today. The absence of the modern brackish-restricted *E. gunteri* from the fossil record is probably a result of the lack of suitably preserved rocks rather than its recent arrival here.

In the present day, some Elphidiidae can live in normal marine salinity but appear to have their greatest abundances in slightly brackish, sheltered environments in the middle and outer parts of estuaries, bays and harbours. The same was probably true in the past, and indeed *E. advenum limbatum* occurs in its greatest fossil abundance (c. 50% of a fauna and codominant with *Haplophragmoides)* in a fauna (S14/f23, core 14.4 m) that has all the characteristics of an intertidal to shallow subtidal, slightly brackish environment. Modern ecological ranges indicate that fossil *E. advenum* group, *E. excavatum* group and *Haynesina depressula* probably were most abundant in slightly brackish conditions.

PALEOTEMPERATURE INFORMATION FROM NEW ZEALAND FOSSIL *ELPHIDIUM*

Present-day distribution patterns provide a basis for determining, albeit coarsely, New Zealand paleotemperature trends using the fossil elphidiid record. *Haynesina depressula* ranges throughout the South-west Pacific today and is therefore of little assistance. As a whole, the genus *Elphidium* is cosmopolitan in present-day seas, but

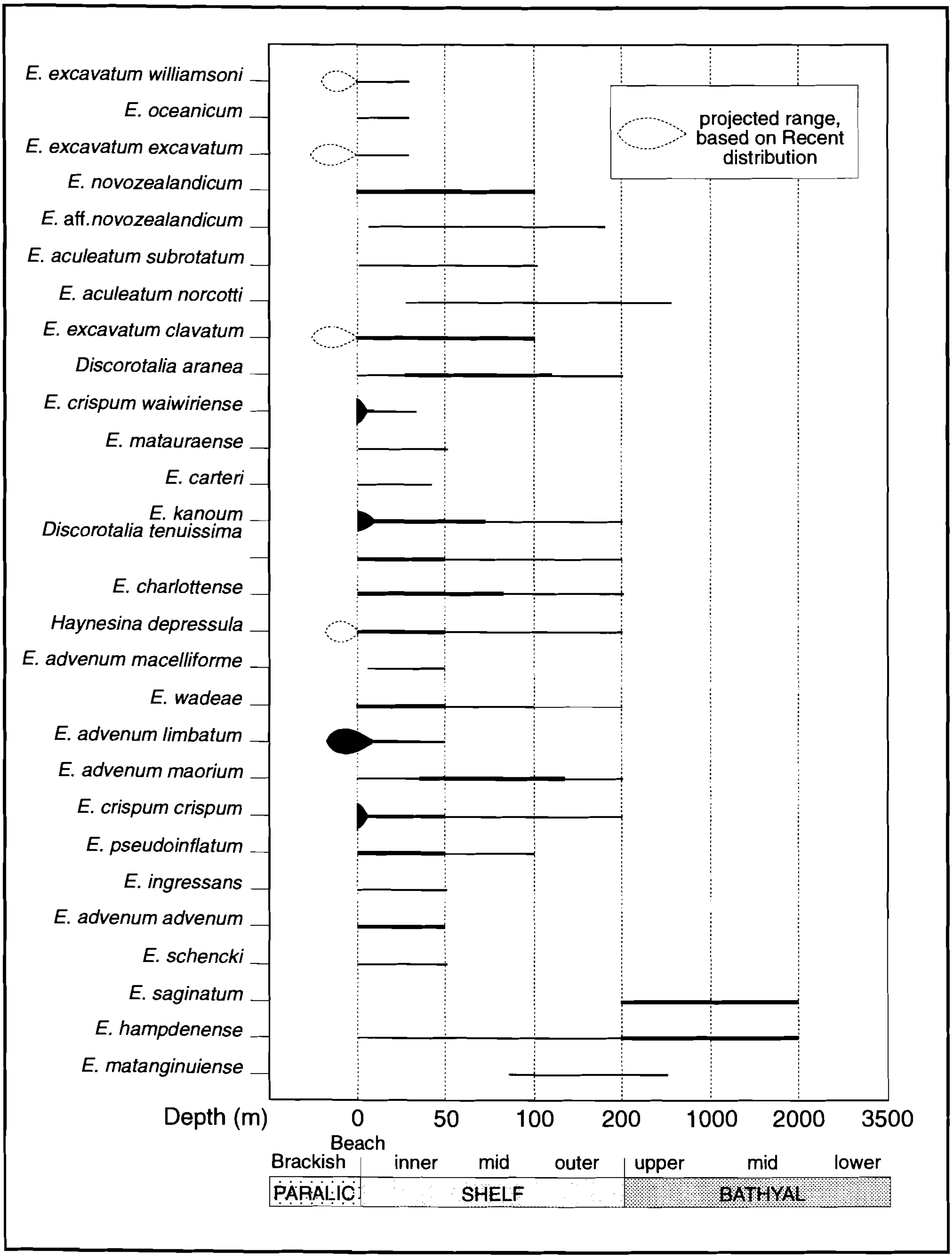


Figure 25 Interpreted paleodepth ranges of fossil New Zealand elphidiids.

studies on the distribution of diversity, individual selected taxa and morphology provide a guide to paleotemperature variations.

Diversity trends in *Elphidium* taxa

Around New Zealand today there is a slight increase in diversity of *Elphidium* from south to north (cool to warm): Stewart Island (7 taxa), South Island (9 taxa), North Island (11 taxa). A similar trend is present if all the mainland areas in the South-west Pacific, with a wide range of brackish, paralic and shallow normal marine environments, are compared:

Temperate - Stewart, South, North Islands (NZ)	11 taxa
Temperate - Tasmania	11 taxa
Cool subtropical - Victoria	17 taxa
Warm subtropical - New South Wales	21 taxa
Tropical - Queensland	18 taxa

The less comprehensive sampling and lower diversity of shallow and brackish environments around the islands in the South-west Pacific makes it more difficult to interpret any diversity trends. By combining species lists for all the islands in different climatic regions, a similar trend of increasing diversity with increasing temperature is obtained:

Subantarctic islands - Chatham, Auckland, Campbell, Antipodes	4 taxa
Warm subtropical islands - Lord Howe, Norfolk, Kermadecs	12 taxa
Eastern tropical islands - Cook, Tonga, Samoa, Fiji	16 taxa
Western tropical islands - New Caledonia, Vanuatu, Solomon	16 taxa

Elphidium diversity through the Cenozoic of New Zealand is shown for each New Zealand stage in Figure 26. The world-wide increase in diversity in the late Eocene is unlikely to be caused by increasing temperatures. Following that, however, there is a steady increase in diversity in New Zealand through to the early Miocene (Otaian) followed by a slow decline through the early and middle Miocene (to Waiauan) and a rapid decrease into the late Miocene (Tongaporutuan).

The early and middle Miocene period of highest diversity corresponds well with the warmest period in the last 40 million years in New Zealand (Hornibrook 1992). The sharp decline in diversity at the end of the middle Miocene coincides with the onset of temperature decline in New Zealand and other high latitude areas (Kennett 1985) and the loss of many warm water taxa (e.g. Hornibrook 1978, 1992; Hayward 1990a).

A diversity of 12–14 *Elphidium* taxa throughout most of the early and middle Miocene in New Zealand corresponds to present-day diversity in the subtropical zone (cf. Lord Howe, Norfolk and Kermadec Islands) of about 18–24°C or about 5–8°C warmer surface water temperatures than at present in New Zealand, which is very similar to that calculated from fossil reef corals and bolivinellid foraminifera (Hayward 1977, 1990a).

The increase in diversity in New Zealand in the Recent does not correspond with any known warming trend, but is explained by the far more extensive sampling undertaken in the Recent and the paucity of brackish faunas in the fossil record.

Distribution of *Elphidium crispum*

The present day distribution of *E. crispum* in the South-west Pacific and especially around New Zealand indicates that it is a tropical and subtropical species. Its southern, probably temperature-controlled, geographic limit is off

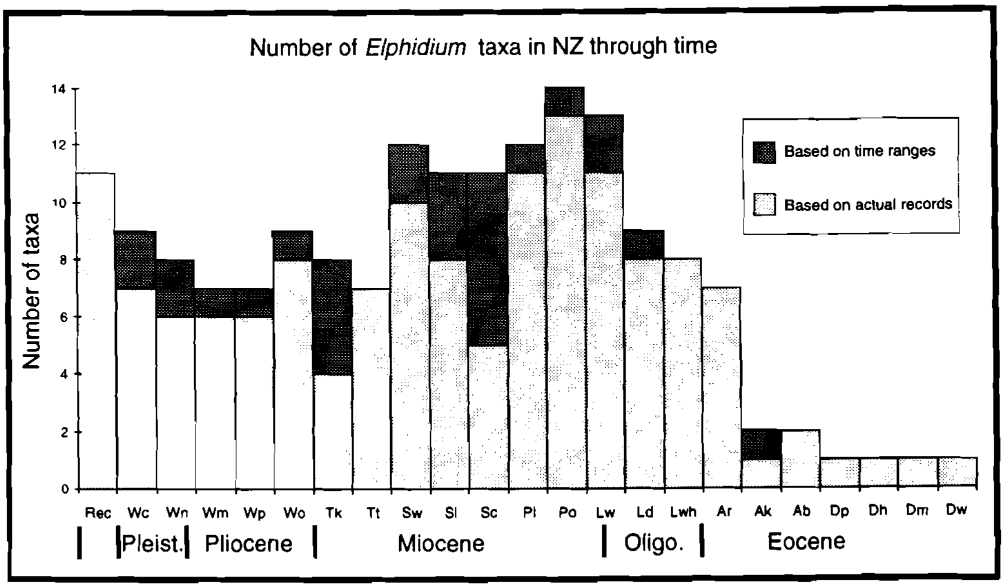


Figure 26 Number of *Elphidium* species and subspecies in each stage through the Eocene to Recent in New Zealand.

eastern Northland (Figure 22), within the influence of the warm East Auckland Current, with a seasonal sea surface temperature range of 16–20°C. The moderately small size (less than 0.6 mm) of these Northland specimens confirms that they are living near their limit of cool water tolerance. Larger specimens (greater than 1 mm) of *E. crispum* are found in warmer subtropical and tropical environments around the South-west Pacific islands and the east coast of Australia.

When applied to the New Zealand fossil record of *E. crispum*, the present distribution of this species provides an indication of seawater paleotemperatures. *E. crispum* occurs throughout New Zealand from latest Eocene to early Pliocene, which suggests that the whole country was probably as warm as, or warmer than, present-day Northland during much of this long period. It is unknown from the South Island later than early Pliocene, although it does occur throughout the Pliocene of the Chatham Islands. Thus it may be inferred that, from the middle Pliocene onwards, the seas around the South Island were probably mostly cooler than at present off the east coast of Northland. This is in good agreement with the oxygen isotope record from the southern Tasman Sea which shows a marked cooling about 3 Ma, after a relatively stable warm period during the early Pliocene (Head and Nelson 1994).

E. crispum occurs throughout most of the Pliocene and Pleistocene in various parts of the North Island, and only became restricted to northeastern New Zealand relatively recently. Thus it appears that during a number of interglacial episodes during the Pliocene and Pleistocene, sea surface temperatures may have become as warm around much of the North Island as they are today off east Northland (c.16–20°C).

Large specimens of *E. crispum* are common in the New Zealand fossil record throughout the Oligocene and Miocene, suggesting that sea surface temperatures during this period were probably significantly warmer than off eastern Northland today and probably more similar to those around the warm subtropical islands of Norfolk or the Kermadecs (c.18–24°C) - the same conclusion as that reached using *Elphidium* diversity levels.

Morphology

As already noted for *E. crispum*, large size of some *Elphidium* tests (greater than 1 mm diameter) often indicates warmer sea temperatures. The largest species of *Elphidium, E. craticulatum* and *E. mortonbayense* are restricted to tropical areas. Apart from *E. crispum crispum*, other fossil *Elphidium* taxa that reach similar large diameters are *E. aculeatum norcotti, E. aculeatum subrotatum, E. crispum waiwiriense* and *E. kanoum*. All these occurrences are in the early Miocene (Otaian and Altonian) which was probably the warmest period in New Zealand since the early Eocene (Hornibrook 1992).

Another morphological trend within *Elphidium* with increasing temperature appears to be an increase in the amount of robust surface ornament. In the present-day South-west Pacific, strongly raised, glassy umbonal bosses appear to be largely restricted to tropical or warm subtropical taxa (e.g. *E. fijiense, E. hispidulum, E. vavauense)*. In the New Zealand fossil record, taxa with similar strongly raised umbonal bosses (*E. aculeatum subrotatum, E. crispum waiwiriense, E. ingressans, E. kanoum)* are restricted to late Eocene to middle Miocene, where many lines of evidence show that sea surface temperatures in the area were at least warm subtropical (4°C or more warmer than today).

SPECULATIVE PHYLOGENY OF NEW ZEALAND *ELPHIDIUM* AND *DISCOROTALIA*

SPECIES DURATION (Figure 27)

Species durations for all *Elphidium* and *Discorotalia* taxa in New Zealand range between <1 and 39 million years, with a mean of 14.5 million years. Taken separately, the mean duration for all fossil taxa that are extinct in New Zealand is 12 million years and for extant New Zealand taxa is 19 million years. These are similar values to the mean of 16 million years recorded by Buzas and Culver (1984) for common benthic foraminiferal species occurring at depths shallower than 200 m off the east coast of North America. They are longer than the values of 6.5 and 3.5 million years for extinct and extant bolivinellid foraminifera worldwide (Hayward 1990a).

The high level of overall endemism for New Zealand elphidiids (48%), relative to the levels during each individual epoch is a reflection of the difference in longevity between endemic and more widespread taxa. On average, endemic taxa have considerably shorter time ranges (range <1–33 million years, mean 10 million years) than those species that also occur elsewhere in the world (range <1–39 million years, mean 19 million years). This observation is strengthened by the fact that the New Zealand stratigraphic range of the non-endemic taxa is a minimum range only.

NEW ZEALAND SEGMENTS OF THE ELPHIDIID PHYLOGENETIC TREE

As the stratigraphic record of the elphidiids from other regions of the world has not been synoptically reviewed and documented, it is difficult to speculate on the overseas origins and relationships of the species that are present in the Cenozoic in New Zealand.

It is clear that New Zealand has received a sporadic flow of immigrant elphidiids from overseas throughout the Cenozoic. There would have been numerous immigrant arrivals that did not survive to proliferate in New Zealand waters. Only those that successfully established breeding populations, dispersed around the country and survived here for many thousands or hundreds of thousands of years are likely to be recorded in the fossil record.

The lack of overseas stratigraphic reviews makes it difficult to determine whether any New Zealand elphidiid species emigrated and became established in other parts of the world. As discussed in the section on "Dispersal mechanisms", most elphidiids were probably brought to New Zealand by currents sweeping across the Tasman Sea from our nearest neighbours in the west or northwest. It is unlikely that currents could take elphidiids back across the Tasman, but they might have successfully transported specimens the much greater distances eastwards across the Pacific to South America. As some intertidal elphidiids may have been transported in by migrating birds, it is equally likely that some taxa successfully emigrated out by this method to Australia, the Pacific islands and Asia.

The New Zealand fossil record only contains a fragmentary elphidiid phylogenetic tree. We have attempted to reconstruct these pieces, particularly where it appears that ancestor-descendant relationships are present in the New Zealand record.

The New Zealand fossil record can be grouped into eight separate branches or lineages, based on gross morphological similarities (Table 3).

Elphidium excavatum branch (Figure 28)

On this branch we include four subspecies of *E. excavatum*, plus three other species with broadly rounded peripheries and lacking keels - *E. saginatum, E. gunteri* and *E. vellai.*

E. excavatum is a cosmopolitan, largely brackish species with a number of recognised subspecies or forms that are widely distributed around the world today. Exactly where and when these taxa evolved is not determinable from the

Table 3. Gross morphological criteria used to group fossil New Zealand *Elphidium* and *Discorotalia* species into speculative phylogenetic branches.

Branch	Profile	Periphery	Ornament	Other
E. excavatum	elliptical	broadly-rounded, no keel		
E. advenum	lenticular	acute		inflated chambers
E. crispum	compressed lenticular	acute, keeled		non-inflated chambers
E. aculeatum	compressed	spines	strong septal bridges	
E. hampdenense	inflated lenticular	acute, keeled	strong reticulate	
E. ingressans	lenticular	acute, keeled	long, concentric septal bridges	
E. novozealandicum	compressed	keeled	strong reticulate	
Discorotalia	compressed	keeled	strong reticulate	loosely coiled test

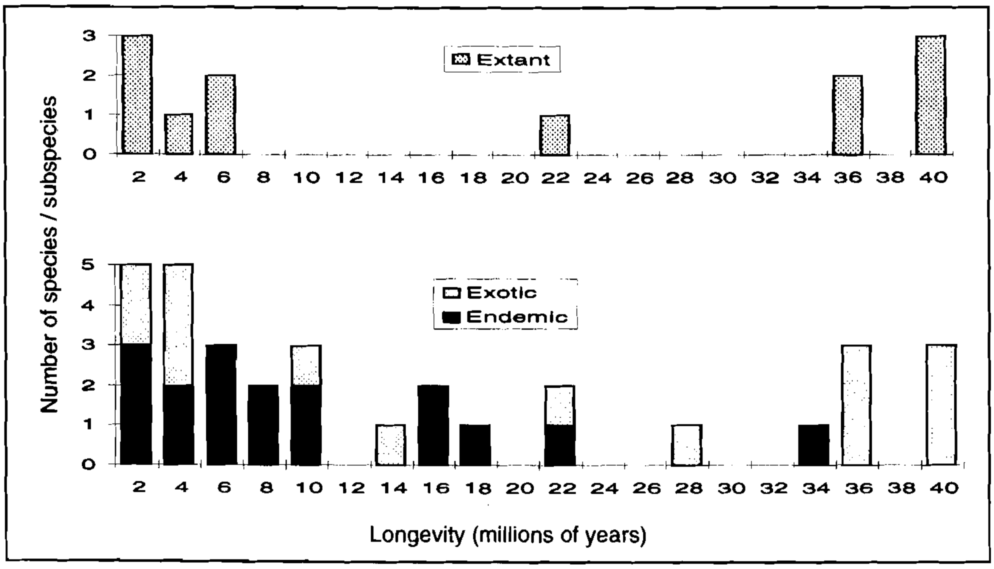


Figure 27 Species duration histograms for New Zealand Elphidium, showing number of species or subspecies against their New Zealand time ranges in millions of years for: **a.** extant species, **b.** total species (endemic and non-endemic).

New Zealand fossil record. It is probable that each, except for the seemingly endemic *E. excavatum oirgi,* arrived in New Zealand as separate immigrant events from overseas.

The earliest record of this branch in New Zealand may be the middle Eocene, southern hemisphere species, *E. saginatum,* which, despite its bathyal depth range, is a possible candidate as an ancestor (possibly via a number of intermediate species in the late Eocene and Oligocene) of the paralic and inner shelf *E. excavatum* group. If so, there was a major ecological shift, possibly accompanying the adoption of a herbivorous feeding strategy and the husbandry of chloroplasts.

E. excavatum first appears in New Zealand as *E. excavatum clavatum* in the early Miocene. Taxa that may have evolved from this stock overseas and later immigrated to New Zealand are *E. excavatum excavatum* with shorter septal bridges (arriving by the Pliocene), *E. excavatum williamsoni* with longer septal bridges (arriving by the Pleistocene), and the coarsely perforate *E. gunteri* (currently only known in New Zealand in the Recent, but occurs in the Miocene of the Dominican Republic).

An alternative scenario is that *E. excavatum excavatum, E. excavatum clavatum* and *E. excavatum williamsoni* are really ecophenotypic forms of a single taxon which only needs to have immigrated to New Zealand on one occasion (in the early Miocene).

Possibly evolving in New Zealand in the late Cenozoic, although lacking a fossil record, are *E. excavatum oirgi,* which is a glassy form of *E. excavatum williamsoni,* and *E. vellai,* which was probably derived from *E. gunteri* with the loss of umbonal tubercles and reduction in the septal bridges.

Although we speculate here that *E. gunteri* and *E. vellai* were possibly part of the *E. excavatum* branch, their more coarsely perforate texture may indicate that they belonged to a separate branch.

This branch is represented in New Zealand today by six species or subspecies.

Elphidium advenum branch (Figure 29)

On this branch we include four subspecies of *E. advenum,* plus *E. carteri* and *E. matanginuiense.* All have somewhat inflated chambers, lenticular profiles with acutely angled peripheries.

E. advenum advenum is cosmopolitan and may have evolved anywhere in the world in the early or middle Eocene. The earliest *Elphidium* in New Zealand, *E. matanginuiense,* has sufficiently similar shape that it could conceivably have evolved, with strengthening of a peripheral keel and lengthening of the septal bridges, into *E. advenum advenum,* although not necessarily in New Zealand.

In the late Eocene, *E. advenum advenum* probably gave rise (with loss of umbonal boss) to *E. advenum limbatum* and in the early Oligocene (with increasing size and inflation) to the *E. advenum macelliforme. E. advenum maorium* probably evolved from *E. advenum limbatum* also in the late Eocene in the South-west Pacific (with weakening of the keel). Alternatively, several of these subspecies may really be ecophenotypic forms of *E. advenum* and not genetically separate taxa.

E. carteri is most similar in gross form to *E. advenum limbatum,* from which it possibly evolved with the devel-

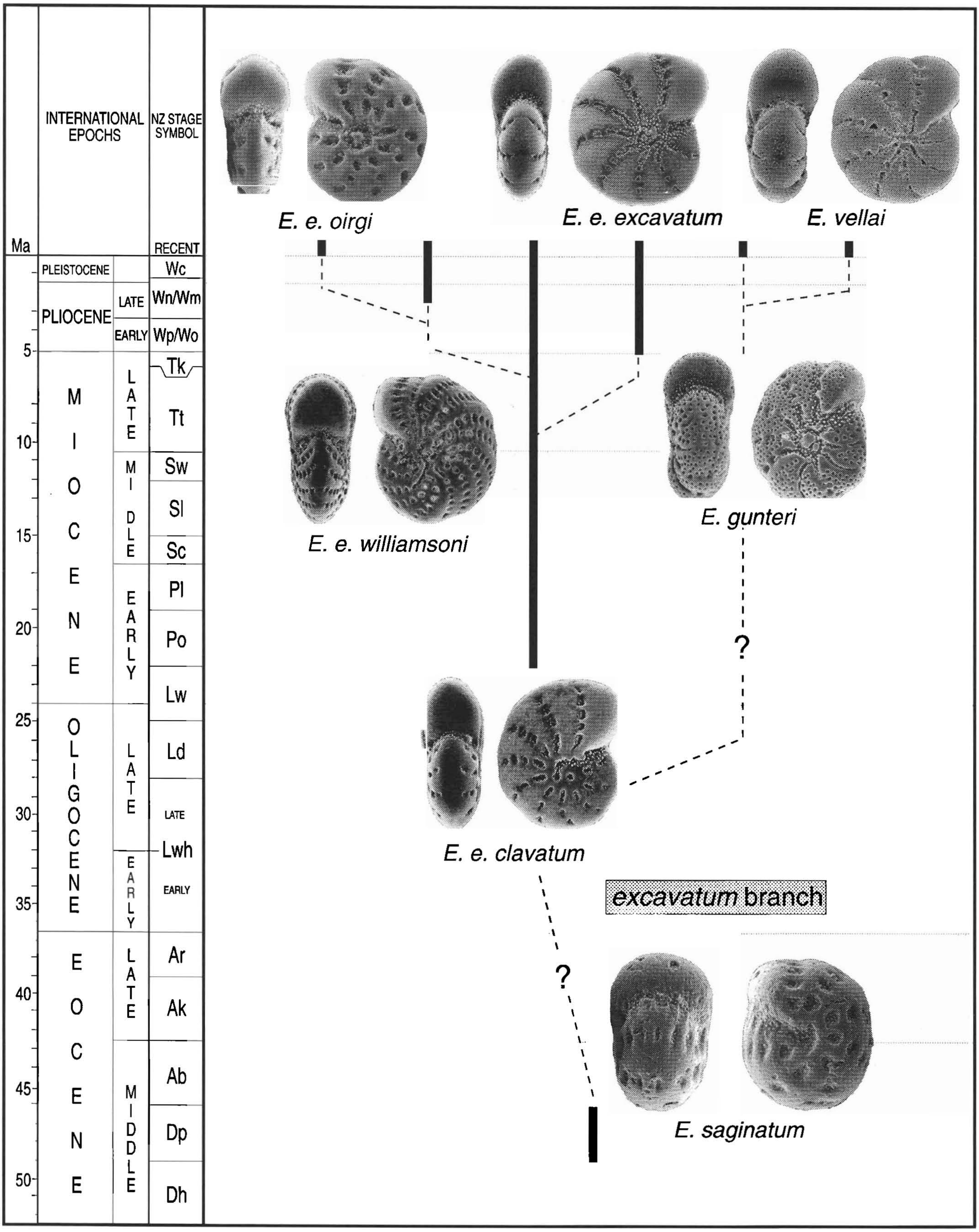


Figure 28 Local stratigraphic ranges and inferred phylogeny for members of the *Elphidium excavatum* branch in New Zealand.

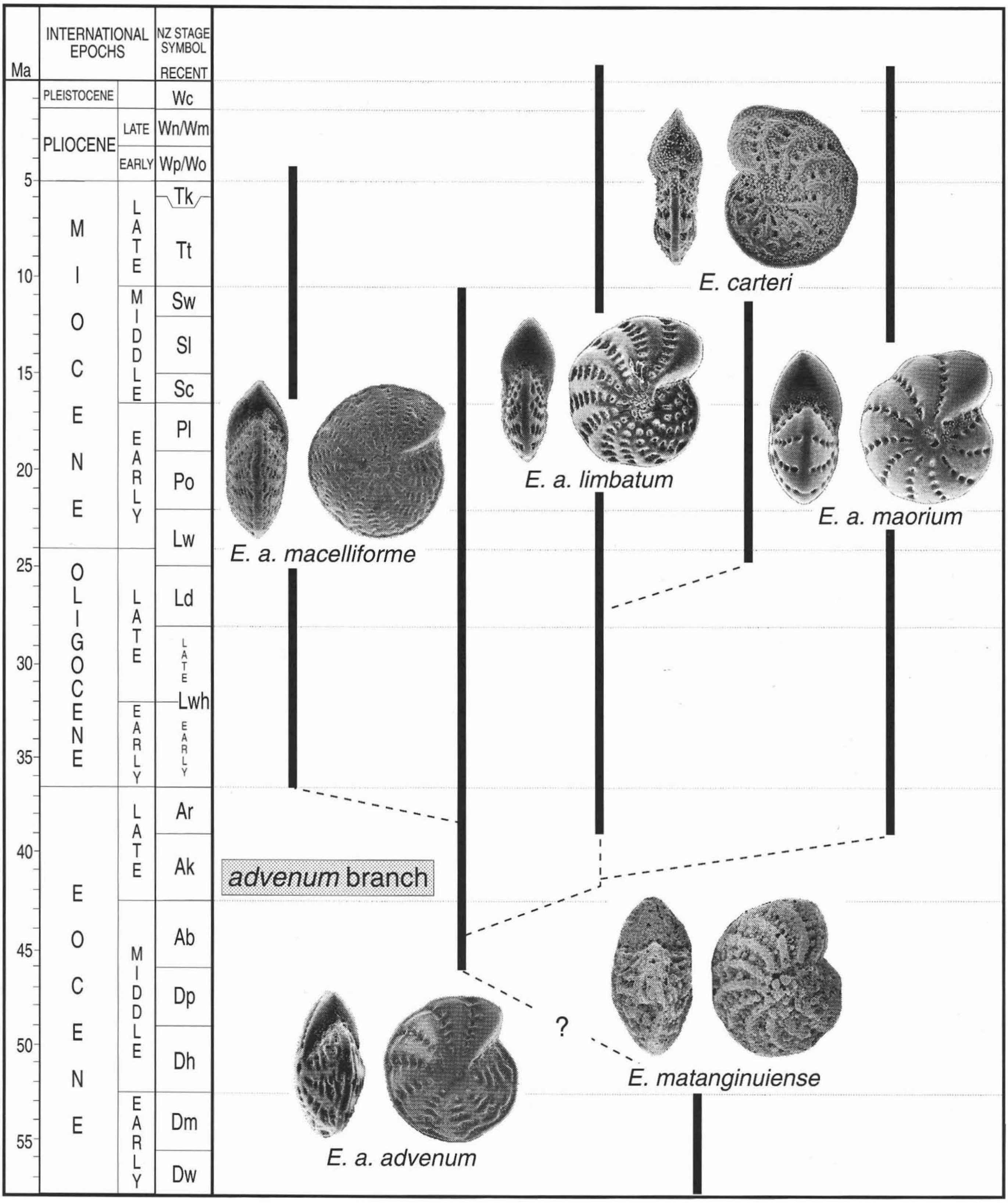


Figure 29 Local stratigraphic ranges and inferred phylogeny for members of the *Elphidium advenum* branch in New Zealand.

opment of radial ribs and coarse pustular ornament in the early Miocene of the South-west Pacific or New Zealand.

Other taxa on this branch that occur in the South-west Pacific today are *E. advenum botaniense* and *E. advenum tongaense.* The latter probably evolved from the former as coiling became more evolute and the chambers slightly longer.

Six members of this branch still live in the South-west Pacific today, with two in New Zealand.

***Elphidium crispum* branch** (Figure 30)

On this branch we include two subspecies of *E. crispum,* plus two other species with acute, keeled peripheries and compressed, lenticular profiles.

As *E. crispum crispum* has a cosmopolitan distribution, it is most probable that it arrived in New Zealand from elsewhere in the late Eocene. The other three taxa on this branch appear to be endemic and are inferred to have evolved from *E. c. crispum* within New Zealand. *E. charlottense* appeared first in the early Oligocene, with fewer chambers, fewer septal bridges and a reduced umbonal boss, and from this *E. matauraense* may have evolved in the early Miocene with a reduced keel and further reduction of the umbonal area with tighter coiling. Also appearing in the early Miocene, most likely from the parent *E. c. crispum* stock is *E. c. waiwiriense* which has a greater number of chambers, septal bridges, a larger and more compressed test and development of a double row of sutural pits in adult tests.

This branch still lives in New Zealand today (*E. c. crispum* and *E. charlottense*).

***Elphidium aculeatum* branch** (Figure 31)

On this branch we include two subspecies of *E. aculeatum,* with their distinctive compressed profiles, strong septal bridges and peripheral spines.

E. aculeatum aculeatum is described from the Miocene of Europe and probably had a widespread distribution. In the earliest Miocene an offspring of this original stock with slightly longer septal bridges and possessing umbonal tubercles arrived in New Zealand as *E. aculeatum norcotti.* Later in the early Miocene within New Zealand, it appears that this subspecies developed a strong, raised umbonal boss and evolved into *E. aculeatum subrotatum.* This branch became extinct in New Zealand in the middle Miocene.

***Elphidium hampdenense* branch** (Figure 30)

On this branch we include two inflated lenticular species with acute, keeled peripheries, depressed umbonal areas and a strong reticulate ornament of raised radial ribs and long septal bridges, namely *E. hampdenense* and *E. pseudoinflatum.*

It seems likely that *E. hampdenense* evolved into *E. pseudoinflatum* in the middle to late Eocene with slight narrowing of the peripheral keel, slight increase in inflation of the chambers and shortening of the septal bridges in early whorls. This evolution was accompanied by a shift in ecological niche from deep to shallow water.

The presence of a stratigraphic gap between the ranges of these two species in New Zealand implies that *E. pseudoinflatum* evolved elsewhere and immigrated here in the latest Eocene.

This branch became extinct in the New Zealand region in the middle Miocene.

***Elphidium ingressans* branch** (Figure 31)

On this branch we include three species with acute, keeled peripheries, glassy umbonal tubercles or bosses and long septal bridges forming weak concentric ribs parallel to the periphery - *E. ingressans, E. wadeae* and *E. kanoum.*

This branch appears to be endemic to New Zealand. The earliest species, *E. ingressans* appeared in the late Eocene. It probably evolved into *E. wadeae* in the early Oligocene with a weakening of the radial ribs and a flattening of the profile. In the late Oligocene, *E. kanoum* probably branched from *E. wadeae* with the development of a solid, glassy umbonal boss from *wadeae*'s umbonal tubercles.

This branch became extinct in the middle Miocene.

***Elphidium novozealandicum* branch** (Figure 32)

On this branch we include two taxa with distinctive compressed profiles and strong reticulate ornament of radial ribs and raised septal bridges.

Both taxa appear to be endemic to New Zealand and probably evolved here. *E.* aff. *novozealandicum* appeared here in the late middle Miocene. It was probably derived from the very similar *E. crespinae* (from the early middle Miocene of Australia). *E. novozealandicum* evolved from *E.* aff. *novozealandicum* in the late Miocene with the development of a regular reticulate ornament of ribs in the umbonal area.

It is tempting to infer that this branch evolved from the rather similar, although trochospiral, *Discorotalia* within New Zealand. *Discorotalia* disappears from the fossil record just as planispiral *E.* aff. *novozealandicum* appears. The greater similarity however of the two *E. novozealandicum* branch taxa to a possible Australian ancestor is a compelling argument to reject *Discorotalia* as the ancestor.

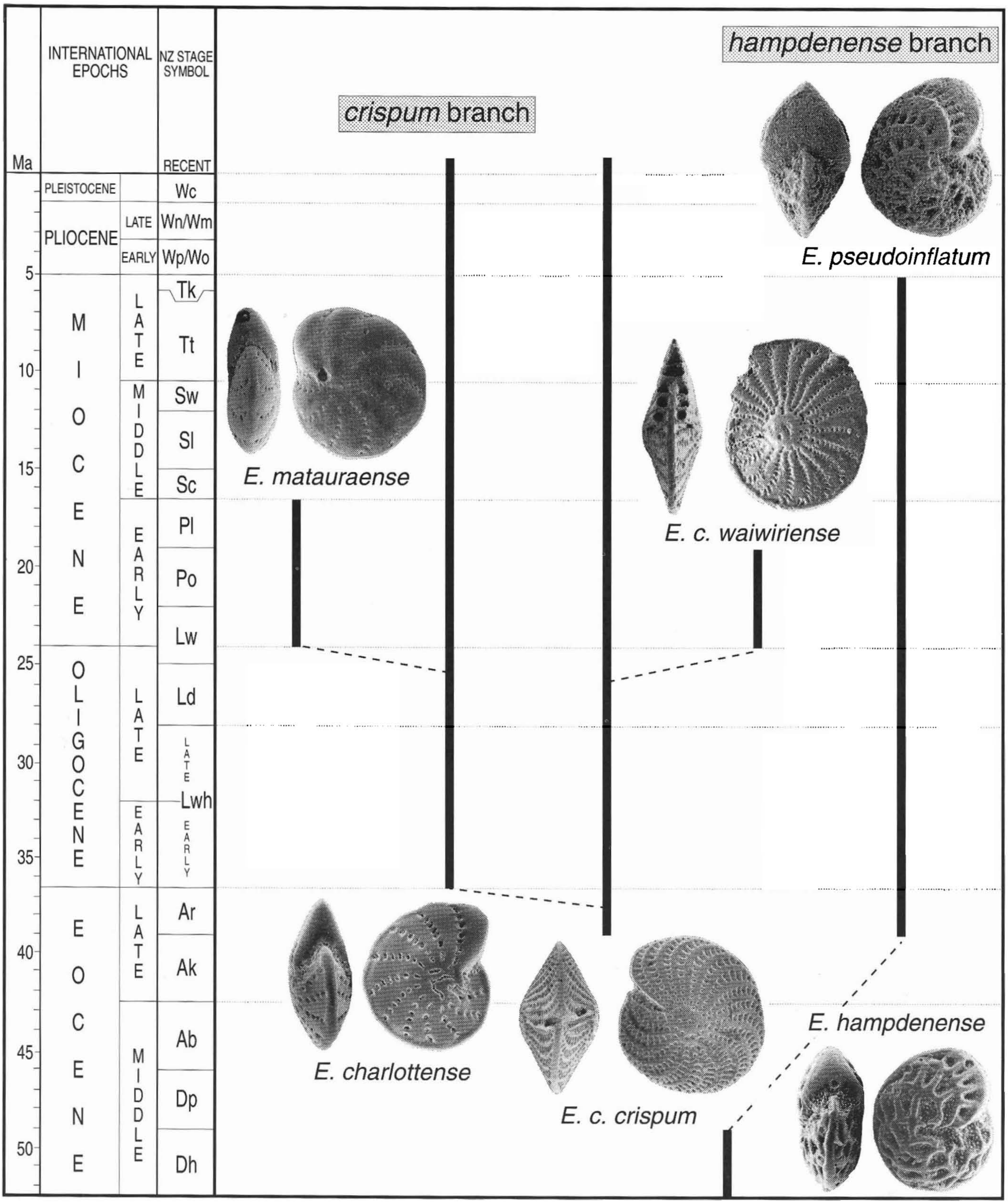


Figure 30 Local stratigraphic ranges and inferred phylogeny for members of the *Elphidium crispum* and *Elphidium hampdenense* branches in New Zealand.

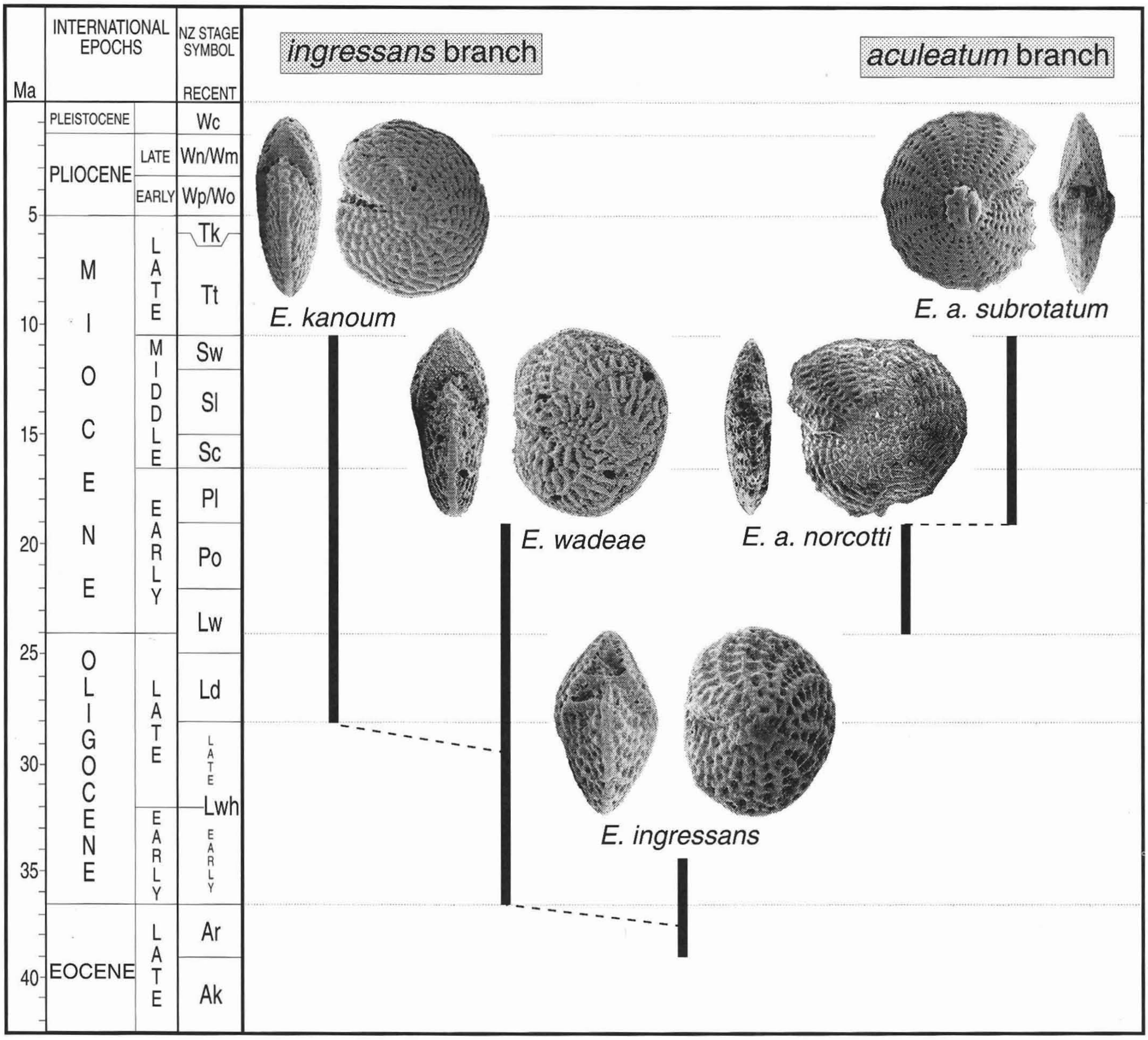


Figure 31 Local stratigraphic ranges and inferred phylogeny for members of the *Elphidium aculeatum* and *Elphidium ingressans* branches in New Zealand.

Discorotalia **branch** (Figure 32)

On this branch we include the two described species of *Discorotalia,* with their compressed profiles, strong reticulate ornament and loosely coiled tests.

This branch appears to be endemic to New Zealand, possibly having evolved from a *Notorotalia* ancestor in the Oligocene with flattening of the test and tightening of the coiling. The earlier species, *D. tenuissima,* appears to have given rise to the smaller, unkeeled *D. aranea* in the early Miocene. Both species became extinct at the end of the middle Miocene.

No recognisable branch

On present knowledge, we are unable to speculate with any confidence on the international relationships of two species that have sparse fossil records in New Zealand.

E. schencki is known from both hemispheres and presumably immigrated to New Zealand in the late middle Eocene.

E. oceanicum is widespread in the tropical and subtropical South-west Pacific today. Its one New Zealand record from the Pleistocene is presumed to be of a short, rather unsuccessful immigration event during a warm interglacial period.

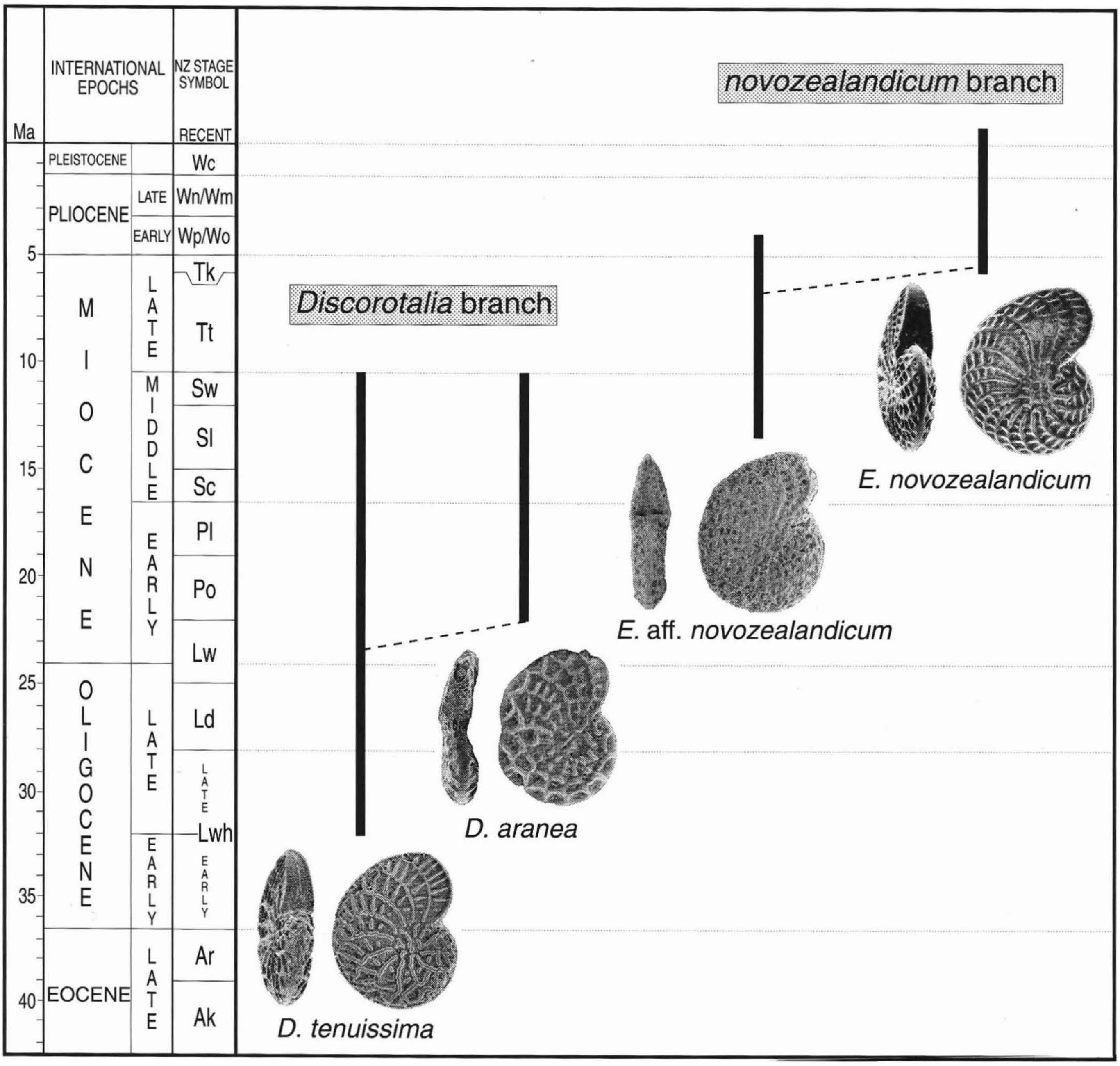


Figure 32 Local stratigraphic ranges and inferred phylogeny for members of the *Discorotalia* and *Elphidium novozealandicum* branches in New Zealand.

PALEOBIOGEOGRAPHY

INCOMPLETENESS OF THE NEW ZEALAND FOSSIL RECORD

The fossil record of *Elphidium, Discorotalia* and *Haynesina* in New Zealand is summarised in Appendices III–IV and Figures 28–43. This record is largely based on the c. 30 000 picked fossil foraminiferal faunas held in the national fossil collections at the Institute of Geological and Nuclear Sciences (Lower Hutt) and their computerised identification records on the New Zealand Fossil Record File. The computerised records were used to give maximum stratigraphic and paleogeographic coverage and all identifications have been checked and where necessary updated. The record from these national collections has been supplemented by all published records and by smaller collections held by Universities around New Zealand, with all records used having being checked and updated.

This is obviously not a complete record of the distribution of these taxa in time and space in New Zealand. Lack of preservation, lack of exposure of a complete sedimentary record throughout the country and incomplete sampling of what is available result in gaps in the stratigraphic, paleoecologic and paleogeographic record. Despite these shortcomings, the Cenozoic foraminiferal fossil record in New Zealand, as documented through the national collections, is one of the best studied and most complete for a region of its size anywhere in the world.

ENDEMISM

Present knowledge suggests that one genus, ten species and five subspecies of fossil or Recent *Elphidium* and *Discorotalia* (48% of New Zealand's taxa) are endemic to New Zealand (Table 4). Further detailed study and comparison with other parts of the world is likely to reduce this list.

Table 4. List of fossil or Recent *Elphidium* and *Discorotalia* taxa that appear to be endemic to New Zealand.

1 genus	*Discorotalia*
10 species	*E. ingressans* *E. kanoum* *E. matanginuiense* *E. matauraense* *E. novozealandicum* *E.* aff. *novozealandicum* *E. vellai* *E. wadeae* *D. aranea* *D. tenuissima*
5 subspecies	*E. aculeatum norcotti* *E. aculeatum aculeatum* *E. advenum macelliforme* *E. crispum waiwiriense* *E. excavatum oirgi*

Endemism in New Zealand increased from the middle Eocene to a peak of 50% in the early Miocene (also diversity peak), followed by a progressive decline to a level of 10% in the Pleistocene and 25% around New Zealand today (Table 5).

Table 5. Level of endemism through time in the New Zealand species of *Elphidium* and *Discorotalia.*

early Eocene	100%	from 1 taxon
middle Eocene	0%	from 4 taxa
late Eocene	14%	from 7 taxa
Oligocene	42%	from 12 taxa
early Miocene	50%	from 18 taxa
middle Miocene	40%	from 15 taxa
late Miocene	38%	from 8 taxa
Pliocene	30%	from 10 taxa
Pleistocene	10%	from 10 taxa
Recent	25%	from 12 taxa
Overall fauna	48%	from 31 taxa

PALEOBIOGEOGRAPHIC RELATIONSHIPS OF NON-ENDEMIC TAXA

Fifteen of the fossil New Zealand taxa considered here are found elsewhere in the world. They fall into three groups:

New Zealand-South American group

The two middle Eocene New Zealand species *E. hampdenense* and *E. saginatum* are both also known from the middle Eocene of South America. Neither has a known possible ancestor in either region. In New Zealand both are short-ranging, bathyal species that suddenly appear and just as suddenly disappear.

South-west Pacific group

Six taxa are in this group. The late Eocene to Miocene *E. pseudoinflatum* and the Miocene and Recent *E. carteri* both have an Australasian distribution. Both could also occur in the islands of the South-west Pacific, but their fossil record there is poor and has not been studied in this work.

E. advenum maorium and *E. charlottense* both occur in the New Zealand fossil record and have a southern South-west Pacific distribution today (Figures 15, 16). Their fossil record outside New Zealand has not been studied nor documented.

E. advenum limbatum and *E. oceanicum* also both occur in the New Zealand fossil record, but their fossil record elsewhere is not documented. They appear to be restricted to the wider South-west Pacific region today (Figures 15, 19).

Cosmopolitan group

Seven New Zealand fossil taxa occur in both hemispheres and six are present in both the Pacific and Atlantic oceans. The late Eocene *E. schencki* is known from California, but further study on similar forms from the late Eocene elsewhere in the world (e.g. Cushman 1939, plate 10) could show this species to have been more widely distributed.

The late Eocene-Recent *E. crispum crispum* is widespread in the tropical and subtropical Indo-Pacific and Mediterranean today and appears to have been as widespread in the Miocene and possibly earlier (Cushman 1939).

Five New Zealand fossil taxa (*E. advenum advenum, E. excavatum clavatum, E. excavatum excavatum, E. excavatum williamsoni, Haynesina depressula depressula)* have a cosmopolitan distribution today and are likely to have been widespread in the past but their fossil record is too poorly known to confirm this. All inhabit intertidal sand and mud flats and their world-wide distribution is possibly a result of dispersal by migrating seabirds.

PALEOBIOGEOGRAPHY OF *ELPHIDIUM, DISCOROTALIA* AND *HAYNESINA* WITHIN NEW ZEALAND (Figures 33–42)

Elphidium excavatum branch (Figure 33)

Probably the oldest member of this branch in New Zealand, *E. saginatum,* has a short middle Eocene time range and occurs in bathyal facies rocks throughout New Zealand, as well as overseas. The next to appear was the long-ranging, shallower water *E. excavatum clavatum,* which is never very abundant in the fossil record. It first appeared in Northland and on the west coast of the South Island in the Otaian (early Miocene) but had spread right around the country by the Altonian (late early Miocene). It continues with sporadic records countrywide through to the present day. The two other members found fossil in New Zealand, *E. excavatum excavatum* and *E. excavatum williamsoni* appear to have arrived much later with records in Hawkes Bay in the Pliocene and Pleistocene respectively. Today all these three subspecies occur right around New Zealand (Figure 23). The three Recent members of this branch that lack a fossil record (*E. excavatum oirgi, E. gunteri, E. vellai*) are all restricted to the northern half of the country.

Elphidium advenum branch (Figure 34)

The oldest member of this branch, *E. matanginuiense,* appears to be endemic to the Chatham Islands throughout its early Eocene range. The next arrival is the long-ranging, cosmopolitan, *E. advenum advenum.* It first appeared in Canterbury on the South-east coast of ancestral New Zealand in the Bortonian (middle Eocene). It appears to have been restricted to the South Island coastline throughout almost all its existence on the New Zealand coast (middle Eocene-middle Miocene), with only a brief excursion to the North Island's Waikato Basin in the Whaingaroan (Oligocene).

The two long-ranging subspecies, *E. advenum limbatum* and *E. advenum maorium,* both appeared in the Runangan (late Eocene) of the South Island. *E. advenum limbatum* spread to the North Island in the Whaingaroan (Oligocene) followed by *E. advenum maorium* in the Otaian (early Miocene). Both taxa appear to have remained widespread, although not particularly common, around all the coast of New Zealand from Miocene to the present day (Figure 22). *E. advenum maorium* appears to have been more common than *E. advenum limbatum* in the Neogene fossil record in New Zealand.

The subspecies, *E. advenum macelliforme,* has scattered sporadic records in the Oligocene, Miocene and Pliocene in New Zealand. The earlier records (Oligocene) are from the South Island coastline and the younger records (late Miocene and Pliocene) from the east coast of the North Island. This apparent biogeographic shift from south to north may be real or simply an artifact of this rare subspecies poor fossil record.

The last member of this branch, *E. carteri,* appeared in Southland in the Waitakian-Otaian (early Miocene) with several scattered subsequent records - one in the North Island in the Altonian (late early Miocene) and two more in the Southland Basin in the middle Miocene.

Although now extinct around New Zealand, *E. advenum advenum, E. advenum macelliforme* and *E. carteri* are still living in parts of the tropical South-west Pacific (Figures 15, 16).

Elphidium crispum branch (Figures 35, 36)

The central, cosmopolitan species in this branch, *E. crispum crispum,* is the most abundant and widespread *Elphidium* taxon in the New Zealand fossil record. It arrived in New Zealand in the Runangan (latest Eocene) and quickly spread all around the coast, where it remained throughout the Oligocene, Miocene and early Pliocene (Opoitian). As the climate cooled, it disappeared from the South Island from the late Pliocene onwards, but remained out to the South-east, around the Chatham Islands until the end of the Pliocene (Mangapanian). It remained around the coasts of the North Island during most of the Pleistocene glaciations but today is restricted to the east coast of northern New Zealand, which is bathed in the warm waters of the East Auckland Current.

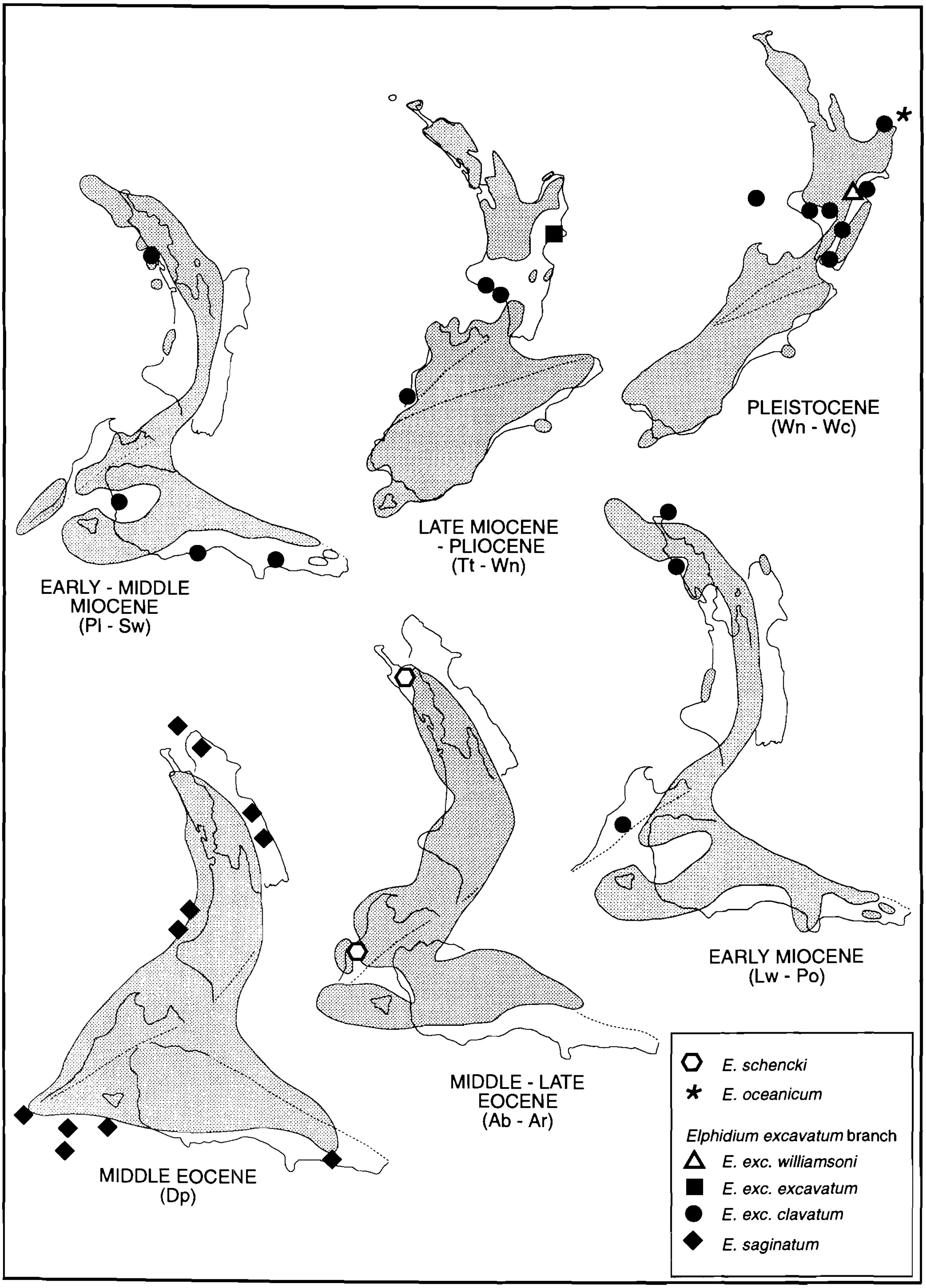


Figure 33 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium excavatum* branch, plus *E. schencki* and *E. oceanicum*.

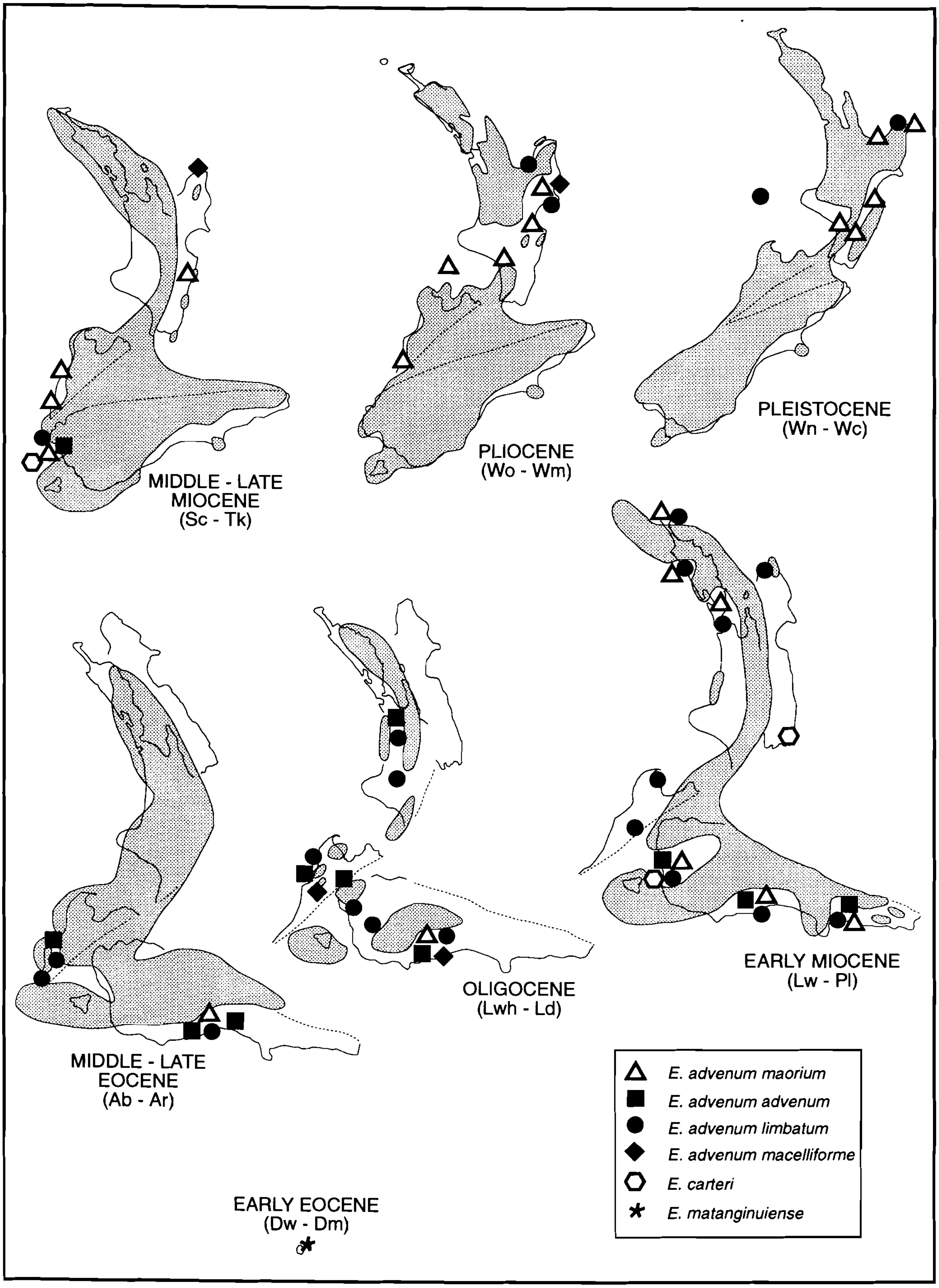


Figure 34 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium advenum* branch.

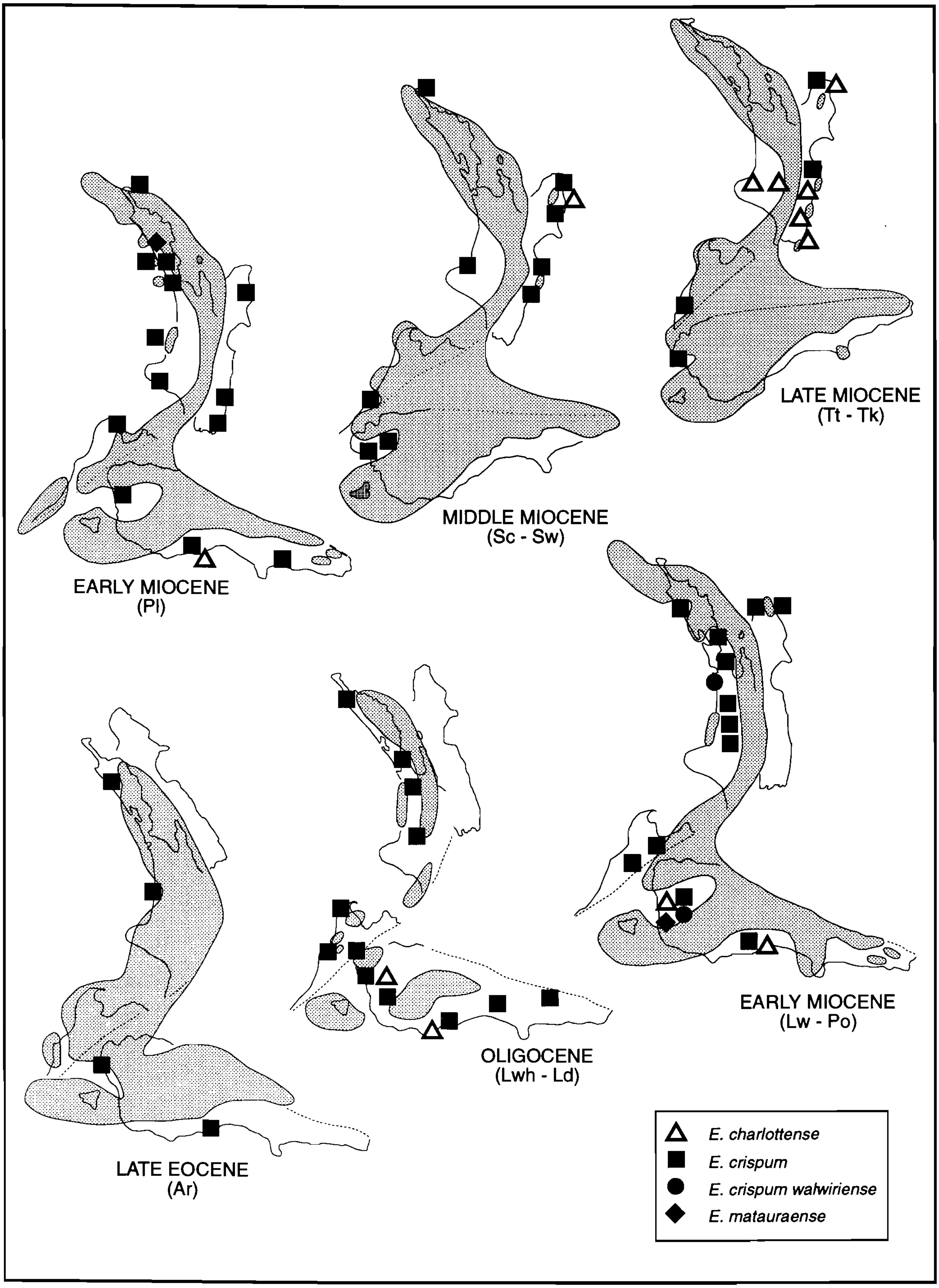


Figure 35 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium crispum* branch from the late Eocene to late Miocene.

The most abundant species around present-day New Zealand, *E. charlottense,* appears to have evolved from *E. crispum crispum* in the Whaingaroan (Oligocene) of the South Island. It appears to have remained relatively uncommon around the South Island throughout the early and middle Miocene, finally spreading to the North Island as temperatures began to fall in the Tongaporutuan (late Miocene). It became the dominant *Elphidium* around the whole country in the Pliocene and has remained so to the present-day (Figure 36).

The rare endemic species, *E. matauraense,* appears to have evolved from *E. charlottense* in the Waitakian or Otaian (early Miocene) of Southland and spread to the North Island in the Altonian (late early Miocene) before disappearing. The second rare endemic member of this branch, *E. crispum waiwiriense,* probably evolved from *E. crispum crispum* somewhere in New Zealand. It appeared in both the North and South Island in the Otaian (early Miocene) and then disappeared.

***Elphidium aculeatum* branch** (Figure 37)

The older of the two New Zealand members of this branch, the apparently endemic *E. aculeatum norcotti,* is only known from the type locality on the east coast of the North Island in the Waitakian or Otaian (early Miocene). It possibly gave rise to the endemic *E. aculeatum subrotatum,* which appeared in the Altonian (late early Miocene) on both coasts of the South Island, and seems to have shifted to the southern North Island in the middle Miocene.

***Elphidium hampdenense* branch** (Figure 38)

The older of the two members of this branch is the widespread Southern Hemisphere species, *E. hampdenense,* which was common in deep water off the east coast of both islands during the short span of its occurrence in the Heretaungan (middle Eocene). It has not been recorded from the west coast despite the presence of rocks of suitable facies in northern offshore Taranaki.

