THE KAPITEAN STAGE
(UPPER MIOCENE)
OF
NEW ZEALAND

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The Kapitean Stage (Upper Miocene) of New Zealand

by J.P. Kennett

ABSTRACT

The ten chapters in this thesis are presented in the form of nine independent papers and a note. A separate abstract is given below for each chapter.

I. The type section of the Kapitean Stage and four other sections in north Westland were examined in detail. The stratigraphy of each section is described and the distribution of 300 species of Foraminifera and 38 species of Mollusca from the Upper Tongaporutuan and Kapitean is discussed. Neogene sediments, previously classed as "Blue Bottom" are separated into four formations. Six zones based on Foraminifera form an essentially continuous sequence ranging from Upper Miocene to Pliocene in age. Four zones based on Mollusca correspond to four of the foraminiferal zones.

Depth of deposition for each formation is inferred from paleoecology and a geological history is inferred for the Upper Miocene and Pliocene in north Westland. The type Kapitean and the Kapitean throughout north Westland consists of relatively shallow-water facies. From this study it could not be correlated satisfactorily with deep-water facies elsewhere in New Zealand and its relationship to the Bolivinita compressa Zone could not be determined.

The taxonomy of one hundred and five species of Foraminifera is discussed and seven species are described as new: Textularia barnwelli, Quinqueloculina waimea, Virgulina vellai, Florilus olsoni, Notorotalia macinnesi, Globorotalia conomiozea and Cibicides gibsoni. A gradational bioseries of Hofkeruva is described and the evolution and first occurrence of Globorotalia crassaformis (Galloway & Wissler) is discussed.

II. About 350 ft. of Kapitean beds exposed in sea cliffs at Cape Foulwind, West Coast, are conformably overlain by Opoitian and conformably underlain by Tongaporutuan. Seven foraminiferal samples were collected from a uniform and continuous section of marine siltstone. A lithological column and a foraminiferal range chart are presented. Paleoecology and stratigraphic paleontology are discussed.

III. At Cape Foulwind specimens of Textularia kapitea Finlay from six samples show a well defined evolutionary change with time. Two subspecies, one of early to middle Kapitean and one of late Kapitean to early Opoitian age, are established. Textularia miozea appears to be the ancestor of T. kapitea.

IV. Upper Miocene to Pliocene strata in north Westland and Marlborough contain abundant fossils representing a bioseries of planktonic Foraminifera showing gradual progressive morphological changes. The bioseries commenced with Globorotalia miozea Finlay and ended with Globorotalia crassaformis (Galloway and Wissler). The form representing the intermediate stage of the bioseries at

Marlborough, differs slightly from the corresponding form at north Westland, 150 miles to the south-west, but the end form is the same in both areas.

V. In Marlborough, two stratigraphic sections ranging from Middle Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene) in age were examined. They lie only 5 miles apart, but one is predominantly deep-water facies and the other is predominantly shallow-water facies. Ranges of Foraminifera and Mollusca are shown on charts and local foraminiferal and molluscan zones are established. By correlating key horizons in these sections it has been possible to determine relative stratigraphic ranges of important deep-water and shallow-water fossils, including key Foraminifera and the Kapitean key Mollusca.

The base of the Kapitean Stage in the shallow-water section is marked by the first appearance of the key Kapitean Mollusca. The corresponding horizon in the deep-water section can be defined by an evolutionary stage of the Globorotalia crassaformis bioseries. The Kapitean Stage is shown to be relatively thin and to be equivalent to about the upper half of the Bolivinita compressa Zone that is found only in deep-water facies.

Paleoecological changes indicate significant changes in depth of deposition in both sections and these depth changes were almost certainly synchronous. The sea was relatively shallow during the Kapitean Age. The biostratigraphic divisions are closely related to the changes in depth of deposition.

VI. Six sections through the Upper Miocene and Lower Pliocene in Wairarapa and southern Hawkes Bay were examined in detail. Ranges of Foraminifera and Mollusca are given for each section and lithologies are shown on columnar sections.

For the stratigraphic interval from Upper Tongaporutuan to Opoitian, two parallel sets of zones are recognised. One set of zones is based on Foraminifera and is applicable mainly to deep-water facies and the other is based on Mollusca and is applicable only to shallow-water facies. Diagnostic species for each zone are listed.

In shallow-water facies the Kapitean Stage is determined mainly by the presence of Sectipecten wollastoni. In deep-water facies which lack the key Mollusca, it is determined by means of the Globorotalia crassaformis bioseries. The absence of the Kapitean in two of the sections is shown mainly by the absence of the characteristic Kapitean parts of the G. crassaformis bioseries and the Siphotextularia wairoana bioseries.

The paleoecology throughout each section is described, and indicates that at most places the sea was relatively shallow during the Kapitean Age.

VII. Four eastern North Island sections through the Upper Miocene and Lower Pliocene were examined: at Maraetotara River, central Hawkes Bay; at Ruakituri River, northern Hawkes Bay; at Waimata River, Gisborne; and near Te Araroa, East Cape. Distribution of Foraminifera is shown on charts, and lithologies are shown on columnar sections. Four well defined biostratigraphic units can be recognised for the Foraminifera, from oldest to youngest;

Pohana Zone, Compressa Zone, Conomiozea Zone, and Crassaformis Zone. Diagnostic species are listed for each of these zones.

In one section the Kapitean Stage is represented by shallow-water facies and is marked by the key Kapitean Mollusca. In two sections it is represented by deep-water facies and is determined by means of the Globorotalia crassaformis bioseries. In the fourth section, the absence of uppermost Upper Tongaporutuan, Kapitean and basal Opoitian is shown by the absence of part of the G. crassaformis bioseries.

The paleoecology throughout each section is described, and indicates that the sea shallowed near the end of the Tongaporutuan Age, remained shallow during the Kapitean Age and deepened again at the beginning of the Opoitian Age.

VIII. The stratigraphic ranges in inland Taranaki are given for some important Foraminifera relative to those of the Mollusca Sectipecten grangei and S. wollastoni.

IX. The following fourteen new species of fossil Foraminifera are described and illustrated from the Upper Miocene and Lower Pliocene of New Zealand: Textularia crater, Siphotextularia dawesi, Ruakituria pseudorobusta, Karrerella fasigatus, Arenodosaria turris, Vaginulinopsis carinata, Bolivinita finlayi, Brizalina srinivasani, Kolesnikovella zealandica, Discorbinella hamasuturalis, Notorotalia mammiligera, Cibicides porrodeliquatus, Cibicides teararus and Pleurostomella parviapertura. Known stratigraphic ranges and inferred depth ranges are given for each species. The new genus Ruakituria (Ataxophragmiidae) is erected for the

species formerly known as Dorothia robusta Keyzer.

X. The salient features of New Zealand Upper Miocene and Lower Pliocene microfaunas are outlined, and criteria for recognising the Kapitean Stage are summarized. Paleocology suggests that the Kapitean Stage represents an interval of time when seas were relatively shallow, that the shallowing took place in the latest part of the Tongaporutuan Age and that deepening took place in the earliest part of the Opoitian Age. The changes in depth of sea caused many temporary "facies" changes in fossil faunas at any particular place, but the Kapitean Stage is soundly based on a few permanent changes of both macrofauna and microfauna. The Kapitean Stage is represented by fairly shallow-water facies at many places but by fairly deep-water facies at other places. Shallow-water and deep-water facies contain very few age diagnostic fossils in common, but can be correlated by means of the Globorotalia crassaformis bioseries, a sequence of planktonic Foraminifera showing gradual progressive morphological change.

In nearly all sections the Kapitean Stage is thin compared with the overlying Opoitian and underlying Upper Tongaporutuan, and this is attributed to a decreased rate of deposition due to shallowing and increased by-passing of sediment.

Kapitean microfaunas show a slight but distinct change from north to south, this being attributed to latitudinal temperature difference.

The previously suggested correlation of the Kapitean Stage with the Pontian Stage of Europe is probably correct. The shallow

seas during the Kapitean Age in New Zealand appear to have coincided with a phase of regression in Europe and in other parts of the world and may have a eustatic rather than a tectonic cause.

FOREWORD.

The ten chapters in this thesis are in the form of nine independent papers and a note. Two of the papers have been published, one has been submitted for publication in Micropaleontology, and the remainder have been prepared for publication.

Chapter I describes the stratigraphy and fauna of the type section and neighbouring sections of the Kapitean Stage near Greymouth, Westland. The second Chapter describes the stratigraphy and faunal succession of the Kapitean Stage in the Cape Foulwind section, S.W. Nelson, while the third outlines a well defined evolutionary lineage in Textularia occurring in this section.

The fourth Chapter describes a bioseries of planktonic Foraminifera in the Upper Miocene to Lower Pliocene strata of north Westland and Marlborough, which is useful for determining the boundaries of the Kapitean Stage in most facies throughout New Zealand.

The fifth, sixth and seventh Chapters outline the faunal succession through Upper Miocene to Lower Pliocene sections in Marlborough, Wairarapa to southern Hawkes Bay, and central Hawkes Bay to East Cape respectively. Biostratigraphic zones based on Foraminifera and where possible Mollusca are established for each of these areas, and the limits of the Kapitean Stage are inferred. The eighth Chapter briefly outlines the faunal succession from the uppermost Upper Tongaporutuan to the basal Opoitian of inland Taranaki, an important area for the Taranaki Series.

The ninth Chapter describes new species and a new genus recognised in the previous regional studies of the Upper Miocene - Lower Pliocene succession and required for the following paper.

The final Chapter summarizes the criteria used to distinguish the Kapitean Stage in both shallow-water and deep-water facies and discusses widespread shallowing of the sea which occurred during the Kapitean Age, latitudinal variation of Kapitean faunas, and overseas correlation of the Kapitean Stage.

The classification adopted in all of this thesis except Chapter IX closely follows that used by Hornibrook (1961) and is based mainly on the classification of Sigal (1952). A heavily revised classification by Loeblich and Tappan (1964) was published near the time of completion of this thesis, and consequently their classification, with some modifications, is used only in Chapter IX.

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CHAPTER I

Stratigraphy and Fauna of the Type Section
and Neighbouring Sections of the Kapitean

Stage, Greymouth, N.Z.

ABSTRACT.VICTORIA UNIVERSITY OF
WELLINGTON LIBRARY.

The lithostratigraphy and biostratigraphy are described for the type section and four neighbouring sections through the Kapitean Stage. Charts give the distribution of over 300 species of Foraminifera (in 58 samples) and 38 species of Mollusca.

The Lower Miocene to Pliocene sediments, previously all classed as "Blue Bottom", are separated into the following five formations: Blue Bottom Mudstone, ammended, (Altonian to Waiauan), Kawhaka Siltstone (Lower Tongaporutuan), Callaghans Conglomerate (Upper Tongaporutuan), Callaghans Greensand (Upper Tongaporutuan to basal Kapitean), and Eight Mile Formation (Kapitean to "Waitotaran").

Six zones based on Foraminifera form an essentially continuous sequence ranging from Upper Miocene to Pliocene in age. Four zones based on Mollusca are equivalent to four of the foraminiferal zones, and do not form a continuous sequence because strata of some ages contain practically no macrofossils.

Depth of deposition for each formation is inferred from paleoecology and a summary is given for the geological history of the Upper Miocene and Pliocene in north Westland.

The type Kapitean and the Kapitean throughout north Westland consists of relatively shallow-water facies and as yet can not be correlated satisfactorily with deep-water facies elsewhere in New Zealand, and its relationship to the Bolivinita compressa Zone cannot be determined from the present study.

In a section on taxonomy, one hundred and five species of Foraminifera are discussed and the following seven are described as new:

Textularia barnwelli, Quinqueloculina waimea, Virgulina vellai, Florilus olsoni, Notorotalia macinnesi, Globorotalia conomiozea and Cibicides gibsoni.

A gradational bioseries is described from Hofkeruva zeacuminata Vella to H. lutorum Vella to H. pliozea Vella. Reference is also made to the evolution and first occurrence of Globorotalia crassaformis (Galloway & Wissler) which has a gradational stratigraphic relationship with the older species G. conomiozea Kennett, n.sp.

The more important Molluscan species from the Upper Tongaporutuan and Kapitean of north Westland are figured, but their taxonomy is not discussed.

INTRODUCTION.

The Kapitean Stage was erected by Finlay and Marwick in 1947 with a brief description of the type locality, the nomination of some key species, and an outline of the distribution of the stage. The faunal and lithological succession of the type Kapitean were never described in detail.

Most of the Foraminifera given as key species for the Kapitean Stage by Finlay and Marwick (1947), Hornibrook (1958), and Fleming (1959) are now known to extend outside the Kapitean. When the writer began to study the type section, the Kapitean Stage could not be distinguished from the underlying Tongaporutuan Stage by means of Foraminifera.

Of the species previously used for identifying Kapitean, the planktonic Foraminifera Globorotalia crassaformis (Galloway and Wissler) and Globorotalia inflata (d'Orbigny) are very satisfactory for determining the boundary of the Kapitean and Opoitian in most facies. Only the Mollusca Sectipecten wollastoni (Finlay), Austrofusus coerulescens (Finlay) and a few others are useful for identifying the Kapitean itself; and only Sectipecten wollastoni in succession with its ancestor S. grangei Boreham (known only in two sections) can be used to identify the base of the Kapitean.

Much of the so-called Kapitean in New Zealand has been determined from Foraminifera, and a full re-evaluation of the Kapitean Stage is necessary. The first requirements are the determination of the complete fossil succession in the type area, near Greymouth, and the sorting out of any species that may be useful for correlation with strata away from the type area.

A reasonably complete account of the faunal succession at Kapitea Creek and four nearby sections is given below. Particular attention has been given to the planktonic Foraminifera, and one group of these will probably be useful for identifying the stage. A few benthonic Foraminifera not mentioned by previous authors may also be useful. As yet the value of

Fig. 1 - Map showing the location of areas shown in Fig. 2 and Fig.5, and of Coreholes D and F.

these species can be discussed only tentatively as they have to be tested by study of sections elsewhere in New Zealand. Much of the vertical change of faunas in the type area is due to facies change with time, and it is very difficult to sort out those faunal changes that have time significance.

Sampled Sections

The five geological sections described (fig. 1) all fall within N.Z.M.S.1 Sheet District S51, Hokitika Sheet. Five days were spent in the area with Dr. H.W. Wellman sampling from Kapitea Creek, Callaghans Creek and Eight Mile Creek. Fossil locality details are given in the Appendix (Table 11 - Index of Fossil Localities). The distribution of Foraminifera in the five sections is shown in the range charts (Tables 6 - 10).

1. Kapitea Creek:

The type section of the Kapitean Stage (fig.2) is rather poorly exposed in low bluffs extending about one mile down Kapitea Creek from its junction with Maori Gully. The section was sampled at intervals of about 100 ft. and from 40 ft. below the base of the Kapitean to about 150 ft. above the top of the Kapitean. Sample locations are shown on fig. 2 and lithologies and sample horizons are shown on a columnar section (fig.3).

2. Callaghans Creek:

Callaghans Creek, 2 miles south-east of Kapitea Creek, is an artificial sludge channel constructed during the late 19th century to drain gold sluicing claims. It flows partly in a narrow 50 ft. deep cut and partly in tunnels. Exposures are good and macrofossils abundant, but access is extremely difficult. The section was sampled at intervals of about 10 ft., from the upper part of the Lower Tongaporutuan, and throughout the Upper

Fig. 3 - Stratigraphic column of the Kapitea Creek section.

Fig. 4 - Stratigraphic column of the Callaghans Creek section.

Tongaporutuan and the lower part of the Kapitean. Sample locations are shown on fig.2 and lithologies and sample horizons are shown on a columnar section (fig.4).

3 and 4 Coreholes D and F:

Coreholes D and F (fig. 1) were drilled by the New Zealand Oil Exploration Ltd. in 1942, the samples being now held by the New Zealand Geological Survey, who loaned them to the writer. Foraminifera are from ditch samples taken usually at 5 or 10 ft. intervals, from middle Kapitean to Opoitian in Corehole F, and from Lower Tongaporutuan, to Kapitean in Corehole D. Sample intervals are shown in the Appendix (Table 11 - Index of Fossil Localities). Sample residues are available only for Corehole D, and lithological information gained from these is shown in the following text section.

Text Section - Corehole D.

Depth.

Kapitean.

- 22 ft. - highly micaceous siltstone with common shell fragments.
- 35 ft. - micaceous slightly glauconitic siltstone with common shell fragments.
- 65 ft. - highly micaceous siltstone with shell fragments.

Upper Tongaporutuan

- 141 ft. - light grey, non-micaceous, silty mudstone with few shell fragments and abundant Foraminifera.
- 160 ft. - light grey, slightly micaceous, silty mudstone with few shell fragments and abundant Foraminifera.

Fig. 5 - Map of the Eight Mile Creek section showing location of samples.

Fig. 6 - Stratigraphic column of the Eight Mile Creek Section.

5. Eight Mile Creek:

Eight Mile Creek is 10 miles north-east of Kapitea Creek and contains a poorly exposed section from Lower Miocene to the top of the Pliocene. The section collected extends for one mile upstream from the Maori Creek Road bridge. Sample locations are shown on fig. 5 and lithologies and sample horizons are shown on a columnar section (fig. 6).

Previous Work

In 1911 P.G. Morgan made use of the old gold-miners' name "Blue Bottom" for the marine blue-grey muddy sediments representing the upper part of the Tertiary in n. Westland, and listed Molluscan fossils found in Callaghans Creek. Geological maps of the area are available in unpublished reports by Brown (1940) and Burr (1941) of the N.Z. Oil Exploration Company Ltd., and Nichols (1943) of the Superior Oil Company. A map was prepared by Dr. H.W. Wellman in 1950 using information from the oil company reports, but was not published. The map presented in this paper (fig. 2) is slightly modified from Wellman's map. The report by Nichols gives detailed thicknesses of late Tertiary sediments in Callaghans Creek and Kapitea Creek, which correspond fairly closely with thickness determinations by the writer.

Bunning (1941) in an unpublished oil report, recognised the major biostratigraphic units but used company numbers instead of species names. Wheatley (1943) in a short unpublished oil report proposed two post-Tongaporutuan zones, one of which has been recognised by the author as corresponding to the Conomiozea Zone, and the other corresponding to the Crassaformis and Finlayi Zones.

All the above oil company reports are available at the New Zealand Geological Survey.

Finlay and Marwick (1947) defined the Kapitean Stage at the type locality (Kapitea Creek) as that part of the section whose lower limit is marked by Sectipecten wollastoni (Finlay) and Austrofuscus coeruleus (Finlay) = A. tuberculatus Marwick , and whose upper limit is immediately below the incoming of the foraminiferal species Globorotalia inflata (d'Orbigny) and the allied species G. crassaformis (Galloway and Wissler) = G. crassula Cushman and Stewart

STRATIGRAPHY.

The Lower Miocene to Pliocene consists predominantly of moderately folded and faulted marine blue-grey muddy sediments that become coarser towards the top, and have generally been known as the Blue-Bottom.

The late Tertiary is conformably overlain by thick Old Man Gravels, which are predominantly fluviatile gravels thought to be early Pleistocene marine and glacial-outwash gravels.

The Kapitean Stage is regarded as uppermost Miocene in age and the sections examined range from about Middle Miocene to near the top of the Pliocene.

In Kapitea Creek and the surrounding area, an unconformity occurs slightly below the Kapitean Stage. A thin conglomerate and a richly glauconitic sandstone indicate an Upper Tongaporutuan age. The unconformity is therefore referred to as the intra-Tongaporutuan unconformity.

The following lithostratigraphic classification is adopted:

Table 1. - Lithostratigraphic Units.

Old Man Gravels	-	(Early Pleistocene)
Eight Mile Formation	-	(Kapitean - "Waitotaran")
Callaghans Greensand	}	(Upper Tongaporutuan to basal Kapitean)
Callaghans Conglomerate		
Intra-Tongaporutuan unconformity		
Kawhaka Siltstone	-	(Lower Tongaporutuan)
Blue Bottom Mudstone	-	(Altonian to Waiauan)

Columnar sections showing correlation of formations of the five sections are given in fig. 7.

Blue Bottom Mudstone

The gold mining term "Blue Bottom" is too firmly entrenched in literature, and too useful to be rejected. Furthermore it is more expressive than any locality name could be. It has been used as a catch-all in the past, and to be useful it needs its meaning restricted. The Blue Bottom Mudstone is here defined as consisting predominantly of blue-grey calcareous mudstone representing approximately the Southland Series (Altonian or possibly Awamoan to Waiauan). As such it is the most extensive and generally the bluest sedimentary unit that forms a bottom to the gold bearing gravels of Westland and West Nelson.

The type locality is nominated as Eight Mile Creek, for $1\frac{1}{2}$ miles upstream from its junction with New River.

Only the upper part (Waiauan) of the Blue Bottom Mudstone as here defined, was examined in detail by the writer.

Fig. 7 - Correlation of formations in some north Westland sections. The intra-Tongaporutuan unconformity is taken as a datum horizon.

Kawhaka Siltstone

The Kawhaka Siltstone consists predominantly of blue-grey calcareous muddy siltstone, but locally grades to silty mudstone or to sandy siltstone. It contains abundant Foraminifera with a fairly high proportion of planktonic specimens, but only rare Mollusca.

The sediments are generally distinctly coarser and slightly lighter in colour than the underlying Blue Bottom Mudstone, and the Molluscan fossils are generally larger and less rare.

The name is from Kawhaka Creek, north Westland, and the type locality is nominated as Callaghans Creek to upper Kapitea Creek. Here, nearly 1800 ft. of Kawhaka Siltstone is unconformably overlain by Callaghans Conglomerate and Greensand. At the Kawhaka Dome seven miles to the south, the Kawhaka Siltstone is about 3500 ft. thick. At most places the Kawhaka Siltstone contains the key Foraminifer Bolivinita quadrilatera (Schwager) and the formation is approximately equivalent to Lower Tongaporutuan.

Callaghans Conglomerate

The Callaghans Conglomerate consists of small pebbles, mainly greywacke, often polished and phosphatised, with a greensand matrix containing Foraminifera that are often broken and worn. At Callaghans Creek the conglomerate is one foot thick and rests on an erosion surface cut on Lower Tongaporutuan Kawhaka Siltstone. Borings infilled with greensand extend six inches into the Kawhaka Siltstone.

Similar conglomerate at Kapitea Creek containing fossils leached out by weathering, but considered to be the Callaghans Conglomerate, rests on a similar erosion surface with borings twelve inches deep, cut on Waiauan Blue Bottom Mudstone.

At Eight Mile Creek the conglomerate contains small pyritic concretions in the matrix.

The type locality of the Callaghans Conglomerate is Callaghans Creek. The age is discussed under the Callaghans Greensand below.

Callaghans Greensand

The Callaghans Greensand immediately overlies the Callaghans Conglomerate. The contact with the conglomerate is gradational, and the greensand is essentially the continuation of the conglomerate matrix without the conglomerate pebbles. The greensand is richly glauconitic medium to coarse sandstone with detrital grains predominantly of quartz, and with glauconite chiefly in the form of pellets up to 1 mm. in diameter. The lower part is more glauconitic than the top, the greensand grading up to the overlying virtually non-glauconitic Eight Mile Formation. At most places the Callaghans Greensand contains a fairly rich molluscan fauna, and unusually common fish teeth and bones, as well as common but not diverse Foraminifera that are often broken and worn.

The type locality is at Callaghans Creek. Greensand at the four other sections examined is shown by fossils to be probably the same age and is considered to be the Callaghans Greensand.

At Callaghans Creek, the lower and greater part of the Callaghans Greensand falls within the zone of Sectipecten grangei Boreham, the uppermost part within the zone of Sectipecten wollastoni (Finlay). The incoming of Sectipecten wollastoni was taken by Finlay and Marwick (1947), and is here accepted as marking the base of the Kapitean Stage. Anne Boreham (1961) considered that S. grangei is ancestral to, and immediately precedes S. wollastoni. The lower and main part of the Callaghans Greensand at Callaghans Creek is therefore considered to be "Upper" Tongaporutuan in age. This usage of "Upper" Tongaporutuan is not to be confused with the more common usage of Upper Tongaporutuan because the Grangei Zone has not been

correlated satisfactorily with the Compressa Zone based on the foraminifer Bolivinita compressa Finlay.

At Kapitea Creek the Callaghans Greensand, 20 ft. thick, is poorly exposed in a bluff at the mouth of Maori Creek and a few chains down Kapitea Creek. The lowest part of the greensand is deeply weathered and non-calcareous and completely unfossiliferous. In spite of the lack of fossils, the lower part is considered to be "Upper" Tongaporutuan as at Callaghans Creek. The uppermost part of the greensand contains abundant Sectipecten wollastoni which mark the base of the type Kapitean.

The Kawhaka Siltstone, the unconformity, the Callaghans Conglomerate and most of the Callaghans Greensand thus lie within the Tongaporutuan Stage. ~~The Kawhaka Siltstone is Lower Tongaporutuan Stage.~~ The Kawhaka Siltstone is Lower Tongaporutuan in the established sense (Vella 1954; Hornibrook, in Fleming ed. 1959). The intra-Tongaporutuan unconformity, the Callaghans Conglomerate, and most of the Callaghans Greensand form a condensed sequence representing possibly Middle and Upper Tongaporutuan. The amount of sediment removed at Kapitea Creek and other places suggests either vigorous or long continued erosion. Deep borings in the erosion surface and phosphatisation of conglomerate pebbles indicates a subsequent long period of still stand under the sea. The greensand with its gradually increasing proportion of clastic sediments presumably indicates gradual increase in the rate of deposition.

Eight Mile Formation

Typically the Eight Mile Formation includes massive muddy sandstone and siltstone, with more or less common Mollusca, overlying the Callaghans Greensand. The middle part of Kapitea Creek is nominated as the type locality. There the Eight Mile Formation includes all but the base of the

type Kapitean, continues up to within the Opoitian, and is 900 ft. thick.

Provisionally, all strata above the Callaghans Greensand and below the Old Man Gravels are included in the Eight Mile Formation. Towards the top ("Waitotaran") these strata include much sandstone and conglomerate and more frequent and less diverse Mollusca, but the change in lithology is gradational.

At Eight Mile Creek the full succession from the top of the Callaghans Greensand up to the base of the Old Man Gravels is represented, though not well exposed at some places, and is estimated to be about 4000 ft. thick.

BIOSTRATIGRAPHY

Large differences in faunal composition between beds above and below the intra-Tongaporutuan unconformity, and between the Upper Tongaporutuan greensand and Kapitean silty mudstones are due to differences in facies more than to widespread extinctions and appearances of species. Many species that are locally useful for zoning are known to have longer stratigraphic ranges elsewhere.

Six foraminiferal zones are distinguished with molluscan zones equivalent to four of them. They are shown in table 2 with their ages, lithostratigraphic equivalents, and on the right the ranges of the zone name fossils.

Stages		Formation	Nth. Westland Zones		Characteristic Zone Fossils
Europe	New Zealand		Foraminiferal Zones	Molluscan Zones	
Astian	Waitotaran	Eight	Finlayi	Chrydaea	Loxostomum truncatum Bolivinita quadrilatera Austrofus cliftonensis Notorotalia macinnesi Sectipecten grangei Globorotalia conomiozea Sectipecten wollastoni Austrofus coerulescens Globorotalia crassaformis Austrofus pagoda Maorimacra chrydaea Notorotalia finlayi
Plaisancian	Opoitian	Mile	Crassaformis	-	
Pontian	Kapitean	Formation	Conomiozea	Coerulescens Wollastoni	
Samatian	Up.	Callaghans Greensand & Conglomerate	Macinnesi	Grangei	
	Mid. Tongaporutuan	Unconformity	Missing	Missing	
	Low.	Kawhaka Siltstone	Quadrilatera	Cliftonensis	
Tortonian	Waiauian	Blue Bottom Mudstone	Truncatum	-	

Table 2 - Biostratigraphic units in north Westland.

Lists of species restricted to each zone and making first and last appearances in each zone are given below.

Truncatum Zone

Last appearances:-

Textularia cf. ototara Hornibrook

Vulvulina pennatula (Batsch)

Dorothia aff. minima (Karrer)

Karrerella cf. ototara Hornibrook

Spiroloculina novozealandica Cushman & Todd

Buliminella missilis Vella

Virgulina n.sp., (long, thin)

Neouvierina cf. interrupta (Brady)

Neouvigerina aff. moorei Vella

Rectuvigerina vesca (Finlay)

Ruatoria n.sp.

Bolivina zedirector Finlay

Loxostomum truncatum Finlay

Cassidulina cuneata Finlay

Ehrenbergina osbornei Finlay

Baggina ampla (Finlay)

Alahamina tenuimarginata (Chapman, Parr & Collins)

Notorotalia n. sp., (strongly biconvex, reticulate ornament)

Globigerina n. sp. cf. nepenthes Todd

Globorotalia barisanensis Le Roy

Globorotalia mayeri Cushman & Ellisor

Globorotalia menardii panda Jenkins

Anomalinoides macraglabra (Finlay)

Anomalinoides subnonionoides (Finlay)

Cibicides amoenis Finlay

Cibicides pseudoungerianus (Cushman)

Cibicides robertsonianus (Brady)

The Waiauan sample from Kapitea Creek seems stratigraphically lower than those examined from Eight Mile Creek, as it contains no Loxostomum truncatum, Notorotalia hurupiensis or Cibicides deliquatus, all of which occur at Eight Mile Creek. In spite of these absences it is considered to be Waiauan in age because of the presence of Karrerella cylindrica Finlay which is supposed to make its first appearance in the Waiauan, and Anomalinoides macraglabra (Finlay) which becomes extinct in the Waiauan.

Quadrilatera Zone

Restricted:-

Bolivinita quadrilatera (Schwager)Austrofusus cliftonensis (Marwick)

First appearances:-

Bolivina numerosa VellaFlorilus flemingi (Vella)Notorotalia taranakia Vella

Last appearances:-

Textularia miozea FinlayTextularia subrhombica StacheSiphotextularia subcylindrica FinlaySiphotextularia n.sp. cf. emaciata HornibrookSiphotextularia n.sp. cf. wairoana FinlaySpiroloculina canaliculata d'OrbignyBulimina vellai GibsonAwhea sinalata (Finlay)Neouvigerina eketahuna VellaVirgulina bradyi CushmanVirgulina bramlettei Galloway & MotreyBolivina albatrossi CushmanBolivina lapsus FinlayBolivina n.sp. cf. striatula CushmanPlectofrondicularia pohana FinlayEhrenbergina willetti FinlayPleurostomella alternans Schwager

(Quadrilatera Zone - cont'd.)