The younger member of this branch, the shallower water Australasian species *E. pseudoinflatum,* appears to have arrived in New Zealand on the west coast of the South Island in the Runangan (latest Eocene). It spread throughout the country in the Whaingaroan (Oligocene) and remained widespread and relatively common during the early and middle Miocene until its disappearance in the Waiauan (late early Miocene).

***Elphidium ingressans* branch** (Figure 39)

The oldest of the three, all endemic, members of this branch, *E. ingressans,* is a rare species which appeared in New Zealand on the west coast of the South Island in the Runangan (latest Eocene) and never seems to have spread beyond that region. It probably gave rise to the more common *E. wadeae* in the Whaingaroan (Oligocene). This species spread around the coast of both islands in the Oligocene but contracted its range to the South Island in the Waitakian and Otaian (early Miocene).

The third and youngest member of this branch, *E. kanoum,* appears to have evolved from *E. wadeae* in the north in the Duntroonian (late Oligocene). It spread right around the New Zealand coast in the Waitakian and Otaian (early Miocene) and was one of the most common *Elphidium* taxa in the Altonian. It dispersed as far south as the Auckland Islands. Numbers of *E. kanoum* declined through the middle Miocene and it eventually became extinct in the Lillburnian or Waiauan (late middle Miocene).

***Elphidium novozealandicum* branch** (Figure 40)

The older of the two members of this branch, *E.* aff. *novozealandicum,* appeared in New Zealand in Northland or Hawkes Bay in the Lillburnian or Waiauan (late middle Miocene) and remained confined to the coast of the North Island throughout its existence. It became extremely rare after the end of the Tongaporutuan (late Miocene) with one last known occurrence in the Opoitian (Pliocene) on the coast south of Auckland.

E. novozealandicum appears to have evolved from *E.* aff. *novozealandicum* in the East Cape area in the Kapitean (latest Miocene) and spread right around the country in the Opoitian (Pliocene) reaching the Chatham Islands by the Nukumaruan (early Pleistocene). *E. novozealandicum* remains the second most common and widespread *Elphidium* species around New Zealand today (Figure 24).

***Discorotalia* branch** (Figure 41)

The older member of this apparently endemic branch, *D. tenuissima,* appears to have evolved in the late Whaingaroan (middle Oligocene) in Southland and dispersed up the west coast of both islands in the Duntroonian (late Oligocene). It spread round to the east coast of both islands in the Waitakian and Otaian (early Miocene) and remained widespread and relatively common during the Altonian (late early Miocene). Its range appears to have contracted to the South Island during the Clifdenian and Lillburnian (middle Miocene) with its last records in the Waiauan (late middle Miocene) of Southland.

D. aranea appears to have evolved from *D. tenuissima* in the Otaian (early Miocene) of the South Island. This small species was widespread around the South Island during the Altonian (late early Miocene) but does not appear to have reached the North Island. The geographic range of *D. aranea* contracted to the Southland Basin in the Clifdenian (late Miocene), and it finally disappeared from there, too, in the Waiauan (late middle Miocene).

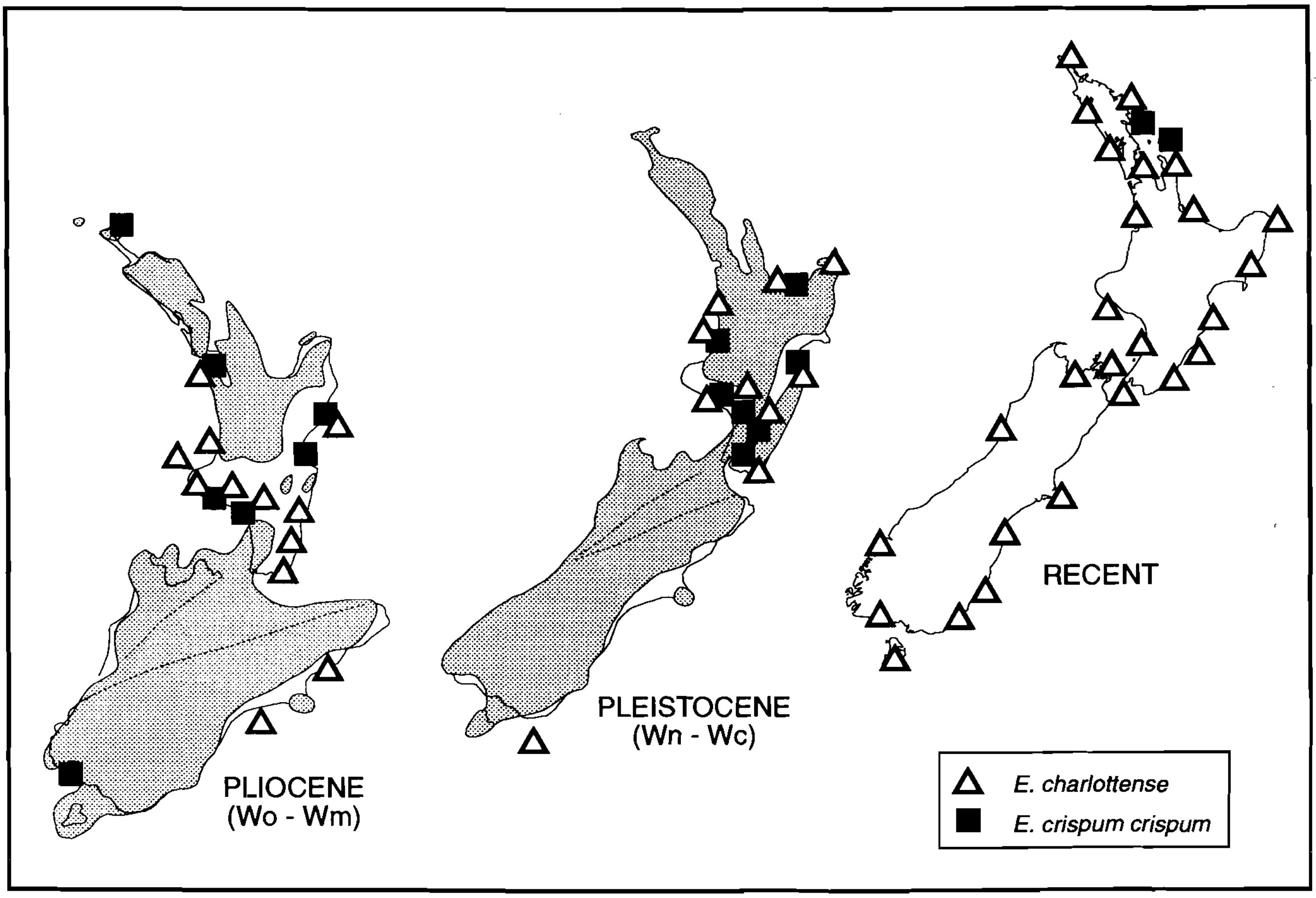


Figure 36 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium crispum* branch from the Pliocene to Recent.

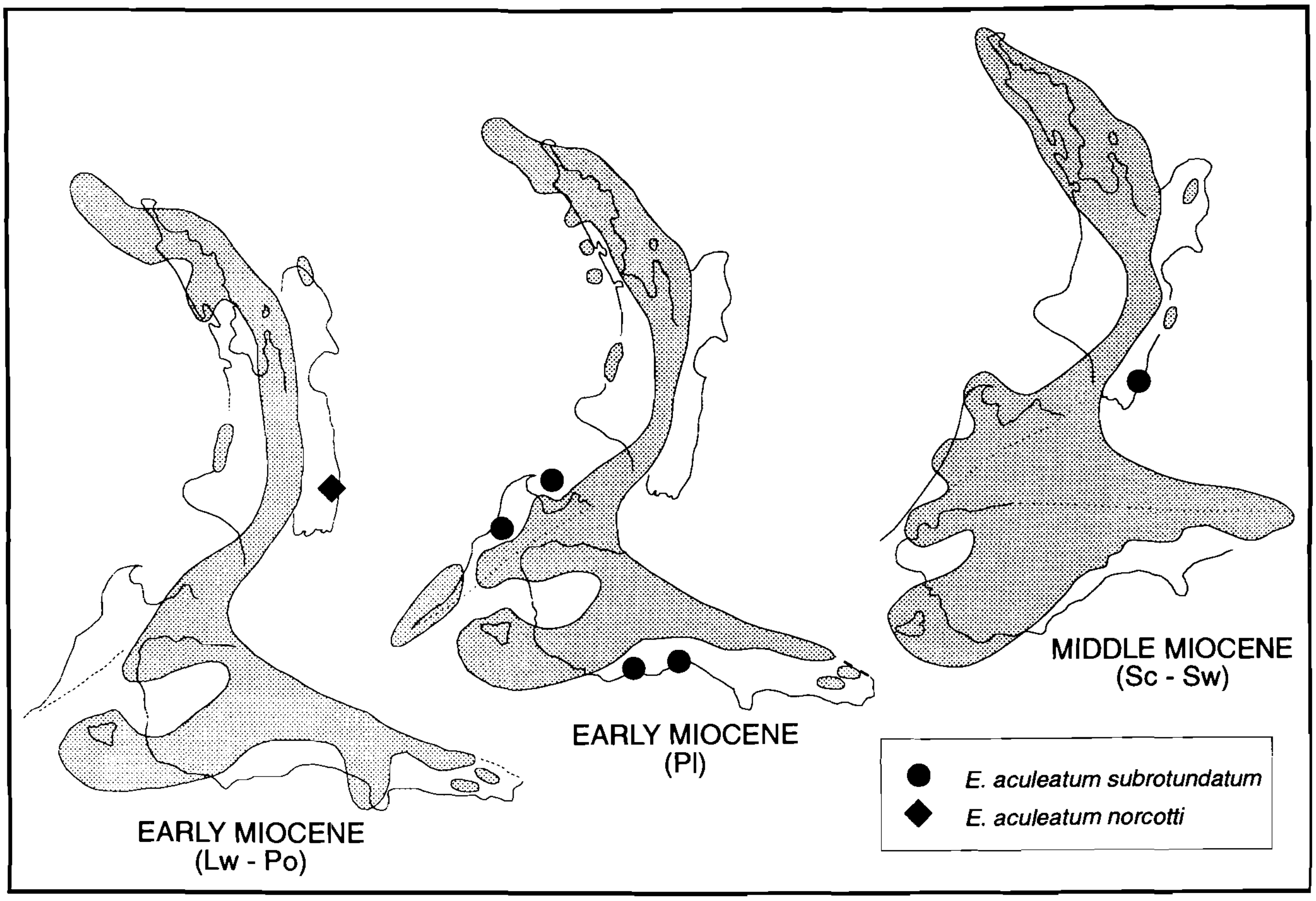


Figure 37 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium aculeatum* branch.

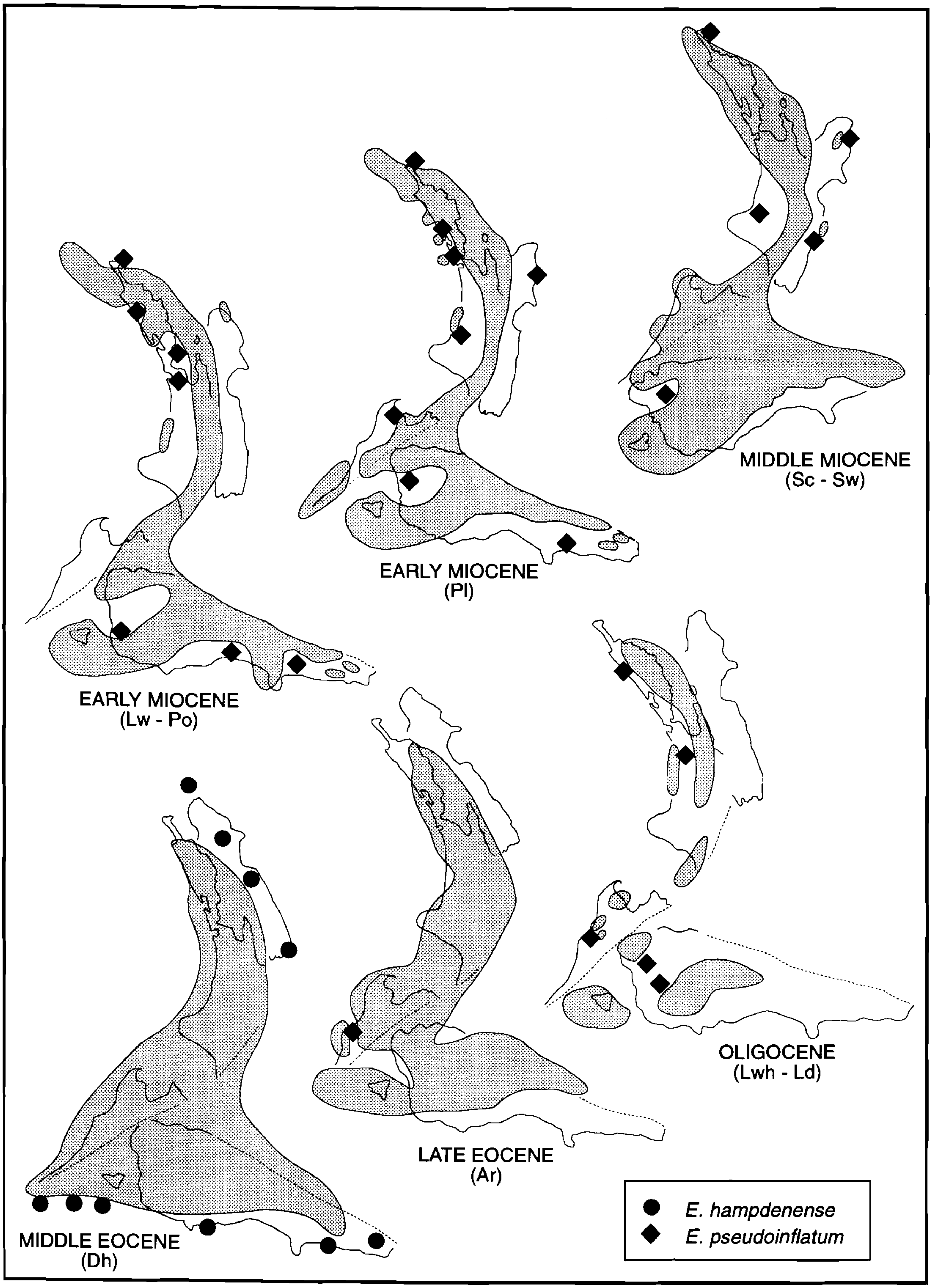


Figure 38 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium hampdenense* branch.

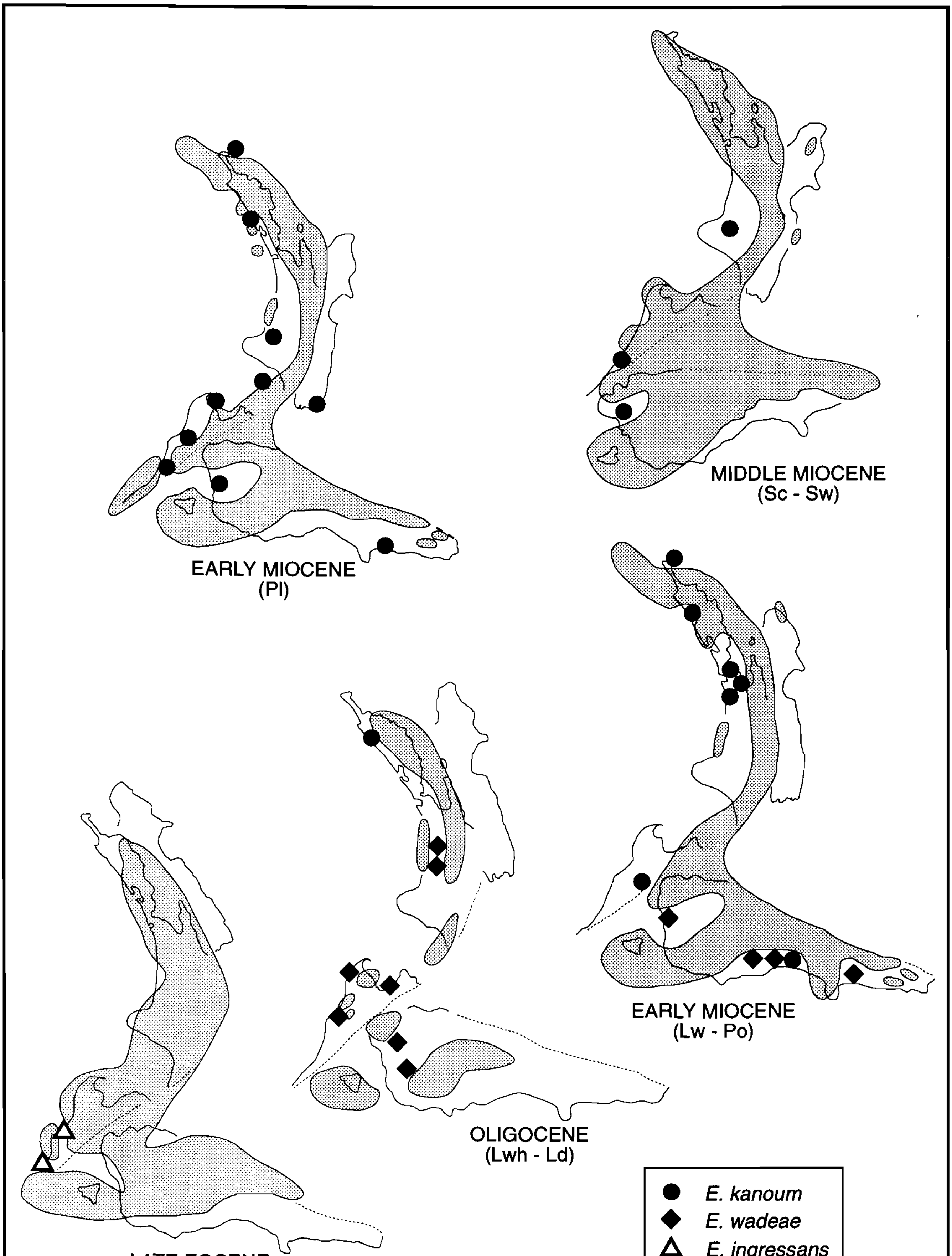


Figure 39 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium ingressans* branch.

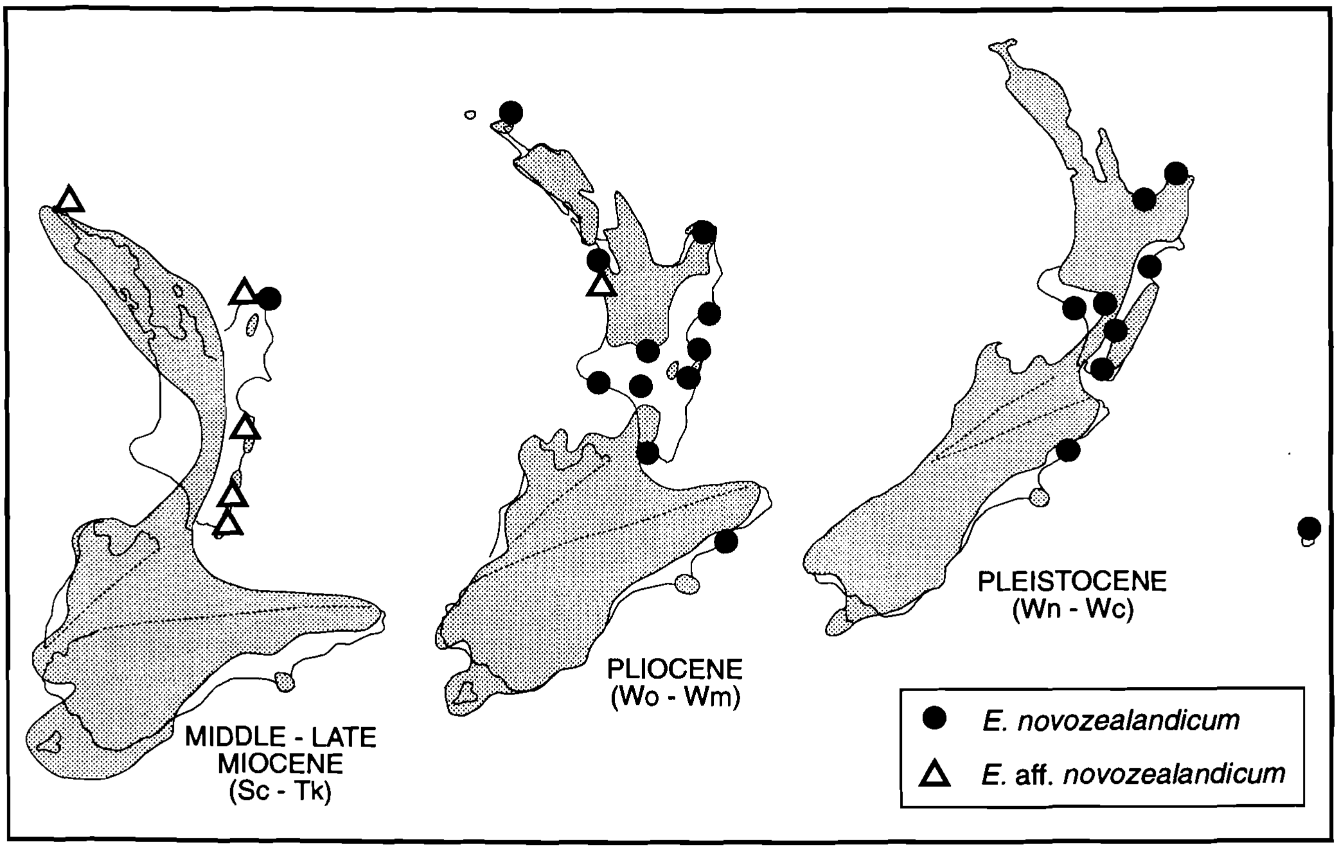


Figure 40 Recorded paleobiogeographic distribution in New Zealand of members of the *Elphidium novozealandicum* branch.

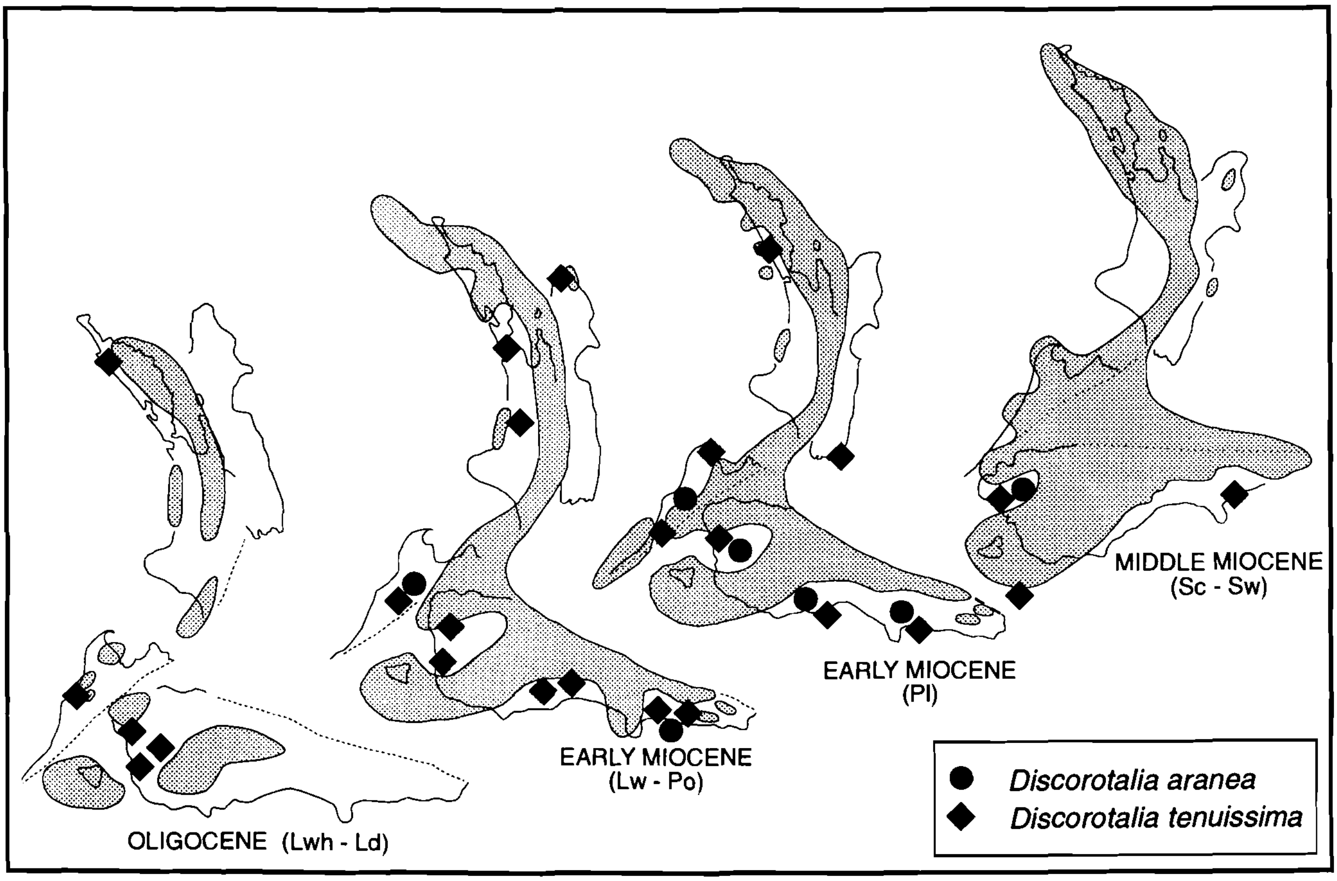


Figure 41 Recorded paleobiogeographic distribution in New Zealand of members of the *Discorotalia* branch.

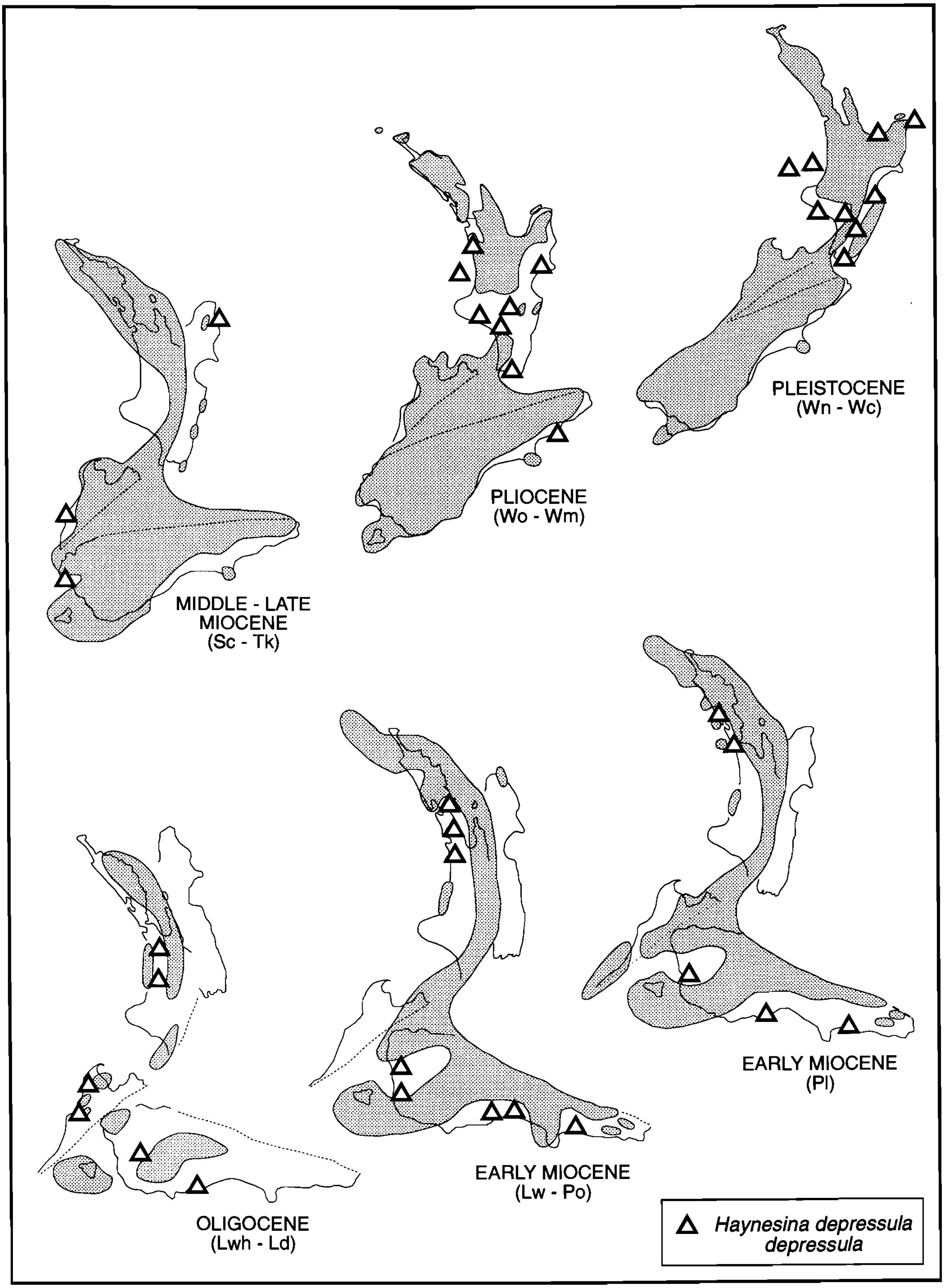


Figure 42 Recorded paleobiogeographic distribution in New Zealand of *Haynesina depressula depressula*.

No recognisable branches

E. schencki appeared in the Bortonian (middle Eocene) in Northland and spread to the west coast of the South Island by the Runangan (latest Eocene). It has not yet been recorded from the east coast of either island (Figure 33).

E. oceanicum made a brief appearance in the Castlecliffian (Pleistocene) at East Cape, presumably arriving in the ancestral, warm-water East Auckland Current during an interglacial period (Figure 33). It does not appear to have survived here through succeeding cold glacial periods and has not returned to the present-day, although it is common in the rest of the South-west Pacific (Figure 19). Its presence around Tasmania today, suggests that conditions would be suitable for it to live around northern New Zealand right now if it managed to cross the oceanic barrier.

The cosmopolitan *Haynesina depressula depressula* appears to have arrived in New Zealand in the Whaingaroan (Oligocene) and quickly spread around the coast of the whole country, a distribution it has maintained through to the present-day (Figure 42). *H. depressula depressula* was moderately common throughout its range except for a period in the middle and late Miocene when it seems to have become much rarer.

OVERALL DISTRIBUTION PATTERNS THROUGH TIME (Table 6)

Of the 12 extant elphidiid taxa in New Zealand, ten occur around both main islands and two are restricted to the northern North Island. A similar pattern is to be found in the fossil record, although a higher percentage appear to have restricted distributions. This may be a result of the imperfect fossil record, especially in the Pliocene and Pleistocene, where there is a poor marine sedimentary record in the South Island.

Diversity had increased sufficiently by the late Eocene to make meaningful paleobiogeographic observations. In the Kaiatan-Runangan (late Eocene) two taxa (30%) occurred throughout New Zealand and five (70%) were restricted to the South Island. Three (40%) were only present on the west coast of ancestral New Zealand at that time. This high percentage of apparently southern-restricted taxa may in part be explained by the sparseness of shallow marine Kaiatan-Runangan rocks in the North Island.

In the Whaingaroan-Duntroonian (Oligocene), seven taxa (60%) had a New Zealand-wide distribution, three were restricted to the South Island and one to the North Island. This is probably fairly accurate as marine Oligocene rocks are well represented throughout much of the country.

In the Waitakian-Otaian (early early Miocene), nine taxa (60%) were New Zealand-wide, six were restricted to the South Island and one to the North Island. In the Altonian (late early Miocene), nine taxa (65%) were New Zealand-wide, three were restricted to the South Island and two to the North Island. The early Miocene marine sedimentary record is good throughout both islands and these results are accepted as a fair reflection of reality. It is curious to note that in the Oligocene and early Miocene there were more taxa restricted to the South Island than the North Island, the reverse of modern diversity trends. We do not believe that there was a greater diversity of shallow marine and paralic paleoenvironments preserved in the south than the north and therefore some other explanation is necessary.

The Clifdenian-Waiauan (middle Miocene) marine sedimentary record is patchy in both islands. The best shallowish water sequence is at Clifden in the Southland Basin. It has been well sampled and studied (Fleming *et al.* 1969) and its fauna skews the results. Only four taxa (30%) occur in both islands with a further three restricted to the North Island and six to the South Island (five of these restricted to the Southland Basin). The most significant result is probably that three taxa were not present in the Southland Basin and South Island, which is similar to the Oligocene and early Miocene.

Tongaporutuan-Kapitean (late Miocene) rocks are well represented in many parts of New Zealand although many are in deeper water facies unfavourable to elphidiids. The eastern North Island record is slightly better than elsewhere and this influences the results. Two taxa (25%) were New

Table 6. Summary of paleobiogeographic distribution patterns of *Elphidium, Discorotalia* and *Haynesina* taxa through time in New Zealand.

NZ Stages	Epoch	NZ wide	North Is	South Is	West coast	East coast	Total taxa
Dh-Dp	m Eocene	1				1	2
Ab	m Eocene		1	1	2		2
Ak-Ar	l Eocene	2		5	3	1	7
Lwh-Ld	Oligocene	7	1	3	1	1	11
Lw-Po	e Miocene	9	1	6	3	1	16
Pl	e Miocene	9	2	3	1		14
Sc-Sw	m Miocene	4	3	6	6	2	14
Tt-Tk	l Miocene	2	4	2	2	3	8
Wo-Wm	Pliocene	6	4		2	3	10
Wn-Wc	Pleist.	2	7			2	9
Rec	Recent	10	2			2	12

Zealand-wide, four were North Island-restricted and two South Island-restricted. Pliocene and Pleistocene results are strongly skewed by the poor South Island sedimentary record.

In summary, the paleobiogeography of elphidiids around New Zealand shows that from their first appearance, there have been many taxa that dispersed right around the country (20–75% in any one time interval) and just as many that had more restricted geographic range. Sometimes they were restricted to either the west or east coast of ancestral New Zealand, but more often they had a latitudinally constrained distribution pattern. In contrast to the present day, the elphidiids appear to have been more diverse in the south than the north throughout at least the Oligocene and Miocene in this country.

NEW ZEALAND BIOSTRATIGRAPHY (Figure 43)

The documented time ranges of the 31 taxa of *Elphidium, Discorotalia* and *Haynesina* recorded from the early Eocene to Recent of New Zealand are of variable biostratigraphic use and reliability.

Taxa of major utility

The two middle Eocene species, *E. hampdenense* and *E. saginatum,* have for many decades been the most useful of *Elphidium* taxa biostratigraphically and are the key species for defining the New Zealand Heretaungan and Porangan stages (Finlay & Marwick 1947, Hornibrook *et al.* 1989). Key factors in this utility, are their distinctive morphology (although *E. hampdenense* is sometimes difficult to distinguish from some forms of the younger *E. pseudoinflatum),* their short time ranges, their widespread occurrence in a range of paleoenvironments. Both species are among the few New Zealand elphidiids that lived in bathyal depths. *E. hampdenense* also appears to have lived in mid and outer shelf depths, but *E. saginatum* may not have lived at shelf depths.

Common taxa of moderate utility

The greatest biostratigraphic value of other elphidiids is in helping to date low diversity shallow water benthic foraminiferal assemblages that lack planktic foraminifera and deeper water benthic taxa that are most used in dating New Zealand Cenozoic strata. It is in these shallow water assemblages that *Elphidium* is often in greatest abundance and diversity, and a combination of several ranges may help give greater precision to a determined age.

Unfortunately most of the common New Zealand elphidiids (e.g. *E. advenum* group, *E. crispum crispum, E. pseudoinflatum, Discorotalia tenuissima* and *Haynesina depressula)* have long time ranges and are of limited use.

Common taxa with relatively short time ranges, although still spanning a number of stages, that have biostratigraphic use are *E. aculeatum subrotatum* (Pl-Sw), *E. kanoum* (Ld-Sw), *E. novozealandicum* (Tk-Rec), *E. wadeae* (Lwh-Po) and *D. aranea* (Po-Sw).

Rarer taxa of potential utility

In addition to the widespread taxa, there are a number of taxa that are of limited geographic or environmental occurrence or of very low abundance in New Zealand. As a result, the time ranges for these taxa cannot be regarded as completely known. Despite these shortcomings, some of these rare taxa appear to have relatively short time ranges and if found in an otherwise poorly dated, probably shallow water fauna, have the potential to improve the precision of the date.

These taxa include *E. aculeatum norcotti* (Lw-Po), *E. carteri* (late Lw-Sw), *E. crispum waiwiriense* (late Lw-Po), *E. ingressans* (Ar-eLwh), *E. matanginuiense* (Dw-Dm), *E. matauraense* (Po-Pl), *E.* aff. *novozealandicum* (late Sl-Wo) and *E. schencki* (Ab-Ar).

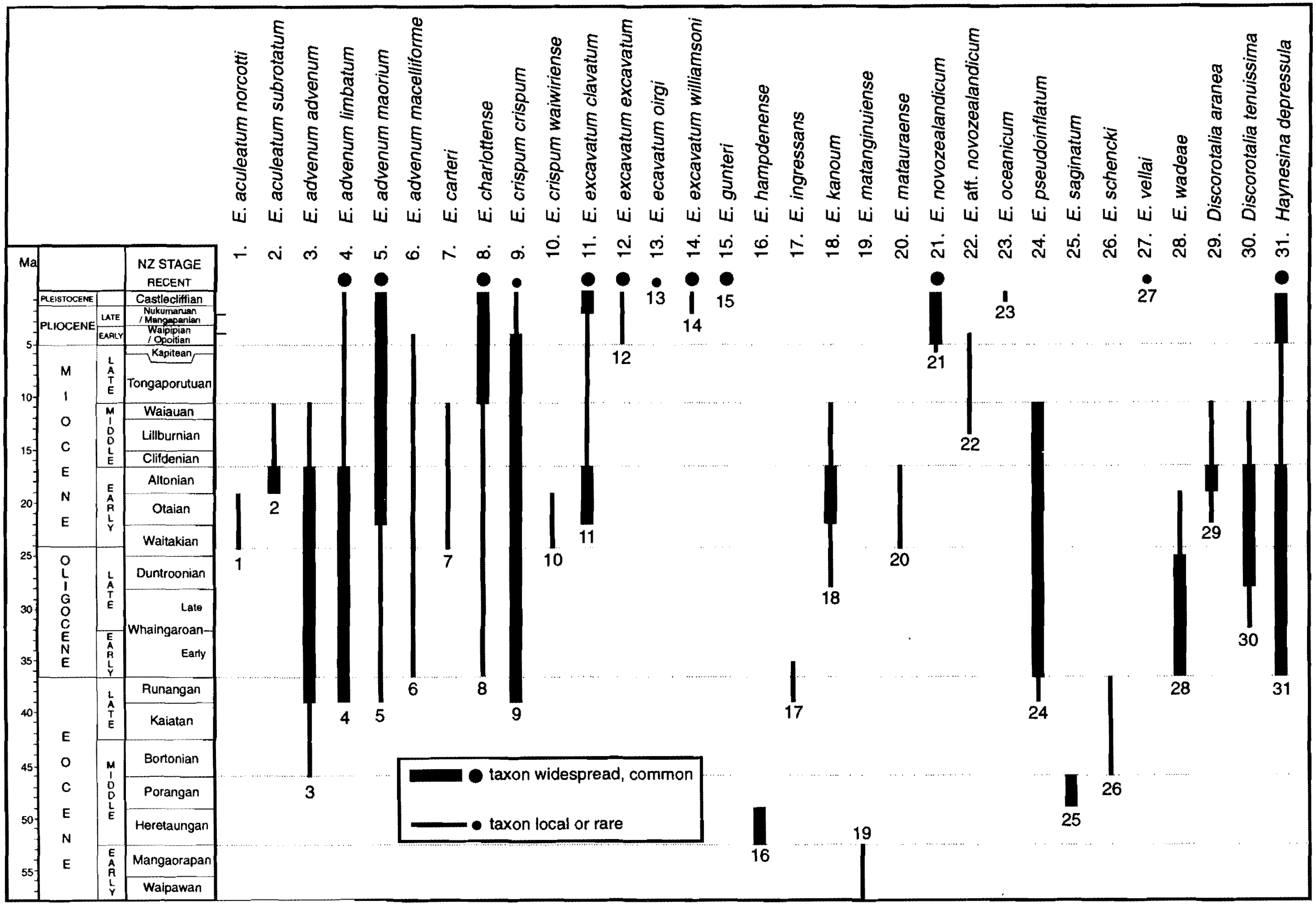


Figure 43 Recorded stratigraphic ranges of species and subspecies of *Elphidium*, *Discorotalia* and *Haynesina* in New Zealand.

KEY TO RECENT SOUTH-WEST PACIFIC AND FOSSIL NEW ZEALAND ELPHIDIIDAE

* = living species

1	Coiling trochospiral	2
	Coiling planispiral	7
2	Coiling slightly trochospiral	3
	Coiling fully trochospiral	5
3	Radial and spiral ribs present almost planispiral	*Notorotalia finlayi*[1] *
	Radial ribs lacking	4
4	Sutures deeply channelised; numerous transverse riblets	*Cristatavultatus pacificus* *
	Sutures slightly depressed; no rib ornament	*Elphidium excavatum sydneyense* *
5	Coiling fully trochospiral; one or both sides inflated and convex	*Notorotalia*
	Coiling slightly evolute/involute; compressed discoidal test	*Discorotalia* 6
6	Test small; 3-5 transverse ribs; no keel	*Discorotalia aranea*
	Test medium size; 7-8 transverse ribs; narrow keel	*Discorotalia tenuissima*
7	Sutures simple; no septal bridges	*Haynesina* 8
	Sutures crossed by bridges or ribs	9
8	Umbilicus filled with tubercles; no boss	*Haynesina depressula depressula* *
	Umbilicus with circular boss	*Haynesina depressula simplex* *
9	Apertural face with radiating papillae or fine riblets; ornament includes anastomosing ribs on sides	*Parrellina* 10
	Lacks anastomosing ornament on sides or radiating ornament on apertural face	*Elphidium* 13
10	Bears 3-5 peripheral spines	*P. imperatrix* *
	Lacks peripheral spines	11
11	Dense ornament of irregular papillae all over	*P. papillosa* *
	Ornament of radial and concentric ribs	12
12	Test large (0.8-1 mm); profile symmetric	*P. verriculata* *
	Test medium-sized (0.4-0.6 mm); profile slightly asymmetric planispiral	*Notorotalia finlayi*[1] *
13	Periphery rounded, lacking a keel	14
	Periphery keeled or limbate	40
14	Wall coarsely perforate; often golden brown	15
	Wall finely perforate; white or glassy	16
15	Possess umbilical tubercles	*E. gunteri* *
	No umbilical tubercles	*E. vellai* *
16	Periphery broadly rounded	17
	Periphery acutely rounded	32

---

[1] see Plate 19, Figs. 8-9

17	Chamber walls coarsely granular; ornament sometimes reticulate	18
	Chamber walls lacking coarse granules or reticulate ornament	19
18	Chamber walls covered in coarse granules; ribs lacking	*E. phillipense* *
	Chamber walls with reticulate rib ornament and granules on last chambers	*E. reticulosum* *
19	Test strongly inflated; few broad septal bridges produce reticulate ornament	*E. saginatum*
	Test moderately inflated; septal bridges narrow	20
20	Test loosely coiled with broad umbilicus filled with numerous papillae	*E. oceanicum* *
	Test involute or almost so	21
21	Boss, raised, glassy; test wall glassy	*E. fijiense* *
	Boss small, flat or lacking	22
22	Sutures and umbilicus without fine papillae	23
	Sutures and umbilicus lined with fine papillae	27
23	Radial ribs strong; septal bridges short tubercular	*E. matanginuiense*
	Radial ribs lacking; septal bridges elongate; sutures deeply incised	24
24	Test strongly compressed	25
	Test moderately to strongly inflated	26
25	9-15 sutural bridges; flat umbilical area, flush with surface	*E. albanii* *
	6-10 sutural bridges; umbilicus depressed sometimes with small boss	*E. lene* *
26	Umbilical boss lacking	*E. sandiegoense* *
	Umbilical boss large and flat	*E. excavatum clavatum* *
27	Septal bridges short, fewer than 6 per suture	28
	Septal bridges, 6 or more per suture	30
28	Test slightly asymmetric in peripheral view	*E. excavatum sydneyense* *
	Test symmetrical in peripheral view	29
29	Umbilicus depressed, lacking a boss; 10 or fewer chambers per whorl	*E. excavatum excavatum* *
	Umbilicus flattish with a collar and often a central boss; 10 or more chambers per whorl	*E. excavatum clavatum* *
30	Test small, up to 0.4 mm; wall glassy	*E. excavatum oirgi* *
	Test medium-sized, up to 0.6 mm; wall shelly	31
31	Extensive papillate ornament on either side of apertural region; septal bridges short	*E. hawkesburiense* *
	Narrow band of fine papillae on either side of apertural region; septal bridges long	*E. excavatum williamsoni* *
32	Periphery with a slightly thickened, imperforate band or concentric ribs	33
	Periphery evenly rounded, lacks imperforate band	37
33	Radial ribs strong; short tubercular septal bridges	*E. matanginuiense*
	Radial ribs lacking; longish septal bridges	34
34	Boss small and flat	*E. advenum maorium* *
	Boss large and raised	35

35	Test and boss glassy	*E. fijiense* *
	Test shelly; periphery with concentric ribs	36
36	Last chambers with hispid ornament; boss narrow	*E. hispidulum* *
	Hispid ornament absent; boss broad	*E. mortonbayense* *
37	Umbilicus depressed and filled with papillae	38
	Umbilicus flat and filled with smooth shell	39
38	Flat chambers and low flat septal bridges	*E. schencki*
	Chambers and septal bridges slightly convex	*E. excavatum williamsoni* *
39	Opaque bands along sutures	*E. albanii* *
	Glassy translucent walls and flush, glassy sutures	*E. vitreum* *
40	Coarse papillae cover all or most of test	41
	Fine papillae, if present, restricted to sutures, umbilicus and apertural area	45
41	Radial ribs present	42
	Radial ribs absent	44
42	Single umbilical boss; 4-6 septal bridges	*E. carteri* *
	Umbilicus with several tubercles; 8-12 septal bridges	43
43	Peripheral spines present	*E. silvestrii* *
	Peripheral spines absent	*E. argenteum* *
44	Umbilicus with several tubercles; apertural face with fine riblets	*E. collinsi* *
	Boss, single, glassy, raised; apertural face finely granular	*E. vavauense* *
45	Peripheral spines present	46
	Peripheral spines absent	48
46	Boss, single, raised, glassy	*E. aculeatum subrotatum*
	Tubercles in umbilicus	47
47	Radial ribs absent; septal bridges strong	*E. aculeatum norcotti*
	Radial ribs strong; septal bridges subordinate	*E. silvestrii* *
48	Single boss fills all or most of umbilicus	49
	Depressed umbilicus, often with several tubercles	64
49	Several concentric ribs on either side of periphery	50
	Single peripheral keel without adjacent concentric ribs	52
50	Boss composite, narrower than 0.3 times width of test; hispid ornament	*E. hispidulum* *
	Boss broad, 0.3-0.5 times width of test; lacks hispid ornament	51
51	Prominent peripheral keel present	*E. craticulatum* *
	Single peripheral keel absent	*E. mortonbayense* *
52	Radial ribs strong or irregular	53
	No radial ribs	57
53	Test strongly inflated with reticulate, spiky ornament	*E. ingressans*
	Test compressed to moderately inflated	54
54	Fewer than 15 chambers per whorl; semicircular boss	*E. advenum tongaense* *
	More than 15 chambers per whorl; circular boss	55

55	Strong circular ornament produced by septal bridges and weak, irregular, beaded . radial ribs	*E. kanoum*
	Moderately strong radial ornament, commonly with radial rib on each chamber	56
56	Peripheral angle 40-50°; width/thickness ratio less than 2.5	*E. crispum crispum* *
	Peripheral angle 20-30°; width/thickness ratio greater than 2.5	*E. crispum waiwiriense*
57	Chambers inflated; sutures deeply incised	58
	Chambers slightly inflated to non-inflated	62
58	Periphery with very weak keel or imperforate limbate zone	59
	Peripheral keel moderate to strong	60
59	Wall glassy; boss strongly raised and glassy	*E. fijiense* *
	Wall finely perforate; boss shelly, small or irregular	*E. advenum maorium* *
60	Boss solid, filling most of umbilical area	61
	Boss semicircular to subcircular half filling umbilicus	*E. advenum botaniense* *
61	12-17 chambers per whorl; distinctly depressed sutures	*E. advenum advenum* *
	18 or more chambers per whorl; weakly incised sutures	*E. advenum macelliforme* *
62	Numerous chambers per whorl (more than 17)	*E. advenum macelliforme* *
	Fewer than 16 chambers per whorl	63
63	Keel strong and rounded; flat umbilical boss	*E. charlottense* *
	Keel weak and rounded or a thickened band; strongly involute	*E. matauraense*
64	Test strongly compressed (inflation >3)	65
	Test moderately compressed to inflated	68
65	Umbilicus with ribbed ornament	66
	Umbilicus with tubercles	67
66	Umbilical ribs form reticulate pattern	*E. novozealandicum* *
	Umbilicus with a spiral rib or irregular broken riblets	*E.* aff. *novozealandicum*
67	Umbilicus narrow, deeply depressed	*E. macellum* *
	Umbilicus broad, slightly depressed	*E. fichtellianum* *
68	Septal bridges short, spanning less than half chamber width	69
	Septal bridges long, spanning more than 3/4 chamber width	70
69	Radial ribs strong; septal bridges tubercular	*E. matanginuiense*
	No radial ribs; septal bridges short and narrow	*E. advenum limbatum* *
70	Umbilicus with strong tubercles; radial ribs weak	*E. wadeae*
	Umbilicus depressed, tubercles weak or lacking; radial ribs strong	71
71	13-16 chambers per whorl	*E. advenum dispar* *
	7-12 chambers per whorl	72
72	Apertural face triangular; reticulate ornament over entire test	*E. hampdenense*
	Apertural face heart-shaped; reticulate ornament often confined to early part of whorl	*E. pseudoinflatum*

TAXONOMY

Order FORAMINIFERIDA
Suborder ROTALIINA
Family ELPHIDIIDAE Galloway, 1933

TYPE GENUS: **Elphidium** de Montfort, 1808

DIAGNOSIS: Test planispiral or trochospiral; sutural canal system opening into single or double row of pores; projections bridging sutures (septal bridges) may be solid or hollow and contain a retral process.

REMARKS: This family was previously distinguished from the Nonionidae by the presence of a radial wall structure (e.g. Loeblich & Tappan 1964). The discovery of elphidiids with granular wall structure has led some workers to return the family to the Nonionidae (e.g. Haynes 1973). We follow Loeblich and Tappan (1988) in distinguishing the elphidiids from the nonionids by the presence of a sutural canal system.

Subfamily ELPHIDIINAE Galloway, 1933

DIAGNOSIS: Test planispiral and bilaterally symmetrical.

SOUTH-WEST PACIFIC GENERA: *Elphidium*

Genus *Elphidium* de Montfort

Elphidium de Montfort 1808
Cribrononion Thalmann 1947
Cribroelphidium Cushman & Bronnimann 1948
Elphidiononion Hofker 1951
Ozawaia Cushman 1931

TYPE SPECIES: *Nautilus macellus* var. B Fichtel & Moll, 1798, p. 68, pl. 10, figs h,i,k.

DIAGNOSIS: Test planispiral, bilaterally symmetrical; sutural canal system opens into a single row of pores; septal bridges usually hollow and contain a retral process, but may be solid; aperture a series of large circular pores at base of apertural face.

REMARKS: The species included in *Elphidium* here have previously been placed in *Elphidiononion* Hofker (1951), *Cribrononion* Thalmann (1947), *Cribroelphidium* Cushman and Bronnimann (1948) and *Ozawaia* (Cushman 1931). Loeblich and Tappan (1964) synonymised *Elphidiononion* with *Cribroelphidium*. They distinguished the latter genus from *Elphidium* by the absence of retral processes, and from *Cribrononion* by the presence of supplementary apertures. They subsequently (1988) restricted the use of *Cribrononion* to species with a very distinctive bulla-like apertural chamberlet. The type species of *Cribroelphidium*, *C. vadescens*, is now considered to be a variety within the *Elphidium excavatum* complex which has been shown to possess retral processes (Miller *et al.* 1982). Although Loeblich and Tappan (1988) prefer to separate *Cribroelphidium* from *Elphidium*, based on the absence of a keel and the presence of a rounded perforate periphery, we follow the recommendations of others (e.g. Haynes 1973; Hansen & Lykke-Andersen 1976) and for the present include such forms within *Elphidium*.

In our earlier speculative phylogeny section, we recognise a number of branches within the genus *Elphidium*. Some of these could conceivably be given separate generic status, but we prefer to wait until a more comprehensive world-wide review has been completed before formalising such divisions.

RECENT SOUTH-WEST PACIFIC SPECIES AND SUBSPECIES:

Elphidium advenum advenum Australia, New Zealand, SW Pacific islands
Elphidium advenum botaniense Australia, SW Pacific islands
Elphidium advenum dispar SW Pacific islands
Elphidium advenum limbatum Australia, New Zealand, SW Pacific islands
Elphidium advenum macelliforme Australia
Elphidium advenum maorium Australia, New Zealand
Elphidium advenum tongaense SW Pacific islands
Elphidium albanii Australia
Elphidium argenteum Australia
Elphidium carteri Australia, SW Pacific islands
Elphidium charlottense Australia, New Zealand
Elphidium collinsi Australia
Elphidium craticulatum Australia, SW Pacific islands
Elphidium crispum crispum Australia, New Zealand, SW Pacific islands
Elphidium excavatum clavatum Australia, New Zealand, SW Pacific islands
Elphidium excavatum excavatum Australia, New Zealand, SW Pacific islands
Elphidium excavatum oirgi New Zealand
Elphidium excavatum sydneyense Australia
Elphidium excavatum williamsoni New Zealand, SW Pacific islands
Elphidium fichtellianum Australia, SW Pacific islands
Elphidium fijiense SW Pacific islands
Elphidium gunteri Australia, New Zealand
Elphidium hawkesburiense Australia
Elphidium hispidulum Australia
Elphidium lene Australia, SW Pacific islands
Elphidium macellum Australia, SW Pacific islands
Elphidium mortonbayense Australia
Elphidium novozealandicum New Zealand
Elphidium oceanicum Australia, SW Pacific islands
Elphidium phillipense Australia
Elphidium reticulosum SW Pacific islands
Elphidium sandiegoense Australia
Elphidium silvestrii Australia
Elphidium vavauense SW Pacific islands
Elphidium vellai New Zealand
Elphidium vitreum Australia

PRESENT-DAY GEOGRAPHIC RANGE: World-wide.

FOSSIL NEW ZEALAND SPECIES AND SUBSPECIES:
Elphidium aculeatum norcotti early Miocene
Elphidium aculeatum subrotatum early to middle Miocene
Elphidium advenum advenum middle Eocene to middle Miocene
Elphidium advenum limbatum late Eocene to Recent
Elphidium advenum maorium late Eocene to Recent
Elphidium advenum macelliforme early Oligocene to Pliocene
Elphidium carteri early to middle Miocene
Elphidium charlottense early Oligocene to Recent
Elphidium crispum crispum late Eocene to Recent
Elphidium crispum waiwiriense early Miocene
Elphidium excavatum clavatum early Miocene to Recent
Elphidium excavatum excavatum Pliocene to Recent
Elphidium excavatum williamsoni Pleistocene to Recent
Elphidium hampdenense middle Eocene
Elphidium ingressans late Eocene
Elphidium kanoum late Oligocene to middle Miocene
Elphidium matanginuiense early Eocene
Elphidium matauraense early Miocene
Elphidium novozealandicum late Miocene to Recent
Elphidium aff. *novozealandicum* middle Miocene to early Pliocene
Elphidium oceanicum Pleistocene
Elphidium pseudoinflatum early Oligocene to middle Miocene
Elphidium saginatum middle Eocene
Elphidium schencki middle to late Eocene
Elphidium wadeae early Oligocene to early Miocene

NEW ZEALAND STRATIGRAPHIC RANGE: early Eocene to Recent

Elphidium aculeatum (d'Orbigny)

Polystomella aculeata D'ORBIGNY, 1846, p.131, pl.6, figs.27-28.

DESCRIPTION: Test medium to large size, evenly rounded to slightly lobulate, strongly compressed; periphery acute, with a strong narrow keel bearing irregular short spines at the end of most sutures; 18–25 flat to slightly inflated chambers in final whorl; 7–10 septal bridges span each suture and extend one to thirds width of chamber; sutures slightly depressed and curved slightly backwards towards the periphery; umbilicus depressed, may bear a single raised boss, several strong tubercles or none of these; sutures and sometimes chamber walls ornamented with fine papillae; wall finely perforate. Greatest diameter 0.6–1.0 mm; width/thickness ratio 3–4.5.

REMARKS: This species exhibits considerable geographic and stratigraphic variation in ornament, which we here use to distinguish three subspecies. *Elphidium macellum aculeatum* (Silvestri) from the Recent of southern Australia is a junior homonym of *E. aculeatum* (d'Orbigny) and is renamed *E. silvestrii,* later in this publication.

TYPE LOCALITY: Europe, Austria, Vienna Basin, Miocene.

TYPE SPECIMENS SEEN: Topotypes (CC5902).

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Two subspecies are recognised from the early Miocene of New Zealand. *E. aculeatum norcotti* appears to be the ancestor of *E. aculeatum subrotatum*.

CONSTITUENT SUBSPECIES:
E. aculeatum aculeatum Europe, Miocene
E. aculeatum norcotti New Zealand, early Miocene
E. aculeatum subrotatum New Zealand, early to middle Miocene

ETYMOLOGY: From the Latin "aculeatus" meaning prickly or sharp-pointed for its peripheral spines.

Elphidium aculeatum norcotti Hayward n.ssp.

Pl. 2, Figs 1–3

DESCRIPTION: Test medium to large in size; outline smoothly rounded; profile compressed with flat to slightly convex sides; periphery acute with a strong narrow keel, bearing a short narrow spine at the peripheral end of each suture; 20–25 flat chambers in adult whorl; 7–10 narrow septal bridges span each suture and extend half to three quarters way across each chamber; septal bridges thickened on earlier parts of whorl; sutures slightly depressed and curved slightly backwards towards the periphery; umbilicus filled with numerous strong tubercles; chamber walls and sutures lined with numerous fine papillae. Greatest diameter 0.6–1.0 mm; width/thickness ratio 3.5–4.5 (in adults).

REMARKS: *E. aculeatum norcotti* appears to be the ancestor of *E. aculeatum subrotatum* from which it differs by the presence of umbilical tubercles rather than a single raised, glassy boss and by its longer septal bridges. Its ornament resembles *E. kanoum* and *E. wadeae* from which it differs by the presence of peripheral spines and a more compressed test.

The European *E. aculeatum aculeatum* lacks the umbilical tubercles and longer septal bridges of *E. aculeatum norcotti*.

TYPE LOCALITY: New Zealand, Wellington, Mangatiti Stream (U25/f6564), early Miocene (late Waitakian or Otaian).

HOLOTYPE: TF1647/1

PARATYPES: 4 paratypes (TF1647/2-3), 3 paratypes (USNM487673) from type locality.

NEW ZEALAND PALEOGRAPHIC DISTRIBUTION (Fig. 37): Only known from the type locality in New Zealand.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: This subspecies is only known from the early Miocene (late Waitakian or Otaian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. aculeatum norcotti* constitutes c. 2% of the sole benthic fauna from which it is known (U25/f6564). This is a diverse fauna with common *Haeuslerella, Vulvulina, Cyclammina, Lenticulina, Uvigerina, Gyroidina, Cibicides, Notorotalia* and c. 50% planktics - typical of outer shelf to uppermost bathyal (100–400 m) conditions. Either *E. aculeatum norcotti* lived at these depths or the specimens were transported downslope.

ETYMOLOGY: Named after the late Dr Norcott de B. Hornibrook, for his contribution to the study of New Zealand foraminifera.

Elphidium aculeatum subrotatum Hornibrook
Pl. 2, Figs 4–8

Elphidium subrotatum HORNIBROOK 1961, p.129, pl.18, figs.384,385.
Elphidium sibirica Goss. CHAPMAN 1926, p.89, pl.17, fig.14.

DESCRIPTION: Test medium to large in size; outline smoothly rounded; profile biconvex in juveniles, becoming strongly compressed with flat or weakly convex sides in adults; periphery sharply acute with a strong, narrow keel, bearing a narrow spine of variable length at the peripheral end of each chamber; 18–25 flat to slightly inflated chambers in adult whorl; no radial ribs; 7–10 narrow septal bridges span each suture and extend about halfway across each chamber; sutures depressed, lined with minute papillae and curved slightly backwards towards the periphery; umbilicus filled with a prominent, raised, glassy, circular boss, sometimes slightly irregular with one or two pits; wall finely perforate. Greatest diameter 0.6–1.0 mm; width/thickness ratio 3.5–4 (in adults).

REMARKS: *E. aculeatum subrotatum* is a distinctive taxon in the New Zealand fossil record because of its compressed test and peripheral spines. It is most similar to *E. aculeatum norcotti* from which it differs by the presence of a raised boss and shorter septal bridges.

The European *E. aculeatum aculeatum* lacks the strongly raised glassy boss of *E. aculeatum subrotatum*. It differs from related species *E. kanoum* and *E. wadeae* by the presence of peripheral spines, generally more compressed test and by its shorter septal bridges. The middle Miocene specimens recorded here differ slightly from the typical early Miocene specimens in having much shorter peripheral spines.

TYPE LOCALITY: New Zealand, Otago, Target Gully (J41/f8498), early Miocene (Altonian).

TYPE SPECIMENS SEEN: Holotype (TF1422/1), 2 paratypes (TF1422/2).

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 37): *E. aculeatum subrotatum* is only known from the South Island of New Zealand (Canterbury and southern Taranaki basins) in the early Miocene and southern North Island (Wairarapa) in the middle Miocene.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: This subspecies mostly occurs in the late early Miocene (Altonian), but persists on into the late middle Miocene (Waiauan) in the southern North Island.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. aculeatum subrotatum* is not known to dominate any fossil assemblage and constitutes 5% or less of faunas in which it occurs. The type fauna from Target Gully is very diverse with about 10 % planktics and common *Notorotalia spinosa, Bolivina, Virgulopsis, Buccella, Florilus, Nonionella* and *Cibicides*. This fauna is typical of relatively quiet, normal marine conditions in fine sediment at deep inner to mid shelf depths (c. 25–100 m). Elsewhere *E. aculeatum subrotatum* may also occur in faunas dominated by *Amphistegina, Cibicides notocenicus, Quinqueloculina* and *Notorotalia* (e.g. D42/f23) suggesting higher energy inner shelf conditions. It would appear that *E. aculeatum subrotatum* lived in a variety of normal marine environments at inner to mid shelf depths (c. 10–100 m).

ETYMOLOGY: Named for its similarity to *Elphidium rotatum* Howchin and Parr.

Elphidium advenum (Cushman)

Polystomella advena CUSHMAN, 1922, p.56, pl.9, fig.11,12.

DESCRIPTION: Test medium-sized, evenly rounded to lobulate, compressed; periphery acutely rounded, limbate, usually with a blunt keel; 10–20 chambers in final whorl, moderately inflated, sides convex; sutures depressed, moderately curved; 6–17 septal bridges, usually short (<0.5 times chamber width), evenly spaced; umbilicus depressed or flat, may bear one or more central bosses; papillae ornament sutural pores, umbilical area and parts of apertural face; aperture a row of small pores at base of apertural face; wall finely perforate, smooth, translucent to semi-transparent, optically granular. Greatest diameter 0.4–0.8 mm; width/thickness ratio 1.8–4.0.

REMARKS: This species exhibits considerable geographic and stratigraphic variation in morphology and ornament, which we use here to distinguish seven subspecies. The *Elphidium advenum* group is distinguished from *E. argenteum* and *E. carteri* by the absence of papillae completely covering the test. It differs from *E. charlottense* by its moderately inflated chambers producing convex sides to the apertural face and by its more strongly curved sutures.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION: The *E. advenum* group is widely distributed in shallow marine, tropical and temperate waters of the Pacific, Indian and western Atlantic Oceans (Cushman 1939; Hottinger *et al.* 1993; Culver & Buzas 1980-1986; Boltovskoy *et al.* 1980).

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Four taxa are recognised from the New Zealand fossil record (late

Eocene-Recent). They have the following known stratigraphic ranges:

E. advenum advenum middle Eocene to middle Miocene (Ab-Sw).
E. advenum limbatum late Eocene to Recent (Ar-Rec).
E. advenum maorium late Eocene to Recent (Ar-Rec).
E. advenum macelliforme Oligocene to early Pliocene (Lwh-Wo).

SOUTH-WEST PACIFIC CONSTITUENT SUBSPECIES:
E. advenum advenum Australia, SW Pacific islands; New Zealand fossil
E. advenum botaniense Australia, SW Pacific islands
E. advenum dispar SW Pacific islands
E. advenum limbatum Australia, New Zealand, SW Pacific islands
E. advenum macelliforme Australia; New Zealand fossil
E. advenum maorium Australia, New Zealand, SW Pacific islands
E. advenum tongaense SW Pacific islands

Elphidium advenum advenum (Cushman)
Pl. 2, Figs 9–18

Polystomella advena CUSHMAN, 1922, p.56, pl.9, fig.11,12.
Elphidium advenum (Cushman). CUSHMAN 1930, p.25, pl.10, fig.2 (fig.1?); CUSHMAN 1933, p.50, pl.12, fig.1-3; CUSHMAN 1939, p.60, pl.16, fig.31, 33-35; PARKER 1952, p.447, pl.3, fig.9; PARKER *et al.* 1953, p.7, pl.3, fig.11; TODD & BRONNIMANN 1957, p.39, pl.6, fig.5-7; COLLINS 1958, p.420; TODD & LOW 1961, p.19, pl.2, fig.8; TODD & LOW 1971, p.15, pl.3, fig.5; APTHORPE 1980, pl.26, fig.10; TODD & LOW 1981, p.35; ALBANI 1968a, p.111, pl.10, fig.6; ALBANI 1968b, p.33, fig.150; COLLINS 1974, p.41; PALMIERI 1976a, p.372; PALMIERI 1976b, p.413; YASSINI & JONES 1986, pl.7, figs.4-5; ALBANI & YASSINI 1993, p.23, figs.34,35; LOEBLICH & TAPPAN 1994, p.168, pl.379, figs.1-4; YASSINI & JONES 1995, p.176, figs.1026-9,1034-6.
Elphidium depressulum Cushman. ALBANI & YASSINI 1993, p.26, figs.59-60,63-64; LOEBLICH & TAPPAN 1994, p.169, pl.379, figs.5-11.
Elphidium omotoensis DORREEN 1948, p.290, pl.37, figs.12a,12b.