Nonion cf. cassidulinoides HornibrookPacinonion n.sp. cf. novozealandicum (Cushman & Edwards)Nonionella novozealandica CushmanGyroidina n.sp. cf. orbicularis d'Orbigny, (compressed, numerous chambers)Parvicarinina altocamerata (Heron-Allen & Earland)Globigerina subcretacea LomnickiGloborotalia mendardii miotumida JenkinsGloborotalia miozea FinlayGloborotalia opima continua BlowCibicides ihungia FinlayGrangei Zone

Restricted:-

Quinqueloculina sp., (low bifid tooth)Sigmomorphina cf. rhomboidalis VellaHofkeruva rodleyi rodleyi VellaFlorilus olsoni Kennett, n.sp.Discorbis cf. dimidiatus Parker & JonesNotorotalia macinnesi Kennett, n. sp.Glycymeris callaghani MarwickSectipecten grangei BorehamKuia cf. macdowellii Marwick

First appearances:-

Textularia kapitea FinlayGuttulina bartschi Cushman & Ozawa

(Grangei Zone - cont'd)

Bulimina aculeata d'OrbignyAstrononion vadorum VellaMelonis zeobesus VellaZeaflorilus parri (Cushman)Elphidium oceanicum CushmanNotorotalia pliozea VellaGlobigerina pachyderma (Ehrenberg)Globigerina quinqueloba Natland

Last appearances:-

Rectobolivina maoria FinlayGloboquadrina dehiscens (Chapman, Parr & Collins)Cibicides mediocris FinlayStruthiolaria cf. praenuntia MarwickBaryspira cf. subhebra (Marwick)Conomiozea - Wollastoni Zone

Restricted:-

Siphotextularia cf. wairoana FinlayQuinqueloculina waimea Kennett, n.sp.Bolivinita pohana FinlayGlobigerinita glutinata (Egger)Globorotalia conomiozea Kennett, n.sp.Sectipecten wollastoni (Finlay)Austrofuscus coerulescens (Finlay)Alcithoe gravicostata King

First appearances:-

Textularia barnwelli Kennett, n.sp.

Haeuslerella finlayi Vella

Bulimina cf. striata d'Orbigny, (small var.) - Upper Tk.

Rectobolivina striatula (Cushman)

Patellinella inconspicua (Brady)

Ammonia aoteanus (Finlay)

Notorotalia aff. taranakia Vella, (reticulate ornament)

Globigerina dutertrei d'Orbigny

Marama cf. murdochi Marwick

Nemocardium quinarium Marwick

Dentalium zelandicum Sowerby

Last appearances:-

Siphotextularia awamoana Finlay - (Lower Tk.)

Bulimina cf. striata d'Orbigny, (large var.) - Lower Tk., rare.

Hofkeruva zeacuminata Vella - (Lower Tk.)

Globigerina cf. falconensis Blow

Cucullaea (as hamptoni Marwick n.sp., in press)

Crassaformis Zone

Restricted:-

Globorotalia cf. menardii (d'Orbigny), (pustulose)

First appearances:-

Haeuslerella parri Finlay

Haeuslerella pliocenica (Finlay)

Siphotextularia wairoana Finlay

Sigmoilopsis zeaserus Vella

(Crassaformis Zone - cont'd.)

Hofkeruva delicatula Vella

Hofkeruva pliozea Vella

Bolivinita pliozea Finlay

Pacinonion neefi Vella

Globigerinoides obliqua Bolli

Globorotalia crassaformis (Galloway & Wissler)

Finlayi Zone

First appearances:-

Pacinonion novozealandicum (Cushman & Edwards)

Notorotalia finlayi Vella

Maorimactra chrydasa (Suter)

The Truncatum Zone and Quadrilatera Zone are well known foraminiferal zones elsewhere in New Zealand. The Truncatum Zone is distinguished by the occurrence of Loxostomum truncatum Finlay and absence of Bolivinita quadrilatera (Schwager). It is generally considered to be Waiauan, though there is some doubt about this age since Hornibrook (pers. comm.) discovered that Loxostomum truncatum occurs in the type Lillburnian at Clifden. The Quadrilatera Zone is distinguished by the occurrence of Bolivinita quadrilatera, and absence of Bolivinita pohana and other derivatives of quadrilatera. It is generally regarded as Lower Tongaporutuan (Vella, 1954; Hornibrook in Fleming ed., 1959) but there is some suggestion that the Lower Tongaporutuan may be equivalent to the type Waiauan (Geiger 1962, p. 307). The uncertainty of the age of these two zones in terms of the New Zealand stages does not seriously affect correlation of the Kapitean because the two zones can be recognised

+ No! at date not. NdsH misunderstanding

over most of New Zealand. The Cliftonensis Zone is the molluscan Zone equivalent to the Quadrilatera Zone and is distinguished by the occurrence of Austrofuscus cliftonensis (Marwick) - Dr. C.A. Fleming, pers. comm. The type Kapitean is underlain by the Grangei Zone of later Tongaporutuan age.

The Grangei Zone directly underlies the Wollastoni Zone, and as the lithological contact seems to be gradational, the Grangei Zone may be assumed to be immediately older than the Wollastoni Zone. By definition the base of the Kapitean Stage is the base of the Wollastoni Zone, and the Grangei Zone is the top of the Tongaporutuan Stage. This does not help much for correlating the Kapitean elsewhere in New Zealand because Sectipecten wollastoni occurs in succession with S. grangei only at Callaghans Creek and between Ratapiko and Te Popo in Taranaki. Sectipecten wollastoni and Austrofuscus coerulescens identify part of the Kapitean at several other places but occur only in a limited range of shallow water facies. Most Upper Miocene and Pliocene sediments in New Zealand are deeper-water facies in which the Kapitean Stage can not be recognised satisfactorily.

A typical succession of zones for the deep water facies given by Vella (1963) and Gibson (in press) for Wairarapa district is shown with ranges of zone name fossils in Table 3.

The Quadrilatera Zone is equivalent to the Quadrilatera Zone of Westland. The Pohana Zone is not recognised in Westland but is probably represented by the intra-Tongaporutuan unconformity. The Compressa Zone also is not recognised but is supposed to be Upper Tongaporutuan in age and should be equivalent to the Macinnesi Zone.

Zone	Stage	Characteristic Zone Fossils				
Inflata	Opoitian	Bolivinita quadrilatera	Bolivinita pohana	Bolivinita compressa	Sigmioilopsis zeaserus	Globorotalia inflata
Zeaserus	Kapitean					
Compressa	Up.					
Pohana	Mid. Tongaporutuan					
Quadrilatera	Low.					

Table 3 - Biostratigraphic units for deep-water facies in Wairarapa.

Vella (1963) has suggested that Bolivinita compressa is restricted to very deep-water facies. Therefore absence of B.compressa from the Callaghans Conglomerate and Callaghans Greensand could be attributed to the shallow-water environment of deposition.

However there is no direct evidence for correlating the Macinnesi Zone with the Compressa Zone, and the Macinnesi Zone could be equivalent to the Pohana Zone or part of the Pohana Zone. The Compressa Zone of deep-water facies, although it has been considered to be Upper Tongaporutuan in age, may well be Kapitean in age, or partly Tongaporutuan and partly Kapitean.

Some support for the suggestion that the Compressa Zone is equivalent to the Kapitean Stage is given by the very deep-water section at Tiniroto in the Wairoa District of the North Island where Gibson (in press) has reported the Compressa Zone directly underlying Opoitian without any sign of a stratigraphic break between to account for the apparently

missing Kapitean. Close sampling of the Palliser Bay section, south Wairarapa, by G. Gibson and the writer showed that Bolivinita compressa there makes its first appearance only slightly below Sigmoilopsis zeaserus, and Vella may be mistaken in giving the Compressa Zone in Wairarapa the same rank as the other zones while separating it from the Zeaserus Zone, and the failure of Sigmoilopsis zeaserus and Bolivinita compressa to occur together may be largely due to difference in facies range, as the former appears to be restricted to a slightly shallower environment ranging from the Robulus Biofacies to the Semipelagic Biofacies.

The benthonic faunas of shallow and deep-water facies are so different that few benthonic species are likely to be useful for interfacies correlation. Planktonic species generally give rather coarse zoning in the Tertiary, but a profound change in the planktonic fauna marks the base of the Opoitian immediately above the Kapitean Stage, and lesser changes, foreshadowing this promise to be the most useful for correlating the Kapitean. The Globorotalia conomiozea-crassaformis bioseries mentioned in the systematic descriptions may be especially useful.

The above mentioned problems concern only the lower boundary of the Kapitean. The definition and correlation of the upper boundary presents no problems. The base of the overlying Opoitian Stage is taken, in accordance with general usage, at the first appearance of Globorotalia crassaformis and/or G. inflata. The true boundary at Kapitea Creek is not clear-cut because it is marked only by G. crassaformis and this is the end of a rapidly changing bioseries. Because of a large sampling interval the gradational change was not clearly distinguished as it was at Corehole F, but many specimens in the highest sample containing G. conomiozea differ little from G. crassaformis. Therefore the true

boundary occurs somewhere between the highest sample referred to Kapitean and the lowest sample referred to Opoitian. In order to make the boundary as definite as possible the first appearance of G. crassaformis is arbitrarily defined as the lowest sample in which typical G. crassaformis makes up more than 50 percent of the G. conomiozea-crassaformis plexus. The same horizon is taken as the boundary between the Conomiozea Zone and the Crassaformis Zone at Kapitea Creek, so that the zone and stage boundaries coincide.

Austrofusus coerulescens (Finlay) occurs with Sectipecten wollastoni immediately above the Callaghans Greensand at Callaghans Creek and also occurs somewhat above S. wollastoni ranging at least 525 ft. up into the Eight Mile Formation. The part of the Eight Mile Formation containing A. coerulescens is distinguished as the Coerulescens Zone. The top of the zone is probably above the highest recorded A. coerulescens but below the top of the Kapitean as defined by Foraminifera.

The Crassaformis Zone, essentially equivalent to the Inflata Zone of Vella (1962, p.189; 1963, p.2.) and Geiger (1962, p. 307), represents the Opoitian Stage and contains the key benthonic Foraminifera Hofkeruva pliozea Vella.

The Finlayi-Chrydaea Zone is named after Notorotalia finlayi Vella and Maorimactra chrydaea (Suter). Both of these, plus associated Pacinonion novozealandicum (Cushman & Edwards), are shallow-water species, and the zone they demark resulted from general shallowing rather than from any time-significant faunal change. This zone is regarded generally as Waitotaran but this is an extremely tentative age. The Waipipian Stage must be represented either in this zone or in the underlying Crassaformis Zone.

The problem of correlating this highest zone of the Eight Mile Formation is of no importance in a survey of the type Kapitean.

PALEOECOLOGY.

Depths of deposition are inferred by depth correlation with Upper Miocene and Pliocene Biofacies (Vella, 1962), and with an additional biofacies defined by Kennett (1962) from the Kapitean at Cape Foulwind, North Westland.

Lithofacies and biofacies differ throughout the Lower Miocene and Pliocene sediments in north Westland. Lithological changes are described in the stratigraphic section and shown on the columnar sections (Figs. 3,4, & 6). The biofacies of the different formations represented are significantly different, and are described in ascending stratigraphic order. A summary of the biofacies present and their inferred depth ranges is given in Table 4.

Formation	Stage	Biofacies	Inferred Depth Range in feet
Eight Mile Formation	"Waitotaran"	Zeaflorilus Biofacies	c20
	Opoitian	Haeuslerella Biofacies (Eight Mile Creek) Karreriella Biofacies (Kapitea Creek)	c400/c1000
	Kapitean	Haeuslerella Biofacies (Shallow)	c400
Callaghans Greensand and Conglomerate	Up. — Tongaporutuan —	Elphidium Biofacies	c200
Kawhaka Siltstone	Low.	Haeuslerella Biofacies (Deep)	c800
Blue Bottom Formation	Waiauau	Karre riella Biofacies	c1000

Table 4 -

Biofacies and inferred depths of deposition of north Westland formations.

Blue Bottom Mudstone.

Foraminifera are abundant; Mollusca are scattered and rare, and Ostracoda infrequent. Lagenidae and planktonic Foraminifera constitute a large proportion of the fauna. The occurrence together of Karreriella cylindrica Finlay and shallower-water species in abundance such as Robulus calcar (Linnaeus) and Anomalinoides spherica (Finlay) indicates the Karreriella Biofacies which has an inferred depth range close to 1000 ft.

Kawhaka Siltstone

Macrofossils are larger and less rare than in the Waiau; Foraminifera are abundant and Ostracoda and echinoid spines rare. The biofacies is similar to that of the Waiau, but significant differences in the fauna together with evidence from the larger grain size of the sediments indicates shallower conditions during deposition. Miliolidae are more common, Karreriella cylindrica is rare and Notorotalia hurupiensis Vella abundant. From the writer's experience, Bolivina affiliata Finlay, Bolivina watti Gibson, and Gyroidinoides zelandica (Finlay), which occur commonly in the Lower Tongaporutuan, are restricted to the Haeuslerella and deeper biofacies. The assemblage of Foraminifera indicates fairly deep Haeuslerella Biofacies which has an inferred depth range centred on 600 ft.

Callaghans Conglomerate and Callaghans Greensand

The greensand contains abundant Mollusca at some levels, with numerous species at Eight Mile Creek, but relatively few species at Callaghans Creek. Thick-shelled Ostracoda and fish teeth are common. Foraminifera are abundant, the fauna consisting of relatively few, generally fairly robust benthonic species, and very rare planktonic species. Many specimens are broken and worn. Elphidiidae constitute a large proportion of the fauna, especially Notorotalia macinnesi Kennett, n.sp. and Elphidium charlottensis (Vella). Other characteristic shallow-water species such as Bulimina

aculeata d'Orbigny, Textularia kapitea Finlay and Zeaflorilus parri (Cushman) occur in variable abundance. The coarseness of the deposit, the conditions of the shells, and the biofacies indicate the Elphidium Biofacies which has an inferred depth range of 10 - 200 ft.

Eight Mile Formation

At Kapitea Creek, the lower part of the Eight Mile Formation (Kapitean to Opoitian) for the most part contains infrequent and scattered Mollusca, more common than in Lower Tongaporutuan, and rare but persistent thin shelled Ostracoda and fish teeth and bones. Spatangid echinoid spines are generally common and indicate soft-bottom conditions.

The common occurrence of shallow-water species such as Robulus calcar, Anomalinoides spherica and Notorotalia hurupiensis, and the general lack of any deeper-water species indicates the Haeuslerella Biofacies.

Although still within the range of the Haeuslerella Biofacies the following criteria indicate a shallower depth of deposition than that of the Kawhaka Siltstone: the Mollusca though infrequent are more common and thicker-shelled than in the Kawhaka Siltstone; the sediment is coarser; Foraminifera are represented by fewer specimens; Lagenidae are especially less common; Karrerella cylindrica is absent; Bolivina affiliata is rare and common shallow-water species such as Bulimina aculeata and Textularia barnwelli Kennett, n.sp. are persistent.

A still shallower depth of deposition for the Base of the Eight Mile Formation is indicated by common Sectipecten wollastoni (Finlay) and Textularia kapitea. Upper Kapitean faunas indicate deeper-water conditions than middle and lower Kapitean; faunas are generally richer, pelagic Foraminifera more abundant, and Notorotalia taranakia Vella and Bolivina watti are common.

The Kapitean at Callaghans Creek and Coreholes D and F are somewhat shallower facies than the type Kapitean at Kapitea Creek. This is shown by the almost complete absence of Bolivina watti and Bolivina affiliata, the abundant, varied, and well preserved molluscan fauna at some horizons at Callaghans Creek, more common and persistent and thicker shelled Ostracoda and more common fish teeth and bones, and more persistent shallower-water species such as Anomalinoides spherica, Notorotalia hurupiensis and Elphidium charlottensis.

Martinottiella clarae Gibson is fairly persistent and common in the Kapitean and Opoitian of Kapitea Creek, but is entirely absent in the shallower-water Kapitean sections, and probably ranges from the deeper part of the Haeuslerella Biofacies into deeper biofacies. Conversely Gavelinopsis lobatulus (Parr) is absent in the Kapitean Creek section, uncommon in the Callaghans Creek section, but is especially common and persistent throughout Corehole F, and probably ranges from the shallower part of the Haeuslerella Biofacies to shallower biofacies.

Biofacies changes indicate an increase in depth at the beginning of Opoitian times in the Kapitea Creek area, but a decrease in depth at the same time in the Eight Mile Creek area, ten miles to the north-east.

In the Kapitea Creek section, Opoitian faunas are generally richer in species of Foraminifera than the Kapitean, with Lagenidae especially more varied and abundant. The association of the two species Karreriella cushmani Finlay and Haeuslerella pliocenica (Finlay), along with shallow-water species such as Robulus calcar, and Bulimina aculeata indicates the Karreriella Biofacies. Supporting evidence for deeper conditions during Opoitian is the occurrence of common Bolivina watti, Sigmoilopsis zeaserus Vella, Pacinoion neefi Vella and more abundant Pullenia bulloides (d'Orbigny).

According to Vella (1963) the last three species range from the Robulus to Semipelagic Biofacies but they are here considered to range into the slightly shallower Karreriella Biofacies.

At Eight Mile Creek the Opoitian fauna, like that of the Kapitean is a Haeuslerella Biofacies. In the Waitotaran, the biofacies indicates rapid shallowing with corresponding increase in coarseness of sediments. Mollusca and Foraminifera are fairly abundant but limited to a small number of species. Thick shelled Ostracoda are abundant and pelagic Foraminifera rare. The foraminiferal association of Zeaflorilus parri (Cushman) and Pacinonion novozealandicum (Cushman & Edwards) indicates the Zeaflorilus Biofacies which has an inferred depth range of 0-20 ft.

Summary of Geological History

Mudstones were deposited in moderately deep-water until about Middle Tongaporutuan times, after which shallower conditions prevailed. Sediments were probably burrowed by mud-ingesting organisms that destroyed any sedimentary structures that might have existed. Disconformity indicates a break in sedimentation and erosion of the sea bottom in about Middle Tongaporutuan times. Varying amounts of Southland and Taranakian sediments were removed at different places. Deposition recommenced in late Tongaporutuan times with a thin glauconitic band with basal conglomerate. This was followed by rapid deposition of siltstone and fine sandstone in a subsiding basin. Moderately shallow conditions continued throughout the Kapitean and into the Opoitian, the water becoming slightly deeper in the Kapitea Creek area but shallower in the Eight Mile Creek area. Towards the end of the Pliocene, in Waitotaran times, shallowing became marked, and coarse sediments with commoner but less diverse Mollusca were deposited.

CONCLUSIONS

The Kapitean Stage is well defined at the type locality by vertical biofacies changes. Permanent faunal changes that might serve to correlate the Kapitean elsewhere in New Zealand are difficult to distinguish from the temporary faunal changes that resulted from local environmental changes. The type Kapitean is a fairly shallow-water facies that can be correlated with shallow-water facies containing the key molluscan fossils elsewhere in New Zealand. However even after the complete survey of the faunal succession in Westland, the Kapitean still can not be recognised definitely in deep-water facies.

The upper boundary of the Kapitean Stage can be correlated readily because the major faunal change in the planktonic fauna that marks the base of the Opoitian can be detected in most marine facies. The problem is to recognise the base of the Kapitean Stage. As yet this can be accomplished only at the two places where the key molluscs Sectipecten wollastoni and Sectipecten grangei are found in sequence. Foraminifera previously used to identify the Kapitean have now been found to be unreliable. A few benthonic species newly found in the type Kapitean have yet to be checked for usefulness. Changes in the planktonic fauna during Kapitean time, especially the bioserial change from Globorotalia conomiozea to G. crassaformis, may be extremely useful, but also still have to be checked in sections away from north Westland.

The state of correlations in the Middle and Upper Miocene of New Zealand is summarised in Table 5. The zones in relatively shallow-water facies in North Westland are shown against zones in deep-water facies in Wairarapa and against stages. The zones for deep-water facies

may be correlated in two ways, shown in the columns headed I and II, and the earlier stage correlations are uncertain.

North Westland Zones	Deep-water Zones		Age
	I	II	
Finlayi-Chrydaea	Kingmai	Kingmai	Waitotaran
	Molestus	Molestus	Waipipian
Crassaformis	Inflata	Inflata	Opoitian
Conomiozea Coerulescens Wollastoni	Zeaserus	Zeaserus Compressa	Kapitean (and Up. Tongaporutuan?)
Macinnesi Grangei	Compressa	Pohana	Up. Tongaporutuan?
Unconformity	Pohana		Mid. Tongaporutuan
Quadrilatera	Quadrilatera	Quadrilatera	Low. Tongaporutuan or Waiauan
Truncatum	Truncatum	Truncatum	Waiauan or Up. Lillburnian

Table 5 - Possible correlations of some New Zealand Middle and Upper Miocene biostratigraphic units.

SYSTEMATICS.

TYPES

The types of Quinqueloculina waimea n.sp. and Virgulina vellai n.sp. will be registered in the New Zealand Geological Survey catalogue of primary foraminiferal types and have been allotted serial numbers prefixed by TF. Figured specimens of borrowed N.Z.G.S. material, without status of primary types are registered in the appropriate N.Z.G.S. catalogue of foraminiferal types prefixed by FP. Paratypes of the other new species will be given to the New Zealand Geological Survey.

All other types will be lodged in the Geology Department, Victoria University of Wellington. Catalogue numbers of the foraminiferal holotypes have the prefix F; paratypes Fp, and figures specimens without status of primary types Ff.

SAMPLE NUMBERS AND LOCATIONS

Sample numbers are the Sheet Fossil Numbers of the N.Z. Fossil Record system based on Sheet districts of the N.Z. map series. All microfossil and macrofossil samples came from Sheet District S51. Samples from the N.Z. Oil Exploration Companies' Corehole D and F, and some from the Eight Mile Creek section were borrowed from the N.Z. Geological Survey.

Grid references are the coordinates based on the national thousand-yard grid. An index of fossil localities, with lithologies and age determinations is given in Table 11. Standard symbols are used for New Zealand stages. Lithologies are given in the code of the N.Z. Fossil Record Form (Wellman, 1953,55).

CLASSIFICATION

The systematic order closely follows that used by Hornibrook (1961)

and is based mainly on the classification of Sigal (1952). The families Globorotaliidae and Orbulinidae, used by Hornibrook are here referred to the family Globigerinidae, following Banner and Blow (1959).

All foraminiferal species in the Kapitean and Upper Tongaporutuan part of the five sections examined are dealt with except those belonging to the Family Lagenidae. Lagenid species are shown on the range charts but are of little stratigraphic value.

SYNONYMY

For each species the type reference and a selected synonymy is given. Hornibrook (1961) gives complete or almost complete synonymies for many species described from New Zealand.

The RECORDED ECOLOGIC RANGE is the published limits for the species in New Zealand, given by Vella (1957, 1962, 1962, and 1963). An OBSERVED ECOLOGIC RANGE is given for benthonic species where no published range exists or where the observed range extends the published range.

Stratigraphic range charts list microfaunas and macrofaunas from the five sections. Abundance of each species in each sample is shown by symbols explained in a key at the bottom of the range charts.

In mentioning the distribution of individual species, the Waiauan fauna of the Kapitea Creek section is neglected, except where indicated.

The figures on Plates 1-12 were drawn by the author with the aid of a camera lucida. The original pencil drawings have been reduced to half by photography. All species from the Kapitean and Upper Tongaporutuan have been illustrated except those belonging to the Family Lagenidae and a few other rare or badly preserved species.

SYSTEMATICS

Order	FORAMINIFERA
Superfamily	LITUOLIDEA
Family	TEXTULARIIDAE
Genus	TEXTULARIA Defrance, 1824.

TYPE SPECIES: Textularia sagittula Defrance

Textularia barnwelli Kennett, n.sp., Pl.I, figs. 1-5

1947. Textularia sp; Finlay, N.Z.J. Sci. Tech. B. 28(5): 280.

1962. Textularia n.sp.; Kennett, N.Z.J. Geol. Geophys.5(4); 623 list.

DESCRIPTION: Test small, slightly longer than wide. At first rapidly increasing in width so that juveniles are wider than long. Bluntly rounded to sharp edges. Broad terminal face curving down on either side, lens-shaped in end view with conspicuous nick at the junction of the final and penultimate chambers. Margins of the terminal face fairly rounded. Chambers gently sloping 5-8 on either side, often becoming less inflated towards the middle to form a medial groove. Last few chambers often more inflated. Sutures gently curved, moderately incised especially on adult part of shell.

Moderate to coarse sand grains give the test a fairly rough surface. Aperture a narrow slit at a re-entrant of the inner margin of the last chamber.

Dimensions of holotype; length 0.31mm., breadth 0.35mm.

Dimensions of figured paratype: length 0.48mm., breadth 0.42mm.

Variability: Most specimens of T. barnwelli have bluntly rounded edges but a few sharper edged specimens occur.

TYPES: Holotype (F378) and 2 paratypes (Fp378). Three additional paratypes (Fp379) from S51f666 and II paratypes (N.Z.G.S. Cat.No. TF1484) from S51f687.

TYPE LOCALITIES: Holotype and 2 paratypes S51f646, Kapitea Creek section, grid ref. 670665; 3 paratypes S51f666, Callaghans Creek section, grid ref. 692621; II paratypes S51f687, N.Z. Oil Exploration Company Corehole D, depth 35 ft., grid ref. 664575; Westland, N.Z.

TYPE LEVELS; Kapitean Stage, Upper Miocene.

REMARKS: Finlay referred to this species as a Textularia "common in the Kapitean of Westland and not seen above it".

Gibson (in press) considered T. barnwelli a coarser variant of T. subrhombica (Stache), but the differences are consistent and the two forms have different stratigraphic ranges at the West Coast. T. subrhombica was found only in the lower Tongaporutuan whereas T. barnwelli is restricted to the Kapitean and Opoitian. There is no gradation between the two forms, T. subrhombica being consistently small, sharply angled, fine grained and smooth walled, with weaker sutures and lacking the median groove of T. barnwelli. T. subrhombica is probably ancestral to T. barnwelli.

The recent species T. subantarctica Vella is similar to T. barnwelli but is much larger, smoother walled, sharp angled and more conical.

DISTRIBUTION: At Kapitea Creek T. barnwelli is rare in the Kapitean and a single specimen was found in the Opoitian.

In the Callaghans Creek and Corehole D sections it occurs in varying abundance in most Kapitean samples. In Corehole F it is ubiquitous and often common throughout the Kapitean but less persistent and rare in the Opoitian.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (common) to Opoitian (rare), (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to (rare) Karreriella Biofacies.

Textularia kapitea Finlay, Pl. I, figs. 6-11.

1947. Textularia kapitea Finlay & Marwick; N.Z. J.Sci. Tech. B.28(4): 235 (nomen nudem).
1947. Textularia kapitea Finlay; N.Z. J. Sci. Tech.B. 28(5): 266-67, Pl. 2, figs. 21, 22.
1959. Textularia kapitea; Fleming, in Fleming ed., Lex. Strat. int. 6 Oceanie (4): 166.
1961. Textularia kapitea; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I):17
1962. Textularia kapitea; Kennett, N.Z. J. Geol. Geophys. 5(4): 622, 623 table, 625.
1963. Textularia kapitea; Kennett, N.Z. J. Geol. Geophys. 6(2): 257-60 Fig. I, Nos. 2-4.
1965. Textularia kapitea; Gibson, (in press).

REMARKS: Specimens are typically coarse grained, non-spinose with a rounded to subrounded rapidly thickening test. They differ from the types (Hicks Bay, East Cape, N.I.) in being coarse grained, in having relatively indistinct sutures and more rapidly thickening test. A single specimen from Corehole F (f676) is closer to the types in having more distinct sutures and in being less swollen.

T. kapitea was formerly regarded as being restricted to the Kapitean Stage, but Kennett (1962) found it in the basal Opoitian at Cape Foulwind (W.Nelson) and Eketahuna (N. Wairarapa) and more recently Gibson (in press) found it in the Lower Tongaporutuan at Cape Foulwind and the Waiauan at Tamumu (S. Hawkes Bay). A possible explanation of the gradational change from T. miozea to T. kapitea at Cape Foulwind (Kennett, 1963) is suggested below (p. 64).

Dimensions: Two Hypotypes, (Ff380), length 0.66 mm., breadth 0.50 mm., (N.Z.G.S. Cat. No. Ff1373), length 0.77 mm., breadth 0.58 mm.

DISTRIBUTION: In the type Kapitean section T. kapitea is common in the lowest sample and rare in two higher samples. It occurs rarely in single samples from the Upper Tongaporutuan greensand and the Kapitean of Corehole D and high in the Kapitean of Corehole F.

The closely related species T. miozea Finlay occurs in variable abundance in the Lower Tongaporutuan and Waiauan, but was not observed above the intra-Tongaporutuan unconformity in north Westland.

RECORDED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene) to Opoitian (Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Genus HAEUSLERELLA Parr, 1935.

TYPE SPECIES: Haeuslerella pukeuriensis Parr, 1935.

Haeuslerella finlayi Vella, Pl. 2, fig. 17.

1963. Haeuslerella finlayi Vella, Trans. roy. Soc. N.Z., Geol. 2(I):

3, Pl. I, fig.II.

REMARKS: The surface of the final adult chamber is less smoothed off with cement than the rest. The tests differ from the types only in having the uniserial chambers increasing relatively rapidly in size and in having the final 2 or 3 chambers of the adult part broader than the juvenile part.

Dimensions: Hypotype (Ff305); length 1.81 mm., breadth 0.46 mm.

DISTRIBUTION: In the Kapitea Creek section H. finlayi occurs only rarely in the highest two Kapitean samples and the lowest Opoitian samples. It is not present in the other sections where the facies is too shallow.

RECORDED STRATIGRAPHIC RANGE: Upper Tongaporutuan? to Opoitian (Upper Miocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Semipelagic Biofacies and probably Eupelagic Biofacies (c.4000 ft. to greater depth).

OBSERVED ECOLOGIC RANGE: Karreriella Biofacies.

Haeuslerella morgani (Chapman), Pl. I, fig. 12.