DESCRIPTION: Test of medium size, outline smoothly circular to very slightly lobulate in latter part; profile biconvex with flat or convex sides; periphery acutely rounded, with moderately strong, narrow, rounded keel; 12 to 17 slightly inflated chambers in adult whorl; radial ribs lacking; numerous (7–11), narrow, septal bridges span the sutures, and extend about one third to one half the width of the chambers; sutures depressed and slightly curved backwards towards periphery; umbilical area filled with a solid, flat, circular boss, sometimes with several pits or surrounded by a spiral suture; fine papillae line the sutures and the basal part of the apertural face of the last chamber; wall texture finely perforate. Greatest diameter 0.4–0.6 mm; width/thickness ratio 2–2.5.

REMARKS: Recent specimens from the South-west Pacific and Australia are very similar to the types from the Recent of Florida (pers. obs.; redrawn by Buzas *et al.* 1985, fig. 6.1,2), although we recognise considerable variation between populations in the character of the umbonal boss. In some populations the boss is broad and flat with pits (Pl. 2, Fig. 11), in others it has a smaller diameter and is raised with no pits and may be surrounded by a circular or spiral suture (Pl. 2, Fig. 9). *E. advenum advenum* is easily distinguished from *E. advenum dispar* and *E. advenum limbatum* by the presence of its substantial umbonal boss. It is less papillate than *E. advenum botaniense* and *E. advenum tongaense,* both of which have the umbilical area half occupied by their distinctive boss and half by papillae. *E. advenum advenum* can be distinguished from the most similar subspecies, *E. advenum maorium* by its stronger peripheral keel, shorter septal bridges, often greater number of chambers and generally larger umbonal boss.

The fossil New Zealand specimens are indistinguishable from the Recent specimens from the South-west Pacific, except that they tend to have a slightly broader keel. Study of the types and topotypes of *E. omotoense* show that it is not possible to distinguish it from *E. advenum advenum.*

TYPE LOCALITY: United States, Florida, Tortugas, 22 m depth, Recent.

TYPE SPECIMENS SEEN: Holotype (CC3282a), 2 paratypes (CC3282b).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 15): This is the most common subspecies of *E. advenum* in the South-west Pacific, north of New Zealand, occurring in samples examined from Lord Howe, Norfolk, Kermadec, Solomon and Cook Islands, New Caledonia, Vanuatu, Fiji, Tonga and Samoa. It also occurs right around the coast of Australia (Albani & Yassini 1993).

ECOLOGIC DISTRIBUTION: *E. advenum advenum* is common in a number of environments around the tropical and subtropical Pacific Islands. It occurs in both normal marine salinity and slightly brackish conditions, is common in intertidal mangrove forests and in sandy beaches, but also lives subtidally in sheltered and exposed conditions on the inner shelf. It lives with faunas dominated by varying combinations of *Elphidium, Ammonia, Quinqueloculina, Peneroplis, Textularia, Helenina, Discorbis, Tinoporus* and *Bolivina.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 34): All the known New Zealand occurrences of *E. advenum advenum* are from the South Island, except one from the earliest Oligocene of the Waikato.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: In New Zealand this subspecies is known from the middle Eocene to middle Miocene (Bortonian to Waiauan).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: Some faunas contain up to 5–10% of *E. advenum advenum* and all in which it occurs have 0–20% planktics. Late Eocene and Oligocene faunas (e.g. J32/f7848, R14/f6541, L28/f7504) are dominated by combinations of *Gaudryina, Melonis maorica, Buliminella, Cribrorotalia, Amphistegina, Asterigerina, Cibicides* and *Elphidium* spp. - assemblages typical of moderately exposed, clean sediment at inner shelf depths (c. 1–40 m, Hayward 1986). Early Miocene faunas (e.g. M34/f7038, I38/f7607, J41/f8498) are dominated by combinations of *Textularia, Quinqueloculina, Amphistegina, Buliminella, Cibicides, Cribrorotalia, Discorbis, Elphidium* spp., *Melonis, Notorotalia spinosa* and *Pileolina* - assemblages also typical of moderately exposed sand at inner shelf depths (c. 1–40 m).

Thus it would appear that *E. advenum advenum* has lived in normal marine salinity in moderately exposed, clean sediment at inner shelf depths since the middle Cenozoic.

Elphidium advenum botaniense Albani
Pl. 3, Figs 1–4

Elphidium botaniensis ALBANI 1981, p.155, figs.4J,N; ALBANI & YASSINI 1993, p.23, figs.43-46; YASSINI & JONES, 1995, p.176, figs.1030-3.

DESCRIPTION: Test of medium size, outline smoothly circular to slightly lobulate in latter part; profile biconvex with convex sides; periphery acutely rounded, with strong, broad, rounded keel; sides of final chamber convex; 10 to 13 inflated chambers in adult whorl; radial ribs lacking; numerous (7–11), narrow, septal bridges span the sutures, and reach about half the width of the chambers; sutures depressed and strongly curved backwards towards periphery; umbilical area partly filled with a solid, circular or semicircular boss and partly with numerous fine papillae; fine papillae extend as a wide band along each suture all the way to the periphery and cover the central portion of the apertural face of the last chamber; wall texture finely perforate. Greatest diameter 0.4–0.5 mm; width/thickness ratio 1.8–2.2.

REMARKS: *E. advenum botaniense* differs from *E. advenum tongaense* by its more inflated test, lack of radial ribs and lack of a tendency to become evolute; from *E. advenum dispar* (from the Pacific islands) by the presence of a boss and more inflated chambers; and from *E. advenum limbatum* by its greater test inflation, stronger keel and presence of a single boss.

E. advenum botaniense is also very similar to the Recent Japanese *E. pacificum* (Ujiie 1956) but *E. advenum botaniense* differs in its greater inflation and smaller, less pronounced umbonal boss.

TYPE LOCALITY: Australia, New South Wales, Botany Bay borehole 420, 54 m depth, Pleistocene.

TYPES: Holotype (Australian Museum, Sydney, AM Z871).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 15): This species is common around the coast of Queensland and New South Wales, and has also been recorded from Tasmania (Albani & Yassini 1993). In this study we also record it from Samoa and the Solomon Islands.

ECOLOGIC DISTRIBUTION: *E. advenum botaniense* is common off the east coast of Australia and around several island groups, in normal marine salinity and slightly brackish environments at depths down to about 50 m. The associated faunas are dominated by combinations of *Reophax, Textularia, Spiroloculina, Quinqueloculina, Triloculina, Peneroplis, Operculina, Discorbis, Discorbis, Ammonia* and *Elphidium*. It also occurs sporadically at greater depths, possibly transported downslope after death.

ETYMOLOGY: From the type locality in Botany Bay.

Elphidium advenum dispar Cushman
Pl. 3, Figs 5–8

Elphidium advenum var. *dispar* Cushman in CUSHMAN, TODD & POST 1954, p.346, pl.86, fig.31.

DESCRIPTION: Test of medium size, outline smoothly circular; profile biconvex with flat or convex sides; periphery acutely rounded, with moderately strong, bluntly rounded keel; 13 to 16 chambers in adult whorl; broad, somewhat flattened, radial ribs present on the leading edge of each except the last chamber; 8–12, narrow, septal bridges span the sutures, and reach three quarters or full width of the chambers, linking together the radial ribs into reticulate ornament; sutures depressed, slightly curved backwards towards periphery and lined with fine papillae; umbilical area depressed, containing numerous fine papillae and sometimes a larger tubercle or two; fine papillae are also present over much of the apertural face of the last chamber; wall texture finely perforate. Greatest diameter 0.4–0.6 mm; width/thickness ratio 1.8–2.2.

REMARKS: *E. advenum dispar* differs from *E. advenum advenum, E. advenum botaniense, E. advenum maorium* and *E. tongaense* by the lack of an umbonal boss. It differs from *E. advenum limbatum* by its greater number of chambers, longer retral processes and more inflated test. It differs from the southern ocean *E. mawsoni* by its smaller test and far fewer septal bridges.

TYPE LOCALITY: Marshall Islands, Rongerik Lagoon, 30 m depth, Recent.

TYPE SPECIMENS SEEN: Holotype (USNM548508) and 26 paratypes (USNM369611-2).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 15): Described as common in the Marshall Islands (Cushman *et al.* 1954), this subspecies is additionally recorded here from Fiji and the Solomon Islands.

Ecologic Distribution: In the South-west Pacific, *E. advenum dispar* occurs in low numbers in slightly brackish to normal salinity shallow subtidal and intertidal habitats in faunas dominated by *Elphidium* and *Quinqueloculina* species with subdominant combinations of *Textularia, Miliammina, Triloculina, Discorbis, Trochammina* and *Ammonia*.

Etymology: Presumably from the Latin "dispar" meaning different, presumably relating to the fact that this variety was different from anything previously described.

Elphidium advenum limbatum (Chapman)
Pl. 3, Figs 9–17; Pl. 4, Figs 1–10

Polystomella macellum var. *limbatum* CHAPMAN 1907, p.142, pl.10, figs.9a-b.
Elphidium macellum var. *limbatum* (Chapman). CUSHMAN 1939, p.52, pl.14, fig.5.
Elphidium limbatum (Chapman). COLLINS 1958, p.421; COLLINS 1974, p.41.
Polystomella striatopunctata (Fichtel & Moll). HERON-ALLEN & EARLAND 1922, p.229.
Cribroelphidium argenteum (Parr). HEDLEY *et al.* 1967, p.48, pl.12, fig.2a,b; COLLEN 1983, p.15,19,24,28,32.
Cribrononion argenteum (Parr). LEWIS 1979, p.35.
Cribrononion sp. SCOTT 1970, fig.6.5.
Elphidium argenteum Parr. HAYWARD 1979, p.184; HAYWARD 1981, p.132; HAYWARD & GRACE 1981, p.52; BROOK *et al.* 1981, p.90.
Elphidium advenum (Cushman). HAYWARD 1990b, p.96; HAYWARD & BROOK 1994, fig.3.14; HAYWARD & HOLLIS 1994, pl.4, fig.13-15; HAYWARD & TRIGGS 1994, pl.2, fig.11; HAYWARD *et al.* 1996, pl.2, figs.6-7.
? *Elphidium* aff. *advenum* (Cushman). KUSTANOWICH 1965, p.53, 61.
Elphidium cf. *advenum* (Cushman). HORNIBROOK 1961, p.129.
Elphidium advenum (Cushman) var. *depressulum* CUSHMAN 1933, p.51, fig.4a,b; CUSHMAN 1939, p.61, pl.17, fig.1.
Elphidium depressulum Cushman. ALBANI 1968b, p.33, fig.152.
Elphidium advenum (Cushman) *depressulum* Cushman. HAYWARD *et al.* 1994, fig.30.
Elphidium earlandi avalonense COLLINS 1974, p.43, pl.3, figs.32a-b.

Description: Test of medium size, outline smoothly circular to slightly lobulate in latter part; lenticular in profile view with flat sides; periphery acutely rounded, with moderately strong, rounded keel; 11 to 14 (occasionally up to 16) slightly inflated chambers in adult whorl; radial ribs lacking; 6–9, narrow, septal bridges span the sutures, and reach one quarter to one half the width of the chambers; sutures depressed, slightly curved backwards towards periphery and lined with fine papillae; umbilical area depressed, containing numerous smaller fine papillae and often several larger tubercles; fine papillae are also present on the lower part of the apertural face of the last chamber; wall texture finely perforate. Greatest diameter 0.4–0.65 mm; width/thickness ratio 2.5–3.2.

Remarks: Examination of a large suite of specimens and populations from New Zealand, eastern Australia and the South-west Pacific islands, together with types of *E. macellum limbatum*, *E. advenum depressulum* and *E. earlandi avalonense* lead us to conclude that they are all one slightly variable taxon, that is closely related to *E. advenum*.

E. advenum limbatum differs from *E. advenum advenum, E. advenum botaniense, E. advenum maorium* and *E. advenum tongaense* by the lack of an umbonal boss. It differs from *E. advenum dispar* by its fewer chambers, shorter retral processes and more compressed test. It differs from the southern ocean *E. mawsoni* by its fewer chambers, smaller test and far fewer septal bridges.

Hedley *et al.* (1967) referred this form in New Zealand to *Cribroelphidium argenteum* (Parr) based on similarities in internal structure, i.e. apparently although not explicitly, the absence of retral processes in "certain New Zealand intertidal specimens" (p.48). As discussed above, this feature is no longer a valid distinction between *Cribroelphidium* and *Elphidium*. Moreover, there is no reason to doubt that the retral processes are as variably developed within the *E. advenum* complex as they are within *E. excavatum*.

Specimens with more than 13 chambers in the final whorl were only encountered in Otago Harbour and the Auckland Islands (both southern New Zealand). These are usually also larger than typical forms, with which they co-occur, and have a more acute periphery. They bear some resemblance to *E. argenteum* but are smaller on average (rarely >0.5 mm) and lack the distinctive finely beaded surface of Parr's species.

Oligocene and early Miocene fossil New Zealand specimens tend to have a stronger keel than most Recent specimens.

Type Locality: Australia, Victoria, Beaumaris, shore sand, Recent.

Type Specimens Seen: Nine paratypes (CC14249).

Present-day Geographic Distribution (Figs 15, 22): Common throughout New Zealand including Stewart, Chatham and Auckland Is. (Brook *et al.* 1981; Hayward 1979, 1981, 1990b; Hayward & Grace 1981; Hayward & Hollis 1994; Hedley *et al.* 1967; Hulme 1964; Lewis 1979). This subspecies occurs around the coast of south-eastern Australia in New South Wales, Victoria and Tasmania (Albani 1968a, this study) and is widespread in the South-west Pacific islands, having been recorded here from Fiji, Tonga, Vanuatu and the Cook, Kermadec, Lord Howe, Norfolk and Solomon Islands.

Ecologic Distribution: In present-day New Zealand, *E. advenum limbatum* is most abundant in very slightly brackish low tidal or shallow subtidal parts of enclosed harbours and inlets with associations dominated by

Haynesina depressula, Ammonia beccarii, E. charlottense and *E. excavatum* (e.g. Hayward *et al.* 1996). It also occurs in lower numbers in normal marine conditions in somewhat sheltered inner shelf depths. It is usually rare in more exposed deeper water locations, although it is reportedly common on the outer shelf off southern Hawkes Bay (Lewis 1979).

Along the east coast of the southern states of Australia, *E. advenum limbatum* has a similar distribution to New Zealand, being most common in very slightly brackish low tidal or shallow subtidal parts of enclosed harbours and bays with associations dominated by *Elphidium, Haynesina, Ammonia, Quinqueloculina, Spiroloculina, Ammotium* and *Cibicides.*

Around many of the Tropical islands of the South-west Pacific, *E. advenum limbatum* is moderately common in normal marine salinity at intertidal and shallow subtidal depths, becoming less abundant below about 20 m. Here the associated faunas are dominated by combinations of *Textularia, Quinqueloculina, Spiroloculina, Triloculina, Peneroplis, Amphistegina, Elphidium, Bolivina, Reusella, Discorbis* and *Rosalina.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 34): All late Eocene records from New Zealand of *E. advenum limbatum* are from the South Island. It occurs throughout the country in the Oligocene and Miocene, but the few Pliocene and Pleistocene records are all from the North Island, possibly because of the sparse Plio-Pleistocene record in the south.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: This subspecies is known from the late Eocene to Recent (Runangan-Recent) in New Zealand. Most fossil records are from the Oligocene and early Miocene with only scattered occurrences in the middle Miocene, Pliocene and Pleistocene.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: In fossil assemblages *E. advenum limbatum* mostly occurs in relative abundances ranging up to c.8% of some faunas. In late Eocene and Oligocene faunas (e.g. J32/f7848, R15/f112, L28/f7504, F45/f8495) planktics comprise 1-10 % and the benthic assemblages are dominated by combinations of *Gaudryina, Amphistegina, Buliminella, Cibicides, Cribrorotalia, Elphidium crispum crispum, Globocassidulina, Gyroidina, Melonis* and *Notorotalia* which are typical of inner shelf, moderately exposed environments. In early Miocene faunas (e.g. M34/f71, 138/f7608, J41/f8498, F46/f8490) planktics comprise 0-30% and the benthic assemblages are dominated by combinations of *Gaudryina, Haeuslerella, Bolivina, Cibicides, Cribrorotalia, Elphidium crispum crispum, Lenticulina, Nonionella* and *Sherbornina,* which indicate a range of environments from shallow, moderately exposed inner shelf to muddy, sheltered mid shelf.

One Oligocene fauna (S14/f23 core 14.4 m) is unusual. It has no planktics and a very low diversity with two codominant species, *Elphidium advenum limbatum* and *Haplophragmoides* sp., constituting 95% of the assemblage. This assemblage is remarkably similar to some found today in slightly brackish intertidal flats in sheltered inlets and the outer parts of estuaries, and this is the inferred paleoenvironment.

It appears that *E. advenum limbatum* probably had a very similar ecologic distribution around New Zealand during the middle Cenozoic as it has today. Its greatest abundances (up to 50% of a fauna) were in slightly brackish tidal flats, possibly filling the niche later occupied by *E. excavatum* s.l.. *E. advenum limbatum* was more widespread in lower abundances in normal marine inner shelf depths becoming less abundant further out on the shelf.

ETYMOLOGY: Presumably named for its inflated or limbate chambers.

Elphidium advenum macelliforme McCulloch, 1981
Pl. 5, Figs 6–12

Elphidium macelliforme McCULLOCH 1981, p.119, pl.40, fig.1; ALBANI & YASSINI 1993, p.28, figs.65,66.

DESCRIPTION: Test of medium to large size, outline smoothly circular; profile biconvex with flat, parallel sides centrally; sides of apertural face convex; periphery acutely rounded, with a moderately strong, rounded keel; 18 to 20 very slightly inflated, almost flat chambers in adult whorl; radial ribs lacking; 9–13, narrow, evenly-spaced, septal bridges span the sutures; sutures slightly depressed and slightly curved backwards towards periphery; umbilical area relatively flat with a small, solid, subcircular boss, surrounded by an irregular spiral suture; fine papillae line the sutures and the basal part of the apertural face of the last chamber; wall texture finely perforate. Greatest diameter 0.5–0.8 mm; width/thickness ratio 2.0–2.8.

REMARKS: *E. advenum macelliforme* is distinguished from all other subspecies of *E. advenum* by its greater number of chambers per whorl, less inflated chambers and narrower, less incised sutures. The presence of an umbonal boss also helps distinguish it from *E. advenum limbatum* of similar age.

E. advenum macelliforme is similar in gross form to the Australian Pliocene, *E. pseudonodosum,* but *E. advenum macelliforme* differs in its narrower more distinct keel, its less inflated chambers and smaller overall test size.

TYPE LOCALITY: Mexico, Tortugas Island, 80 m, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 15): *E. advenum macelliforme* occurs in the east Pacific (McCulloch, 1981) and right around Australia (Albani & Yassini 1993). In the study area it is only known from Victoria.

New Zealand Paleogeographic Distribution (Fig. 34): *E. advenum macelliforme* is currently only known from New Zealand. Its Oligocene records are from the South Island and its younger records are all from the eastern North Island.

New Zealand Stratigraphic Distribution: This subspecies is only known from five widely spaced fossil localities in New Zealand: two from the Oligocene (Whaingaroan-Duntroonian) and the other three from the late Miocene and early Pliocene (late Tongaporutuan-Opoitian).

New Zealand Paleoecologic Distribution: The faunas in which this subspecies occurs have c. 10–30% planktics. They have typical inner shelf (c. 5–50 m) benthic assemblages dominated by combinations of *Textularia, Cibicides, Elphidium crispum crispum* (Tt), *Cribrorotalia* (Ld), *Notorotalia* (Tt) and *Amphistegina* (Ld).

Etymology: For its superficially similar morphology to the genotype, *E. macellum.*

Elphidium advenum maorium Hayward n.ssp.
Pl. 1, Fig. 7; Pl. 4, Figs 11–16; Pl. 5, Figs 1–5

Elphidium advenum (Cushman). FINLAY in MARPLES 1952, p.61,62; COLLINS 1974, p.41; HAYWARD & BUZAS 1979, p.52, pl.12, fig.157.

Elphidium advenum var. *depressulum* Cushman. HAYWARD 1990b, p.96; HAYWARD *et al.* 1984, p.162.

Elphidium sp. cf. *simplex* Cushman. PARR, 1945, p.216, pl.11, fig.8.

Elphidium charlottense (Vella). KENNETT 1966a, p.61, pl.8, figs.123,124; KENNETT 1966b, p.206-207.

Description: Test of small to medium size, outline smoothly circular to very slightly lobulate in latter part; profile biconvex with flat, parallel sides centrally; periphery acutely rounded, with a very weak, rounded keel or no keel but a smooth, thickened area along the periphery; 10 to 13 slightly inflated chambers in adult whorl; radial ribs lacking; 6–10, narrow, short, septal bridges span the sutures; sutures depressed and slightly curved backwards towards periphery; umbilical area with a small, solid, circular or irregular boss, sometimes with one or several pits; fine papillae line the sutures and the basal part of the apertural face of the last chamber; wall texture finely perforate. Greatest diameter 0.35–0.5 mm; width/thickness ratio 2.3–3.0.

Remarks: *E. advenum maorium* is distinguished from the most similar subspecies *E. advenum advenum* by its much weaker keel, often lacking, its shorter retral processes, weaker boss and often fewer chambers. It differs from *E. advenum limbatum,* with which it co-occurs in New Zealand, by its weak or absent keel, and by the presence of an umbonal boss. *E. advenum maorium* is distinguished from *E. charlottense* by more strongly curved sutures, a weaker keel, distinctly convex sides to the apertural face and a smaller umbonal boss.

We tentatively include within this subspecies, a very compressed variant with weak or no keel (Pl. 4, Figs 15–16) which has been encountered in a few localities around New Zealand (e.g. Waitemata Harbour; Stewart Island (F201109): width/thickness ratio 3.1–3.6).

Type Locality: New Zealand, Auckland, Waitemata Harbour, Parnell Reef, low tide (F201347), Recent.

Holotype: TF1648/1

Paratypes: Six paratypes (TF1648/2-3, F201347); 5 paratypes (USNM487674, F201347).

Present-day Geographic Distribution (Figs 15, 22): *E. advenum maorium* occurs throughout New Zealand, including the Chatham Islands, although it is rarely common. In this study we have also recorded it from the east coast of Australia and the southern group of tropical South-west Pacific islands of Lord Howe, Norfolk and Kermadecs.

Ecologic Distribution: In New Zealand, *E. advenum maorium* is generally rare in sheltered nearshore, normal marine salinity locations, but is sometimes common in slightly brackish parts of enclosed harbours and inlets in associations dominated by *Haynesina depressula, Ammonia beccarii, E. charlottense* and *Quinqueloculina seminula* (Waitemata and Raglan Harbours, Tasman Bay, Dusky Sound, Paterson Inlet and Islet Cove, Port Pegasus).

E. advenum maorium is moderately rare around the southern tropical islands of the South-west Pacific and south-east Australia, where it occurs in normal marine salinity at intertidal and shallow subtidal depths.

New Zealand Paleogeographic Distribution (Fig. 34): Late Eocene and Oligocene records of *E. advenum maorium* in New Zealand are all from the South Island. Its Miocene and Pliocene records are from both islands and the rare Pleistocene records are from the North Island only.

New Zealand Stratigraphic Distribution: This subspecies is known from scattered fossil records from around New Zealand from the late Eocene to Recent (Runangan onwards). It is more common in the early Miocene, Pliocene and Pleistocene.

New Zealand Paleoecologic Distribution: *E. advenum maorium* is not common in the New Zealand fossil record and has not been recorded in relative abundances greater than 5% of the total fauna. It mostly occurs in faunas (e.g. V22/f7470, K29/f8514, M34/f7038, J41/f8498) containing 5–30% planktics, and dominated by combinations of the benthics *Haeuslerella, Astrononion, Bolivina, Cibicides, Discorbis, Florilus, Nonionella, Notorotalia* and

Uvigerina that are typical of deep inner, mid and outer shelf depths (30–200 m) in normal marine salinity (Hayward 1986). Some of these may have been transported into deeper water after death. Even so, fossil *E. advenum maorium* appear to have lived in deeper environments than their modern counterparts.

ETYMOLOGY: From the native people of New Zealand, the Maori.

Elphidium advenum tongaense (Cushman)
Pl. 5, Figs 13–18

Ozawaia tongaensis CUSHMAN 1931, p.80, pl.10, figs.7-10; CUSHMAN 1933, p.53, pl.12, figs.10-12; CUSHMAN 1939, p.67, pl.19, figs.5-8; LOEBLICH & TAPPAN 1964, p.C640, fig.510,3,4; LOEBLICH & TAPPAN 1988, p.675, pl.791, figs.1-4.
Elphidium subevolutum CUSHMAN 1933, p.52, pl.12, figs.6a,b; CUSHMAN 1939, p.63, pl.18, fig.5.
Elphidium macellum var. *limbatum* (Chapman). CUSHMAN 1933, p.50, pl.11, figs.9a,b.
Elphidium jenseni (Cushman). LOEBLICH & TAPPAN 1994, p.169 (part), pl.381, figs.4-5.

DESCRIPTION: Test of medium to large size, outline smoothly circular to slightly lobulate; profile compressed with flat to slightly concave sides; periphery acutely rounded, with strong, slightly rounded keel; sides of final chamber convex; 12 to 14 chambers in adult whorl; broadly rounded radial rib developed on the umbilical half of all except the last one or two chambers; numerous (7–17), narrow, septal bridges span the sutures, but seldom extend far over the preceding chamber; sutures depressed and strongly curved backwards towards periphery and towards the umbilical area; subevolute coiling results in a wide umbilical area, partly filled with a solid, semicircular boss and partly with numerous fine papillae; fine papillae also extend as a wide band along each suture all the way to the periphery and also cover the central portion of the apertural face of the last chamber; in adult specimens, the last few chambers may become evolute or uncoiled. Greatest diameter 0.6–0.7 mm; width/thickness ratio 3–4.

REMARKS: The type population of *Ozawaia tongaense* consists of the holotype and 38 paratypes. This population contains two deformed specimens (the holotype and one paratype) having three and one additional chambers respectively (with circular cross-sections) added in a linear series. Cushman (1931) erected his new genus *Ozawaia*, based on these two specimens which we interpret to be aberrant forms. The remainder of the type population is identical to the planispiral portion of the two aberrant specimens, and appear to be conspecific with the types of *Elphidium subevolutum* (CC15672, CC19899, CC19900). There can be little justification to retaining the genus Ozawaia, based as it is on two unusual deformed specimens. The taxon clearly belongs in the *Elphidium advenum* group and is very similar to *E. advenum botaniense*, from which it is distinguished by its more compressed form, bluntly shaped final chamber and strong radial ribs. The semi-circular boss and short radial ribs distinguish *E. advenum tongaense* from all the other *E. advenum* subspecies.

TYPE LOCALITY: Tonga, Vava'u Anchorage, Recent.

TYPE SPECIMENS SEEN: Holotype (CC15676), 38 paratypes (CC15677, CC15678, CC19903, CC19904, CC37302).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 16): *Elphidium advenum tongaense* appears to be endemic to the tropical South-west Pacific. In this study we have recorded it from the Cook Islands, Fiji, Samoa, Tonga and Vanuatu.

ECOLOGIC DISTRIBUTION: *E. advenum tongaense* is a common species in normal marine salinity at inner shelf depths (0–30 m) around tropical islands in diverse faunas dominated by combinations of *Textularia, Reophax, Quinqueloculina, Spiroloculina, Triloculina, Sorites, Tinoporus* and *Elphidium.*

ETYMOLOGY: From the type locality in Tonga.

Elphidium albanii Hayward n.sp.
Pl. 6, Figs 1–5

Cribrononion oceanicus (Cushman); ALBANI 1978, p.387, fig. 9B; YASSINI & JONES 1995, p.179, fig.1050.

DESCRIPTION: Test of small to medium size; outline circular to slightly lobulate; profile moderately compressed with parallel or slightly convex sides; acutely rounded periphery with no keel nor thickened band; 9–12 non-inflated chambers per adult whorl; radial ribs lacking; 9–15 short, broad, septal bridges span each suture, separated by extremely small sutural pits; sutural pits often closed over towards the umbilicus; sutures narrow and slightly depressed, straight to slightly curved backwards towards the periphery, marked by a band of opaque imperforate shell; umbilical area flat to slightly depressed, filled with opaque shell wall; chamber walls very finely perforate. Maximum diameter 0.35–0.5 mm; width/thickness ratio 2.2–3.0.

REMARKS: *E. albanii* is characterised by its smooth shell, flat infilled umbilicus, numerous small sutural pits and opaque sutural bands. It is very similar to *E. cristobalense* McCulloch from Panama, which has a more broadly rounded periphery and more translucent test and to *E. galeroense* McCulloch from Colombia, which has a distinct glassy umbo and is more transparent and more coarsely perforate than *E. albanii.*

HOLOTYPE: TF1649/1

PARATYPES: Five paratypes (TF1649/2-3), 4 paratypes (USNM487982), 4 paratypes (AK74083), all from type locality.

Type Locality: Australia, Queensland, Great Barrier Reef, Claremont Lightship (F201595), Recent.

Present-day Geographic Distribution (Fig. 16): *E. albanii* is recorded here from the coast of the east Australian states of Queensland and New South Wales and from nearby Lord Howe Island.

Ecologic Distribution: *E. albanii* lives in shallow inner shelf depths in normal marine salinity in faunas dominated by combinations of *Textularia, Reophax, Spiroloculina, Quinqueloculina, Triloculina, Elphidium, Peneroplis, Operculina, Ammonia* and *Bolivina.*

Etymology: Named after prominent Australian micropaleontologist, Dr A. Albani, who has studied the Recent Elphidiidae of Australia.

Elphidium argenteum Parr
Pl. 6, Figs 6–7

Elphidium argenteus PARR 1945, p.216, pl.12, fig.7; COLLINS 1974, p.41; YASSINI & JONES 1986, pl.7, figs. 12-14; YASSINI & JONES 1988, p.263, fig.16, nos.12-14.
Cribrononion argenteum (Parr). ALBANI 1978, p.385, fig.9F; ALBANI & YASSINI 1993, p.18, figs.18,21; YASSINI & JONES 1995, p.178, figs.1038-9.
Polystomella striatopunctata (Fichtel & Moll). CHAPMAN 1907, p.141.

Description: Test of medium size; outline circular to slightly lobulate; profile moderately compressed with parallel or slightly concave sides; acutely rounded periphery with a weak keel; 12–17 slightly inflated chambers per adult whorl; radial ribs lacking or very weakly developed over central part of test; 8–15 narrow septal bridges span each suture, with each bridge about 1/3 to 3/4 chamber width; sutures depressed and slightly curved backwards towards the periphery; umbilical area small, depressed, containing several small tubercles; most of chamber walls, sutures and apertural face are covered with numerous fine papillae; optically granular wall texture. Maximum diameter 0.6 mm; width/thickness ratio 2.8–3.5.

Remarks: This species has the typical shape of *E. advenum* group, but has a distinctive covering of fine papillae over most of the test. The papillae give the appearance of a coarse wall texture under a light microscope making specimens resemble the optically radial, North American species *E. margaritaceum* (Buzas *et al.* 1985). *E. argenteum* is larger, has more septal bridges, weaker radial ribs, weaker peripheral keel and finer papillae than the superficially similar species, *E. carteri.*

Type Locality: Australia, Victoria, Barwon Heads, shore sand, Recent.

Type Specimens Seen: Holotype (Vict. Mus. F41264).

Present-day Geographic Distribution (Fig. 16): *E. argenteum* is only known from around the coast of Australia off Queensland, New South Wales, Victoria and West Australia (Albani & Yassini 1993).

Ecologic Distribution: *E. argenteum* appears to live in its greatest abundance in intertidal beach and shallow subtidal sand in normal marine salinity, in faunas dominated by combinations of *Quinqueloculina, Elphidium, Ammonia, Bolivina* and *Triloculina.*

Etymology: From the Latin "argenteum" meaning silvery, possibly for a superficial silvery appearance created by its papillate wall texture.

Elphidium carteri Hayward n.sp.
Pl. 1, Fig. 15; Pl. 6, Figs 8–12

Elphidium macellum (Fichtel & Moll). MATHER & BENNETT 1993, p. 18, fig. 9.19.

Description: Test of small to medium size, outline smoothly circular to slightly lobulate in latter part; profile strongly compressed with flat to slightly concave sides; periphery acutely rounded, with strong, slightly rounded keel; 12 to 14 chambers in adult whorl; strong, rounded, radial rib developed on the umbilical half of all except the last one or two chambers; a few (about 5), narrow, septal bridges span the sutures, and extend about one third of the chamber width; sutures depressed and curved backwards towards periphery; wide umbilical area, partly filled with numerous coarse papillae and usually partly filled with a solid, semicircular boss; coarse papillae also extend over almost all the chamber walls and sutures, with finer papillae covering most of the apertural face of the last chamber. Greatest diameter 0.35–0.5 mm; width/thickness ratio 3–4.

Remarks: *E. carteri* differs from the Recent *E. pustulosum* Cushman & McCulloch (1940) from the Galapagos Islands by its smaller size and presence of a semicircular umbonal boss. It differs from *E. advenum* group by the coarse papillae covering almost all the test. It is more compressed than *E. advenum botaniense* and has fewer septal bridges than *E. advenum tongaense.* It differs from the coarsely pustular *E. argenteum* by its fewer chambers, fewer septal bridges and by the presence of a distinct umbonal boss. The presence of an umbonal boss and coarsely pustular surface texture also distinguish *E. carteri* from *E. macellum.* The fossil specimens from New Zealand are remarkably similar to the Recent specimens from Queensland; the fossil specimens may have slightly weaker radial ribs and sometimes lack a semicircular boss in part of the umbilicus.

Type Locality: Australia, Queensland, Great Barrier reef, Claremont lightship (F201595).

Holotype: TF1650/1

PARATYPE: 2 paratypes (TF1650/2-3), 1 paratype (USNM487676) from type locality.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 16): This species is known in the Recent from the New South Wales and Queensland on the east coast of Australia, from Malaita in the Solomon Islands and fossil from the Miocene of New Zealand.

ECOLOGIC DISTRIBUTION: This rather rare species appears to live in normal marine salinity on the inner shelf (0–30 m) in diverse faunas dominated by combinations of *Textularia, Spiroloculina, Quinqueloculina, Triloculina* and *Elphidium*.

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 34): The Miocene records of *E. carteri* in New Zealand are from both the south of the South Island and south of the North Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Fossil *E. carteri* is only known from five localities spread throughout the Miocene (Waitakian-Waiauan) in New Zealand.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: The fossil faunas in which *E. carteri* is known, have low diversity, no planktics and are dominated by *Cribrorotalia, Elphidium crispum crispum, Sherbornina, Notorotalia* and *Cibicides*, associations typical of clean, moderately exposed sediments at shallow inner shelf depths (c. 0–30 m).

ETYMOLOGY: Named after the late Alan Carter, a prominent Australian foraminiferal micropaleontologist during the 1960s–1980s.

Elphidium charlottense (Vella)

Pl. 6, Figs 13–16; Pl. 7, Figs 1–2

Elphidiononion charlottensis VELLA 1957, p.38, pl.9, fig.187-188; KUSTANOWICH 1965, P.53.

Polystomella subnodosa (Munster). BRADY 1884, p.734, pl.110, fig.1; MESTAYER 1916, p.130; HERON-ALLEN & EARLAND 1922, p.229.

Polystomella crispa (Linné). HAEUSLER 1887, p.200; HERON-ALLEN & EARLAND 1922, p.229; CUSHMAN 1919, p.632.

Elphidium advenum (Cushman). HORNIBROOK in KNOX 1951, p.43; HORNIBROOK in FLEMING 1952, p.82.

Cribroelphidium charlottensis (Vella). HEDLEY *et al.* 1967, p.50, pl.12, fig.3a,b; COLLEN 1983, p.15,18,24,28,32.

Elphidium charlottensis (Vella). VELLA 1962, p.192; VELLA, 1963, p.790; GIBSON 1967, p.54; TOPPING 1973, p.31, pl.9, fig.4,5; THOMPSON 1975, p.88; HOSKINS, 1978, p.274, pl.5, figs.1-2; ADAMS 1979, p.144; HAYWARD 1979, p.184, fig.3h; BROOK *et al.* 1981, p.90; HAYWARD 1981, p.132, fig.3b; HAYWARD 1982a, fig.5a; HAYWARD 1982b, p.64, fig.3d; HAYWARD 1990b, p.96, fig.3b; HAYWARD & GRACE 1981, p.52; HAYWARD *et al.* 1984, p.162, fig.7b; HAYWARD 1993, figs.3o-p; HAYWARD & TRIGGS 1994, pl.2, fig.12; HAYWARD & GRENFELL 1994, fig.20; HAYWARD *et al.* 1996, pl.2, figs.10-11; COLLEN 1995, pl.10, figs.5-6.

Cribrononion charlottensis (Vella). LEWIS 1979, p.35.

? *Elphidium advenum* (Cushman). CUSHMAN 1939, p.60, pl.16, fig.32.

DESCRIPTION: Test medium-sized, slightly lobulate outline; slightly compressed, biconvex profile; periphery acute with a strong, rounded keel; 12–15 non-inflated to slightly inflated chambers in final whorl, sides flattened to slightly concave; sutures flush to slightly depressed, slightly curved, ornamented with fine papillae; 8–10 short septal bridges, evenly spaced; umbilical area covered by a flattened boss not protruding beyond the outline of the test; wall finely perforate, translucent to opaque white. Greatest diameter 0.2–0.55 mm; width/thickness ratio 2.2–2.8.

REMARKS: This species is distinguished from *E. advenum* by its less inflated chambers, its flattened to slightly concave sides and slightly curved sutures. It consistently has fewer chambers per whorl than *E. crispum crispum*, and is less tightly involute with a stronger keel than *E. mataurаense*.

TYPE LOCALITY: New Zealand, Marlborough, Queen Charlotte Sound, 8 m (F201283), Recent.

TYPE SPECIMENS SEEN: Holotype (TF1306/1); 3 paratypes (TF1306/2, USNM689251, VFp77).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 16, 22): *E. charlottense* is almost exclusively found in New Zealand, occurring throughout the country, including Stewart Island. It appears to be more rare in southernmost New Zealand and Stewart I. than further north. It is not known from Campbell or Snares islands. This species is also recorded here from Lord Howe Island.

ECOLOGIC DISTRIBUTION: A ubiquitous species in all settings from marginal marine to outer shelf, rare at depths > 200 m (Lewis 1979). It is abundant in sandy, sheltered nearshore locations (0–20 m) of normal marine salinity, with its greatest abundance (up to 70 % of the benthic fauna) on sheltered intertidal and subtidal (to 3 m depth) sand beaches (Hayward 1982a). It probably does not live in depths greater than 100 m.

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 35): The earlier records (Oligocene and early Miocene) of *E. charlottense* in New Zealand are all from the South Island. Thereafter it becomes more widespread in both islands, although all its Pleistocene records are from the North Island, reflecting the poor Pleistocene record in the South island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Oligocene to Recent (Whaingaroan onwards). This species is common in the New Zealand fossil record from late Miocene (Tongaporutuan) onwards. There are currently no known mid Miocene records and only five from the early Miocene and Oligocene, all from the south of the South Island.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. charlottense* occurs in relative abundances of up to 5% in a number of fossil faunas (e.g. W15/f9540, Z16/f12, V20/f8580, T25/f126), having 0-20% planktics and the benthic assemblages dominated by varying combinations of *Ammonia, Bolivina, Bolivinita, Cibicides, Elphidium, Lenticulina, Nonionella, Notorotalia* and *Uvigerina*. These faunas are typical of sheltered, normal marine salinity at inner, mid and perhaps outer shelf depths (c. 5–200 m, Hayward 1986). Thus it appears that in the past *E. charlottense* lived in a wide range of normal marine salinity environments similar to that of today, although it may not have become a dominant member of intertidal and subtidal beach assemblages until relatively recently (Quaternary) with the decline in *E. crispum crispum* in New Zealand.

ETYMOLOGY: From the type locality, Queen Charlotte Sound.

Elphidium collinsi Hayward n.sp.
Pl. 1, Fig. 16; Pl. 7, Figs 3–4

DESCRIPTION: Test of medium to large size; outline smoothly circular to very slightly lobulate in later part of whorl; profile biconvex with flat, parallel sides; periphery acutely rounded with a narrow, weak keel; 16–20 flat to slightly inflated chambers in adult whorl; ornament of coarse granular papillae over entire chamber and in sutures; sutures depressed, straight to slightly curved back towards the periphery; 6–8 short, septal bridges span each suture; umbilical area flat or slightly depressed and occupied by a number of strong, irregular, glassy tubercles that almost unite into a single flat boss; apertural face ornamented with numerous fine riblets interspersed with fine papillae radiating outwards from apertural suture; chamber walls perforate. Greatest diameter 0.5–0.7 mm; width/thickness ratio 2.3–2.6.

REMARKS: *E. collinsi* lacks the hispid ornament and strong umbonal boss of *E. hispidulum;* it lacks the radial ribs of *E. reticulosum. E. collinsi* is characterised by its extensive granular papilla over all the test, its short radial riblets over part of the apertural face, its flat umbilical area and narrow, weak keel.

TYPE LOCALITY: Australia, New South Wales, Watsons Bay, Recent (F201331).

HOLOTYPE: TF1651/1

PARATYPES: 2 paratypes (TF1651/2), 2 paratypes (USNM487678) from type locality.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 16): This species is only recorded from the type locality in New South Wales, eastern Australia.

ECOLOGIC DISTRIBUTION: *E. collinsi* is only known from a sheltered, shallow water, normal marine salinity environment in a diverse fauna dominated by *Reophax, Textularia, Spiroloculina, Quinqueloculina, Buliminella, Nonionella, Ammonia* and *Elphidium.*

ETYMOLOGY: Named after the late Arthur Collins, prominent amateur Australian foraminiferal micropaleontologist, who described a number of Recent foraminiferal species from the east coast of Australia.

Elphidium craticulatum (Fichtel & Moll)
Pl. 7, Figs 5–12

Nautilus craticulatus FICHTEL & MOLL 1798, p.51, pl.5, figs.h,i,k.

Polystomella craticulata (Fichtel & Moll). BRADY 1884, p.739, pl.110, figs.16,17; CUSHMAN 1918, p.289.

Elphidium craticulatum (Fichtel & Moll). CUSHMAN 1933, p.48, pl.11, figs.5a,b; CUSHMAN 1939, p.56, pl.15, figs.14-17; KLEINPELL 1954, p.42, pl.2, fig.4; COLLINS 1958, p.420; ALBANI 1968a, p.111, pl.9, figs.19,20; ALBANI 1968b, p.33, fig.151; ROGL & HANSEN 1984, p.40, pl.9, figs.5,6; DEBENAY 1988, p.166; LOEBLICH & TAPPAN 1988, pl.788, figs.6-13; ALBANI & YASSINI 1993, p.25, figs.51-53; MATHER & BENNETT, 1993, p.18, fig.9.15.

Cellanthus craticulatus (Fichtel & Moll). LOEBLICH & TAPPAN 1964, fig.507,1-6; PALMIERI 1976a, p.372; PALMIERI 1976b, p.413; HATTA & UJIIE 1992, p.203, pl.49, figs.7a,b; LOEBLICH & TAPPAN 1994, p.167(part), pl.380, figs.1,2,7,8.

Elphidium parri CUSHMAN 1936, p.81, pl.14, figs.7a,b; CUSHMAN 1939, p.47, pl.12, fig.18.

DESCRIPTION: Test large and inflated; outline smoothly circular; profile biconvex to strongly inflated; periphery acute with one narrow, rounded keel; 20–40 chambers in adult whorl; 7–12 narrow septal bridges span the sutures; sutures slightly depressed, straight to very slightly curved back towards the periphery; large, flat to slightly raised, shelly boss, spanning one quarter to one third diameter of test; boss pierced by numerous pits; sutures, chamber walls and base of apertural face lined with very fine papillae. Greatest diameter 0.8–1.6 mm; width/thickness ratio 1.5–2.

REMARKS: This species is characterised by its large size, its inflation, numerous chambers and large shelly boss. It is easily distinguished from *E. mortonbayense* by the presence of its single, narrow, peripheral keel. Our material compares well with the lectotype, illustrated by Rogl and Hansen (1984).

TYPE LOCALITY: Indian Ocean, Arabian Sea, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 17): This species has a widespread Indo-Pacific distribution (e.g. Hatta & Ujiie 1992, Hottinger *et al.* 1993, Loeblich & Tappan 1994). In this study we have recorded it from northern, more tropical parts of the South-west Pacific (Tonga, Fiji, Solomon Islands, Vanuatu, Queensland and New South Wales). It is also recorded from Victoria by Albani and Yassini (1993) and New Caledonia by Debenay (1988).

ECOLOGIC DISTRIBUTION: *E. craticulatum* is a common member of low tidal and shallow subtidal (0–20 m) foraminiferal associations living in clean sand in normal marine salinity off the northeast coast of Australia and around many of the tropical island groups of the South-west Pacific. The associated faunas are dominated by combinations of *Textularia, Reophax, Quinqueloculina, Spiroloculina, Triloculina, Elphidium, Peneroplis, Amphistegina, Baculogypsina, Reusella, Tinoporus, Bolivina, Ammonia, Discorbis* and *Operculina*.

ETYMOLOGY: Presumably from the crater-like pits in the umbonal boss.

Elphidium crispum (Linné)

Nautilus crispus LINNÉ, 1758, p.709.
Elphidium crispum (Linné). CUSHMAN 1933, p.47, pl.11, fig.4; CUSHMAN 1939, p.50, pl.13, fig.17-21; KLEINPELL 1954, p.43, pl.2, figs.8,10; LOEBLICH & TAPPAN 1994, p.168, pl.378, figs.4-6.
Elphidium parri Cushman. LEITCH *et al.* 1969, p.29.

DESCRIPTION: Test large, evenly rounded outline; profile biconvex; periphery acute with strong keel; 20–40 chambers in final whorl; chambers not inflated but commonly with anterior part of each chamber slightly raised to form radiating ridges; sutures slightly depressed, strongly curved, tending to be sigmoidal; septal bridges, narrow, numerous, about one third to half the width of each chamber; umbilical area covered by a rounded boss, often raised and pitted; aperture a row of pores at base of apertural face. Greatest diameter 0.4–2.5 mm; width/thickness ratio 1.5–4.0.

REMARKS: *E. crispum* is characterised by its large size, numerous chambers and septal bridges, about half the width of each chamber, its wide, pitted umbonal boss, and biconvex profile. It is distinguished from *E. macellum* by the presence of an umbonal boss and from *E. craticulatum* by the much smaller size of the boss.

TYPE LOCALITY: Italy, Rimini Beach, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION: *E. crispum* occurs in many parts of the tropical and subtropical Indo-Pacific and Mediterranean.

SOUTH-WEST PACIFIC CONSTITUENT SUBSPECIES:
E. crispum crispum late Eocene-Recent (New Zealand), Recent (Australia, New Zealand, SW Pacific islands)
E. crispum waiwiriense early Miocene (New Zealand)

ETYMOLOGY: From the Latin "crispus" meaning curled, in reference to the strongly curved sutures.

Elphidium crispum crispum (Linné)
Pl. 7, Figs 13–16; Pl. 8, Figs 1–9

Nautilus crispus LINNÉ, 1758, p.709.
Elphidium crispum (Linné). CUSHMAN 1933, p.47, pl.11, fig.4; CUSHMAN 1939, p.50, pl.13, fig.17-21; KLEINPELL 1954, p.43, pl.2, figs.8,10; COLLINS 1958, p.420; ALBANI 1968a, p.111, pl.10, fig.7; ALBANI 1968b, p.33, fig.153; COLLINS 1974, p.42; PALMIERI 1976a, p.372; PALMIERI 1976b, p.413; LOEBLICH & TAPPAN 1994, p.168, pl.378, figs.4-6; YASSINI & JONES 1995, p. 177, figs.1015-6.
Polystomella subnodosa Munster. CHAPMAN 1926, p.89, pl.1, fig.20.
Elphidium macellum (Fichtel & Moll). APTHORPE 1980, pl.26, fig.11.
Elphidium cf. *chapmani* Cushman. KENNETT 1966a, p.61.
Elphidium gibsoni Hayward in HAYWARD & BUZAS 1979, p.52, pl.12, figs.158-160, pl.15, fig.182; HAYWARD & BROOK 1994, fig.3.15.
Elphidium jenseni (Cushman). YASSINI & JONES 1995, p.177, figs.1017-8,1021.
Cellanthus cf. *craticulatus* (Fichtel & Moll). McCULLOCH 1977, p.224, pl.97, fig.3.

DESCRIPTION: Test large, evenly rounded outline; profile biconvex to rhomboidal; periphery acute with strong, narrow keel; sides of final chamber, straight to slightly concave; 20–40 chambers in final whorl; chambers not inflated but commonly with anterior part of each chamber slightly raised to form radiating ridges; sutures slightly depressed, strongly curved, tending to be sigmoidal; septal bridges long, narrow numerous (0.3–1 x chamber width, 10–20 in side view); umbilical area covered by a rounded boss protruding beyond the peripheral outline; boss sometimes opaque and bearing 10–20 small pits and sometimes strongly raised and glassy with or without pits; aperture a row of pores at base of apertural face. Greatest diameter 0.4–1.5 mm; width/thickness ratio 1.5–2.5.

REMARKS: Most Recent records of this species from the South-west Pacific appear to refer to a variant which bears a small but prominent glassy boss which lacks a pitted surface (e.g. Cushman 1933; Albani 1968a, b; Collins 1974). We also have encountered this variant in our samples from eastern and southern Australia and the tropical Pacific. Recent and fossil New Zealand and some Australian specimens however bear closer resemblance to typical forms (based on examination of topotypic material from Rimini, Italy) by having a broad pitted boss of low relief. Recent specimens from off northern New Zealand differ slightly from typical forms by having a more compressed test, more flattened septal bridges and radial ridges and a white opaque test and boss.

In New Zealand small specimens of *E. crispum crispum* are similar to *E. charlottense* in profile but are readily distinguished by more numerous chambers and more curved sutures. *E. crispum crispum* is distinguished from *E. macellum* by its distinctive boss, and from *E. craticulatum* by its less inflated, rhomboidal profile and generally smaller boss.

TYPE LOCALITY: Italy, Rimini Beach, Recent.

TYPE SPECIMENS SEEN: Numerous topotypes.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 17, 22): *E. crispum crispum* occurs in many parts of the tropical and subtropical Indo-Pacific and Mediterranean. It is known from a few nearshore samples from islands off the east coast of northern New Zealand (Rimariki, Mokohinau, Great Barrier and Cuvier Islands). In the South-west Pacific it occurs in New Caledonia, Tonga, Fiji, Vanuatu, Solomon Islands, Lord Howe Island, Kermadec Islands and the Queensland, New South Wales, Victoria, South Australia and Tasmania coasts of Australia.

ECOLOGIC DISTRIBUTION: *E. crispum crispum* is one of the most common species of *Elphidium* along the east coast of Australia and around some of the South-west Pacific islands. It is abundant in sandy, shallow subtidal (0–20 m) environments of normal marine salinity. Associated faunas are dominated by combinations of *Reophax, Textularia, Spiroloculina, Quinqueloculina, Triloculina, Peneroplis, Operculina, Elphidium, Discorbis, Bolivina, Ammonia* and *Cibicides.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 35): *E. crispum crispum* occurs throughout New Zealand from the latest Eocene to the early Pliocene. It is unknown from the South Island above the early Pliocene, although it does occur in the late Pliocene of the Chatham Islands. It occurs throughout most of the Pliocene and Pleistocene in various parts of the North Island, but had become restricted to northeastern New Zealand by the Recent.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Late Eocene (Runangan) to Recent. Specimens in the late Eocene are mostly small individuals, but in all later periods except the Quaternary, they occur in a range of sizes, frequently growing quite large.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. crispum crispum* is the most common and abundant *Elphidium* in the New Zealand Oligocene and Miocene fossil record. It occasionally is the single dominant species (70–90%) in faunas (e.g. R11/f8-10), with 0% planktics. These assemblages are interpreted to have lived in a moderately sheltered, mid tidal to subtidal (c. 0–2 m depth) beach (Hayward & Brook 1994). *E. crispum crispum* is commonly one of the codominant species (5–20% relative abundance) in faunas (e.g. R11/f21, M34/f7038, I38/f7607, F45/f126) with 0–10% planktics. Other codominant benthic species include various combinations of *Gaudryina, Textularia, Quinqueloculina, Amphistegina, Buliminella, Cibicides, Cribrorotalia, Discorbis, Gyroidina allani, Melonis maorica, Notorotalia, Pileolina* and *Sherbornina* that are typical inner shelf, high to moderate energy assemblages.

E. crispum crispum also occurs in lower abundances in faunas (e.g. Y14/f7506, V20/f8580, S27/f8587, J41/f8498, D45/f8624) with 10–50% planktics, dominated by the benthics *Haeuslerella, Anomalinoides, Bolivina, Cibicides, Gyroidina, Lenticulina, Nonionella, Notorotalia* and *Uvigerina,* that are inferred to be mid or outer shelf assemblages (Hayward 1986).

It appears that *E. crispum crispum* has always lived in normal marine salinity, with its greatest abundances on moderately sheltered low tidal and subtidal beaches. It was also abundant in a variety of high and moderate energy environments at inner shelf depths (c. 0–30 m) but probably lived in fewer numbers out into mid and possibly outer shelf depths (c. 50–200 m) although some of these occurrences are undoubtedly due to post-mortem transport.

Elphidium crispum waiwiriense Hayward n.ssp.
Pl. 1, Fig. 13; Pl. 8, Figs 10–13

Elphidium ornatissimum (Karrer). HORNIBROOK & SCHOFIELD 1963, p.47.

DESCRIPTION: Test large to extremely large; outline circular; profile strongly compressed and biconvex; periphery acutely angled (20–30°) with strong, narrow keel; 20–40 chambers in final whorl; chambers not inflated but sometimes with anterior part of each chamber slightly raised; sutures slightly depressed, curved, tending to be sigmoidal; 15–30 narrow, septal bridges (0.3–0.6 x chamber width) separated by small sutural pits; in the largest adult shells, sutures sometimes develop a double row of pits, near the periphery on the latter chambers (Pl. 1, Fig. 13); umbilicus completely filled with a strongly raised rounded boss with several pits; in the largest adults, this boss may be partly buried by the inner ends of chambers in the last whorl. Greatest diameter 0.8–2.5 mm; width/thickness ratio 2.8–4.0.

REMARKS: Juvenile *E. crispum waiwiriense,* with diameters less than 1 mm are very similar to *E. c. crispum,* differing mostly in the more strongly compressed test with a more acute periphery (20–30° compared with 40–50°). Adults of *E. crispum waiwiriense* grow larger than the nominate subspecies, are flattened and may develop a double row of pits at the peripheral ends of later sutures.

TYPE LOCALITY: New Zealand, South Auckland, Waiwiri Beach, Tipakuri Sandstone Formation, Otangaroa Member (Hayward & Brook 1984, p.116), R13/f57, early Miocene (Otaian).

HOLOTYPE: TF1652/1.

PARATYPES: 2 figured paratypes from R13/f57 (TF1652/2,3), 9 paratypes from R13/f6551, Waiwiri Beach (TF1652/4); 5 paratypes from R13/f55, Waiwiri Beach (USNM487678).

PALEOGEOGRAPHIC DISTRIBUTION (Fig. 35): *E. crispum waiwiriense* is only known from New Zealand, where it occurs in a number of samples at the type locality in South Auckland and one sample in Southland.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Only known from the early Miocene (Otaian and possibly the Waitakian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. crispum waiwiriense* is codominant with *Elphidium kanoum, Haplophragmoides* and *Bulimina pupula* in faunas from the type locality at Waiwiri Beach (e.g. R13/f55, f57, f59, f6551). These are low diversity faunas, lacking planktics and containing many reworked foraminifera eroded from the soft underlying calcareous siltstone. They are typical of a moderately sheltered beach or shallow subtidal (0–3 m) sand environment (Hayward 1986). In the Southland sample (F46/f43) *E. crispum waiwiriense* is rare and the fauna contains c. 25% planktics and a deep inner to mid shelf (30–100 m) benthic assemblage.

It appears that *E. crispum waiwiriense* lived in normal marine salinity, with its greatest abundances on moderately sheltered low tidal and subtidal beaches.

ETYMOLOGY: From the type locality at Waiwiri Beach.

Elphidium excavatum (Terquem)

Polystomella excavata TERQUEM 1875, p.25, pl.2, fig.2a-f.
Elphidium excavatum (Terquem). FEYLING-HANSSEN 1972, p. 339-344, pl. 1-6; MILLER *et al.* 1982, p. 124-139, pl. 1-6 (in part); BUZAS *et al.* 1985, p.1083, fig.6.7-6.10,7.1,7.2.

DESCRIPTION: Test involute, evenly rounded to lobulate; periphery broadly rounded to sub-acute, no keel; 7–15 moderately inflated chambers; sutures depressed to flush, moderately curved, crossed by 1–10 septal bridges on each side; papillae ornament sutural pits, umbilicus and base of apertural face; umbilicus depressed or filled with one or more bosses; aperture a series of pores at base of apertural face.

REMARKS: This name is applied to forms which have a broadly rounded unkeeled periphery, usually fewer than 12 chambers in the final whorl and papillae covering sides of sutural pits, umbilical area and base of apertural face. This species is more tightly involute than *E. oceanicum* and less inflated than *E. saginatum*.

STRATIGRAPHIC DISTRIBUTION: *E. excavatum* is recorded from late Pliocene to Recent worldwide (Miller *et al.* 1982), with the earliest known occurrences in the Miocene of eastern North America (M.A. Buzas pers.comm.) and early Miocene of New Zealand (this study).

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Early Miocene to Recent.
E. excavatum clavatum early Miocene to Recent
E. excavatum excavatum Pliocene to Recent
E. excavatum williamsoni Pleistocene to Recent

CONSTITUENT RECENT SOUTH-WEST PACIFIC SUBSPECIES:
E. excavatum clavatum Australia, New Zealand, SW Pacific islands
E. excavatum excavatum Australia, New Zealand, SW Pacific islands
E. excavatum oirgi New Zealand
E. excavatum sydneyense Australia
E. excavatum williamsoni Australia, New Zealand, SW Pacific islands

ETYMOLOGY: Presumably named for its excavated sutures.

Elphidium excavatum clavatum Cushman
Pl. 8, Figs 14–17; Pl. 9, Figs 1–8

Elphidium incertum (Williamson) var. *clavatum* Cushman 1930, p.20, pl.7, fig.10a-b; CUSHMAN 1939, p.57, pl.16, fig.1-2.
Elphidium clavatum Cushman. LOEBLICH & TAPPAN 1953, p.98, pl.19, fig.8-10.
Elphidium excavatum (Terquem) forma *clavatum* Cushman. HAYWARD & HOLLIS 1994, pl.5, fig.6-8.
Elphidium excavatum (Terquem). PALMIERI 1976a, p.372; BUZAS *et al.* 1985, p.1083, figs.6.7,6.8; HAYWARD 1993, figs.3m-n; HAYWARD & TRIGGS 1994, pl.2, fig.10; HAYWARD & GRENFELL 1994, fig.19; HAYWARD *et al.* 1996, pl.2, figs.8-9.
Elphidium articulatum (d'Orbigny). APTHORPE 1980, p.225, pl.28, figs.6,7.
Elphidium incertum (Williamson). COLLEN 1973, p.113, pl.V, figs.8,11; COLLEN 1995, pl.10, fig.11.
Cribroelphidium incertum (Williamson). COLLEN 1983, p.19,28,32.
Cribrononion sydneyensis Albani. YASSINI & JONES 1986, pl.7, figs.9-11; YASSINI & JONES 1988, p.263, fig.16, nos.9-11; YASSINI & JONES 1995, p.179, figs.1046-47,1054,1073,1076-7.
Cribrononion sp. YASSINI & JONES 1995, p.180, figs.1048-9.
Cribrononion illawaraensis ALBANI & YASSINI 1993, p.19, figs.24-25.

DESCRIPTION: Test small to medium-sized, evenly rounded to slightly lobulate in outline; periphery broadly rounded to sub-acute, sides parallel in profile; 10–14 slightly inflated chambers in final whorl; sutures slightly depressed to flush, moderately curved; sutural pits circular or elliptical (elongate radially) with scattered papillae; septal bridges moderately short, wide, few (4–6); umbilicus flush to slightly raised with an imperforate collar, usually with a small central boss. Greatest diameter 0.2–0.4 mm; width/thickness ratio 2.5–3.0.

REMARKS: *E. excavatum clavatum* is distinguished from other subspecies by the intermediate length of the septal bridges, its umbilical collar and small umbonal boss. An imperforate umbilical collar is sometimes absent from New Zealand early Miocene specimens. Scanning electron microscope examination of a suite of specimens from Lake Illawara (e.g. Pl. 9, Figs 6–8) indicate that *Cribrononion illawaraensis* is a junior synonym of *E. excavatum clavatum*. The holotype of *C. illawaraense* (Albani and Yassini 1993, figs 24–25) has a large flat boss and no collar and appears to be an unusual juvenile form.

TYPE LOCALITY: United States, Maine, Frenchmans Bay, Recent.

TYPE SPECIMEN SEEN: Holotype (CC10403).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 17, 23): *E. excavatum clavatum* occurs throughout New Zealand and in eastern Australia (Palmieri 1976a, Cann & de Deckker 1981). It has also been recorded from the Solomon Islands and Vanuatu and is widely distributed in polar and temperate waters in the Northern Hemisphere (Feyling-Hanssen 1972; Miller *et al.* 1982).

ECOLOGIC DISTRIBUTION: Restricted to brackish or marginal marine environments in New Zealand, Australia and the South-west Pacific islands, but apparently tolerant of normal marine salinities in high to intermediate latitudes in the Northern Hemisphere. *E. excavatum clavatum* is the dominant subspecies in the middle parts of New Zealand estuaries and enclosed inlets, especially in intertidal associations dominated by *Ammonia* or *Elphidium excavatum* (Hayward & Hollis 1994). It lives in similar intertidal or shallow subtidal, middle sections of estuaries or brackish lagoons in eastern Australia.

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 33): *E. excavatum clavatum* occurs in the Miocene of both main islands, but is only known from the North Island in Pliocene and Pleistocene rocks.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: *E. excavatum clavatum* is known from a number of records from early Miocene to Recent in New Zealand (Otaian onwards).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: Early Miocene *E. excavatum clavatum* makes up no more than 1–2% of faunas with 5–20 % planktics. The benthic assemblages (e.g. M34/f7038, J41/f8498, D45/f8487) are dominated by varying combinations of *Gaudryina, Haeuslerella, Quinqueloculina, Anomalinoides, Cibicides, Cribrorotalia, Florilus, Nonionella, Notorotalia spinosa* and *Virgulopsis* indicative of normal marine salinity at a range of inner to mid shelf depths (c. 0–100 m).

Pliocene and Pleistocene occurrences of *E. excavatum clavatum* are in faunas (e.g. V20/f8580, S27/f8587) with benthic assemblages dominated by combinations of *Quinqueloculina, Bolivina, Bolivinita, Elphidium* spp., *Notorotalia* and *Uvigerina* typical of sheltered deep inner or mid shelf depths (c. 30–100 m).

Whereas modern *E. excavatum clavatum* in New Zealand predominantly occurs in sheltered, slightly brackish environments, all its known fossil occurrences are in normal marine, inner and mid shelf assemblages. Since brackish foraminiferal assemblages are virtually unknown from the Neogene of New Zealand, it is possible that *E. excavatum* s.l. existed in great abundances in these environments in the past, just as it does today.

ETYMOLOGY: From "clavate", means studded with nails or knobs, apparently referring to the umbonal boss.

Elphidium excavatum excavatum (Terquem)

Pl. 1, Figs 3, 12; Pl. 9, Figs 9–18

Polystomella excavata TERQUEM 1875, p.25, pl.2, fig.2a-f.
Elphidium cf. *lidoense* Cushman. HULME 1964, p.337.
Elphidium cf. *selseyense* (Heron-Allen & Earland). HULME 1964, p.338.
Elphidium selseyense (Heron-Allen & Earland). COLLINS 1974, p.41.
Elphidium sp. MURRAY 1968, p.94, pl.1, fig.4; MURRAY 1971, p.167, pl.70, fig.1-7.
Elphidium excavatum (Terquem). MURRAY 1971, p.159, pl.66, fig.1-7; LEVY *et al.* 1975, p.176, pl.3, fig.5,6; BOLTOVSKOY *et al.* 1980, p.29, pl.13, fig.8-11.
Nonion depressulum (Walker & Jacob). APTHORPE 1980 (in part), pl.27, fig.12.
Cribroelphidium poeyanum (d'Orbigny). APTHORPE 1980, p.225, pl.28, figs.3,8.
Elphidium excavatum (Terquem) forma *excavatum* (Terquem). HAYWARD & HOLLIS 1994, pl.5, fig.1-5; HOLLIS *et al.* 1996, fig.3m.
Elphidium sp. aff. *articulatum* (d'Orbigny). PARR, 1945, p.216, pl.11, fig.9.

DESCRIPTION: Test small to medium-sized, evenly rounded to lobulate; periphery broadly rounded, sides parallel-sided in profile; 7–10 moderately inflated chambers in final whorl; sutures depressed, slightly to moderately curved; septal bridges thin, few (1–5), short and irregularly disposed; sutural pits narrow radial slits lined with fine papillae; umbilical area slightly depressed and covered with fine papillae, forming a star shape. Greatest diameter 0.2–0.35 mm; width/thickness ratio 2–2.5.

REMARKS: *E. excavatum excavatum* is distinguished from other subspecies by its short, irregular septal bridges and depressed star-shaped umbilicus lined with papillae.

TYPE LOCALITY: France, Atlantic coast, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 17, 23): *E. excavatum excavatum* occurs throughout New Zealand (Hayward & Hollis, 1994) and in southern and eastern Australia (Apthorpe 1980; Cann & de Deckker 1981), the Cook and Fiji Islands. It is common in high and intermediate latitudes in the Northern Hemisphere (Feyling-Hanssen 1972; Miller *et al.* 1982) and the south-west Atlantic (Boltovskoy *et al.* 1980).

ECOLOGIC DISTRIBUTION: Restricted to brackish or marginal marine environments in New Zealand, Australia and the SW Pacific islands. *E. excavatum excavatum* is the dominant subspecies in the more brackish parts of New Zealand estuaries and enclosed inlets in intertidal associations dominated by *Haplophragmoides* or *Miliammina* (Hayward & Hollis 1994). It is also common together with *E. excavatum clavatum* in intertidal associations dominated by *Ammonia* and *Miliammina* or *Elphidium excavatum* (Hayward & Hollis 1994). It is a common or subdominant member of associations in the middle parts of estuaries or brackish lagoons in Australia and the tropical islands (e.g. Apthorpe 1980) together with *E. excavatum clavatum, Ammonia* and *Eggerella.*

New Zealand Paleogeographic Distribution (Fig. 33): In the fossil record, *E. excavatum excavatum* is currently only known from Hawkes Bay, but undoubtedly was much more widespread in brackish environments that are rarely preserved.