1926. Spiroplecta morgani Chapman; N.Z. geol. Surv. paleont. Bull. II: 32, Pl. 8, fig. 2.

1959. Haeuslerella morgani; in Fleming ed., Lex. Strat. int. 6 Oceanie (4) 125, 461, Fleming; 404, Hornibrook.

1961. Haeuslerella morgani; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I) 20, 21.

1965. Haeuslerella morgani; Gibson, (in press).

REMARKS: Shells referred to this species have a relatively cylindrical test, many specimens with two, three, or rarely four, staggered uniserial chambers. Samples from the type Kapitean are dominated by relatively cylindrical forms. Opoitian samples show a slight dominance of compressed forms with strongly angled sides, referable to H. parri Finlay. Coarseness of the test varies considerably within some populations.

Dimensions: Hypotype (Ff306); length 1.29 mm., breadth 0.39 mm.

DISTRIBUTION: H. morgani is ubiquitous and abundant in the type Kapitean. It is generally abundant throughout the other sections but is absent from the Callaghans Greensand.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Lower Wanganui Series (Middle Miocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies.

Genus SIPHOTEXTULARIA Finlay, 1939

TYPE SPECIES: Siphotextularia wairoana Finlay

Siphotextularia awamoana Finlay, Pl.I, figs. 15, 16.

1939. Siphotextularia awamoana Finlay, Trans. roy. Soc. N.Z. 69(I): 91, Pl.14, figs. 89, 90.

1961. Siphotextularia awamoana; Hornibrook, N.Z. geol. Surv. Paleont. Bull. 34 (I), 22, Pl.I, figs. II, 12.

1965. Siphotextularia awamoana; Gibson, (in press).

Dimensions: Hypotype (Ff307); length 0.43 mm., breadth 0.36 mm.

DISTRIBUTION: Rare in two isolated Kapitean samples in the Callaghans Creek section and in the Lower Tongaporutuan of Corehole D. In the Lower Tongaporutuan of the Callaghans Creek section, abundant specimens show a gradation between typically strongly tapering S. awamoana and typically subparallel sided S. subcylindrica Finlay.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Kapitean.

RECORDED STRATIGRAPHIC RANGE: Upper Waitakian to Tongaporutuan (Upper Oligocene to Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough.)

Siphotextularia cf. wairoana Finlay, Pl. I, fig. 13.

1939. Siphotextularia wairoana Finlay; Trans. roy. Soc. N.Z. 68: 511, Pl.68, fig.2.

1940. Siphotextularia wairoana; Finlay & Marwick, Trans. roy. Soc. N.Z. 70(I), 125.

1959. Siphotextularia wairoana; Fleming, in Fleming ed., Lex. Strat. int.6 Oceanie (4): 65, 280, 281.

1962. Siphotextularia wairoana; Vella, Trans. roy. Soc. N.Z. Geol. I(12): 193.

REMARKS: Differs from typical S. wairoana in having the test less quadrate in section, more gradually tapering with a deeper medial groove and slightly more convex sides. Typical S. wairoana was found only above the Kapitean in the Opoitian of Corehole F and Eight Mile Creek sections.

In the Lower Tongaporutuan mudstone of Corehole D and Callaghans Creek and the Waiauian Mudstone of Eight Mile Creek, rare specimens given on the range charts as Siphotextularia n. sp. cf. wairoana differ even more markedly from S. wairoana in having a longer, narrower and more gradually tapering test with eight chambers instead of six on each side.

Dimensions: Figured specimen (Ff308); length 0.48 mm. breadth 0.30 mm.

DISTRIBUTION: In the type Kapitean S. cf. wairoana was observed as a single specimen from near the middle of the section and in abundance in the top sample. S. wairoana occurs in abundance in single samples from the Opoitian of Corehole F and Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE:

Siphotextularia

1. n.sp. cf. wairoana. Lower Tongaporutuan.
2. cf. wairoana. Kapitean.
3. wairoana (s.s.) Opoitian to Castlecliffian.

RECORDED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene) to Castlecliffian (Upper Pleistocene).

RECORDED ECOLOGIC RANGE: (all forms?) Elphidium Biofacies to Haeuslerella Biofacies (c.200 to c.600 ft.).

Family VERNEULINIDAE

Genus GAUDRYINA d'Orbigny, 1839.

TYPE SPECIES: Gaudryina rugosa d'Orbigny

Subgenus PSEUDOGAUDRYINA Cushman, 1936.

TYPE SPECIES: Gaudryina (Pseudogaudryina) atlantica (Bailey)Gaudryina (Pseudogaudryina) kingi Parr.1936. Gaudryina kingi Parr; Trans. roy. Soc. N.Z. 65(2): 83, Pl.20, figs.1a-c1959. Gaudryina kingi; Hornibrook, in Fleming ed., Lex. Strat. int. 6

Oceania (4): 404.

1965. Gaudryina (Pseudogaudryina) kingi; Gibson, (in press).

DISTRIBUTION: A single juvenile specimen in the Kapitean of Corehole D (f688).

OBSERVED STRATIGRAPHIC RANGE: Kapitean.

RECORDED STRATIGRAPHIC RANGE: Lower to Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Family VALVULINIDAE

Genus KARRERIELLA Cushman, 1933.

TYPE SPECIES: Gaudryina siphonella Reuss.Karrerrella cylindrica Finlay, Pl. 2, fig. 18.1935. Karrerrella siphonella (Reuss); Parr, Trans. roy. Soc. N.Z.65(2):84,
Pl.20, fig.3.1940. Karrerrella cylindrica Finlay; Trans. roy. Soc. N.Z. 69(4): 452,
pl. 63, figs. 43-46.1959. Karrerrella cylindrica; in Fleming ed., Lex. Strat. int. 6 Oceania(4):
404, Hornibrook; 461, Fleming.

1961. Karreriella cylindrica; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 28.
1962. Karreriella cylindrica; Vella, Trans. roy. Soc. N.Z. Geol. I (12): 188, 193.
1965. Karreriella cylindrica; Gibson, (in press).

Dimensions: Hypotype (Ff309); length 0.60 mm., breadth 0.30 mm.

DISTRIBUTION: In the Kapitean Creek section K. cylindrica was not found above the Waiauan, while the more lobulate species K. cushmani Finlay was found only in the Opoitian.

Rare specimens with little inflated chambers, shallow sutures and cylindrical shape referable to K. cylindrica were found in the lower Tongaporutuan of Callaghans Creek and a single specimen was found in the Kapitean of Callaghans Creek.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Waitotaran (Middle Miocene to Upper Pliocene).

RECORDED ECOLOGIC RANGE: Karreriella Biofacies to Eupelagic Biofacies (1000 ft. and deeper),

Genus MARTINOTTIELLA Cushman, 1933.

TYPE SPECIES: Clavulina communis d'Orbigny.

Martinottiella clarae Gibson, Pl. I, fig. 14.

1965. Martinottiella clarae Gibson; (in press).

REMARKS: This relatively short, robust species with fairly rough surface, shows much variation in the relationship of the multiserial to the uniserial part and in the rapidity of increase of the uniserial chambers. Specimens

vary from having a marked constriction between multiserial and uniserial parts to having no constriction. In most specimens the uniserial chambers decrease steadily in size towards the adult end, in some the uniserial chambers are uniform in size forming a cylindrical test, and in a few the uniserial chambers increase in size.

Dimensions: Hypotype (Ff309); length 1.27 mm., breadth 0.30 mm.

DISTRIBUTION: Generally abundant in samples from the Kapitea Creek section, but almost absent from the other sections. Rare specimens occur in the Waiauan sample from Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Waiauan to Kapitean (Middle Miocene to Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

Superfamily MILIOLIDEA

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826.

TYPE SPECIES: Serpula seminulum Linne

Quinqueloculina contorta d'Orbigny

1846. Quinqueloculina contorta d'Orbigny; Foraminifères fossiles du bassin Tertiaire de Vienne (Autriche) Gide et comp: 298.

REMARKS: From the type figure this species is distinguished by subquadrate chambers with concave sides and acute angles, distinct slightly depressed sutures, and a small circular aperture with simple tooth. A single Kapitean

specimen differs only in being slightly broader and thicker.

DISTRIBUTION: Kapitean of Corehole D (f687).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Quinqueloculina incisa Vella, Pl. 2, figs. 26-28.

1957. Quinqueloculina incisa Vella; N.Z. geol. Surv. paleont. Bull. 28:

24, Pl. 6, figs. 118-121.

REMARKS: A single specimen with the typical rounded chambers, narrower at the apertural end, aperture not produced and tooth with a short septum and broad platform; differs from the types only in having the aperture surrounded by a thin lip.

Dimensions: Hypotype (Ff310); length 0.55 mm., breadth 0.31 mm., thickness 0.22mm

DISTRIBUTION: Kapitean of Callaghans Creek (f661).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Depth range in Cook Strait: 0-1320 ft.

(probably washed down from shallow to deep-water).

Quinqueloculina kapitensis Vella.

1957. Quinqueloculina kapitensis; N.Z. geol. Surv. paleont. Bull. 28:

26, 27, Pl. 4, figs. 74, 80, 81.

REMARKS: Specimens are typical in being moderately small, with chambers narrower at the aperture end, and having concave sides and weak striations.

DISTRIBUTION: Rare in one sample from the Kapitean of Corehole D (f688), rare in several samples from the Tongaporutuan of Callaghans Creek and Corehole D, and in the Waiauan of Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Depth in Cook Strait: 60-1320 ft.

Quinqueloculina pygmaea Reuss, Pl. 2, figs. 29-31.

1850. Quinqueloculina pygmaea Reuss; K. Akad. Wiss. Wien, Math.-Nat. Cl.,
Denkschr., Wien, Osterreich, 1850, Bd.I, p.384.

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1375), length 0.40 mm., breadth 0.17 mm
thickness 0.10 mm.

DISTRIBUTION: A single specimen from the highest Kapitean sample of Corehole
F(f667), although more elongate, seems to be closest to Q. pygmaea.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Quinqueloculina triangularis d'Orbigny.

1846. Quinqueloculina triangularis d'Orbigny; Foraminiferes Fossils due
Bassin Tertiaire de Vienne. Gide, Paris: 288, Pl. 18, figs. 7-9.

1957. Quinqueloculina (Quinqueloculina) triangularis; Vella, N.Z. geol. Surv.
paleont. Bull. 28: 23, Pl. 6, figs. 100, 101, 108.

1965. Quinqueloculina triangularis; Gibson (in press).

REMARKS: Vella (1957) revived the species for large specimens with
subrounded peripheral angles and a large tooth. Specimens differ from the
Cook Strait form in having slightly more narrowly rounded angles.

DISTRIBUTION: Rare in two Kapitean samples of Corehole F, and in the top
Opoitian sample of the Kapitea Creek section.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Depth range in Cook Strait: 60-630 ft.

Quinqueloculina waimea Kennett, n.sp., Pl. 2, figs. 19-21.

DESCRIPTION: Test small, broadly ovate, one and a quarter times as long as wide, porcellanous, white, smooth and glossy. Test in end view roughly triangular in shape, angles bluntly rounded. Strongly concave on the front side with a strong low keel; opposite side slightly convex in the middle and concave near the edges. Sutures flush. Aperture circular, not produced with tooth broken but probably short and simple.

Dimensions of holotype: length 0.35 mm., width 0.30 mm., thickness 0.20 mm.

TYPES: N.Z. Geological Survey Cat. No. TF1486. Holotype and one paratype.

TYPE LOCALITY: S51f672, N.Z. Oil Exploration Company Corehole F, depth 130 - 140 ft., grid ref. 672582, Westland, N.Z.

TYPE LEVEL: Kapitean Stage, Upper Miocene; 5 ft. below base of Opoitian Stage (Lower Pliocene).

REMARKS: Distinguished by the deep concavity on the front side, the low strong keel, and the triangular outline in end view. The nearest described species is Q. inaequalis d'Orbigny which is more rounded ventrally and more acutely angled.

DISTRIBUTION: Found only in the top Kapitean sample of Corehole F.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Quinqueloculina sp., (low bifid tooth), Pl. 2, figs. 22-25.

DESCRIPTION: Shell moderately small, subovate, porcellanous, white and glossy, chambers moderately rounded, large at the distal end, narrowing towards the apertural end, with deeply incised sutures. Aperture ovate, slightly produced, with a fairly broad slightly reflexed lip; furnished with

a bifid tooth consisting of a low broad arcuate platform but no septum.
 Dimensions: Figured specimen (Ff311); length 0.68 mm., breadth 0.37 mm.,
 thickness 0.26 mm.

REMARKS: This is certainly an undescribed species but is not named because
 it is represented by only one specimen and the distinctive apertural tooth
 was inadvertently destroyed after the specimen was illustrated. It is
 similar to Q. incisa Vella, but distinguished by the broad and unusual tooth.
Q. stalkeri Loeblich & Tappan, has a similar tooth but has a fine-grained
 agglutinated surface.

DISTRIBUTION: One specimen from the Callaghans Greensand at Callaghans
 Creek (f658).

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Genus SCUTULORIS Loeblich & Tappan, 1953

TYPE SPECIES: Scutuloris tegminis Loeblich & Tappan.

(= Quinquinella Vella, 1957)

Scutuloris is distinguished by having quinqueloculine test and a semi-
 circular plate over the aperture. The distinguishing characters of
Quinquinella are identical, and Quinquinella is therefore regarded as a
 junior synonym of Scutuloris.

Scutuloris hornibrooki (Vella)

1957. Quinquinella hornibrooki Vella; N.Z. geol. surv. paleont. Bull. 28:
 21, Pl. 7, fig. 127-9.

1961. Quinquinella hornibrooki; Hornibrook, N.Z. geol. Surv. paleont.
 Bull. 34(1):34.

1965. Scutuloris hornibrooki; Gibson, (in press).

DISTRIBUTION: A single specimen only in the lowest Kapitean sample of Callaghans Creek section (f659).

RECORDED STRATIGRAPHIC RANGE: Tongaporutuan (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Depth in Cook Strait: 253 to 630 ft.

Genus PYRGO Defrance, 1824.

TYPE SPECIES: Pyrgo laevis Defrance.

Pyrgo elongata (d'Orbigny).

1826. Biloculina elongata d'Orbigny, Ann. Sci. I. Nat., 7(4): 298.

1929. Pyrgo elongata: Cushman, U.S.N.M., Bull. 104, (6), p.70, Pl.19, figs.2,3.

1935. Pyrgo elongata; Parr, Trans. Proc. Roy. Soc. N.Z. 65 (2): 86.

DISTRIBUTION: One specimen from near the middle of Corehole F (f678).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Superfamily LAGENIDEA

Family POLYMORPHINIDAE

Genus GUTTULINA d'Orbigny, 1839.

TYPE SPECIES: Polymorphina (Guttulina) communis d'Orbigny

Guttulina bartschi Cushman & Ozawa, Pl.2, fig. 32.

1930. Guttulina bartschi Cushman & Ozawa; Proc. U.S. nat. Mus. 77 (2829); 23, 24, Pl. I, fig. 10.

Dimensions: Hypotype (Ff312); length 0.62 mm., breadth 0.45 mm.

DISTRIBUTION: Fairly common in two samples from Callaghans Creek, one from the Upper Tongaporutuan greensand, and the other from the Kapitean siltstone. The species has previously been reported by Cushman & Ozawa living off the Poor Knights Island in the north of New Zealand.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Depth off Poor Knights Island; 360 ft.

Genus SIGMOMORPHINA Cushman & Ozawa, 1928.

TYPE SPECIES: Sigmomorphina yokoamai Cushman & Ozawa

Sigmomorphina cf. rhomboidalis Vella; Pl.2, fig. 33

1957. Sigmomorphina rhomboidalis Vella; N.Z. geol. Surv. paleont. Bull.

28: 31, Pl.8, fig. 154.

REMARKS: Differs from typical S. rhomboidalis in being less compressed and in having a more rounded outline and fewer less curved chambers.

Dimensions: Figured specimen (Ff313); length 0.70 mm., breadth 0.37 mm.

DISTRIBUTION: Rare in the two samples from the Callaghans Greensand at Callaghans Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Genus GLANDULINA d'Orbigny, 1826.

TYPE SPECIES: Nodosaria (Glandulina) laevigata d'Orbigny.

Glandulina symmetrica Stache, Pl. 2, fig. 34.

1865. Glandulina symmetrica Stache; Novara-Exped., Geol.Theil, 1(2): 187,

Pl. 22, fig. 9.

1961. Glandulina symmetrica; Hornibrook, N.Z.geol.Surv.paleont.Bull. 34(1):

Pl. 8, fig. 132.

Dimensions: Hypotype (Ff314); length 0.53 mm., breadth 0.38 mm.

DISTRIBUTION: Rare in a few samples from the type Kapitean, two samples from Callaghans Creek and one sample from Corehole F.

RECORDED STRATIGRAPHIC RANGE: Lower Tertiary to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Superfamily BULIMINIDEA

Family BULIMINIDAE

Genus BULIMINA d'Orbigny, 1826.

TYPE SPECIES: Bulimina marginata d'Orbigny

Bulimina aculeata d'Orbigny, Pl.3, figs. 35, 36.

1826. Bulimina aculeata d'Orbigny; Ann.Sci. nat., Ser.7(7): 269.

1947. Bulimina aculeata; Finlay, Trans. roy. Soc. N.Z. 76(3): 347, 348.

1947. Bulimina aculeata; Cushman & Parker, U.S. geol. Surv.prof. pa.210-D:120-21,
pl. 28, figs. 8-11.

1958. Bulimina aculeata; Hornibrook, Micropaleontology 4(1): 29 table, 31. 32.

1959. Bulimina aculeata; in Fleming ed., Lex.Strat.int. 6 Oceanie (4): 167,
Fleming; 404, Hornibrook.

1961. Bulimina aculeata; Boreham, Trans. roy. Soc. N.Z. 88(4): 656, 657 table.

1962. Bulimina aculeata; Vella, Trans. roy.Soc.N.Z. Geol. I. (12): 192.

1962. Bulimina aculeata; Kennett, N.Z.J. Geol. Geophs. 5(4):622, 624 table.

1965. Bulimina aculeata; Gibson, (in press).

REMARKS: Most specimens have a long, delicate apical spine surrounded by a tuft of short fine spines; some have an apical spine with no tuft, while

others have no apical spine, but evenly spaced moderate sized spines half way up the test.

Hornibrook (1958) considered that B. aculeata makes its first appearance in the Kapitean but Boreham (1961, 656-7) found it preceding the incoming of Sectipecten wollastoni (Finlay) in Taranaki, and Gibson (in press) reported it from the Lower Tongaporutuan of the Taranaki and Palliser Bay coastal sections. Dimensions: Two Hypotypes, (Ff315; S51f648), length 0.45 mm., breadth 0.25 mm.; (Ff316; S51f643), length 0.39 mm., breadth 0.26 mm.

DISTRIBUTION: Occurs in variable abundance in most Kapitean samples from all sections and also occurs very commonly in the Callaghans Greensand of the Callaghans Creek section and the Waitotaran of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Lower Tongaporutuan (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies (200 to 2000 ft.)

Bulimina inflata Sequenza, Pl. 3, fig. 37.

1862. Bulimina inflata Sequenza; Accad. gioenia sci. nat. Att., 2 (18): 25, Pl. I, fig. 10.

1947. Bulimina inflata; Cushman & Parker, U.S. Geol. Surv. Prof. Paper 210-D: 118, Pl. 27, figs. 16, 17.

REMARKS: A single specimen is provisionally referred to B. inflata but lacks the basal spine and has much less marked break in costae at the sutures.

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1376), length 0.40 mm., breadth 0.25 mm.

DISTRIBUTION: From the lower Kapitean of Corehole F (f685).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Bulimina cf. striata d'Orbigny, Pl. 3, fig. 38.

1826. Bulimina striata d'Orbigny; Ann. Sci, nat., Serv. 7(2): 269.

1947. Bulimina striata; Cushman & Parker, U.S. geol.Surv.prof. Pap. 210-D: 119,
Pl. 28, figs. 1-3.

1962. Bulimina cf. striata; Vella, Trans. roy. Soc. N.Z. Geol. 1(12): 192.

1962. Bulimina n.sp. cf. striata; Kennett, N.Z.J. Geol. Geophys. 5(4): 624
table.

1965. Bulimina cf. striata; Gibson, (in press).

REMARKS: Similar to B. striata in having an apical spine and discontinuous costae produced to form spines overhanging the sutures but differs in having costae more widely spaced and extending a shorter distance up the chambers of the final whorl.

Two distinct varieties are distinguished and are referred to on the range charts as B. cf. striata, (small var.) and B. cf. striata, (large var.)

The small variety is consistently tiny and thin walled and has the last whorl making up over half the test. The sculpture varies; in some specimens costae extend a short distance up the final whorl; in others the costae are obsolete, and the only sculpture may be short spines at the base of entirely smooth chambers.

The large variety is more robust, and has a stronger apical spine and stronger costae that extend slightly further up onto the final whorl, the chambers increase in size more rapidly, and the final whorl generally makes up a smaller part of the test.

Dimensions: Figured specimen; small var.(Ff318), length 0.22 mm.

DISTRIBUTION: The small variety is common in the upper Kapitean and all Opoitian samples from the Kapitea Creek section. Elsewhere only one specimen is known in the Opoitian of Corehole F. This form may be restricted stratigraphically and may be a useful age indicator. The large variety is generally common in Waiauan and Lower Tongaporutuan samples, and one specimen was found in the Kapitean at Callaghans Creek.

OBSERVED STRATIGRAPHIC RANGE: Waiauan to Kapitean (Middle to Upper Miocene).

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies (c.600-c.2000 ft.)

Bulimina vellai Gibson

1965. Bulimina vellai Gibson; (in press).

REMARKS: Characterised by its smooth polished surface, semicircular aperture, fusiform shell with both ends narrowly rounded and the last whorl making up half the test.

DISTRIBUTION: A single doubtful specimen was found in the Kapitean of Callaghans Creek. Common to abundant in all Lower Tongaporutuan samples of Callaghans Creek and Corehole D.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Kapitean.

RECORDED STRATIGRAPHIC RANGE: Lower to Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Genus VIRGULINA d'Orbigny, 1826.

TYPE SPECIES: Virgulina squamosa d'Orbigny.

Virgulina vellai Kennett n.sp., Pl. 3, figs. 40-42

DESCRIPTION: Test small, about 4 times as long as broad, with oval to subcircular cross section. Sides parallel to subparallel for most of the

length; initial end strongly tapering to sharp, sometimes with a short spine; apertural end bluntly rounded. Earlier chambers triserial, twisted, later chambers biserial. Chambers increasing in length as added, earlier ones more inflated. Sutures distinct, oblique, slightly curved, less depressed in later part of test. Wall smooth, very finely perforate. Aperture elongate, slightly curved, fairly narrow to broad, often broadest at base. Dimensions of holotype: length 0.38 mm., breadth 0.13 mm.

Dimensions of figured paratype: length 0.48 mm., breadth 0.15 mm.

Variability: A few specimens have a curved test and a few are gradually tapering.

TYPES: Holotype and 24 paratypes. N.Z.G.S. Cat. No. TF1485.

TYPE LOCALITY: S51f674, N.Z. Oil Exploration Company Corehole F, depth 165-170 ft. grid ref. 672582, Westland N.Z.

TYPE LEVEL: Kapitean Stage (Upper Miocene); 35 ft. below the base of the Opoitian Stage.

REMARKS: Distinguished by the parallel to subparallel sides, sharp initial end and oval to subcircular cross section. V.complanata Egger is strongly compressed and tapering throughout. Named after Dr. Paul Vella in appreciation of help and guidance with this work.

DISTRIBUTION: Common in many Kapitean and Opoitian samples from Corehole F, rare in the type Kapitean (S51f648) and in the Lower Tongaporutuan of Callaghans Creek and Corehole D.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Opoitian (Upper Miocene to Lower Eocene).

OBSERVED ECOLOGIC RANGE: *Hauserella* Biofacies.

Genus NEOUVIGERINA Thalmann, 1952.

TYPE SPECIES: Uvigerina ampullacea Brady.

Neouvigerina vadeszens (Cushman), Pl. 3, fig. 39.

1933. Uvigerina proboscidea Schwager var. vadeszens Cushman; Contr. Cush.

Lab. 9 (4); p.85, Pl. 8, figs. 14-15.

1963. Neouvigerina vadeszens; Vella, Trans. roy. Soc. N.Z. Geol. 2(I): II, Pl. 2, fig. 17.

REMARKS: The specimens show some variation in the roundness of the apex.

A few specimens in each sample bear an apical spine.

Dimensions: Hypotype (Ff319); length 0.33 mm., breadth 0.19 mm.

DISTRIBUTION: Variable in abundance in the top Kapitean and Opoitian samples of the Kapitea Creek section. Rare in the Lower Tongaporutuan of Corehole D.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Genus HOFKERUVA Vella, 1961.

TYPE SPECIES: Hofkeruva mata Vella.

Subgenus LAMINIUVA Vella, 1961.

TYPE SPECIES: Hofkeruva (Laminiuva) tutamoea Vella

Hofkeruva (Laminiuva) rodleyi rodleyi Vella, Pl. 3, fig. 43.

1963. Hofkeruva (Laminiuva) rodleyi rodleyi Vella; Trans. roy. Soc. N.Z. Geol. 2 (I): 9, Pl. 2, fig. 28, 29.

1965. Hofkeruva (Laminiuva) rodleyi rodleyi; Gibson (in press).

REMARKS: Long, narrowly fuseform with strong, continuous, narrowly rounded costae.

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1377); length 0.53 mm., breadth 0.22 mm.

DISTRIBUTION: Abundant in the Callaghans Conglomerate of Eight Mile Creek and common in the Lower Tongaporutuan of Callaghans Creek.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Hautawan (Middle Miocene to Upper Pliocene).

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies (c.20 to less than 900 ft.)

Subgenus TEREUVA Vella, 1961

TYPE SPECIES: Hofkeruva (Tereuva) paeniteres (Finlay) = Uvigerina paeniteres Finlay 1939

Hofkeruva (Tereuva) paeniteres (Finlay), Pl. 3 fig. 47.

1939. Uvigerina paeniteres Finlay; Trans. roy. Soc. N.Z. 69(1): 103.

1961. Hofkeruva (Tereuva) paeniteres; Vella, Micropaleontology 7(4): 476.

1961. Hofkeruva (Tereuva) euteres; Vella, Micropaleontology 7(4): 476,
Pl. 1, figs. 6-7.

REMARKS: Almost smooth forms to entirely smooth forms are referable to this species. Staining with ink shows faint traces of costae extending up onto later chambers on some specimens. From comparison of the types, H. euteres Vella is considered to be a junior synonym of H. paeniteres (Finlay).

Dimensions: Hypotype (Ff320); length 0.43 mm., breadth 0.30 mm.

DISTRIBUTION: Abundant in one sample from the lower part of the type Kapitean and rare in one Lower Tongaporutuan sample from the Callaghans Creek section.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Kapitean (Middle Miocene to Upper Miocene). OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Subgenus TRIGONOUVA Vella, 1961

TYPE SPECIES: Hofkeruva (Trigonouva) zeacuminata Vella

Hofkeruva (Trigonouva) lutorum Vella Pl. 3, figs. 46, 48.

1963. Hofkeruva (Tereuva) lutorum Vella; Trans. roy. Soc. N.Z., Geol. 2 (1):
8-9. Pl. 2, figs. 26-27.

1965. Hofkeruva (Tereuva) lutorum; Gibson, (in press).

Gradational relationships described below between H. zeacuminata, H. lutorum and H. pliozea indicate that H. lutorum was incorrectly referred to the subgenus Tereuva by Vella (1961, p. 476) and it is here transferred to the subgenus Trigonouva.

REMARKS: Medium to large specimens with strong costae produced to form small spines at the blunt apex, are referable to this species.

In the Kapitean and Opoitian, especially in Corehole F, a continuous gradational change can be observed from H. zeacuminata, through H. lutorum to forms referable to H. pliozea. The gradation is best seen in the closely sampled Corehole F section but can also be seen in the Kapitean Creek section. The lowest part of the sequence is represented in the Callaghans Creek and Corehole D sections.

In the Corehole F section the lowest two samples that contain Hofkeruva have abundant specimens referable to H. zeacuminata. These specimens have acutely pointed, non-spinose apices, but grade towards forms referable to H. lutorum with moderately blunt apices rimmed by a few very tiny prickles.

In the sample immediately higher in the section H. lutorum is dominant over H. zeacuminata, and generally has a blunter apex with more numerous and larger spines than in lower samples.

Specimens in higher samples begin to show a gradual strengthening of the apical spines and a corresponding increase in the height of the costae which tend to become flange like.

Specimens of H. lutorum have ribs most prominent and distantly spaced in the highest sample examined, immediately above the base of the Opoitian. In this sample there is already a slight tendency for specimens to develop a single apical spine by coalescence of the numerous smaller apical spines.

The same sequence of changes is shown in the Kapitean Creek section, but not as continuously as in Corehole F, because of wider sampling. In the highest Kapitean and lowest two Opoitian samples, specimens of H. lutorum are larger than in lower samples, and grade towards forms with a single, short, often heavy apical spine, and referable to H. pliozea Vella.

In the Corehole D and Callaghans Creek sections, where only the lower part of the Kapitean is represented; population samples are dominantly of moderately weakly costate forms with acute non-spinose apices and are referable to H. zeacuminata. These grade towards a few specimens like H. lutorum with tiny apical spines.

Gibson (in press) stated that H. lutorum was the most abundant species of that genus in the Taranakian sections that he studied. Specimens referable to H. lutorum but grading to H. zeacuminata are also present in the Lower Tongaporutuan of Corehole D. Because of these lower occurrences of H. lutorum the gradational change shown in the Kapitean from H. zeacuminata to H. lutorum is considered to be due either to gradational facies change or heterochronous homeomorphy. Facies control is not favoured as the explanation because in Corehole F the facies seems to be nearly uniform throughout the Kapitean and Opoitian. Specimens from below the Kapitean that have been referred to H. lutorum thus appear to be heterochronous homeomorphs.

A similar explanation may account for the occurrence of forms like Textularia kapitea Finlay in the Lower Tongaporutuan of Callaghans Creek and the Waiauan of Hawkes Bay. These forms are considerably older than the T. miozea-kapitea bioseries of Cape Foulwind (Kennett, 1963.)