New Zealand Stratigraphic Distribution: Two fossil occurrences are known from the Pliocene (Opoitian).

Elphidium excavatum oirgi Hayward n.ssp.
Pl. 10, Figs 1–8

Polystomella milletti (Heron-Allen & Earland). CUSHMAN 1919, p.633.
Polystomella striatopunctata (Fichtel & Moll). HERON-ALLEN & EARLAND 1922, p.229 (part).
Elphidium oceanicum Cushman. HOSKINS 1978, p.274, pl.5, figs.4-5; BROOK *et al.* 1981, p.90; HAYWARD 1981, p.132, fig.3c; HAYWARD 1982a, fig.5b.
Elphidium aff. *oceanicum* Cushman. HAYWARD *et al.* 1984, p.162; HAYWARD 1990b, p.96.
Elphidium excavatum n.f. HAYWARD & GRENFELL 1994, p.267.

Description: Test small to medium-sized, evenly rounded to lobulate; inflated with rounded periphery; 10–13 chambers in final whorl (average 11); sutures flush to slightly depressed, straight to slightly curved; sutural pits rectangular, elongate parallel to peripheral margin; septal bridges elongate, narrow, very regularly disposed, numerous (6–9); umbilicus flush to slightly depressed, may bear one or more irregular bosses. Wall thick, glassy. Greatest diameter 0.2–0.4 mm; width/thickness ratio 1.9–2.2.

Remarks: This distinctive subspecies is provisionally included within the *E. excavatum* complex because of close similarities between it and *E. excavatum williamsoni.* In general, *E. excavatum oirgi* is distinguished by its glassy appearance, inflated test, fewer chambers and less curved sutures. However, in areas where the two subspecies cooccur (e.g. entrance to Parengarenga Harbour and Cooks Beach, Coromandel) separation between them is somewhat arbitrary. *E. oceanicum* differs from *E. excavatum oirgi* by having a more compressed test with a thin semitransparent wall, lobulate chambers and a wide, depressed, finely tuberculate umbilical area.

This subspecies may be identical to a form from Southwest Atlantic which Boltovskoy *et al.* (1980) referred to *E. articulatum* d'Orbigny. However, the name cannot be applied with confidence although d'Orbigny described the species from the same area (Patagonian coast and Falklands). D'Orbigny's types are lost and the concept of the species has become confused and the name has been subsequently applied to several distinct forms within the *E. excavatum* group (see discussion in Haynes 1973, p.245).

Type Locality: New Zealand, Northland, Cavalli Islands, 1.5 m, (F201739, stn. 28 of Hayward 1982a), Recent.

Holotype: TF1653/1

Paratypes: 9 paratypes (TF1653/5), 10 paratypes (USNM487679), 10 paratypes (AK74002) all from type locality; 1 paratype (TF1653/3) from Northland, Cavalli Islands, 7 m (F201742), stn. 31 of Hayward 1982a; 2 paratypes (TF1753/2,4) from Northland, Tutukaka Harbour, 3 m (F201841), stn. 24 of Brook *et al.* (1981).

Present-day Geographic Distribution (Figs 17, 23): This subspecies appears to be endemic to New Zealand and is restricted to the north-eastern North Island (North Cape to Bay of Plenty, and off-lying islands).

Ecologic Distribution: Appears to be restricted to areas of normal marine salinity and to depths less than 10 m. Most common in nearshore sands in sheltered bays, rare in more exposed locations.

Etymology: Named after the Offshire Islands Research Group (OIRG), on whose trips BWH has undertaken considerable fieldwork on Recent foraminifera.

Elphidium excavatum sydneyense (Albani)
Pl. 10, Figs 9–10

Crircrononion sydneyensis ALBANI 1978, p.387, figs.9I-K,M,N; ALBANI & YASSINI 1993, p.21, figs.30-33.

Description: Test small, with circular outline; moderately inflated with flat, parallel sides; periphery broadly rounded, unkeeled; coiling slightly asymmetric in the last formed adult chambers, becoming evolute on one side and partly involute on the other; 12–14 non-inflated chambers in final whorl; sutures flush to slightly depressed, slightly curved back towards the periphery; sutural pits small; 4–6 moderately short, wide, flat septal bridges span each suture; umbilicus flush on both sides, filled with a distinct boss on the evolute side; coarse papillae ornament apertural face and adjacent periphery, and extend into depressions around umbonal boss; finely perforate wall. Greatest diameter 0.2–0.3 mm; width/thickness ratio 2.2–2.6.

Remarks: This subspecies is most similar to *E. excavatum clavatum* but differs from it and all others by its slight asymmetry.

Type Locality: Australia, New South Wales, Broken Bay, 9 m depth, (station 152 of Albani 1978), Recent.

Present-day Geographic Distribution (Fig. 17): This subspecies is only known from the coast of New South Wales, Australia, where it has been recorded from Broken Bay and near Wollongong, to the north and south of Sydney (Albani & Yassini 1993).

ECOLOGIC DISTRIBUTION: *E. excavatum sydneyense* appears to live in areas of normal or near normal marine salinity, at shallow depths less than 20 m.

ETYMOLOGY: From the type locality, Broken Bay, which is near the Australian city of Sydney.

Elphidium excavatum williamsoni Haynes
Pl. 10, Figs 11–18

Elphidium williamsoni HAYNES 1973, p.207, pl.24, fig.7, pl.25, fig.6,9, pl.27, fig.1-3. BUZAS *et al.* 1985, p.1087, fig.8.3, 8.6.
Elphidium excavatum (Terquem). CUSHMAN 1939 (in part), p.58, pl.16, fig.10-12; TODD & LOW 1961, p.19, pl.2, fig.5.
Elphidium aff. *bosoense* (Fujita). HULME 1964, p.338.
Elphidium articulatum (d'Orbigny). MURRAY 1971, p.153, pl.63, fig.1-7; BOLTOVSKOY *et al.* 1980, p.29, pl.13, fig.1-4.
Elphidium sp. aff. *articulatum* (d'Orbigny). PARR 1945, p.216, pl.11, figs.9a-b.
Elphidium articulatum multicameratum COLLINS 1974, p.43, pl.3, figs.31a-b.
Elphidium gunteri carioense COLLINS 1974, p. 44, pl.3, figs.34a-b.
Cribrononion umbilicatulum (Williamson). SCOTT & MEDIOLI 1980, p.40, pl.5, fig.4.
Elphidium excavatum (Terquem) forma *williamsoni* Haynes. HAYWARD & HOLLIS 1994, pl.5, fig.9-12.
Elphidium argenteum Parr. TOPPING 1973, p.30, pl.9, figs.1-3; ADAMS 1979, p.144 (part).

DESCRIPTION: Test large for species, evenly rounded outline, becoming lobulate in later part; periphery broadly rounded to sub-acute, sides parallel in profile; 11–17 moderately inflated chambers in final whorl; sutures flush to slightly depressed, moderately to strongly curved; sutural pits lozenge-shaped, elongate parallel to peripheral margin; septal bridges long, evenly spaced, numerous (7–10); umbilicus slightly depressed to flush, filled with irregular ends of chambers. Greatest diameter 0.4–0.55 mm; width/thickness ratio 2.1–2.5.

REMARKS: *E. excavatum williamsoni* differs from other subspecies by its more numerous chambers and septal bridges, its longer septal bridges and lack of an umbonal boss. In general New Zealand specimens differ from those placed in synonymy above by having more strongly curved sutures and shorter septal bars in early chambers. We include large specimens from the Manukau Harbour which have a minimum of 15 narrow chambers in the final whorl, strongly curved sutures and 8–10 septal bridges which are as long as chamber width. *E. bosoense*, the species to which Hulme (1964) uncertainly referred this subspecies, is much smaller (diameter 0.35–0.45 mm) and has a thinner, more delicate wall (Fujita 1956). This subspecies is identical to the holotypes and topotypes of *E. articulatum multicameratum* and *E. gunteri carioense* which Collins (1974) described from Port Phillip, Victoria (Pl. 10, Figs 15–18).

TYPE LOCALITY: Wales, Cardigan Bay, Dovey Marshes, 0 m, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 18, 23): *E. excavatum williamsoni* occurs throughout New Zealand, south-east Australia (Collins 1974, Apthorpe 1980), Norfolk Island and Fiji (herein). It is not known from the Pacific coast of North America but is common north of the Gulf of Mexico on the Atlantic coast (Todd & Low 1961; Scott & Medioli 1980) and in the north-east Atlantic (Haynes 1973, and references therein).

ECOLOGIC DISTRIBUTION: *E. excavatum williamsoni* occurs in New Zealand in the slightly brackish, middle and outer parts of estuaries and enclosed inlets. It is most common, sometimes together with *E. excavatum clavatum,* in intertidal associations dominated by *Ammonia* and *Elphidium excavatum* (Hayward & Hollis 1994). In eastern Australia and Fiji this subspecies lives in the very slightly brackish outer parts of estuaries and enclosed bays in intertidal and shallow subtidal situations in faunas dominated by *Ammotium, Elphidium, Ammonia, Quinqueloculina* and *Spiroloculina.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 33): In New Zealand, *E. excavatum williamsoni* is currently only known as a fossil from Hawkes Bay, North Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: *E. excavatum williamsoni* is only known from two localities in the early Pleistocene (Nukumaruan).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. excavatum williamsoni* is uncommon (less than 2% of foraminifera) in the two fossil faunas (V20/f8582, V21/f8634) in which it has been found. The assemblages have 0–1% planktics with benthics dominated by *Notorotalia zealandica, Ammonia, Astrononion, Elphidium crispum crispum, E. charlottense* and *Quinqueloculina seminula* - faunas typical of shallow inner shelf (0–20 m) and normal marine salinity.

ETYMOLOGY: Named after early British foraminiferal micropaleontologist, W.C. Williamson.

Elphidium fichtellianum (d'Orbigny)
Pl. 11, Figs 1–8

Polystomella fichtellianum D'ORBIGNY 1846, p.125, pl.6, figs.7,8.
Elphidium fichtellianum (d'Orbigny). CUSHMAN 1939, p.42, pl.11, fig.12.
Elphidium subplanatum CUSHMAN 1936, p.82, pl.14, figs.11a,b; CUSHMAN 1939, p.42, pl.11, fig.7.
Polystomella macella (Fichtel & Moll) var. JENSEN 1904, p.817, pl.23, fig.4.
Polystomella jenseni CUSHMAN 1924, p.49, pl.16, figs.4,6.
Elphidium jenseni (Cushman). CUSHMAN 1939, p.62, pl.17, figs.14,15; PARR 1950. p.372; ALBANI 1968a, p.112, pl.10, fig.8; PALMIERI 1976a, p.372; HATTA & UJIIE 1992, p.203, pl.49, figs.6a,b.

Parrellina verriculata (Brady). LOEBLICH & TAPPAN 1994, p.170, pl.386, figs.11,12.

Description: Test moderately large with an evenly rounded outline; profile strongly compressed with flat sides; periphery subrounded with a strong, crisp, narrow keel; chambers numerous (16–20) in adult whorl, not inflated; strong reticulate ornament largely consisting of 7 to 10 narrow, elongate, septal bridges extending across each suture and most of each chamber; each septal bridge is posteriorly inflated, sometimes with partial development of a disjointed radial rib; sutures slightly depressed, strongly curved backwards towards both the periphery and the umbilical area; umbilical area wide and flat with umbilical ends of chambers covered in fine tubercles; apertural face ornamented with numerous fine papillae; wall finely perforate and glassy. Greatest diameter 0.4–0.7 mm; width/thickness ratio 3.5–4.5.

Remarks: Close comparison of the types of *E. jenseni* (CC3323, CC3324, CC3325, CC18895) from the Recent of Samoa, with 36 topotypes of *E. fichtellianum* (CC22611) from the Miocene of Austria and with the types of *E. subplanatum* (CC23552, CC23553) from the Oligocene of Germany, show the three to be conspecific. *E. fichtellianum* is easily distinguished from other strongly compressed species, by the extensive development of tubercles in the umbilical area and over the umbilical ends of chambers. It lacks the reticulate ornament in the umbilical area of *E. novozealandicum* and lacks the solid radial ribs of *E. macellum.*

Type Locality: Europe, Austria, Vienna Basin, Nussdorf, Miocene.

Type Specimens Seen: Thirty-six topotypes (CC22611).

Stratigraphic Distribution: *E. fichtellianum* occurs throughout much of Europe and the tropical Indo-Pacific at various times from the Oligocene onwards.

Present-day Geographic Distribution (Fig. 18): *E. fichtellianum* occurs widely throughout the tropical western Pacific but not as far south as New Zealand. In this study we record it from the east coast of Australia, around Victoria and Tasmania (Parr 1950), and in the South-west Pacific from Vanuatu, Solomon Islands, Fiji, Samoa, Tonga and Norfolk Island.

Ecologic Distribution: *E. fichtellianum* appears to be a common species in normal marine salinity on moderately sheltered sandy beaches and at inner shelf depths, sometimes reworked down to bathyal depths. It occurs in faunas dominated by combinations of *Elphidium, Quinqueloculina, Peneroplis, Spiroloculina, Discorbis, Ammonia, Baculogypsina* and *Amphistegina.*

Etymology: Named after pioneer foraminiferal research micropaleontologist, L. von Fichtel.

Elphidium fijiense Hayward n.sp.
Pl. 11, Figs 9–12

Description: Test small to medium size; outline smoothly circular to slightly lobulate on the later chambers; profile biconvex; periphery acutely rounded with slightly thickened shell but no keel; 16–18 chambers in adult whorl; 6–7 narrow septal bridges completely span the sutures, and do not become stronger on early parts of the whorl; sutures depressed, very slightly curved back towards the periphery and lined with fine papillae; prominent, raised, subcircular or irregular, glassy boss with one or several prominent pits; test wall somewhat translucent and glassy. Greatest diameter 0.4–0.5 mm; width/thickness ratio 1.8–2.2.

Remarks: This species is characterised by its raised, glassy boss, its rounded angular periphery and glassy test. It differs from *E. excavatum* group by its more sharply angled, acute periphery, its prominent raised boss and greater number of chambers per whorl.

Type Locality: Fiji: Suva, Suva Point, low tide (F202149), Recent.

Holotype: TF1654/1

Paratypes: 9 paratypes (TF1654/2-3) 12 paratypes (USNM487680), 5 paratypes (AK74000) from the type locality.

Present-day Geographic Distribution (Fig. 18): This species is known from the tropical South-west Pacific island groups of Fiji, Lord Howe, Solomons and Tonga.

Ecologic Distribution: This species lives intertidally and at shallow subtidal depths in normal or near-normal marine salinity, in sheltered environments sometimes on beaches and sometimes in mud around mangrove roots. It occurs in greatest abundance in faunas dominated by *Elphidium* and *Ammonia.*

Etymology: From the type locality in Fiji.

Elphidium gunteri Cole
Pl. 11, Figs 13–15

Elphidium gunteri COLE 1931, p.34, pl.4, fig.9,10; HULME 1964, p.337; POAG 1978, p.402, pl.2, fig.1-23; BOLTOVSKOY *et al.* 1980, p.30, pl.13, fig.15-18; BUZAS *et al.* 1985, p.1084, fig.7.4,7.5; HAYWARD & HOLLIS 1994, pl.4, fig.10-12.

Elphidium gunteri Cole var. *waddensis* VOORTHUYSEN 1951, p.25, pl.2, fig.10,11.

Elphidium oceanensis (d'Orbigny). MURRAY 1971, p.165, pl.69, fig.1-7; MURRAY 1979, p.52, fig.16a,c; APTHORPE 1980, pl.28, fig.1,2.

Elphidium waddensis (Voorthuysen). HAYNES 1973, p.206, pl.24, fig.4,10, pl.26, fig.1, pl.28, fig.10,11.

Cribroelphidium vadescens CUSHMAN & BRONNIMANN 1948, p.18, pl.4, fig.5; ALBANI & YASSINI 1993, p.18,

figs.16-17,19-20; YASSINI & JONES 1995, p.178, fig.1043.
Elphidium littorale LE CALVEZ & LE CALVEZ 1951, p.251, fig.5a,b.

DESCRIPTION: Small inflated test, outline slightly to irregularly lobulate; profile inflated, parallel-sided; periphery broadly rounded; 8–15 chambers in final whorl; sutures depressed, straight to slightly curved; septal bridges irregular in number and degree of development; umbilicus may be slightly depressed or raised due to growth of irregular tubercles; papillae ornament sutural pits, umbilical depression and base of apertural face; chamber walls coarsely perforate and usually golden brown. Greatest diameter 0.2–0.4 mm; width/thickness ratio 1.8–2.1.

REMARKS: Close study and comparison of the types of *Cribroelphidium vadescens* (CC56643, CC56749) and of *Elphidium gunteri* show these two species to be conspecific. New Zealand specimens are smaller than typical *E. gunteri*, have fewer chambers in the final whorl, shorter and more rudimentary septal bridges and smaller umbilical tubercles. They compare well with *E. gunteri* f. *salsa* (Cushman & Bronnimann) of Poag (1978). *E. gunteri* is distinguished from *E. excavatum* complex by its coarsely perforate wall, irregularly lobulate outline and distinctive golden brown colour. It differs from the New Zealand endemic *E. vellai* by the presence of umbilical tubercles and longer septal bridges.

TYPE LOCALITY: United States, Florida, Caloosahatchee Marl, Pliocene.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 18, 24): In New Zealand this species is common in Northland, with sporadic distribution south of Kawhia on the west coast and Napier on the east. We have not found it south of Nelson-Marlborough and northern Westland. *E. gunteri* occurs on the southeast coast of Australia (Apthorpe 1980, Albani & Yassini 1993), at mid to low latitudes on the Pacific and Atlantic coasts of North America (Culver & Buzas, 1981-1986), on the Atlantic coasts of South America and Africa (Boltovskoy *et al.* 1980; Debenay 1990) and in the north-east Atlantic (Haynes 1973). North American records of the species support the warm-water preference indicated by its New Zealand distribution.

ECOLOGIC DISTRIBUTION: In New Zealand, *E. gunteri* is restricted to brackish environments where it is most common in muddy substrates in the middle and seaward parts of estuaries, in associations dominated by *Miliammina* and *Ammonia*, and in intertidal locations in the upper reaches of harbours and inlets in associations dominated by *Haplophragmoides, Elphidium* or *Ammonia* (Hayward & Hollis 1994).

In Australia, *E. gunteri* is uncommon, having been recorded as codominant with *Ammonia* in shallow slightly brackish lagoons (Apthorpe 1980).

ETYMOLOGY: Named after the micropaleontologist Dr Gunter.

Elphidium hampdenense Finlay
Pl. 1, Fig. 11; Pl. 11, Figs 16–19

Elphidium hampdenensis FINLAY 1939, p.127, pl.12, figs.29,30; FINLAY 1940, p.457; HORNIBROOK 1968, p.49,51; WEBB 1970, fig.1, table 3; HORNIBROOK *et al.* 1989, p.92, fig.15:30; KAIHO *et al.* 1993, p.77, pl.4, figs.24-25, 29-30.
Elphidium patagonicum TODD & KNIKER 1952, p.18, pl.3, figs.35a-b.

DESCRIPTION: Test of medium size; outline smoothly circular; moderately inflated profile with biconvex or parallel, flat sides; periphery acute with strong, bluntly rounded keel; 7–10 non-inflated chambers in adult whorl; sutures depressed strongly curved back towards the periphery; leading edge of each chamber bears a narrow, strong, curved, radial rib; 4–6 narrow, long septal bridges extend forwards from each radial rib right across each chamber to form a strong reticulate ornament; umbilical area small and slightly depressed; fine papillae line pits and umbilical area, with larger papillae extending over lower half of apertural face. Greatest diameter 0.4–0.8 mm; width/thickness ratio 2.3–2.7.

REMARKS: *E. hampdenense* is characterised by its inflation, strong reticulate ornament with narrow ribs and bridges and small depressed umbilical area. It is most similar to the Oligocene-Miocene *E. pseudoinflatum* from which it differs by its broader, blunter keel, its shallow umbilicus and fine papillae, and in having consistent, reticulate ornament over the entire test. Examination of the types (CC64411, CC64412) of *E. patagonicum* show it to be conspecific with *E. hampdenense.*

TYPE LOCALITY: New Zealand, Otago, Hampden Beach section (J42/f8532), middle Eocene (Heretaungan).

TYPE SPECIMENS SEEN: Holotype (TF1080/1), 1 paratype (TF1080/2), 2 paratypes (USNM689058).

PALEOGEOGRAPHIC DISTRIBUTION (Fig. 38): *E. hampdenense* occurs in the middle Eocene throughout New Zealand and also in South America (Todd & Kniker 1952).

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: *E. hampdenense* has a restricted stratigraphic range in New Zealand of several million years within the middle Eocene. Its first appearance is in the middle of the *Globorotalia crater crater* zone and its last appearance approximates the first appearance of *E. saginatum* and disappearance of *G. crater crater* (Hornibrook *et al.* 1989). *E. hampdenense* is the index species for the Heretaungan stage.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. hampdenense* does not dominate any fossil faunas but may occur in abundances up to 10% of the total benthic foraminifera. The type fauna in Otago is dominated by a combination of *Ammodiscus, Haplophragmoides, Cyclammina, Stilostomella, Bulimina, Bathysiphon, Pullenia, Oridorsalis* and *Cibicides* and includes deep bathyal restricted *Nuttallides* and *Pleurostomella.* This is inferred to be a mid bathyal assemblage. In Northland and the East Coast (e.g. Q08/f278, P05/f115, V22/f8840) *E. hampdenense* occurs in similar deep bathyal faunas with common radiolaria and dominated by a combination of Nodosariidae, *Ammodiscus, Cyclammina, Nuttallides, Stilostomella* and *Uvigerina.* In the Great South Basin (Raine *et al.* 1993), *E. hampdenense* occurs in a wider variety of foraminiferal assemblages - from mid to outer shelf depths (5–10% planktics) dominated by *Bulimina bortonica, Melonis maorica, Cibicides parki, Lenticulina, Cyclammina* and *Vaginulinopsis* (drillholes Toroa-1, Pakaha-1) down to upper and mid bathyal depths, dominated by *Vaginulinopsis, Gyroidina neosoldanii, Osangularia, Oridorsalis, Nuttallides* and *Anomalina visenda. E. hampdenense* has not been found in assemblages that are inferred to have lived shallower than about 50 m.

It appears that *E. hampdenense* lived in normal marine salinity in a range of water depths extending from mid shelf to mid bathyal (c. 50–2000 m).

ETYMOLOGY: From the type locality at Hampden Beach.

Elphidium hawkesburiense (Albani)
Pl. 12, Figs 1–4

Cribrononion hawkesburiensis ALBANI 1974, p.38, pl.1, figs.12-14; ALBANI & YASSINI 1993, p.19, figs.22-23.

DESCRIPTION: Test of small to medium size; outline circular; profile moderately compressed with parallel or slightly convex sides; acutely rounded periphery with no keel; 11–13 non-inflated chambers per adult whorl; radial ribs lacking; 8–12 short, broad, septal bridges span each suture, separated by small sutural pits; sutures narrow and slightly depressed, straight to slightly curved backwards towards the periphery, marked by a band of nearly opaque imperforate shell; umbilical area filled with a flat circular boss surrounded by a narrow, depressed suture ornamented with small papillae; lower half of apertural face and periphery of first two chambers of last whorl ornamented with small papillae; chamber walls finely perforate and translucent. Maximum diameter 0.35–0.5 mm; width/thickness ratio 1.5–2.4.

REMARKS: *E. hawkesburiense* differs from *E. albanii* by the papillate ornament around the apertural face and umbonal boss, and the presence of a discrete boss. *E. hawkesburiense* differs from *E. advenum* group by its less inflated chambers and lack of a keel; and from *E. excavatum* group by its acutely rounded periphery, lack of papillae in sutural pits and papillate apertural face.

TYPE LOCALITY: Australia, New South Wales, Broken Bay, Hawkesbury River estuary, 10 m, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 18): *E. hawkesburiense* is known only from the east coast of Australia. It is recorded in this study from New South Wales and Tasmania. Albani and Yassini (1993) also record it from Queensland.

ECOLOGIC DISTRIBUTION: This species lives in slightly brackish outer parts of estuaries and shallow bays with normal marine salinity (Albani 1974, Albani & Yassini 1993).

ETYMOLOGY: From the type locality, Hawkesbury River.

Elphidium hispidulum Cushman
Pl. 1, Fig. 14; Pl. 12, Figs 5–7

Elphidium hispidulum CUSHMAN 1936, p.83, pl.14, fig.13; CUSHMAN 1939, p.63, pl.18, fig.2; COLLINS 1958, p.420; McCULLOCH 1977, p.221, pl.97, fig.10.

Cribrononion hispidulus (Cushman). PALMIERI 1976a, p.372; ALBANI 1978, p.387, figs.9C-D.

Parrellina hispidula (Cushman). DEBENAY 1988, p.166; ALBANI & YASSINI 1993, p.31, figs.79-82; LOEBLICH & TAPPAN 1988, pl.793, figs.5-8; LOEBLICH & TAPPAN 1994, p.170, pl.384, figs.5-7, pl.387, figs.1-3; YASSINI & JONES 1995, p.180, figs.1066-8.

Elphidium reticulosum Cushman. LOEBLICH & TAPPAN 1994, p.169, pl.382, figs.1-5.

DESCRIPTION: Test of medium to large size; slightly evolute; outline smoothly circular to very slightly lobulate in later part of whorl; profile biconvex with convex sides; periphery acutely rounded with no keel; 12–17 non-inflated chambers in adult whorl; ornament on last formed chambers consists of numerous, small, hispid papillae which strengthen on earlier chambers into an irregular series of concentric costae that in places join to form an anastomosing pattern; costae near periphery on early part of whorl unite to form a series of concentric ribs that completely span a number of chambers; hispid papillae extend over strong costate ornament on early chambers adjacent to apertural area; sutures distinctly depressed and visible only in the later part of the adult whorl; sutures radial to slightly curved; umbilical area occupied by a number of strong, irregular bosses that may unite into a semicircular rib; apertural face ornamented with numerous fine, slightly hispid papillae; chamber walls coarsely perforate, where visible. Greatest diameter 0.6–0.8 mm; width/thickness ratio 1.6–2.

REMARKS: This species is characterised by its hispid ornament that develops into strong concentric costae. It is distinguished from *Elphidium reticulosum* and *Elphidium sharkianum* (from West Australia) by its more lenticular profile, more sharply rounded periphery, and strong umbonal bosses.

TYPE LOCALITY: Australia, Queensland, Albany Passage, 8–30 m, Recent.

TYPE SPECIMENS SEEN: Holotype (CC23028), 2 paratypes (CC9874).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 18): *E. hispidulum* is known from the western Pacific (McCulloch 1977, Loeblich & Tappan 1988, 1994), and is recorded in this study and by Albani and Yassini (1993) from the coast of New South Wales and Queensland in Australia and from New Caledonia (Debenay, 1988) and the Solomon Islands.

ECOLOGIC DISTRIBUTION: *E. hispidulum* lives in inner shelf depths in normal marine salinity in faunas dominated by combinations of *Textularia, Spiroloculina, Quinqueloculina, Triloculina, Elphidium, Peneroplis, Operculina* and *Discorbis*.

ETYMOLOGY: After the hispid ornament on the surface of chambers.

Elphidium ingressans Dorreen
Pl. 12, Figs 8–10

Elphidium ingressans DORREEN 1948, p.290, pl.37. figs.10a,10b.

DESCRIPTION: Test of medium size; circular outline to very slightly lobulate; strongly inflated rhomboidal profile; periphery sharply acute with a strong, bluntly rounded keel; 16–19 chambers in adult whorl; each chamber bears a narrow, strongly raised, slightly curved radial rib extending unbroken from the umbilical area to the periphery; 4–8 narrow, raised, septal bridges span each suture and link with the radial ribs forming a fine, reticulate pattern of ornament; on the early part of the whorl, nodules form at the junctions of the septal bridges with the radial ribs producing a spiky appearance; sutures deeply depressed, slightly curved back towards the periphery; narrow, raised, irregular umbonal boss composed of coalescing ribs; wall finely perforate. Greatest diameter 0.4–0.6 mm; width/thickness ratio 1.3–1.6.

REMARKS: This is a distinctive species, characterised by its strong inflation, rhomboidal profile, and unique, spiky, reticulate ornament. It is most similar to the more compressed *Elphidium wadeae* and *E. kanoum*, from which it differs in its stronger radial ribs , spiky reticulate ornament and stronger inflation.

TYPE LOCALITY: New Zealand, West Coast, Greymouth, Ethel Creek, Omotumotu Formation (J32/f7848), late Eocene (Runangan).

TYPE SPECIMENS SEEN: Holotype (CC64152); 4 paratypes (USNM688473).

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 39): A rare species only known from West Coast, New Zealand.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Late Eocene to possibly earliest Oligocene (Runangan to ?early Whaingaroan).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. ingressans* is a rare species. The type assemblage from Westland has c. 1% planktics and is dominated by *Gaudryina, Asterigerina, Quinqueloculina, Reusella, Buliminella, Melonis, Cribrorotalia* and *Cibicides vortex*. This assemblage is typical of normal salinity conditions at inner shelf depths (c. 0–50 m).

ETYMOLOGY: Presumably named from the Latin "ingressio" meaning an entering or opening.

Elphidium kanoum Hayward
Pl. 12, Figs–11-16

Elphidium kanoum Hayward in HAYWARD & BUZAS 1979, p.53, pl.13, figs.169,170, pl.15, figs.183,184; HAYWARD & BROOK 1994, fig.3.16.

DESCRIPTION: Test medium to large size; outline smoothly rounded; profile biconvex, sometimes compressed and flattened; periphery acute, sharp to slightly rounded with strong, broadly rounded keel; 18–25 chambers in adult whorl; 7–10 strong, raised, septal bridges span each suture and the full width of each chamber, producing strong circular ornament near the periphery; septal bridges short and tubercular near the umbilicus; distal ends of many septal bridges are slightly inflated giving the impression of irregular, beaded radial ribs in parts; sutures depressed, radial and curved slightly back towards periphery; umbilicus filled with a raised, glassy, irregularly tuberculate boss; wall finely perforate. Greatest diameter 0.6–1.0 mm; width/thickness ratio 2.5–3.5.

REMARKS: *E. kanoum* closely resembles *E. wadeae*, from which it can be distinguished by its raised, glassy boss rather than small, discrete, umbilical tubercles. Compressed specimens of *E. kanoum* resemble *E. aculeatum subrotatum* but lack the peripheral spines and more regular glassy boss of that species.

TYPE LOCALITY: New Zealand, Northland, Pakaurangi Point, Q08/f9457, Pakaurangi Formation, early Miocene (Altonian).

TYPE SPECIMENS SEEN: Holotype (TF1580/1), 18 paratypes (TF1580/2-3, F84a-d in University of Auckland, USNM243360, USNM243361).

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 39): *E. kanoum* appears to be restricted to New Zealand, first appearing in the late Oligocene of Northland, but quickly spreading throughout the country.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Late Oligocene (Duntroonian) to middle Miocene (Lillburnian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. kanoum* is widespread in New Zealand and occurs in abundances up to about 15% of some benthic foraminiferal assemblages.

Where it occurs in greatest abundance (e.g. Waiheke Island, R11/f8, f9), there are no planktics and the benthic fauna is dominated by *E. crispum crispum* (c. 80 %). These assemblages are interpreted to have lived in a moderately sheltered, mid tidal to subtidal (c. 0–2 m depth) beach (Hayward & Brook 1994). Elsewhere (e.g. N02/f7554, I38/f7628, M34/f7038, D45/f8487), *E. kanoum* occurs in relative abundances up to 5 % and is associated with diverse faunas dominated by combinations of *Gaudryina, Textularia, Quinqueloculina, Amphistegina, Anomalinoides, Bolivina, Buliminella, Cibicides, Cribrorotalia, Florilus, Notorotalia spinosa* and *Virgulopsis* that are typical of moderately sheltered inner shelf depths (c. 0–50 m, Hayward 1986). *E. kanoum* also occurs in low abundance in other faunal associations (e.g. R14/f6573, D45/f8477) dominated by *Haeuslerella, Anomalinoides, Bolivina, Cibicides, Ehrenbergina, Gyroidina, Lenticulina, Pullenia, Trifarina* and *Uvigerina* that are inferred to have lived at mid to outer shelf depths (c. 50–200 m).

It appears that *E. kanoum* lived in normal marine salinity with its greatest abundances close to low tide level on moderately sheltered beaches, but also lived in lower numbers elsewhere at inner shelf depths. It is not possible to determine whether the occurrences in mid to outer shelf depths indicate that *E. kanoum* lived at these greater depths or whether arrived there by post-mortem transport.

ETYMOLOGY: From the New Zealand Maori "kano" meaning seed for the inflated lenticular seed shape of the shell.

Elphidium lene Cushman & McCulloch
Pl. 13, Figs 1–8

Elphidium incertum (Williamson) var. *lene* CUSHMAN & McCULLOCH, 1940, p.170, pl.19, figs.2,4.

Cribroelphidium poeyanum (d'Orbigny). ALBANI 1981, p.159; ALBANI & YASSINI 1993, p.17, figs. 12-15; YASSINI & JONES 1995, p.178, figs.1074-5.

DESCRIPTION: Test of small to medium size; outline circular to very slightly lobulate; profile strongly compressed with parallel or slightly concave sides; broadly rounded periphery with no keel; 9–10 slightly inflated chambers per adult whorl; radial ribs lacking; 6–10 short, septal bridges span each suture; sutures depressed, straight to slightly curved backwards towards the periphery, unornamented or ornamented with scattered papillae; umbilical area small, depressed, lacking tubercles, occasionally bearing a small, low boss; inner ends of chambers form a low, circular collar around the umbilicus; chamber walls finely perforate. Maximum diameter 0.35–0.45 mm; width/thickness ratio 2.5–3.5.

REMARKS: *E. lene* is more compressed and with a higher apertural face than *E. excavatum excavatum* and *E. excavatum clavatum*, has more septal bridges and generally has less papillose ornament in the sutures. It has similar form and profile to the Caribbean *E. poeyanum*, but differs in being smaller and finely rather than coarsely perforate (Pl. 15, Figs 5–6). *E. lene* differs from *E. sandiegoense* in its depressed rather than incised sutures and more numerous and more regular septal bridges. Comparison of these South-west Pacific specimens with a paratype from California, show them to be identical in most features. The paratype has a very fine sugary chamber texture not usually seen in our material and has 8 chambers per whorl, rather than our normal 9–10.

TYPE SPECIMENS SEEN: Paratype (CC48724).

TYPE LOCALITY: United States, California, Los Angeles, 15 m, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 19): *E. lene* is recorded from the length of the east coast of Australia (Albani & Yassini 1993, this study) and many of the tropical islands of the South-west Pacific (Solomon, New Caledonia, Lord Howe, Fiji, Tonga, Samoa, Cook islands).

ECOLOGIC DISTRIBUTION: *E. lene* lives intertidally and at inner shelf depths in slightly brackish and normal salinity conditions in the outer parts of estuaries, in harbours, bays and in lagoons in the shelter of fringing reefs. The associated faunas are dominated by combinations of *Reophax, Textularia, Trochammina, Spiroloculina, Quinqueloculina, Triloculina, Elphidium, Peneroplis, Operculina, Ammonia, Baculogypsina, Bolivina, Bulimina, Discorbis, Elphidium* and *Tinoporus*.

ETYMOLOGY: From the Latin "lene" meaning smooth and referring to the lack of ornament on the chambers.

Elphidium macellum (Fichtel & Moll)
Pl. 13, Figs 9–14

Nautilus macellus varietas B FICHTEL & MOLL 1798, p.68, pl. 10, figs.h,i,k.

Elphidium macellum (Fichtel & Moll). CUSHMAN 1939, p.51, pl.14, figs.1-3; PARR 1945, p.217; KLEINPELL 1954 (in part), p.43, pl.2, fig.9; COLLINS 1974, p.42; PALMIERI 1976a, p.372; PALMIERI 1976b, p.413; HUGHES 1977, p.48, pl.1, fig.16; ROGL & HANSEN 1984, p.50, pl.15, figs.1,2; YASSINI & JONES 1986, pl.7, figs. 6-8; ALBANI & YASSINI 1993, p.28, figs.68-71; YASSINI & JONES, 1995, p.177, figs.1020,1022-5.

Elphidium crispum (Linne). YASSINI & JONES 1988, p.263, fig.17, nos.5-6.

Elphidium jenseni (Cushman). ALBANI & YASSINI 1993, figs.49-50; LOEBLICH & TAPPAN 1994, p.169(part), pl.381, figs.6-11.

Elphidium sculpturatum CUSHMAN 1936, p.84, pl.15, figs.2a,b; CUSHMAN 1939, p.64, pl.18, fig.7.

Parrellina verriculata (Brady). LOEBLICH & TAPPAN 1994, p.170, pl.386, figs.11,12.

DESCRIPTION: Test large, involute; outline evenly rounded to very slightly lobulate; profile compressed with biconvex to flat sides; periphery acute with narrowly rounded keel; sides of final chamber flat to convex; chambers numerous (15–22) in adult whorl; anterior part of each chamber slightly raised and bearing a narrow radial rib that meets the peripheral keel; 7–15 narrow, elongate, septal bridges extend over most of the width of each chamber and often join posteriorly to the adjacent radial rib; sutures slightly depressed and strongly curved back towards the periphery; umbilical area open, depressed, with 6–10 narrow, stalked or irregular papillae. Greatest diameter 0.6–0.8 mm, width/thickness ratio 2.5–4.

REMARKS: Examination of the types of *E. sculpturatum* (CC15653, CC23030) from the Recent of Black Rock, Melbourne, Victoria, shows this species to be a junior synonym of *E. macellum*.

In the South-west Pacific, *E. macellum* is distinguished from other compressed species by its distinct, narrow, radial ribs that extend to meet the peripheral keel, and by its deeply depressed umbilical area with a few irregular papillae. Living forms of *E. macellum* in the Mediterranean Sea and Indian Ocean grow larger and are more involute with a flatter umbilical area than this Pacific form. Our material compares well with the lectotype illustrated by Rogl and Hansen (1984).

TYPE LOCALITY: Mediterranean Sea, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 19): *E. macellum* occurs widely throughout the Indo-Pacific and Mediterranean. In this study it is recorded from along the east coast of Australia (Queensland, New South Wales, Victoria, Tasmania) and around Lord Howe and Norfolk Islands, New Caledonia, Fiji, Tonga, Samoa, Vanuatu and the Solomon Islands.

ECOLOGIC DISTRIBUTION: *E. macellum* is a common species in normal salinity conditions on moderately sheltered beaches and at inner shelf depths throughout much of the South-west Pacific. It is sometimes reworked into bathyal depths. In eastern Australia *E. macellum* is frequently a major component of low tidal and shallow subtidal (0–20 m depth) foraminiferal associations, with faunas dominated by combinations of *Textularia, Quinqueloculina, Spiroloculina, Triloculina, Discorbis* and *Elphidium*. Around the tropical islands, *E. macellum* is a common member of foraminiferal faunas living in clean sand in coral-enclosed lagoons, bays and outer reef slopes in diverse faunas dominated by combinations of *Textularia, Quinqueloculina, Spiroloculina, Triloculina, Elphidium, Peneroplis, Amphistegina, Baculogypsina, Tinoporus, Discorbis* and *Operculina*.

ETYMOLOGY: From the Latin "macellus" meaning thin, presumably for the thin compressed test.

Elphidium matanginuiense **Hayward n.sp.**

Pl. 13, Figs 15–16; Pl. 14, Figs 1–2

Elphidium cf. *hampdenensis* Finlay. CAMPBELL *et al.* 1993, table 4.10.
Elphidium sp. CAMPBELL *et al.* 1993, table 4.10.

DESCRIPTION: Test of medium size; outline smoothly rounded to very slightly lobulate; profile compressed to biconvex; periphery acutely rounded, limbate, but not keeled; 12–15 chambers in adult whorl; strong, rounded radial rib developed along the proximal edge of each chamber; 5–7 very short, septal bridges span each suture between the radial ribs; sutures depressed, curved backwards towards the periphery and lined with small papillae around the larger tubercles; umbilical area filled with 4–7 large tubercles, level with the radial ribs. Maximum diameter 0.45–0.7 mm; width/thickness ratio 2.8–3.2.

REMARKS: This is the earliest species of *Elphidium* found in New Zealand and one of the oldest records in the world. It is unlike any other fossil or Recent species recorded from the South-west Pacific region, being characterised by its strong radial ribs and short tubercular septal bridges. It appears to possess the distinctive elphidiid characters of a sutural canal system and arched, pore-like apertures along the base of the apertural face.

TYPE LOCALITY: New Zealand, Chatham Island, South-west of Takapu Creek, (CH/f3), early Eocene (early Waipawan); Tumaio Limestone Member.

HOLOTYPE: TF1655/1

PARATYPES: 6 paratypes (TF1655/2-3); 4 paratypes (USNM487682) from the type locality.

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 34): *E. matanginuiense* is currently known only from the Chatham Islands, offshore to the east of New Zealand's South Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Early Eocene (early Waipawan to Mangapanian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: The faunal assemblages in which *E. matanginuiense* occurs are diverse and dominated by *Melonis, Bulimina, Cibicides, Alabamina, Lenticulina, Stilostomella, Pullenia, Gyroidina, Osangularia* and *Pleurostomella*. This assemblage is inferred to be representative of normal marine salinity at outer shelf or uppermost bathyal depths (c. 100–400 m, Hayward 1986).

ETYMOLOGY: Named after the locality (CH/f54) where it was first recognised, 0.5 km south of the mouth of Matanginui Stream, Chatham Island. This name was coined but never published by the late Dr Norcott Hornibrook, who first recognised that this form was a new species in the 1970s.

Elphidium matauraense Hayward n.sp.

Pl. 14, Figs 3–5

DESCRIPTION: Test of moderately small size; outline circular to very slightly lobulate; profile moderately compressed with parallel or slightly convex sides; acutely rounded periphery with a weak, broad, rounded keel or thickened band; 9–11 non-inflated chambers per adult whorl; radial ribs lacking; 8–10 short, narrow, septal bridges span each suture, separated by small sutural pits; sutural pits sometimes closed over towards the umbilicus; sutures narrow and slightly depressed, strongly curved backwards towards the periphery; umbilical area flat, filled with opaque shell wall; chamber walls finely perforate. Maximum diameter 0.3–0.4 mm; width/thickness ratio 2.2–2.8.

REMARKS: *E. matauraense* differs from *E. charlottense* by its more strongly involute coiling and weaker keel; from *E. advenum maorium* by its less inflated chambers and lack of a discrete umbonal boss; and from *E. albanii* by the fewer septal bridges and presence of a keel.

TYPE LOCALITY: New Zealand, Southland, Mataura drillhole, F46/f52 cuttings 78.68–78.73 m, Chatton Formation (Isaac & Lindqvist 1990), early Miocene (Waitakian or Otaian).

HOLOTYPE: TF1656/1

PARATYPES: 6 paratypes (TF1656/2-4), 2 paratypes (USNM487682) from type locality.

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 35): *E. matauraense* appears to be restricted to New Zealand, where it has only been found so far in Northland and Southland at opposite ends of New Zealand.

STRATIGRAPHIC DISTRIBUTION: Early Miocene (Waitakian to early Altonian).

PALEOECOLOGIC DISTRIBUTION: *E. matauraense* occurs in carbonaceous sandstone and muddy sandstone that were deposited during a marine incursion within the dominantly non-marine period of lignite accumulation in the Oligocene and Miocene in this region. The associated molluscs are a typical shallow inner shelf assemblage (Maxwell in Isaac & Lindqvist 1990, p. 28). The foraminiferal assemblages (e.g. F46/f42, f52) are dominated by *Notorotalia spinosa, Discorotalia tenuissima, Cribrorotalia* and *Elphidium*, that are inferred to have lived in moderately sheltered, normal salinity conditions at inner shelf depths (c. 5–50 m, Hayward & Hornibrook in Isaac & Lindqvist 1990, p. 32).

ETYMOLOGY: Named after the type locality, near Mataura. This name was coined but never published by the late Dr Norcott Hornibrook, who first recognised that this form was a new species in the early 1980s.

Elphidium mortonbayense Albani & Yassini

Pl. 14, Figs 6–9

Elphidium mortonbayensis ALBANI & YASSINI 1993, p.30, figs.74,78.

Elphidium discoidale multiloculum Cushman & Ellisor. ALBANI & YASSINI 1993, p.27, figs. 61,62; YASSINI & JONES, 1995, p.177, figs.1069-72.

Elphidium striatopunctatum (Fichtel & Moll). ALBANI & YASSINI 1993, p.30, figs.75-77.

Cellanthus discoidale (d'Orbigny). PALMIERI 1976a, p.372; PALMIERI 1976b, p.413.

Cellanthus multiloculus (Cushman & Ellisor). PALMIERI 1976a, p.372.

DESCRIPTION: Test large to moderately large; outline smoothly circular to slightly lobulate in later part of whorl; profile broadly biconvex, periphery acutely rounded with no single keel; 16–25 chambers in adult whorl; 7–9 strong, flattened septal bridges span the sutures; bridges link together towards the periphery on earlier chambers, to form several concentric ribs over and adjacent to the rounded periphery; sutures slightly depressed, straight to very slightly curved back towards the periphery and lined with very fine papillae; large, raised, shelly boss, spanning one quarter to one third diameter of test; umbonal boss with numerous large pits. Greatest diameter 0.6–1.0 mm; width/thickness ratio 1.8–2.2.

REMARKS: This species is characterised by its large, raised boss, its distinctive peripheral concentric ribs and its acutely rounded periphery. It is readily distinguished from *E. craticulatum* by its lack of a peripheral keel.

TYPE LOCALITY: Queensland, Morton Bay, Recent

TYPES: Holotype (Australian Geological Survey, CPC31040), paratypes (CPC31041).

GEOGRAPHIC DISTRIBUTION (Fig. 19): To date *E. mortonbayense* is only known from the Recent of Queensland and New South Wales, Australia (Albani & Yassini 1993, this study).

ECOLOGIC DISTRIBUTION: *E. mortonbayense* lives in normal marine salinity, in exposed to moderately sheltered situations at inner shelf depths, in diverse faunas dominated by combinations of *Textularia, Spiroloculina, Quinqueloculina, Triloculina, Peneroplis, Elphidium* and *Operculina*.

ETYMOLOGY: From the type locality in Morton Bay, Queensland.

Elphidium novozealandicum Cushman
Pl. 1, Fig. 9; Pl. 14, Figs 10–14

Elphidium novozealandicum CUSHMAN 1936, p.85, pl.15, fig.4a,b; CUSHMAN 1939, p.63, pl.17, fig.18; HORNIBROOK in FLEMING 1952, p.82; VELLA 1957, p.11,13; VELLA 1962, p.193; VELLA 1963, p.790; HULME 1964, p.338; KUSTANOWICH 1965, p.53,61; KENNETT 1966b, p.204; HEDLEY *et al.* 1967, p.47, pl.12, fig.4a,b; HORNIBROOK 1968, p.75,77; COLLEN 1973, pl.5, figs.7,10; GREGORY 1973, p.198, fig.2, no.8; TOPPING 1973, p.31, pl.9, fig.9; THOMPSON 1975, p.88; HOSKINS 1978, p.274, pl.4, fig.12; ADAMS 1979, p.145; LEWIS 1979, p.35; HAYWARD 1979, p.184; BROOK *et al.* 1981, p.90; HAYWARD 1981, p.132, fig.3e; HAYWARD 1982a, fig.5e; HAYWARD 1990b, p.96, fig.3f; HAYWARD & GRACE 1981, p.52; HAYWARD *et al.* 1984, p.162; COLLEN 1983, p.15,19,24,28,32. HORNIBROOK *et al.* 1989, p.92, fig.23:9; CAMPBELL *et al.* 1993, p.160; HAYWARD *et al.* 1994, fig.3P; COLLEN 1995, pl.10, figs.7-8.
Polystomella macella (Fichtel & Moll). BRADY 1884 (in part), p.737, pl.110, fig.8; HAEUSLER 1887, p.200; CUSHMAN 1919, p.633; HERON-ALLEN & EARLAND 1922, P.230.
Polystomella. MORTON & MILLER 1968, p.509, fig. 188.

DESCRIPTION: Large evenly rounded test, very compressed with acutely rounded periphery and blunt keel; 20 or more chambers in final whorl; strong reticulate ornament; narrow radial ribs; sutures depressed, curved backwards; 15 septal bridges, narrow, long, extending across each chamber; umbilical area slightly depressed with reticulate ornament of narrow ribs; wall finely perforate, glassy. Greatest diameter 0.5–0.8 mm; width/thickness ratio 3.5–4.8.

REMARKS: *E. novozealandicum* differs from *E. macellum* by having a less acute periphery and a depressed um-bilical area with reticulate ornament. A similar species occurring in the tropical Pacific and eastern Australia, *E. fichtellianum*, is distinguished by its finely tuberculate umbilical area.

TYPE LOCALITY: New Zealand, Fiordland, Dusky Sound, Recent.

TYPE SPECIMENS SEEN: Holotype (CC23046); 5 paratypes (CC9872).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs. 19, 24): *E. novozealandicum* is endemic to New Zealand, where it occurs between the Three Kings Islands in the north and Stewart and Antipodes Islands in the south, including the Chatham Islands out to the east.

ECOLOGIC DISTRIBUTION: A common species in moderately high energy areas on the inner shelf (*Quinqueloculina, Zeaflorilus* associations).

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 40): *E. novozealandicum* is also endemic to New Zealand in the fossil record. Apart from one South Island record it is only known from the North Island and Chatham Islands as fossils, in part reflecting the sparseness of the latest Miocene, Pliocene and Quaternary marine sedimentary record of the South Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Latest Miocene to Recent (Kapitean onwards).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. novozealandicum* is nowhere the dominant member of a fossil assemblages, but may occur as a codominant up to c. 10% relative abundance. It occurs in fossil faunas (e.g. Y14/f7841, V21/f8521, S27/f8587) dominated by the benthics *Haeuslerella, Textularia, Bolivina, Bolivinita, Cibicides, Elphidium, Notorotalia* and *Uvigerina,* that are inner and mid shelf assemblages (Hayward 1986).

It appears that *E. novozealandicum* has lived in normal salinity conditions at inner and sometimes mid shelf depths (c. 0–100 m) throughout its stratigraphic range.

ETYMOLOGY: From New Zealand.

Elphidium aff. **_novozealandicum_** Cushman
Pl. 1, Fig. 8; Pl. 14, Figs 15–17

Elphidium aff. *novozealandicum* Cushman. GIBSON 1967, p.54.
Discorotalia cf. *aranea* (Hornibrook). GIBSON 1967, pl.13, figs.210,211.

DISTINGUISHING FEATURES: Slightly evolute (esp. in N02/f7584), strongly compressed test; variable umbilical ornament with a spiral rib or irregular tubercles and ribs (esp. in V21/f8521, R13/f6009A). Greatest diameter 0.4–0.6 mm.

REMARKS: *E.* aff. *novozealandicum* appears to be a form with variable umbilical ornament predating *E. novozealandicum.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 40): This taxon is only known from New Zealand. It occurs throughout the different basins of the North Island but has not been recorded from the South Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Late middle Miocene to early Pliocene (Waiauan, Tongaporutuan and Opoitian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E.* aff. *novozealandicum* is a rare species, never found in relative abundances greater than c.1% of the total fauna. It occurs in some faunas (e.g. Y14/f7841, V21/f8521) with 10–30% planktics, dominated by *Haeuslerella, Textularia, Cibicides, Gyroidina, Lenticulina, Notorotalia* and *Uvigerina,* that are typically mid or outer shelf assemblages. It also occurs in some faunas (e.g. N02/f7584) with fewer than 5% planktics, dominated by *Amphistegina, Elphidium* and *Notorotalia,* that are clearly inner shelf assemblages (Hayward 1986).

It appears that *E.* aff. *novozealandicum* lived in low numbers in a wide range of normal salinity environments at inner to outer shelf depths (c. 0–200 m).

Elphidium oceanicum Cushman
Pl. 15, Figs 1–5

Elphidium oceanicum CUSHMAN 1933, p.52, pl.12, figs.7a-b; CUSHMAN 1939, p.59, pl.16, fig.23; COLLINS 1958, p.421.
Polystomella sp. CUSHMAN 1924, p.49, pl.16, fig.5.
Cribrononion schmitti (Cushman & Wickenden). ALBANI 1981, p.115, fig.40; ALBANI & YASSINI 1993, p.21, figs.27,28; YASSINI & JONES 1995, p.179, fig.1040,1042.

DESCRIPTION: Test of medium size; outline lobulate; profile moderately compressed with flat to concave sides; periphery broadly rounded with no keel; 8–12 slightly inflated chambers in adult whorl; 7–12 short (ca. 0.25 chamber width), narrow, septal bridges span the sutures; sutures quite deeply depressed, straight to slightly curved backwards towards the periphery; sutures lined with minute papillae at their umbilical end; umbilical area wide and depressed with numerous small papillae. Greatest diameter 0.35–0.45 mm; width/thickness ratio 3.

REMARKS: Examination of the types of *E. schmitti* (USNM20776, CC10562) from the Recent of Chile show it to be a distinctly different species, lacking septal bridges and with much larger and more prominent umbilical tubercles. *E. oceanicum* is one of many South-west Pacific species that lack a keel, have a lobulate outline and short retral processes. It is distinguished from *E. excavatum* by its wide, papillate umbilicus and looser coiling. It is very similar to the Eocene *E. schencki* from which it differs by its looser coiling, more numerous umbilical tubercles and more evenly rounded periphery..

TYPE LOCALITY: Fiji, Levuka, 25 m, Recent.

TYPE SPECIMEN SEEN: Holotype (CC15673).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 19): *E. oceanicum* occurs widely in the tropical South-west Pacific. In this study it is recorded from around the Solomon Islands, Lord Howe Island, Fiji, Samoa and Tonga. Albani & Yassini (1993) and this study record it from the east coast of Australia (Queensland, New South Wales, Victoria, Tasmania).

ECOLOGIC DISTRIBUTION: *E. oceanicum* is a common species in normal salinity conditions on beaches, in intertidal channels among mangroves and in inner shelf sediments in moderately sheltered environments such as inside fringe reefs and in sheltered passages. It occurs in faunas dominated by combinations of *Textularia, Trochammina, Spiroloculina, Peneroplis, Quinqueloculina, Triloculina, Ammonia, Bolivina, Discorbis, Elphidium* and *Haynesina.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 33): The only New Zealand record of *E. oceanicum* is from a warm interglacial association near East Cape, North Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: This species is only known in New Zealand from one specimen in the Pleistocene (Castlecliffian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: The only fossil specimen of this species in New Zealand occurs in the Te Piki Bed (East Cape), which has a rich macrofauna inferred to have accumulated in a sheltered muddy environment at 5–10 m depth (Grant-Mackie & Chapman-Smith 1971).

ETYMOLOGY: Presumably after its occurrence around the oceanic islands in the Pacific or oceania.

Elphidium phillipense new name
Pl. 15, Figs 6–9

Elphidium granulosum COLLINS 1974, p.43, pl. 3, figs.33a-c.

DESCRIPTION: Test of small size; involute; outline lobulate especially in adult part of whorl; profile moderately compressed with flat sides; periphery broadly rounded with no keel; 10–13 inflated chambers in adult whorl; ornament on last formed chambers consists of scattered, small, papillae which strengthen on earlier chambers into a mosaic of coarse overlapping granules; sutures distinctly depressed and most visible in the later part of the adult whorl; sutures straight to slightly curved; 5–7 short and extremely narrow, septal bridges usually ornamented with 3–4 papillae; umbilical area depressed and occupied by the irregular, granular ends of the chambers; apertural face ornamented with scattered papillae; chamber walls very finely perforate. Greatest diameter 0.3–0.35 mm; width/thickness ratio 1.8–2.2.

REMARKS: *E. granulosum* Collins is a homonym of *E. granulosum* (Sidebottom 1909 - described as *Polystomella macellum* var. *granulosum)* and therefore a new name is here proposed for the Australian species.

E. phillipense is similar to *E. excavatum* s.l. but differs in its coarse granular ornament. It differs from *E. gunteri* by its finely perforate walls. It has superficially similar coarse ornament to *E. hispidulum, E. collinsi* and *E. reticulosum* - the first two have umbonal bosses and keels and the latter develops reticulate ornament over the earlier chambers.

TYPE LOCALITY: Australia, Victoria, Port Phillip, Swan Bay north shore, stn. 49-C5, beach sand, Recent.

TYPE SPECIMEN SEEN: Holotype (Vict.Mus. F42145).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 19): This species is only known from its type locality in Victoria, Australia.

ECOLOGIC DISTRIBUTION: *E. phillipense* is only known from intertidal and shallow subtidal environments in slightly brackish to near normal salinity conditions in a moderately sheltered bay in faunas dominated by *Ammonia, Elphidium* and *Quinqueloculina.*

ETYMOLOGY: From the type locality in Port Phillip Bay, Victoria.

Elphidium pseudoinflatum Cushman
Pl. 15, Figs 12–18

Elphidium pseudoinflatum CUSHMAN 1936, p.80, pl.14, figs.5a,b; CUSHMAN 1939, p.41, pl.11, fig.8; HAYWARD & BUZAS 1979, p.53, pl.13, figs.166-168.

Elphidium nigarense CUSHMAN 1936, p.85, pl.15, figs.3a,b; CUSHMAN 1939, p.63, pl.17, fig.19; HAYWARD & BUZAS 1979, p.53, pl.13, figs.161-165.

Elphidium subinflatum CUSHMAN 1936, p.84, pl.15, figs.1a,b; CUSHMAN 1939, p.48, pl.12, fig.20.

Elphidium hornibrooki SRINIVASAN 1966, p. 248, pl.4, figs.8,12.

Elphidium aff. *hornibrooki* Srinivasan. LEITCH *et al.* 1969, p.29.

DESCRIPTION: Test of medium size; outline circular to very slightly lobulate; profile strongly inflated, biconvex with sides of apertural face distinctly convex; periphery acute with a strong, narrow keel; 8–13 slightly inflated chambers in adult whorl; a crisp, narrow, curved, radial rib runs along the slightly elevated proximal edge of each chamber, extending from the umbilicus one half to two thirds of the distance to the periphery; 5–10 narrow septal bridges span each suture; septal bridges generally span all or most of the width of each chamber in the early part of the whorl, producing a reticulate pattern of ornament; in the latter part of the whorl, septal bridges generally extend only one third to one half way across each chamber but in some specimens may extend the full distance; papillae fill the strongly curved, depressed sutures and also extend over large areas of the chambers and the apertural face; umbilicus usually narrow and deeply depressed, occasionally containing several small tubercles; wall finely perforate. Greatest diameter 0.5–0.75 mm; width/thickness ratio 1.7–2.

REMARKS: This species is characterised by the combination of strong inflation, distinct keel, heart-shaped apertural face, a deep narrow umbilicus and the reticulate ornament of narrow ribs and septal bridges, at least over the first half of the whorl. It is most similar to the middle Eocene *E. hampdenense* which always has reticulate ornament over the entire test and has a triangular apertural face. *E. hampdenense* also has a broader, blunter keel than *E. pseudoinflatum.*

Elphidium hornibrooki appears to be a junior synonym of *E. pseudoinflatum,* for although the original description and illustration of *E. hornibrooki* (Srinivasan 1966) are suggestive of *E. advenum* group, close examination of the holotype (VF619) clearly shows the presence of elevated, crisp radial ribs and septal bridges of variable length and the distinctive profile of *E. pseudoinflatum.*

TYPE LOCALITY: Australia, Victoria, Batesford, Lepidocyclina Limestone, Miocene.

TYPE SPECIMENS SEEN: Holotype (CC23545), 2 paratypes (CC23546).

PALEOGEOGRAPHIC DISTRIBUTION(Fig. 38): *E. pseudoinflatum* is known from both islands of New Zealand and from the Miocene of southern parts of Australia.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Late Eocene to middle Miocene (Runangan-Waiauan).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. pseudoinflatum* is never one of the dominant species in a fauna. It occurs in relative abundances up to c. 5%, and frequently less. In the Oligocene it occurs in faunas (e.g. R14/f6541, L28/f7504) with 0–10% planktics, dominated by the benthics *Amphistegina, Cancris, Cibicides, Cribrorotalia, Elphidium wadeae* and *Melonis maorica,* and inferred to have accumulated at inner shelf depths. In the Miocene, *E. pseudoinflatum* occurs in faunas (e.g. N02/f7554, M34/f7038, I38/f7628, D45/f8487) with c. 2–20% planktics, dominated by the benthics *Gaudryina, Textularia, Quinqueloculina, Amphistegina, Anomalinoides, Buliminella, Cibicides, Cribrorotalia, Elphidium crispum crispum, Lenticulina, Notorotalia spinosa* and *Pileolina,* and inferred to have accumulated mostly at inner shelf depths but in some instances (e.g. D45/f8477) perhaps at mid shelf depths.

It appears that *E. pseudoinflatum* lived in normal marine environments mostly at inner shelf depths (c. 0–50 m) in moderate to high energy situations, but at times perhaps as deep as mid shelf (up to 100 m).

ETYMOLOGY: Named for its resemblance to the inflated European Miocene species *E. inflatum.*

Elphidium reticulosum Cushman
Pl. 16, Figs 1–4

Elphidium reticulosum CUSHMAN 1933, p.51, pl.12, figs.5a,b; CUSHMAN 1939, p.59, pl.16, fig.24; HUGHES 1977, p.48, pl.2, fig.42.

DESCRIPTION: Test of medium size; outline slightly lobulate, especially in later part of whorl; profile moderately compressed with flat sides; periphery broadly rounded with no keel; 11–13 slightly inflated chambers in adult whorl; 7–9 short, indistinct septal bridges span the sutures between the last few chambers, but develop into long narrow concentric ribs that completely span each chamber earlier in the whorl, and join ribs from adjacent chambers to form disjointed, beaded radial ribs on each early chamber; these concentric and radial ribs form a dense reticulate ornament over the entire first half to two thirds of the whorl; later chambers have a surface texture of fine, irregular, anastomosing, short, worm-like riblets; sutures distinctly depressed, slightly curved and lined with minute papillae; umbilical area small, flat and covered with a mix of small and minute papillae; apertural face ornamented with minute papillae. Greatest diameter 0.4–0.5 mm; width/thickness ratio 2.5–3.

REMARKS: This species is characterised by its reticulate ornament. *Cristatavultatus pacificus* is distinguished by stronger and more irregular ribbed ornament, more lobulate periphery and more channelised sutures. *E. reticulosum* differs from the similar *Elphidium sharkianum* (from West Australia) by its stronger development of reticulate ornament and weaker radial ribs. It differs from *Elphidium hispidulum* by its more compressed profile, more broadly rounded periphery and weaker umbilical ornament.

TYPE LOCALITY: Tonga, Vava'u Anchorage, 36 m, Recent.

TYPE SPECIMENS SEEN: Holotype (CC15671); 1 paratype, Rotonga, 15 m (CC19901).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 20): This species appears to be restricted to the tropical to subtropical South-west Pacific islands. In this study we have recorded it from the waters around Fiji, Kermadec, Lord Howe, New Caledonia, Norfolk, Samoa, Solomon, Tonga and Vanuatu islands.

ECOLOGIC DISTRIBUTION: *E. reticulosum* is a reasonably common species in normal salinity, on sandy beaches, in intertidal channels among mangroves and at inner shelf depths (0–30 m) around many of the tropical islands. It occurs in faunas dominated by varying combinations of *Ammonia, Peneroplis, Quinqueloculina, Spiroloculina, Bolivina, Discorbis, Elphidium* and *Reusella.*

ETYMOLOGY: From its reticulate ornament.

Elphidium saginatum Finlay
Pl. 16, Figs 5–8

Elphidium saginatum FINLAY 1939, p.127, pl.12, figs.31-33; FINLAY 1940, p.457; WEBB 1970, fig.1, table 3; HORNIBROOK 1968, p.49,51; HORNIBROOK *et al.* 1989, p.92, fig.15:31; MALUMIAN 1990, p.359, pl.4, figs.7-8; KAIHO *et al.* 1993, p.77, pl.4, figs.26-28; CAMPBELL *et al.* 1993, table 4.15.

Elphidium lauritaense TODD & KNIKER 1952, p.19, pl.3, figs.36a.b.

DESCRIPTION: Test of medium to large size; outline smoothly circular, becoming slightly lobulate in larger specimens; profile strongly inflated with flat sides; periphery broadly rounded with no keel; 8–11 slightly inflated chambers in adult whorl; 4–6 broadly inflated, septal bridges span each suture and extend half to two thirds the distance across the chambers, producing a distinctive coarse reticulate ornament, especially in subadult tests; sutures straight and deeply depressed, giving the appearance of deep pits between the septal bridges; sutures lined with small papillae; umbilical area a small, deep, circular depression lined with small papillae; wall finely perforate and opaque. Greatest diameter 0.4–0.75 mm; width/thickness ratio 1.5–2.

REMARKS: *E. saginatum* is distinguished from other unkeeled species by its greater inflation, its near circular outline and its broad septal bridges that produce the characteristic coarsely reticulate ornament which distinguishes it from *E. excavatum* s.l..

TYPE LOCALITY: New Zealand, Wairarapa, Mangatoro (U24/f9142), middle Eocene (Porangan).

TYPE SPECIMENS SEEN: Holotype (TF1081/1), 3 paratypes (TF1081/2-4), 2 paratypes (USNM689074).

PALEOGEOGRAPHIC DISTRIBUTION (Fig. 33): *E. saginatum* occurs throughout the New Zealand region and has been recorded from Tierra del Fuego and Chile, South America (Todd & Kniker 1952, Malumian 1990).

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: *E. saginatum* has a restricted stratigraphic range in New Zealand, with its first appearance very close to the last appearance of *E. hampdenense.*

Its presence is used as the index species for the middle Eocene, Porangan stage, in New Zealand.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. saginatum* is not known to dominate any fossil faunas in New Zealand but occurs in abundances up to 10% of the total benthic foraminifera. The fauna of the type locality in Wairarapa is a typical mid bathyal assemblage being dominated by *Hyperammina, Ammodiscus, Cyclammina,* nodosariids, *Pleurostomella, Pullenia, Gyroidina, Bulimina bortonica, Osangularia* and *Cibicides parki. E. saginatum* occurs in similar mid bathyal assemblages in Canterbury (e.g. N33/f8168) and the Great South Basin (Pakaha-1, Pukaki-1, Kawau-1A, Raine *et al.* 1993). In Northland (e.g. O05/f7728), the Chatham Islands (e.g. CH/f507) and the Great South Basin (Toroa-1), *E. saginatum* occurs in somewhat shallower upper bathyal assemblages dominated by *Vaginulinopsis, Melonis, Cibicides parki, Bulimina, Cyclammina* and *Lenticulina. E. saginatum* is not known from typically shelf depth assemblages.

It appears that *E. saginatum* lived in normal marine salinity at upper and mid bathyal depths (c. 200–2000 m).

ETYMOLOGY: From the Latin "saginatus" meaning fattened.

Elphidium sandiegoense (Lankford)
Pl. 16, Figs 9–11

Cribrononion sandiegoense LANKFORD in LANKFORD & PHLEGER, 1973, p.118, pl.3, figs. 19a-b.

DESCRIPTION: Test of small size; outline circular; profile moderately compressed with parallel or slightly concave sides; acutely rounded periphery with no keel; 8–9 non-inflated chambers per adult whorl; radial ribs lacking; 1–3 extremely short, irregular septal bridges span each suture; a strong sutural pit occurs at the umbilical end of each suture adjacent to the umbilical suture; sutures deeply incised, slightly curved backwards towards the periphery;

umbilical area small, depressed, with a low circular collar; chamber walls finely perforate. Maximum diameter 0.25–0.35 mm; width/thickness ratio 1.8–2.2.

REMARKS: *E. sandiegoense* has a similar shape to *E. excavatum,* but differs in its more deeply incised sutures and lack of fine papillate sutural ornament. This species differs from the Miocene *E. vulgare* Voloshinova by its fewer septal bridges and fewer chambers.

TYPE LOCALITY: United States, California, San Diego, La Jolla Bay, 17 m, Recent.

TYPE SPECIMEN: Holotype (USNM188027).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 20): In the South-west Pacific region, *E. sandiegoense* is only known from the Great Barrier reef off Queensland, Australia.

ECOLOGIC DISTRIBUTION: This species occurs in normal marine salinity at inner shelf depths in a diverse fauna dominated by *Textularia, Spiroloculina, Quinqueloculina, Triloculina, Peneroplis, Operculina* and *Elphidium.*

ETYMOLOGY: After the type locality, near San Diego.

Elphidium schencki Cushman & Dusenbury
Pl. 16, Figs 12–15

Elphidium schencki CUSHMAN & DUSENBURY 1934, p.60, pl.8, figs.8a,b; CUSHMAN 1939, p.40, pl.10, fig.20.
Elphidium nitidum DORREEN 1948, p.290, pl.37, figs.11a-b.

DESCRIPTION: Test of medium size; outline circular to very slightly lobulate; profile moderately inflated with flat, parallel sides; periphery acutely rounded, no keel; 8–12 non-inflated chambers in adult whorl; no radial ribs; 6–9 low, broadly rounded, septal bridges span each suture, but generally do not extend onto the chamber surface; sutures narrowly incised, slightly curved backwards towards the periphery; umbilical area wide, depressed, filled with fine tubercles, which also extend as a narrow band around the whorl along the base of the apertural face; wall finely perforate. Greatest diameter 0.6 mm; width/thickness ratio 1.8–2.3.

REMARKS: Close examination of types of *E. nitidum* (CC64154, USNM688474) from New Zealand and a paratype of *E. schencki,* shows these two late Eocene species to be conspecific. The species is characterised by its moderate inflation, rounded periphery, non-inflated chambers, low septal bridges, and narrow sutures. It differs from the similar Recent species *E. oceanicum* by its tighter coiling, fewer umbilical tubercles and more acutely rounded periphery.

TYPE LOCALITY: United States of America, California, La Jolla, Murray County, Eocene.

TYPE SPECIMEN SEEN: 1 paratype (CC24102).

PALEOGEOGRAPHIC DISTRIBUTION (Fig. 33): *E. schencki* is known only from the late Eocene of California and New Zealand.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: This is a rare species in New Zealand, known only from the middle and possibly late Eocene (Bortonian and possibly up to Runangan) of Northland and the latest Eocene (Runangan) of Westland.

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. schencki* occurs in only a few New Zealand fossil samples and nowhere in abundances greater than c. 3%. In Westland (J32/f7848) it occurs in assemblages dominated by *Gaudryina, Asterigerina, Quinqueloculina, Reusella, Buliminella, Melonis, Cribrorotalia* and *Cibicides vortex.* This fauna is typical of inner shelf depths (c. 0–50 m). In Northland (e.g. Q08/f289, f9018), *E. schencki* occurs in faunas with less than c. 2% planktics and assemblages typical of inner shelf environments. It appears that *E. schencki* lived in normal salinity environments at inner shelf depths (c. 0–50 m).

ETYMOLOGY: Named after foraminiferal micropaleontologist, H.G. Schenck.

Elphidium silvestrii new name
Pl. 16, Figs 16–17

Polystomella macella var. *aculeatum* SILVESTRI 1901, p.45.
Elphidium macellum var. *aculeatum* (Silvestri). CUSHMAN 1939, p.52, pl.15, figs. 11-13; BARKER 1960, pl.110, fig.10.
Elphidium macellum aculeatum (Silvestri). ALBANI 1978, p.385, fig.9E; ALBANI & YASSINI 1993, p.29, fig.67; YASSINI & JONES 1995, p.178, fig.1019.

DESCRIPTION: Test small to medium size, involute; outline evenly rounded to very slightly lobulate; profile strongly compressed with flat sides; periphery acutely rounded with weak, narrowly rounded keel and short, needle-like spines arising from the radial ribs; sides of final chamber slightly convex; 13–17 chambers in adult whorl; anterior part of each chamber slightly raised and bearing a narrow radial rib that usually extends to the peripheral keel; 6–9 narrow, septal bridges extend about one half the width of each chamber; sutures slightly depressed and curved back towards the periphery; umbilical area open, flat or slightly depressed, with about 4–8 narrow, stalked or irregular papillae; granular wall texture, with fine papillae over most of chamber. Greatest diameter 0.3–0.6 mm; width/thickness ratio 3–4.

REMARKS: As noted by Barker (1960), *Elphidium aculeatum* (Silvestri) is a homonym of *Elphidium aculeatum* (d'Orbigny) and the latter has priority. Thus *Elphidium silvestrii* is here proposed as a new name for the former. *Elphidium silvestrii* is characterised by numerous short spines and a strongly compressed test. It further differs from *E. macellum* by its smaller test and significantly shorter septal bridges.

TYPE LOCALITY: Sicily, Contrada La Croce, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 20): This species has a sporadic distribution with records from the Mediterranean, south Atlantic and Australia. In the study region it has been recorded from the New South Wales and Victoria coast (Albani & Yassini 1993) of Australia and was found by us in Tasmania.

ECOLOGIC DISTRIBUTION: This species occurs in moderately sheltered, near normal salinity in the mouths of large harbours in diverse faunas dominated by *Reophax, Quinqueloculina, Trochammina, Elphidium, Zeaflorilus, Discorbis* and *Cibicides*.

ETYMOLOGY: Named after prominent Italian foraminiferal micropaleontologist A. Silvestri, who first recognised this species as a distinct entity.

Elphidium vavauense Hayward n.sp.
Pl. 17, Figs 1–3

DESCRIPTION: Test small to medium size; outline smoothly circular; profile biconvex; periphery acute with a narrow, rounded keel; 18–20 chambers in adult whorl; 7-8 narrow septal bridges span the sutures, becoming stronger and longer on early part of whorl and almost uniting into raised circular ribs; sutures slightly depressed, straight to very slightly curved back towards the periphery; prominent, raised, circular to subcircular, glassy boss with several prominent pits; boss surrounded by an area, up to half the diameter of the shell, covered by increasingly thickened shell; chamber walls lined with coarse papillae, becoming more raised and hispid over earliest chambers on the whorl. Greatest diameter 0.5–0.6 mm; width/thickness ratio 1.8–2.2.

REMARKS: This species is characterised by its raised, glassy boss, its coarsely papillate wall ornament and narrow peripheral keel. It is similar to the fossil New Zealand species *E. kanoum*, from which it is distinguished by its weaker septal bridges, especially on later parts of the whorl.

TYPE LOCALITY: Tonga, Vava'u, 30 m (F201081), Recent.

HOLOTYPE: TF1657/1

PARATYPES: 3 paratypes (TF1657/2-3); 3 paratypes (USNM487683) from type locality.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 20): This species is only known from the type locality in Tonga.

ECOLOGIC DISTRIBUTION: *E. vavauense* occurs in the deeper (30 m), sheltered parts of Vava'u Harbour in normal marine salinity in a diverse fauna dominated by *Textularia, Quinqueloculina, Operculina, Cibicides, Tinoporus* and *Amphistegina*.

ETYMOLOGY: From the type locality, Vava'u Island, Tonga.

Elphidium vellai Hayward n.sp.
Pl. 17, Figs 4–7

DESCRIPTION: Test of small to medium size; outline circular to slightly lobulate; profile moderately compressed with parallel or slightly concave sides; broadly rounded periphery with no keel; 8–9 slightly inflated chambers per adult whorl; radial ribs lacking; 3–6 short, septal bridges span each suture; sutures depressed, straight to slightly curved backwards towards the periphery, and lined with sparse fine papillae; umbilical area small, depressed, lacking tubercles; chamber walls coarsely perforate and usually golden brown; apertural face finely perforate. Maximum diameter 0.35–0.45 mm; width/thickness ratio 2.3–2.7.

REMARKS: *E. vellai* has similar coarsely perforate wall texture, brown colour and overall shape to *E. gunteri*, from which it differs in its shorter septal bridges and lack of umbilical tubercles. It differs from *E. excavatum* group by its coarser wall texture. *E. vellai* is similar to the coarsely perforate Caribbean species, *E. poeyanum* (Pl. 15, Figs 10–11), from which it differs by its colour, thicker shell, and more inflated profile. *E. vellai* differs from the Recent *E. wordeni* McCulloch (1977) in its more coarsely perforate walls, its golden brown colour and more regular septal bridges.

TYPE LOCALITY: New Zealand, South Island, Marlborough, Queen Charlotte Sound, off Ship Cove, 16 m, L631, Recent.

HOLOTYPE: TF1658/1

PARATYPES: 7 paratypes (TF1658/2-3); 9 paratypes (AK74001); 9 paratypes (USNM487684) from type locality.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs 20, 24): *E. vellai* seems to be endemic to New Zealand, where it is currently only known from the Marlborough Sounds area in the northern South Island and in the Waitemata Harbour in the North Island.

ECOLOGIC DISTRIBUTION: *E. vellai* occurs in near normal salinity waters in muddy sand in the semi-exposed open mouth of Queen Charlotte Sound, Marlborough. We have recorded it from depths ranging between 0.5 and 40 m, with its greatest abundance (20–40% of the fauna) at 10–20 m depth, in association with common *Notorotalia, Evolvocassidulina, Haynesina, Loxostomum, Bulimina* and *E. charlottense*.

ETYMOLOGY: After prominent New Zealand foraminiferal micropaleontologist, Paul Vella, whose pioneer study of New Zealand's Recent foraminifera (Vella, 1957) included the description of *E. charlottense* from the type area of this species.

Elphidium vitreum Collins
Pl. 1, Fig. 1–2

Elphidium vitreum COLLINS 1974, p.43, pl.3, figs. 35a-c.

DESCRIPTION: Test of small to medium size; outline circular, slightly lobulate; profile moderately compressed with parallel or slightly convex sides; acutely rounded periphery with no keel nor thickened band; 12–15 non-inflated chambers per adult whorl; surface ornament lacking; short, septal bridges span each suture beneath translucent, imperforate shell that fills each suture; sutures straight to slightly curved backwards towards the periphery, narrow and flush with chamber surfaces; thread-like septal canals visible through translucent walls; umbilical area flat, filled with transparent glassy, imperforate umbo; apertural face ornamented with fine papillae; chamber walls finely perforate and glassy. Maximum diameter 0.3–0.6 mm; width/thickness ratio 2.2–2.6.

REMARKS: *E. vitreum* is distinguished from all other species in the South-west Pacific by its glassy, translucent walls and flush, glassy sutures through which internal septal bridges can be easily seen.

TYPE LOCALITY: Australia, Victoria, Port Phillip survey stn. 62-99, (Vict.Mus. F42261), Recent.

TYPE SPECIMENS SEEN: Holotype (Vict.Mus. F42147).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 21): *E. vitreum* appears to be endemic to Victoria, southern Australia, where it is known only from just inside the entrance to Port Phillip Bay.

ECOLOGIC DISTRIBUTION: *E. vitreum* is only known from relatively sheltered subtidal sand in normal salinity (Collins 1974), in a fauna dominated by *Quinqueloculina, Triloculina, Elphidium, Ammonia* and *Rosalina.*

ETYMOLOGY: Named for its glassy or vitreous appearance.

Elphidium wadeae (Hornibrook)
Pl. 17, Figs 8–13

Parrellina wadeae HORNIBROOK 1961, p.142, pl.18, fig.386, pl.28, figs.548,549; HORNIBROOK 1996, p. 39, pl. 19, figs.7-9.

DESCRIPTION: Test of medium to large size; outline smoothly circular to slightly lobulate; profile moderately compressed with flat or slightly convex sides; periphery acute with strong, narrow keel; 12–20 non-inflated chambers in adult whorl; sutures depressed, strongly curved back towards periphery; leading edge of each chamber slightly raised, with a narrow radial rib especially at the umbilical end or disjointed sections of rib or no rib at all; 5–9 narrow, long, septal bridges extend most or all of the way across each chamber; sparse, coarse papillae ornament chambers between septal bridges and cover much of the apertural face; shallow umbilical area filled with a cluster of tubercles. Greatest diameter 0.5–0.8 mm; width/thickness ratio 2.8–3.2.

REMARKS: *E. wadeae* is characterised by its strong, narrow septal bridges and keel; irregular or absent radial ribs and its umbilical tubercles. It is most similar to *E. kanoum* which has a glassy umbonal boss rather than umbilical tubercles. It also resembles *Parrellina verriculata* from the Australian Recent, but *E. wadeae* differs in lacking any slightly wavy ribs and in having papillae over the apertural face rather than fine ribs. *E. wadeae* lacks the ornament typical of the Notorotaliinae and is clearly more closely associated with some *Elphidium* species than our restricted concept of *Parrellina.*

TYPE LOCALITY: New Zealand, Southland, Chatton, G45/f8499, late Oligocene (Duntroonian).

TYPE SPECIMENS SEEN: Holotype (TF1429/1), 2 paratypes (TF1429/2).

PALEOGEOGRAPHIC DISTRIBUTION (Fig. 39): *E. wadeae* has only been recorded from New Zealand, with scattered Oligocene occurrences in both islands and early Miocene occurrences in the South Island.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Early Oligocene to early Miocene (early Whaingaroan to Otaian).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *E. wadeae* is never a dominant member of benthic foraminiferal associations, but may occur in relative abundances up to c. 5% of the total fauna. Most of these faunas (e.g. R14/f6541, I38/f7607, L28/f7504, F45/f9494) contain less than 5% planktics and are dominated by combinations of *Textularia, Quinqueloculina, Amphistegina, Bolivina, Buliminella, Cibicides. Cribrorotalia, Elphidium crispum crispum, Gyroidina allani, Melonis* and *Notorotalia.* These faunas are typical of inner shelf depths (c. 0–50 m). *E. wadeae* occurs in low numbers in a few faunas (e.g. M34/f71) with c. 30% planktics and dominated by *Haueslerella, Anomalinoides, Bolivina, Bulimina pupula, Cibicides, Lenticulina, Nonionella* and *Notorotalia.* These faunas are typical of mid to outer shelf depths (Hayward 1986).

It appears that *E. wadeae* lived in normal marine environments mostly at inner shelf depths (c. 0–50 m) in moderate to high energy situations.

ETYMOLOGY: Named "after Mary Wade, of the University of Adelaide, in recognition of her valuable contribution to the knowledge of *Parrellina* (Wade, 1957)" - Hornibrook (1961).

Subfamily Notorotaliinae Hornibrook, 1961

Diagnosis: Test trochospiral.

South-west Pacific Constituent Genera:
Cribrorotalia, New Zealand, Australia, Eocene-Miocene
Cristatavultatus, Australia, SW Pacific islands, Recent
Discorotalia, New Zealand, Oligocene-Miocene
Notorotalia, New Zealand, Australia, Eocene-Recent
Parrellina, Australia, ?Oligocene-Recent

Genus *Cristatavultatus* Loeblich & Tappan

Cristatavultatus Loeblich & Tappan, 1994

Type Species: *Elphidium pacificum* Collins, 1958

Diagnosis: Test inflated, irregularly trochospiral; crisp irregular ribs over chambers and fine ribs extend over apertural face; aperture a single, large opening at the base of the apertural face.

Remarks: This genus differs from all others in the Notorotaliinae by its single, high aperture.

South-west Pacific Constituent Species:
C. pacificus Australia, SW Pacific islands

Cristatavultatus pacificus (Collins)
Pl. 17, Figs 14–15; Pl. 18, Figs 1–3

Elphidium pacificum COLLINS 1958, p.421, pl.5, fig.13.
Parrellina pacifica (Collins). HATTA & UJIIE 1992, p.204, pl.49, figs.8a-b, pl.50, figs.1a-c.
Elphidium millettiforme McCULLOCH 1977, p.222-3, pl.97, fig.12.
Polystomella milletti (Heron-Allen & Earland). CUSHMAN 1924, p.48, pl.16, figs.8,9.
Elphidium milletti (Heron-Allen & Earland). CUSHMAN 1933, p.49, pl.11, figs.8a,b; CUSHMAN 1939, p.58, pl.16,figs.22a,b; ALBANI 1968b, p.34, fig.156.
Cristatavultatus pacificus (Collins). LOEBLICH & TAPPAN 1994, p.168, pl.377, figs.7,8, pl.378, figs.1-3.
Cristatavultatus milletti (Heron-Allen & Earland). LOEBLICH & TAPPAN 1994, p.168, pl.377, figs.1-6.

Description: Test small to medium size, slightly trochospiral; outline lobulate; profile ovate, with involute side nearly flat and evolute side convex; periphery very broadly rounded; 7–9 strongly inflated chambers in adult whorl; sutures deeply impressed to channelised, radial; no radial or sutural ribs; numerous, narrow, fine, irregular, transverse riblets ornament the later chambers, and develop into an anastomosing network of crisp, sharp ridges on earlier chambers; apertural face ornamented with narrow, fine riblets radiating outwards from around the aperture; aperture a large semicircular opening located at the base of the apertural face; coarsely perforate wall texture. Greatest diameter 0.8–1.0 mm; width/thickness ratio 3.2–3.6.

Remarks: This species has for many years been confused with *Elphidium milletti* from the west Indian Ocean. Close examination shows the two species to be quite distinct and that *E. milletti* may be best placed in the genus *Parrellina*. *Cristatavultatus pacificus* differs from *Parrellina milletti* in its slight trochospiral coiling, its more deeply incised sutures, its stronger ribs and much larger aperture.

Type Locality: Not designated, but Collins (1958) material is from 600 m depth in Trinity Opening, off the Great Barrier Reef, Queensland, Recent.

Present-day Geographic Distribution (Fig. 21): *Cristatavultatus pacificus* occurs in the tropical West Pacific, from the Ryukyus Islands (Hatta & Ujiie 1992), Philippines (McCulloch 1977), northern Australia (Loeblich & Tappan 1964), Queensland, Vanuatu, Fiji, Tonga and Samoa (this study).

Ecologic Distribution: *C. pacificus* appears to live in normal marine salinity at inner shelf depths on the sandy slopes of coral reefs around the tropical shores of Queensland and many Pacific islands. It occurs in faunas dominated by combinations of *Textularia, Quinqueloculina, Spiroloculina, Amphistegina, Elphidium, Operculina* and *Reusella.* Small numbers of specimens, including the holotype, have come from greater depths and are inferred to have been transported downslope following their death.

Etymology: Name refers to this species' distribution in the Pacific Ocean.

Genus *Discorotalia* Hornibrook, 1961

Discorotalia Hornibrook, 1961

Type Species: *Polystomella tenuissima* Karrer, 1864

Diagnosis: Test compressed, discoidal; partly evolute on the spiral side, involute on the umbilical side; no umbilical plug; surface with narrow intersutural ribs extending between sutural ribs; aperture consisting of small rimmed areal pores near the base of the apertural face.

Remarks: *Discorotalia* is distinguished from the more common and widespread southern Hemisphere genus *Notorotalia* by its more compressed, discoidal test and incompletely trochospiral coiling.

New Zealand Paleogeographic Distribution (Fig. 41): *Discorotalia* appears to be endemic to New Zealand.

South-west Pacific Recent Species: None

Fossil New Zealand Species:
D. aranea New Zealand early-middle Miocene
D. tenuissima New Zealand, Oligocene- middle Miocene

New Zealand Stratigraphic Range: Oligocene-Miocene.

Discorotalia aranea (Hornibrook)
Pl. 18, Figs 4–6

Notorotalia aranea HORNIBROOK 1958, p.662, figs.12-14.
Discorotalia aranea (Hornibrook). HORNIBROOK *et al.* 1989, p.155, figs.36:2a-c.

DESCRIPTION: Small evenly rounded test; strongly compressed with acutely rounded periphery, lacking a distinct keel; involute on one side and partly evolute on the other; 14–15 chambers in adult whorl; chambers curved strongly backwards towards periphery; strong reticulate ornament consisting of narrow, radiating, sometimes discontinuous sutural ribs, and 3–5 narrow transverse ribs extending 0.5 to 0.8 of the width of each chamber; umbilical ornament of irregular narrow ribs; apertural face relatively smooth. Greatest diameter 0.25–0.35 mm; width/thickness ratio 4–5.

REMARKS: *D. aranea* is distinguished from *D. tenuissima* by its smaller size, its more numerous chambers, its fewer transverse ribs and its lack of peripheral keel.

TYPE LOCALITY: Otago, Oamaru, J41/f8790, Old Rifle Butts, early Miocene (Altonian).

TYPE SPECIMEN SEEN: Holotype (TF1331/1).

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 41): *D. aranea* is only known from the South Island of New Zealand. It occurs throughout the South Island (West Coast, Canterbury and Southland Basins) in the early Miocene, but appears to persist after this only in the Southland Basin.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Early to middle Miocene (Otaian-Waiauan).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *D. aranea* has always been found in low relative abundances (c. less than 2% of total benthic fauna). It occurs in faunas (eg. M34/f7038, J41/f8793, D45/f8624) with 2–20% planktics, dominated by combinations of the benthics *Haeuslerella, Quinqueloculina, Anomalinoides, Cibicides, Bolivina, Discorotalia tenuissima, Florilus, Nonionella* and *Notorotalia,* that are inferred to have accumulated in a variety of inner, mid and perhaps outer shelf environments (c. 10–150 m depth).

It appears that *D. aranea* lived in normal salinity conditions, with greatest abundance at mid shelf depths (c.50–100 m) but also extending into inner and outer shelf depths.

ETYMOLOGY: Name refers to this species' mostly sandy (or arenaceous) habitat.

Discorotalia tenuissima (Karrer)
Pl. 1, Fig. 5; Pl. 18, Figs 7–9

Polystomella tenuissima KARRER 1864, p.80, pl.16, fig.12.
Discorotalia tenuissima (Karrer). HORNIBROOK 1961, p. 141, pl.18, figs.387-8, pl.28, fig.547; HORNIBROOK 1968, p.98, fig.20; HOFKER 1969, p.470, figs.45-56; HORNIBROOK 1971, p.21, pl.3, figs.50-54; HORNIBROOK *et al.* 1989, p.155, figs.36:1a,b; HORNIBROOK 1996, p. 39, pl. 19, figs.1-6.
Polystomella macella Fichtel & Moll. CHAPMAN 1926, p.89, pl. 1, figs.15,16, pl.17, fig.13.

DESCRIPTION: Moderately large evenly rounded test, strongly compressed with acutely rounded periphery and weak, narrow, rounded keel; involute on one side and partly evolute on the other; 10–15 chambers in adult whorl; chambers curved strongly backwards towards periphery; strong reticulate ornament consisting of narrow, radiating sutural ribs, sometimes discontinuous towards the periphery, and 7–8 narrow transverse ribs extending most or all the full width of each chamber; umbilical ornament of irregular narrow ribs; chamber walls ornamented with very fine papillae; apertural face ornamented with fine papillae, a straight, very fine riblet running up the centre and short radiating riblets on each side. Greatest diameter 0.45–0.9 mm; width/thickness ratio 3.5–5.

REMARKS: *D. tenuissima* is distinguished from *D. aranea* by its larger size, coarser ornament and greater degree of uncoiling on the evolute side.

TYPE LOCALITY: R11/f7555, Auckland, Hobson Bay, Orakei Greensand, early Miocene (Otaian).

TYPE SPECIMENS SEEN: Matched topotypes (FP2019-20).

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 41): *D. tenuissima* is apparently endemic to New Zealand, where it occurs throughout the country in the Oligocene and early Miocene, although it is more common and abundant in the south than the north. *D. tenuissima* persists into the middle Miocene but is only known in the South Island during this period.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Early Oligocene to middle Miocene (late Whaingaroan-Waiauan).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *D. tenuissima* is not a dominant member of any known fauna but may occur in relative abundances up to c. 5% of the total benthic foraminifera. In the Oligocene (e.g. L28/f7504, I38/f7628) it occurs in faunas with c. 1–10% planktics, dominated by the benthics *Gaudryina, Textularia, Amphistegina, Bolivina, Buliminella, Cibicides, Cribrorotalia, Elphidium crispum crispum, Discorbis, Globocassidulina* and *Melonis maorica,* and inferred to have lived at inner shelf depths. In the Miocene (e.g. M34/f7038, I38/f7607, J41/f8498, D45/f8487) *D. tenuissima* mostly occurs in faunas with c. 2–10% planktics, dominated by combinations of the benthics *Gaudryina, Textularia, Quinqueloculina, Amphistegina, Bolivina, Buliminella, Cibicides, Cribrorotalia, Discorbis, Florilus stachei, Melonis, Notorotalia spinosa* and *Pileolina,* and inferred to be inner shelf assemblages from exposed to moderately sheltered environments (Hayward 1986). *D. tenuissima* also occurs occasionally in lower abundances in faunas (e.g. M34/f71, J41/f8498, D45/f8477) with 20–30% planktics, dominated by benthics *Haeuslerella, Anomalinoides, Bolivina, Cibicides, Ehrenbergina, Gyroidina, Lenticulina, Nonionella* and *Notorotalia,* that are inferred to have lived at mid to outer shelf depths (Hayward 1986)

It appears that *D. tenuissima* lived in normal marine salinity, in greatest abundance at inner shelf depths (c. 0–50 m), in high to moderate energy situations. It may also lived in lower abundances at mid to outer shelf depths (c. 50–200 m), although postmortem transport down into these depths cannot be discounted.

ETYMOLOGY: From the Latin "tenuis" meaning thin, presumably referring to the thin, flattened shell.

Genus *Parrellina* Thalmann, 1951

Parrellina Thalmann 1951
Elphidioides Parr, 1950 (non *Elphidioides* Cushman, 1945)

TYPE SPECIES: *Polystomella imperatrix* Brady, 1881, p.66.

DIAGNOSIS: Test planispiral, bilaterally symmetrical, involute to slightly evolute; sutural canal system opens into a single row of indistinct pores, quite different from the characteristic sutural fossettes of *Elphidium*; narrow, raised, often slightly wavy sutural ribs, linked by a series of similar intersutural ribs, at times forming an anastomosing pattern of ornament; apertural face strongly ornamented all over with radiating pustules and/or fine ribs; aperture a series of large circular pores at base of apertural face.

REMARKS: In our opinion this genus, characterised by its type species *P. imperatrix,* is closely linked to *Notorotalia* and has not evolved from *Elphidium.* We restrict it purely to those species having typical *Notorotalia*-like ornament, with narrow, raised, often slightly wavy sutural and intersutural ribs, radiating ribs on the apertural face and lacking the characteristic sutural fossettes and septal bridges of the Elphidiidae.

There has been considerable confusion as to the diagnostic characteristics of this genus, which have led to differing opinions as to which subfamily or family it should be placed in. We follow Hornibrook (1961), Hofker (1969) and Loeblich & Tappan (1988) in placing it in the Notorotaliinae of the Elphidiidae. We note that Hornibrook (1996) has proposed raising the status of the Notorotaliinae to family level.

SOUTH-WEST PACIFIC CONSTITUENT SPECIES:
P. imperatrix Australia
P. papillosa Australia
P. verriculata Australia

PRESENT-DAY GEOGRAPHIC RANGE: Australia

Parrellina imperatrix (Brady)
Pl. 18, Figs 10–12

Polystomella imperatrix BRADY 1881, p.66, pl.110, figs.13-15.
Elphidioides imperatrix (Brady). PARR 1950, p.373.
Elphidium imperatrix (Brady). PARR 1945, p.217; ALBANI 1968a, p.112, pl.9, figs.13-14; ALBANI 1968b, p.34, fig.154; ALBANI 1970, p.73.
Parrellina imperatrix (Brady). THALMANN 1951, p.224; HOFKER 1969, p.478, figs. 57-73; LOEBLICH & TAPPAN 1964, fig.513(3); PALMIERI 1976b, p.414; YASSINI & JONES 1988, p.263, fig.17, nos.1-2; ALBANI & YASSINI 1993, p.32, figs.83-87; YASSINI & JONES 1995, p.180, figs.1044-5.

DESCRIPTION: Test large, slightly evolute; profile strongly compressed and parallel-sided; periphery acute with narrow keel and 4–5 strong, rod-like peripheral spines per whorl; 12–17 slightly inflated chambers in adult whorl; sutural ribs narrow, fine, slightly irregular; sutures flush to slightly depressed, curved backwards towards the periphery; 8–12 narrow, wavy or irregular, transverse ribs extend over the full width of each chamber; sutural and transverse ribs become irregular and anastomosing over the wide, flat umbilical area; numerous fine papillae cover the test wall between the ribs; apertural face ornamented with fine, papillate riblets radiating out from the apertural area. Greatest diameter 0.8–1.0 mm; width/thickness ratio 3–4.

REMARKS: *Parrellina imperatrix* is the genotype of *Parrellina* and is easily distinguished by its 4–5 long, solid spines per whorl.

TYPE LOCALITY: Not given by Brady, presumably Australia, Sydney, 4-20 m, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 21): *P. imperatrix* is only recorded from the coast of Australia (Queensland, New South Wales, Victoria and Tasmania).

ECOLOGIC DISTRIBUTION: *P. imperatrix* lives around the coast of eastern Australia in normal marine salinity, mostly at inner shelf depths. It is particularly common in the open mouths of large estuaries and bays at 5–30 m depth (e.g. Albani 1968, 1978) in association with faunas dominated by combinations of *Reophax, Textularia, Gaudryina, Spiroloculina, Quinqueloculina, Peneroplis, Triloculina, Discorbis* and *Elphidium.*

ETYMOLOGY: From the Latin "imperator" meaning emperor, possibly because the peripheral spines may be said to produce a crown effect.

Parrellina papillosa (Cushman)
Pl. 18, Figs 13–14

Elphidium papillosum CUSHMAN, 1936, p.83, pl.14, fig.12.
Parrellina papillosa (Cushman). ALBANI 1978, p.388, fig.9G; ALBANI & YASSINI 1993, p.32, figs.88-89,92-93; YASSINI & JONES 1995, p.181, figs.1063-5.
Parrellina verriculata (Brady). HOFKER 1969, figs.77-78.

DESCRIPTION: Test large; outline smoothly circular; profile moderately compressed with flat sides; periphery broadly rounded with no keel; non-inflated chambers, sutures and flat umbilical area completely obscured by ornament; ornament of numerous, large, close-spaced papillae often fused together in twos or threes to form short wavy or worm-like irregular costae; papillae around the periphery on the early part of the whorl are stronger and more regularly circular; apertural face ornamented with numerous, wavy, radiating riblets and papillae; chamber walls not visible. Greatest diameter 1.0–1.5 mm; width/thickness ratio 2.0–2.5.

REMARKS: The shape, ornament style and apertural face characters all suggest that this species is most appropriately placed in the genus *Parrellina*, even though it lacks the typical narrow, wavy sutural and intersutural ribs. *Parrellina papillosa* is readily distinguished from all others by its dense ornament that obscures all chambers and sutures.

TYPE LOCALITY: Australia, New South Wales, 25 km east of Wollongong, 200 m, Recent.

TYPE SPECIMENS SEEN: Holotype (CC23027), 2 paratypes (CC23026).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 21): *P. papillosa* appears to be endemic to the east coast of Australia where it is only recorded from New South Wales and Queensland (Albani & Yassini 1993, this study).

ECOLOGIC DISTRIBUTION: *P. papillosa* lives in normal marine salinity at inner shelf depths and possibly deeper, especially in the open entrance to large harbours or bays (e.g. Albani 1978) in association with *Textularia, Quinqueloculina, Triloculina, Cibicides, Elphidium* and *Rosalina*.

ETYMOLOGY: For its papillose surface ornament.

Parrellina verriculata (Brady)
Pl. 19, Figs 1–3

Polystomella verriculata BRADY 1881, p.66; BRADY 1884, p.738, pl.110, fig.12; CHAPMAN, 1907, p.142, pl.10, fig.10; CUSHMAN 1939, p.61, pl.17, fig.13.
Elphidium jenseni (Cushman). YASSINI & JONES 1988, p.263, pl.17, nos.7-8.
Elphidioides verriculatus (Brady). PARR 1950, p.374, pl.15, fig.17.
Parrellina verriculata (Brady). ALBANI & YASSINI 1993, p.34, figs.97-102, 105; HOFKER 1969, p.478, figs.74-76, 79-85; PALMIERI 1976b, p.414; YASSINI & JONES 1995, p.181, figs.1014,1041,1062.

DESCRIPTION: Test large, involute; profile strongly compressed and parallel-sided; periphery broadly rounded with or without a narrow irregular keel; 11–14 non-inflated chambers in adult whorl; sutural ribs narrow, fine, slightly wavy; sutures flush, curved backwards towards the periphery; 8–10 narrow, wavy or straight, transverse ribs extend over the full width of each chamber, linking up with the sutural ribs on both sides; sutural and transverse ribs are more irregular and anastomosing over the earlier chambers in the whorl and may form a strong regular reticulate pattern over the later or more adult chambers; flat umbilical area filled with several small wavy ribs or strong papillae; numerous fine papillae may cover the test wall between the ribs; apertural face ornamented with narrow, fine riblets radiating outwards from the apertural area. Greatest diameter 0.8–1.0 mm; width/thickness ratio 3.2–3.6.

REMARKS: *Parrellina verriculata* is very similar to *Parrellina imperatrix*, from which it is mainly distinguished by the lack of peripheral spines.

TYPE LOCALITY: Not stated, but probably the site of Brady's figured specimen in Bass Strait, Challenger Station 162, 80 m, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 21): *P. verriculata* appears to be endemic to the east coast of Australia, where it has been recorded from the coast of Queensland to Victoria (Brady 1884, Albani & Yassini 1993, Collins 1974, this study).

ECOLOGIC DISTRIBUTION: *P. verriculata* lives in normal marine salinity at inner shelf depths and possibly deeper, especially in the open entrance to large harbours or bays (e.g. Collins 1974) in association with *Textularia, Quinqueloculina, Triloculina, Cibicides* and *Elphidium*.

ETYMOLOGY: From the Latin "verriculum" meaning net, probably relating to the surface rib ornament.

Family NONIONIDAE

DIAGNOSIS: Test planispiral to slightly asymmetrical; wall usually optically granular, rarely radial; no sutural canal system, septal bridges or retral processes.

Genus *Haynesina* Banner & Culver

Haynesina Banner & Culver, 1978

DIAGNOSIS: Test planispiral, bilaterally symmetrical; sutures radial, slightly curved, deeply incised near the umbilicus; chamber walls bend inward posteriorly and fuse to the preceding septal face to form narrow intercameral lacunae; umbilicus narrow, open; tubercles cover base of apertural face, umbilicus and inner part of sutures; primary aperture a low interiomarginal arch; internally an interiomarginal aperture connects intercameral lacunae to the following chamber; supplementary areal apertures may connect lacunae to both preceding and following chambers.

REMARKS: This genus is distinguished from *Elphidium* by the absence of septal bridges and numerous interiomarginal apertures; from *Nonion* by the presence of intercameral lacunae, open tuberculate umbilici and optically radial walls.

Haynesina depressula (Walker & Jacob)

Nautilus depressulus WALKER & JACOB 1798, p.641, fig.33.

DESCRIPTION: Planispiral, evenly rounded to lobulate, involute test; compressed with rounded periphery; 8–14 chambers in final whorl; sutures curved backwards, slightly depressed in early portion, becoming deeply depressed; large umbilicus filled with tubercles which extend along the sutures producing a star shape; aperture a series of pores at base of apertural face, partly obscured by tubercular ornament; very finely perforate wall texture. Greatest diameter 0.3–0.65 mm; width/thickness ratio 2.1–2.9.

REMARKS: This species name is applied in the sense of Hayward and Hollis (1994). It appears that the species attains a greater size and is less compressed in the Southwest Pacific than is known in the British Isles where its greatest diameter rarely exceeds 0.4 mm and inflation is usually > 3 (Murray 1965; Haynes 1973).

Two subspecies are recognised in this study, one without an umbonal boss (ssp. *depressula)* and one with an umbonal boss (ssp. *simplex)*.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION: *Haynesina depressula* is widespread in nearshore environments in both the Pacific and Atlantic Oceans.

SOUTH-WEST PACIFIC CONSTITUENT SPECIES AND SUBSPECIES:
H. depressula depressula Australia, New Zealand, SW Pacific islands
H. depressula simplex Australia, SW Pacific islands

NEW ZEALAND FOSSIL SPECIES AND FORMS:
H. depressula depressula New Zealand

NEW ZEALAND STRATIGRAPHIC RANGE: Oligocene to Recent.

Haynesina depressula depressula (Walker & Jacob)
Pl. 1, Figs 6,10; Pl. 19, Figs 4–7

Nautilus depressulus WALKER & JACOB 1798, p.641, fig.33.
Nonionina depressula Walker & Jacob. HAEUSLER 1887, p.200; CHAPMAN 1926, p.88, pl.17, fig.11.
Nonionina asterizans (Fichtel & Moll). HERON-ALLEN & EARLAND 1922, p.226.
Elphidium simplex Cushman. GREGORY 1973, p.198, fig.2, no.5; TOPPING 1973, p.32, pl.9, figs.6-8; THOMPSON 1975, p.88; HOSKINS 1978, p.274; ADAMS 1979, p.145; HAYWARD 1979, p.184, fig.3g; BROOK *et al.* 1981, p.90; HAYWARD 1981, p.132, fig.3d; HAYWARD & GRACE 1981, p.52; CAMPBELL *et al.* 1993, table 4.31; COLLEN 1995, pl.10, figs.9-10.
Elphidiononion simplex (Cushman) *aoteanum* VELLA 1957, p.38, pl.9, fig.185, 186; KUSTANOWICH 1965, p.53.
Elphidiononion aoteanum Vella. VELLA 1962, p.192.
Nonion depressulum (Walker & Jacob). PARR 1945, p.215; MURRAY 1965, p.148, pl.25, fig.6,7, pl.26, fig.7,8; APTHORPE 1980 (in part), pl.27, fig.11; HAYNES 1973, p.209, pl.22, fig.8-11, pl.29, fig.9, text-fig.44, no.1-3.
Cribroelphidium simplex (Cushman). HEDLEY *et al.* 1967, p.47, pl.12, fig.1a,b; COLLEN 1983, p.15,19,24,32.
Cribrononion simplex (Cushman). LEWIS 1979, p.35; YASSINI & JONES 1995, p.179, figs.1051-2,1057-8.
Elphidium spinatum Cushman & Valentine. COLLEN 1983, p.8.
Cribroelphidium spinatum (Cushman & Valentine). COLLEN 1983, p.28.
Haynesina depressula (Walker & Jacob). BANNER & CULVER 1978, p.200, pl.10, fig.1-10; HAYWARD 1982a, fig.5d; HAYWARD 1990b, p.96; HAYWARD *et al.* 1984, p.163; HAYWARD *et al.* 1994, fig.4B; HAYWARD & HOLLIS 1994, pl.5, fig.13-16; HAYWARD & TRIGGS 1994, pl.2, fig.13; HAYWARD & GRENFELL 1994, fig.25; HAYWARD *et al.* 1996, pl.2, figs.12-13.
Nonion tuberculatum (d'Orbigny). HAYWARD & BUZAS 1979, p.66, pl.22, figs.272,273.

DIAGNOSTIC FEATURES: This subspecies is distinguished by its lack of a solid umbonal boss and the presence of densely packed tubercles in the broad, depressed umbilicus.

REMARKS: This subspecies conforms well with specimens illustrated from the type area in the United Kingdom (Murray 1965, Haynes 1973, Banner & Culver 1978). Examination of the types of *Elphidiononion simplex* var. *aoteanum* (TF1305/1-2, USNM689249, VFp76) from the Recent of New Zealand, show that it is a junior synonym of *Haynesina depressula depressula*.

Examination of Collen's (1983) recorded specimens of *E. spinatum* from the Pliocene of Wanganui region shows that they are damaged tests of *H. depressula depressula* with spinose projections remaining on the outside of an earlier whorl, where chambers were attached and have broken off.

TYPE LOCALITY: England, Kent, Recent.

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Figs. 21, 24): *Haynesina depressula depressula* is widespread in marginal to fully marine nearshore environments in the eastern Pacific from California to Baja (Culver & Buzas 1986) and in the Atlantic around the British Isles (see Haynes 1973), the Gulf of Mexico (Culver & Buzas 1981) and the Argentine coast (Boltovskoy *et al.* 1980).

This is the only subspecies that occurs in New Zealand, including the Kermadec Islands, where it is a common member of nearshore communities (Adams 1979; Brook *et al.* 1981; Hayward 1979, 1981, 1990b; Hayward &

Hollis 1994; Hedley *et al.* 1967; Thompson 1975; Topping 1973).

In the tropical South-west Pacific (Cook, Fiji, Lord Howe, Samoa, Solomon, Tonga) and around eastern Australia (Queensland, New South Wales, Victoria), this subspecies is often, but not consistently, present in populations of *Haynesina depressula* that are always dominated by ssp. *simplex* (this study).

ECOLOGIC DISTRIBUTION: In New Zealand *H. depressula depressula* is absent or very rare in brackish parts of estuaries. It is most abundant (up to 40% of benthic foraminiferal faunas) in the sheltered, very slightly brackish seaward parts of enclosed harbours and inlets in low tidal or shallow subtidal (0–20 m) environments (Fig. 34), especially in associations dominated by *E. advenum, Ammonia beccarii, E. excavatum* or *E. charlottense* (Hayward & Triggs 1994, Hayward & Grenfell 1994, Hayward *et al.* 1996). *H. depressula depressula* also occurs in lower abundances in normal marine salinity conditions at inner shelf depths, especially or more sheltered bays and sounds. It may live down to depths of about 75 m (e.g. Lewis 1979), with occasional tests transported to greater depths (e.g. Hoskins 1978).

Around the east coast of Australia and the South-west Pacific islands *H. depressula depressula* lives in both slightly brackish and normal marine salinity, especially intertidally and in shallow subtidal depths in the outer parts of enclosed inlets, in the entrances to large bays and harbours, in the lee of fringing reefs and also at inner shelf depths on the exposed sandy slopes of islands and coral reefs. It lives in association with faunas dominated by combinations of *Reophax, Textularia, Trochammina, Peneroplis, Quinqueloculina, Spiroloculina, Triloculina, Sorites, Ammonia, Bolivina, Discorbis, Elphidium* and *Reusella.*

NEW ZEALAND PALEOGEOGRAPHIC DISTRIBUTION (Fig. 42): *H. depressula depressula* occurs throughout both islands in the Oligocene, Miocene and Pliocene, but is unknown from the South Island in the Pleistocene. It also occurs on Chatham Island in the Pliocene and Pleistocene.

NEW ZEALAND STRATIGRAPHIC DISTRIBUTION: Early Oligocene to Recent (Whaingaroan onwards).

NEW ZEALAND PALEOECOLOGIC DISTRIBUTION: *H. depressula* in the New Zealand fossil record is never the dominant species in an assemblage, although it sometimes occurs in relative abundances up to c. 10% as a codominant. It occurs in faunas with c. 0–30% planktics dominated by various combinations of *Haeuslerella, Textularia, Quinqueloculina, Ammonia, Anomalinoides, Bolivina, Buliminella, Cibicides, Cribrorotalia, Discorbis, Elphidium, Florilus, Gyroidina, Lenticulina, Nonionella, Notorotalia* and *Virgulopsis.* Most of these faunas are typical of inner and mid shelf depths, although several with fewer *Haynesina* specimens may have accumulated in slightly deeper outer shelf locations.

It appears that *Haynesina depressula* has lived in normal marine environments mostly at inner and mid shelf depths (c. 0–100 m), similar to the present day, throughout its Oligocene to Recent time range.

ETYMOLOGY: Presumably named for its depressed umbilicus.

Haynesina depressula simplex (Cushman)

Pl. 19, Figs 8–10

Elphidium simplex CUSHMAN 1933, p.52, pl.12, fig.8,9; CUSHMAN 1939, p.62, pl.17, fig.10; ALBANI 1968a, p.113, pl.10, fig.4; ALBANI 1968b, p.34, fig.155; COLLINS 1974, p.42.

Haynesina simplex (Cushman). ALBANI & YASSINI 1993, p.22, figs.36-42.

Nonion depressulum (Brady). YASSINI & JONES 1986, pl.7, figs.17-18.

Cribrononion simplex (Cushman). YASSINI & JONES 1995, p.179, fig.1053.

DIAGNOSTIC FEATURES: This subspecies is distinguished by the presence of a circular boss that largely fills the umbilicus. The boss is usually attached to earlier chambers in the whorl but separated from later chambers by a depressed, papillae-filled semicircular suture.

REMARKS: This subspecies was described from the South-west Pacific as *Elphidium simplex* by Cushman (1933).

TYPE LOCALITY: Tonga, Vava'u, Recent.

TYPE SPECIMENS SEEN: Holotype (CC15674), 1 paratype (CC15675).

PRESENT-DAY GEOGRAPHIC DISTRIBUTION (Fig. 21): This subspecies is widespread throughout eastern Australia (Queensland, New South Wales, Victoria) and the tropical islands of the South-west Pacific (Cook, Fiji, Lord Howe, Samoa, Solomon, Tonga, Vanuatu).

ECOLOGIC DISTRIBUTION: *H. depressula simplex* appears to live in the same wide range of slightly brackish and normal marine salinity conditions at intertidal and inner shelf depths as *H. depressula depressula.*

ETYMOLOGY: Presumably named for the simple appearance of the shell, lacking any ornament on the chambers.

TAXA RECOGNISED AS SUBJECTIVE JUNIOR SYNONYMS

JUNIOR SYNONYM	SENIOR SYNONYM
Elphidium advenum var. *depressulum* Cushman, 1933	*E. advenum limbatum*
Elphidium articulatum multicameratum Collins,1974	*E. excavatum williamsoni*
Elphidium earlandi avolonense Collins, 1974	*E. advenum limbatum*
Elphidium gibsoni Hayward, 1979	*E. crispum*
Elphidium granulosum Collins, 1974	*E. phillipense* (new name)
Elphidium gunteri carioense Collins, 1974	*E. excavatum williamsoni*
Elphidium gunteri var. *waddensis* Voorthuysen, 1951	*E. gunteri*
Elphidium hornibrooki Srinivasan, 1966	*E. pseudoinflatum*
Cribrononion illawaraensis Albani & Yassini, 1993	*E. excavatum clavatum*
Polystomella jenseni Cushman, 1924	*E. fichtellianum*
Elphidium lauritaense Todd & Kniker, 1952	*E. saginatum*
Elphidium littorale Le Calvez & Le Calvez, 1951	*E. gunteri*
Polystomella macella var. *aculeatum* Silvestri, 1901	*E. silvestrii* (new name)
Elphidium millettiforme McCulloch, 1977	*C. pacificus*
Elphidium nigarense Cushman, 1936	*E. pseudoinflatum*
Elphidium nitidum Dorreen, 1948	*E. schencki*
Elphidium omotoensis Dorreen, 1948	*E. advenum advenum*
Elphidium parri Cushman, 1936	*E. craticulatum*
Elphidium patagonicum Todd & Kniker, 1952	*E. hampdenense*
Elphidium sculpturatum Cushman, 1936	*E. macellum*
Elphidiononion simplex aoteanum Vella, 1957	*H. depressula depressula*
Elphidium subevolutum Cushman, 1933	*E. advenum tongaense*
Elphidium subinflatum Cushman, 1936	*E. pseudoinflatum*
Elphidium subplanatum Cushman, 1936	*E. fichtellianum*
Cribroelphidium vadescens Cushman & Bronnimann, 1948	*E. gunteri*

REFERENCES

Adams, A.G. 1979: Recent foraminifera and sediments of Rangaunu Harbour and inner Rangaunu Bay, Northland. Unpublished M.Sc. thesis, University of Auckland.

Albani, A.D. 1968a: Recent Foraminiferida from Port Hacking, New South Wales. *Contributions from the Cushman Foundation for foraminiferal research 19(3):* 85-119.

Albani, A.D. 1968b: Recent Foraminiferida of the central coast of New South Wales. *Australian Marine Sciences Association handbook no. 1.*

Albani, A.D. 1974: New benthonic foraminifera from Australian waters. *Journal of foraminiferal research 4:* 33-39.

Albani, A.D. 1978: Recent foraminifera of an estuarine environment in Broken Bay, New South Wales. *Australian Journal of marine and freshwater research 29:* 355-398.

Albani A.D. 1981: Pleistocene foraminifera from Botany Bay, New South Wales. *Alcheringa 5:* 147-160.

Albani, A. D.; Yassini, I. 1993: Taxonomy and distribution of the foraminifera of the family Elphidiidae from Shallow Australian waters. *University of New South Wales Centre for marine science, technical contribution 5,* 51pp.

Apthorpe, M. 1980: Foraminiferal distribution in the estuarine Gippsland Lakes System, Victoria. *Proceedings of the Royal Society of Victoria 91:* 207-232.

Banner, F.T.; Culver, S.J. 1978: Quaternary *Haynesina* n.gen. and Paleogene *Protelphidium* Haynes; their morphology, affinities and distribution. *Journal of foraminiferal research 8(3):* 177-207.

Barker, R.W. 1960: Taxonomic notes on the species figured by H.B. Brady in his report of the foraminifera dredged by HMS Challenger during the years 1973-1876. *American Association of Petroleum Geologists, special publication 9,* 238 pp.

Bermudez, P.J. 1952: Estudio sistematico de los Foraminiferos rotaliformes. *Venezuela Minist. Minas and Hidrocarb. bulletin geology 2(4):* 1-230.

Blow, W.H. 1979: *The Cainozoic Globigerinidae.* E.J. Brill, Leiden, 1410 pp.

Boltovskoy, E. 1964: Seasonal occurrences of some living foraminifera in Puerto Deseado (Patagonia, Argentina). *Journal du Conseil International pour l'Exploration de la Mer 39:* 136-145.

Boltovskoy, E.; Giussani, G.; Watanabe, S.; Wright, R. 1980: *Atlas of benthic shelf foraminifera of the Southwest Atlantic.* The Hague, Junk Publishers, 147 pp.

Brady, H.B. 1881: On some Arctic foraminifera from soundings obtained on the Austro-Hungarian North Polar Expedition of 1872-1874. *Annals and magazine of natural history, series 5, 8:* 393-418.

Brady, H.B. 1884: Report on the Foraminifera dredged by HMS Challenger, during the years 1873-1876. *Reports of the scientific results of the voyage of HMS Challenger, zoology 9,* 814 pp.

Brook, F.J.; Grace, R.V.; Hayward B.W. 1981: Soft-bottom benthic faunal associations of Tutukaka Harbour, Northland, New Zealand. *Tane 27:* 69-92.

Buzas, M.A.; Culver, S.J. 1984: Species duration and evolution: Benthic foraminifera on the Atlantic continental margin of North America. *Science 225:* 829-830.

Buzas, M.A.; Culver, S.J. 1991: Species diversity and dispersal of benthic foraminifera. Analysis of extant organisms and fossils of the waters around North America. *Bioscience 41(7):* 483-489.

Buzas, M.A.; Culver, S.J.; Isham, L.B. 1985: A comparison of fourteen elphidiid (Foraminiferida) taxa. *Journal of paleontology 59(5):* 1075-1090.

Campbell, H.J.; Andrews, P.B.; Beu, A.G.; Maxwell, P.A.; Edwards, A.R.; Laird, M.G.; Hornibrook, N.deB.; Mildenhall, D.C.; Watters, W.A.; Buckeridge, J.S.; Lee, D.E.; Strong, C.P.; Wilson, G.J.; Hayward, B.W. 1993: Cretaceous-Cenozoic geology and biostratigraphy of the Chatham Islands, New Zealand. *Institute of geological and nuclear sciences monograph 2,* 269 pp.

Cann, J.H.; De Deckker, P. 1981: Fossil Quaternary and living foraminifera from Athalassic (non-marine) saline lakes, southern Australia. *Journal of paleontology 55(3):* 660-670.

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

Chapman, F. 1926: The Cretaceous and Tertiary foraminifera of New Zealand, with an appendix on the Ostracoda. *New Zealand Geological Survey paleontological bulletin 11,* 119 pp.

Cole, W.S. 1931: The Pliocene and Pleistocene foraminifera of Florida. *Florida State Geological Survey bulletin 6:* 7-79.

Collen, J.D. 1973: Morphology and development of the test surface in some species of *Notorotalia* (Foraminiferida). *Revista Espanola de micropaleontologia 5(1):* 113-132.

Collen, J.D. 1983: Foraminifera from South Wanganui Basin: sample localities and faunal distribution. *Victoria University of Wellington Geology Department publication 26.*

Collen, J.D. 1995: Micropaleontology Laboratory Manual. *Victoria University of Wellington, Research School of Earth Sciences,* 68 pp.

Collins, A.C. 1958: Foraminifera. *Great Barrier Reef expedition 1928-29 scientific reports 6:* 335-437.

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

Culver, S.J.; Buzas, M.A. 1980: Distribution of Recent benthic foraminifera off the North American Atlantic Coast. *Smithsonian contributions to the marine sciences 6,* 512 pp.

Culver, S.J.; Buzas, M.A. 1981: Distribution of Recent benthic foraminifera in the Gulf of Mexico. *Smithsonian contributions to the marine sciences 8,* 2 vols, 898 pp.

Culver, S.J.; Buzas, M.A. 1986: Distribution of Recent benthic foraminifera of the North American Pacific Coast from California to Baja. *Smithsonian contributions to marine sciences 28,* 634 pp.

Cushman, J.A. 1918: The foraminifera of the Atlantic Ocean. Part 1. Astrorhizidae. *Bulletin of the United States National Museum 104(1):* 1-112.

Cushman, J.A. 1919: Recent foraminifera from off New Zealand. *Proceedings of the United States National Museum 56:* 593-640.

Cushman, J.A. 1922: Shallow-water foraminifera of the Tortugas region. *Publications of the Carnegie Institution of Washington 311. Department of marine biology 17:* 1-85.

Cushman, J.A. 1924: Samoan foraminifera. *Publications of the Carnegie Institution of Washington 342. Department of marine biology 21:* 1-75.

Cushman, J.A. 1927: An outline of a re-classification of the foraminifera. *Contributions from the Cushman laboratory for foraminiferal research 3:* 1-105.

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: The foraminifera of the Atlantic Ocean. Part VIII - Rotaliidae, Amphisteginidae, Calcarinidae, Cymbaloporettidae, Globorotaliidae, Anomalinidae, Planorbulinidae, Rupertiidae, and Homotremidae. *United States National Museum bulletin 104(8):* 1-179.

Cushman, J.A. 1933: The foraminifera of the tropical Pacific collections of the "Albatross", 1899-1900. Part 2: Lagenidae to Alveolinellidae. *United States National Museum bulletin 161,* 79 pp.

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. 1939: A monograph of the foraminiferal Family Nonionidae. *Geological Survey professional paper 191,* 100 pp.

Cushman, J.A. 1945: A foraminiferal fauna from the Twiggs clay of Georgia. *Contributions from the Cushman laboratory for foraminiferal research 21:* 1-11.

Cushman, J.A.; Bronnimann, P. 1948: Some new genera and species of foraminifera from brackish water of Trinidad. *Contributions from the Cushman laboratory for foraminiferal research 24:* 15-21.

Cushman, J.A.; Dusenbury, W. 1934: Eocene foraminifera of the Poway Conglomerate of California. *Contributions from the Cushman laboratory for foraminiferal research 10:* 51-65.

Cushman, J.A.; McCulloch, I. 1940: Some Nonionidae in the collections of the Allan Hancock Foundation. *Allan Hancock Pacific expedition 6(3).*

Cushman, J.A.; Todd, R.; Post, R.J. 1954: Recent foraminifera from the Marshall Islands, Bikini and nearby atolls. *U.S. Geological Survey professional paper 260-H:* 319-384.

Dawson, E.W. 1992: The marine fauna of New Zealand: Index to the Fauna: 1. Protozoa. *New Zealand Oceanographic Institute memoir 99,* 368 pp.

Debenay, J.P. 1988: Foraminifera larger than 0.5 mm in the southwestern lagoon of New Caledonia: distribution related to abiotic properties. *Journal of foraminiferal research 18:* 158-175.

Debenay, J.P. 1990: Recent foraminiferal assemblages and their distribution relative to environmental stress in the paralic environments of West Africa (Cape Timiris to Ebrie Lagoon). *Journal of foraminiferal research 20(3):* 267-282.

de Montfort, P. D. 1808: "*Conchyliologie systematique et classification methodique des coquilles*", v.1, Paris, F. Schoell.

D'Orbigny, A.D. 1846: "*Foraminiferes fossiles du Bassin Tertiare de Vienne (Autriche)*". Gide et Comp, Paris, 312pp.

Dorreen, J.M. 1948: A foraminiferal fauna from the Kaiatan Stage (Upper Eocene) of New Zealand. *Journal of paleontology 22(3):* 281-300.

Eade, J.V. 1967: A checklist of Recent New Zealand foraminifera. *New Zealand Oceanographic Institute memoir 44,* 72 pp.

Edwards, A.R.; Hornibrook, N.deB.; Raine, J.I.; Scott, G.H.; Stevens, G.R.; Strong, C.P.; Wilson, G.J. 1988: A New Zealand Cretaceous-Cenozoic geological time scale. *New Zealand Geological Survey record 35:* 135-149.

Feyling-Hanssen, R.W. 1972: The foraminifer *Elphidium excavatum* (Terquem) and all its variant forms. *Micropaleontology 18(3):* 337-354.

Fichtel, L.von; Moll, J.P.C. 1798: Testacea microscopia, aliaque minuta ex generibus Argonauta et Nautilus, ad naturam picta et descripta. *Wien, Camesina:* 1-123.

Finlay, H.J. 1939: New Zealand foraminifera: Key species in stratigraphy - No. 2. *Transactions of the Royal Society of New Zealand 69(1):* 89-128.

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

Finlay, H.J.; Marwick, J. 1947: New divisions of the New Zealand upper Cretaceous and Tertiary. *New Zealand journal of science and technology 28(4):* 228-236.

Fleming, C.A. 1952: A Foveaux Strait oyster-bed. *New Zealand journal of science and technology B34(2):* 73-85.

Fleming, C.A.; Hornibrook, N.deB.; Wood, B.L. 1969: Geology of the Clifden section. *New Zealand Geological Survey bulletin 79:* 71-117.

Foster, B.A.; Baettaerd, W.R. 1985: Distribution of zooplankton in a coastal upwelling in New Zealand. *New Zealand journal of marine and freshwater research 19:* 213-226.

Fujita, Y. 1956: On some species of genera *Elphidium, Elphidiella,* and *Cribroelphidium* - variation of Japanese *Elphidium crispum. Science reports of the Tokyo Kyoiku Daigaku (C) 4(45):* 219-234.

Galloway, J.J. 1933: "*Manual of foraminifera.*" Bloomington: Principia Press.

Gibson, G.W. 1967: Foraminifera and stratigraphy of the Tongaporutuan stage in the Taranaki coastal and six other sections. Part 1- systematics and distribution. *Transactions of the Royal Society of New Zealand (geology) 5(1):* 1-70.

Grant-Mackie, J.A.; Chapman-Smith, M. 1971: Paleontological notes on the Castlecliffian Te Piki Bed, with descriptions of new molluscan taxa. *New Zealand journal of geology and geophysics 14(4):* 655-704.

Gregory, M.R. 1973: Benthonic foraminifera from a mangrove swamp, Whangaparapara, Great Barrier Island. *Tane 19:* 193-203.

Haake, F.W. 1967: Zum jahresgang von populationen einer foraminiferen-art in der westlichen Ostee. *Meyniana 17:* 13-27.

Haeusler, R. 1887: Notes on some foraminifera from the Hauraki Gulf. *Transactions and proceedings of the New Zealand Institute 19:* 196-200.

Hansen H.J.; Lykke-Andersen A.L. 1976: Wall structure and classification of fossil and recent elphidiid and nonionid foraminifera. *Fossils and strata 10:* 1-37.

Hatta, A.; Ujiié, H. 1992: Benthic foraminifera from coral seas between Ishigaki and Iriomote Islands, Southern Ryukyu Island Arc, northwestern Pacific. *Bulletin of the College of Science, University of the Ryukyus (53):* 49-119; *(54):* 163-287.

Haynes, J.R. 1973: Cardigan Bay foraminifera (cruises of the R.V. Antur, 1962-1964). *Bulletin of the British Museum (Natural History), zoology, supplement 4,* 245 pp.

Hayward, B.W. 1977: Lower Miocene corals from the Waitakere Ranges, North Auckland, New Zealand. *Journal of the Royal Society of New Zealand 7(1):* 99-111.

Hayward, B.W. 1979: An intertidal *Zostera* pool community at Kawerua, Northland and its foraminiferal microfauna. *Tane 25:* 173-186.

Hayward, B.W. 1981: Foraminifera in near-shore sediments of the eastern Bay of Islands, New Zealand. *Tane 27:* 123-134.

Hayward, B.W. 1982a: Associations of benthic foraminifera (Protozoa:Sarcodina) of inner shelf sediments around the Cavalli Islands, north-east New Zealand. *New Zealand journal of marine and freshwater research 16:* 27-56.

Hayward B.W. 1982b: Foraminifera and ostracoda in nearshore sediments, Little Barrier Island, northern New Zealand. *Tane 28:* 53-66.

Hayward, B.W. 1986: Abundant planktic foraminifera in intertidal sediments, Kawerua, Northland. *Tane 31:* 1-12.

Hayward, B.W. 1990a: Taxonomy, paleogeography and evolutionary history of the Bolivinellidae (Foraminiferida). *New Zealand Geological Survey paleontological bulletin 63,* 132 pp.

Hayward, B.W. 1990b: Foraminifera in nearshore sediments, Whale Island, Bay of Plenty. *Tane 32:* 93-99.

Hayward, B.W. 1993: Estuarine foraminifera, Helena Bay, Northland, New Zealand. *Tane 34:* 79-88.

Hayward, B.W.; Brook, F.J. 1984: Lithostratigraphy of the basal Waitemata Group, Kawau Subgroup (new), Auckland, New Zealand. *New Zealand journal of geology and geophysics 27:* 101-123.

Hayward, B.W.; Brook, F.J. 1994: Foraminiferal paleoecology and initial subsidence of the early Miocene Waitemata Basin, Waiheke Island, Auckland. *New Zealand journal of geology and geophysics 37:* 11-24.

Hayward, B.W.; Buzas, M.A. 1979: Taxonomy and paleoecology of early Miocene benthic foraminifera of northern New Zealand and the north Tasman Sea. *Smithsonian contributions to paleobiology 36:* 1-154.

Hayward, B.W.; Grace, R.V. 1981: Soft bottom macrofauna and foraminiferal microfauna off Cuvier Island, north-east New Zealand. *Tane 27:* 43-54.

Hayward, B.W.; Grace, R.V.; Bull, V.H. 1984: Soft bottom macrofauna, foraminifera and sediments off the Chickens Islands, northern New Zealand. *Tane 30:* 141-164.

Hayward, B.W.; Grenfell, H. 1994: Foraminiferal associations around northern Great Barrier Island, New Zealand. *Records of Auckland Institute and Museum 31:* 231-273.

Hayward, B.W.; Grenfell, H.; Reid, C. in press: Foraminiferal associations in Queen Charlotte Sound and Wanganui Bight. *New Zealand journal of marine and freshwater research.*

Hayward, B.W.; Grenfell, H.; Cairns, G.: Smith, A. 1996: Environmental controls on benthic foraminiferal and thecamoebian associations in a tidal New Zealand inlet. *Journal of foraminiferal research 26(2):* 150-171.

Hayward, B.W.; Hollis, C.J. 1994: Brackish Foraminifera in New Zealand: a taxonomic and ecologic review. *Micropaleontology 40(3):* 185-222.

Hayward, B.W.; Hollis, C.J.; Grenfell, H. 1994: Foraminiferal associations in Port Pegasus, Stewart Island, New Zealand. *New Zealand journal of marine and freshwater research 28(1):* 69-95.

Hayward, B.W.; Triggs, C.M. 1994: Computer analysis of benthic foraminiferal associations in a tidal New Zealand inlet. *Journal of micropalaeontology 13:* 103-117.

Head, P.S.; Nelson, C.S. 1994: A high-resolution oxygen isotope record for the past 6.4 million years at DSDP site 593, Challenger Plateau, southern Tasman Sea. Pp.159-179 *in* van der Lingen, G.J.; Swanson, K.M.; Muir, R.J. (eds.) *"Evolution of the Tasman Sea Basin."* A.A. Balkecua, Rotterdam.

Hedley, R.H.; Hurdle, C.M.; Burdett, I.D.J. 1967: The marine fauna of New Zealand. Intertidal foraminifera of the *Corallina officinalis* zone. *New Zealand D.S.I.R. bulletin 180:* 1-88.

Heron-Allen, E.; Earland, A. 1922: Protozoa, Part 2. Foraminifera. *Natural History reports of the British Antarctic ("Terra Nova") expedition, 1910, 6(2):* 25-268.

Hofker, J. 1951: The toothplate foraminifera. *Archives Neerlandaises de zoologie 8(4):* 353-372.

Hofker, J. 1969: An analysis of the subfamily Notorotaliinae (Foraminifera) Hornibrook, 1961. *New Zealand journal of geology and geophysics 12(2 and 3):* 460-483.

Hollis, C.; Jenns, E.; Begbie, M.; Pullin, A. 1995: Benthic foraminifera and other microbiotic remains in Waimamaku River estuary, west coast, Northland. *Tane 35:* 195-205.

Hornibrook, N. deB. 1958: New Zealand foraminifera: Key species in stratigraphy-No.6. *New Zealand journal of geology and geophysics 1(4):* 653-76.

Hornibrook, N. deB. 1961: Tertiary foraminifera from Oamaru district (N.Z.). Part 1 - systematics and distribution. *New Zealand Geological Survey paleontological bulletin 56:* 175 pp.