Dimensions: Two Hypotypes (Ff321; S51f648) length 0.58 mm., breadth 0.33 mm., (Ff322; S51f646) length 0.55 mm., breadth 0.33 mm.

DISTRIBUTION: H. lutorum occurs fairly abundantly in the middle and upper part of the Kapitea Creek section. It is rare and H. zeacuminata is dominant in the Kapitean of the Callaghans Creek and Corehole D sections. In Corehole F it is almost ubiquitous, occurring commonly in most samples but is rarer at the base where H. zeacuminata is again dominant. In the Lower Tongaporutuan of Corehole D it varies in abundance and grades into H. zeacuminata.

RECORDED STRATIGRAPHIC RANGE: Waiauian to Opoitian (Middle Miocene to Pliocene)

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Robulus Biofacies (c.1000 to c. 2000 ft.).

Hofkeruva (Trigonouva) pliozea Vella, Pl. 3, fig. 45.

1962. Hofkeruva (Trigonouva) n.sp., Kennett, N.Z.J.Geol. Geophys. 5(4):
624 table, 625.

1963. Hofkeruva (Trigonouva) pliozea Vella; Trans. roy. Soc. N.Z.Geol. 2(I):
8, Pl. 2, figs. 23-25.

REMARKS: Large moderately strongly costate forms, with a short, usually large, apical spine in the microspheric form, are referred to this species. The highest Kapitean and lowest two Opoitian samples of the Kapitea Creek section contain forms grading between H. pliozea and H. lutorum. Some forms have a fairly weak apical spine surrounded by a tuft of smaller spines.

In the highest sample from the Opoitian of Kapitea Creek, the costae are much more widely separated and flange like than in lower populations and the tests differ from the type only in having the costae dying out on the final chamber instead of extending to the base of the apertural neck.

H. pliozea is considered to be a descendent of H. lutorum.

Dimensions: Hypotype (Ff323); length 0.61 mm., breadth 0.38 mm.

DISTRIBUTION: Seen only in the Kapitean Creek section where it is rare in the highest Kapitean and abundant in two Opoitian samples.

OBSERVED STRATIGRAPHIC RANGE: Uppermost Kapitean to Opoitian (Uppermost Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Opoitian and possibly Waipipian (Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Robulus Biofacies and ? shallower (c.1000 to 2000 ft.).

Hofkeruva (Trigonouva) zeacuminata ^{Vella} Pl. 3, fig. 44.

1961. Hofkeruva (Trigonouva) zeacuminata Vella; Micropaleontology 7 (4): 476, Pl. 1, figs. 15, 16.

1965. Hofkeruva (Trigonouva) zeacuminata; Gibson, (in press).

REMARKS: Moderate to large tapering forms with acutely pointed apices, and with costae that die on the final chambers; ancestral to H. lutorum.

Dimensions: Hypotype (Ff324); length 0.65 mm., breadth 0.38 mm.

DISTRIBUTION: Fairly abundant in the lower part of the Kapitea Creek section and the most abundant form in the Tongaporutuan and Kapitean of Callaghans Creek, the Kapitean of Corehole D and the lowest two samples of Corehole F. In the Lower Tongaporutuan of Corehole D it is rare and intergrades with the more dominant species H. lutorum.

OBSERVED STRATIGRAPHIC RANGE: Tongaporutuan to Lower Kapitean (Upper Miocene).

RECORDED STRATIGRAPHIC RANGE: Lower Altonian ? to Kapitean (Lower Miocene to Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Genus TRIFARINA Cushman, 1923.

TYPE SPECIES: Trifarina bradyi Cushman.

Trifarina bradyi Cushman, Pl. 3, figs. 49, 50.

1923. Trifarina bradyi Cushman; U.S. nat.Mus.Bull. 104: 99, Pl. 22, figs.3-9.

1961. Trifarina bradyi; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34 (I):
70, Pl. 9, fig. 163, 164.

Trifarina bradyi; Gibson, (in press).

Dimensions; Hypotype (Ff325); length 0.31 mm, breadth 0.12 mm.

DISTRIBUTION: Occasional tiny specimens were found throughout the Kapitea Creek and Eight Mile Creek sections and in the Kapitean of Callaghans Creek. More common and larger specimens occur in the Lower Tongaporutuan of Callaghans Creek and Corehole D.

RECORDED STRATIGRAPHIC RANGE: Bortonian (Middle Eocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Genus BOLIVINA d'Orbigny, 1939.

TYPE SPECIES: Bolivina plicata d'Orbigny.

Bolivina cf. acerosa Cushman, Pl. 4, figs. 51, 52.

1936. Bolivina acerosa Cushman; Spec. Publ. Cushman Lab. 6; 54. Pl. 8, fig. 1.

1961. Bolivina cf. acerosa; Hornibrook, N.Z. geol. Surv. paleont. Bull.34(I):
73, Pl. 9, fig. 174.

REMARKS: Rare specimens of a long slender Bolivina with rounded periphery and almost straight sutures are referred to B cf. acerosa on the range charts. They differ from typical B. acerosa in having less oblique sutures and in the lack of longitudinal costae on the early portion of the test, and closely

resemble the form illustrated by Hornibrook.

Dimensions: Figured specimen (N.Z.G.S.Cat. No. FP378) length 0.36 mm., breadth 0.09 mm.

DISTRIBUTION: Single specimens occur in the top Kapitean sample and one Opoitian sample of Corehole F and in the Waiauan sample of the Kapitea Creek section.

OBSERVED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Waitakian to Awamoan (Upper Oligocene to Lower Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

Bolivina affiliata Finlay.

1939. Bolivina affiliata Finlay; Trans.roy.Soc. N.Z. 69(3): 320

1959. Bolivina affiliata; in Fleming ed., Lex. strat. int. 6 Oceanie (4): 76, Hornibrook; 267, Fleming.

1965. Bolivina affiliata; Gibson, (in press).

DISTRIBUTION: The species occurs rarely in a few samples from the Kapitea Creek section and in a single sample from the Corehole F section. It is common in the Lower Tongaporutuan of Callaghans Creek and Corehole D.

RECORDED STRATIGRAPHIC RANGE: Clifdenian to Nukumaruan (Lower Miocene to Pleistocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Bolivina lapsus Finlay.

1939. Bolivina lapsus Finlay; Trans. roy.Soc.N.Z. 69(I); 98, Pl. II, fig.9.

1959. Bolivina lapsus in Fleming ed., Lex. Strat. int. 6 Oceanie (4): 166,
73, Pl. 10, fig. 184.

1965. Bolivina lapsus; Gibson, (in press).

DISTRIBUTION: Bolivina lapsus is very common in the Waiauan to Lower Tongaporutuan mudstones below the intra-Tongaporutuan unconformity.

One specimen in a Kapitean sample from Corehole F and another from Corehole D may be the result of a contamination. Thus possibly due to facies control, Lower Tongaporutuan may be its upper limit in the Greymouth area. Though Fleming (in Fleming ed; 1959) and Hornibrook, (in Fleming ed; 1959) considered Bolivina lapsus not to persist above Tongaporutuan, Mr. B.A. McInnes (pers. comm.), has found it considerably higher in Hawkes Bay.

RECORDED STRATIGRAPHIC RANGE: Whaiangaroan to Tongaporutuan (Lower Oligocene to Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Bolivina numerosa Vella, Pl. 4, fig. 60.

1957. Bolivina numerosa Vella; N.Z. geol. Surv. paleont. Bull. 28: 33, Pl. 8,
figs. 160, 161.

1965. Bolivina numerosa; Gibson, (in press).

REMARKS: Compressed Bolivina with down curving sutures that are heavily limbate towards the middle of the test.

Dimensions: Hypotype (Ff326); length 0.41 mm., breadth 0.15 mm.

DISTRIBUTION: Infrequent but persistent in the type Kapitean; and sporadic from Lower Tongaporutuan to Waitotaran in all sections.

RECORDED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Bolivina petiae Gibson, Pl. 4, figs. 57, 58.

1961. Bolivina aff. parri: Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 73-4, Pl. 9, fig. 175.

1962. Bolivina aff. parri; Kennett, N.Z.J. Geol. Geophys. 5(4): 624, Table 2.

1965. Bolivina petiae Gibson; (in press).

REMARKS: B. petiae shows considerable variation in chamber shape, incision of sutures, and ornament within each sample. In addition to this, Upper Tongaporutuan to Opoitian forms show general differences from Waiauan to Lower Tongaporutuan forms. The Upper Tongaporutuan to Opoitian forms are generally smaller, covered with tubercles, and have less deeply excavated sutures and more evenly inflated chambers. The Waiauan to Lower Tongaporutuan forms commonly lack tubercles over most of the test, instead having them concentrated near the base of each chamber forming a prominent fringe. The general differences could be of stratigraphic value, but the two forms may be ecological variants of B. petiae, the fringed form occurring in deeper-water facies.

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1379) length 0.40 mm., breadth 0.20mm.

DISTRIBUTION: In the Kapitea Creek section B. petiae is common in the Waiauan and lower Kapitean, absent in the middle Kapitean and rare in the upper Kapitean. It occurs in variable abundance in many Waiauan to Opoitian samples of the other sections and is especially persistent in Corehole F.

RECORDED STRATIGRAPHIC RANGE: Hutchinsonian to Opoitian (Lower Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Bolivina watti Gibson, Pl. 4, figs., 53, 54.

1965. Bolivina watti Gibson; (in press).

REMARKS: A distinctive long, slender and moderately compressed species.

Dimensions: Hypotype (Ff327); length 0.51 mm., breadth 0.13 mm.

DISTRIBUTION: Fairly common in the upper Kapitean and Opoitian at Kapitea Creek. It was also found in the Waiauan at Kapitea Creek and in the Lower Tongaporutuan of the Callaghans Creek and Corehole D sections. B. watti is mainly associated with deeper-water faunas.

OBSERVED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Waiauan to Kapitean (Middle Miocene to Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Genus RECTOBOLIVINA Cushman, 1927.

TYPE SPECIES: Sagrina bifrons Brady.

Rectobolivina maoria Finlay, Pl. 4, figs. 55, 56.

1939. Rectobolivina maoria Finlay; Trans. roy.Soc.N.Z. 69(3): 320, Pl.27, fig. 82-84.

1959. Rectobolivina maoria; in Fleming ed; Lex.Strat.int. 6 Oceanie (4): 22, 74, 76, Hornibrook; 125, 461, Fleming.

Dimensions: Hypotype (N.Z.G.S. Cat.No. FP 1380): length 0.48 mm., breadth 0.20mm

DISTRIBUTION: Rare in the Callaghans Conglomerate at Eight Mile Creek, and in the Lower Tongaporutuan of Corehole D; abundant in the Waiauan of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Upper Altonian to Waitotaran. (Lower Miocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Rectobolivina striatula (Cushman), Pl. 4, fig. 59.

1913. Siphogenerina striatula Cushman; U.S. Nat. Mus. Bull. 71(3): 108, Pl. 47, figs. 1a, b.

1940. Rectobolivina striatula; Finlay & Marwick, Trans. roy. Soc. N.Z. 70 (I); 125.

1958. Rectobolivina striatula; Hornibrook, Micropaleontology, 4 (I): 29 table, 31.

1959. Rectobolivina striatula; in Fleming ed; Lex. Strat. int. 6 Oceanie (4): 267, Fleming; 405, Hornibrook.

1962. Rectobolivina striatula; Vella, Trans. roy. Soc. N.Z. Geol. I (12): 193.

REMARKS: This species is characterised by its large size, fine striated ornament, and well developed lip surrounding the aperture.

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP381); length 0.77 mm., breadth 0.25 mm

DISTRIBUTION: Absent from the type Kapitean, rare in one Kapitean sample from Callaghans Creek and in two Kapitean samples from Corehole F and in the Waitotaran of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Middle Tongaporutuan (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium Biofacies to Haeuslerella Biofacies (c.200 to c. 600 ft.)

Genus ROBERTINOIDES Höglund, 1947.

TYPE SPECIES: Bulimina normani Goess.

Robertinoides cf. pukeuriensis (Hornibrook).

1961. Robertina pukeuriensis Hornibrook; N.Z. geol. Surv. paleont. Bull. 34(I):81, Pl. 10, fig. 192, 193.

1965. Robertinoides cf. pukeuriensis; Gibson, (in press).

REMARKS: A single specimen compares well with specimens from the Uremui Formation of the Taranaki Coast and from the Middle Tongaporutuan of Palliser Bay, referred by Gibson (in press) to R. cf. pukeuriensis. It differs only in having the supplementary aperture closed by secondary callous and represented by a shallow pit.

DISTRIBUTION: Found only in sample f646 near the middle of the type Kapitean.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

RECORDED STRATIGRAPHIC RANGE: Middle Tongaporutuan to Upper Tongaporutuan (Upper Miocene).

R. pukeuriensis was recorded from Otaian to Altonian by Hornibrook (1961).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Family HETEROHELICIDAE

Genus BOLIVINITA Cushman, 1927.

TYPE SPECIES: Textularia quadrilatera Schwager.

Bolivinita pohana Finlay, Pl. 4, figs. 61, 62.

1939. Bolivinita pohana Finlay; Trans. roy. Soc. N.Z. 69(3): 319, Pl.27 figs. 99, 100.

1940. Bolivinita pohana; Finlay, Trans. roy. Soc. N.Z. 70(I): 122.

1959. Bolivinita pohana; in Fleming ed; Lex. Strat. int. 6 Oceanie (4): 405, Hornibrook.

1963. Bolivinita pliobliqua Vella; Trans. roy. Soc. N.Z. Geol. 2(I): 7,8,
Pl. 1, figs. 12, 13.

1965. Bolivinita pohana; Gibson, (in press).

REMARKS: Examination of the types of B. pohana shows that they vary from quadrate to rhomboid in transverse section. The quadrate forms have four nearly equally strong large longitudinal keels while the rhomboid forms have two of the keels more strongly developed. Costae in all cases are fairly weak. Bolivinita is common in all West Coast Kapitean sections examined. Specimens referred to B. pohana are a little less compressed than the holotype but correspond to some paratypes in having the four keels well developed. All specimens are rhomboid in section and all have stronger costae than the types.

They differ from typical B. pliozea Finlay in being oblique, in having less convex periphery, less deeply, more broadly concave sides, stronger keels and fewer costae.

Nearly typical B. pliozea (Pl. 4, figs. 63, 64. N.Z.G.S. Cat. No.FP382) first appears in the Opoitian of the Kapitea Creek and Corehole F.sections. It grades towards B. pohana but differs in lesser obliquity, more strongly convex periphery, narrower and more deeply concave sides, weaker keels, more tapering and narrow outlines.

Dimensions: Hypotype (Ff328); length 0.55 mm., breadth 0.22 mm.

DISTRIBUTION: In the Kapitea Creek section B. pohana is abundant in all Kapitean samples and is replaced by abundant B. pliozea in the Opoitian. Elsewhere B. pohana is generally abundant in the Kapitean and B. pliozea varies in abundance in the Opoitian and Waitotaran.

RECORDED STRATIGRAPHIC RANGE: Middle Tongaporutuan to Nukumaruan (Upper Miocene to Pleistocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826TYPE SPECIES: Cassidulina laevigata d'OrbignyCassidulina laevigata d'Orbigny, Pl. 4, fig. 65.1826. Cassidulina laevigata d'Orbigny; Ann.Sci.nat., ser.I, 7: 282, Pl.15, figs. 4-5.1961. Cassidulina laevigata; Hornibrook, N.Z.geol.Surv.paleont.Bull 34(I): 85, Pl. 10, fig. 199.1962. Cassidulina laevigata; Vella, Trans. roy.Soc.N.Z.Geol. 1(12): 192.1965. Cassidulina laevigata; Gibson, (in press).

Dimensions: Hypotype (Ff329); diameters 0.33mm., 0.27 mm.

DISTRIBUTION: Generally scarce and restricted to isolated samples in the type Kapitean, and in the Tongaporutuan of the Callaghans Creek and Corehole D sections.

RECORDED STRATIGRAPHIC RANGE: Runangan (Upper Eocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium Biofacies to ? Haeuslerella Biofacies (c.200 to c.600 ft.)

Cassidulina neocarinata Thalmann, Pl. 4, fig. 67.1922. Cassidulina laevigata d'Orbigny, var. carinata Cushman; U.S. nat. Mus. Bull.104 (3): 124. Pl. 25. fig. 6-7. (not Cassidulina laevigata d'Orbigny var. carinata Silvestri 1896).1950. Cassidulina neocarinata Thalmann; Contr. Cushman Fnd. I (3-4): 44.1961. Cassidulina neocarinata; Hornibrook, N.Z.Geol.Surv. paleont.Bull.34(I): Pl. 10, fig. 200.

1965. Cassidulina neocarinata; Gibson (in press).

Dimensions: Hypotype (Ff330); diameters 0.20 mm., 0.20 mm.

DISTRIBUTION: Occurs in varying abundance in nearly all samples, except those from the Callaghans Conglomerate and Callaghans Greensand. The most common and widespread species of Cassidulina.

RECORDED STRATIGRAPHIC RANGE: Waitakian (Upper Oligocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Cassidulina subglobosa Brady, Pl. 4, fig. 66.

1881. Cassidulina subglobosa Brady; Quart; J. micro.Sci. (n.s.) 21:60.

1961. Cassidulina subglobosa; Hornibrook, N.Z.geol.Surv.paleont. Bull.34(I): 85, Pl. 10, fig. 198.

1965. Cassidulina subglobosa; Gibson, (in press).

Dimensions: Hypotype (Ff331); diameters 0.23 mm., 0.18 mm.

DISTRIBUTION: In the Kapitea Creek section it is scarce in the Kapitean but more common in the Opoitian. Occasional specimens occur in the Callaghans Greensand of Callaghans Creek and in the Kapitean of the Corehole F and Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Porangan (Middle Eocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Genus CASSIDULINOIDES Cushman, 1927.

TYPE SPECIES: Cassidulina parkeriana Brady.

1884. Cassidulina bradyi Norman; Brady, Rep. Voy. Challenger. Zool. 9: Pl. 54, Fig. 10 (not of Norman).

1922. Cassidulina orientalis Cushman; U.S.nat.Mus.Bull. 104: 129.
1961. Cassidulinoides orientalis; Hornibrook, N.Z.geol.Surv.paleont. Bull.34(I): 86, Pl. 10, fig. 201.
1965. Cassidulinoides orientalis; Gibson, (in press).

REMARKS: Specimens from below the intra-Tongaporutuan unconformity are more inflated than those higher in the succession and are more like topotypes that were available for comparison at N.Z. Geological Survey. The more inflated typical form seems to be associated with deeper-water facies, the compressed form with shallower-water facies.

Dimensions: Hypotypes (Ff332); diameters, 0.37 mm., 0.22 mm.

DISTRIBUTION: Occurs in variable abundance in most samples; particularly common in the Lower Tongaporutuan mudstone of Callaghans Creek; generally rare in the Callaghan Greensand.

RECORDED STRATIGRAPHIC RANGE: Waitakian (Upper Oligocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Family CHILOSTOMELLIDAE

Genus CHILOSTOMELLA Reuss, 1850.

TYPE SPECIES: Chilostomella ovoidea Reuss.

1850. Chilostomella ovoidea Reuss; Denkschr. Akad. Wiss. Wien, Math. - nat. K1. I: 380, Pl. 48, fig. 12.
1961. Chilostomella ovoidea; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 89, Pl. II, fig. 209.
1965. Chilostomella ovoidea; Gibson, (in press).

REMARKS: Characterized by having a test only slightly longer than broad and a distinct apertural lip. The specimens show some variation in the angularity

of the test with the aboral side of the test usually broadly rounded (Pl. 4, fig. 70) but sometimes subangular (Pl. 4, fig. 69) due to protruding initial chambers.

Dimensions: Two hypotypes (N.Z.G.S. Cat. No. FP1838), S51f676, length 0.48 mm., breadth 0.38 mm.; (Ff333; S51f665), length 0.50 mm., breadth 0.37 mm.

DISTRIBUTION: Occurs in isolated samples from the Kapitean and Opoitian of Kapitea Creek. More common and persistent in the Callaghans Creek section, though absent from the Callaghans Greensand. Scarce in the Tongaporutuan of Corehole D and in isolated samples throughout Corehole F.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Awamoan to Upper Tongaporutuan (Lower Miocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

Genus SPHAEROIDINA d'Orbigny, 1826.

TYPE SPECIES: Sphaeroidina bulloides d'Orbigny.

Sphaeroidina bulloides d'Orbigny, Pl. 4, fig. 72.

1826. Sphaeroidina bulloides d'Orbigny; Ann. Sci. nat., Ser. I, (7): 267, Modeles 65, 3 me livr.

1961. Sphaeroidina bulloides; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 90, Pl. II, fig. 210.

1965. Sphaeroidina bulloides; Gibson, (in press).

Dimensions: Hypotype (Ff334); diameters 0.27 mm., 0.25 mm.

DISTRIBUTION: Occurs in variable abundance in nearly all samples from all sections. Is most abundant in the Kapitea Creek section but is rare in the Callaghans Greensand. The largest specimens generally occur in the deepest-water facies.

RECORDED STRATIGRAPHIC RANGE: Runangan (Upper Eocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies (Known from Rubulus Biofacies at Blind River, Marlborough).

Genus PULLENIA Parker & Jones, 1862.

TYPE SPECIES: Nonionina bulloides d'Orbigny.

Pullenia bulloides (d'Orbigny), Pl. 5, figs. 73, 74.

1846, Nonionina bulloides d'Orbigny; Foraminifères Fossiles du Bassin.

Tertiaire de Vienne Gide et Comp., Paris: 107, Pl. 5, figs. 9 - 10.

1961. Pullenia bulloides; Hornibrook, N.Z. geol. surv. paleont. Bull. 34(I): 90, Pl. 11, figs. 207, 208.

1963. Pullenia bulloides; Vella, Trans. roy. Soc. N.Z. Geol. 2 (I): 12-13, Pl. 1, figs. 7, 8.

1965. Pullenia bulloides; Gibson, (in press).

Dimensions: Hypotype (Ff335); diameter 0.21 mm., 0.17 mm.

DISTRIBUTION: Generally scarce in the Kapitea Creek section but is more persistent in the upper Kapitean and Opoitian. Elsewhere rare from Waiauan to Kapitean.

RECORDED STRATIGRAPHIC RANGE: Haumurian (Maestrichtian) to Recent.

OBSERVED ECOLOGIC RANGE: (rare) Haeuslerella to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Robulus Biofacies to Semipelagic Biofacies and possibly Eupelagic Biofacies (1,000 ft. to deeper than 4,000 ft.)

Pullenia quinqueloba (Reuss), Pl. 5, figs. 75, 76.

1851. Nonionina quinqueloba Reuss; Z. dtsh. geol. Ges. 3: 71, Pl.5,fig. 31.

1961. Pullenia quinqueloba; Hornibrook, N.Z. geol. Surv. paleont. Bull.
34(I): 90: Pl. 11, fig. 207, 208.

1963. Pullenia quinqueloba; Vella, Trans. roy. Soc. N.Z.Geol. 2(I): 12,

1965. Pullenia quinqueloba; Gibson, (in press).

Dimensions: Hypotype (Ff336); diameters, 0.31 mm., 0.27 mm.

DISTRIBUTION: Essentially the same as for P. bulloides.

RECORDED STRATIGRAPHIC RANGE: Teurian (Danian to Paleocene) to Recent.

RECORDED ECOLOGIC RANGE: Haeuslerella Biofacies to Karreriella Biofacies.

(possibly Robulus Biofacies) (c.600 to c. 1000 ft.).

Family NONIONIDAE

Subfamily NONIONINAE

Genus ASTRONONION Cushman & Edwards, 1937.

TYPE SPECIES: Nonionina stelligera d'Orbigny.

Astrononion vadorum Vella, Pl. 5, figs. 77, 78.

1962. Astrononion vadorum Vella; Trans. roy. Soc. N.Z. Geol. I(20): 288,
289, Pl. 1, fig. 4, 5.

Dimensions; Hypotype (N.Z.G.S. Cat. No. FP1384); diameters 0.34 mm., 0.30 mm.

DISTRIBUTION: A single specimen from the Callaghans Conglomerate at Eight Mile Creek compares well with the types, differing only in having the posterior edges of the supplementary chambers less open.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

RECORDED STRATIGRAPHIC RANGE: Waipipian or Waitotaran (Middle or Upper Pliocene).

RECORDED ECOLOGIC RANGE: Zeaflorilus or Elphidium Biofacies (0 to c.200 ft.).

Genus PACINONION Vella, 1962.

TYPE SPECIES: Astrononion novozealandicum Cushman & Edwards.

Pacinonion parki (Hornibrook), Pl. 5, figs. 81, 82.

1961. Astrononion parki Hornibrook; N.Z. geol. Surv. paleont. Bull. 34(I):
95, Pl. 12, fig. 230, 237.

1962. Pacinonion cf. parki; Vella, Trans. roy. Soc. N.Z. Geol. I(20):
290-91, Pl. 1, fig. 8, 9.

1965. Pacinonion parki; Gibson, (in press).

REMARKS: The form here referred to P. parki is intermediate between typical P. parki (Awamoan, Lower Miocene) and the Pliocene to Recent species P. novozealandicum (Cushman & Edwards). Specimens differ from the types of P. parki in being less compressed, generally having a less lobulate outline, flush or only slightly incised sutures, 9 to 10 rather than 11 to 12 in the adult whorl, and a stronger tendency to develop callous around the umbilicus and over the supplementary chambers.

They differ from P. novozealandicum in being smaller and having the periphery narrowly rounded instead of broadly rounded.

Dimensions: Hypotype (N.Z.G.S.Cat. No. FP1385); Diameters 0.37 mm., 0.32 mm.

DISTRIBUTION: In the Kapitea Creek section it is abundant in a few samples from the upper part. It is almost ubiquitous and usually abundant from Waiauan to Waitotaran in the other sections.

The closely related species P. novozealandicum is abundant in the Waitotaran of the Eight Mile Creek section where it is associated with other shallow-water species, including Zeaflorilus parri (Cushman) and the Pelecypod Maorimactra chrydaea (Suter).

RECORDED STRATIGRAPHIC RANGE: Runangan to Waitotaran (Upper Eocene to Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium to Robulus Biofacies (c.200 to c.1000 ft.).

Subfamily MELONISINAE

Genus MELONIS Montfort, 1808.

TYPE SPECIES: Nautilus pompilioides Fichtel & Möll.

Melonis zeobesus Vella, Pl. 5, figs. 79-80.

1962. Melonis zeobesus Vella; Trans. roy. Soc.N.Z.Geol. I(20): 292, 293,
Pl. 1, fig. 14, 15.

REMARKS: Easily confused with Anomalinoidea subnonionoides (Finlay), but the two sides of M. zeobesus are equally involute.

Dimensions: Hypotype (Ff337); diameters 0.48 mm., 0.41 mm.

DISTRIBUTION: Infrequent in the upper Kapitean and Opoitian at Kapitea Creek. Sporadic and varying in abundance from Upper Tongaporutuan to Opoitian elsewhere.

RECORDED STRATIGRAPHIC RANGE: Tongaporutuan to Waipipian (Upper Miocene to Middle Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Robulus and ? Semipelagic Biofacies (c.2000 to c. 3000 ft.).

Genus FLORILUS Montfort, 1808.

TYPE SPECIES: Nautilus asterizans Fichtel & Möll.

Florilus flemingi (Vella), Pl. 5, figs. 83, 84.

1957. Nonion flemingi Vella; N.Z.geol.Surv.paleont.Bull.28:37, Pl.9, fig.183, 184

1962. Florilus flemingi; Vella, Trans.roy.Soc.N.Z.Geol.I(20): 293.

1965. Florilus flemingi; Gibson, (in press).

REMARKS: Specimens referable to Florilus flemingi differ from the types (Recent, Auckland Islands) in being less compressed and having only about 8 chambers as against 10 to 13 in the final whorl.

Dimensions: Hypotype (Ff338); diameters, 0.49 mm., 0.37 mm.

DISTRIBUTION: Almost ubiquitous; occurring in varying abundance in all sections.

RECORDED STRATIGRAPHIC RANGE: Waiauan (Upper Miocene) to Recent.

RECORDED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies (0 to 1000 ft.).

Florilus olsoni Kennett, n. sp., Pl. 5, figs. 85 - 88.

DESCRIPTION: Test planispiral, moderately compressed, slightly assymetrical, tiny, smooth and glossy, subovate in outline, about $1\frac{1}{2}$ times as long as broad. Chambers distinct, about 9 or 10 in the adult whorl, increasing gradually in height and degree of inflation. Sutures gently curved, flush or slightly raised. Umbilical area ornamented with fine papillae that occasionally extend out to the periphery. Aperture 2 or 3 small perforations at the base of the terminal face.

Dimensions of holotype: diameters, 0.28 mm., 0.20 mm.

Dimensions of figured paratype: diameters, 0.28 mm., 0.19 mm.

Dimensions of figured juvenile paratype: diameters 0.21 mm., 0.17 mm.

Variability: The periphery varies from angular to narrowly rounded. On some specimens a few small peripheral spines occur on the early chambers of the adult whorl. In one young paratype a radial row of small papillae extends from the umbilicus to the periphery on each of the 6 earlier chambers of the outer whorl.

TYPES: Holotype (F339) and II paratypes (Fp339).

TYPE LOCALITY: S51f656, Callaghans Creek section, Westland, N.Z. grid ref. 697626.

TYPE LEVEL: 6ft. above the base of the Callaghans Greensand, Upper Tongaporutuan ^{sub} stage, Upper Miocene.

REMARKS: Distinguished by the tiny, slightly assymetrical glassy test with strongly limbate sutures, and the finely papillate umbilical area.

Differs from Florilus mesonense (Cole and Gillespie) mainly in having less strongly curved sutures and less narrow chambers. Florilus dingdeni (Cushman) has incised sutures and more acute periphery.

Named after the late Mr. O.P. Olson of the New Zealand Geological Survey.

DISTRIBUTION: Found only in the Callaghans Greensand at Callaghans Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Genus ZEAFLORILUS Vella, 1962.

TYPE SPECIES: Nonionella parri Cushman.

Zeaflorilus parri Cushman, Pl. 6, figs. 89, 90.

1936. Nonionella parri Cushman; Contr. Cush. Lab. 12, p.89, Pl. 13, figs.17-a-c

1940. Pseudononionparri; Finlay & Marwick, Trans. roy.Soc.N.Z. 70(I): 122.

1962. Zeaflorilus parri; Vella, Trans. roy.Soc. N.Z.Geol. I(20): 294.

1965. Zeaflorilus parri; Gibson, (in press).

Dimensions: Hypotype (Ff340); diameters, 0.64 mm., 0.47 mm.

DISTRIBUTION: Single specimens were found in isolated samples from the type Kapitean section, from the Upper Tongaporutuan greensand of Callaghans Creek and from the Kapitean and Opoitian of Corehole F. Zeaflorilus parri is abundant in the Waitotaran of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Lillburnian (Middle Miocene) to Recent.

RECORDED ECOLOGIC RANGE: Zeaflorilus Biofacies (0 to 20 ft.).

Subfamily NONIONEELLINAE

Genus NONIONEELLA Cushman, 1926.

TYPE SPECIES: Nonionella miocenica Cushman.

Nonionella magnalingua Finlay, Pl. 6, figs. 91, 92.

1940. Nonionella magnalingua Finlay; Trans. roy. Soc. N.Z. 69(4): 456, Pl. 65, fig. 144, 146.

1961. Nonionella magnalingua; Hornibrook, N.Z. Geol. Surv. paleont. Bull. 34(I): Pl. 12, fig. 226, 232-3.

1962. Nonionella magnalingua; Vella, Trans. roy. Soc. N.Z. Geol. I(20): 295.

1965. Nonionella magnalingua; Gibson, (in press).

REMARKS: Specimens have a more inflated and more embracing final chamber than the types.

Dimensions: Hypotype (Ff341): diameters 0.33 mm., 0.20 mm.

DISTRIBUTION: Scarce in the lower part of the Kapitea Creek section but more persistent in the upper part. Rare in a few isolated Lower Tongaporutuan to Kapitean samples in other sections.

RECORDED STRATIGRAPHIC RANGE: Duntroonian to Wanganui Series (Lower Oligocene to Pleistocene).

RECORDED ECOLOGIC RANGE: Haeuslerella (part) to Robulus Biofacies (less than 900 to c. 1000 ft.).

Nonionella zenitens Finlay, Pl. 6, figs. 93-96.

1940. Nonionella zenitens Finlay; Trans. roy. Soc. N.Z. 69(4): 457, Pl. 65, fig. 145, 152-56.

1961. Nonionella zenitens; Hornibrook, N.Z. Geol.Surv.paleont. Bull. 34(I): 93, Pl. 12, fig. 225, 231.

1962. Nonionella zenitens; Gibson, (in press).

Dimensions: Two Hypotypes, (N.Z.G.S.Cat. No. FP1386), diameters 0.31 mm., 0.25 mm.; (Ff342), diameters 0.34 mm., 0.23 mm.

DISTRIBUTION: One specimen from the Callaghans Creek Greensand of Callaghans Creek and one specimen from the Kapitean of Corehole F. The Upper Tongaporutuan specimen is more compressed and less asymmetrical than the types.

RECORDED STRATIGRAPHIC RANGE: Waipawan to Waitotaran (Upper Paleocene to Upper Pliocene).

RECORDED ECOLOGIC RANGE: ? Haeuslerella Biofacies to Robulus Biofacies (less than 900 to c. 2000 ft.).

Superfamily ROTALIDEA

Family DISCORBIIDAE

Subfamily PATELLININAE

Genus PATELLINELLA Cushman, 1928.

TYPE SPECIES: Textularia inconspicua Brady.

Patellinella inconspicua (Brady), Pl. 6, figs. 97, 98.

1884. Textularia inconspicua Brady; Rep. Voy. Challenger, Zool. 9: 357, Pl. 42 fig. 6a-c.

1928. Patellinella inconspicua; Cushman, C.C.L.F.R. 4: 5, Pl. 1, fig. 8 a-c.

1930. Patellinella inconspicua; Parr & Collins, Proc.Roy.Soc.Victoria, 43(I) (N.S.): 92, Pl.4, fig. 7.

1957. Patellinella inconspicua; Vella, N.Z.Geol.Surv. paleont. Bull. 28: 10, 13 lists.

1958. Patellinella inconspicua; Hornibrook, Micropaleontology, 4(I):

6 Oceania (4): 167.

1959. Patellinella inconspicua; Fleming in Fleming ed; Lex. Strat. int.

6 Oceania (4): 167.

Dimensions: Hypotype (Ff343); diameters 0.32 mm., 0.22 mm.

DISTRIBUTION: A single specimen from the Lower Kapitean of Callaghans Creek (f662) differs from the typical only in having strongly limbate sutures.

RECORDED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Subfamily DISCORBINAE

Genus DISCORBIS Lamarck, 1804.

TYPE SPECIES: Discorbis vesicularis Lamarck.

Discorbis cf. dimidiatus (Parker & Jones), Pl. 6, figs. 99-101.

1862. Discorbina dimidiatus Parker & Jones; in Carpenter; Introduction to the Study of Foraminifera. Ray Society, London: 201, text - fig. 32b.

1957. Discorbis dimidiatus, var; Vella, N.Z. geol. Surv. paleont. Bull. 28: 35, Pl. 8, fig. 166, 172-4.

REMARKS: Differs from the Recent Cook Strait form referred to D. dimidiatus var. by Vella (1957, p. 35, Pl. 8, fig. 166, 172-4) in having 14 as against 22 chambers in the whorl, and wider, deeper sutural grooves on the ventral surface. As in some Cook Strait specimens, callous covers most of the umbilical area.

Dimensions: Figured specimen (Ff344); diameters 0.53 mm., 0.47 mm.

DISTRIBUTION: Found only in the Callaghans Greensand at Callaghans Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Discorbis subcomplanatus Parr.

1950. Discorbis subcomplanatus Parr; B.A.N.Z. Ant. Res. Exped. Ser. B. 5(6): 355, Pl. 14, fig. 1, 2.

REMARKS: Typically depressed with margin bluntly keeled and limbate, sutures limbate and recurved, 7 chambers in the final whorl. It has the typical aperture of Discorbis with covering tooth plates. D. subcomplanatus is a Recent species described from off Antarctica.

DISTRIBUTION: A single specimen was found in the highest sample from the Callaghans Creek section (Kapitean, f666).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Genus GAVELINOPSIS Hofker, 1951.

TYPE SPECIES: Discorbina praegeri Heron - Allen & Earland.

Gavelinopsis lobatulus (Parr), Pl. 6, figs. 102-105.

1950. Discorbis lobatulus Parr; B.A.N.Z. Ant. Res. Exped. B. 5(6): 354, Pl. 13, fig. 23-25.

1957. Gavelinopsis lobatulus; Vella, N.Z. geol. Surv. paleont. Bull. 28: 10 (list.)

1960. Gavelinopsis lobatulus; Barker, Spec. Publ. Soc. econ. Paleont. and Min. 9: 182, Pl. 88, fig. I.

1961. Gavelinopsis lobatulus; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 104.

REMARKS: Usually 6, sometimes 7 chambers in the final whorl, very compressed with a strong thin keel and a depressed umbilical area that is sometimes filled with a glassy plug. There is considerable variation in the width

of the keel. Specimens differ from the types only in having less strongly recurved dorsal sutures.

Dimensions: Two Hypotypes (N.Z.G.S.Cat. No. FP1387; S51f674), diameters 0.33 mm 0.28 mm.; (Ff345; S51666), diameters 0.35 mm., 0.33 mm.

DISTRIBUTION: It is almost ubiquitous but usually rare in Lower Tongaporutuan and younger strata in Callaghans Creek, Corehole D and Corehole F. It was found only in the Opoitian at Eight Mile Creek, and was not found at all in the Kapitea Creek section.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies (shallow part).

Genus EPONIDES Montfort, 1808.

TYPE SPECIES: Nautilus repandus Fichtel & Moll.

Eponides broeckhianus (Karrer), Pl. 7, fig. 112.

1878. Rotalia broeckhiana Karrer; Die Foraminiferen der Tertiären Thone von Luzon. In: Drasch, Fragmente zu einer Geologie der Insel Luzon (Philippinen). Wien, 1878, p. 98, Pl. 5, fig. 26.

1961. Epondies broeckhianus; Hornibrook, N.Z. geol.Surv.paleont. Bull. 34(I): 109, Pl. 15. fig. 321 - 2.

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1388); diameters 0.13 mm., 0.12 mm.

DISTRIBUTION: Rare, and found only in the Lower Tongaporutuan of Corehole D, the Upper Tongaporutuan of Eight Mile Creek and a few Kapitean and Opoitian samples from Corehole F.

RECORDED STRATIGRAPHIC RANGE: Bortonian to Waitotaran (Middle Eocene to Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies (Known from Karreriella and Robulus Biofacies at Blind River, Marlborough.)

Subfamily DISCORBINELLINAE

Genus DISCORBINELLA Cushman & Martin, 1935.

TYPE SPECIES: Discorbinella montereyensis Cushman & Martin.Discorbinella cf. rarescens (Brady), Pl. 7, figs. 106-108.1884. Discorbina rarescens Brady; Rep.Voy. Challenger, Zool. (9): 651,
Pl. 90, fig. 2 - 3.1961. Discorbinella rarescens; Hornibrook, N.Z. geol. Surv. paleont. Bull.
34(I): 117, Pl. 14, fig. 292 - 294, 298.

REMARKS: A single specimen is strongly planoconvex, with a wide peripheral flange and has a tiny peripheral aperture. It differs markedly from typical D. rarescens in the initial coiling on the dorsal side, but this may be a pathological deformity and it is provisionally listed as D. cf. rarescens.
Dimensions: Figured specimen (N.Z.G.S.Cat. No. FP1389); Diameters 0.29 mm., 0.21 mm.

DISTRIBUTION: Found only in the Callaghans Conglomerate of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Whaiangaroan (Lower Oligocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Discorbinella aff. rarescens (Brady), Pl. 7, figs. 110, 111.

REMARKS: A single robust specimen differs from the typical in lacking the wide peripheral flange.

Dimensions: Figured specimen (N.Z.G.S. Cat. No. FP1390); diameters 0.30 mm., 0.27 mm.

DISTRIBUTION: Callaghans Conglomerate, Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Genus LATICARININA Galloway & Wissler, 1927.

TYPE SPECIES: Pulvinulina repanda, var. menardii subvar.
pauperata Parker & Jones.

Laticarinina pauperata (Parker & Jones), Pl. 7, fig. 109.

1865. Pulvinulina repanda var. menardii subvar. pauperata Parker & Jones,
Phil. Trans. 155: 395, Pl. 16, fig. 50, 51.

1959. Laticarinina halophora; Hornibrook in Fleming ed. Lex. Strat. int.
6 Oceania (4): 51.

1959. Laticarinina halophora; Hornibrook. N.Z. Geol. Surv. paleont. Bull.
34(I): 119, Pl. 14, fig. 300, 303 - 4.

1965. Laticarinina halophora; Gibson, (in press).

Dimensions: Hypotype (Ff345); diameters 0.65 mm., 0.45 mm.

DISTRIBUTION: In the Kapitea Creek section, rare and sporadic in the
Waiauian and lower Kapitean, uncommon and persistent in the upper Kapitean
and Opoitian. It occurs in variable abundance in the Tongaporutuan of
Corehole D and the Waiauian of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Bartonian (Middle Eocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies. (Known
from Robulus Biofacies from Blind River, Marlborough).

Family EPISTOMINIDAE

Genus HÖGLUNDINA Brotzen, 1948.

TYPE SPECIES: Rotalia elegans d'Orbigny.

Höglundina elegans (d'Orbigny) Pl. 7, figs. 113, 114.

1826. Rotalia (Turbinuline) elegans d'Orbigny; Ann. Sci. nat., Ser. I, 276.

1959. Höglundina elegans; Hornibrook in Fleming, ed. Lex. Strat. int. 6 Oceanie (4): 51.
1961. Epistomina elegans; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 122, Pl. 17, fig. 367.
1965. Höglundina elegans; Gibson, (in press).

Dimensions: Hypotype (Ff346); diameters 1.27 mm., 1.15 mm.

DISTRIBUTION: Generally scarce throughout the upper part of the Kapitea Creek section. Rare in the Lower Tongaporutuan of Callaghans Creek and Corehole D, the Waiauuan of Eight Mile Creek, and the Opoitian of Corehole F and Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Bortonian (Middle Eocene) to Recent.

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies. (Known from Robulus Biofacies at Blind River, Marlborough).

Genus PSEUDOEAPONIDES Uchio, 1950.

TYPE SPECIES: Pseudoeponides japonicus Uchio.

Pseudoeponides prominula (Stache), Pl. 7, figs. 120 - 122.

1865. Rotalia soldani d'Orbigny, var. prominula; Stache, Novara - Exped. Geol. Theil. I(2): 274, Pl. 24, fig. 24.
1961. Gyroidina prominula; Hornibrook, N.Z. Geol. Surv. paleont. Bull. 34(I): I, Pl. 16, fig. 348 - 9.
1965. Pseudoeponides prominula; Gibson, (in press).

REMARKS: Gibson (in press) transferred this species to Pseudoeponides because of its supplementary apertures. Many Westland specimens also have supplementary apertures.

Dimensions: Hypotype (Ff347); diameters 0.22 mm., 0.20 mm.

DISTRIBUTION: In the Kapitea Creek section it is generally scarce in the lower Kapitean and abundant in the upper Kapitean and Opoitian. Elsewhere it is mostly rare but is fairly abundant in the Tongaporutuan of Callaghans Creek and Corehole D.

RECORDED STRATIGRAPHIC RANGE: Bortonian to Nukumaruan (Middle Eocene to Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies (Known from Robulus Biofacies from Blind River, Marlborough).

Pseudoeponides tenera (Brady), Pl. 7, figs. 118, 119.

1884. Truncatulina tenera Brady; Rep.Voy. Challenger, Zool. 9: Pl. 95, fig. 11 a - c.

1954. Pseudoeponides tenera; Parker, Bull. Mus. Comp. Zool. Harvard 3(10):530.

1960. Eponides ? tenera; Barker, Spec. Publ. Soc. econ. Paleont. and Min. 9: 196, Pl. 95, fig. 11 a - c.

1965. Pseudoeponides tenera; Gibson, (in press),

REMARKS: Parker (1954) transferred this species to Pseudoeponides because of supplementary apertures on the dorsal side. Gibson (in press) figured supplementary apertures on ventral and dorsal sides. Some specimens examined by the writer clearly show the supplementary apertures which show in the figured specimen more clearly than usual.

Dimensions: Hypotype (N.Z.G.S.Cat. No. FP1391); diameters 0.38 mm., 0.36 mm.

DISTRIBUTION: In the Kapitea Creek section it is rare but fairly persistent. Elsewhere it is rare and occurs in few samples only.

OBSERVED STRATIGRAPHIC RANGE: Kapitean to Opoitian.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Upper Tongaporutuan (Middle Miocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies (Known from Robulus Biofacies at Blind River, Marlborough).

Family ROTALIIDAE

Genus AMMONIA Brunnich, 1772.

TYPE SPECIES: Nautilus beccarii Linnaeus.Ammonia aoteanus (Finlay), Pl. 7, figs. 115 - 117.1940. Streblus aoteanus Finlay; Trans. roy. Soc. N.Z. 69(4): 461, 462.1957. Streblus aoteanus; Vella, N.Z. geol. Surv. paleont. Bull 28; 7, 11,
13 lists.1962. Streblus aoteanus; Vella, Trans. roy. Soc. N.Z. geol. 1(12); 193.

REMARKS: The single specimen closely resembles the types of A. aoteanus from Dunedin Harbour but differs in the nature of the sutures. The Kapitean specimen has the periphery swollen at each suture and so has a more or less polygonal outline, and has sutures not incised and more limbate near the margins.

Dimensions: Hypotype (N.Z.G.S.Cat. No. FP1392); diameters 0.43 mm., 0.42 mm.

DISTRIBUTION: Kapitean of Corehole D. (f687).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene) to Recent.

RECORDED ECOLOGIC RANGE: Elphidium Biofacies (c. 200 ft.).

Family ELPHIDIIDAE

Subfamily ELPHIDIINAE

Genus ELPHIDIUM Montfort, 1808.

TYPE SPECIES: Nautilus macellus Fichtel & Moll.Elphidium cf. chapmani Cushman.

1936. Elphidium chapmani Cushman; Contr. Cushman, Lab. Foram. Res. 12(4): 80,
Pl. 14, fig. 6.

REMARKS: A single broken specimen is referred to E. cf. chapmani described from the Miocene of Australia. It has numerous chambers, a sharp weakly keeled periphery, and a heavily calloused coarsely perforated boss in the umbilical region. Differs from E. chapmani in being less rhomboid in peripheral view and in having a thin keel, and from E. crispum (Linnaeus) in having shorter retral processes, and depressed sutures.

Dimensions: Figured specimen (Ff378); diameter 0.50 mm.

DISTRIBUTION. From low in the type Kapitean section.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: (shallow) Haeuslerella Biofacies.

Elphidium charlottensis (Vella), Pl. 8, figs. 123, 124.

1957. Elphidiononion charlottensis Vella; N.Z. geol. Surv. paleont. Bull. 28: 38, Pl. 9, fig. 187, 188.

1961. Elphidium charlottensis; Vella, Trans. roy. Soc. N.Z. Geol. I(12): 192, list.

1965. Elphidium charlottensis; Gibson, (in press).

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1393); diameters 0.32 mm., 0.27 mm.

DISTRIBUTION: Sporadic and usually rare from Waiauan to Opoitian in all sections; abundant in the Callaghans Greensand of Callaghans Creek and Eight Mile Creek and the Waitotaran of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene) to Recent.

RECORDED ECOLOGIC RANGE: Zeaflorilus or Elphidium to (rare) Haeuslerella Biofacies (0 to 1000 ft.).

Elphidium oceanicum Cushman, 1933, Pl. 8, figs. 125, 126.

1933. Elphidium oceanicum Cushman, U.S.Nat.Mus.Bull. 161 (2): 52, Pl. 12, fig. 7.

1957. Elphidium cf. oceanicum; Vella, N.Z.geol. Surv.pal.Bull. 28; II list.

REMARKS: This species from the Recent of Fiji Islands (72 ft.) has a broadly rounded periphery, a depressed umbilical region and distinct retral processes occupying only a narrow bed.

Dimensions: Hypotype (N.Z.G.S.Cat. No. FP1394); diameters 0.25 mm., 0.21 mm.

DISTRIBUTION: One specimen from the Callaghans Conglomerate at Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan.

RECORDED STRATIGRAPHIC RANGE: Depth in Cook Strait: 60 to 120 ft.

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Subfamily NOTOROTALIINAE

Genus NOTOROTALIA Finlay, 1939.

TYPE SPECIES: Notorotalia zelandica Finlay.

Notorotalia hurupiensis Vella, Pl. 8, figs. 127 - 129.

1957. Notorotalia hurupiensis Vella; N.Z. geol.Surv.paleont. Bull. 28: 49, 56 table 7, Pl. 1, fig. 15.

1959. Notorotalia hurupiensis; in Fleming ed., Lex. Strat. int. 6 Oceanie (4): 281, Fleming; 404, Hornibrook.

1962. Notorotalia hurupiensis; Vella, Trans. roy.Soc.N.Z.geol. I(12): 193, table.

1965. Notorotalia hurupiensis; Gibson, (in press).

REMARKS: In large samples from the Opoitian of Corehole F (f667, f668, & f670) and from the lowest Kapitean sample (f644) from Kapitea Creek, a few specimens

show spiral ribs dying out on the anterior parts of each chamber. These specimens show the beginning of the change from N. hurupiensis to N. finlayi which became universal in the Waitotaran with N. hurupiensis giving rise to N. finlayi Vella.

Dimensions: Hypotype (Ff348); diameters 0.54 mm., 0.47 mm.

DISTRIBUTION: In the Kapitea Creek section it is rare and restricted to the lower Kapitean in which it is associated with other shallower-water species. In other sections it occurs commonly in most Kapitean samples, ubiquitous in Corehole F and absent from the Callaghans Greensand.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Pliocene).

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies (20 to 1000 ft.).

Notorotalia macinnesi Kennett, n. sp., Pl. 8, figs. 130-132.

DESCRIPTION: Shell large, thick walled, biconvex, but the ventral side more strongly convex than the dorsal. Dorsal surface with central raised area. Ventral surface convex at the sides, flat or slightly concave at the centre. Periphery narrowly rounded to acute with a distinct, narrow, rounded keel. Sculpture moderately heavy, rounded and fairly dense. Final whorl with II to 13 chambers. Transverse sutural ribs straight to gently arcuate on the dorsal side, gently arcuate on the ventral.

Spiral sculptural ribs typically extending from suture to suture, heavy at posterior ends, narrowing towards anterior end.

Dimensions of Holotype: diameters 0.75 mm., 0.63 mm.

Variability: A few specimens have a small raised callous knob on the centre of the dorsal surface, some have a flat dorsal surface; and in some a few of the sculptural ribs die out before reaching the anterior sutural rib,

TYPES: Holotype (F349) and 13 paratypes (Fp349).

TYPE LOCALITY: S51f656, Callaghans Creek section, Westland, N.Z. grid ref. 697626.

TYPE LEVEL: 6 ft. above the base of Callaghans Greensand, Upper Tongaporutuan "sub Stage", Upper Miocene.

REMARKS: Distinguished by the large size, II to 13 chambers in the final whorl, narrowly rounded to acute periphery with distinct keel.

Differs from N. zelandica mangaoparia Vella in being generally smaller, having fewer chambers and distinct callous knob in some specimens, being less concave in centre of ventral side and having more regular sculpture. Differs from N. zelandica zelandica in having less convex and calloused dorsal surface, sharper periphery and more distinct keel.

N. macinnesi appears to be an early member of the N. zelandica group.

Named after Mr. B. A. McInnes.

DISTRIBUTION: Infrequent to abundant in samples from the Callaghans Greensand at Callaghans Creek, Corehole D, and Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Notorotalia pliozea Vella.

1957. Notorotalia pliozea Vella; N.Z. geol. Surv. paleont. Bull. 28: 52 table 5, 54, 56 table 7, Pl. 2, figs. 25, 26.

1959. Notorotalia pliozea; Fleming, in Fleming ed., Lex. Strat. int. 6 Oceanie (4): 167.

1962. Notorotalia pliozea: Vella, Trans. roy. Soc. N.Z. Geol. I(12): 193, table.

REMARKS: Specimens compare well with the types having a prominent flange-like peripheral keel and raised widely spaced slightly sinuous sculptural ribs.

DISTRIBUTION: One specimen was found in the Callaghans Greensand at Callaghans Creek and one specimen in the Waitotaran of Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

RECORDED STRATIGRAPHIC RANGE: Kapitean to Waitotaran (Upper Miocene to Pliocene).

RECORDED ECOLOGIC RANGE: Elphidium? to Haeuslerella Biofacies (20 to 1000 ft.)

Notorotalia taranakia Vella.

1957. Notorotalia taranakia; N.Z. geol. Surv. paleont. Bull. 28: 48, 56
tabel 7, Pl. 1, figs. 1-3.

1959. Notorotalia taranakia; Hornibrook in Fleming ed., Lex. strat.int.
6 Oceanie (4): 404.

1962. Notorotalia taranakia; Vella, Trans. roy.Soc.N.Z.geol. I (12):
193, table.

1965. Notorotalia taranakia; Gibson, (in press).

REMARKS: Typical N. taranakia is not common in the examined sections.

Instead a form referred to on the range charts as N. aff. taranakia, (reticulate ornament) is dominant. It is generally more compressed than N. taranakia, and has strongly reticulate ornament due to the strengthening of the numerous radial ribs between the spiral sculptural ribs. The dorsal surface is usually flat or slightly convex but is strongly convex in a few specimens. A similar form in the type Opoitian, Wairoa valley (pers. comm. Mr. B. A. McInnes) is even more strongly reticulate and has no keel.

DISTRIBUTION: Typical N. taranakia was observed in varying abundance in a few samples from the Kapitean at Kapitea Creek, and in the Lower Tongaporutuan at Callaghans Creek. N. aff. taranakia is common in all samples from the Kapitea Creek section and rare in the Waitotaran of Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: N. taranakia (sensu stricto) Lower Tongaporutuan to Kapitean.

N. aff. taranakia Kapitean to Opoitian.

RECORDED STRATIGRAPHIC RANGE: Waiauian to Lower Waitotaran (Upper Miocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Uncommon in Haeuslerella and Karreriella Biofacies.

RECORDED ECOLOGIC RANGE: Robulus to Eupelagic Biofacies (1000 to 4000 ft.)

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826.

TYPE SPECIES: Globigerina bulloides d'Orbigny.

Globigerina bulloides d'Orbigny, Pl. 8, 133-135.

1826. Globigerina bulloides d'Orbigny; Ann. Sci. Nat. I (7): 277.

1960. Globigerina bulloides; Bermudez, Memoria del III Congreso Geologico Venezolano - Tomo III Boletin de Geologia - Spec. Publ. 3: 1161 - 64
Pl. 1 fig. 7 a - c.

1961. Globigerina bulloides; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I):
146, Pl. 21, fig. 430, 431, 434.

1965. Globigerina bulloides; Gibson, (in press).

REMARKS: The name G. bulloides has been applied probably rather loosely to forms throughout the Middle and Upper Tertiary of New Zealand. It is here used in the restricted sense of Blow (1959).

Dimensions: Hypotype (Ff350); diameters 0.35 mm., 0.31 mm.

DISTRIBUTION: Occurs in variable abundance in isolated Kapitean and Opoitian samples in all sections except the Eight Mile Creek section. More common in the Lower Tongaporutuan of Callaghans Creek and Corehole D.

OBSERVED STRATIGRAPHIC RANGE: G. bulloides (sensu stricto) Lower Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: G. bulloides (sensu stricto) Waiauan to Upper Tongaporutuan (Middle to Upper Miocene).

Globigerina dutertrei d'Orbigny, Pl. II, figs. 173 - 178.

1839. Globigerina dutertrei d'Orbigny; in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferos", 8: 84, Pl. 4, fig. 19 - 21.

1962. Globoquadrina dutertrei; Parker, Micropaleontology, 8(2): 242, 244. Pl. 7, fig. 1-13, Pl. 8, fig. 1 - 4.

REMARKS: Specimens are of moderate size, have 4 to 5 chambers in the final whorl, a thick coarsely perforate wall, and an arched aperture that varies from umbilical to umbilical-extraumbilical in position and possesses a fairly narrow lip. All specimens coil to the left. As no umbilical plates were observed and because a gradation seems to exist between G. dutertrei and G. pachyderma (Ehrenberg) the species is placed in Globigerina rather than Globoquadrina. A few specimens are difficult to distinguish from G. semivera Hornibrook.

Dimensions: Two Hypotypes (Ff365; S51f647); diameters 0.33 mm., 0.27 mm. (Ff363; S51f648); diameters 0.30 mm., 0.28 mm.

DISTRIBUTION: Ubiquitous but rare throughout the Kapitea Creek section.

Rare in a few Kapitean samples from Callaghans Creek, Corehole D and Corehole F.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene) to Recent.

Globigerina cf. falconensis Blow, Pl. 8, figs. 136 - 138.

1959. Globigerina falcomensis Blow; Bull. Amer. Paleont. 39 (178): 177, Pl. 9, fig. 40 a - c, 41.

1962. Globigerina falconensis; Takayanagi & Saito, Sci.Rpts. Tohoku.

Univ. 2nd Ser. (Geol.) Spec. Vol. 5: 86, Pl. 25, fig. 1 a - c.

REMARKS: The Westland form agrees with the types in having chambers characteristically increasing slowly in size, the aperture an elongate low arch with a well developed lip and the wall fairly coarsely perforate. It differs in having more embracing chambers.

Dimensions: Two figured specimens (Ff351; S51f646); diameters 0.27 mm., 0.22 mm. (Ff352; S51f648); diameters 0.20 mm., 0.17 mm.

DISTRIBUTION: Rare, occurring in some isolated samples from the Kapitean of Kapitea Creek section, the Lower and Upper Tongaporutuan of the Callaghans Creek section and the Callaghans Conglomerate and Opoitian of the Eight Mile Creek section.

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Opoitian (Upper Miocene to Pliocene).

Globigerina nepenthes Todd, Pl. II, figs. 179, 180.

1957. Globigerina nepenthes Todd: U.S. geol. Surv. prof. Pap. 280-H: 301, Pl. 78, fig. 7.

1959. Globigerina nepenthes; Hornibrook in Fleming ed., Lex.Strat.int. 6 Oceanie (4): Table 6.

1960. Sphaeroidinellopsis nepenthes; Bermudez, Memoria del III Congreso Geologico Venezolano - Tomo III Boletin de Geologia - Spec.Publ. 3. Separate 1961: 1277-78, Pl. 10, fig. I a-b.

1962. Globigerina nepenthes; Geiger, N.Z.J. Geol. Geophys. 5(2): 307, fig. 2.

1962. Globigerina nepenthes; Saito, Trans. Prof.Palaeont.Soc. Japan, N.S.48; Pls. 51,52.

1965. Sphaeroidinellopsis nepenthes; Gibson, (in press).

REMARKS: A single specimen, small compactly coiled, the last chamber distinctly protruding, with five chambers in the final whorl, and the aperture high, arched and bordered by a thickened lip. A form similar to G. nepenthes occurs fairly commonly in the Waiau sample from immediately below the intra-Tongaporutuan unconformity at Kapitea Creek. Like G. nepenthes it is thick walled, has a protruding final chamber and a high arched aperture with slightly upturned lip. It differs from G. nepenthes in having four chambers in the final whorl, is lower spired and has a less protruding final chamber. It is shown as G. n.sp.cf. nepenthes and may be a useful stratigraphic fossil. Dimensions: Hypotype (Ff368); diameters 0.25 mm., 0.23 mm.

DISTRIBUTION: Typical G. nepenthes was found only in one sample from about the middle of the type Kapitean.

RECORDED STRATIGRAPHIC RANGE: Waiau to Lower Opoitian (Middle Miocene to Lower Pliocene).

Globigerina pachyderma (Ehrenberg), Pl. 9, figs. 139 - 145.