Hornibrook, N. deB. 1968: Handbook of New Zealand microfossils (Foraminifera and Ostracoda). *Department of Scientific and Industrial Research information series 62:* 1-136.

Hornibrook, N. deB. 1971: Revision of the Oligocene and Miocene foraminifera from New Zealand, described by Karrer and Stache in the reports of the "Novara" Expedition (1864). *New Zealand Geological Survey paleontological bulletin 43,* 85 pp.

Hornibrook, N. deB. 1978: Tertiary climate. Pp. 436-443 *in* Suggate, R.P. *et al.* (eds.) *"The geology of New Zealand",* Government Printer, Wellington.

Hornibrook, N. deB. 1992: New Zealand Cenozoic marine paleoclimates: A review based on the distribution of some shallow water and terrestrial biota. Pp. 83-106 *in* Tsuchi, R. and Ingle, J.C. (eds.) *Pacific Neogene environment, evolution and events.* University of Tokyo Press.

Hornibrook, N. deB. 1996: New Zealand Eocene and Oligocene benthic foraminifera of the Family Notorotaliidae. *Institute of Geological & Nuclear Sciences monograph 12,* 51 pp.

Hornibrook, N. deB.; Brazier, R.C.; Strong, C.P. 1989: Manual of New Zealand Permian to Pleistocene foraminiferal biostratigraphy. *New Zealand Geological Survey paleontological bulletin 56,* 175 pp.

Hornibrook, N. deB.; Schofield, J.C. 1963: Stratigraphic relations in the Waitemata Group of the lower Waikato district. *New Zealand journal of geology and geophysics 6:* 38-51.

Hoskins, R.H. 1978: New Zealand middle Miocene foraminifera: The Waiauan stage. Unpublished Ph.D. thesis, University of Exeter (UK).

Hottinger, L.; Halicze, E.; Reiss, Z. 1993: Recent Foraminiferida from the Gulf of Aqaba, Red Sea. *Opera Sazu 33,* 179 pp.

Hottinger, L.; Leutenegger, S. 1980: The structure of calcarinid foraminifera. *Schweizerische Palaontologische abhandlungen 101:* 115-127.

Hughes, G.W. 1977: Recent foraminifera from the Honiara Bay area, Solomon Islands. *Journal of foraminiferal research 7:* 45-57.

Hulme, S.G. 1964: Recent foraminifera from Manukau Harbour, Auckland, New Zealand. *New Zealand Journal of science 7(3):* 305-40.

International Commission on Zoological Nomenclature 1964: *"International code of zoological nomenclature"*, International Trust for Zoological Nomenclature, London, 179p.

Isaac, M.J.; Lindqvist, J.K. 1990: Geology and lignite resources of the east Southland Group, New Zealand. *New Zealand Geological Survey bulletin 101,* 202 pp.

Jensen, H.I. 1904: Contributions to a knowledge of Australian foraminifera: Part 1. *Proceedings of the Linnean Society of New South Wales 29 (4):* 810-832.

Jepps, M.W. 1942: Studies on *Polystomella* Lamarck (Foraminifera). *Journal of the Marine Biological Association of the United Kingdom 25:* 607-666.

Kaiho, K.; Morgans, H.E.G.; Okada, H. 1993: Faunal turnover of intermediate-water benthic foraminifera during the Paleogene in New Zealand. *Marine micropaleontology 23:* 51-86.

Karrer, F. 1864: Die foraminiferen-fauna des Tertiaren grunsandsteines der Orakei-bei, Auckland. *Novara expedition 1857-59 report, Wien., geologie theil 1(2):* 69-86.

Kennett, J.P. 1966a: Stratigraphy and fauna of the type section and neighbouring sections of the Kapitean Stage, Greymouth, N.Z. *Transactions of the Royal Society of New Zealand, geology 4(1):* 1-77.

Kennett, J.P. 1966b: Four upper Miocene to lower Pliocene sections, Hawkes Bay to East Cape, New Zealand. *Transactions of the Royal Society of New Zealand, geology 4(10):* 189-209.

Kennett, J.P. (ed.) 1985: "The Miocene Ocean: Paleoceanography and Biogeography. *Geological Society of America memoir 163.*

Kleinpell, R.M. 1954: Neogene smaller foraminifera from Lau, Fiji. *Bernice P. Bishop Museum bulletin 211,* 96 pp.

Knox, G.A. 1951: A rock bottom fauna from fathoms off Banks Peninsula. *Records of the Canterbury Museum (New Zealand) 6(1):* 43.

Kustanowich, S. 1965: Foraminifera of Milford Sound. In: Skerman,T.M.(Ed). Studies of a southern fiord. *New Zealand D.S.I.R. bulletin 157:* 49-63.

Lamarck, J.B. 1822: Histoire naturelle des animaux sans vertebres 7, Paris, 711pp.

Lankford, R.R.; Phleger, F.B. 1973: Foraminifera from the nearshore turbulent zone, western North America. *Journal of foraminiferal research 3(3):* 101-132.

Le Calvez, J.; Le Calvez, Y. 1951: Contribution à l'étude des foraminifères des eaux saumâtres: I. Étangs de Canet et de Salses. *Vie and Milieu 2:* 237-45.

Lee, J.J. 1980: Nutrition and physiology of the foraminifera. Pp. 43-46 *in "Biochemistry and physiology of Protozo"*, 2nd Ed, v.3, Academic Press, London.

Lee, J.J.; Anderson, O.R. 1991: Symbiosis in foraminifera. Pp. 157-220 *in* Lee, J.J.; Anderson, O.R. (eds.) *"Biology of Foraminiferida."* Academic Press, London.

Lee, J.J.; Faber, W.W.; Anderson, O.R.; Pawlowski, J. 1991: Life cycles of foraminifera. Pp. 285-334 *in* Lee, J.J.; Anderson, O.R. (eds.) *"Biology of Foraminiferida."* Academic Press, London.

Lee, J.J.; Lanners, E.; ter Kuile, B. 1988: Retention of chloroplasts by the foraminifer Elphidium crispum. *Symbiosis 5:* 45-60.

Lee, J.J. and Lee, R.E. 1990: Chloroplast retention in elphidiids (Foraminifera). Pp. 215-220 *in* Nardon *et al.* (eds.) *"Endocytobiology IV"*, Institut National de la Recherche Agronomique, Paris.

Leitch, E.C.; Grant-Mackie, J.A.; Hornibrook, N.deB. 1969: Contributions to the geology of northernmost New Zealand: 1 - The mid-Miocene Waikuku Limestone. *Transactions of the Royal Society of New Zealand, earth sciences 7(2):* 21-32.

Lévy, A.; Poignant, A.; Rosset-Moulnier, M.; Rouvillois, A. 1975: Sur quelques foraminifères actuels des plages de Dunkerque et des environs: néotypes et espècies nouvelle. *Revue de micropaleontologie 17:* 171-181.

Lewis, K.B. 1979: Foraminifera on the continental shelf and slope off southern Hawkes Bay, New Zealand. *New Zealand D.S.I.R. bulletin 163,* 45 pp.

Linné, C. 1758: *Systema naturae,* 10th edition, vol.1. Leipzig, G. Engelmann, 824 pp.

Lister, J.J. 1895: Contributions to the life history of the foraminifera. *Philosophical Transactions of the Royal Society of London B186:* 401-453.

Loeblich, A.R.; Tappan, H. 1953: Studies of Arctic foraminifera. *Smithsonian miscellaneous collections 21(7),* 150 pp.

Loeblich, A.R.; Tappan, H. 1964: Sarcodina, chiefly "Thecamoebians" and Foraminiferida. In: R.C. Moore (ed.). "Treatise of Invertebrate Paleontology, Protista 2, part C". Geological Society of America and University of Kansas Press, Lawrence. 2 vols, 900 pp.

Loeblich, A.R.; Tappan, H. 1988: *"Foraminiferal genera and their classification"*. Van Nostrand Reinhold, New York. 2 vols, 1182 pp.

Loeblich, A.R.; Tappan, H. 1994: Foraminifera of the Sahul Shelf and Timor Sea. *Cushman Foundation for foraminiferal research special publication 31,* 661 pp.

Lopez, R. 1979: Algal chloroplasts in the protoplasm of three species of benthic foraminifera: Taxonomic affinity, viability and persistence. *Marine Biology 53:* 201-211.

Lutze, G.F. 1968: Jahresgang der foraminiferen-fauna in der Bottsand Lagune (Westliche Ostsee). *Meyniana* 18: 13-30.

McCulloch, I. 1977: *"Qualitative observations on Recent foraminiferal tests with emphasis on the Eastern Pacific"*. University of Southern California, Los Angeles, 3 vols.

McCulloch, I. 1981: *"Qualitative observations on Recent foraminiferal tests. Part IV, with emphasis on the Allan Hancock Atlantic Expedition collections"*. University of Southern California, Los Angeles, 364 pp.

Malumian, N. 1990: Foraminiferos bentonicos de la localidad Tipo de la Formacion la despedida (Eoceno, Isla Grande de Tierra del Fuego). Part II. Nodosariacea, Buliminacea, Elphidiidae y Rotalidos tuberculados. *Ameghiniana 27(3-4):* 343-363.

Marples, B.J. 1952: Early Tertiary penguins of New Zealand. *New Zealand Geological Survey paleontology bulletin* 20, 66pp.

Mather, P.; Bennett, I. (eds.) 1993: "*A coral reef handbook: a guide to the geology, flora and fauna of the Great Barrier Reef*". Australia, 3rd ed., 264 pp.

Mestayer, R.L. 1916: List of foraminifera dredged from 15' South of the Big King at 98 fathoms depth. *Transactions and proceedings of the New Zealand Institute 48:* 128-130.

Miller, A.A.L.; Scott D.B.; Medioli, F.S. 1982: *Elphidium excavatum* (Terquem): Ecophenotypic versus subspecific variation. *Journal of foraminiferal research 12(2):* 116-144.

Morton, J.E.; Miller, M.C. 1968: "*The New Zealand sea shore.*" Collins, Auckland, 638 pp.

Murray, J.W. 1965: Two species of Recent Foraminiferida. *Contributions from the Cushman Foundation for foraminiferal research 16(4):* 148-150.

Murray, J.W. 1968: The living Foraminiferida of Christchurch Harbour, England. *Micropaleontology 14(1):* 83-96.

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

Murray, J.W. 1979: "*British nearshore foraminiferids*". London, Academic Press (for the Linnean Society of London), 68 pp.

Murray, J.W. 1983: Population dynamics of benthic foraminifera: results from the Exe Estuary, England. *Journal of foraminiferal research 13:* 1-12.

Murray, J.W. 1991a: Ecology and distribution of benthic foraminifera. Pp. 221-254 *in* Lee, J.J.; Anderson, O.R. (eds.) "*Biology of Foraminiferida.*" Academic Press, London.

Murray, J.W. 1991b: "*Ecology and paleoecology of benthic foraminifera*". Longman Scientific and Technical, Avon, 397p.

Murray, J.W.; Sturrock, S.; Weston, J.F. 1982: Suspended load transport of foraminiferal tests in a tide- and wave-swept sea. *Journal of foraminiferal research 12:* 51-65.

Myers, E.H. 1942: Biological evidence as the rate at which tests of foraminifera are contributed to the sediments. *Journal of paleontology 16:* 397-398.

Myers, E.H. 1943: Life activities of foraminifera in relation to marine ecology. *Proceedings of the American Philosophical Society 86:* 439-459.

Palmieri, V. 1976a: Recent and subrecent foraminifera from the Wynnum 1:2500 sheet area, Moreton Bay, Queensland. *Queensland government mining journal 77:* 365-384.

Palmieri, V. 1976b: Modern and relict foraminifera from the central Queensland continental shelf. *Queensland government mining journal 77:* 407-423.

Parker, F.L. 1952: Foraminiferal distribution in the Long Island Sound - Buzzards Bay area. *Bulletin of the Museum of Comparative Zoology (Harvard College, Cambridge) 106(10):* 428-473.

Parker, F.L.; Phleger, F.B.; Peirson, J.F. 1953: Ecology of foraminifera from San Antonio Bay and environs, southwest Texas. *Cushman Foundation for foraminiferal research, special publication 2,* 75 pp.

Parr, W.J. 1945: Recent foraminifera from Barwon Heads, Victoria. *Proceedings of the Royal Society of Victoria 56(2):* 189-228.

Parr, W.J. 1950: Foraminifera. *Reports of the British, Australian and New Zealand Antarctic Research Expedition 1929-1931, series B (zoology and botany) 5:* 233-392.

Patterson, R.T. 1987: Arcellaceans and foraminifera from Pleistocene Lake Tecopa, California. *Journal of foraminiferal research 15:* 333-343.

Poag, C.W. 1978: Paired foraminiferal ecophenotypes in Gulf Coast estuaries: Ecological and paleoecological implications. *Transactions of the Gulf Coast Association of geological societies 28:* 395-421.

Raine, J.I.; Strong, C.P.; Wilson, G.J. 1993: Biostratigraphic revision of petroleum exploration wells, Great South Basin, New Zealand. *Institute of Geological and Nuclear Sciences science report 93/32,* 146 pp.

Resig, J.M. 1974: Recent foraminifera from a landlocked Hawaiian lake. *Journal of foraminiferal research 4(2):* 69-76.

Reuss, A.E.; Fritsch, A. 1861: Verzeichniss von 100 Gypsmodellen von foraminiferen, welche unter der Leitung des Prof. Dr. A. Reuss und Dr. Anton Fritsch gearbeitat wurden. Prague, Karl Setfried.

Richter, G. 1964: Zur okologie der foraminiferen II. Lebensraum und Lebensweise von *Nonion depressulum, Elphidium excavatum* and *Elphidium selseyense. Natur und Museum, Frankfurt 94:* 421-430.

Rögl, F.; Hansen, H.J. 1984: Foraminifera described by Fichtel and Moll in 1798: A revision of Testacea Microscopica. *Neue Denkschriften des Naturhistorischen Museum in Wien 3:* 1-143.

Schnitker D. 1974: Ecotypic variation in *Ammonia beccarii* (Linne). *Journal of foraminiferal research 4(4):* 217-223.

Scott, D.B.; Medioli, F.S. 1980: Quantitative studies of marsh foraminiferal distributions in Nova Scotia: Implications for sea level studies. *Cushman Foundation for foraminiferal research, special publication 17,* 58 pp.

Scott, G.H. 1970: Miocene foraminiferal biotopes in New Zealand: Waitemata Group, Kaipara, Northland. *New Zealand journal of geology and geophysics 13(2):* 316-342.

Sidebottom, H. 1909: Report on the Recent foraminifera from the coast of Delos (Grecian Archipelago). *Memoirs and proceedings of the Manchester Literary and Philosophical Society 53(21):* 1-32.

Silvestri, A. 1901: Appunti sui rizopodi reticolari della Sicilia. *Atti dell'Accademia di scienze e lettre, Acireale 10(7).*

Srinivasan, M.S. 1966: Foraminifera and age of the type of the Tahuian stage. *New Zealand journal of geology and geophysics 9(4):* 504-512.

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

Thalmann, H.E. 1947: Mitteilungen uber foraminiferen, V. *Eclogae geologicae Helvetiae (1946) 39:* 309-314.

Thalmann, H.E. 1951: Mitteilungen uber foraminiferen, IX. *Eclogae geologicae Helvetiae (1950) 43:* 221-225.

Thompson, I.C. 1975: Recent foraminifera and superficial sediments on an area of the continental shelf and upper slope east of the North Island, New Zealand. Unpublished M.Sc. thesis, University of Auckland.

Todd, R.; Bronnimann, P. 1957: Recent foraminifera and thecamoebina from the eastern Gulf of Paria, Trinidad. *Cushman Foundation for foraminiferal research, special publication 3,* 43 pp.

Todd, R.; Kniker, H.T. 1952: An Eocene foraminiferal fauna from the Agua Fresca Shale of Magallanes Province, southernmost Chile. *Cushman Foundation for foraminiferal research special publication 1.*

Todd, R.; Low, D. 1961: Near-shore foraminifera of Martha's Vineyard Island, Massachussetts. *Contributions from the Cushman Foundation for foraminiferal research 12:* 5-21.

Todd, R.; Low, D. 1971: Foraminifera from the Bahama Bank west of Andros island. *United States Geological Survey professional paper 683-C:* 22 pp.

Todd, R.; Low, D. 1981: Marine flora and fauna of the northeastern United States. Protozoa: Sarcodina: benthic foraminifera. *N.O.A.A. technical report N.M.F.S. circular 439,* 51 pp.

Topping, R.M. 1973: Benthonic foraminifera from Puhoi estuary, Auckland. Unpublished B.Sc.(Hons) thesis, University of Auckland.

Ujiié, H. 1956: The internal structures of some Elphidiidae. *Scientific report of the Tokyo Kyoiku Daigaku, series C, 4:* 267-282.

Vella, P. 1957: Studies in New Zealand foraminifera; Part 1- Foraminifera from Cook Strait. Part 11- Upper Miocene to Recent species of the genus *Notorotalia. New Zealand Geological Survey paleontological bulletin 28,* 64 pp.

Vella, P. 1962: Biostratigraphy and paleoecology of Mauriceville District, New Zealand. *Transactions of the Royal Society of New Zealand, geology 1(12):* 183-199.

Vella, P. 1963: Foraminifera from upper Miocene turbidites, Wairarapa, New Zealand. *New Zealand journal of geology and geophysics 6(5):* 775-793.

Voorthysen, J. H. van 1951: Recent (and derived Upper Cretaceous) foraminifera of the Netherlands Wadden Sea (tidal flats). *Mededelingen van de geologisiche Stichting 5:* 23-32.

Wade, M. 1957: Morphology and taxonomy of the foraminiferal family Elphidiidae. *Journal of the Washington Academy of sciences 47:* 330-339.

Walker, G.; Jacob, E. 1798: In: Adams, G., "*Essays on the Microscope*", 2nd edition. London. 712 pp.

Webb, P.N. 1970: A preliminary statement on type material of New Zealand upper Cretaceous, Paleocene and Eocene foraminifera described by H.J.Finlay. *New Zealand journal of geology and geophysics 13(3):* 663-675.

Wefer, G. 1976: Environmental effects on growth rates of benthic foraminifera. *Maritime sediments special publication 1:* 39-50.

Yassini, I.; Jones, B.G. 1986: Foraminifera in Lake Illawarra: Environmental factors and assemblages. *Lake Illawarra management committee publication*, 40 pp.

Yassini, I.; Jones, B.G. 1988: Estuarine foraminiferal communities in Lake Illawarra, N.S.W. *Proceedings of the Linnean Society of New South Wales 110(3):* 229-266.

Yassini, I.; Jones, B.G. 1995: "*Foraminiferida and ostracoda from estuarine and shelf environments on the southeastern coast of Australia*". University of Wollongong Press, 484 pp.

APPENDIX I
Recent elphidiid specimens examined from New Zealand, east Australia and South-west Pacific Islands

Specimen and sample repositories

CC	Cushman Collection, held at Natural History Museum, Smithsonian Institution, Washington DC, USA
F, FP, TF	Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand
L, AK	Auckland Institute and Museum, Marine Departments, Auckland, New Zealand
NZOI	New Zealand Oceanographic Institute, Wellington, New Zealand
USNM	Natural History Museum, Smithsonian Institution, Washington DC, USA
VF, VFp	Victoria University of Wellington, Department of Geology, PO Box 600, Wellington, New Zealand
Vict.Mus. F	National Museum of Victoria, Melbourne, Australia

KEY: LT, MT, HT, EHT = low, mid, high, extreme high tide

Genus *Elphidium*

Elphidium advenum advenum (Cushman)

SW PACIFIC ISLANDS. Cook Is.: Rarotonga (F201639). **Fiji:** 80-100m (CC19888); Mokaujar Anchorage (CC19887); Suva (F201636); Suva, Lami, LT (F202148); Suva, Suva Point, LT (F202149); Levuka, 24m (CC15706, CC15708, CC23017). **Kermadec Is.:** Cheeseman Is., 30m (F202268); Nugent Is., 16m (F202269); north Meyer Is., 15m (L1599). **Lord Howe Is.:** lagoon beach, MT (F202266). **New Caledonia:** Noumea, Anse Vata Beach (F201585). **Norfolk Is.:** off Captain Cook monument, 18m (F202332); 83 m (NZOI-G8). **Samoa:** Apia, 4m (F201642); Apia Harbour, Upolu (CC13009). **Solomon Is.:** Malaita, MT (L1402,3). **Tonga:** Vava'u, 8m (F201635); Vava'u, Hinakauea Beach, LT (F202150); Vava'u, Ahanga Passage, MT (F202154); Vava'u Anchorage (CC19877). **Vanuatu:** Espiritu Santo, HT (L5736).

Elphidium advenum botaniense Albani

EAST AUSTRALIA. Queensland: Great Barrier Reef, Claremont Lightship (F201595); Great Barrier Reef, Piper Is. (F201127); Murray Is., 60m (USNM); Cape York, Albany Passage, 828m (CC9893); Port Denison (CC9878, CC23011); Cape Bedford, 24m (F201594). **New South Wales:** Sydney, Watsons Bay (F201331, CC23014, CC23015); off Wollongong, 200m (USNM); Port Hacking, 80m (F201554); off Narrabeen, 160m (USNM).

SW PACIFIC ISLANDS. Samoa: PagoPago Harbour, 26-32m (CC3290, CC3292, CC3295, CC18896, CC23011). **Solomon Is.:** Malaita, MT (L1402,3).

Elphidium advenum dispar Cushman

SW PACIFIC ISLANDS. Fiji: Suva (F201636). **Solomon Is.:** Malaita, MT (L1402,3).

Elphidium advenum limbatum Chapman

NEW ZEALAND. Northland: Parengarenga Hbr, 2m (F201943); Cavalli Islands, 1.5m (F201739) Hayward 1982; Helena Bay, MT (F202956) Hayward 1993. **Auckland/Waikato:** Rakitu Is., 9m (F201847) Hayward & Grenfell 1994; Riverhead, MT (L661) Hayward & Hollis 1994; Waitemata Hbr (F201472); Orakei, 0.5m (F201349); Manukau Hbr, LT (F201505) Hulme 1964; Raglan Hbr, MT (F202088); Aotea Hbr, LT (F202092); Cook's Beach, MT (F202267).. **Taranaki/Wanganui:** Mokau, MT (F202086); Urenui, HT (F202085); Patea R., LT (F202083). **Bay of Plenty/East Coast/Hawkes Bay:** Tauranga, LT (F202114); Cooks Cove, MT (L2058). **Wellington:** Castlepoint Beach, LT (F201881); Kapiti Is., 38m (F201982); Pauatahanui, 1m (F202003) Hayward & Triggs 1994. **Nelson/Marlborough:** D'Urville Is., LT (F202234); Chetwode Is., 8m (F202109). **Canterbury/Otago:** Akaroa, MT (F201888); Oamaru Port, LT (L6973); Portobello Bay, HT (F202255); Port Chalmers, MT (F202066). **Southland/Stewart Is.:** Chalky Inlet, North Port, 25m (L13562); Patersons Inlet, LT (F201109, L6982); Port Pegasus, H-MT (F202285) Hayward et al. 1994; Maori Beach estuary, MT (L6974). **Chatham Islands:** Waitangi, 13m (F201913). **Auckland Islands:** (F201002); Tagua Bay, 3m (L6184).

EAST AUSTRALIA. Queensland: Great Barrier Reef, Piper Is. (F201127). **Tasmania:** Derwent estuary, 20m (F201332). **Victoria:** Bass Strait (USNM); Beaumaris, beach sand, type locality (9 paratypes, CC14249); Port Fairy, beach sand (CC7899, CC15651); Port Phillip survey stns. 26-C3, 39-313, 49-C5, 62-99 (includes holotype of *E. earlandi avalonense*, Vict.Mus. F42144, F42191, F42209, F42218, F42261, F76944, F76945).

SW PACIFIC ISLANDS. Cook Is.: Rarotonga, (F201639). **Fiji:** Laucula, Suva (F201130); Suva (F201636); Viti Levu Bay, 6m (CC14253). **Kermadec Is.:** Cheeseman Is., 30m (F202268). **Lord Howe Is.:** Old Settlement Beach, 0.5m (F202329). **Norfolk Is.:** off Captain Cook Monument, 18m (F202332); Duncombe Bay, 15m (L4350). **Solomon Is.:** Guadalcanal Is., Mica Depot drillhole WR-65-2, cuttings 14m (USNM); Uepi, 1m (L3669). **Tonga:** Vava'u Anchorage, type locality (holotype CC15670). **Vanuatu:** Epi Is., 10m (L5738); Port Vila, 6m (L5737).

Elphidium advenum macelliforme McCulloch

EAST AUSTRALIA. Victoria: Port Phillip Bay, 10m (FP4336).

Elphidium advenum maorium Hayward n.sp.

NEW ZEALAND. Northland: Parengarenga Hbr, 2m (F201943). **Auckland/Waikato:** Rakitu Is., 9m (F201847) Hayward & Grenfell 1994; Waitemata Hbr (F201472); Orakei, MT (includes holotype and paratypes, F201347, TF1648/1-3, USNM487674); Manukau Hbr, LT (F201505) Hulme 1964; Raglan, LT (F202091); Kawhia, MT (F202094). **Taranaki/Wanganui:** Urenui R., HT (F202085); Patea R., MT (F202084). **Bay of Plenty/East Coast/Hawkes Bay:** Mahia, Maungawhio Lagoon, LT (L2053). **Nelson/Marlborough:** D'Urville Is., LT (F202234); Marahau Est., HT (L614); Chetwode Is. (F202109); **Canterbury:** Akaroa, MT (F202259). **Southland/Stewart Is.:** Oreti Est., MT (F202250); Dusky Sound, 55m (F202071); Foveaux Strait (F201210); Paterson's Inlet (F201109); Port Pegasus, M-HT (F202285) Hayward et al. 1994. **Chatham Islands:** Waitangi, 13m (F201913).

EAST AUSTRALIA. Victoria: Barwon Heads, shore sand (Vict.Mus. F76316).

SW PACIFIC ISLANDS. Kermadec Is.: Cheeseman Is., 30m (F202268). **Lord Howe Is.:** lagoon beach, MT (F202266). **Norfolk Is:** off Capt Cook monument, 18 m (F202332).

Elphidium advenum tongaense (Cushman)

SW PACIFIC ISLANDS. Cook Is.: Rarotonga, 15m (holotype and 10 paratypes of *E. subevolutum* CC15672, CC19899, CC19900). **Fiji:** Lami, LT (F202148); Laucula (F201130); Suva (F201636); Viti Levu Bay, 6m (CC14252); Viva, 6m (CC19902, USNM433662) Loeblich & Tappan 1964. **Samoa:** Apia, 14 m (F201085); Pago Pago Harbour, 100m (USNM). **Tonga:** (NZOI-A406), Vava'u, 8m (F201635), Ahanga Passage, MT (F202154), Vava'u Anchorage, type locality (F201638, CC23035, holotype CC15676, 38 paratypes CC15677, CC15678, CC19903, CC19904, CC37302). **Vanuatu:** Port Vila, 6m (L5737); Espiritu Santo, HT (L5736, USNM).

Elphidium albanii Hayward n.sp.

EAST AUSTRALIA. Queensland: Great Barrier Reef, Claremont Lightship (includes holotype and 17 paratypes, TF1649/1-3, USNM487982, AK74083, F201595); Cape Bedford, 24m (F201594); Great Barrier Reef, Bird Is. (F201120); Great Barrier Reef, Hannibal Is (F201121); Great Barrier Reef, Piper Is. (F201127); Cleveland Bay (F201122). **New South Wales:** Sydney, Watsons Bay (F201331); Malabar, 20m (FP4365).

SW PACIFIC ISLANDS. Lord Howe Is.: Old Settlement Beach, 0.5m (F202329); lagoon beach, MT (F202266).

Elphidium argenteum Parr

EAST AUSTRALIA. New South Wales: Newcastle, beach sand (CC23010). **Queensland:** Great Barrier Reef, Claremont Lightship (F201595). **Victoria:** Barwon Heads, shore sand (holotype, Vict.Mus. F41264); Hardwick Bay (USNM); Point Lonsdale, beach sand (CC15652); Port Phillip, Barwon Heads, MT (F201584); Port Phillip survey stn. 62-99 (Vict.Mus. F42261); Bass Strait, Torquay, beach sand (CC23012, CC23013).

Elphidium carteri Hayward n.sp.

EAST AUSTRALIA. Queensland: Great Barrier Reef, Claremont Lightship (holotype and paratypes, TF1650/1-3, USNM487676, F201595). **New South Wales:** Sydney, Watsons Bay (F201331).

SW PACIFIC ISLANDS. Solomon Islands: Malaita, Tarapaina, intertidal channel (L13518).

Elphidium charlottense (Vella)

NEW ZEALAND. Northland: Tapotupotu, HT (F202121); Parengarenga Hbr, 2m (F201943); Cavalli Islands, 1.5m (F201739) Hayward 1982; Helena Bay, HT (F201955) Hayward 1993; Parua Bay, MT (F201977); Whangateau Hbr (F201353); Kawerua, MT (F201682) Hayward 1979; Kaipara Hbr, MT (L597). **Auckland/Waikato:** Tryphena, MT (F202100); Rakitu Is., 6m. (F201848) Hayward & Grenfell 1994; Cuvier Is., 37m (F201838) Hayward & Grace 1981; Riverhead, 4m (L841) Hayward & Hollis 1994; Watchmans Is. (F201472); Parnell Reef, LT (F201346); Orakei, 0.5m (F201349); Manukau Hbr (F201421); Miranda, MT (F202113); Cook's Bch, MT (F202267); Raglan, LT (F202091); Kawhia, MT (F202094). **Bay of Plenty/East Coast/Hawkes Bay:** Tauranga, LT (F202114); Cooks Cove, MT (L2058); Mahia, Maungawhio Lagoon, LT (L2053); Napier, LT (F202229). **Wellington:** Castlecliff, LT (F201881); Pauatahanui Inlet, 2m (F202024) Hayward & Triggs 1994; Cook Strait, 167m (F201234). **Nelson/Marlborough:** Delaware Bay, M-HT (F202097); Tahunanui Inlet, MT (F202237); Chetwode Is., 8m (F202109); Lake Grassmere, HT (F202263); Queen Charlotte Sound, Rellings Bay, type locality (holotype and 3 paratypes, TF1306/1-2, USNM689251, VFp77). **Canterbury/Otago:** Lyttleton, HT (F202260); Akaroa Hbr, MT (F201887); Timaru, MT (F202258); Oamaru Port, LT (L6973); Blueskin Bay, HT (F202257); Port Chalmers, MT (F202066); off Clutha R. mouth, 32m (F201160). **Southland/Stewart Is.:** Riverton Est., M-HT (F202246); Port Pegasus, 15m (F202272) Hayward et al. 1994.; Oban, MT (L6975); Maori Beach, MT (L6974).

SW PACIFIC ISLANDS. Lord Howe Is.: Lagoon Beach MT (F202266).

Elphidium collinsi Hayward n.sp.

EAST AUSTRALIA. New South Wales: Sydney, Watsons Bay (holotype and paratypes, TF1651/1-2, USNM487677, F201331). **Queensland:** Great Barrier Reef, Bird Is. (F201120).

Elphidium craticulatum (Fitchel & Moll)

EAST AUSTRALIA. Queensland: Cape Bedford, 24m (F201594); Cape York, Albany Passage, 8-28m (CC9895); Great Barrier Reef, Claremont Lightship (F201595); Great Barrier Reef, Hannibal Is (F201121); Heron Is boring, cuttings 90m (CC38715) Cushman 1942; Murray Is.(CC3343, CC19405, CC19406) Cushman 1918; Port Denison (CC9877, CC22739). **New South Wales:** Sydney, Watsons Bay (F201331).

SW PACIFIC ISLANDS. Fiji: Nairai, 24m (CC19882); Suva (F201636). **Solomon Is.:** Guadalcanal Is., Mica depot drillhole WR-65-2, cuttings 30m (USNM); Malaita, MT (L1402,3); Uepi, 13m (L3668). **Tonga:** (NZOI-A406); Vava'u Anchorage, 8m (F201638); Vava'u Hbr, 8m (F201635), Ahanga Passage, MT (F202154). **Vanuatu:** Port Vila, 6m (L5737).

Elphidium crispum crispum (Linné)

NEW ZEALAND. Northland: Rimariki Is (F201947). **Auckland/Waikato:** Mokohinau Is, 30m (L14328); Rakitu Is., 1.5-60m (F201847-79) Hayward & Grenfell 1994. **Auckland/Waikato:** Cuvier Is., 37m (F201838) Hayward & Grace 1981.

EAST AUSTRALIA. Queensland: Cape York, Albany Passage, 8-28m (CC9893); Cape Bedford, 24m (F201594); Great Barrier Reef, Claremont Lightship (F201595); Great Barrier Reef, Masthead Is., 34-40m (USNM); Cairns beach (F201600); Great Barrier Reef, Bird Is. (F201120); Great Barrier Reef, Piper Is. (F201127). **New South Wales:** off Narrabeen, 160m (USNM); Sydney, Watsons Bay (F201331, USNM). **South Australia:** Adelaide, Henley Beach (F201592). **Tasmania:** Derwent estuary, 20m (F201332); Oyster Bay, 80m (F201075). **Victoria:** Port Phillip, Barwon Heads, MT (F210584); Port Phillip survey stns. 26-C3, 39-

313, 49-C5, 62-99 (Vic.Mus. F42191, F42209, F42218, F42261).

SW PACIFIC ISLANDS. Kermadec Is.: Cheeseman Is., 30 m (F202268). **New Caledonia:** Noumea, Anse Vata Beach (F201585). **Fiji:** Suva (F201636). **Lord Howe Is.:** Old Settlement Beach, 0.5m (F202329). **Solomon Is.:** Guadalcanal, Mica Depot drillhole Wr-65-2, cuttings 30m (USNM). **Tonga:** off Tongatapu, 914m (NZOI-B74); Vava'u, 30m (F201081). **Vanuatu:** Port Vila, 6m (L5737).

Elphidium excavatum clavatum Cushman

NEW ZEALAND. Northland: Tapotupotu Bay, HT (F202121); Parengarenga Hbr, MT (F201892); Ranganu Hbr, HT (F201890); Manganui Hbr, MT (F202078); Whangaroa Hbr, HT (F202077); Opua, HT (F202076); Helena Bay, EHT (F201953) Hayward 1993; Parua Bay, MT (F201977); Herekino Hbr, MT (F202118); Whangape Hbr, MT (F202119); Hokianga Hbr, MT (F201894); Pahi, LT (F201987); Kaipara, MT (L597). **Auckland/Waikato:** Tryphena, MT (F202100); Riverhead, 3m (L839) Hayward & Hollis 1994; Watchmans Is. (F201472); Orakei, 5-20m (L509); Manukau Hbr, 4m (F201357); Miranda, MT (F202113); Cook's Bch, MT (F202267); Raglan, MT (F202088); Aotea Hbr, LT (F202092); Kawhia Hbr, MT (F201912); Marakopa Est., LT (F202095). **Bay of Plenty/East Coast/Hawkes Bay:** Tauranga (F201827); Ohiwa, MT (F202103); Tolaga Bay, MT (F201936); Mahia, Maungawhio Lagoon, LT (L2053); Napier, LT (F202229). **Wellington:** Lake Ferry, MT (F202070); Pauatahanui Inlet, MT (F202035) Hayward & Triggs 1994. **Taranaki/Wanganui:** Mokau Est., MT (F202086); Urenui Est., HT (F202085); Patea Est., LT (F202083). **Nelson/Marlborough:** D'Urville Is., LT (F202234); Marahau Est., HT (L614); Delaware Bay, M-HT (F202097); Nelson, HT (F202098); Tahunanui Inlet, MT (F202237), Kenepuru Head, HT (L611); Waimea Inlet, MT (F202099); Anakiwa, MT (F202235). **Canterbury/Otago:** Lyttleton, HT (F202260); Blueskin Bay, HT (F202257); Hooper's Inlet, HT (F202254). **Southland/Stewart Is.:** Waikawa Hbr, HT (F202248); Haldane Est., HT (F202247); Bluff, HT (F202249); Oreti Est., HT (F202251); Riverton Est., M-HT (F202246); Big River, Fiordland, HT (F202233); Port Pegasus, MT (F202305) Hayward et al. 1994.; Oban salt marsh, MT (L6975); Maori Beach estuary, MT (L6974). **West Coast:** Oparara, MT (L653) Hayward & Hollis 1994; Orowaiti Est., MT (F202240). **Snares Islands:** 92m (F202072).

EAST AUSTRALIA. New South Wales: Sydney (F201593); Lake Illawara, Duck Creek, 2m (FP4370-1, type locality of *E. illawaraense*). **Tasmania:** Derwent estuary, 20m (F201332). **Victoria:** Port Phillip, Barwon Heads, MT (F210584); Port Phillip survey stn. 39-313 (Vict.Mus. F42209).

SW PACIFIC ISLANDS. Vanuatu: Epi Is., 10m (L5738). **Solomon Is.:** Malaita, MT (L1403); Uepi, 1m (L3669).

Elphidium excavatum excavatum (Terquem)

NEW ZEALAND. Northland: Tapotupotu Bay, HT (F2021212); Parengarenga, HT (F201893); Whangaroa Hbr, HT (F202077); Opua, HT (F202076); Helena Bay, EHT (F201953) Hayward 1993; Parua Bay, MT (F201977); Herekino Hbr, MT (F202118); Whangape Hbr, MT (F202119); Kaipara Hbr, LT (F201987). **Auckland/Waikato:** Riverhead, MT (L845) Hayward & Hollis 1994; Orakei, 5-20m (L509); Manukau Hbr, 4m (F201357); Miranda, MT (F202113); Cook's Bch, MT (F202267); Raglan, LT (F202091); Kawhia, MT (F201912). **Bay of Plenty/East Coast/Hawkes Bay:** Tauranga, HT (F202116); Tolaga Bay, MT (F201936). **Wellington:** Lake Ferry, MT (F202070); Pauatahanui, HT (F202037) Hayward & Triggs 1994; Little Karaka Bay, MT (F202089). **Taranaki/Wanganui:** Urenui, HT (F202085). **Nelson/Marlborough:** Marahau Est., HT (L614); Delaware Bay, M-HT (F202097); Nelson, HT (F202098); Tahunanui Est., MT (F202237); Waimea Inlet, MT (F202099); Anakiwa, MT (F202235). **Canterbury/Otago:** Hooper's Inlet, HT (F202254). **Southland/Stewart Is.:** Haldane Est., HT (F202247); Bluff, HT (F202249); Port Pegasus, H-MT (F202285) Hayward et al. 1994.; Golden Bay, LT (L6982); Oban salt marsh, MT (L6975); Maori Beach estuary, MT (L6974). **West Coast:** Oparara Lagoon, MT (L654) Hayward & Hollis 1994; Orowaiti Est., MT (F202240); Okarito, M-HT (F202244). **Chatham Islands:** Te Whanga Lagoon, MT (L14050). **Snares Islands:** 92m (F202072).

EAST AUSTRALIA. New South Wales: Port Jackson, Watson Bay (USNM). **Queensland:** Great Barrier Reef, Claremont Lightship (F201595). **Tasmania:** Derwent estuary, 20m (F201332). **Victoria:** Port Phillip, Barwon Heads, MT (F210584); Barwon Heads, beach sand (Vict.Mus. F76317); Port Phillip survey stn. 56-C9, 49-C5 (Vict.Mus. F42240, F42218, F76950, F76953).

SW PACIFIC ISLANDS. Cook Is.: Rarotonga (F201639). **Fiji:** Suva (F201636).

Elphidium excavatum oirgi Hayward n.sp.

NEW ZEALAND. Northland: Parengarenga Hbr, 2m (F201943); Cavalli Islands, 1.5m (holotype and paratypes, TF1653/1,5, AK74002, USNM487679, F201739) Hayward 1982; Cavalli Islands, 7m (includes 1 paratype, TF1653/3, F201742); Bay of Islands, LT (F201799), Hayward 1981; Tutukaka Hbr, 3m (includes 2 paratypes, TF1653/2,4, F201841), Brook et al. 1981; Chickens Islands, 53m (F201922), Hayward et al. 1984. **Auckland/Waikato:** Great Barrier Is., Rangiwhakaea Bay, 14m (F202048), Hayward & Grenfell 1994; Cook's Bch, MT (F202267). **Bay of Plenty:** Whale Is., 7.5m (F202207), Hayward 1990b.

Elphidium excavatum sydneyense Albani

No specimens examined.

Elphidium excavatum williamsoni Haynes

NEW ZEALAND. Northland: Tapotupotu Bay, HT (F202121); Parengarenga Hbr, HT (F201893); Ranganu Hbr, HT (F201890); Manganui, MT (F202078); Helena Bay, HT (F201955) Hayward 1993; Parua Bay, MT (F201977); Whangateau Hbr (F201353); Hokianga Hbr, MT (F201894); Kaipara Hbr, MT (L597). **Auckland/Waikato:** Tryphena, MT (F202100); Riverhead, MT (L847) Hayward & Hollis 1994; Watchmans Is. (F201472); Parnell Reef, LT (F201346); Orakei Basin, 5-20m (L509); Manukau Hbr (F201421); Miranda, MT (F202113); Cook's Bch, MT (F202267); Raglan, MT (F202088); Aotea Hbr, LT (F202092); Kawhia Hbr, MT (F202094). **Bay of Plenty/East Coast/Hawkes Bay:** Tauranga, HT (F202166); Ohiwa, MT (F202103); Gisborne, MT (F201935); Napier, LT (F202229). **Wellington:** Pauatahanui, HT (F202037) Hayward & Triggs 1994; Kapiti Is., 38m (F201982). **Taranaki/Wanganui:** Mokau Est., MT (F202086); Patea Est., LT (F202083). **Nelson/Marlborough:** Delaware Bay, M-HT (F202097); Nelson, HT (F202098); Tahunanui Inlet, MT (F202237); Waimea Inlet, MT (F202099); Anakiwa, MT (F202235). **Canterbury/Otago:**

Lyttleton, HT (F202260); Akaroa Hbr, MT (F201887); Blueskin Bay, HT (F202257); Portobello, HT (F202255); Hooper's Inlet, HT (F202254). **Southland/Stewart Is.:** Waikawa Hbr, HT (F202248); Bluff, HT (F202249); Oreti Est., MT (F202250); Riverton Est., M-HT (F202246); Port Pegasus, LT (F202305) Hayward et al. 1994. **West Coast:** Oparara Lagoon, MT (L654) Hayward & Hollis 1994.

EAST AUSTRALIA. Victoria: Port Phillip, Barwon Heads, MT (F210584); Port Phillip survey stn. 56-C9, 39-313 (includes holotypes of *E. articulatum multicameratum* Collins and *E. gunteri carioense* Collins, Vict.Mus. F42143, F42209, F42240, F76946, F76947, F76949); Hardwick Bay (CC23058).

SW PACIFIC ISLANDS. Fiji: Vatuwannga Est., HT (F202144). **Norfolk Is.:** Duncombe Bay, 15m (L4350).

Elphidium fichtellianum (d'Orbigny)

EAST AUSTRALIA. Victoria: Port Phillip, Barwon Heads, MT (F201584).

SW PACIFIC ISLANDS. Fiji: Makaujar Anchorage (CC19893); Levuka, 24m (CC19898); Nairai, 24m (CC19897); Suva, Lami, LT (F202148); Suva, Suva Point, LT (F202149). **Norfolk Is.:** off Captain Cook Monument, 18m (F202332); 83m (NZOI-G8); Duncombe Bay, 15m (L4350). **Samoa:** Apia, 14m (F201085); PagoPago Harbour, 26-50m, type locality (CC3291, CC3327, CC18841, CC22770, CC23036, CC23037, holotype CC3323, 6 paratypes CC3324, CC3325, CC18895) Cushman, 1918, 1933. **Solomon Is.:** Uepi, 13m (L3668). **Tonga:** off Tongatapu, 914m (NZOI-B74); Vava'u Anchorage, 8m (F201638); Vava'u Hbr, 8m (F201635), 30m (F201081); Vava'u, Hinakauea Beach, LT (F202150); Vava'u Anchorage, 36m (CC15704, CC19895) Cushman 1933. **Vanuatu:** Espiritu Santo (USNM).

Elphidium fijiense Hayward n.sp.

SW PACIFIC ISLANDS. Fiji: Suva Point, intertidal (holotype and paratypes, TF1654/1-3, AK74000, USNM487680, F202149). **Lord Howe Is.:** lagoon beach, MT (F202266). **Solomon Is.:** Malaita, MT (L1403). **Tonga:** Vava'u, Ahanga Passage, MT (F202154).

Elphidium gunteri Cole

NEW ZEALAND. Northland: Tapotupotu Bay, HT (F202120); Whangaroa Hbr, HT (F202077); Opua, HT (F202076); Whangape Hbr, MT (F202119); Hokianga Hbr, MT (F201894); Kaipara Hbr, LT (F201987). **Auckland/Waikato:** Riverhead, MT (L845) Hayward & Hollis 1994; Orakei Basin, 5-20m (L509); Manukau Hbr, LT (F201505); Kawhia, MT (F201912). **Bay of Plenty/East Coast/Hawkes Bay:** Napier, LT (F202229). **Wellington:** Little Karaka Bay, MT (F202089). **Nelson/Marlborough:** Nelson, HT (F202098). **West Coast:** Oparara Lagoon, MT (L654) Hayward & Hollis 1994.

Elphidium hawkesburiense Albani

EAST AUSTRALIA. New South Wales: Sydney, Watsons Bay (F201331); Twofold Bay, 6m (FP4368-9). **Tasmania:** Derwent estuary, 20m (F201332).

Elphidium hispidulum Cushman

EAST AUSTRALIA. Queensland: Cape Bedford, 24m (F201594); Great Barrier Reef, Claremont Lightship (F201595); Great Barrier Reef, Bird Is. (F201120); Great Barrier Reef, Hannibal Is (F201121); Great Barrier Reef, Piper Is. (F201127); Cairns beach (F201600); Cleveland Bay (F201122); Albany Passage, 8-30m (holotype and 2 paratypes, CC23028, CC9874).

SW PACIFIC ISLANDS. Solomon Is.: Malaita, MT (L1403).

Elphidium lene Cushman & McCulloch

EAST AUSTRALIA. Queensland: Murray Is., 60m (CC3343, USNM). **Victoria:** Port Phillip survey stns. 26-C3, 49-C5 (Vict.Mus. F42144, F42218, F76943, F76954); Black Rock (CC15654). **Tasmania:** Derwent estuary, 20m (F201332).

SW PACIFIC ISLANDS. Cook Is.: Aitutaki (F201132). **Fiji:** Suva, Laucua (F201130); Suva (F201636). **Lord Howe Is.:** Old Settlement Beach, 0.5m (F202329). **New Caledonia:** Noumea, Anse Vata Beach (F201585). **Samoa:** Apia, 14m (F201085), 4m (F201642). **Solomon Is.:** Malaita, MT (L1402). **Tonga:** Vava'u, Hinakauea Beach, LT (F202150), Vava'u Anchorage, 8m (F201638).

Elphidium macellum (Fitchel and Moll)

EAST AUSTRALIA. Queensland: Great Barrier Reef, Masthead Is., 34-40m (CC23044). **New South Wales:** Newcastle, beach sand (CC23010, CC23045); Port Hacking, 80m (F201554). **Tasmania:** Derwent estuary, 20m (F201332). **Victoria:** Bass Strait, Torquay, beach sand (CC23012, CC23013); Hardwick Bay, beach sand (USNM); Port Phillip survey stns. 26-C3, 39-313, 49-C5, 56-C9, 62-99 (Vic.Mus. F42191, F42209, F42218, F42239, F42261).

SW PACIFIC ISLANDS. Fiji: Suva, Suva Point, LT (F202149). **Lord Howe Is.:** lagoon beach, MT (F202266); Old Settlement Beach, 0.5m (F202329). **New Caledonia:** Noumea, Anse Vata Beach (F201585); **Norfolk Is.:** off Captain Cook monument, 18m (F202332); Duncombe Bay, 15m (L4350). **Samoa:** Apia, 14m (F201085). **Solomon Is.:** Guadalcanal, Mica depot drillhole WR-65-2, cuttings 30m (USNM). **Tonga:** off Tongatapu, 914m (NZOI-B74). **Vanuatu:** Espiritu Santo, HT (L5736, USNM).

Elphidium mortonbayense Albani and Yassini

EAST AUSTRALIA. Queensland: Cape Bedford, 24m (F201594); Cape York, Albany Passage, 8-28m (CC9895); Great Barrier Reef, Claremont Lightship (F201595); Great Barrier Reef, Bird Is. (F201120); Great Barrier Reef, Piper Is. (F201127); Cleveland Bay (F201122).

Elphidium novozealandicum Cushman

NEW ZEALAND. Northland: Tapotupotu Bay, HT (F202120); Parengarenga Hbr, 2m (F201943); Cavalli Islands, 1.5m (F201739) Hayward 1982; Kawerua (F201683) Hayward 1979; Helena Bay, HT (F201955) Hayward 1993; Whangteau Hbr (F201353). **Auckland/Waikato:** Rakitu Is., 10m (F201851) Hayward & Grenfell 1994; Cuvier Is., 37m (F201838) Hayward & Grace 1981; Parnell Reef, LT (F201346); Manukau Hbr, LT (F201505); Miranda, MT (F202113); Cook's Bch, MT (F202267); Raglan, LT (F202091). **Bay of Plenty/East Coast/Hawkes Bay:** Whale Is., LT (F202102) Hayward 1990; Cooks Cove, MT (L2058); Mahia, Maungawhio Lagoon, LT (L2053). **Wellington:** Castlepoint, LT (F201881); Cook Strait, 167m (F201234). **Taranaki/Wanganui:** Patea Est., LT (F202083). **Nelson/Marlborough:** D'Urville Is., LT (F202234); Chetwode Is., 8m (F202109). **Canterbury/Otago:** Akaroa Hbr, MT (F201887); Oamaru Port, LT (L6973); Portobello, HT (F202255); Port Chalmers, MT (F202066). **Southland/**

Stewart Is.: Big River, Fiordland, HT (F202233); Dusky Sound, 55m, type locality (F202071, CC22767, holotype CC23046, 5 paratypes CC9872) Cushman 1936; Chalky Inlet, North Port, 25m (L13562); Foveaux Strait (F201210); Paterson's Inlet (F201109); Port Pegasus, H-MT (F202285) Hayward et al. 1994; Oban, MT (L6975); Maori Beach, MT (L6974). **Chatham Islands:** Waitangi, 13m (F201913). **Antipodes Islands:** 103m (USNM). **Auckland Islands:** (F201107).

Elphidium oceanicum Cushman

EAST AUSTRALIA. Queensland: Great Barrier Reef, Claremont Lightship (F201595); Cleveland Bay (F201122). **Tasmania:** Derwent estuary, 20m (F201332). **Victoria:** Port Phillip survey stn. 49-C5 (Vic.Mus. F42218).

SW PACIFIC ISLANDS. Fiji: Levuka, 24m, type locality (CC19913, holotype CC15673); Mokaujar Anchorage (CC19911); Nairai, 24m (CC19910); Suva (F201636). **Lord Howe Is.:** Old Settlement Beach, 0.5m (F202329). **Samoa:** Apia, 4m (F201642); Pago Pago Harbour, 34m (CC3393, CC23056, CC23057). **Solomon Is.:** Malaita, MT (L1402, L1403). **Tonga:** Vava'u Anchorage, 6-8m (F201638, CC19912, CC19914).

Elphidium phillipense new name

AUSTRALIA. Victoria: Port Phillip survey stn. 49-C5, type locality (holotype and topotypes of *Elphidium granulosum* Collins, Vict.Mus. F42218, F76951, F76952).

Elphidium reticulosum Cushman

SW PACIFIC ISLANDS. Fiji: Nairai, 24m (CC19879); Suva (F201636), Suva Point, LT (F202149). **Kermadec Is.:** Nugent Is., 16m (F202269); Raoul Is., Lava Pt, HT (L451); North Meyer Is., 15m (L1599). **Lord Howe Is.:** Old Settlement Beach, 0.5m (F202329). **New Caledonia:** Noumea, Anse Vata Beach (F201585). **Norfolk Is.:** off Captain Cook Monument, 18m (F202332); Duncombe Bay, 15m (L4350). **Samoa:** Apia, 4m (F201642). **Solomon Is.:** Malaita, MT (L1402); Uepi, 1m, 13m (L3668,3669). **Tonga:** Vava'u, Ahanga Passage, MT (F202154); Vava'u Anchorage, type locality (holotype CC15671). **Vanuatu:** Port Vila, 6m (L5737).

Elphidium sandiegoense (Lankford)

EAST AUSTRALIA. Queensland: Great Barrier Reef, Claremont Lightship (F201595).

Elphidium silvestrii new name

EAST AUSTRALIA. Tasmania: Derwent estuary, 20m (F201332).

Elphidium vavauense Hayward n.sp.

SW PACIFIC ISLANDS. Tonga: Vava'u, 30m (holotype and paratypes, TF1657/1-3, USNM487683, F201081); (NZOI-A406).

Elphidium vellai Hayward n.sp.

NEW ZEALAND. Auckland: Waitemata Harbour, Hobsonville, MT, 8m (L840, L9819). **Nelson/Marlborough:** Queen Charlotte Sound, 3-37m (L626, L633, L637); Queen Charlotte Sound, 16m (TF1658/1-3; AK74000, USNM487684, L631); D'Urville Is, Kupe Bay, 0.3m (F202234).

Elphidium vitreum Collins

EAST AUSTRALIA. Victoria: Port Phillip survey stn. 62-99, type locality (Vict.Mus. F42261, holotype Vict.Mus. F42147).

Genus *Cristatavultatus*

Cristatavultatus pacificus (Collins)

EAST AUSTRALIA. Queensland: Great Barrier Reef, Trinity Opening, 600m, Collins 1958.

SW PACIFIC ISLANDS. Fiji: Makaujar Anchorage (USNM). **Samoa:** Apia, 4m (F201642); Pago Pago Harbour, 34m (CC3344, CC18903). **Tonga:** Vava'u Anchorage, 36m (CC15705, CC19880). **Vanuatu:** Port Vila, 6m (L5737).

Genus *Parrellina*

Parrellina imperatrix (Brady)

EAST AUSTRALIA. New South Wales: Port Hacking, 80m (F201554); Port Jackson, Watsons Bay (F201331, CC7880, CC22738, USNM422660) Loeblich & Tappan, 1964; east of Wollongong, 200m (CC22751). **Queensland:** Gulf of Carpentaria, Van Diemans Is., 20m (CC22736); Port Denison (CC22737). **South Australia:** Curteis Strait (USNM). **Tasmania:** Derwent estuary, 20m (F201332). **Victoria:** Ninety Mile Beach (CC12856).

Parrellina papillosa (Cushman)

EAST AUSTRALIA. New South Wales: off Wollongong, 200m, type locality (holotype CC23027, 2 paratypes CC23026); Bermegui shelf, 89m (FP4419-20).

Parrellina verriculata (Brady)

EAST AUSTRALIA. New South Wales: Cape Byron, 220m (CC22753); off Nonabeca, 160m (CC22752); off Wollongong, 200m (CC22751, USNM). **Queensland:** Gulf of Carpentaria, Van Diemans Is., 20m (CC22736, CC22750). **Tasmania:** Derwent R. estuary, 20m (F201332); Oyster Bay, 80m (F201075).

Genus *Haynesina*

Haynesina depressula depressula (Walker and Jacob)

NEW ZEALAND. Northland: Tapotupotu Bay, HT (F202120); Parengarenga Hbr, MT (F201892); Manganui, MT (F202078); Cavalli Islands, 1.5m (F201739) Hayward 1982; Helena Bay, HT (F201955) Hayward 1993; Whangateau Hbr (F201353); Kawerua, LT (F201682) Hayward 1979; Hokianga Hbr, MT (F201894); Kaipara Hbr, MT (L597). **Auckland/Waikato:** Tryphena, MT (F202100); Rakitu Is., 9.5m (F201851) Hayward & Grenfell 1994; Riverhead, MT (L661) Hayward & Hollis 1994; Watchmans Is. (F201472); Parnell Reef, LT (F201346); Orakei Basin, 5-20m (L509); Manukau Hbr (F201421); Miranda, MT (F202113); Cook's Bch, MT (F202267); Raglan, LT (F202091); Aotea Hbr, LT (F202092); Kawhia Hbr MT (F202094). **Bay of Plenty/East Coast/Hawkes Bay:** Tauranga, LT (F202114); Cooks Cove, MT (L2058); Mahia, Maungawhio Lagoon, LT (L2053); Napier, LT (F202229). **Wellington:** Castlecliff, LT (F201881); Pauatahanui, 2m (F202024) Hayward & Triggs 1994; Kapiti Is., 38m (F201982); Little Karaka Bay, MT (F202089), Cook Strait, 167m (F201234). **Taranaki/Wanganui:** Mokau Est., MT (F202086); Patea Est., LT (F202083). **Nelson/Marlborough:** D'Urville Is., LT

(F202234); Tahunanui Inlet, MT (F202237); Waimea Inlet, MT (F202099); Chetwode Is., 8m (F202109); Lake Grassmere, HT (F202263). **Canterbury/Otago:** Lyttleton, HT (F202260); Akaroa Hbr, MT (F201887); Timaru, MT (F202258); Blueskin Bay, HT (F202257); Portobello, HT (F202255); Port Chalmers, MT (F202066); Hooper's Inlet, HT (F202254); Clutha Est., 32m (F201160). **Southland/ Stewart Is.:** Waikawa Hbr, HT (F202248); Bluff, HT (F202249); Oreti Est., MT (F202250); Riverton Est., M-HT (F202246); Chalky Inlet, North Port, 25m (L13562);Port Pegasus, 2m (F202281) Hayward et al. 1994; Maori Beach, MT (L6974). **West Coast:** Dusky Sound, 55m (F202071). **Chatham Islands:** 20m (F201914). **Auckland Islands:** Musgrove Peninsula, type locality of *E. simplex aoteanum* (F201002, holotype and 4 paratypes TF1305/1-2, USNM689249, VFp76); Tagua Bay, 3m (L6184).

EAST AUSTRALIA. New South Wales: Sydney, Watsons Bay (F201331). **Queensland:** Great Barrier Reef, Claremont Lightship (F201595). **Victoria:** Port Phillip survey stn. 49-C5 (Vic.Mus. F42218).

SW PACIFIC ISLANDS. Cook Is: Rarotonga (F201639). **Fiji:** Lami, LT (F202148); Levuka, 24m (CC19909); Laucua (F201130); Vatuwangga Est., HT (F202144,5). **Lord Howe Is.:** lagoon beach, MT (F202266); Old Settlement Beach, 0.5m (F202329). **Kermadec Is.:** Cheeseman Is., 30m (F202268); Nugent Is., 16m (F202269). **Samoa:** Apia, 4m (F201642). **Solomon Is.:** Malaita, MT (L1402,3) [bosses]. **Tonga:** (NZOI-A406).

Haynesina depressula simplex (Cushman)

EAST AUSTRALIA. New South Wales: Sydney, Watsons Bay (F201331, USNM). **Queensland:** Great Barrier Reef, Claremont Lightship (F201595); Great Barrier Reef, Piper Is. (F201127); Cleveland Bay (F201122). **Victoria:** Port Phillip survey stn. 49-C5 (Vic.Mus. F42218).

SW PACIFIC ISLANDS. Cook Is: Rarotonga (F201639). **Fiji:** Lami, LT (F202148); Levuka, 24m (CC19909); Laucua (F201130); Nairai, 24m (CC19903, 1 paratype CC15675); Suva (F201636); Suva Pt, LT (F202149); Vatuwangga Est., HT (F202144,5); Viva Anchorage, 6m (CC19906). **Lord Howe Is.:** lagoon beach, MT (F202266); Old Settlement Beach, 0.5m (F202329). **Samoa:** Apia, 4m (F201642). **Solomon Is.:** Malaita, MT (L1402,3). **Tonga:** (NZOI-A406); Vava'u Anchorage, type locality (CC19907, holotype CC15674). **Vanuatu:** Epi Is., 10m (L5738); Port Vila, 6m (L5737).

APPENDIX II

Recent records of *Elphidium, Cristatavultatus, Parrellina* and *Haynesina* from the South-west Pacific by country, state or island

NEW ZEALAND
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium advenum maorium
Elphidium charlottense
Elphidium crispum
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum oirgi
Elphidium excavatum williamsoni
Elphidium gunteri
Elphidium novozealandicum
Elphidium reticulosum
Elphidium vellai
Haynesina depressula depressula

NEW ZEALAND, KERMADEC ISLANDS
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium crispum
Elphidium reticulosum
Haynesina depressula depressula

NEW ZEALAND, NORTH ISLAND
Elphidium advenum limbatum
Elphidium advenum maorium
Elphidium charlottense
Elphidium crispum
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum oirgi
Elphidium excavatum williamsoni
Elphidium gunteri
Elphidium novozealandicum
Haynesina depressula depressula

NEW ZEALAND, SOUTH ISLAND
Elphidium advenum limbatum
Elphidium advenum maorium
Elphidium charlottense
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum williamsoni
Elphidium gunteri
Elphidium novozealandicum
Elphidium vellai
Haynesina depressula depressula

NEW ZEALAND, STEWART ISLAND
Elphidium advenum limbatum
Elphidium advenum maorium
Elphidium charlottense
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum williamsoni
Elphidium novozealandicum
Haynesina depressula depressula

NEW ZEALAND, CHATHAM ISLANDS
Elphidium advenum limbatum
Elphidium advenum maorium
Elphidium excavatum excavatum
Elphidium novozealandicum
Haynesina depressula depressula

NEW ZEALAND, ANTIPODES ISLANDS
Elphidium novozealandicum

NEW ZEALAND, AUCKLAND ISLANDS
Elphidium advenum limbatum
Elphidium charlottense
Elphidium novozealandicum
Haynesina depressula depressula

NEW ZEALAND, CAMPBELL ISLAND
Elphidium novozealandicum

NEW ZEALAND, SNARES ISLANDS
Elphidium excavatum clavatum
Elphidium excavatum excavatum

COOK ISLANDS
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium advenum tongaense
Elphidium excavatum excavatum
Elphidium lene
Haynesina depressula depressula
Haynesina depressula simplex

FIJI
Cristatavultatus pacificus
Elphidium advenum advenum
Elphidium advenum dispar
Elphidium advenum limbatum
Elphidium advenum tongaense
Elphidium craticulatum
Elphidium crispum crispum
Elphidium excavatum excavatum
Elphidium excavatum williamsoni
Elphidium fichtellianum
Elphidium fijiense
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium reticulosum

Elphidium reticulosum
Haynesina depressula depressula
Haynesina depressula simplex

NEW CALEDONIA
Elphidium advenum advenum
Elphidium craticulatum
Elphidium crispum crispum
Elphidium hispidulum
Elphidium lene
Elphidium macellum

SAMOA
Cristatavultatus pacificus
Elphidium advenum advenum
Elphidium advenum botaniense
Elphidium advenum tongaense
Elphidium fichtellianum
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium reticulosum
Haynesina depressula depressula
Haynesina depressula simplex

SOLOMON ISLANDS
Elphidium advenum advenum
Elphidium advenum botaniense
Elphidium advenum dispar
Elphidium advenum limbatum
Elphidium carteri
Elphidium craticulatum
Elphidium crispum crispum
Elphidium excavatum clavatum
Elphidium fichtellianum
Elphidium fijiense
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium reticulosum
Haynesina depressula depressula
Haynesina depressula simplex

TONGA
Cristatavultatus pacificus
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium advenum tongaense
Elphidium craticulatum
Elphidium crispum crispum
Elphidium fichtellianum
Elphidium fijiense
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium reticulosum
Elphidium vavauense
Haynesina depressula depressula
Haynesina depressula simplex

VANUATU
Cristatavultatus pacificus
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium advenum tongaense
Elphidium craticulatum
Elphidium crispum crispum
Elphidium excavatum clavatum
Elphidium fichtellianum
Elphidium macellum
Elphidium reticulosum
Haynesina depressula simplex

EAST AUSTRALIA
Cristatavultatus pacificus
Elphidium advenum advenum
Elphidium advenum botaniense
Elphidium advenum limbatum
Elphidium advenum maorium
Elphidium albanii
Elphidium argenteum
Elphidium carteri
Elphidium charlottense
Elphidium collinsi
Elphidium craticulatum
Elphidium crispum crispum
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum sydneyense
Elphidium excavatum williamsoni
Elphidium fichtellianum
Elphidium phillipense
Elphidium gunteri
Elphidium hawkesburiense
Elphidium hispidulum
Elphidium lene
Elphidium macellum
Elphidium mortonbayense
Elphidium oceanicum
Elphidium sandiegoense
Elphidium silvestrii
Elphidium vitreum
Parrellina imperatrix
Parrellina papillosa
Parrellina verriculata
Haynesina depressula depressula
Haynesina depressula simplex

EAST AUSTRALIA, QUEENSLAND
Cristatavultatus pacificus
Elphidium advenum advenum
Elphidium advenum botaniense
Elphidium advenum limbatum
Elphidium albanii
Elphidium argenteum
Elphidium carteri
Elphidium collinsi
Elphidium craticulatum
Elphidium crispum crispum

Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium fichtellianum
Elphidium hawkesburiense
Elphidium hispidulum
Elphidium lene
Elphidium mortonbayense
Elphidium oceanicum
Elphidium sandiegoense
Parrellina imperatrix
Parrellina papillosa
Parrellina verriculata
Haynesina depressula depressula
Haynesina depressula simplex

EAST AUSTRALIA, NEW SOUTH WALES
Elphidium advenum advenum
Elphidium advenum botaniense
Elphidium advenum limbatum
Elphidium albanii
Elphidium argenteum
Elphidium carteri
Elphidium collinsi
Elphidium craticulatum
Elphidium crispum crispum
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum sydneyense
Elphidium fichtellianum
Elphidium gunteri
Elphidium hawkesburiense
Elphidium hispidulum
Elphidium lene
Elphidium macellum
Elphidium mortonbayense
Elphidium oceanicum
Elphidium silvestrii
Parrellina imperatrix
Parrellina papillosa
Parrellina verriculata
Haynesina depressula depressula
Haynesina depressula simplex

EAST AUSTRALIA, VICTORIA
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium advenum macelliforme
Elphidium advenum maorium
Elphidium argenteum
Elphidium crispum crispum
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium excavatum williamsoni
Elphidium fichtellianum
Elphidium phillipense
Elphidium gunteri
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium silvestrii
Elphidium vitreum
Parrellina imperatrix
Parrellina verriculata
Haynesina depressula depressula
Haynesina depressula simplex

EAST AUSTRALIA, TASMANIA
Elphidium advenum advenum
Elphidium advenum botaniense
Elphidium advenum limbatum
Elphidium crispum crispum
Elphidium excavatum clavatum
Elphidium excavatum excavatum
Elphidium hawkesburiense
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium silvestrii
Parrellina imperatrix

AUSTRALIA, LORD HOWE ISLAND
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium albanii
Elphidium charlottense
Elphidium fijiense
Elphidium lene
Elphidium macellum
Elphidium oceanicum
Elphidium reticulosum
Haynesina depressula depressula
Haynesina depressula simplex

AUSTRALIA, NORFOLK ISLAND
Elphidium advenum advenum
Elphidium advenum limbatum
Elphidium excavatum williamsoni
Elphidium fichtellianum
Elphidium macellum
Elphidium reticulosum

APPENDIX III
Fossil New Zealand *Elphidium, Discorotalia* and *Haynesina* specimens examined

Fossil record locality numbers in the format A34/f are of the New Zealand Fossil Record File, of the Geological Society of New Zealand. All specimens are held in the collections of the Institute of Geological and Nuclear Sciences, Lower Hutt, unless indicated otherwise.