1861. Aristerospira pachyderma Ehrenberg; K. Preuss. Akad. Wiss. Berlin, Monatsber., p. 276, 277, 303 - Ehrenberg, 1872, K. Akad. Wiss. Berlin, Abh., Jahrg. 1873, Pl. 1, fig. 4.
1960. Globigerina pachyderma; Bé, Contr. Cushman. Found. Foram. Res. II.(2): 64 - 68.
1960. Globigerina pachyderma; Bandy, J. of Pal. 34(4): 671-681.
1962. Globigerina pachyderma; Parker, Micropaleontology, 8(2): 224, 225, Pl. 1, fig. 26-35; Pl. 2, fig. 1 - 6.

REMARKS: The Westland fossils show the ontogenetic stages described by Bé (1960). The young form has a weak apertural lip and a relatively large aperture extending from umbilicus to near the periphery and faces obliquely

sideways. The adult form has usually four chambers in the last whorl, and has coarsely perforate walls; the final chamber is smaller than the penultimate and is more finely perforate, and the aperture has a strong lip, is narrower than in juveniles, and is directed towards the umbilicus.

In some samples, G. pachyderma grades towards G. dutertrei d'Orbigny. Various authors have mentioned latitudinal variation of the species in present day faunas. Bandy (1960) showed that Arctic and Antarctic populations are dominantly left coiling, and described a gradual change to right coiling towards higher latitudes. The species is abundant in the Upper Tongaporutuan to Opoitian of Westland, and about 99 percent of specimens coil to the left suggesting that the sea was cool. This conflicts with warm temperatures suggested by the occurrence of Cucullaea, Polinices, Olivella and other Mollusca of tropical affinities that are now extinct in New Zealand.

Dimensions: Three Hypotypes (Figs. 139, 140 - Ff353); diameters 0.27 mm., 0.22 mm.; (Fig. 141 - Ff354), diameters 0.27 mm., 0.26 mm.; (Figs. 142, 143- Ff355), diameters 0.25 mm., 0.22 mm., (Figs. 144, 145- Ff356), diameters 0.24 mm., 0.22 mm.

DISTRIBUTION: In the Kapitea Creek section G. pachyderma is ubiquitous and common to abundant in all Kapitean and Opoitian samples. In the other sections it occurs in varying abundance in many samples ranging from the Upper Tongaporutuan to Opoitian.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene) to Recent.

Globigerina parabolloides Blow, pl. 9, figs. 146 - 149.

1959. Globigerina parabolloides Blow; Bull. Amer. Paleont. 39 (178): 179, Pl. 10, fig. 46 a-c.

1962. Globigerina parabolloides; Takayanagi & Saito, Sci. Rpts. Tohoku. Univ. 2nd Ser.(Geol).Spec. Vol. 5: 90, Pl. 25, figs. 3 a-c.

1962. Globigerina parabulloides, Blow & Banner, in Eames, Banner, Blow and Clarke. Fundamentals of Mid-Tertiary Stratigraphic Correlation, 137 table, 138.

1965. Globigerina parabulloides; Gibson, (in press).

REMARKS: Small elongate specimens, with four rather embracing chambers in the final whorl, and a low laterally restricted aperture with a distinct thin lip were referred to this species.

Dimensions: Two Hypotypes (Figs. 146 - 148 - Ff357), diameters 0.30 mm., 0.27 mm. (Fig. 149 - Ff358), diameters 0.31 mm., 0.27 mm.

DISTRIBUTION: Varying in abundance in the upper part of the Kapitea Creek section, in the Tongaporutuan and Kapitean of the Callaghans Creek section, and in many Kapitean and Opoitian samples from Corehole F.

OBSERVED STRATIGRAPHIC RANGE: Kapitean and Opoitian (Upper Miocene to Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Lower to Upper Tongaporutuan (Upper Miocene).

Globigerina praebulloides Blow, Pl. 9, figs. 150 - 152.

1959. Globigerina praebulloides Blow; Bull. Amer. Paleont. 39 (178): 180 - 81, Pl. 8, fig. 47 a-c. Pl. 9, fig. 48.

1960. Globigerina praebulloides; Jenkins, Micropaleontology, 6(4): 352, Pl. 2, fig. I a-c.

1962. Globigerina praebulloides; Takayanagi & Saito, Sci. Rpts. Tohoku. Univ. 2nd Ser.(Geol). Spec.Vol. 5: 90, Pl. 25, fig. 4 a-c.

1962. Globigerina praebulloides praebulloides; Blow & Banner, in Eames, Banner, Blow and Clark. Fundamentals of Mid-Tertiary Stratigraphical Correlation. Univ. Press, Cambridge: 92-3, 137 table, 138, Pl. 9, fig. 0 - Q.

1965. Globigerina praebulloides; Gibson, (in press).

REMARKS: Many specimens are identical in shape with Globigerina praebulloides (emended, Blow, 1962) and have an elongate equatorial profile, chambers increasing rapidly in size, an assymetric arched aperture with a distinct rim like lip. There is considerable variation, in the size and shape of the aperture and some specimens have no lip. In some samples G. praebulloides grades into forms referred to G. parabulloides Blow. The elongate shape and smaller less strongly arched aperture of G. praebulloides distinguish it from G. bulloides.

Dimensions: Hypotype (N.Z.G.S.Cat. No. FP1395); diameters 0.33 mm., 0.27 mm.

DISTRIBUTION: This is the dominant pelagic species. It is ubiquitous and generally abundant in the Kapitea Creek section. It occurs in varying abundance in many other samples from the Lower Tongaporutuan to Opoitian in other sections.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Pliocene).

Globigerina quinqueloba Natland, Pl. 9, figs. 153, 154.

1938. Globigerina quinqueloba Natland, Scripps. Inst. Oceanography Bull. Tech. Ser. 4(5): 149, Pl. 6, fig. 7.

1962. Globigerina quinqueloba; Parker, Micropaleontology, 8(2): 225-226, Pl. 2, fig. 7 -16.

1963. Globigerina quinqueloba; Kustanovich, N.Z.J. Geol. Geophys. 6(4): 556, Pl. 3, fig. 42, 43.

1965. Globigerina quinqueloba; Gibson, (in press).

Dimensions: Hypotype (Ff359); diameter 0.16 mm.

DISTRIBUTION: Typical specimens occur in varying abundance in a few isolated Kapitean samples from the Kapitea Creek, Corehole F and Eight Mile Creek sections, and two samples from the Callaghans Greensand of the Callaghans Creek section.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan to Kapitean.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Upper Tongaporutuan. (Middle Miocene to Upper Miocene).

Globigerina trilocularis d'Orbigny, Pl. 9, figs. 185, 186.

1826. Globigerina trilocularis d'Orbigny, Ann. Sci. Nat. 7: 277, No. 2.
(nom. nud.)

1832. Globigerina trilocularis; Deshayes, Encyclopedie Methodique, 2(2):
170.

1897. Globigerina trilocularis d'Orbigny; Fornasini, Rend. R.Accad.Sci.Ist.
Bologna. 2(I): 12, Pl. 1, fig. 6 - 7a.

1960. Globigerina trilocularis; Bermudez, Memoria del III Congreso Geologico
Venezolano - Tomo III Boletin de Geologia - Spec.Publ.3: 1202-1204,
Pl. 5, fig. 10, 11.

REMARKS: A single specimen compares well with the figured types of Fornasini.
It characteristically has three chambers in the last whorl, chambers
increasing rapidly in size as added and a low arched aperture with a thin
narrow lip.

Dimensions: Hypotype (Ff360); diameters 0.32 mm., 0.23 mm.

DISTRIBUTION: Middle of the type Kapitean section. (f647).

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

Globigerina woodi Jenkins, Pl. 10, figs. 157 - 159.

1960. Globigerina woodi Jenkins; Micropaleontology, 6(4): 352, Pl. 2,
fig. 2 a - c.

1961. Globigerina apertura; Hornibrook, N.Z.geol.Surv.paleont. Bull. 34(I)
148. Pl. 21, fig. 432-3, 435.

1965. Globigerina woodi; Gibson, (in press).

REMARKS: The characteristic medium sized arched aperture, radial sutures and coarsely pitted ornament makes this species easily identifiable.

Dimensions: Hypotype (Ff361); diameters 0.36 mm., 0.30 mm.

DISTRIBUTION: Generally abundant from Waiauan to Waitotaran.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Pliocene)

Globigerina zealandica Hornibrook, Pl. 10, fig. 160.

1961. Globigerina zealandica Hornibrook, N.Z. geol. Surv. paleont. Bull.

34(I): 150, Pl. 21, fig. 436 - 8, Pl. 28, fig. 551.

1965. Globigerina zealandica; Gibson, (in press).

REMARKS: Specimens are densely and finely spinose, have a small aperture hemmed in by the surrounding chambers and strong spines at the aperture in some specimens. Chambers are a little more embracing than in the types.

Dimensions: Hypotype (N.Z.G.S. Cat.No. FP1396); diameters 0.28 mm., 0.20 mm.

DISTRIBUTION: In the Kapitean Creek section G. zealandica is common in the highest Kapitean sample. Elsewhere it occurs rarely in scattered Kapitean samples from Corehole F and from Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Waitakian to Waitotaran (Upper Oligocene to Pliocene).

Genus GLOBIGERINITA Bronnimann, 1951 emended Parker, 1962.

TYPE SPECIES: Globigerinita naparimaensis Bronnimann.

Globigerinita glutinata (Egger), Pl. 10, fig. 161 - 165.

1893. Globigerina glutinata Egger; Abh. K. bayer. Akad. Wiss., math - phys.

Kl., 18: 371, Pl. 13, fig. 19 - 21.

1962. Globigerina glutinata; Belford, Bur.Min. Res. Bull. 62(I): 11, 12.
Pl. 2, fig. 10 - 16; Text. fig. 2, 1 - 6.
1962. Globigerina glutinata; Takayanagi & Saito, Sci. Rpts. Tohoku. Univ.
2nd ser. (Geol.) Spec. Vol. 5: 86-88, Pl. 27, fig. 13 a-c, 17 a-c.
1962. Globigerinita glutinata; Parker, Micropaleontology, 8(2): 246, 248,
249, Pl. 9, fig. 1 - 16.
1965. Globigerina incrusta; Gibson, (in press).

REMARKS: Parker gives a summary of the literature dealing with the two related species G. glutinata and G. naparimaensis Bronnimann, and reveals some of the taxonomic problems. Belford, and Takayanagi and Saito, have treated G. glutinata as a Globigerina, regarding the bullae as having no taxonomic significance. Parker however stated (P. 246) that it is not the presence of a bullae which defines Globigerinita but a combination of the various possible chamber arrangements together with the character of the wall (non-spinose living condition, smooth or finely hispid walls).

Takayanagi & Saito regard G. naparimaensis as a synonymy of G. glutinata but Parker on comparison of types of G. naparimaensis and G. glutinata regards them as having small but significant differences. (G. glutinata has slightly more inflated chambers which increase more rapidly in size as added; only very minute spiral apertures can be detected in G. naparimaensis).

A form of Globigerinita is abundant in the Callaghans Creek section. Spiral apertures where present are small as in G. naparimaensis, but other characters are like those of G. glutinata.

The following different forms were observed:

Specimens with a single simple primary aperture, one, two or three spiral apertures; some spiral apertures covered by small bullae; spiral bulla having apertures at their junction with primary sutures; simple umbilical

bullae with infralaminar apertures only at the contact of the bulla and the sutures of the primary chambers; infralaminar apertures at the contact suture of the bulla and the primary chambers; umbilical bulla as a tube-like extension along the sutures of the primary chambers, or expanded to about the same diameter as the final primary chamber.

When the bullae are removed no distinction can be made from forms having no bullae. The test in all specimens is either smooth or finely hispid.

Dimensions: Two Hypotypes (Figs. 161, 162 - Ff362), diameters 0.30 mm., 0.25 mm (Figs; 163-165- Ff363), diameters 0.33 mm., 0.27 mm.

DISTRIBUTION: Found only in a number of Kapitean samples from Callaghans Creek, particularly abundant in f665.

OBSERVED STRATIGRAPHIC RANGE: Kapitean.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Upper Tongaporutuan (Middle Miocene to Upper Miocene).

Globigerinita uvula (Ehrenberg), Pl. 10, figs. 167, 168.

1861. Pylodexia uvula Ehrenberg; K. Preuss. Akad. Wiss. Berlin, Monatsber.: 276, 277, 308.

1931. Globigerina bradyi; Weisner, in Drygalski, Deutsche Subpolar - Exped. 1901 - 1903. 20 (Zool. 12) : 133.

1962. Globigerinita uvula; Parker, Micropaleontology, 8(2): 252 - 253, Pl. 8, fig. 14 - 26.

1965. Globigerina bradyi; Gibson, (in press).

REMARKS: Tiny, high spired forms are referred to this species. The aperture varies from a low slit to a moderately high arch at the base of the final chamber, and in all cases is bordered by a thin lip.

One specimen (Pl. 10, figs. 167, 168) has a small supplementary aperture

at the junction of the spiral suture and a radial suture of the final whorl.

Dimensions: Hypotype (Ff364), diameters 0.20 mm., 0.18 mm.

DISTRIBUTION: Rare in a sample from high in the Kapitean of Corehole F, and common in the Lower Tongaporutuan of Corehole D.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Upper Tongaporutuan (Middle Miocene to Upper Miocene).

Globigerinita aff. uvula (Ehrenberg), Pl. 10, fig. 166.

REMARKS: A single specimen is larger, thicker walled and more coarsely pitted than G. uvula and compares well with the form distinguished by Gibson (in press) as G. aff. bradyi.

Dimensions: Figured specimen (N.Z.G.S.Cat. No. FP1397); diameters 0.30 mm., 0.27 mm.

DISTRIBUTION: A Kapitean sample (f687) from Corehole D.

OBSERVED STRATIGRAPHIC RANGE: Kapitean.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Middle Tongaporutuan (Middle Miocene to Upper Miocene).

Genus GLOBOQUADRINA Finlay, 1947.

TYPE SPECIES: Globorotalia dehiscens Chapman, Parr & Collins.

Globoquadrina altispira globosa Bolli, Pl. 10, figs. 169, 171.

1957. Globoquadrina altispira globosa Bolli; U.S. Nat.Mus.Bull. 215: 111, 112, pl. 24, figs. 9a - 10c.

1959. Globoquadrina altispira globosa; Blow, Bull., Amer. Pal. 39 (178): 183, Pl. 11, figs. 52a - c.

1962. Globoquadrina altispira globosa; Takayanagi & Saito, Sci. Rpts. Tohoku. Univ. 2nd. ser. (Geol.) Spec. Vol. 5: 92, Pl. 25, figs. 8a, b.

REMARKS: Two specimens with axially elongate globular chambers are referred to this species, not previously mentioned in New Zealand literature.

Dimensions: Hypotype (N.Z.G.S.CAT. No. FP1398); diameters 0.25 mm., 0.22 mm.

DISTRIBUTION: One specimen from the top Kapitean sample of Corehole F and one in a lower Kapitean sample from Corehole D.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

Globoquadrina dehiscens (Chapman, Parr & Collins)

1934. Globorotalia dehiscens Chapman, Parr & Collins; J. Linn. Soc. (Zool.) 38 (262): 569, Pl. II, fig. 36.

1959. Globoquadrina dehiscens; in Fleming ed; Lex. Strat. int. 6 Oceanie (4): 166 Fleming; table 6, Hornibrook.

1961. Globoquadrina dehiscens; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 153, Pl. 22, figs. 446, 447, 449.

1965. Globoquadrina dehiscens; Gibson, (in press).

DISTRIBUTION: A single specimen was found in the Upper Tongaporutuan of Corehole D, the highest reported occurrence in Westland to date. Common in the Waiauan of Kapitea Creek.

RECORDED STRATIGRAPHIC RANGE: Waitakian to Opoitian (Upper Oligocene to Lower Pliocene).

Genus ORBULINA d'Orbigny, 1839.

TYPE SPECIES: Orbulina universa d'Orbigny.

Orbulina universa d'Orbigny, Pl. 10, fig. 172.

1839. Orbulina universa d'Orbigny; in De la Sagra, Hist. Phys. Pol. Nat. Cuba. "Foraminiferes": 35, Pl. I, fig. 1.

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1959. Orbulina universa; Hornibrook, in Fleming ed; Lex. Strat. int. 6
Oceania (4): 76, 191, table 6.

Orbulina universa; Gibson.

Dimensions: Hypotype (Ff367); diameter 0.53 mm.

DISTRIBUTION: Fairly common in many samples ranging throughout the sections; especially persistent in the Kapitea Creek section.

RECORDED STRATIGRAPHIC RANGE: Lillburnian (Middle Miocene) to Recent.

Genus GLOBOROTALIA Cushman, 1927.

TYPE SPECIES: Pulvinulina menardii (d'Orbigny), var. tumida Brady.

Globorotalia conomiozea Kennett, n.sp., Pl. II, figs. 181 - 183.

1962. Globorotalia cf. miozea (conical); Kennett, N.Z.J. Geol. Geophys.
5(4): 625 list.

DESCRIPTION: Test planoconvex, spiral side typically flat but sometimes slightly convex. Umbilical side strongly vaulted. Peripheral outline subovate, fairly weakly lobulate. Margin acute with a strong to weak keel. Wall finely perforate with varying ornament but typically with pustules developed strongly on the umbilical side of the first 2 or 3 chambers of the final whorl, and weakly or not at all on later chambers. Chambers total 14 - 17 with 4 - 4 $\frac{1}{2}$ chambers in the final whorl, inflated on the umbilical side. Sutures on the spiral side thickened, transverse sutures strongly curved; on the umbilical side slightly curved, depressed. Umbilicus small, deep. Aperture high arched generally bordered by a distinct lip, interior-marginal, extraumbilical.

Dimensions of Holotype: diameters 0.45 mm., 0.38 mm., thickness 0.27 mm.

Variability: Specimens show considerable variation in the degree of development of the keel and the shape of the umbilical side, ranging from conical

to convexly rounded. Rounded forms are less common and some have a weak keel and small final chamber and are sub-spherical in outline.

TYPES: Holotype (F369) and 26 paratypes (Fp369).

TYPE LOCALITY: S51f648, Kapitea Creek section, Westland, N.Z. grid ref. 668668.

TYPE LEVEL: Kapitean Stage, Upper Miocene.

REMARKS: Fleming (1959) in discussing the Kapitean Stage, referred to this species as an unnamed Globorotalia, a highly conical member of the G. miozea lineage. G. conomiozea differs from G. menardii miocenica Palmer in being more strongly vaulted on the umbilical side, in having $4-4\frac{1}{2}$ instead of 6 chambers per whorl, a stronger keel, more highly arched aperture and hispid ornament.

G. conomiozea is a conical member of the G. miozea plexus. In the Kapitea Creek and Corehole F sections it shows a well defined evolutionary change with time and gives rise to G. crassaformis (Galloway & Wissler) in the Opoitian. A separate paper deals in detail with this evolutionary change (Kennett, in press), but briefly the sequence is as follows: From about the base of the Kapitean the average conical angle of population increases, the keel becomes reduced and the periphery broadly rounded to give rise in the Opoitian to G. crassaformis.

Populations in samples near the Kapitean - Opoitian boundary in Corehole F show gradation between G. conomiozea and G. crassaformis. In Kapitea Creek due to a large sampling interval, the gradational change was not clearly distinguished, but many specimens in the highest sample containing G. conomiozea differ from G. crassaformis only in possessing a weak keel. The G. crassaformis population typically has most individuals with fairly flat spiral sides, but some have more convex spiral sides, are generally more inflated and quadrate, and are similar to G. inflata (d'Orbigny). It is possible that G. crassaformis

is no more than a variant of G. inflata.

DISTRIBUTION: Occurs fairly abundantly in nearly all Kapitean samples from all sections. In the Kapitea Creek, Corehole F and Eight Mile Creek sections it is replaced by G. crassaformis in the Opoitian.

OBSERVED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

Globorotalia menardii (d'Orbigny) ^{cf.} miotumida Jenkins.

1960. Globorotalia menardii (d'Orbigny) miotumida Jenkins; Micropaleontology, 6 (4): 362, Pl. 4, fig. 9 a - c.

Globorotalia cultrata miotumida: Gibson.

REMARKS: Moderately compressed, strongly keeled and fairly smooth forms are referred to G. menardii cf. miotumida. They differ from typical forms of the subspecies in having less convex spiral sides. The number of chambers in the final whorl varies from 4 to $4\frac{1}{2}$.

A distinct form referred to on the range charts as G. menardii (d'Orbigny) - (pustulose) occurs abundantly in an Opoitian sample from Kapitea Creek. It is distinguished by unusually large size, a strongly vaulted umbilical side, and on many specimens dense pustules over the entire test.

The widely used name G. menardii (d'Orbigny) is used instead of the recently revived name G. cultrata (d'Orbigny) in agreement with the view put forward by Ruth Todd (1961).

DISTRIBUTION: G. menardii cf. miotumida was found only in the Callaghans Creek section where it is abundant in Lower Tongaporutuan but scarce in Upper Tongaporutuan and Kapitean.

RECORDED STRATIGRAPHIC RANGE: Waiauian to Kapitean (Middle Miocene to Upper Miocene).

Globorotalia scitula (Brady), Pl. II, figs. 185 - 189.

1882. Pulvinulina scitula Brady; Proc. Roy. Soc. Edinburgh, II: 716.

1940. Globorotalia scitula; Finlay & Marwick, Trans. roy. Soc. N.Z. 70(I):123

1959. Globorotalia scitula scitula Blow; Bull. Amer. Pal. 39 (178): 219,
Pl. 19, fig. 126 1-c.

1960. Globorotalia scitula; Bermudez, memoria del III congreso Geologica
Venezolano - Tomo III Boletin de Geologia - Spec. Publ. 3 separate 1961
1301-2, Pl. 14, fig. 4.

1962. Globorotalia scitula; Parker, Micropaleontology, 8(2): 238, 239, Pl. 6,
fig. 4 - 6.

1965. Globorotalia scitula; Gibson, (in press).

Dimensions: Three Hypotypes (Figs. 185, 186, 188 - Ff 370), diameters, 0.21 mm
0.20 mm. (Fig. 187 - Ff371) diameters 0.13 mm., 0.12 mm. (Fig. 189 - Ff372,)
diameters 0.41 mm., 0.35 mm.

DISTRIBUTION: Generally scarce and occurs in isolated samples from most
sections, but ranges from Lower Tongaporutuan to Opoitian.

RECORDED STRATIGRAPHIC RANGE: Waiauan to ? Kapitean (Middle Miocene to
Upper Miocene).

OBSERVED STRATIGRAPHIC RANGE: Lower Tongaporutuan to Opoitian (Upper
Miocene to Pliocene).

Family ANOMALINIDAE

Genus ANOMALINOIDES Brotzen, 1942.

TYPE SPECIES: Anomalinoides plummerae Brotzen = Anomalina
grosserugosa Plummer (not Gumbel).

Anomalinoides parvumbilia (Finlay), Pl. 12, figs. 190 - 192.

1940. Anomalina parvumbilia Finlay; Trans. roy. Soc. N.Z. 69 (4): 461, Pl. 65, fig. 157 - 159.
1959. Anomalinoides parvumbilia; Fleming, in Fleming ed; Lex. Strat. int. 6 Oceanie (4): 65, 267.
1961. Anomalinoides parvumbilia; Hornibrook, N.Z. geol. Surv. paleont. Bull. 34(I): 156, Pl. 23, fig. 458 - 60.

REMARKS: Specimens differ from the types (Hutchinsonian, Lower Miocene) and from the specimen figured by Hornibrook (1961) (Awamoan, Lower Miocene) in having about 20 instead of 28 chambers, and 10 or 11 instead of 12 to 13 chambers in the final whorl.

Dimensions: Hypotype (Ff373); diameters 0.29 mm., 0.22 mm.

DISTRIBUTION: Almost ubiquitous, and fairly common throughout all sections.

RECORDED STRATIGRAPHIC RANGE: Whaitangaroan to Nukumaruan (Lower Oligocene to Pleistocene).

Anomalinoides spherica (Finlay), Pl. 12, figs. 193 - 195.

1940. Anomalina spherica Finlay; Trans. roy. Soc. N.Z. 69(4): 460, 461, Pl. 66 fig. 166 - 171.
1940. Anomalina spherica; Finlay & Marwick, Trans. roy. Soc. N.Z. 70(I): 22
1957. Anomalinoides spherica (Finlay) spherica; Vella, N.Z. geol. Surv. paleont. Bull. 28: 39.
1959. Anomalinoides spherica; Fleming, in Fleming ed; Lex. Strat. int. 6 Oceanie (4): 167.
1961. Anomalinoides spherica; Hornibrook, N.Z. geol. Surv. Paleont. Bull. 34(I): 156.
1962. Anomalinoides spherica; Vella, Trans. roy. Soc. N.Z. Geol. I (12): 192 table.

1965. Anomalinoides spherica; Gibson (in press).

Dimensions: Hypotype (N.Z.G.S. Cat. No. FP1374); diameters 0.32 mm. 0.30 mm.

DISTRIBUTION: Generally scarce in the lowest 2 or 3 Kapitean samples from the Kapitea Creek, Callaghans Creek and Corehole D sections; fairly common in nearly all Kapitean to Opoitian samples from Corehole F and in the Waiauan, Callaghans Conglomerate, Opoitian and Waitotaran of Eight Mile Creek.

RECORDED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene) to Recent.

Genus CIBICIDES Montfort, 1808.

TYPE SPECIES: Cibicides refulgens Montfort.

Cibicides deliquatus Finlay, Pl. 12, figs. 196, 197, 201.

1940. Cibicides deliquatus Finlay; Trans. roy. Soc. N.Z. 69 (4): 465

1959. Cibicides deliquatus; Hornibrook, in Fleming ed; Lex. Strat. int.
6 Oceanie (4): 404, 428.

1962. Cibicides deliquatus; Vella, Trans.Roy.Soc. N.Z.Geol. I (12): 192 table.

1965. Cibicides deliquatus; Gibson, (in press).

REMARKS: Shows considerable variation in convexity of the dorsal surface and the width of the keel. Forms from the upper part of the Kapitea Creek section commonly have transparent keels.

Dimensions: Hypotype (Ff375); diameters 0.77 mm., 0.57 mm.

DISTRIBUTION: In the Kapitea Creek section it is ubiquitous and abundant in all samples. In the other sections it occurs in varying abundance in most Waiauan to Waitotaran samples, but in Corehole F is restricted to the lower Kapitean.

RECORDED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene) to Recent.

RECORDED ECOLOGIC RANGE: ? Haeuslerella to Robulus Biofacies (? 200 - 2000 ft.)

Cibicides molestus Hornibrook, Pl. 12, figs. 202 - 204.

1959. Cibicides n.sp. (sinuous ventral sutures); Hornibrook, in Fleming ed;
Lex. Strat. int. 6 Oceanie (4): 404.

1961. Cibicides molestus, Hornibrook; N.Z. geol. Surv. paleont. Bull. 34(I):
163, Pl. 24, fig. 478, 479, 483.

1962. Cibicides molestus; Vella, Trans.roy.Soc.N.Z.geol.I(12): 192 list.

1965. Cibicides molestus; Gibson, (in press).

REMARKS: Shows considerable variation in convexity of dorsal and ventral surfaces. Most specimens are biconvex with the dorsal side slightly more convex.

Dimensions: Hypotype (Ff377); diameters 0.42 mm., 0.41 mm.

DISTRIBUTION: In the Kapitea Creek section it is ubiquitous and abundant in all samples. In the other sections it occurs in variable abundance in most Waiauian to Opoitian samples but is restricted to the lower half of the Corehole F section.

RECORDED STRATIGRAPHIC RANGE: Bortonian to Middle Waitotaran (Middle Eocene to Pliocene).

RECORDED ECOLOGIC RANGE: *Haeuslerella* to *Robulus* Biofacies (200 - 2000 ft.).

Cibicides gibsoni Kennett, n.sp., Pl. 12, figs. 198 - 200.

DESCRIPTION: Test medium sized, compact, dorsal surface slightly convex to flat, coarsely perforate, with sutures of the early whorls obscured by a deposit of opaque calcite, often penetrated by coarse pores. Ventral surface very convex, smooth without pits. Dorsal sutures strongly limbate moderately recurved, flush between early chambers, slightly depressed between later chambers. Umbilicus covered by a flush to slightly depressed

glassy knob. Periphery marked by a strong, rounded to sharp keel. The aperture a narrow slit that extends from just under the periphery of the ventral to just over onto the dorsal side and occasionally half way along the width of the final chamber. About 8 - 10 chambers in the final whorl.

Dimensions of holotype: diameters 0.35 mm., 0.30 mm.

Variability: The size of the dorsal perforations vary considerably and in some individuals the umbilical plug is large and raised.

TYPES: Holotype (F376) and 15 paratypes (Fp 376).

TYPE LOCALITY: S51f648, Kapitea Creek section, Westland, N.Z., grid ref. 668668.

TYPE LEVEL: Kapitean Stage, Upper Miocene.

REMARKS: Distinguished by the slightly convex, strongly perforate and calloused dorsal side with straight sutures, and the ventral side strongly convex, smooth with umbilical plug. Differs from C. marlboroughensis Vella in being more strongly perforate dorsally and less strongly perforate ventrally, ventral side less convex, less limbate ventral sutures and straight instead of curved dorsal sutures. G. ihungia Finlay differs mainly in being dorsally flat to slightly concave, in having ventral surface with pits and a less strong keel.

Named after Dr. G.W. Gibson.

DISTRIBUTION: In the Kapitea Creek section C. gibsoni is mostly abundant in most Kapitean and Opoitian samples. It occurs fairly rarely in some Kapitean and Opoitian samples of the other sections, and is abundant in the Waiauan of Eight Mile Creek.

OBSERVED STRATIGRAPHIC RANGE: Waiauan to Opoitian (Middle Miocene to Lower Pliocene).

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Table II - Index of Fossil Localities

(Full locality details are recorded in the Sheet Fossil Master-file for Westland at the N.Z. Geological Survey, Greymouth.)

<u>Sheet fossil number</u>	<u>Locality</u>	<u>Grid ref.</u>	<u>Lithology</u>	<u>Age</u>
f642	Kapitea Creek	673660	9943d	Sw
f643		673660	7431hG	Tk
f644		672662	9942dM	Tk
f645		674664	9942dM	Tk
f646		670665	9942dM	Tk
f647		669667	9942dM	Tk
f648		668668	9942dM	Tk
f649		664672	9942cM	Wo
f650		663674	9942cM	Wo
f651		660675	9942dM	Wo
f652	Callaghans Creek	698627	9933cM	L.Tt
f653		698627	9933cM	L.Tt
f654		698627	6441GG	U.Tt
f655		697626	6441GG	U.Tt
f656		697626	6441G	U.Tt
f657		697626	6441kGGS	U.Tt
f658		697626	7924hG	U.Tt
f659		697625	7742dMG	Tk
f661		694625	7742dMSG	Tk
f662		693625	7842dMO	Tk
f663		692623	7842dM	Tk
f664		692621	7742dMO	Tk
f665		692620	7742a	Tk
f666		692619	8742dMO	Tk

<u>Sheet fossil number</u>	<u>Locality</u>	<u>Grid ref.</u>	<u>Lithology</u>	<u>Age</u>
f667	depth 30-40 ft.	672583		Wo
f668	depth 40-50 ft.	672583		Wo
f669	depth 50-52 ft.	672583	No Lithologies	Wo
f670	Corehole F. depth 90-100ft.	672583	or residues	Wo
f671	depth 125-130ft.	672583	available	Wo
f672	depth 130-140ft.	672583		Tk
f673	depth 150-155ft.	672583		Tk
f674	depth 165-170ft.	672583		Tk
f675	depth 170-175ft.	672583		Tk
f676	depth 175-180ft.	672583	No	Tk
f677	depth 190-200ft.	672583	Lithologies	Tk
f678	depth 200-210ft.	672583	or	Tk
f679	depth 210-220ft.	672583	Residues	Tk
f680	depth 220-230ft.	672583	available.	Tk
f681	depth 230-240ft.	672583		Tk
f682	depth 250-260ft.	672583		Tk
f683	depth 270-290ft.	672583		Tk
f684	depth 300-310ft.	672583		Tk
f685	depth 340-350ft.	672583		Tk
f686	depth 22 ft.	664575	MMS.	Tk
f687	depth 35 ft.	664575	MS.	Tk
f688	Corehole D. depth 65 ft.	664575	MMS.	Tk
f689	depth 126ft.	664575	GS.	U.Tt
f690	depth 131ft.	664575	GS.	U.Tt

Only residues available.

<u>Sheet fossil number</u>	<u>Locality</u>	<u>Grid ref.</u>	<u>Lithology</u>	<u>Age</u>
f691 |	depth 141ft.	664575	Mudstone	L.Tt
f692 } Corehole D.	depth 160ft.	664575	Mudstone	L.Tt
f694 Corehole F.	depth 80-90 ft.	672583		Wo
f695 }		826755	8742dM.	Tk.
f696 }		823758	8842dMM	Sw
f697 }		823758	3562eP.	U.Tt
f698 } Eight Mile Creek		823758	6654GGSS	U.Tt
f699 }		830755	8842dM	Wo
f700 }		833753	9852dMS.	Ww
f701 }		834750	9852dMS	Ww

Plate 5.

- Figs. 73, 74 - Pullenia bulloides (d'Orbigny), f648; X100.
Figs. 75, 76 - Pullenia quinqueloba (Reuss), f648; X100.
Figs. 77, 78 - Astrononion vadorum Vella, 78, f697; X72.
Figs. 79, 80 - Melonis zeobesus Vella, f666; X72.
Figs. 81, 82 - Pacinonion parki (Hornibrook), f687; X72.
Figs. 83, 84 - Florilus flemingi (Vella), f665; X72.
Figs. 85, 88 - Florilus olsoni Kennett, n. sp., 85, holotype; X150; 86, paratype, side view, 87, same paratype, peripheral view; 88, juvenile paratype; X100. S51f656.

Plate 4.

- Figs. 51, 52 - Bolivina cf. acerosa Cushman, 52, apertural view; f668; X100.
- Figs. 53, 54 - Bolivina watti Gibson, 53, apertural view; f648; X72.
- Figs. 55, 56 - Rectobolivina maoria Finlay, 56, apertural view, f697; X72.
- Figs. 57, 58 - Bolivina petiae Gibson, 57, apertural view; f688; X72.
- Fig. 59 - Rectobolivina striatula (Cushman), f685; X50.
- Fig. 60 - Bolivina numerosa Vella, f644; X72.
- Figs. 61, 62 - Bolivinita pohana Finlay, 62, apertural view; f666; X72.
- Figs. 63, 64 - Bolivinita pliozea Finlay, 63, apertural view; f672; X72.
- Fig. 65 - Cassidulina laevigata d'Orbigny, f646; X72.
- Fig. 66 - Cassidulina subglobosa d'Orbigny, f646; X72.
- Fig. 67 - Cassidulina neocarinata Thalmann, f643; X72.
- Fig. 68 - Cassidulinoides orientalis (Cushman), f643; X72.
- Figs. 69 - 71 - Chilostomella ovoidea Reuss, 69, f676; 70, 71, S51f665; X50.
- Fig. 72 - Sphaeroidina bulloides d'Orbigny, f644; X72.

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Plate 3.

- Figs. 35, 36 - Bulimina aculeata d'Orbigny, 35, f648; 36, f643; X72.
- Fig. 37 - Bulimina inflata Sequenza, f685; X100.
- Fig. 38 - Bulimina cf. striata d'Orbigny, (small var.) f648; X100.
- Fig. 39 - Neouvigerina vadeszens (Cushman), f648; X72.
- Figs. 40 - 42 - Virgulina vellai Kennett, n. sp., 40, holotype; 41, paratype (S51f674), peripheral view; 42, same paratype, side view; X100.
- Fig. 43 - Hofkeruva (Laminiuva) rodleyi rodleyi Vella, f697; X72.
- Fig. 44 - Hofkeruva (Trigonouva) zeacuminata Vella, f646; X50.
- Fig. 45 - Hofkeruva (Trigonouva) pliozea Vella, f648; X72.
- Figs. 46, 48 - Hofkeruva (Trigonouva) lutorum Vella, 46, f648; 48, f646; X72.
- Fig. 47 - Hofkeruva (Tereuva) paeniteres (Finlay), f644; X72.
- Figs. 49, 50 - Trifarina bradyi Cushman, f654; X72.

Plate 2.

- Fig. 17 - Haeuslerella finlayi Vella, f648; X32.
- Fig. 18 - Karrerella cylindrica Finlay, f665; X72.
- Figs. 19-21- Quinqueloculina waimea Kennett, n. sp., Holotype, 19, front view
20, rear view; 21, apertural view; S51f672; X72.
- Figs. 22-25- Quinqueloculina sp., (low bifid tooth), 22, apertural view; 23,
detail of aperture; 24, rear view; 25, front view; f658; X50.
- Figs. 26-28- Quinqueloculina incisa Vella, 26, rear view; 27, front view; 28,
apertural view; f661; X50.
- Figs. 29-31- Quinqueloculina pygmaea Reuss, 29, apertural view; 30, rear view;
31, front view; f672; X72.
- Fig. 32 - Guttulina bartschi Cushman & Ozawa, f656; X50.
- Fig. 33 - Sigmomorphina cf. rhomboidalis Vella, f656; X50.
- Fig. 34 - Glandulina symmetrica Stache, f648; X50.

Plate 1.

- Figs. 1 - 5. - Textularia barnwelli Kennett, n. sp. I, side view of holotype; 2, peripheral view of holotype; 3, apertural view of holotype; 4, side view of paratype S51f666; 5, apertural view of same paratype; X72.
- Figs. 6 - 11. - Textularia kapitea Finlay, 7, apertural view; 8, peripheral view, f643; 10, peripheral view, II, apertural view, f676; X50.
- Fig. 12. - Haeuslerella morgani Finlay, f646; X32
- Fig. 13. - Siphotextularia cf. wairoana Finlay, f646; X72.
- Fig. 14. - Martinottiella clarae Gibson, f648; X32.
- Figs. 15, 16. - Siphotextularia awamoana Finlay, 16, apertural view, f661; X72.

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Plate 6.

- Figs. 89, 90 - Zeaflorilus parri (Cushman), f645; X50.
Figs. 91, 92 - Nonionella magnalingua Finlay, f644; X100.
Figs. 93, 96 - Nonionella zenitens Finlay, 93, f679; 94-96, f644; X100.
Figs. 97, 98 - Patellinella inconspicua (Brady), f662; X100.
Figs. 99, 101 - Discorbis cf. dimidiatus (Parker & Jones), f656; X50.
Figs. 102, 105 - Gavelinopsis lobatulus (Parr), 102-104, f674; 105, f666;
X72.

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Plate 7.

- Figs. 106 - 108 - Discorbinella cf. rarescens (Brady), f697; X100.
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M.D. King, photo

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M.D. King, photo

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M.D. King, photo

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M.D. King, photo

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THE KAPITEAN STAGE (UPPER MIOCENE)
AT CAPE FOULWIND, WEST COAST

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ABSTRACT

About 350 ft of Kapitean beds exposed in sea cliffs at Cape Foulwind are conformably overlain by Opoitian and conformably underlain by Tongaporutuan. Seven foraminiferal samples were collected from a uniform and continuous section of marine siltstone. A lithological column and a foraminiferal range chart are presented. Paleoeology and stratigraphic paleontology are discussed.

INTRODUCTION

Some 900 ft of Upper Tertiary rocks are exposed in sea cliffs west of Carters Beach, Cape Foulwind, Nelson, Sheet District S24 (Fig. 1A). P. G. Morgan and J. A. Bartrum (1915) correlated the rocks with the Upper Blue Bottom Formation of Westland of Upper Oamaru (Upper Miocene) age. More recent unpublished field work by members of the Geological Survey,

FIG. 1—A, Locality Map. B, Cape Foulwind section, showing location of samples.

particularly Dr H. W. Wellman, and micropaleontology by the late Dr H. J. Finlay have shown that the two stages of the Taranaki Series are represented.

Two one-day visits were made to the area (Jan. 1961; Jan. 1962). The succession consists of moderately soft, medium blue-grey, slightly micaceous siltstone with numerous bands of moderately soft, medium blue-grey sandstone. Bands of calcareous concretions occur throughout and are abundant near the top of the section. The strata dip south-east at about 9°. Outcrops are continuous except in the top 70 ft, where macrofossils are represented by casts only. Of the part of the section described, about 90 ft is Upper Tongaporutuan, about 350 ft Kapitean, and about 85 ft Opoitian.

Fossil samples are referred to by their Sheet Fossil Numbers. Sample localities are shown on Fig. 1 B. A detailed lithological succession and the stratigraphic positions of fossil samples are shown in Table 1.

TABLE 1—Cape Foulwind Section (upper part)

<i>Opoitian</i>	<i>Feet</i>
Siltstone weathered light brown	30
Medium grey siltstone bands alternating with thin medium-grained sandstone bands weathered light brown	40
Medium blue-grey siltstone (f523 at base)	14
Light blue-grey medium-grained sandstone	1
Medium blue-grey calcareous siltstone with concretion band	18
Light blue-grey medium-grained sandstone	1
<i>Kapitean</i>	
Medium blue-grey calcareous siltstone	24
Medium blue-grey calcareous siltstone with two 6 in. concretion bands	10
Light blue-grey fine-grained sandstone (f524 at base)	2
Medium blue-grey calcareous siltstone with four 3-6 in. concretion bands	18
Medium blue-grey calcareous siltstone with scattered macrofossils	24
Concretion layer	3
Medium blue-grey calcareous siltstone	3
Concretion band	1
Medium blue-grey calcareous siltstone with scattered macrofossils (f525 at base)	40
Band of lenticular concretions	2
Medium blue-grey calcareous siltstone	60
Grey medium-grained sandstone	1
Medium blue-grey siltstone with thin sandstone bands (f528 at base)	50
Band of lenticular concretions	2
Medium blue-grey calcareous siltstone with scattered well preserved macrofossils (f527)	18
Blue-grey medium-grained sandstone	3
Medium blue-grey calcareous siltstone with scattered macrofossils (f529)	7
As above but without macrofossils	23
Thin (1 ft 6 in.) bands of alternating siltstone and muddy siltstone	10
<i>Tongaporutuan</i>	
Concretion band	2
Medium blue-grey calcareous siltstone	10
Medium blue-grey calcareous mudstone	3
Medium blue-grey calcareous siltstone	15
As above but with lenticular concretions	30
Medium blue-grey coarse sandstone with poorly preserved shells and shell fragments	1
Medium blue-grey calcareous siltstone (f530)	3

PALEOECOLOGY

Lithofacies and biofacies vary only slightly from Upper Tongaporutuan through Kapitean to Opoitian. Foraminifera are frequent to abundant except in a few bands; Mollusca are scattered, poorly preserved, and infrequent to rare except in a few bands; ostracodes are infrequent; and echinoid spines and fish teeth and otoliths are rare (Table 2).

The biofacies is depth correlated with Pliocene and Upper Miocene biofacies in Wairarapa described by Vella (1962). According to Vella the Foraminifera *Karreriella cylindrica* Finlay and *Bigenerina pliocenica* Finlay occur in the Robulus, Semipelagic, and Eupelagic Biofacies with an estimated depth range of 1,000 ft to more than 4,000 ft, but *Robulus calcar* (Linnaeus) indicates the Haeuslerella Biofacies with an estimated depth range of 600 to 1,000 ft. The writer considers that *Textularia kapitea* Finlay (and *miozea* Finlay) and possibly *Bulimina aculeata* d'Orbigny are restricted to the Haeuslerella Biofacies and shallower biofacies. *Karreriella cylindrica*, *Bigenerina pliocenica*, and these inferred shallower-water species all occur together at Cape Foulwind and are considered to define a biofacies which has not yet been recognised in New Zealand and which is in effect a combination of the Haeuslerella Biofacies and the Robulus Biofacies. This previously unrecognised biofacies is here named the Karreriella Biofacies.

The depth range of the Karreriella Biofacies is probably narrow, being equal to the overlapping limits of the Haeuslerella Biofacies and the Robulus Biofacies as originally defined and is assumed to be at about 1,000 ft.

Karreriella cylindrica occurs only in two samples near the middle of the Kapitean and in the one Opoitian sample. *Bigenerina pliocenica* occurs only in the Opoitian sample. The shallower-water species are abundant in most parts of the section. The predominant biofacies is therefore the Haeuslerella Biofacies with the Karreriella Biofacies appearing only briefly near the middle of the Kapitean and again in the Basal Opoitian.

PALEONTOLOGICAL AGES

The distribution of Foraminifera is shown by a range chart (Table 2).

Typical *Textularia miozea* indicates that the lowest sample, f530, is older than Kapitean. *Globoquadrina debiscens* (Chapman, Parr, & Collins) is elsewhere rare above the base of the Kapitean. *Bolivinita* n. sp. aff. *pliozea* Finlay indicates that f530 is not older than Tongaporutuan and is probably Upper Tongaporutuan.

In the next higher sample, f529, *T. miozea* is replaced by *T. kapitea*, considered to indicate a Kapitean age. The Kapitean key gastropod species *Austrofusus coerulescens* Finlay (= *tuberculatus* Marwick) occurs in f527, 10 ft above f529, and the foraminifer *Bulimina aculeata*, generally considered to appear near the base of the Kapitean, appears first in f528, 30 ft above f529.

TABLE 2—Range Chart of Fossils from Cape Foulwind Section

(1 = rare; 2 = common; 3 = abundant)

	f530	f529	f527	f528	f526	f525	f524	f523
FORAMINIFERA								
<i>Textularia kapitea kapitea</i> Finlay		1		3	3	3		
<i>Textularia kapitea maritima</i> n. sp. (see Kennett, in press)							2	3
<i>Textularia miozea</i> Finlay	3							
<i>Textularia</i> n. sp. (see Finlay, 1947, p. 280)				1			2	
<i>Haeslerella morgani</i> (Chapman)		2		3	3	3	3	3
<i>Haeslerella parri</i> Finlay	3							
<i>Bigennerina pliocenica</i> Finlay								2
<i>Siphotextularia ihungia</i> Finlay							1	
<i>Siphotextularia subcylindrica</i> Finlay	1							
<i>Karrerella cylindrica</i> Finlay				2	1			2
<i>Martinottiella communis</i> d'Orbigny		1		1	3	1	1	2
<i>Spiroloculina novozealandica</i> Cushman & Todd				1				
<i>Lagena asperoides</i> Galloway & Morrey	1							
<i>Lagena aspera</i> Reuss								1
<i>Lagena distoma</i> Parker & Jones	1					1		
<i>Lagena laevis</i> (Montagu)				1	1	1	1	1
<i>Lagena striata</i> (d'Orbigny)	1	1		2	1	1	1	1
<i>Lagena sulcata</i> (Walker & Jacob)	1						1	
<i>Lagena chasteri</i> Millett					1			
<i>Oolina hexagona</i> (Williamson)							1	
<i>Oolina globosa</i> (Montagu)				1				
<i>Fissurina laevigata</i> Reuss				1				
<i>Fissurina marginata</i> (Walker & Boys)	1			1	1	1	1	1
<i>Fissurina quadrata</i> (Williamson)								1
<i>Robulus calcar</i> (Linneaus)	3	1		1	1	1	2	1
<i>Robulus gyrosalpinx</i> (Stache)				1			1	1
<i>Robulus loculosus</i> (Stache)	1	1		2	1	1	2	1
<i>Robulus totus</i> (Cushman)	1							
<i>Lenticulina peregrina</i> (Schwager)				2				1
<i>Lenticulina gibba</i> (d'Orbigny)	1							
<i>Saracenaria italica</i> Defrance	1	1		1	1	1	2	1
<i>Saracenaria angularis</i> Natland							1	
<i>Vaginulinopsis</i> n. sp.								2
<i>Vaginulinopsis sublegumen</i> Parr					1	1	1	1
<i>Vaginulina elegans</i> d'Orbigny							1	
<i>Marginulina subbullata</i> Hantken	2	1		1				
<i>Marginulina</i> spp.	1				1			
<i>Dentalina communis</i> d'Orbigny	1	1		2			1	1
<i>Dentalina consobrina</i> d'Orbigny				1				
<i>Dentalina soluta</i> Reuss	1	1		1	1		1	1
<i>Dentalina substrigata</i> Stache				1	1		1	
<i>Dentalina</i> cf. <i>baggi</i> Galloway & Wissler								
<i>Nodosaria affinis</i> Reuss	1				1		1	
<i>Nodosaria calomorphia</i> Reuss							1	
<i>Nodosaria filiformis</i> d'Orbigny				1				
<i>Nodosaria lamnulifera</i> Boomgart	1	1		1			1	1
<i>Nodosaria longiscata</i> d'Orbigny					1			
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)	3	2		3	3	3	3	3
<i>Lagenonodosaria</i> cf. <i>scalaris</i> (Batsch)				1	1			
<i>Lagenonodosaria</i> (smooth)	1			1				1
<i>Rectoglandulina rotundata</i> (Reuss)				1				
<i>Rectoglandulina</i> cf. <i>torrida</i> (Cushman)	1							

TABLE 2—continued

	f530	f529	f527	f528	f526	f525	f524	f523
<i>Glandulina symmetrica</i> Stache								1
<i>Guttulina</i> sp. indet.		1						1
<i>Bulimina aculeata</i> d'Orbigny				3	3			
<i>Bulimina</i> n. sp. cf. <i>striata</i> d'Orbigny	2			3	1			
<i>Bulimina notovata</i> Chapman		1						
<i>Globobulimina pacifica</i> Cushman					1			
<i>Hofkeruva</i> (<i>Trigonouva</i>) <i>zeacuminata</i> Vella	3	3		3	3			
<i>Hofkeruva</i> (<i>Trigonouva</i>) n. sp. (spined apex)								3
<i>Hofkeruva</i> (<i>Laminiuva</i>) cf. <i>zelamina</i> Vella				3	1	3	3	
<i>Hofkeruva</i> (<i>Tereuva</i>) <i>enteres</i> Vella					1			1
<i>Neonvigerina</i> sp.								
<i>Trifarina bradyi</i> Cushman		1						
<i>Bolivina affiliata</i> Finlay		1						
<i>Bolivina numerosa</i> Vella		2						
<i>Bolivina</i> aff. <i>parri</i> Cushman				1	2	1	1	
<i>Bolivina</i> n. sp. (long and thin)	1			1	1			
<i>Bolivinita pliozea</i> Finlay						1		2
<i>Bolivinita</i> n. sp. aff. <i>pliozea</i> Finlay	3	3		3	3	3	2	
<i>Cassidulina neocarinata</i> Thalmann	2	2		1				
<i>Cassidulina subglobosa</i> d'Orbigny							2	
<i>Cassidulinoides orientalis</i> (Cushman)	2	2		1	2	1	2	1
<i>Chilostomella ovoidea</i> Reuss				1		2		1
<i>Sphaeroidina bulloides</i> d'Orbigny	2	1		1	1	1	2	1
<i>Pullenia quinqueloba</i> (Reuss)	1	2		2	1	1	2	2
<i>Nonion flemingi</i> Vella				1		1	1	
<i>Nonion</i> cf. <i>flemingi</i> Vella				1				
<i>Pseudononion parri</i> (Cushman)								1
<i>Nonionella</i> cf. <i>norozelandica</i> Cushman								1
<i>Nonionella zenitens</i> Finlay							1	
<i>Astrononion parki</i> Hornibrook	1	1		1	1			
<i>Discopulvinulina bertheloti</i> (d'Orbigny)							1	
<i>Eponides tenera</i> (Brady)	1							
<i>Gyroidina</i> cf. <i>orbicularis</i> d'Orbigny					2		2	1
<i>Gyroidina prominula</i> (Stache)	2							
<i>Gyroidinoides zelandica</i> (Finlay)	3	3		2	1	2		
<i>Laticarinina halophora</i> (Stache)	1			2	1			1
<i>Epistomina elegans</i> d'Orbigny	2							1
<i>Notorotalia depressa</i> Vella							1	
<i>Notorotalia taranakia</i> Vella	2	1		2		3	1	1
<i>Globorotalia</i> cf. <i>miozea</i> (conical)				1				3
<i>Globorotalia inflata</i> (d'Orbigny)								1
<i>Globorotalia menardii</i> motumida Jenkins	1			1				
<i>Globorotalia</i> cf. <i>menardii</i> d'Orbigny		1				1	2	
<i>Globorotalia miozea</i> Finlay		1		1	1			1
<i>Orbulina universa</i> d'Orbigny	3	1		3	1	1	2	3
<i>Orbulina suturalis</i> Bronnimann		1		1			1	
<i>Globigerinoides triloba</i> (Reuss)							1	
<i>Globigerina apertura</i> Cushman	2			3		1	2	1
<i>Globigerina bulloides</i> d'Orbigny	2					1		
<i>Globigerina</i> cf. <i>bulloides</i> d'Orbigny	3	2		3	3	2	3	3
<i>Globigerina</i> cf. <i>semivera</i> Hornibrook		1		2				1
<i>Globigerina</i> sp.								1
<i>Globoquadrina debiscens</i> (Chapman, Parr, & Collins)	1							
<i>Anomalinoidea parvumbilia</i> (Finlay)		2		2	2	2	2	2

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TABLE 2—continued

	f530	f529	f527	f528	f526	f525	f524	f523
<i>Cibicides deliquatus</i> Finlay	2	1	3	3	3	3	3	2
<i>Cibicides ihungia</i> Finlay	2	1	3	3	1	1	1	3
<i>Cibicides molestus</i> Hornibrook	2	1	2	2	1	1	1	2
<i>Cibicides</i> cf. <i>temperata</i> Vella	1	1	1	1	1	1	1	1
<i>Dyocibicides biserialis</i> Cushman & Valentine	1	1	1	1	1	1	1	1
<i>Dyocibicides</i> sp. indet. (juvenile)	1	1	1	1	1	1	1	1
MOLLUSCA								
<i>Austrofusus coerulescens</i> (Finlay)	2	1	1	1	1	1	1	1
<i>Poirieria primigena</i> Finlay	1	1	1	1	1	1	1	1
<i>Waibaoia rugosa</i> Marwick	1	1	1	1	1	1	1	1
<i>Comitas</i> aff. <i>bilix</i> Marwick	1	1	1	1	1	1	1	1
<i>Micantapex paucispiralis</i> Powell	1	1	1	1	1	1	1	1
<i>Dentalium solidum</i> Hutton	1	1	1	1	1	1	1	1
OSTRACODA								
	1	1	1	1	1	1	1	1
ECHINOID SPINES								
	1	1	1	1	1	1	1	1
FISH TEETH and OTOLITHS								
	1	1	1	1	1	1	1	1

The important pelagic species *Globorotalia inflata* d'Orbigny (one specimen only) and the benthonic species *Hofkeruva* (*Trigonouva*) n. sp. (single-spined apex), considered by the author to be Opoitian in age, occur in the highest fauna (f523). An Opoitian age is favoured in spite of the occurrence of *T. kapitea*, which has previously been regarded as restricted to the Kapitean. *Textularia kapitea* occurs with *Globorotalia inflata* in sediments considered to be lower Opoitian in Eketahuna district, Wairarapa (sample N153/f841). Other typically Miocene species, *Siphotextularia subcylindrica* Finlay and *Norcottia mioindex* (Finlay), also occur with *Globorotalia inflata* in Wairarapa and define a zone provisionally distinguished as Basal Opoitian (Vella, pers. comm.)

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EVOLUTION OF *TEXTULARIA KAPITEA* FINLAY, CAPE FOULWIND, NEW ZEALAND

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ABSTRACT

At Cape Foulwind specimens of *Textularia kapitea* Finlay from six samples show a well defined evolutionary change with time. Two subspecies, one of early to middle Kapitean (Pontian) and one of late Kapitean to early Opoitian (Plaisancian) age, are established. *Textularia miozea* appears to be an earlier member of the evolutionary lineage.

Apart from the types of *Textularia kapitea*, the samples described in this account came from rocks exposed in the sea cliffs west of Carters Beach, Cape Foulwind (Sheet District S24) (Kennett, 1962).

Finlay (1947) recognised the *T. miozea-kapitea* lineage and stated that *T. miozea* remained unchanged to the end of the Tongaporutuan Stage (Samartian) and that *T. kapitea* appeared at the beginning of the Kapitean Stage (Pontian). He noted that *T. kapitea* differed from *T. miozea* in its evenly swollen form and that its thickness did not increase much after the first few chambers (*T. miozea* usually increases progressively). He also noted that although some specimens were fairly smooth, it was typically coarse textured.

Sample numbers, stratigraphic height above f530 (800 ft ESE of Giants Tooth), age of samples, number of specimens of *T. miozea-kapitea*, the average of the ratios of width/depth, and the standard deviation are shown in Table 1.

TABLE 1—Details of Samples

Sample No.	f530	f529	f528	f526	f525	f524	f523
Stratigraphic position (feet above f530)	0	100	140	230	300	386	446
Age	Tt	Tk	Tk	Tk	Tk	Tk	Wo
Number of specimens	15	3	26	16	15	9	19
Average ratio of width/ depth	1.56	1.40	1.32	1.27	1.24	1.18	1.10
Standard deviation	0.08	0.07	0.05	0.08	0.06	0.03	0.08

About 300 g of moderately soft siltstone were processed for each sample. *Textularia miozea* was common in f530. *T. kapitea* was common in all higher samples except f529 where it was rare. The continuous stratigraphic distri-

FIG. 1—Bioseries showing decrease in width/depth ratio in the *Textularia miozea-kapitea* lineage. Every gradation exists between adjacent stages. A, front view. B, side view.

No. 1. *Textularia miozea* Finlay, f530.

No. 2. *Textularia kapitea kapitea* Finlay, f528.

No. 3. *Textularia kapitea kapitea* Finlay, f525.

No. 4. *Textularia kapitea maritima* n. subsp., f523 (holotype).

All figures $\times 30$.

FIG. 2.—Curve showing average width/depth ratios for successive population samples of the *Textularia miozea-kapitea* lineage at Cape Foulwind. The standard deviation for each sample is shown.

bution of *Textularia*, from late Tongaporutuan to earliest Opoitian time, is attributed to the nearly uniform moderately shallow conditions indicated by the associated Foraminifera listed by Kennett (1962).

Enough specimens were recovered from Cape Foulwind for a statistical study to be made of the *T. miozea-kapitea* lineage with time.

T. miozea from f530 is fairly sharply angled and spinose. *T. kapitea* is considered to have evolved from *T. miozea* at the end of the Tongaporutuan by suppression of the spines and rounding of the periphery. From visual inspection, *T. kapitea* shows a gradual swelling of the test and a general increase in coarseness from Lower Kapitean to Basal Opoitian (Fig. 1).

The width and depth of all well preserved adult specimens of *T. kapitea* were measured with an ocular scale. The width/depth ratio was determined for each specimen. The average of the ratios for each sample decreases upward as shown in Fig. 2. The standard deviation for each sample is also shown. No other section is known where *T. kapitea* occurs commonly throughout the Kapitean and the stratigraphic value of the change shown at Cape Foulwind is uncertain.

On the basis of the width/depth (W/D) ratios (Fig. 2) *T. kapitea* is divided into two subspecies.

Textularia kapitea kapitea Finlay (Fig. 1, Nos. 2 and 3)

Textularia kapitea Finlay, N.Z. J. Sci. Tech. B 28 (5): 266; pl. 2, figs. 21, 22.

Average W/D of holotype and 12 topotypes, 1.27. Standard deviation, .07.

Locality of Types: G.S. 1155. Hicks Bay, East Cape.

Repository of Types: N.Z. Geological Survey, Lower Hutt.

Remarks: The subspecies includes forms from a population with an average W/D ratio from 1.2 to about 1.4.

Textularia kapitea maritima n. subsp. (Fig. 1, No. 4)

Average W/D ratio of type sample, 1.1. Standard deviation, .07.

Dimensions of holotype: Length 1.125 mm, width 0.70 mm, depth, 0.625 mm.

Locality of types: Holotype and 18 paratypes from S24/f523, Cape Foulwind (Basal Opoitian). 9 Paratypes from S24/f524, Cape Foulwind (Upper Kapitean).

Repository of Types: Geology Department, Victoria University, Wellington.

Remarks: The subspecies includes the Upper Kapitean and Basal Opoitian forms from populations with an average W/D ratio of 1.2 to 1.1 and less.

Provisionally *T. kapitea kapitea* is regarded as characteristic of the Lower and Middle Kapitean and *T. kapitea maritima* of the Upper Kapitean and Basal Opoitian.