Specimen and sample repositories

CC	Cushman Collection, held at Natural History Museum, Smithsonian Institution, Washington DC, USA
FP, TF	Institute of Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand
USNM	Natural History Museum, Smithsonian Institution, Washington DC, USA
VF	Victoria University of Wellington, Department of Geology, PO Box 600, Wellington, New Zealand

Genus *Elphidium*

Elphidium aculeatum norcotti Hayward n.sp.

EARLY MIOCENE. Wellington: U25/f6564 (TF1647/1-3, USNM487673), type locality, late Lw-Po.

Elphidium aculeatum subrotatum Hornibrook

MIDDLE MIOCENE. Wellington: T27/f176, f310, Sc; T27/f51, Sl; T27/f140, Sw.

EARLY MIOCENE. Nelson: SE40173/f4, Surville-1 cuttings 669-672 m, Pl. West Coast: L29/f8773, Pl. Canterbury: J39/f9483, Pl. Otago: J41/f8498 (TF1422/1-2), type locality, Pl.

Elphidium advenum advenum Cushman

MIDDLE MIOCENE. Southland: D45/f8671, Sw.

EARLY MIOCENE. Canterbury: I38/f7628, f7607, Lw; M34/f7038, Pl.

Otago: J41/f8498, Pl. Southland: D45/f8480, Po; D45/f8482, f8487, Pl.

OLIGOCENE. Waikato: R14/f6541, eLwh. West Coast: K29/f253, f255, Lwh; L28/f7504, Ld. Otago: J41/f9592,f8893, Lwh; J41/f9599, Ld. Southland: A45/f9543,f9553, Lwh.

LATE EOCENE. West Coast: J32/f7848 (CC64155-6, USNM688751), Ethel Creek type locality of *E. omotoense*, Ar; K29/f6504, Ar. Otago: J41/f8817, Ar.

MIDDLE EOCENE. Canterbury: J40/f200, McCulloch's Bridge, Ab (Canterbury University collection).

Elphidium advenum limbatum (Cushman)

PLEISTOCENE. East Coast: Y14/f7505, Wc. Taranaki: SE38172/f1, Tane-1, ctgs. 790-800m, Wn-Wc.

PLIOCENE. Hawkes Bay: X19/f7773, f7754, Wo; W15/f8503, Wm.

MIDDLE MIOCENE. Southland: C45/f9454, Sl.

EARLY MIOCENE. Northland: N02/f112, Po; O05/f2, Po; Q08/f9794 (FP2094), ePl; Q08/f9914, ePl. Auckland: R11/f9,11 (FP4042), Po; Q11/f6537 (USNM243348), ePl. East Coast: Y14/f7811, Po. Nelson: N25/f8480, Pl. West Coast: L30/f6594, Lw; L30/f6793, Po. Canterbury: I38/f7608, f7607, Lw; M34/f71, J39/f7642, Po. Otago: J41/f8498, ePl. Southland: F46/f8490, Lw-Po; D45/f8487, Pl.

OLIGOCENE. Waikato: R15/f112, eLwh; S14/f23, core 14.5-14.5 m, Lwh-Lw. Taranaki: S19/f9509, Ld. West Coast: K29/f253, Lwh; L28/f7504, Ld. Otago: J41/f8896, Lwh; J41/f9597, Ld. Southland: D45/f29, Lwh; F45/f8492, f8495, Ld.

LATE EOCENE. West Coast: J32/f7848, Ar; K29/f6503, Ar. Otago: J41/f8817,f8886, Ar.

Elphidium advenum macelliforme Hayward n.ssp.

PLIOCENE. Hawkes Bay: X19/f7771,f82, Wo.

LATE MIOCENE. East Coast: Y14/f7841, late Tt.

OLIGOCENE. West Coast: L28/f7504 (TF1649/1-3, USNM487675), Ld. Otago: J41/f9546, Lwh.

Elphidium advenum maorium Hayward n.ssp.

PLEISTOCENE. Wanganui: S22/f6567, Wn. Manawatu: T24/f6597, Wn; T24/f6599, Wc. Bay of Plenty: W15/f7501, Wc. East Coast: Y14/f7505, Wc. Hawkes Bay: V20/f8580, Wn; V21/f6005, Wn.

PLIOCENE. Taranaki: SE39173/f2, Maui-2 ctgs. 375-384m, Wm. Wanganui: T21/f8511, Wo; T22/f8539, Wp; S22/f6557, Wm. Hawkes Bay: X19/f9521, Wp; W19/f8503,f7, Wm; V21/f8632, Wm. West Coast: K32/f8701, Wp-Wm.

LATE MIOCENE. West Coast: K29/f8513, Sw-Tt; K29/f8514, Tt-Tk; J32/f9655, f9656, late Tt.

MIDDLE MIOCENE. Hawkes Bay: V22/f7470, Sw. Southland: D45/f8656,f8659, Sl; D45/f8674,f8675, Sw.

EARLY MIOCENE. Northland: N02/f112, Po; O05/f2, Po; O06/f23, Po; Q08/f9679, f9914, ePl. Auckland: Q11/f6537 (USNM243348), ePl. Canterbury: J39/f7635, Po. M34/f7038, Pl. Otago: J41/f8498-9, Pl. Southland: D45/f8480, Po.

OLIGOCENE. Otago: J41/f8896, Lwh.

LATE EOCENE. Southland: J41/f8882,f8883, Ar.

Elphidium carteri Hayward n.sp.

MIDDLE MIOCENE. Southland: D45/f8662, Sl; D45/f8671, Sw.

EARLY MIOCENE. Wellington: T27/f170,f174, late Pl. Southland: F46/f8490, Lw-Po.

Elphidium charlottense (Vella)

PLEISTOCENE. Taranaki: SE37174/f1, Tuatua-1 ctgs. 650m, Wn; SE38174/f1, Mangaa-1 ctgs. 960-981m, Wn. Wanganui: R22/f6348, Wn; R22/f111, f161, f6521, Wc. Manawatu: T22/f8554, f8555, Wn; T24/f6597, Wn; T24/f6599, Wc. Bay of Plenty: V15/f26, Wc; W15/f9540, Wc. East Coast: Y14/f7505, Wc. Hawkes Bay: V20/f149, f8580, f8581, Wn. Wellington: S27/f8587, f8724, Wn. Great South Basin: SE47169/f2, Tara-1, Wn.

PLIOCENE. Waikato: R13/f6009A, Wo. Taranaki: P20/f14, Te Kiri- ctgs. 350m, Wo; SE38174/f1, Mangaa-1 ctgs. 2240-2249m, Wp; SE38173/f1, Wainui-1 ctgs. 1600m, Wp. Wanganui: R20/f2, Wo; T21/f8514, Wp; S21/f8548, Wm;

T20/f8510, Wp-Wm. Hawkes Bay: X19/f345, f9506, f9521, Wp; U22/f8544, Takapau-1, 243m, Wm; W19/f7, Wm. Wellington: T26/f345, Wp; S27/f443, Wm. Canterbury: M33/f2, Wo-Wm; SE44172/f1, Resolution-1 ctgs. 545-550m, Wo-Wp.

LATE MIOCENE. Taranaki: Q19/f60, Tt. Wanganui: T20/f2, Tk. East Coast: Z14/f9512, Tk. Hawkes Bay: U23/f132, Tt-Tk. Wellington: S28/f39, Tt; T26/f217, Tt; T25/f126, Tk. West Coast: J32/f9673 (FP1393, Kennett 1966a), Tk.

MIDDLE MIOCENE. East Coast: Z16/f12, Sw-eTt.

EARLY MIOCENE. Canterbury: J39/f9510, Po. Otago: J41/f8790, Pl. Southland: F46/f8490, Lw.

OLIGOCENE. Otago: J41/f9601, Ld. Southland: D45/f29, Lwh.

Elphidium crispum crispum (Linne)

PLEISTOCENE. Taranaki: SE38174/f1, Mangaa-1 ctgs. 960981m, Wn. Wanganui: R22/f6348, Wn; R22/f111,f6521, Wc. Manawatu: T22/f8555, Wn; T24/f6597, Wn; T24/f6599, Wc. Bay of Plenty: W15/f7501, Wc. Hawkes Bay: V20/f149, f8580, Wn. Wellington: S27/f8587, Wn.

PLIOCENE. Northland: SE34173/f1, Wo. Waikato: R13/f6009A, Wo. Wanganui: Q22/f7667, Wp; S22/f6557, Wm. East Coast: Y14/f7618, eWo. Hawkes Bay: X19/f7772,f82, Wo; V21/f8628, Mason Ridge-1, 1524m, Wp. Southland: C45/f81, Wo. Chatham Islands: CH/f281, f293, Wo; CH/f296, Wo-Wp; CH/f312, Wm.

LATE MIOCENE. East Coast: Y14/f7506, f7841, late Tt-Tk; Hawkes Bay: V22/f361, Tt. West Coast: J32/f9644 (VF399), Tk. Southland: C45/f163, Tt-Tk.

MIDDLE MIOCENE. Northland: N02/f7584, Sl-Sw. Taranaki: Q19/f34, Manganui-1, ctgs. 1800m, Sc. East Coast: Z15/f6188, Sc; Y16/f603, Sl; Y16/f746, Sl-Sw. Hawkes Bay: V21/f8521, Sw; V23/f6438, Sw. West Coast: K32/f6716, Sc. Southland: C43/f13, Sl; D45/f8471, Sl; C45/f9, Sw; D45/f8673, Sw. Auckland Islands: AK/f25, Pl-Sw.

EARLY MIOCENE. Northland: O06/f7564, Lw; P06/f7573, Lw; N02/f7554, Po; O05/f2-3, Po; O06/f23, Po; N02/f7544, ePl; Q08/f9455,f9792 (USNM243349, 243351) type locality of *E. gibsoni,* ePl; N02/f113, mPl. Auckland: R09/f72, Po; R11/f8,f9,f7709 (FP4043, USNM243350), Po; R11/f6537, ePl; R11/f7589, mPl. Waikato: R14/f6527, Lw; R13/f6579, Po; S16/f8003, Po. Taranaki: SE38173/f8, Kora-4 ctgs. 2305m, m Pl; Q21/f6572, Kapuni-1 ctgs. 2420m, late Pl. East Coast: Y14/f7811, Po; Z14/f192, Po; Y16/f8787, f7822, late Pl. Wellington: U25/f127, Pl; T27/f169, Pl; T27/f170, late Pl. Nelson: N25/f18, Pl; West Coast: M29/f8624, Lw; L30/f6502, Po. Canterbury: I38/f7607, f7608, Lw; I38/f6502, Po; M34/f7038, Pl. Otago: I40/f9519, Lw; J41/f8498, Pl. Southland: F45/f52 ctgs. 78.68-78.73m, Lw-Pl; F46/f8490, Lw-Po; D45/f8480, Po; D45/f8624, f8487, Pl.

OLIGOCENE. Northland: O04/f54, eLwh; O06/f7564, Ld. Auckland: T10/f8505, Ld. Waikato: R14/f6541, eLwh; R15/f8067, Lwh; R14/f59, f23, Ld. Taranaki: S19/f9509, Ld. West Coast: L28/f69, Lwh; L26/f12, Lwh; L26/f9, Lwh-Ld; L25/f14, Lwh-Ld; L28/f7504, f7543, Ld. Canterbury: K34/f54, Lwh; K36/f6505, Lwh-Ld; K34/f16, Ld. Otago: J41/f8731,f8892, Lwh. Southland: A45/f9542, Lwh; D45/f29, Lwh; F45/f126, Ld-Lw; F45/f8492, f8498, Ld; G45/f8499, Ld.

LATE EOCENE. Northland: O05/f7501, f7646, Ar. Waikato: S16/f72 ctgs. 274-8m, Ar. Otago: J41/f8591, f8726, Ar. Southland: A45/f9528, Ar.

Elphidium crispum waiwiriense Hayward n.ssp.

EARLY MIOCENE. Waikato: R13/f6551,f6579,f55,f57,f59 (TF1652/1-4, USNM487678), Waiwiri Beach type locality, Po. Southland: F46/f43, Lw-Po.

Elphidium excavatum clavatum (Terquem)

PLEISTOCENE. Taranaki: SE38172/f1, Tane-1 ctgs. 590-600m, Wn-Wc. Wanganui: R22/f6348, Wn; S22/f6565 (VF1000), Wn. Manawatu: T22/f8555, Wn; T24/f6597, Wn; T24/f6599, Wc. East Coast: Y14/f7505, Wc. Hawkes Bay: V20/f149, f8580, Wn; V21/f8634, Wn. Wellington: S27/f8587, Wn.

PLIOCENE. Wanganui: Q22/f7667, Wp; S22/f6557, Wm.

LATE MIOCENE. West Coast: K32/f8697 (FP1394), Tt.

MIDDLE MIOCENE. Southland: D45/f8657,f8659,f8664, Sl; D45/f8671,f8675, Sw.

EARLY MIOCENE. Northland: N02/f112, Po; O06/f28,f38, Po; Q08/f9680,f9914, ePl. West Coast: L30/f6793, Po. Canterbury: M34/f7038, Pl. Otago: J41/f8498,f8499, Pl. Southland: D45/f8487, Pl.

Elphidium excavatum excavatum (Terquem)

PLIOCENE. Hawkes Bay: X19/f7765, f7755, Wo.

Elphidium excavatum williamsoni Haynes

PLEISTOCENE. Hawkes Bay: V20/f8582, Wn; V21/f8634, Wn.

Elphidium hampdenense Finlay

MIDDLE EOCENE. Northland: Q08/f278, f9749 Dh; P05/f115 Dh. East Coast: X17/f183, Rere-1 ctgs. 1650-1800 m, Dh. Hawkes Bay. V22/f8840, f8922, Dh. Wellington: S28/f8572, Dh. Marlborough: O29/f15, Dh. Canterbury: N33/f9054, Dh. Otago: J42/f8532 (TF1080/1-4), Hampden Beach type locality, Dh. Great South Basin (Raine et al. 1993): SE47169/f1, Toroa-1 ctgs. 969-996 m, Dh; SE48169/f1, Pakaha-1 ctgs. 1703-1914 m, Dh; SE48169/f2, Kawau-1A ctgs. 1883-1990 m, Dh; SE49169/f1, Hoiho-1C ctgs. 1317-1400 m, Dh.

Elphidium ingressans Dorreen

LATE EOCENE. West Coast: J32/f7848 (CC64152-3, USNM688473), Ethel Creek type locality, Ar; K29/8633, Charleston-1, Ar-eLwh.

Elphidium kanoum Hayward

MIDDLE MIOCENE. Taranaki: R19/f1, Sc-Sw. West Coast: K32/f6716, Sc. Southland: D45/f8641, f8477, Sc; D45/f8664, Sl; D45/f8651, Sc-Sl.

EARLY MIOCENE. Northland: N02/f7554, Po; O06/f8534, Po; N02/f7551, Pl; N02/f113, mPl; Q08/f9454,9608,f9792, (TF1580/2-3, USNM243360-1), ePl; Q08/f9457 (TF1580/1), type locality, ePl. Auckland: R11/f8, f7514 (FP4044), Po; S12/f9560, Po. Waikato: R13/f6551, Lw; R14/f6573, f23, Lw; R13/f6553, f6579, Po; Taranaki: R18/f55, Pl; SE39174/f1, Kupe-1 ctgs. 2528-38m, Pl. Wellington: T27/f174, late Pl. Nelson: N25/f18, Pl; West Coast: L30/f6502, Po; L29/f8555, Pl; K32/f6139, Pl. Canterbury: I38/f7608, f7628, Lw; I38/f6502, Po; M34/f7038, Pl. Southland: D45/f8636, f8487, Pl. Auckland Islands: AK/f25, Pl-Sw.

OLIGOCENE. Northland: O06/f7564, Ld.

Elphidium matanginuiense Hayward n.sp.

EARLY EOCENE. Chatham Islands: CH/f3 (TF1655/1-3, USNM487681) type locality, eDw; CH/f374, f387, Dw; CH/f54, Dm.

Elphidium matauraense Hayward n.sp.

EARLY MIOCENE. Northland: Q08/f9914, ePl. Southland: F46/f42, F46/f52 ctgs. 78.68-78.73m (TF1561/1-3, USNM487682) type locality, Lw-Po.

Elphidium novozealandicum Cushman

PLEISTOCENE. Wanganui: R22/f161, Wc; Manawatu: T22/f8554, Wn; T24/f6555, Wc. Bay of Plenty: W15/f7501, Wc; W15/f9540, Wc. East Coast: Y14/f7505, Wc. Hawkes Bay: V20/f149, f8580, Wn. Wellington: S27/f8587, f8724, Wn. Canterbury: O32/f8110, Wn-Wc. Chatham Islands: CH/f423, Wn-Wc.

PLIOCENE. Northland: SE34173/f1, Wo. Waikato: R13/f6009A, Wo. Wanganui: Q22/f7667, Wp; S22/f6558, Wm; T20/f8510, Wp-Wm. East Coast: Y14/f7618, eWo. Hawkes Bay: X19/f7761,f82, Wo; U22/f8544, Takapau-1, 880m, Wo-Wp; X19/f9506, Wp; V21/f8628, Mason Ridge-1, 1524m, Wp; U22/f8544, Takapau-1, 243m, Wm; V21/f7, Wm. Wellington: R27/f156, Printers Flat-1, 56m, Wo. Canterbury: O32/f8936, Wm-Wn.

LATE MIOCENE. East Coast: Y14/f7506, f7581, Tk; Z14/f9504, f9671, f9509, Tk.

Elphidium* aff. *novozealandicum Cushman

PLIOCENE. Waikato: R13/f6009A, Wo.

LATE MIOCENE. East Coast: Y14/f7841, late Tt. Hawkes Bay: V22/f361, late Tt. Wellington: T26/f217, f259, Tt; S28/f6688 (VFf269), Tt.

MIDDLE MIOCENE. Northland: N02/f7584, Sl-Sw. Hawkes Bay: V21/f8521, Sw.

Elphidium oceanicum Cushman

PLEISTOCENE. East Coast: Y14/f7505, Te Piki, Wc.

Elphidium pseudoinflatum Cushman

MIDDLE MIOCENE. Northland: N02/f7584, Sl-Sw. Hawkes Bay: V23/f6438, Sw. Taranaki: R19/f1, Sc-Sw. East Coast: Y16/f451, Sl. Southland: D45/f8477, Sc; D45/f8471, f8475, Sl; C45/f9, Sw; D45/f8673, Sw.

EARLY MIOCENE. Northland: O06/f7564, Lw; N02/f7554, Po; O05/f2-3, Po; N02/f112, Po; Q08/f9455, f9457, (USNM243358-9), ePl; Q09/f9505, f9532, f9581, (USNM243355-7), ePl; N02/f113, mPl. Auckland: R09/f72, f75, Po; R11/f126, Po; S11/f11, Po; R11/f7589, Pl. Waikato: R13/f59, Lw-Po. Taranaki: R18/f40 cuttings 349-354m, Pl. East Coast: Y16/f8787, late Pl. Nelson: N26/f8508, Pl. Canterbury: I38/f7607, f7608, f7628, Lw; M34/f71, Po; M34/f7038, Pl. Southland: F46/f8490, Lw-Po; D45/f8487, Pl.

OLIGOCENE. Northland: O06/f7564, Ld. Waikato: R14/f6541, eLwh; R15/f8067, Lwh. West Coast: K29/f253 (VF619, VF619p, TF1548/2,3), types of *E. hornibrooki*, Lwh; L28/f43, eLwh; L28/f7504, f7543, Ld. Southland: D45/f29, Lwh; C46/f7574, Lwh-Ld; F45/f8495, Ld; F45/f126, Ld-Lw.

LATE EOCENE. West Coast: K29/f6504,f6505, Ar.

Elphidium saginatum Finlay

MIDDLE EOCENE. Northland: O05/f7728, Dp. Taranaki: SE38173/f3, Wainui-1 ctgs. 3200-3205m, Dp; SE38173/f7, Te Kumi-1 ctgs. 3820m, Dp. East Coast: Y16/f210, Dp. Hawkes Bay: V22/f8837, Dp; U24/f9142 (TF1081/1-4, USNM689074), Mangatoro type locality, Dp; West Coast: G36/f2, Dp. Canterbury: N33/f8168, Dp. Chatham Islands: CH/f507, Dp. Great South Basin (Raine et al. 1993): SE47169/f1, Toroa-1 ctgs. 823-965 m, Dp; SE48169/f1, Pakaha-1 ctgs. 1439-1703 m, Dp; SE 48170/f1, Pukaki-1 ctgs. 1825-2400m, Dp.

Elphidium schencki Cushman & Dusenbury

LATE EOCENE. Northland: Q08/f289, Ab-Ak; Q08/f308, Ab-Ar. West Coast: J32/f7848 (CC64154, USNM688474), Ethel Creek type locality of *E. nitidum*, Ar.

MIDDLE EOCENE. Northland: Q08/f9018, Ab.

Elphidium wadeae (Hornibrook)

EARLY MIOCENE. Canterbury: Tengawai, Lw; I40/f9519, Lw; I38/f7607, Lw; M34/f71, Po. Southland: D45/f8678, Po.

OLIGOCENE. Waikato: R14/f6541, eLwh; R15/f104,f112, eLwh; S16/f6590, Ld; R14/f23, Ld. Nelson: O27/f28, Lwh. West Coast: L28/f43, eLwh; L26/f9, f10, f12, Lwh; L25/f14, Lwh-Ld; L28/f7504, Ld. Southland: F45/f8492, f9494A, Chatton, Ld. G45/f8499 (TF1429/1-2), Chatton type locality, Ld; D45/f8498, Ld; D45/f29, Lwh.

Genus *Discorotalia*

Discorotalia aranea (Hornibrook)

MIDDLE MIOCENE: Southland: D45/f8645, f8646, Sc; C45/f9547, Sw; D45/f8673, Sw.

EARLY MIOCENE. West Coast: L30/f6793, Po; L29/f9726, Po; L30/f6517, Pl. Canterbury: N33/f35, Po; N34/f7507, Pl; M34/f7038, Pl. Otago: J41/f8818, Pl; J41/f8790 (TF1331/1), Old Rifle Butts type locality, Pl; J41/f8793, Pl. Southland: D45/f8487, f8624, Pl.

Discorotalia tenuissima (Karrer)

MIDDLE MIOCENE. Canterbury: M34/f7605, Sl. Southland: D45/f8477, Sc; D45/f8471, Sl; C45/f9, f9546, Sw; D45/f8670, Sw. Great South Basin: SE47169/f2, Tara-1 ctgs., Sw.

EARLY MIOCENE. Northland: Q08/f33, Pl. Auckland: R11/f7555 (FP2019-20), Hobson Bay type locality, Po. Taranaki: R17/f8512, (FP1833), Po. East Coast: Y14/f7811, Po. Wellington: T27/f174, late Pl. Nelson: N25/f18,f8480, Pl; N26/f8508, Pl. West Coast: L30/f6594, Lw; L30/f6767, Po; N33/f35, Po; K32/f6142, Pl. Canterbury: I38/f7607,f7608, Lw; I40/f9519, Lw; M34/f71, Po; M34/f7038, Pl. Otago: J41/f8498, f8793, Pl. Southland: F46/f8491, Lw-Po; D45/f8678, Po; D45/f8487,f8624, Pl.

OLIGOCENE. Northland: O06/f7564, Ld. West Coast: L28/f7543, Ld; Southland: D45/f29,f9494, late Lwh; E44/f8587, late Lwh; F45/f8495,f8498, Ld; F45/f126, Ld-Lw.

Genus *Haynesina*

Haynesina depressula depressula (Walker and Jacob)

PLEISTOCENE. Taranaki: SE38173/f3, Wainui-1 ctgs. 600m, Wn; SE38174/f1 Mangaa-1 ctgs. 850-868m, Wn. Wanganui: R22/f6348, Wn; R22/f111, f161, f6521, Wc. Manawatu: T22/f8554, f8555, Wn; T24/f6597, Wn; T24/f6599, Wc. Bay of Plenty: W15/f7501, Wc. East Coast: Y14/f7505, Wc. Hawkes Bay: V20/f8580, Wn; V21/f8634, Wn. Wellington: S27/f8587, Wn. Chatham Islands: CH/f406, Wn.

PLIOCENE. Waikato: R13/f6009A, Wo. Taranaki: SE38174/f1, Mangaa-1 ctgs. 2240-2249m, Wp. Wanganui: T21/f8511, Wo; Q22/f7667, Wp; S22/f6558, Wm. Hawkes Bay: X19/f7749, Wo; W19/f8503, Wm. Wellington: R27/f8573, Wo. Canterbury: O33/f48, Wp-Wm. Chatham Islands: CH/f302, Wo-Wp.

LATE MIOCENE. West Coast: K29/f8514, Tt-Tk. Southland: D45/f8442, Tt.

MIDDLE MIOCENE. East Coast: Z16/f12, Sw-eTt. Southland: D45/f8471, Sl.

EARLY MIOCENE. Northland: Q07/f9580, Po; Q08/f33, ePl. Auckland: R11/f8,f7555, Po; Q10/f9531, ePl. Waikato: R13/f57, Lw-Po; R13/f61, Po. Canterbury: I38/f7608, Lw; I40/f9519, Lw; M34/f71, Po; M34/f7038, Pl. Otago: J41/f8498, Pl. Southland: D45/f8469, Lw; F46/f43, Lw; F46/f52 ctgs. 78.68-73m, Po-Pl.

OLIGOCENE. Waikato: S12/f9554, Lwh; R12/f1, Lwh; R14/f37, late Lwh; R13/f6016, Ld; R15/f94, Ld. West Coast: L26/f10, Lwh; L28/f7504, Ld. Otago: J41/f9499, Lwh. Southland: F45/f8492, Ld.

APPENDIX IV
Fossil New Zealand records of *Elphidium, Discorotalia* and *Haynesina* by epoch and stage

New Zealand stage symbols (Figure 1) are used for the time ranges of individual taxa.

Early Eocene
E. matanginuiense Dw-Dm

Middle Eocene
E. advenum advenum Ab-
E. hampdenense Dh
E. saginatum Dp
E. schencki Ab-

Late Eocene
E. advenum advenum -Ar-
E. advenum limbatum Ar-
E. advenum maorium Ar-
E. crispum crispum Ar-
E. ingressans Ar
E. pseudoinflatum Ar-
E. schencki -Ak-Ar

Oligocene
E. advenum advenum -Lwh-Ld-
E. advenum limbatum -Lwh-Ld-
E. advenum macelliforme Lwh-Ld-
E. advenum maorium -Lwh-
E. charlottense Lwh-Ld-
E. crispum crispum -Lwh-Ld-
E. kanoum Ld-
E. pseudoinflatum -Lwh-Ld-
E. wadeae Lwh-Ld-
H. depressula depressula Lwh-Ld-
D. tenuissima Lwh-Ld-

Early Miocene
E. aculeatum norcotti Lw-Po
E. aculeatum subrotatum Pl-
E. advenum advenum Lw-Pl-
E. advenum limbatum -Lw-Pl-
E. advenum maorium -Po-Pl-
E. carteri Lw-Pl-
E. charlottense Lw-Pl-
E. crispum crispum -Lw-Pl-
E. crispum waiwiriense Lw-Po
E. excavatum clavatum Po-Pl-
E. kanoum -Lw-Pl-
E. matauraense Lw-Pl
E. pseudoinflatum -Lw-Pl-
P. wadeae -Lw-Po
H. depressula depressula -Lw-Pl-
D. tenuissima -Lw-Pl-
D. aranea Po-Pl-

Middle Miocene
E. aculeatum subrotatum -Sc-Sw
E. advenum advenum -Sw
E. advenum limbatum -Sl-
E. advenum maorium -Sl-Sw-
E. carteri -Sl-Sw
E. charlottense -Sw-
E. crispum crispum -Sc-Sw-
E. excavatum clavatum -Sl-Sw-
E. kanoum -Sc-Sw
E. aff. *novozealandicum* Sw-
E. pseudoinflatum -Sc-Sw
H. depressula depressula -Sl-Sw-
D. aranea -Sc-Sw
D. tenuissima -Sc-Sw

Late Miocene
E. advenum macelliforme -Tt-
E. advenum maorium -Tt-Tk-
E. charlottense -Tt-Tk-
E. crispum crispum -Tt-Tk-
E. excavatum clavatum -Tt-
E. aff. *novozealandicum* -Tt-
E. novozealandicum Tk-
H. depressula depressula -Tt-Tk-

Pliocene
E. advenum limbatum -Wo-Wm-
E. advenum macelliforme -Wo
E. advenum maorium -Wo-Wm-
E. charlottense -Wo-Wm-
E. crispum crispum -Wo-Wm-
E. excavatum clavatum -Wp-Wm-
E. excavatum excavatum Wo-
E. novozealandicum -Wo-Wm-
E. aff. *novozealandicum* -Wo
H. depressula depressula -Wo-Wm-

Pleistocene
E. advenum limbatum -Wc-
E. advenum maorium -Wn-Wc-
E. charlottense -Wn-Wc-
E. crispum crispum -Wn-Wc-
E. excavatum clavatum -Wn-Wc-
E. excavatum williamsoni Wn-
E. novozealandicum -Wn-Wc-
E. oceanicum Wc
H. depressula depressula -Wn-Wc-

Recent
E. advenum limbatum Ar-Rec
E. advenum maorium Ar-Rec
E. charlottense Lwh-Rec
E. crispum crispum Ar-Rec
E. excavatum clavatum Po-Rec
E. excavatum excavatum Wo-Rec
E. excavatum oirgi Rec
E. excavatum williamsoni Wn-Rec
E. gunteri Rec
E. novozealandicum Tk-Rec
E. vellai Rec
H. depressula depressula Lwh-Rec

PLATES 1–19

Plate 1

Fig. 1–2 ***Elphidium vitreum*** Collins, holotype, Vict F42147, Port Phillip, Victoria, Australia, Recent. **p. 93**

3 ***Elphidium excavatum excavatum*** (Terquem). Apertural face and apertures. FP4306, F201585, Stewart Island, New Zealand, Recent.

4 ***Elphidium novozealandicum*** Cushman. Apertural face and apertures. FP4384, Y14/f7505, Te Piki, East Coast, New Zealand, Wc, Pleistocene.

5 ***Discorotalia tenuissima*** (Karrer). Apertural face. FP4416, J41/f8498, Target Gully, Otago, New Zealand, Pl, early Miocene.

6 ***Haynesina depressula depressula*** (Walker & Jacob). Apertural face and apertures. FP4031, F2010002, Auckland Islands, New Zealand, Recent.

7 ***Elphidium advenum maorium*** Hayward. Small umbilical boss and inner ends of chambers. Holotype, TF1648/1, Waitemata Harbour, Auckland, New Zealand, Recent.

8 ***Elphidium* aff. *novozealandicum*** Cushman. Umbilical ornament. FP4307, V21/f361, Hawkes Bay, New Zealand, Tt, late Miocene.

9 ***Elphidium novozealandicum*** Cushman. Umbilical ornament. F201838, FP4383, Cuvier Island, Waikato, New Zealand, Recent.

10 ***Haynesina depressula depressula*** (Walker & Jacob). Umbilical ornament. FP4030, F201002, Auckland Islands, New Zealand, Recent.

11 ***Elphidium hampdenense*** Finlay. Radial ribs and septal bridges surround small, depressed umbilical area. Topotype, FP4367, J42/f8532, Otago, New Zealand, Dh, middle Eocene.

12 ***Elphidium excavatum excavatum*** (Walker & Jacob). Sutural ornament and short septal bridges. FP4306, F201585, Stewart Island, Recent.

13 ***Elphidium crispum waiwiriense*** Hayward. Peripheral portion showing development of double row of septal pores. Holotype, TF1652/1, Waikato, New Zealand, Po, early Miocene.

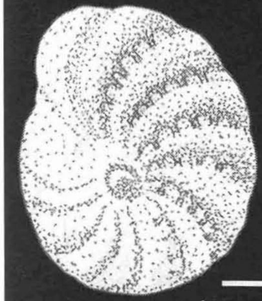
14 ***Elphidium hispidulum*** Cushman. Close-up of hispid ornament around base of apertural face. FP4372, F201595, Claremont Lightship. Queensland, Australia, Recent.

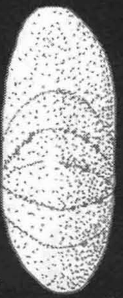
15 ***Elphidium carteri*** Hayward. Close-up of radial ribs, short septal bridges, small umbonal boss and coarse granular ornament. Paratype, TF1650/2, F201595, Claremont Lightship, Queensland, Australia, Recent.

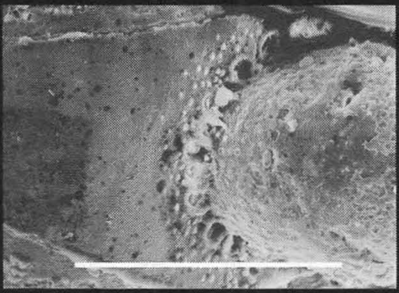
16 ***Elphidium collinsi*** Hayward. Close-up of ornament around the umbilical region. Holotype, TF1651/1, F201331, Watsons Bay, New South Wales, Australia, Recent.

(Scale bar = 0.1 mm)

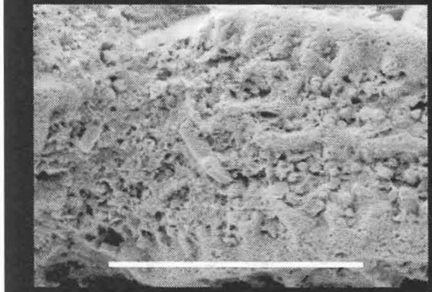
PLATE 1

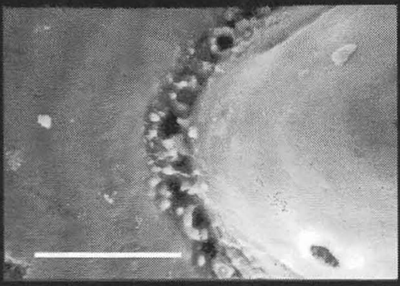

1

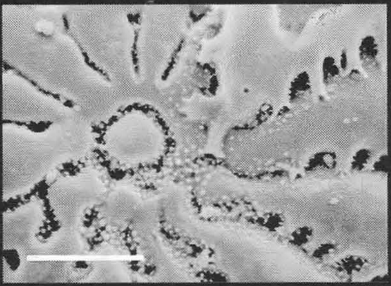

2

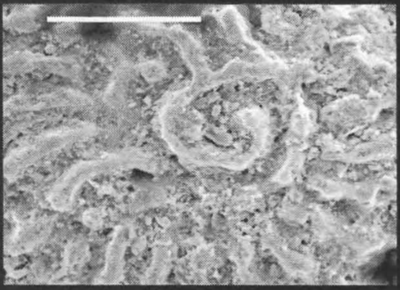

3

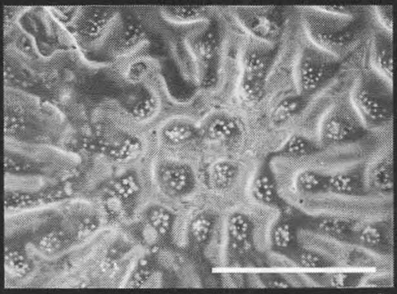

4

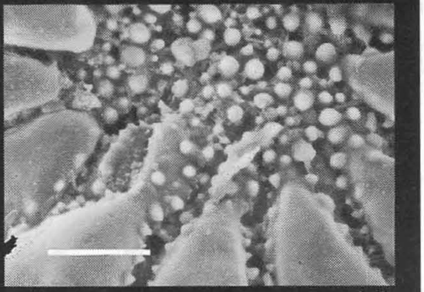

5

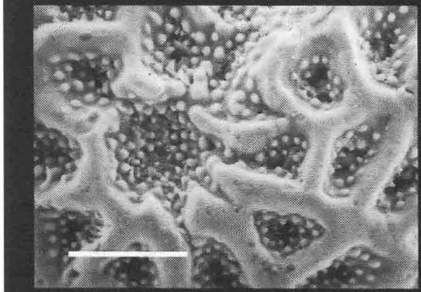

6

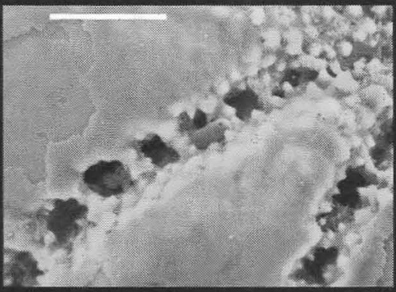

7

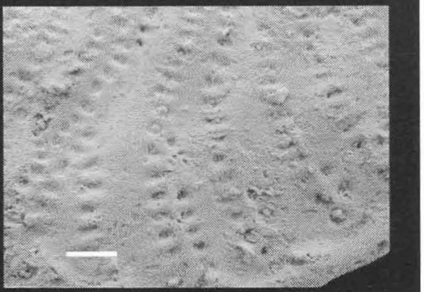

8

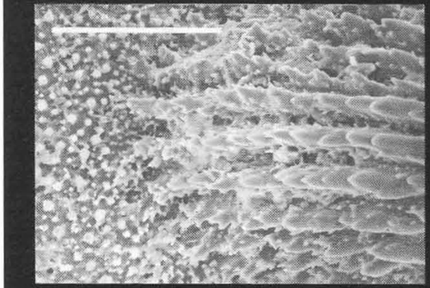

9

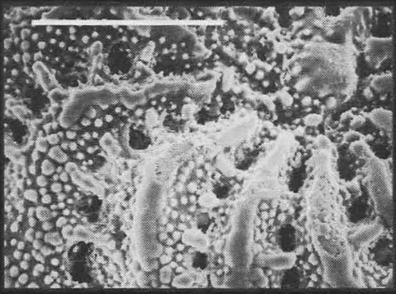

10


11


12


13


14


15

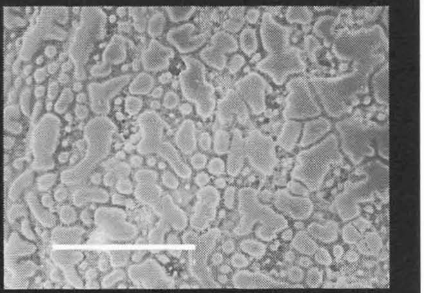

16

Plate 2

Fig.	1	***Elphidium aculeatum norcotti*** Hayward, holotype, TF1647/1, U25/f6564, Wellington, New Zealand,late Lw-Po, early Miocene.	**p. 63**
	2	***Elphidium aculeatum norcotti*** Hayward, late Lw-Po, paratype, TF1647/2, U25/f6564, Wellington,New Zealand, early Miocene.	
	3	***Elphidium aculeatum norcotti*** Hayward, late Lw-Po, paratype, TF1647/4, U25/f6564, Wellington,New Zealand, early Miocene.	
	4–5	***Elphidium aculeatum subrotatum*** (Hornibrook), topotype, FP4308, J41/f8498, Otago, New Zealand,Pl, early Miocene.	**p. 64**
	6–7	***Elphidium aculeatum subrotatum*** (Hornibrook), topotype, FP4309, J41/f8498, Otago, New Zealand, Pl, early Miocene.	
	8	***Elphidium aculeatum subrotatum*** (Hornibrook), topotype, FP4310, J41/f8498, Otago, New Zealand, Pl, early Miocene.	
	9	***Elphidium advenum advenum*** (Cushman), FP4311, F202149, Suva Pt., Fiji, Recent.	**p. 65**
	10–11	***Elphidium advenum advenum*** (Cushman), FP4312, F201635, Vava'u, Tonga, Recent.	
	12–13	***Elphidium advenum advenum*** (Cushman), FP4313, F201636, Suva, Fiji, Recent.	
	14–15	***Elphidium advenum advenum*** (Cushman), FP4314, J32/f7848, West Coast, New Zealand, late Eocene. Topotype of *E. omotoense* Dorreen.	
	16	***Elphidium advenum advenum*** (Cushman), FP4315, J32/f7848, West Coast, New Zealand, late Eocene. Topotype of *E. omotoense* Dorreen.	
	17–18	***Elphidium advenum advenum*** (Cushman), FP4316, J32/f7848, West Coast, New Zealand, late Eocene. Topotype of *E. omotoense* Dorreen.	

(Scale bar = 0.1 mm)

PLATE 2

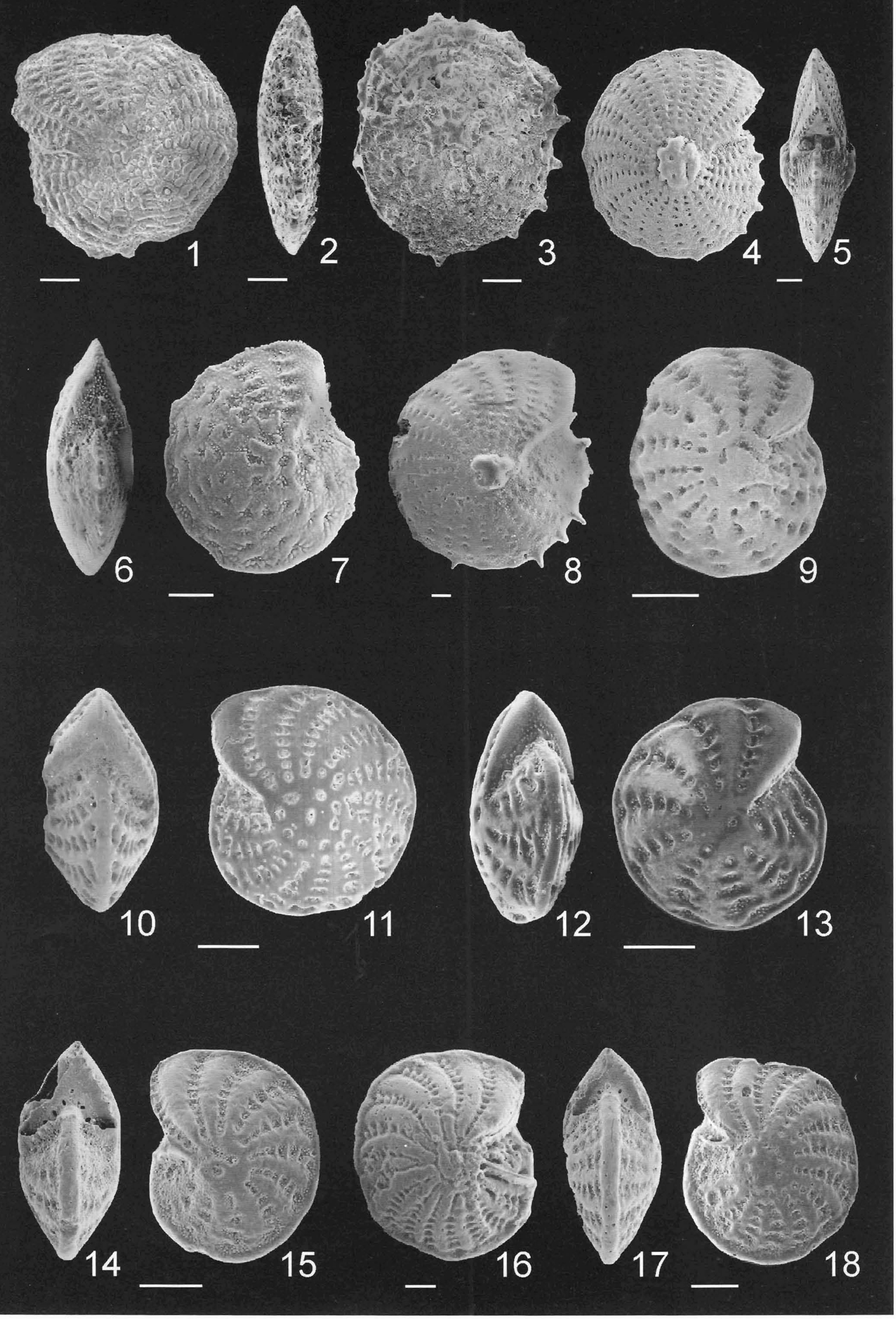


Plate 3

Fig.	1–2	***Elphidium advenum botaniense*** Albani, CC18896, PagoPago, Samoa, Recent.	**p. 66**
	3–4	***Elphidium advenum botaniense*** Albani, FP4317, F201595, Claremont Lightship, Queensland, Australia, Recent.	
	5–6	***Elphidium advenum dispar*** Cushman, topotype, USNM, Rongerik Lagoon, Marshall Islands, Recent.	**p. 66**
	7–8	***Elphidium advenum dispar*** Cushman, FP4318, F201636, Suva, Fiji, Recent.	
	9–10	***Elphidium advenum limbatum*** (Chapman), paratype, CC14249, Beaumaris, Victoria, Australia, Recent.	**p. 67**
	11	***Elphidium advenum limbatum*** (Chapman), Vict F76944, Port Phillip, Victoria, Australia, Recent. Topotype of *E. earlandi avolonense* Collins.	
	12	***Elphidium advenum limbatum*** (Chapman), FP4020, F202026, Pauatahanui Inlet, Wellington, New Zealand, Recent.	
	13–14	***Elphidium advenum limbatum*** (Chapman), FP4028, F201883, Otago Harbour, New Zealand, Recent.	
	15–16	***Elphidium advenum limbatum*** (Chapman), FP4319, F201109, Paterson Inlet, Stewart Island, New Zealand, Recent.	
	17	***Elphidium advenum limbatum*** (Chapman), FP4320, F201106, Auckland Islands, New Zealand, Recent.	

(Scale bar = 0.1 mm)

PLATE 3

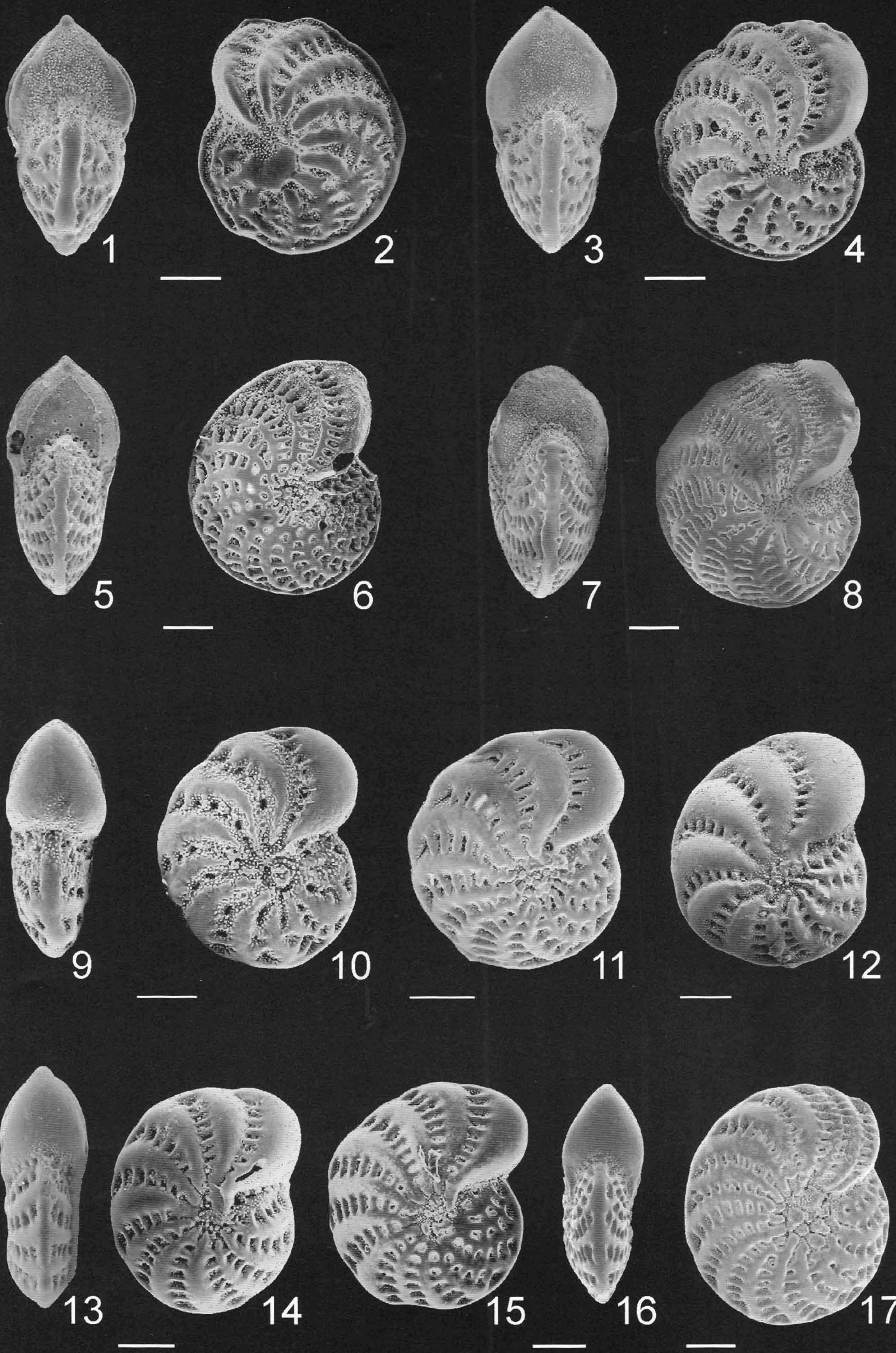


Plate 4

Fig.	1–2	***Elphidium advenum limbatum*** (Chapman), FP4321, F201636, Suva, Fiji, Recent.	p. 67
	3–4	***Elphidium advenum limbatum*** (Chapman), FP4322, R14/f6541, Waikato, New Zealand, eLwh, Oligocene.	
	5	***Elphidium advenum limbatum*** (Chapman), FP4323, S14/f23 core 14.4-14.5m, Waikato, New Zealand, Lwh-Lw, Oligocene.	
	6	***Elphidium advenum limbatum*** (Chapman), FP4324, M34/7038, Canterbury, Pl, early Miocene.	
	7–8	***Elphidium advenum limbatum*** (Chapman), FP4325, Q08/f9914, Northland, New Zealand, Pl, early Miocene.	
	9–10	***Elphidium advenum limbatum*** (Chapman), FP4326, K29/f253, West Coast, New Zealand, Lwh, Oligocene.	
	11	***Elphidium advenum maorium*** Hayward, holotype, TF1648/1, F201347, Waitemata Harbour, Auckland, New Zealand, Recent.	p. 69
	12	***Elphidium advenum maorium*** Hayward, paratype, TF1648/2, F201347, Waitemata Harbour, Auckland, New Zealand, Recent.	
	13–14	***Elphidium advenum maorium*** Hayward, FP4327, F202302, Port Pegasus, Stewart Island, New Zealand, Recent.	
	15–16	***Elphidium advenum maorium*** Hayward, FP4328, F201109, Stewart Island, New Zealand, Recent.	

(Scale bar = 0.1 mm)

PLATE 4

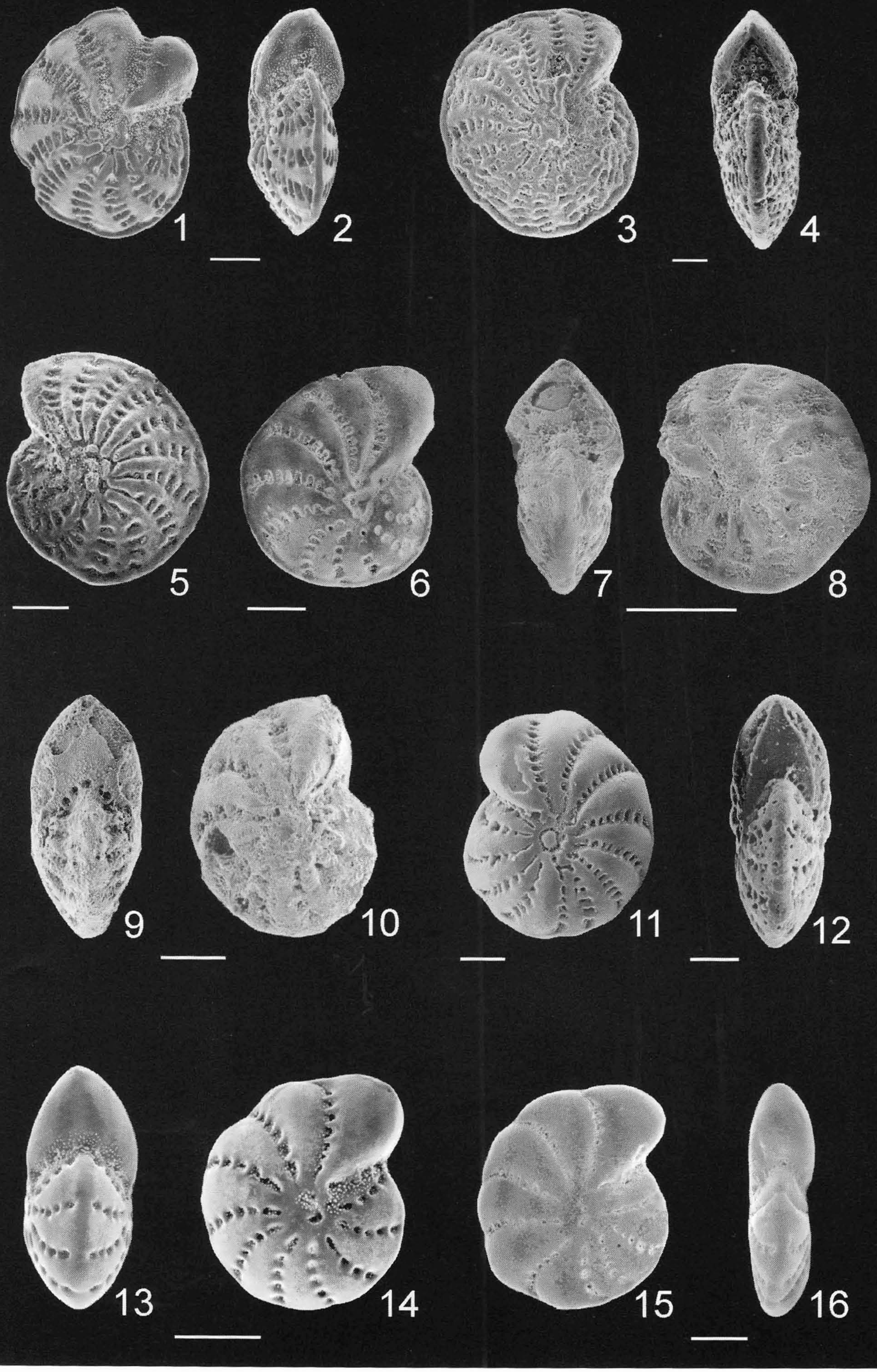


Plate 5

Fig. 1–2	***Elphidium advenum maorium*** Hayward, FP4329, U14/f7505, Te Piki, East Coast, New Zealand, Wc, Pleistocene.	**p. 69**
3	***Elphidium advenum maorium*** Hayward, FP4330, Q08/f9679, Pakaurangi Pt, Northland, New Zealand, ePl, early Miocene.	
4	***Elphidium advenum maorium*** Hayward, FP4331, Q08/f9679, Pakaurangi Pt, Northland, New Zealand, ePl, early Miocene.	
5	***Elphidium advenum maorium*** Hayward, FP4332, J41/f8498, Target Gully, Otago, New Zealand, Pl, early Miocene.	
6–7	***Elphidium advenum macelliforme*** McCulloch, FP4333, L28/f7504, Little Wanganui Head, West Coast, New Zealand, Ld, late Oligocene.	**p. 68**
8–9	***Elphidium advenum macelliforme*** McCulloch, FP4335, Y14/f7841, East Coast, New Zealand, late Tt, late Miocene.	
10	***Elphidium advenum macelliforme*** McCulloch, FP4334, L28/f7504, Little Wanganui Head, West Coast, New Zealand, Ld, late Oligocene.	
11–12	***Elphidium advenum macelliforme*** McCulloch, FP4336, 10m, Port Phillip Bay, Victoria, Australia, Recent.	
13–14	***Elphidium advenum tongaense*** (Cushman), paratype, CC19904, Vava'u, Tonga, Recent.	**p. 70**
15–16	***Elphidium advenum tongaense*** (Cushman), FP4337, F201130, Suva, Fiji, Recent.	
17–18	***Elphidium advenum tongaense*** (Cushman), FP4338, F201130, Suva, Fiji, Recent.	

(Scale bar = 0.1 mm)

PLATE 5

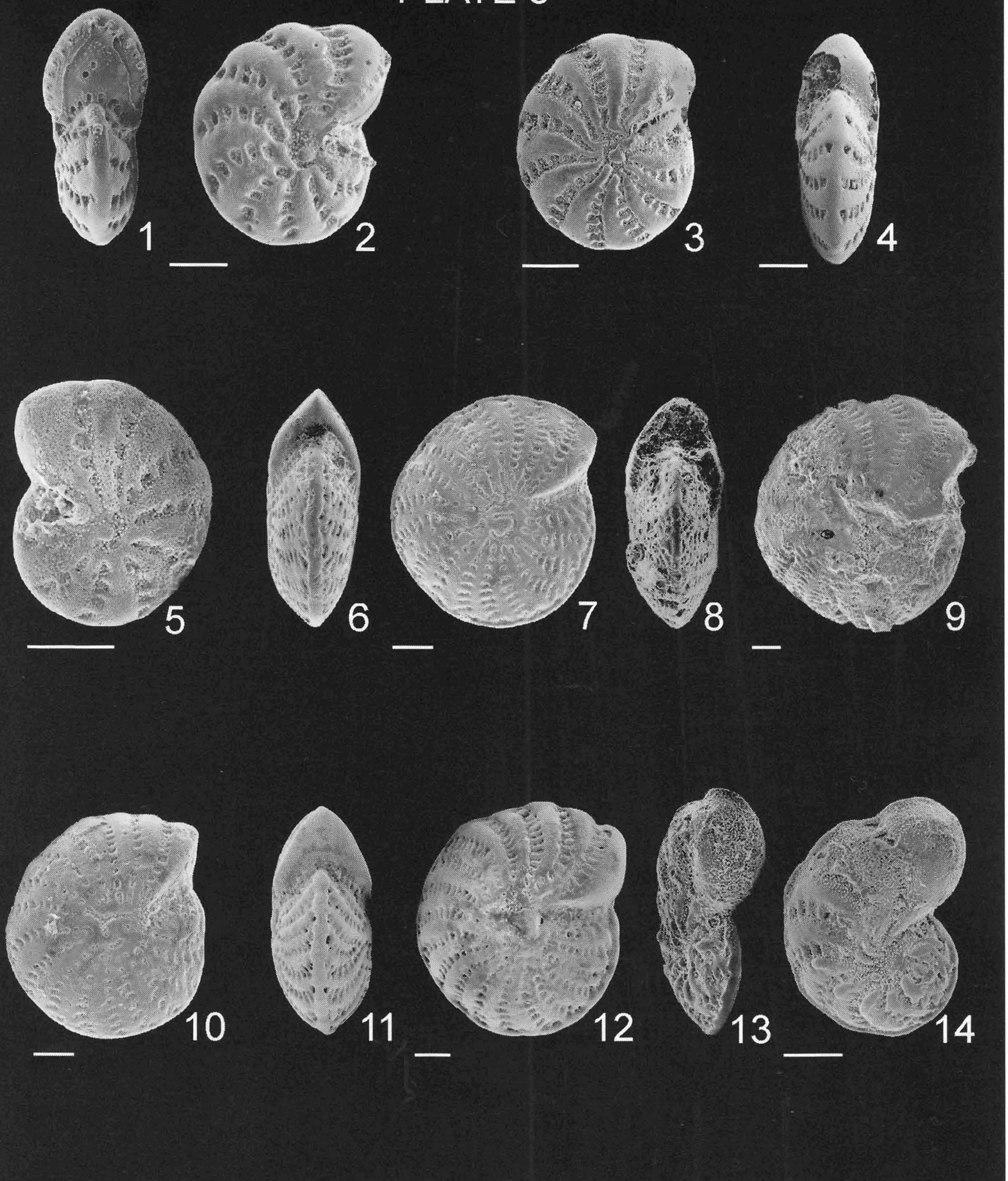


Plate 6

Fig. 1–2	***Elphidium albanii*** Hayward, holotype, TF1649/1, F201595, Claremont Lightship, Queensland, Australia, Recent.	**p. 70**
3–4	***Elphidium albanii*** Hayward, paratype, TF1649/2, F201595, Claremont Lightship, Queensland, Australia, Recent.	
5	***Elphidium albanii*** Hayward, FP4365, 20 m, off Malabar, New South Wales, Australia, Recent.	
6–7	***Elphidium argenteum*** Parr, topotype, FP4339, F201584, Barwon Heads, Victoria, Australia, Recent.	**p. 71**
8–9	***Elphidium carteri*** Hayward, holotype, TF1650/1, F201595, Claremont Lightship, Queensland, Australia, Recent.	**p. 71**
10	***Elphidium carteri*** Hayward, paratype, TF1650/2, F201595, Claremont Lightship, Queensland, Australia, Recent.	
11–12	***Elphidium carteri*** Hayward, FP4340, F46/f8490, Southland, New Zealand, Lw, early Miocene.	
13–14	***Elphidium charlottense*** (Vella), topotype, FP4341, F201283, Queen Charlotte Sound, Marlborough, New Zealand, Recent.	**p. 72**
15–16	***Elphidium charlottense*** (Vella), AK92429, L6740, Purakanui Inlet, Otago, New Zealand, Recent.	

(Scale bar = 0.1 mm)

PLATE 6

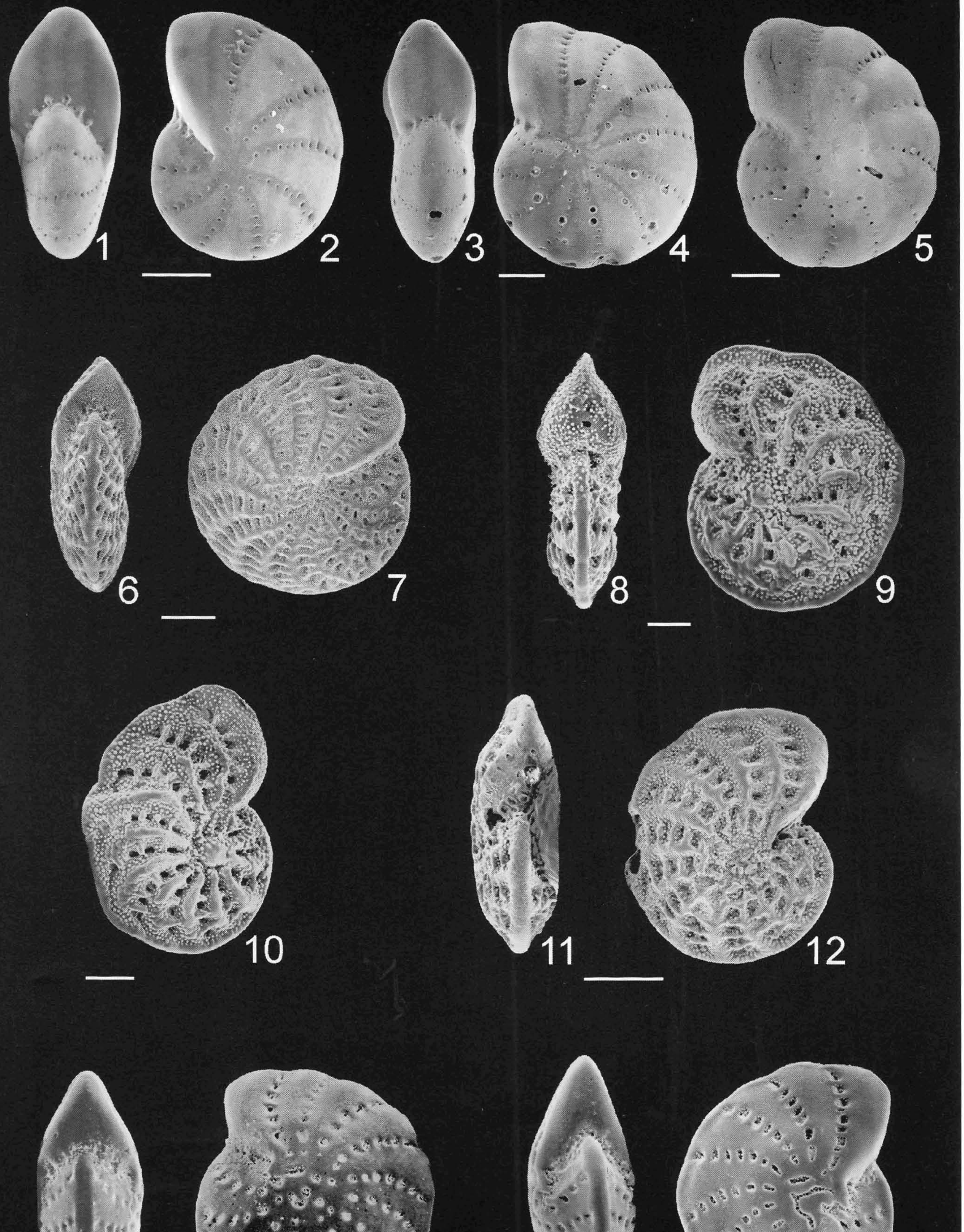
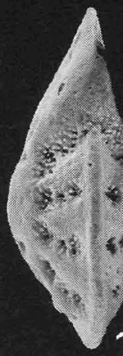


Plate 7

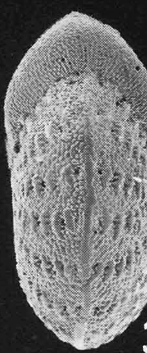
Fig.	1–2	***Elphidium charlottense*** (Vella), FP4342, F46/f8490, Southland, New Zealand, Lw, early Miocene.	**p. 72**
	3–4	***Elphidium collinsi*** Hayward, holotype, TF1651/1, F201331, Watsons Bay, New South Wales, Australia, Recent.	**p. 73**
	5–6	***Elphidium craticulatum*** (Fichtel & Moll), FP4343, F201594, Cape Bedford, Queensland, Australia, Recent.	**p. 73**
	7–8	***Elphidium craticulatum*** (Fichtel & Moll), FP4344, F201595, Claremont Lightship, Queensland, Australia, Recent.	
	9	***Elphidium craticulatum*** (Fichtel & Moll), CC9893, Albany Passage, Queensland, Australia, Recent.	
	10	***Elphidium craticulatum*** (Fichtel & Moll), USNM, Mica Depot well 30 m, Guadalcanal, Solomon Islands, Pleistocene.	
	11–12	***Elphidium craticulatum*** (Fichtel & Moll), FP4345, F201636, Suva, Fiji, Recent.	
	13	***Elphidium crispum crispum*** (Linné), topotype, FP4346, F201292, Rimini Beach, Italy, Recent.	**p. 74**
	14	***Elphidium crispum crispum*** (Linné), topotype, FP4347, F201292, Rimini Beach, Italy, Recent.	
	15	***Elphidium crispum crispum*** (Linné), CC9893, Albany Passage, Queensland, Australia, Recent.	
	16	***Elphidium crispum crispum*** (Linné), FP4348, F201864, Rakitu Island, Auckland, New Zealand, Recent.	

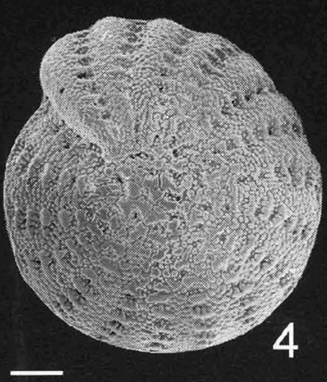
(Scale bar = 0.1 mm)

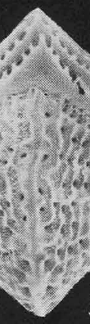
PLATE 7

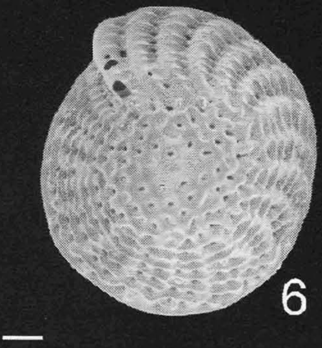

1


2

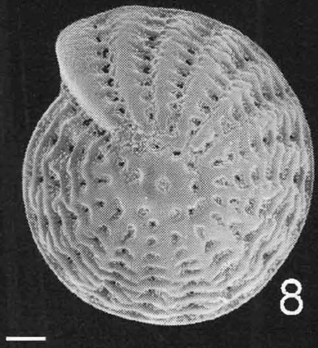

3

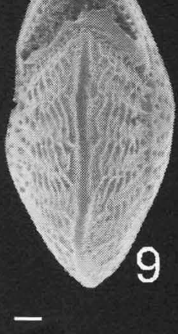

4

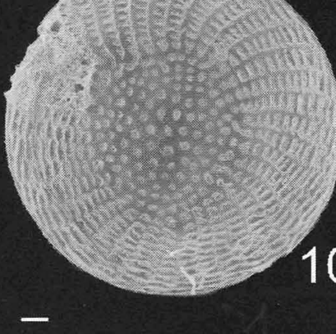

5

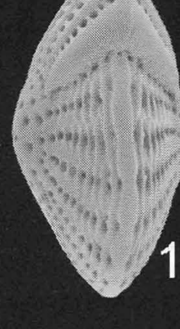

6

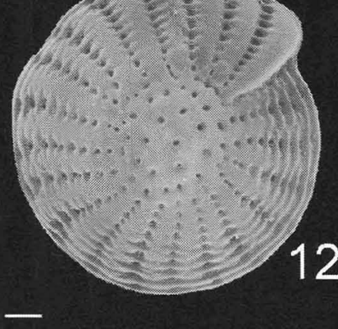

7

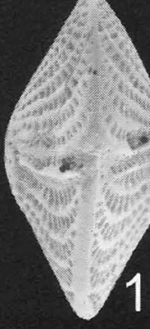

8

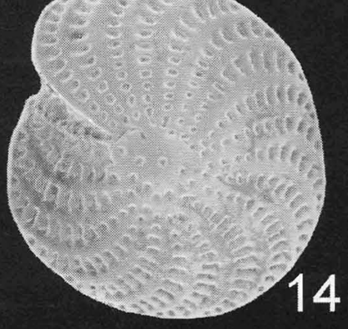

9

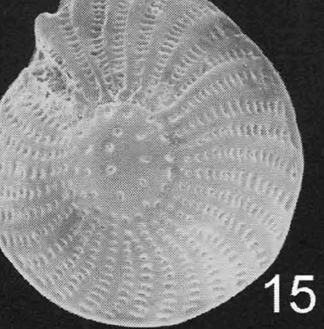

10


11


12


13


14


15

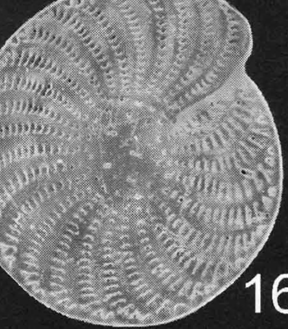

16

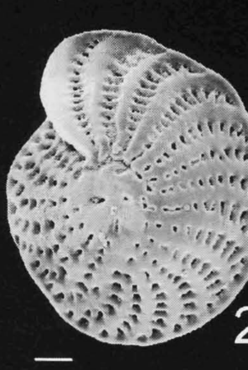
Plate 8

Fig.	1-2	***Elphidium crispum crispum*** (Linné), FP4349, F201595, Claremont Lightship, Queensland, Australia, Recent.	**p. 74**
	3	***Elphidium crispum crispum*** (Linné), FP4350, F201877, Rakitu Island, Auckland, New Zealand, Recent.	
	4	***Elphidium crispum crispum*** (Linné), FP4351, F201877, Rakitu Island, Auckland, New Zealand, Recent.	
	5	***Elphidium crispum crispum*** (Linné), FP4352, CH/f281, Chatham Island, New Zealand, Wo, Pliocene.	
	6–7	***Elphidium crispum crispum*** (Linné), FP4353, R11/f23, Waiheke Island, Auckland, New Zealand, Po, early Miocene.	
	8	***Elphidium crispum crispum*** (Linné), FP4354, F46/f8490, Southland, New Zealand, Lw-Po, early Miocene.	
	9	***Elphidium crispum crispum*** (Linné), FP43555, G45/f8499, Chatton, Southland, New Zealand, Ld, late Oligocene.	
	10	***Elphidium crispum waiwiriense*** Hayward, holotype, TF1652/1, Waiwiri Beach, Waikato, New Zealand, Po, early Miocene.	**p. 75**
	11–12	***Elphidium crispum waiwiriense*** Hayward, paratype, TF1652/2, Waiwiri Beach, Waikato, New Zealand, Po, early Miocene.	
	13	***Elphidium crispum waiwiriense*** Hayward, paratype, TF1652/3, Waiwiri Beach, Waikato, New Zealand, Po, early Miocene.	
	14–15	***Elphidium excavatum clavatum*** Cushman, AK76435, L615, Marahau estuary, Nelson, New Zealand, Recent.	**p. 76**
	16–17	***Elphidium excavatum clavatum*** Cushman, FP4356, F201936, Tolaga Bay, East Coast, New Zealand, Recent.	

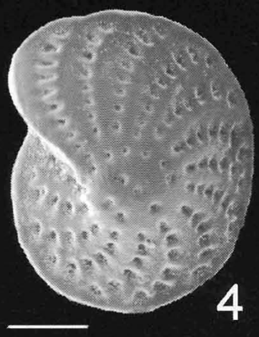
(Scale bar = 0.1 mm)

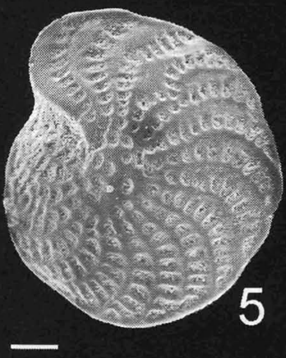
PLATE 8


1


2

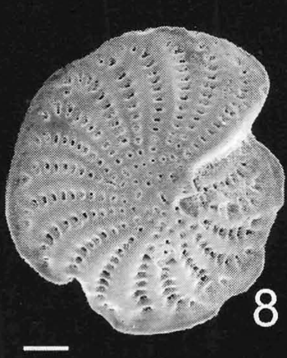

3

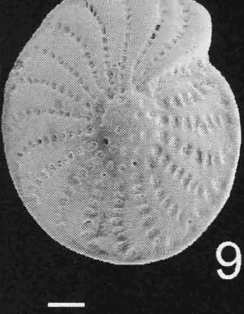

4

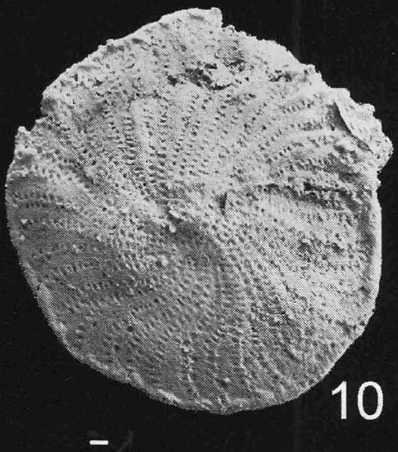

5


6

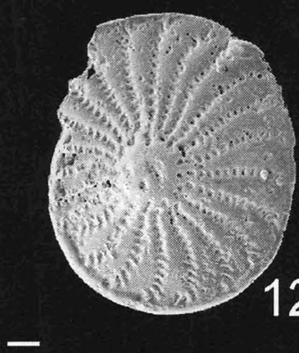

7

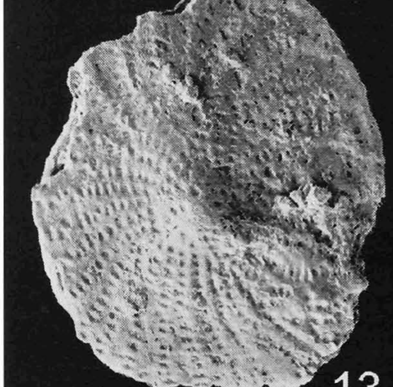

8


9

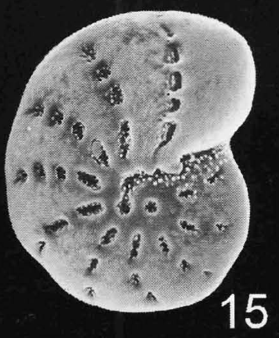

10


11


12


13


14


15


16

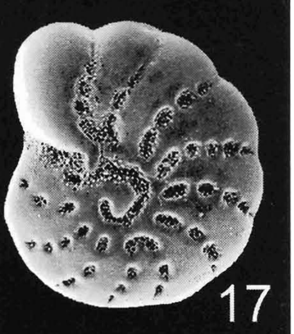

17

Plate 9

Fig. 1–2 ***Elphidium excavatum clavatum*** Cushman, FP4357, Y14/f7505, Te Piki, East Coast, New Zealand, Wc, Pleistocene. **p. 76**

3–4 ***Elphidium excavatum clavatum*** Cushman, FP4358, Q08/f9680, Pakaurangi Point, Northland, New Zealand, ePl, early Miocene.

5 ***Elphidium excavatum clavatum*** Cushman, AK76434, F202088, Raglan Harbour, Waikato, New Zealand, Recent.

6–7 ***Elphidium excavatum clavatum*** Cushman, topotype of *Cribrononion illawaraensis* Albani and Yassini, FP4370, 2 m, Lake Illawara, New South Wales, Australia, Recent.

8 ***Elphidium excavatum clavatum*** Cushman, topotype of *Cribrononion illawaraensis* Albani and Yassini, FP4371, 2 m, Lake Illawara, New South Wales, Australia, Recent.

9–10 ***Elphidium excavatum excavatum*** (Terquem), FP4359, F202307, Port Pegasus, Stewart Island, New Zealand, Recent. **p. 77**

11–12 ***Elphidium excavatum excavatum*** (Terquem), AK76430, L615, Marahau estuary, Nelson, New Zealand, Recent.

13 ***Elphidium excavatum excavatum*** (Terquem), Vict F76950, Port Phillip, Victoria, Australia, Recent.

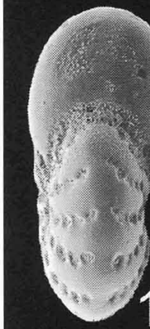
14 ***Elphidium excavatum excavatum*** (Terquem), Vict F76953, Port Phillip, Victoria, Australia, Recent.

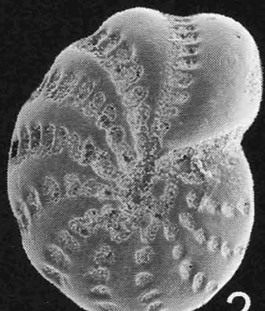
15–16 ***Elphidium excavatum excavatum*** (Terquem), FP4360, F201595, Claremont Lightship, Queensland, Australia, Recent.

17–18 ***Elphidium excavatum excavatum*** (Terquem), FP4361, F201639, Rarotonga, Cook islands, Recent.

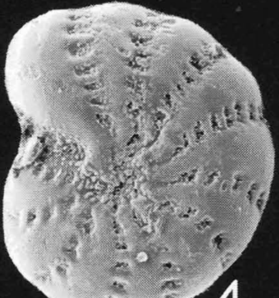
(Scale bar = 0.1 mm)

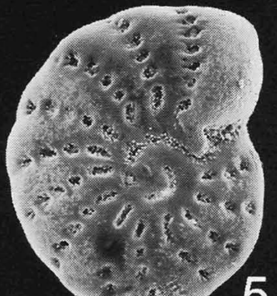
PLATE 9

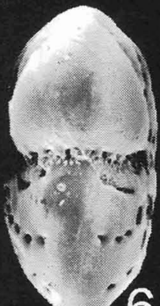

1

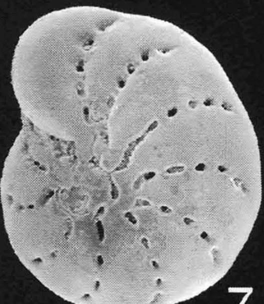

2

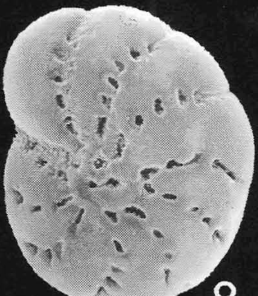

3


4

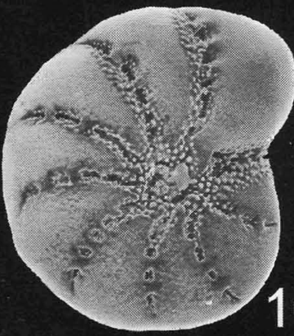

5


6

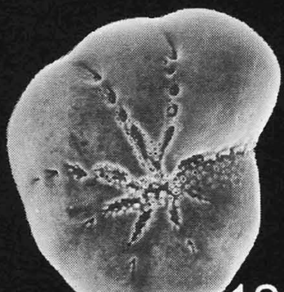

7

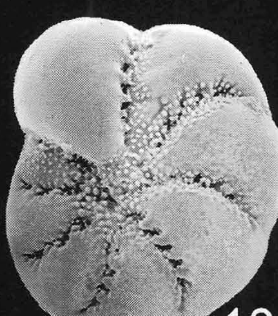

8

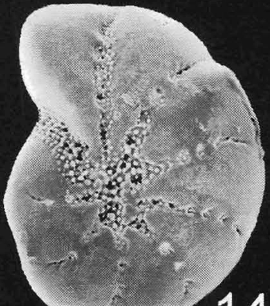

9

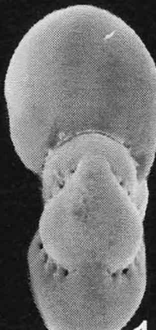

10

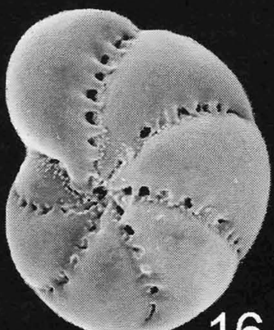

11

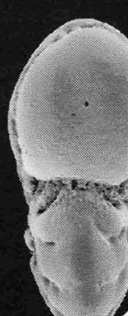

12


13


14


15


16


17

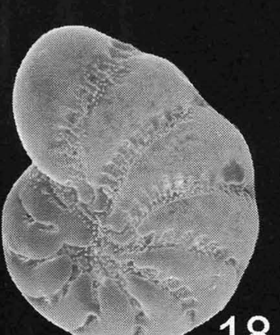

18

Plate 10

Fig. 1–2 ***Elphidium excavatum oirgi*** Hayward, TF1653/1, F201739, holotype, Cavalli Islands, Northland, Recent. **p. 78**

3–4 ***Elphidium excavatum oirgi*** Hayward, paratype, TF1653/2, F201742, Cavalli Islands, Northland, New Zealand, Recent.

5–6 ***Elphidium excavatum oirgi*** Hayward, paratype, TF1653/4, F201841, Tutukaka Harbour, Northland, New Zealand, Recent.

7–8 ***Elphidium excavatum oirgi*** Hayward, paratype, TF1653/3, F201841, Tutukaka Harbour, Northland, New Zealand, Recent.

9–10 ***Elphidium excavatum sydneyense*** (Albani), holotype, figures from Albani (1978). **p. 78**

11–12 ***Elphidium excavatum williamsoni*** Haynes, AK76438, F202092, Aotea Harbour, Waikato, New Zealand, Recent. **p. 79**

13–14 ***Elphidium excavatum williamsoni*** Haynes, FP4362, F202307, Port Pegasus, Stewart Island, New Zealand, Recent.

15–16 ***Elphidium excavatum williamsoni*** Haynes, Vict F76949, Port Phillip, Victoria, Australia, Recent. Topotype of *E. articulaum multicameratum* Collins.

17–18 ***Elphidium excavatum williamsoni*** Haynes, Vict F76947, Port Phillip, Victoria, Australia, Recent. Topotype of *E. gunteri carioense* Collins.

(Scale bar = 0.1 mm)

PLATE 10

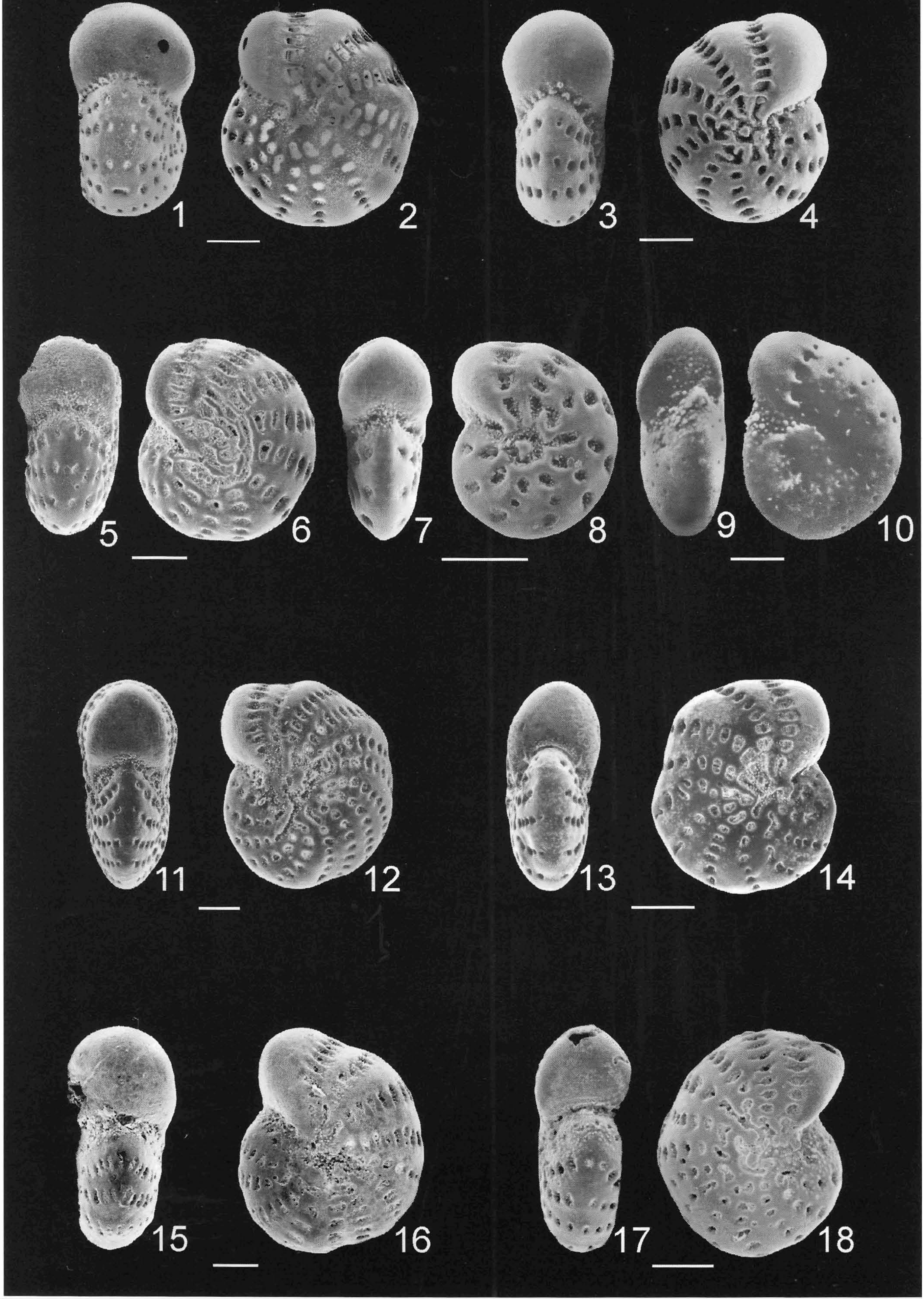


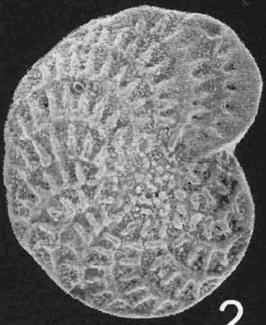
Plate 11

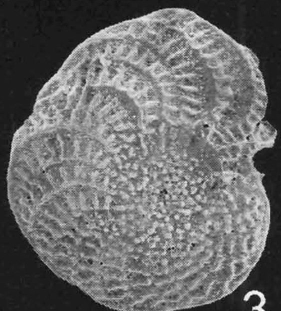
Fig.	**1–2**	***Elphidium fichtellianum*** (d'Orbigny), topotype, CC22611, Austria, Miocene.	**p. 79**
	3	***Elphidium fichtellianum*** (d'Orbigny), topotype, CC22611, Austria, Miocene.	
	4–5	***Elphidium fichtellianum*** (d'Orbigny), AK78037, F201081, Vava'u Harbour, Tonga, Recent.	
	6–7	***Elphidium fichtellianum*** (d'Orbigny), FP4363, F201081, Vava'u Harbour, Tonga, Recent.	
	8	***Elphidium fichtellianum*** (d'Orbigny), FP4364, F202332, Norfolk Island, Australia, Recent.	
	9–10	***Elphidium fijiense*** Hayward, holotype, TF1654/1, F202149, Suva Point, Fiji, Recent.	**p. 80**
	11–12	***Elphidium fijiense*** Hayward, paratype, TF1654/2, F202149, Suva Point, Fiji, Recent.	
	13–14	***Elphidium gunteri*** Cole, AK76427, L509, Orakei Basin, Auckland, New Zealand, Recent.	**p. 80**
	15	***Elphidium gunteri*** Cole, AK78053, L509, Orakei Basin, Auckland, New Zealand, Recent.	
	16–17	***Elphidium hampdenense*** Finlay, topotype, FP4366, J42/f8532, Hampden Beach, Otago, New Zealand, Dh, middle Eocene.	**p. 81**
	18–19	***Elphidium hampdenense*** Finlay, topotype, FP4367, J42/f8532, Hampden Beach, Otago, New Zealand, Dh, middle Eocene.	

(Scale bar = 0.1 mm)

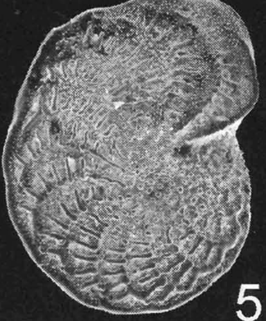
PLATE 11


1

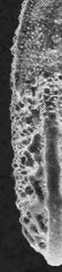

2

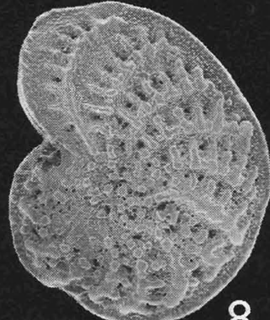

3

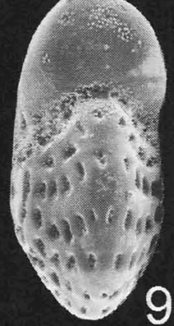

4

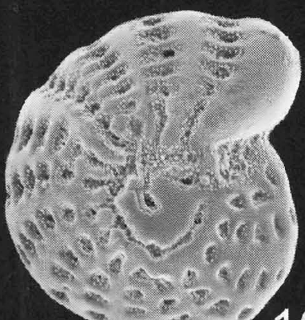

5

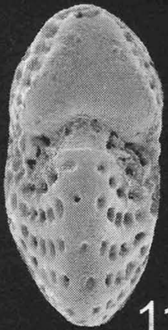

6

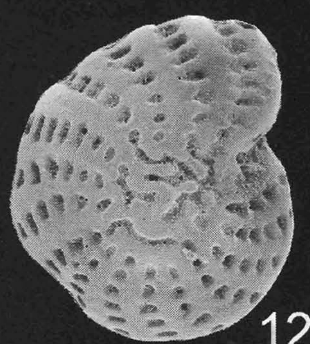

7

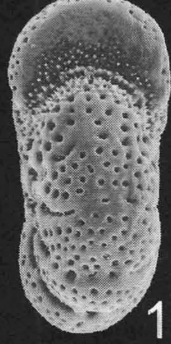

8

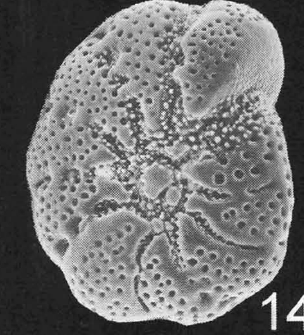

9

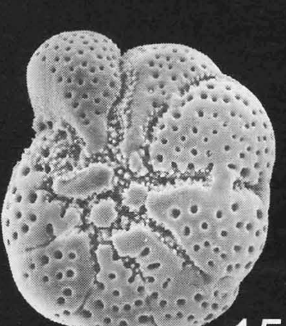

10


11


12


13


14


15


16


17


18

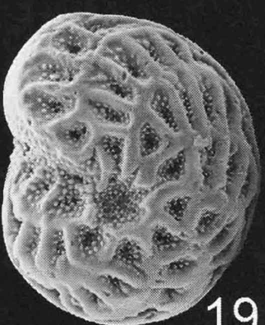
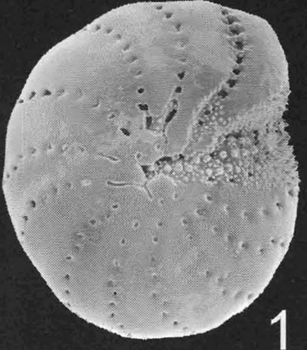

19

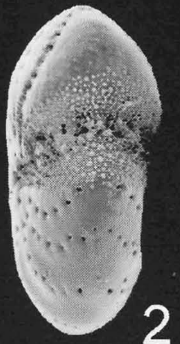
Plate 12

Fig.	1–2	***Elphidium hawkesburiense*** (Albani), FP4368, 6m, Twofold Bay, New South Wales, Australia, Recent.	**p. 82**
	3–4	***Elphidium hawkesburiense*** (Albani), FP4369, 6m, Twofold Bay, New South Wales, Australia, Recent.	
	5–6	***Elphidium hispidulum*** Cushman, FP4372, F201595, Claremont Lightship, Queensland, Australia, Recent.	**p. 82**
	7	***Elphidium hispidulum*** Cushman, FP4373, F201594, Cape Bedford, Queensland, Australia, Recent.	
	8	***Elphidium ingressans*** Dorreen, topotype, FP4374, J32/f7848, Greymouth, West Coast, New Zealand, Ar, late Eocene.	**p. 83**
	9–10	***Elphidium ingressans*** Dorreen, topotype, FP4375, J32/f7848, Greymouth, West Coast, New Zealand, Ar, late Eocene.	
	11–12	***Elphidium kanoum*** Hayward, paratype, USNM243360, Q08/f9792, Pakaurangi Point, Northland, New Zealand, Pl, early Miocene.	**p. 83**
	13–14	***Elphidium kanoum*** Hayward, FP4376, R11/f7514, Waiheke Island, Auckland, New Zealand, Po, early Miocene.	
	15–16	***Elphidium kanoum*** Hayward, FP4377, R11/f7514, Waiheke Island, Auckland, New Zealand, Po, early Miocene.	

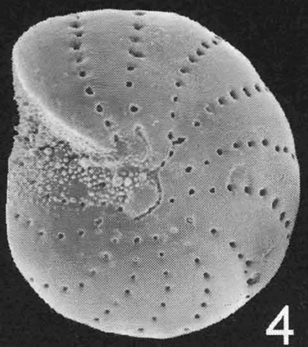
(Scale bar = 0.1 mm)

PLATE 12

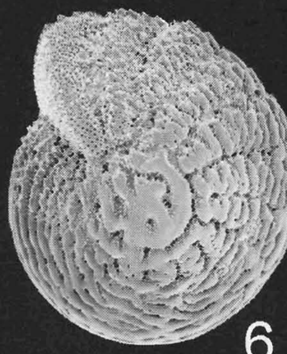

1

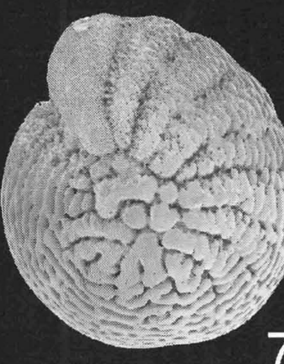

2

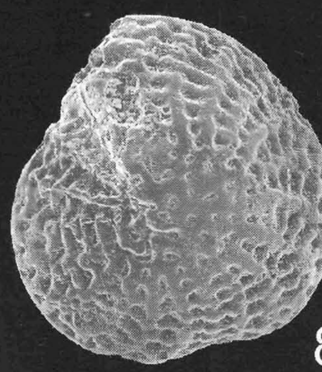

3


4

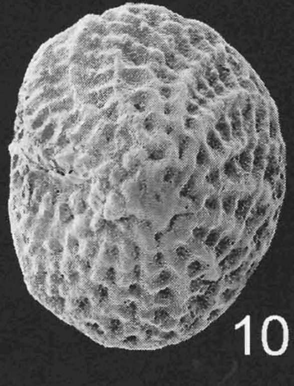

5


6


7

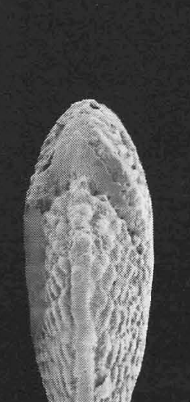

8

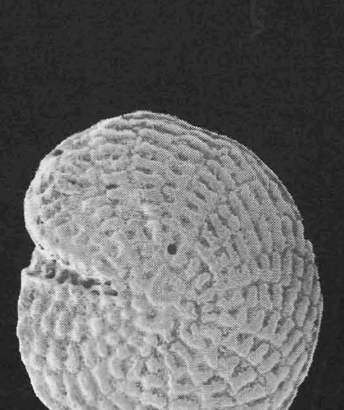

9

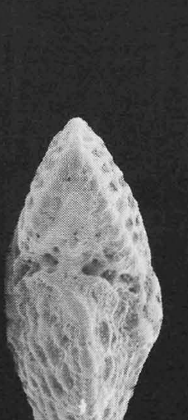

10


11


12


13


14


15

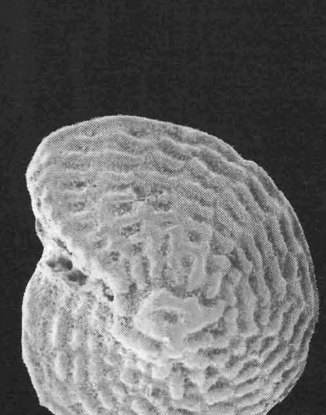

16

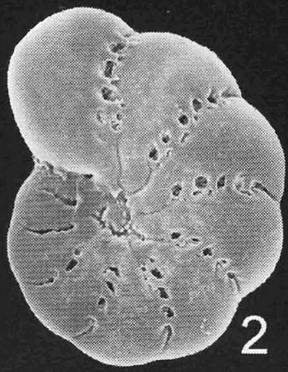
Plate 13

Fig.	**1–2**	***Elphidium lene*** Cushman & McCulloch, CC15654, Black Rock, Melbourne, Victoria, Australia, Recent.	**p. 84**
	3–4	***Elphidium lene*** Cushman & McCulloch, Vict F76954, Port Phillip, Victoria, Australia, Recent.	
	5–6	***Elphidium lene*** Cushman & McCulloch, FP4378, F201332, Derwent River, Tasmania, Australia, Recent.	
	7–8	***Elphidium lene*** Cushman & McCulloch, FP4379, F201636, Suva, Fiji, Recent.	
	9–10	***Elphidium macellum*** (Fichtel & Moll), FP4380, F202266, Lord Howe Island, Australia, Recent.	**p. 84**
	11–12	***Elphidium macellum*** (Fichtel & Moll), CC, Torquay, Victoria, Australia, Recent.	
	13–14	***Elphidium macellum*** (Fichtel & Moll), FP4381, F202332, Norfolk Island, Australia, Recent.	
	15–16	***Elphidium matanginuiense*** Hayward, holotype, TF1655/1, CH/f3, Chatham Island, New Zealand, Dw, early Eocene.	**p. 85**

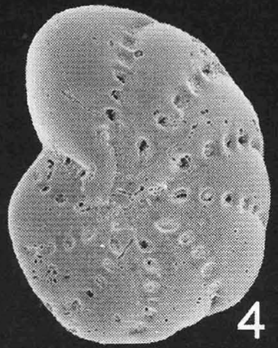
(Scale bar = 0.1 mm)

PLATE 13

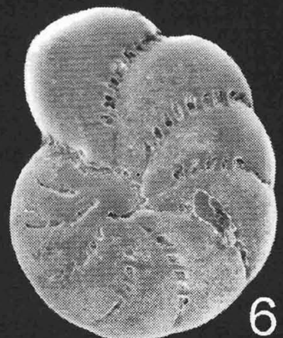

1

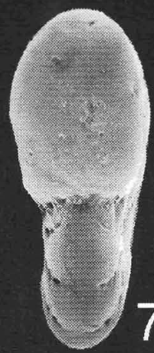

2

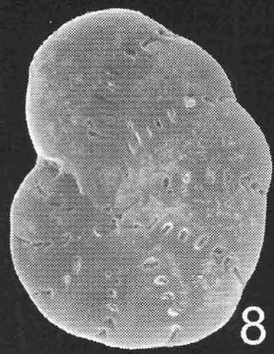

3

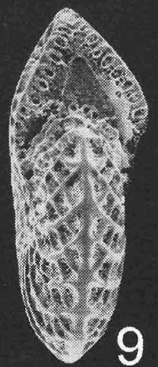

4

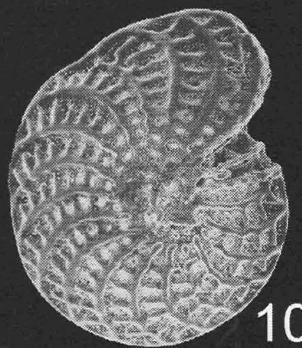

5


6

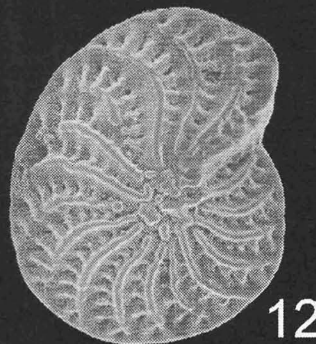

7

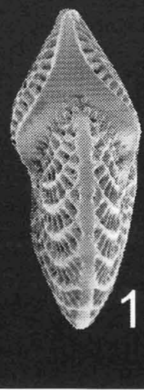

8

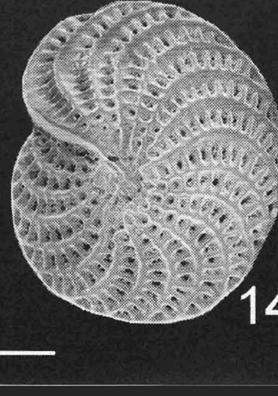

9


10


11


12


13


14


15

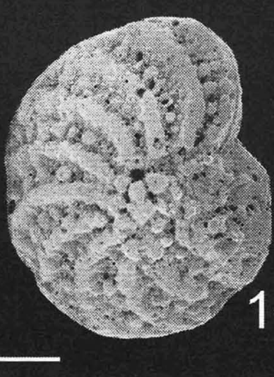

16

Plate 14

Fig.	1–2	***Elphidium matanginuiense*** Hayward, paratype, TF1655/2, CH/f3, Chatham Island, New Zealand, Dw, early Eocene.	**p. 85**
	3–4	***Elphidium matauraense*** Hayward, holotype, TF1656/1, F46/f52, Mataura, Southland, New Zealand, Lw-Po, early Miocene.	**p. 86**
	5	***Elphidium matauraense*** Hayward, paratype, TF1656/2, F46/f52, Mataura, Southland, New Zealand, Lw-Po, early Miocene.	
	6–7	***Elphidium mortonbayense*** Albani & Yassini, CC9895, Albany Passage, Queensland, Australia, Recent.	**p. 86**
	8–9	***Elphidium mortonbayense*** Albani & Yassini, FP4382, F201595, Claremont Lightship, Queensland, Australia, Recent.	
	10–11	***Elphidium novozealandicum*** Cushman, FP4383, F201838, Cuvier Island, Waikato, New Zealand, Recent.	**p. 87**
	12–13	***Elphidium novozealandicum*** Cushman, FP4384, Y14/f7505, Te Piki, East Coast, New Zealand, Recent.	
	14	***Elphidium novozealandicum*** Cushman, FP4385, R13/f6009, Kaawa, Waikato, New Zealand, Wo, Pliocene.	
	15	***Elphidium* aff. *novozealandicum*** Cushman, FP4386, V22/f361, Hawkes Bay, New Zealand, Tt, late Miocene.	**p. 87**
	16–17	***Elphidium* aff. *novozealandicum*** Cushman, FP4387, N02/f7584, Waikuku, Northland, New Zealand, Sw, middle Miocene.	

(Scale bar = 0.1 mm)

PLATE 14

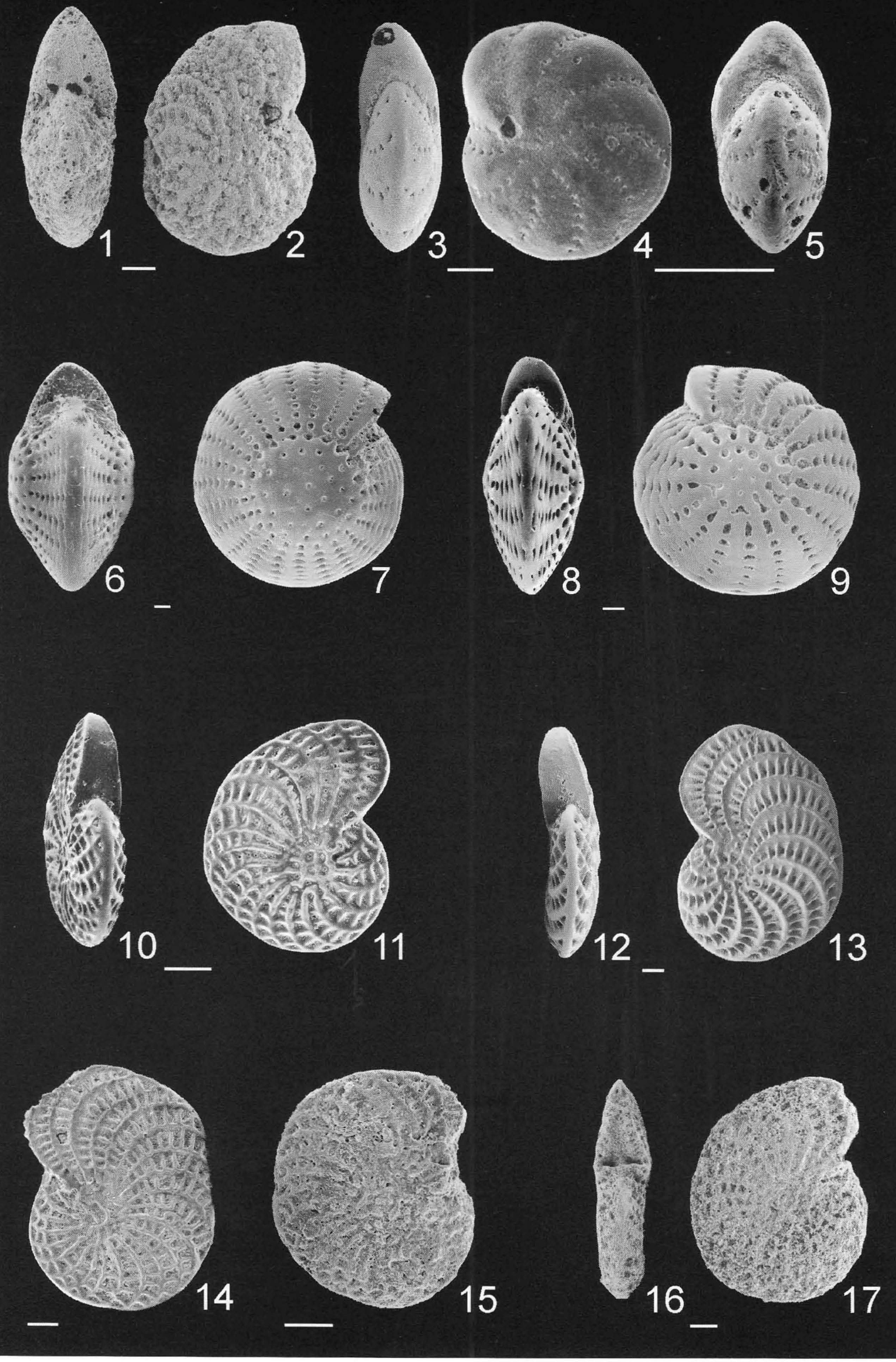


Plate 15

Fig. 1–2	***Elphidium oceanicum*** Cushman, FP4388, F201595, Claremont Lightship, Queensland, Australia, Recent.	**p. 88**
3	***Elphidium oceanicum*** Cushman, FP4389, F201636, Suva, Fiji, Recent.	
4–5	***Elphidium oceanicum*** Cushman, FP4390, Y14/f7505, Te Piki, East Coast, New Zealand, Recent.	
6–7	***Elphidium phillipense*** Hayward, topotype, Vict F76951, Port Phillip, Victoria, Australia, Recent.	**p. 88**
8–9	***Elphidium phillipense*** Hayward, topotype, Vict F76952, Port Phillip, Victoria, Australia, Recent.	
10	***Elphidium poeyanum*** (d'Orbigny), FP4392, F201664, St Thomas, West Indies, Recent.	
11	***Elphidium poeyanum*** (d'Orbigny), FP4391, F201664, St Thomas, West Indies, Recent.	
12–13	***Elphidium pseudoinflatum*** Cushman, FP4393, V23/f6438, Hawkes Bay, New Zealand, Sw, middle Miocene.	**p. 89**
14	***Elphidium pseudoinflatum*** Cushman, FP4394, Q08/f9682, Northland, New Zealand, ePl, early Miocene.	
15	***Elphidium pseudoinflatum*** Cushman, FP4395, Q08/f9682, Northland, New Zealand, ePl, early Miocene.	
16–17	***Elphidium pseudoinflatum*** Cushman, FP4396, L28/f7504, West Coast, New Zealand, Ld, late Oligocene.	
18	***Elphidium pseudoinflatum*** Cushman, FP4397, Q08/f9679, Northland, New Zealand, ePl, early Miocene.	

(Scale bar = 0.1 mm)

PLATE 15

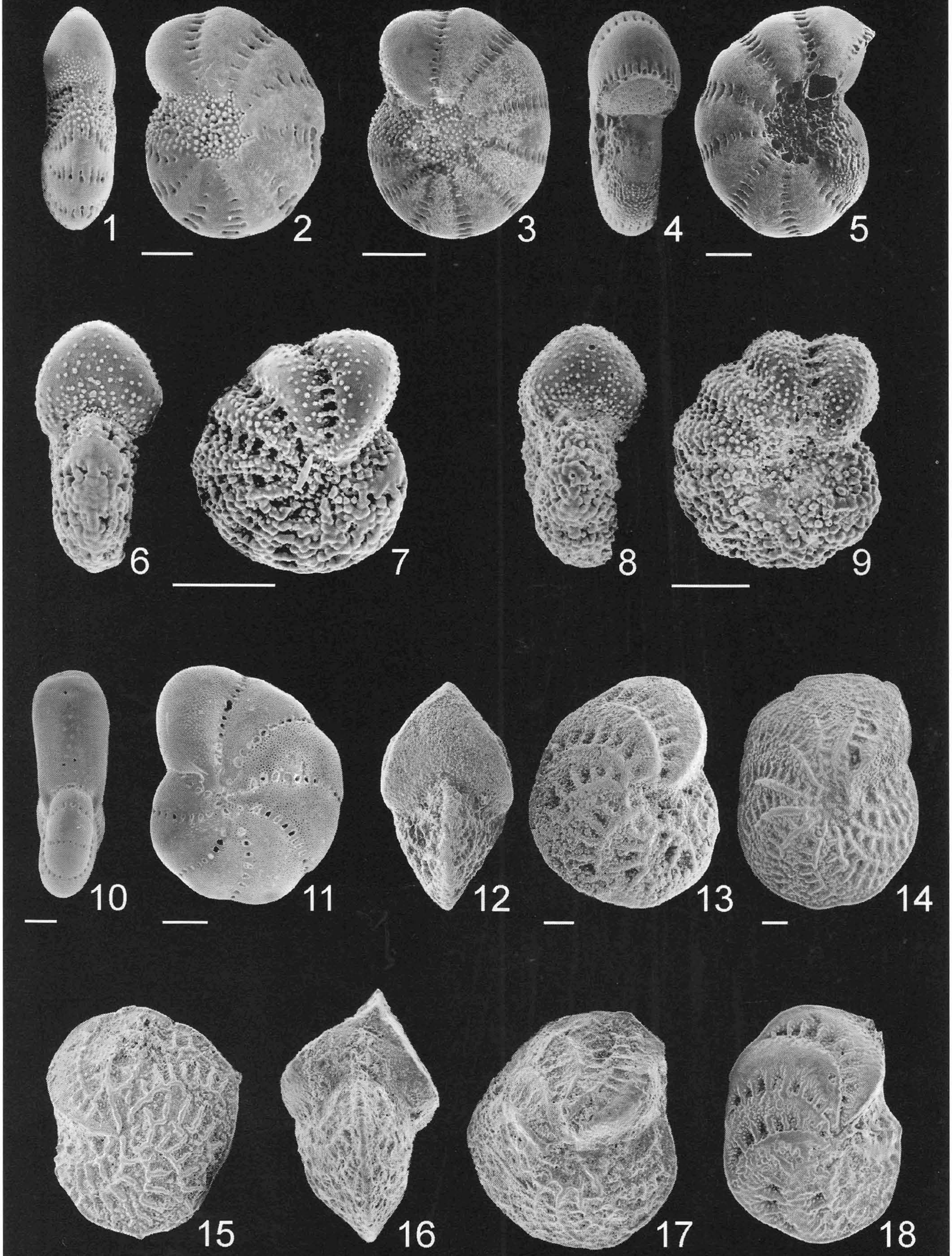


Plate 16

Fig.	1–2	***Elphidium reticulosum*** Cushman, FP4398, F202149, Suva Point, Fiji, Recent.	p. 89
	3	***Elphidium reticulosum*** Cushman, FP4399, F202154, Vava'u, Tonga, Recent.	
	4	***Elphidium reticulosum*** Cushman, FP4400, F202332, Norfolk Island, Australia, Recent.	
	5–6	***Elphidium saginatum*** Finlay, topotype, FP4401, U24/f9142, Mangatoro, Wellington, New Zealand, Dp, middle Eocene.	p. 90
	7–8	***Elphidium saginatum*** Finlay, FP4402, N37/f8168, Canterbury, New Zealand, Dp, middle Eocene.	
	9–10	***Elphidium sandiegoense*** (Lankford), FP4403, F201595, Claremont Lightship, Queensland, Australia, Recent.	p. 90
	11	***Elphidium sandiegoense*** (Lankford), FP4404, F201595, Claremont Lightship, Queensland, Australia, Recent.	
	12–13	***Elphidium schencki*** Cushman & Dusenbury, FP4405, J32/f7848, West Coast, New Zealand, Ar, late Eocene. Topotype of *Elphidium nitidum* Dorreen.	p. 91
	14	***Elphidium schencki*** Cushman & Dusenbury, FP4406, Q08/f9018, Northland, New Zealand, Ab, middle Eocene.	
	15	***Elphidium schencki*** Cushman & Dusenbury, FP4407, Q08/f9018, Northland, New Zealand, Ab, middle Eocene.	
	16–17	***Elphidium silvestrii*** Hayward, FP4408, F201332, Derwent estuary, Tasmania, Australia, Recent.	p. 91

(Scale bar = 0.1 mm)

PLATE 16

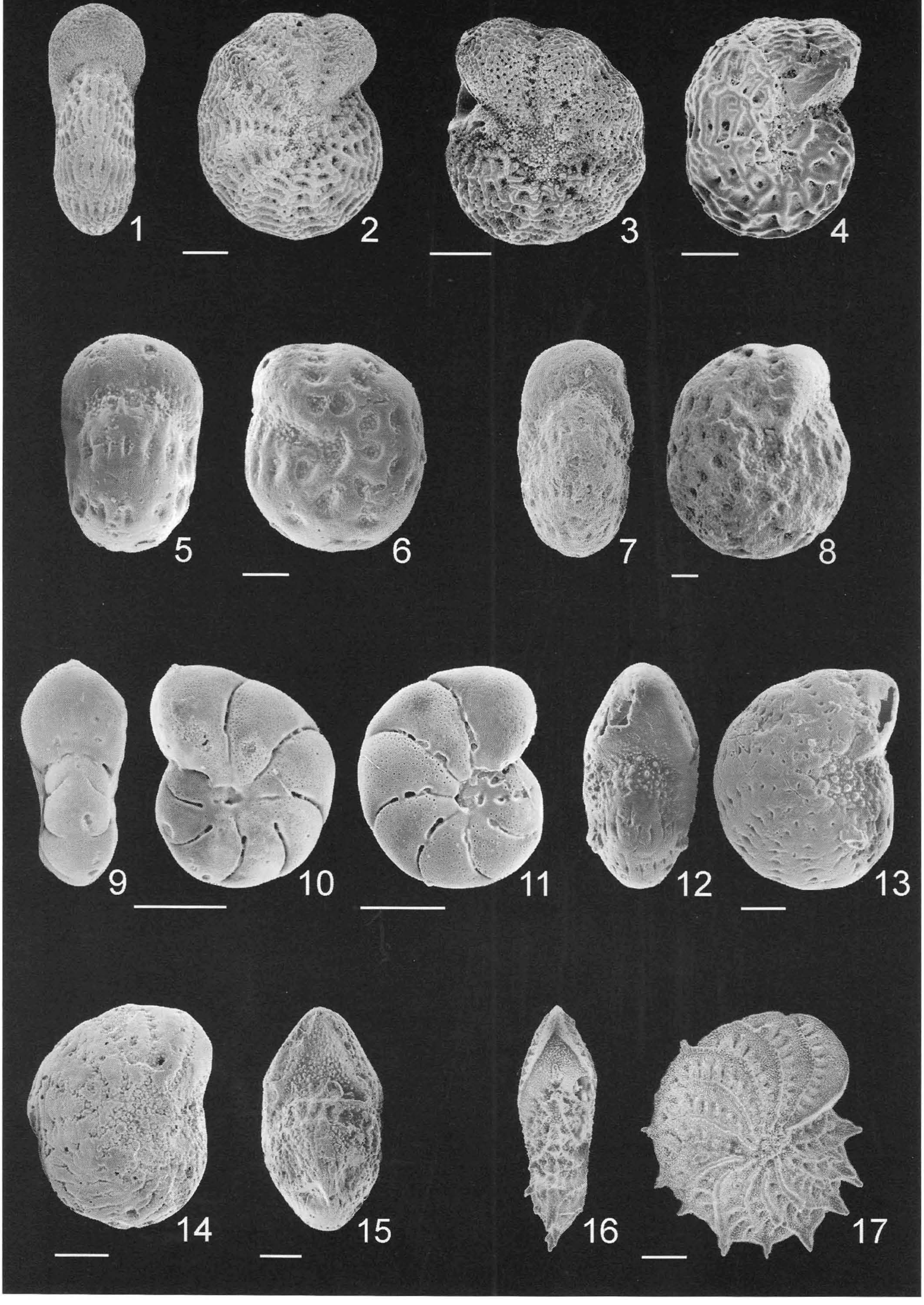
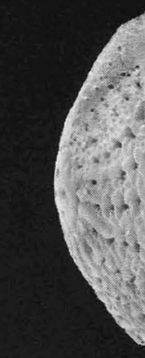


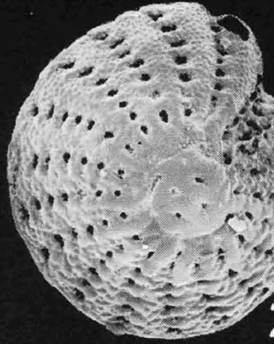
Plate 17

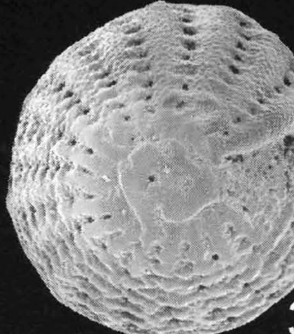
Fig.	1–2	***Elphidium vavauense*** Hayward, holotype, TF1657/1, F201081, Vava'u, Tonga, Recent.	**p. 92**
	3	***Elphidium vavauense*** Hayward, paratype, TF1657/2, F201081, Vava'u, Tonga, Recent.	
	4–5	***Elphidium vellai*** Hayward, holotype, TF1658/1, L631, Queen Charlotte Sound, Marlborough, New Zealand, Recent.	**p. 92**
	6–7	***Elphidium vellai*** Hayward, paratype, TF1658/2, L631, Queen Charlotte Sound, Marlborough, New Zealand, Recent.	
	8–9	***Elphidium wadeae*** (Hornibrook), topotype, FP4409, G45/f8499, Chatton, Southland, New Zealand, Ld, late Oligocene.	**p. 93**
	10–11	***Elphidium wadeae*** (Hornibrook), topotype, FP4410, G45/f8499, Chatton, Southland, New Zealand, Ld, late Oligocene.	
	12–13	***Elphidium wadeae*** (Hornibrook), FP4411, R14/f6541, Waikato, New Zealand, eLwh, early Oligocene.	
	14–15	***Cristatavultatus pacificus*** Collins, FP4412, F201642, Apia, Samoa, Recent.	**p. 94**

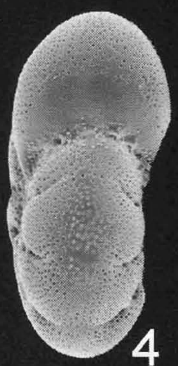
(Scale bar = 0.1 mm)

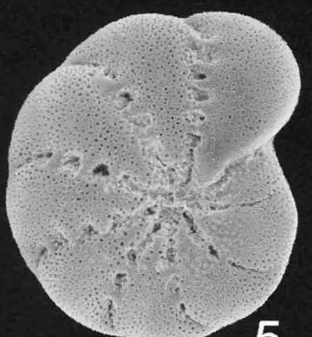
PLATE 17


1


2


3


4


5

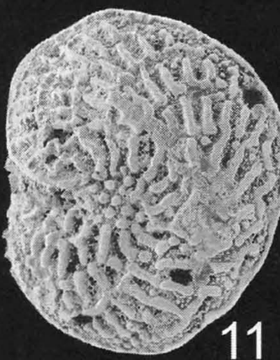

6


7

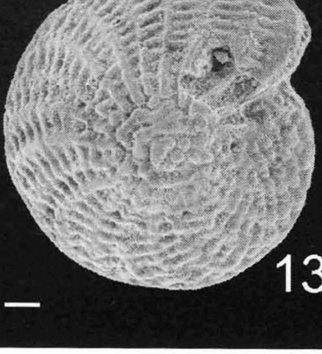

8

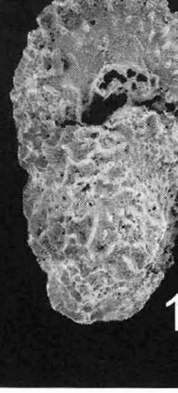

9


10


11


12


13


14

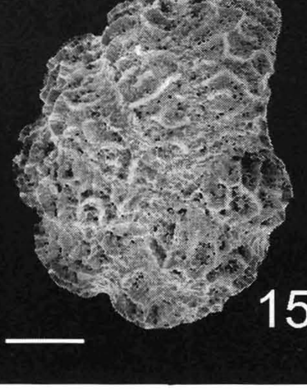
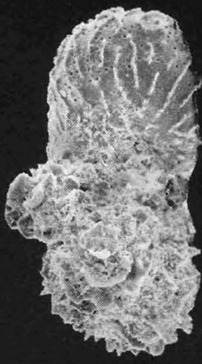

15

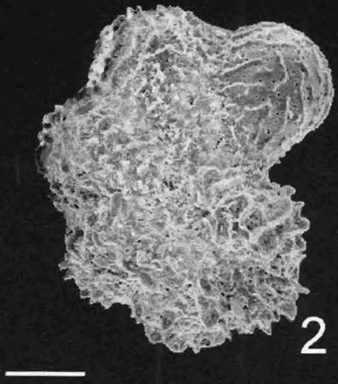
Plate 18

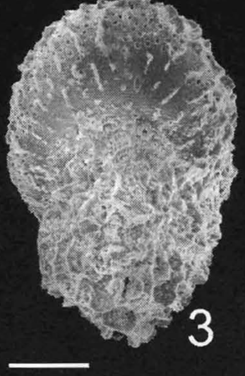
Fig.	**1–2**	***Cristatavultatus pacificus*** Collins, CC18903, PagoPago, Samoa, Recent.	**p. 94**
	3	***Cristatavultatus pacificus*** Collins, CC, Mokoujar Passage, Fiji, Recent.	
	4	***Discorotalia aranea*** (Hornibrook), topotype, FP4413, J41/f8793, Old Rifle Butts, Otago, New Zealand, Pl, early Miocene.	**p. 95**
	5–6	***Discorotalia aranea*** (Hornibrook), FP4414, J41/f8498, Target Gully, Otago, New Zealand, Pl, early Miocene.	
	7–8	***Discorotalia tenuissima*** (Karrer), FP4415, I38/f7607, Canterbury, New Zealand, Lw, early Miocene.	**p. 95**
	9	***Discorotalia tenuissima*** (Karrer), FP4416, J41/f8498, Target Gully, Otago, New Zealand, Pl, early Miocene.	
	10–11	***Parrellina imperatrix*** (Brady), FP4417, F201595, Claremont Lightship, Queensland, Australia, Recent.	**p. 96**
	12	***Parrellina imperatrix*** (Brady), FP4418, F201595, Claremont Lightship, Queensland, Australia, Recent.	
	13	***Parrellina papillosa*** (Cushman), FP4420, 89 m, Bermegui Shelf, New South Wales, Australia, Recent.	**p. 97**
	14	***Parrellina papillosa*** (Cushman), FP4419, 89 m, Bermegui Shelf, New South Wales, Australia, Recent.	

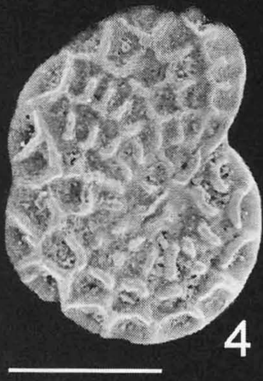
(Scale bar = 0.1 mm)

PLATE 18


1

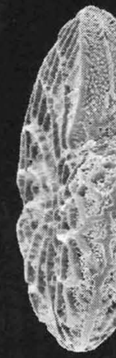

2

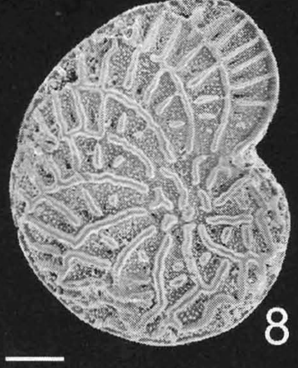

3


4

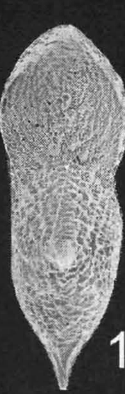

5

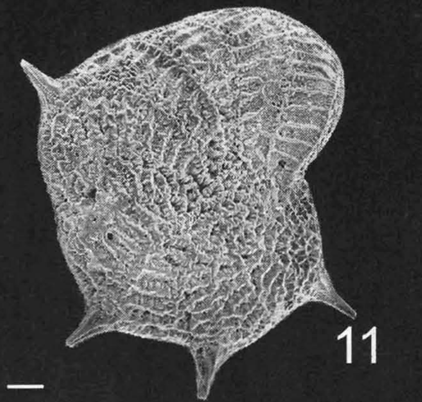

6

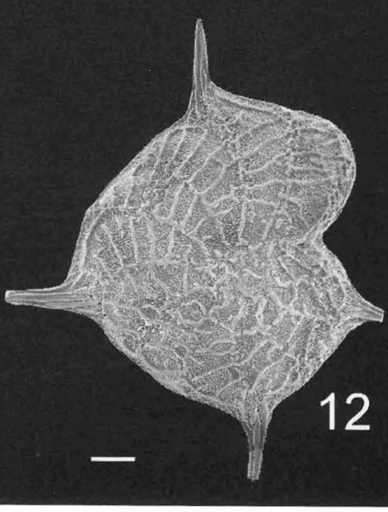

7

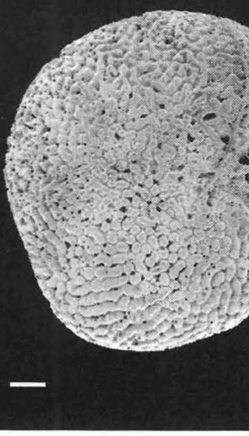

8


9


10


11


12


13

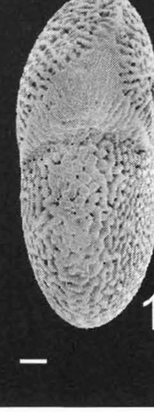
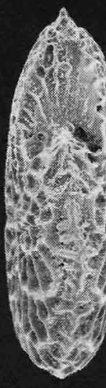

14

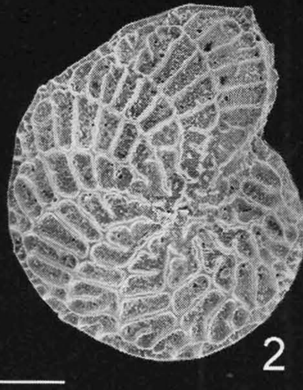
Plate 19

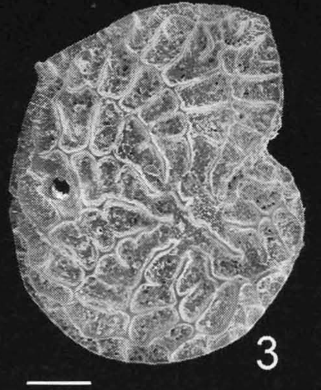
Fig.	1–2	***Parrellina verriculata*** (Brady), FP4421, F201332, Derwent estuary, Tasmania, Australia, Recent.	**p. 97**
	3	***Parrellina verriculata*** (Brady), CC22752, Nonabeca, New South Wales, Australia, Recent.	
	4–5	***Haynesina depressula depressula*** (Walker & Jacob), FP4422, F201002, Auckland Islands, New Zealand, Recent. Topotype of *Elphidiononion simplex aoteanum* Vella.	**p. 98**
	6	***Haynesina depressula depressula*** (Walker & Jacob), FP4423, F201728, Cavalli Islands, New Zealand, Recent.	
	7	***Haynesina depressula depressula*** (Walker & Jacob), FP4424, J41/f8498, Target Gully, Otago, New Zealand, Pl, early Miocene.	
	8–9	***Haynesina depressula simplex*** (Cushman), FP4425, F202148, Lami, Fiji, Recent.	**p. 99**
	10	***Haynesina depressula simplex*** (Cushman), FP4426, F201642, Apia, Western Samoa, Recent.	
	11–12	*Notorotalia finlayi* Vella, planispiral form, FP4427, Wellington Harbour, New Zealand, Recent.	

(Scale bar = 0.1 mm)

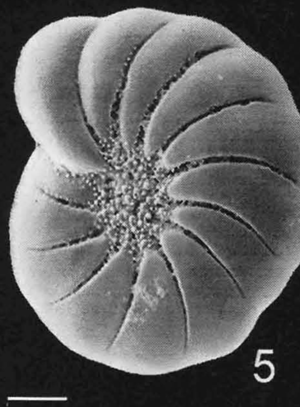
PLATE 19

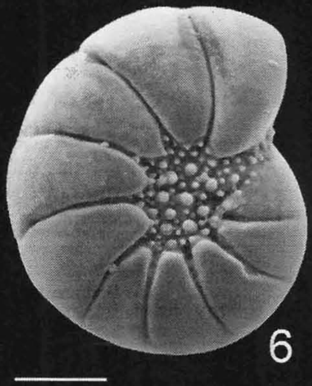

1

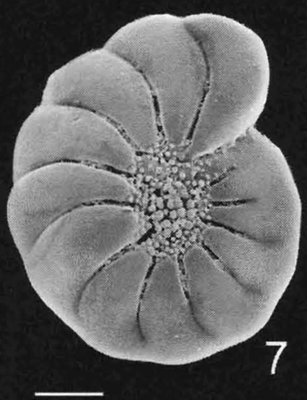

2


3

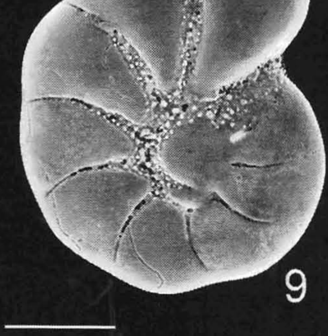

4

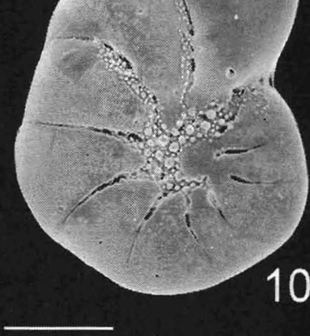

5


6

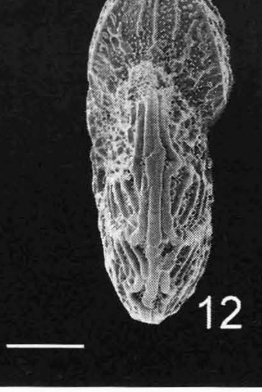

7


8


9


10


11


12

INDEX