ACKNOWLEDGMENTS

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The Globorotalia crassaformis Bioseries in
North Westland and Marlborough, New Zealand

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ABSTRACT

Upper Miocene to Pliocene strata in north Westland and Marlborough contain abundant fossils representing a bioseries of planktonic Foraminifera showing gradual progressive morphological changes. The bioseries commenced with Globorotalia miozea Finlay and ended with Globorotalia crassaformis (Galloway and Wissler). The form representing one stage of the bioseries at Marlborough, differs slightly from the corresponding form at north Westland, 150 miles to the south-west, but the end form is the same in both areas.

INTRODUCTION

During examination of Foraminifera of the Upper Miocene and basal Pliocene of north Westland (text-figure 1), Globorotalia conomiozea Kennett was found to be replaced upwards by forms increasingly resembling Globorotalia crassaformis (Galloway and Wissler). In north Westland G. conomiozea is predominant in the Kapitean Stage which is

Text-Figure 1. Map showing location of sections mentioned in text.

considered to represent the uppermost Miocene, and G. crassaformis is predominant in the Opoitian which is considered to represent the Lower Pliocene. Rocks directly below the Kapitean contain only sparse planktonic Foraminifera and the immediate forerunner of G. conomiozea is not seen.

Essentially the same gradational change from G. conomiozea to G. crassaformis was subsequently observed in rocks of the same age range in Marlborough, 150 miles north-east of north Westland (text-figure 1.). Furthermore in immediately older rocks Globorotalia miozea Finlay grades stratigraphically upwards into G. conomiozea.

The sequence of forms from G. miozea to G. crassaformis appears to be a gradational evolutionary bioseries comparable with the well known Orbulina bioseries (Blow, 1956).

The G. crassaformis bioseries is described from three sections in north Westland - Corehole F, Kapitea Creek and Callaghans Creek - and from one section in Marlborough - Blind River. Maps and columns showing north Westland sample localities are given in figs. 1 - 4 and table 11 of Kennett (in press), and for Marlborough in figs. 1 - 5 of Kennett (in press).

All the sections except Corehole F were collected by the writer and about 300 g. of muddy sediment was processed for each sample. Corehole F was drilled by New Zealand Oil Exploration Ltd. in 1942, the samples now being held by the New Zealand Geological Survey, who loaned them to the writer.

Enough specimens were recovered for a statistical

analysis of the changes in morphology with time. Selected specimens were drawn with the aid of a camera lucida (Plates 1 - 4) to show the gradational change with time and some of the range of variation at particular times.

TAXONOMIC NOMENCLATURE

Selected synonymy lists for the three species are given below.

Genus GLOBOROTALIA Cushman, 1927

Globorotalia miozea Finlay

Globorotalia miozea FINLAY, 1939, Trans. roy. Soc. N.Z. vol.69, no.3, p.326, pl.29, figs.159-161.

Globorotalia miozea Finlay - HORNIBROOK, 1958, Micro-paleontology, vol.4, no.1, p.33, pl.1, figs.6-10.

Globorotalia miozea Finlay - HORNIBROOK, 1961, N.Z. geol. Surv. paleont. Bull. 34, pt.1, pp.144, 145, pl.22, figs.450, 453, 454.

Globorotalia conomiozea Kennett

Globorotalia cf. miozea Finlay (conical) - KENNETT, 1962, N.Z.J. Geol. Geophys. vol. 5, no. 4, 624, list.

Globorotalia conomiozea KENNETT, (in press),

Globorotalia crassaformis (Galloway and Wissler)

Pulvinulina crassa (d'Orbigny) - BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p.694, pl.103, figs.11-12.

Globigerina crassaformis GALLOWAY and WISSLER, 1927, Jour. Pal., Vol.1, p.41, pl.7, fig.12.

Globorotalia (Turborotalia) oceanica CUSHMAN and BERMUDEZ, 1949, Cush. Lab. Foram. Res., Contr. vol.25, p.43, pl.8, figs.13-15.

Globorotalia punctulata (Fornasini) - PHLEGER, PARKER and PEIRSON, 1953, Swedish Deep-Sea Exped., Repts., vol.7, fasc.1, p.20, pl.4, figs.8-12.

Globorotalia cf. oceanica Cushman and Bermudez - TAKAYANAKI and SAITO, 1962, Sci. Rpt. Tohoku Univ. 2nd series, spec. vol.5, pp.79, 80, pl.27, figs.6-12.

Globorotalia crassaformis Galloway and Wissler - PARKER, 1962, Micropaleontology, vol.8, no.2, p.235, pl.4, figs.17, 18, 20, 21.

Globorotalia crassaformis Galloway and Wissler - SAITO, 1963, Sci. Rpt. Tohoku Univ. 2nd series, vol.35, no.2, p.175.

PREVIOUS WORK

McInnes (in press) described a gradational bioseries from G. miozea to G. inflata (d'Orbigny) in Upper Miocene to Lower Pliocene strata of northern Hawkes Bay, in the North Island of New Zealand, 260 miles north-east of Marlborough. This is referred to as the G. inflata bioseries, and occurs in rocks of the same age range as the G. crassaformis bioseries and undergoes similar though not identical morphological changes. The relationship between the G. inflata bioseries and the G. crassaformis bioseries is still uncertain. The difference in the morphological changes might reflect merely geographic

variations in a single evolving plexus. On the other hand they might represent divergence into two species. Saito (1963) discussing an early form of G. inflata from Tsuchizaki, Japan, has already suggested that G. inflata and G. crassaformis might have a common ancestor.

THE G. CRASSAFORMIS BIOSERIES IN NORTH WESTLAND

Lower Kapitean samples consist solely of forms fairly close to the type of G. conomiozea. Upper Kapitean to lower Opoitian samples contain more variable forms ranging from typical G. conomiozea to almost typical G. crassaformis, and higher Opoitian samples consist solely of forms fairly close to G. crassaformis.

The following gradational changes take place:

1. The keel characteristic of G. conomiozea becomes weaker and disappears. Non-keeled forms appear fairly abruptly at about the middle of the Kapitean where they make up an appreciable proportion of the fauna. Weak-keeled forms appear slightly earlier. The numbers of non-keeled, weak-keeled and strong-keeled forms of successive samples from Corehole F and Kapitea Creek are shown in tables 1 and 2. Text-figure 2 gives a graph of the percentages of non-keeled and strong-keeled forms. The percentages of strong-keeled and non-keeled forms show an approximately reciprocal relationship and the percentage of weak-keeled forms is at a maximum near the horizon where non-keeled and strong-keeled forms are about in equal proportions.

Depth in feet from ground level	Number of specimens		
	Strong	Keel Weak	None
40-552	-	-	5
80-100	-	-	6
125-140	7	6	5
150-155	8	8	5
170-175	6	1	4
190-200	9	1	3
210-220	10	4	-
220-230	13	2	1
250-260	13	2	-
270-290	6	-	-
300-310	2	-	-
340-350	2	-	-

Table 1. Numbers of strong-keeled, weak-keeled and non-keeled forms of successive samples of the G. crassaformis bioseries from Corehole F.

Sample number	Number of specimens		
	Strong	Keel Weak	None
f 651	-	-	8
f 650	-	-	18
f 649	-	-	26
f 648	9	9	9
f 647	3	5	4
f 646	25	1	-
f 644	13	1	1
f 643	9	-	-

Table 2. Numbers of strong-keeled, weak-keeled and non-keeled forms of successive samples of the G. crassaformis bioseries from Kapitea Creek.

Text-Figure 2. Graph showing approximately reciprocal relationship between percentages of non-keeled forms (squares) and strong-keeled forms (circles) in successive samples of the G. crassaformis bioseries from Corehole F. Ordinate gives depth in feet from ground level. Abscissa gives relative percentages of non-keeled and strong-keeled forms.

2. In lower Kapitean samples, the umbilical side of G. conomiozea is strongly conical, but towards the upper Kapitean becomes progressively more dome shaped. In side view, the roughly triangular outline of G. conomiozea changes to the roughly quadrate outline of G. crassaformis. An angle referred to as the "conical angle" was measured by means of a camera lucida. The conical angle is observed in side view and is the angle between the lateral surface of the final chamber and the plane dividing the umbilical surface from the spiral side. (text-figure 3).

Text-Figure 3 - Side view of a specimen of Globorotalia conomiozea showing the "conical angle".

All unbroken specimens were measured except for a few specimens of G. crassaformis which are rounded instead of angular at the periphery.

Tables 3, 4, and 5 show sample numbers; stratigraphic position; age; numbers of specimens of G. conomiozea - crassaformis; the average "conical angle" and the standard

Sample number	f 643	f 644	f 646	f 647	f 648	f 649	f 650
* Stratigraphic position	0	90	350	440	500	760	840
Age	Tk	Tk	Tk	Tk	Tk	Wo	Wo
Number of specimens	9	15	26	12	27	26	18
Average "conical angle"	60	62	65	70	75	93	98
Standard deviation	0.06	0.09	0.06	0.09	0.09	0.12	0.16

* Above lowest sample

Table 3. Data for successive samples of the G. crassaformis bioseries from Kapitea Creek.

Sample number	f 685	f 684	f 683	f 682	f 679 f 680	f 677	f 675	f 673	f 671 f 672	f 694 f 670	f 668 f 669
* Stratigraphic position	340 to 350	300 to 310	270 to 290	250 to 260	210 to 230	190 to 200	170 to 175	150 to 155	125 to 140	80 to 100	40 to 52
Age	Tk	Tk	Tk	Tk	Tk	Tk	Tk	Tk	Tk	Wo	Wo
Number of Specimens	2	2	6	14	30	13	12	21	18	5	4
Average "conical angle"	62	60	63	64	66	68	71	70	80	90	94
Standard deviation	0.02	0.01	0.08	0.07	0.07	0.07	0.07	0.08	0.11	0.07	0.05

* Depth from ground level.

Table 4. Data for successive samples of the G. crassaformis bioseries from Corehole F.

Sample number	f661	f662	f665	f666
* Stratigraphic position	28	40	77	97
Age	Tk	Tk	Tk	Tk
Number of Specimens	5	9	7	3
Average "conical angle"	64	63	66	67
Standard deviation	0.08	0.10	0.09	0.03

* Above top of Callaghans Conglomerate

Table 5. Data for successive samples of the G.
crassaformis bioseries from Callaghans
Creek.

Text-Figure 4. Graph showing increase of the average "conical angle" in successive samples of the G. crassaformis bioseries from Kapitea Creek. The standard deviation is shown for each sample. Ordinate gives stratigraphic thickness in feet above datum which is taken as the lowest sample studied.

Text-Figure 5. Graph showing the increase of the average "conical angle" in successive samples of the *G. crassaformis* bioseries from Corehole F. The standard deviation is shown for each sample. Ordinate gives depth in feet from ground level.

Text-Figure 6. Graph showing change in the average "conical angle" in successive samples of the *G. crassaformis* bioseries from the basal Kapitean at Callaghans Creek. The standard deviation is shown for each sample. Ordinate gives stratigraphic thickness in feet above the Callaghans Conglomerate (datum).

deviation, for the samples from Kapitea Creek, Corehole F and Callaghans Creek. The average "conical angle" increases gradually from the bottom to the top of each section, as shown in text-figures 4, 5 and 6.

3. In the basal Kapitean at Kapitea Creek and Callaghans Creek the number of chambers in the final whorl of G. conomiozea varies from 5 to 4. In all younger samples the number of chambers in the final whorl is never as great as 5, and is generally close to 4.
4. In lower samples some specimens of G. conomiozea have a broad, low arched to slit-like aperture. In the upper Kapitean and lower Opoitian, most specimens of G. conomiozea have a narrower high arched aperture. In the lowest samples of G. crassaformis, specimens have similar apertures to specimens in the highest G. conomiozea samples, but higher in the Opoitian the apertures generally become larger by increasing in width.

The apertural lip which is very strong in lower samples of G. conomiozea becomes generally weaker in later samples of G. conomiozea and early samples of G. crassaformis, and is absent in many specimens of the highest G. crassaformis samples.

5. On the spiral side the chamber height is reduced and transverse sutures become less curved to allow a change in test shape from fairly rounded in lower G. conomiozea samples to more quadrate in the highest G. conomiozea and the G. crassaformis samples. Sutures on the umbilical side

remain nearly radial throughout the bioseries.

Nearly all specimens have granulate to pustulate test surfaces. The pustules and granules are more numerous and more strongly developed on the umbilical side and are generally absent on the last one or two chambers. No consistent progressive change in the pustules can be observed through the bioseries, but G. crassaformis generally has slightly smoother surfaces and has no pustules, only granules on the spiral side. No change in test thickness could be observed, all shells being thick walled.

THE G. CRASSAFORMIS BIOSERIES IN MARLBOROUGH

At Blind River, through successively higher samples in the Upper Tongaporutuan, G. miozea gradually changes to G. conomiozea and in the Kapitean G. conomiozea in turn changes to G. crassaformis.

Each sample of G. miozea generally contains forms grading from G. miozea (s.s.) to a widely recognised but unnamed spherical variety of G. miozea. G. miozea (spherical var.) is generally more rounded than G. miozea (s.s.) and has the keel restricted to the last one or two chambers and represented by a thickened rim on the rest of the periphery. G. conomiozea (s.s.) typically has a well developed keel around the entire periphery.

The following gradational changes take place:

1. The gently to moderately convex umbilical side of G. miozea becomes progressively higher and more conical to give G.

conomiozea, which then changes to G. crassaformis in the same way as at North Westland. Throughout the bioseries a small number of typical specimens have a final chamber smaller and more compressed than the penultimate. These forms have a much smaller "conical angle" than the average and therefore were not measured. The "conical angle" of all other specimens was measured for each sample. Table 6 gives sample numbers; stratigraphic position above the lowest sample; age; number of specimens of G. miozea - G. conomiozea - G. crassaformis; the average "conical angle" and the standard deviation. The average "conical angle" increases upwards (text-figure 7).

2. At North Westland all specimens of G. conomiozea have the keel completely surrounding the periphery.

At Blind River the G. conomiozea samples include some specimens with keels completely surrounding the periphery, but a larger number with keels restricted to the last one or two chambers as on the spherical variety of G. miozea.

Through successively higher samples from those with G. miozea, strong-keeled forms including those with the keel on part of the periphery and those with the keel on the whole of the periphery are gradually replaced by weak-keeled and non-keeled forms. Still higher, all keeled forms completely disappear leaving only typical G. crassaformis.

Table 6 shows numbers of strong-keeled, weak-keeled, and non-keeled forms for successive samples from Blind River.

Sample number	f618	f635	f636	f637	f638	f639	f640	f643	f644	f645	f646	f647	f648	f650	f651	f652	f653	f655	f656
Thickness in feet above sample f618	0	780	1480	1930	2460	2690	2860	3350	3450	3600	3750	3880	3980	4160	4200	4230	4530	5730	6310
Age	M. Tt	U. Tt	U. Tt	U. Tt	U. Tt	U. Tt	U. Tt?	Tk	Tk	Tk	Wo	Wo	Wo	Wo	Wo	Wo	Wo	Wo	Wo
No. of specimens used for "conical angle"	22	27	8	14	33	17	10	14	41	60	11	18	5	12	16	17	39	2	7
Average "conical angle"	57	50	61	62	61	65	67	70	70	73	77	74	81	86	85	84	89	90	91
Standard deviation	0.09	0.05	0.10	0.08	0.08	0.06	0.06	0.06	0.07	0.09	0.13	0.13	0.11	0.09	0.12	0.13	0.15	0.14	0.13
No. non-keeled forms	-	-	-	-	2	-	4	5	27	37	12	22	3	13	21	23	61	2	8
No. strong-keeled forms	23	47	9	17	47	18	7	8	14	13	2	2	1	1	-	1	-	-	-
No. weak-keeled forms	3	5	-	7	6	5	3	6	23	27	2	9	1	1	1	1	-	-	-
No. with 4-4 1/4 chambers in final whorl	5	6	2	11	29	18	12	17	55	72	15	29	5	14	20	24	60	2	8
No. with > 4 1/4 chambers in final whorl	22	44	7	12	26	5	2	2	7	5	1	3	-	1	1	1	1	-	-
% specimens with 4-4 1/4 chambers in final whorl	19	12	22	50	53	78	86	89	89	93	94	91	100	93	95	96	98	100	100

Table 6. Data for successive samples of the G. crassaformis bioseries from Blind River.

Text-Figure 7. Graph showing increase of the average "conical angle" in successive samples of the *G. crassaformis* bioseries from Blind River. The standard deviation is shown for each sample. Ordinate gives stratigraphic thickness in feet above the lowest sample studied.

Text-Figure 8. Graph showing the approximately reciprocal relationship of the percentages of non-keeled and strong-keeled forms in successive samples of the G. crassaformis bioseries from Blind River. Ordinate gives stratigraphic thickness in feet above the lowest sample (datum).

Text-Figure 9. Graph showing the general increase of the percentage of forms with 4 - 4½ chambers in the final whorl in successive samples of the *G. crassaformis* bioseries from Blind River. Ordinate gives stratigraphic thickness in feet above the lowest sample (datum).

Text-figure 8 gives a graph of the percentages of non-keeled, and strong-keeled forms. The percentages of strong-keeled and non-keeled forms have an approximately reciprocal relationship and the percentage of weak-keeled forms is at a maximum just above the horizon where non-keeled and strong-keeled forms are about in equal proportions and within the zone of most rapid change from strong-keeled to non-keeled.

3. The number of chambers in the final whorl gradually decreases from dominantly $4\frac{1}{2}$ - 5 chambers in G. miozea, to dominantly 4 - $4\frac{1}{2}$ chambers in G. conomiozea and dominantly 4 - $4\frac{1}{4}$ chambers in G. crassaformis (Table 6 and text-figure 9).
4. The apertures which are mainly slit-like or low and arched in G. miozea are replaced by generally higher, arched apertures of G. conomiozea and G. crassaformis.
5. On the spiral side the width of each chamber (radial direction) decreases and spiral sutures become less curved and at the same time the equatorial profile changes from fairly rounded in G. miozea and G. conomiozea to subquadrate in G. crassaformis.

The surface of the spiral side in samples throughout the entire bioseries varies from gently convex to almost planar and shows no consistent changes.

CONCLUSIONS

In north Westland, because of the shallow-water facies representing the Upper Tongaporutuan, and the

unconformity below the Upper Tongaporutuan, the bioseries is known only from the base of the Kapitean Stage up to the Opoitian. The lowest samples at Callaghans Creek and Kapitea Creek includes some specimens with 5 chambers in the last whorl, with narrow elongate apertures, and relatively low conical angle that are intermediate between G. miozea and G. conomiozea. The Kapitea Creek and Corehole F sections show the complete gradation through G. conomiozea to G. crassaformis.

At Blind River, Marlborough, the sequence is unbroken from Middle Tongaporutuan to Opoitian, and all stages of the bioseries from typical G. miozea are represented by common to abundant specimens.

At Westland, nearly all specimens classed as G. conomiozea have the keel completely surrounding the periphery, but at Blind River more than half the specimens have the keel restricted to the last 2 chambers. In spite of this difference, the two forms definitely grade up to G. crassaformis.

The parallel and very similar G. inflata bioseries described by McInnes (in press), occurs in rocks of the same age range, 260 miles to the north-east of Marlborough. McInnes's variety of G. miozea is closely related to G. conomiozea, and G. inflata seems to be close to G. crassaformis. Consequently, the G. inflata bioseries is likely to be closely connected with the G. crassaformis bioseries.

Progressive cooling in late Tertiary times is well established in New Zealand from changes in various groups of

fossils (Fleming 1953, 1962) Hornibrook (1953), Fell (1954), Squires (1958), and Couper (1960). At present, keeled Globorotalias are restricted to waters warmer than 17°C and non-keeled Globorotalias to waters warmer than 9°C (Bandy, 1964). The most important change in the G. crassaformis bioseries is the loss of the peripheral keel, and this may well have been a response to cooling of New Zealand waters in uppermost Miocene times.

It is uncertain whether the gradational changes shown by the G. crassaformis bioseries and the G. inflata bioseries are true evolutionary changes, or whether they represent the gradual replacement of one ecologically restricted species by another interbreeding with it. G. crassaformis and G. inflata have not been reported with certainty any earlier than in New Zealand, and the bioseries probably represents evolution, which itself could have resulted from cooling.

If the G. crassaformis bioseries represents evolution, then there can be no significant genetic difference between the partly keeled and fully keeled ancestral forms, and both forms must be included in one species. On the other hand, if the bioseries represents gradual replacement of one ecologically restricted species by another, then the partly keeled and fully keeled forms might be genetically different, and could be considered as different species. They are here classed as one species.

G. conomiozea, as used here, thus includes two

distinct varieties. Furthermore, judging from the G. inflata bioseries it is probably part of a plexus of intergrading forms exhibiting an even greater range of variation.

The appearance of G. crassaformis (G. inflata) has long been taken as marking the boundary between the Taranaki Series and the Wanganui Series and this has been regarded as the Miocene - Pliocene boundary in New Zealand. The writer arbitrarily places the Taranaki-Wanganui boundary within the range of the G. crassaformis bioseries at the point where the number of forms typical of G. crassaformis equals the number of forms typical of G. conomiozea.

This boundary is a well defined datum plane in the late Tertiary of New Zealand. G. crassaformis and G. inflata occur in Pliocene and "uppermost Miocene" rocks in many parts of the world and their first appearance probably marks the same datum plane as in New Zealand.

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Plate 1.

Globorotalia crassaformis bioseries at North Westland:
Illustrations show gradual changes in morphology from
G. conomiozea at the base of the Kapitean Stage (bottom
row) up to G. crassaformis low in the Opoitian Stage
(top row).

Figs. 1 - 7 - Globorotalia crassaformis;

1 - 2, Sf650. 3 - 4, Sf668.

5 - 7, Sf644.

Figs. 8 - 18 - Globorotalia conomiozea;

8 - 11, Sf672. 12 - 14, Sf683.

15, Sf644. 16 - 18, Sf665; all X50.

(Figs. 1, 2, 15 - 18 Victoria University
of Wellington Cat. Nos. Ff400 - Ff405;

Figs. 3 - 14 N.Z. Geological Survey
Cat. Nos. FPI416 - FPI427).

1a

1b

1c

2a

2b

2c

3a

3b

4a

4b

4c

5

6

7a

7b

7c

8

9

10a

10b

11a

11b

11c

12

13a

13b

14a

14b

14c

15a

15b

16

17

18a

18b

Plate 2.

Globorotalia crassaformis bioseries at Blind River, Marlborough - Lower to middle part: Illustrations show gradual changes in morphology from G. miozea high in the Middle Tongaporutuan (bottom row) up to G. conomiozea in the Kapitean Stage (top row).

Figs. 1 - 5 - Globorotalia conomiozea;

1 - 2, Sf643. 3 - 5, Sf639.

Figs. 6 - 13 - Globorotalia miozea

6 - 7, Sf683. 8 - 9, Sf637.

10 - 11, Sf636. 12 - 13, Sf618;

all X50. (Figs 1 - 13 Victoria

University of Wellington Cat. Nos.

Ff406 - Ff418).

1a

1b

2a

2b

2c

3a

3b

3c

4

5a

5b

6a

6b

6c

7a

7b

8a

8b

9a

9b

10a

10b

11a

11b

11c

12a

12b

13a

13b

13c

Plate 3.

Globorotalia crassaformis bioseries at Blind River, Marlborough - Upper part: Illustrations show gradual changes in morphology from G. conomiozea high in the Kapitean Stage (bottom row) up to G. crassaformis in the Opoitian Stage (top row).

Figs. 1 - 5 - Globorotalia crassaformis;

1 - 2, Sf653. 3 - 5, Sf650.

Figs. 6 - 8 - Globorotalia conomiozea;

Sf645; all X50. (Victoria University of Wellington Cat. Nos. Ff419 - Ff426).

1a

1b

1c

2a

2b

3a

3b

4a

4b

5a

5b

5c

6a

6b

7a

7b

7c

8a

8b

Faunal Succession in Two Upper Miocene - Lower
Pliocene Sections, Marlborough, New Zealand.

by J. P. Kennett

Victoria University of Wellington

ABSTRACT

Two stratigraphic sections ranging from Middle Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene) in age are examined. They lie only 5 miles apart, but one is mostly deep-water facies and the other is predominantly shallow-water facies. Ranges of Foraminifera and Mollusca are shown on charts and local foraminiferal and molluscan zones are established. By correlating key horizons in these sections it has been possible to determine relative stratigraphic ranges of important deep-water and shallow-water fossils, including key Foraminifera and the Kapitean key Mollusca.

The base of the Kapitean Stage in the deep-water section was determined by an evolutionary stage of the Globorotalia crassaformis bioseries, and in the shallower-water section by the first appearance of the key Kapitean Mollusca.

The Kapitean Stage is shown to be relatively thin and to be equivalent to about the upper half of the Bolivinita compressa Zone in deep-water facies.

Paleoecological changes indicate significant changes

in depth of deposition in both sections and these depth changes were almost certainly synchronous. A marked shallowing of the sea took place during the Kapitean Age and the biostratigraphic divisions are closely related to the changes in depth of deposition.

INTRODUCTION

Throughout New Zealand the key Kapitean Molluscan species are restricted to relatively shallow-water facies like that of the type Kapitean in Westland and consequently the Kapitean Stage is difficult to recognise in deep-water facies.

As noted by Kennett (1965a, in press) the relationship of the Kapitean Stage and the Bolivinita compressa Zone, generally classed as Upper Tongaporutuan, and known only in deep-water facies, is difficult to determine.

Two Upper Miocene to Pliocene sections in the Lower Awatere Valley, Marlborough, are useful for determining the relative stratigraphic ranges of some species that are confined to shallow-water biofacies (including the key Kapitean Mollusca) and others that are confined to deep-water biofacies. The Upton Brook section is predominantly shallower-water facies while the Blind River section, only five miles to the east, is mostly much deeper-water facies. Vertical biofacies and lithofacies changes indicate changes in depth of deposition

Fig. 1 - Map showing the location of areas shown in Fig. 2 and Fig. 4.

in both sections. All the well defined changes in depth can be recognised in both sections and are used to reinforce paleontological correlation.

Sections Studied

The Blind River section falls within N.Z.M.S.I. Sheet District S29, Seddon Sheet and extends from two to five miles south-south-west of Seddon township (fig. 1). The lower part of the section lies in the upper reaches of Blind River below its gorge; the middle part in Stace Stream from the Waterfalls Road crossing downstream to the junction with Blind River; and the upper part in the lower reaches of Blind River from the junction of Stace Stream towards the Blenheim-Christchurch main highway. The section is fairly well exposed in low bluffs and was sampled at stratigraphic intervals of about 150 ft. in the Kapitean and lower Opoitian, and about 500 ft. in the Middle and Upper Tongaporutuan and the Upper Opoitian. Sample locations are shown in fig. 2 and lithologies and sample horizons are shown on a columnar section (fig. 3).

The Upton Brook section falls within N.Z.M.S.I. Sheet District S28 (Blenheim Sheet) and is 9 miles south-west of Seddon (fig. 1). It extends from near the junction of Upton Brook and Awatere River to about half way up Upton Brook. It is well exposed in a deep, fairly narrow gorge, and was sampled at stratigraphic intervals of about 300 ft. Abundant macrofossils were collected from the upper part of

Fig. 2 - Map of the Blind River section
showing location of samples.

Fig. 3 - Stratigraphic column of the Blind River section. Curve indicates relative depth changes derived from plotting the biofacies of each sample. Biofacies are represented by symbols as follows:
 E = Elphidium Biofacies; H = Maeuslerella Biofacies;
 K = Karreriella Biofacies; R = Robulus Biofacies.

the section. Sample locations are shown in fig. 4 and lithologies and sample horizons are shown on a columnar section (fig. 5).

An index of fossil localities, with lithologies and age determinations is given in the appendix.

In 1934 King published the first map of the lower Awatere River area, and using macrofossils and lithologies recognised the following threefold division of the Tertiary rocks. The ages in parentheses are those assigned by King:

- a: Starborough Series (Waitotaran)
- b: Upton Series (Taranakian)
- c: Medway Series (Awamoan)

Of the two sections studied by the writer, neither paleontological nor lithological boundaries coincide with those of King and King's classification is not followed. A simple lithological correlation between Upton Brook and Blind River is unsatisfactory because of the marked facies differences. The macrofossils that King heavily relied on for tracing his divisions are mostly too sporadic for reliable paleontological correlation and Foraminifera, which can be collected at relatively close intervals, are far more satisfactory.

In place of King's nomenclature, the writer has set up a series of local foraminiferal and molluscan zones (table 1) which are correlated with the standard N.Z. series and stages some of which were established after King's work in the area.

Fig. 4 - Map of the Upton Brook section
showing location of samples.

Fig. 5 - Stratigraphic column of the Upton Brook section. Curve indicates relative depth changes inferred from biofacies and lithofacies changes. Biofacies are represented by symbols as follows:
 E = Elphidium Biofacies; H = Haeuslerella Biofacies.

The two sections range from within the Middle Tongaporutuan to within the Opoitian. At the base of each section, a conglomerate rests on a planed surface of greywacke basement rocks. Blue-grey muddy marine sediments dominate throughout both sections. Siltier and sandier strata occur near the middle of the Blind River section and well bedded sandstone occurs near the middle of the Upton Brook section.

For convenience in relating lithological changes to paleoecological changes described later, the sections are divided into lithological units which are given informal lithological names as shown in the following table:

Blind River Section

Opoitian massive mudstone
 Blind River shell beds
 Opoitian siltstone and mudstone
 Kapitean silty mudstone
 Stace Stream shell bed
 Kapitean silty mudstone
 Tongaporutuan massive mudstone
 Middle Tongaporutuan sandstone and siltstone
 basal conglomerate

Upton Brook Section

Upton upper siltstone
 Upton sandstone
 Upton lower siltstone
 Tongaporutuan mudstone and silty mudstone
 Middle Tongaporutuan muddy siltstone and silty mudstone
 basal conglomerate

BIOSTRATIGRAPHY

The distribution of Foraminifera in the two sections are shown on range charts (table 11 - Blind River and table 12 - Upton Brook). The lists given below, show those species that are restricted to or have first or last appearances in the zones shown in table 1. Many species that are considered to be locally useful for zoning are known to have longer stratigraphic ranges elsewhere in New Zealand. The ranges shown for molluscan species compare reasonably well with ranges shown by King's lists, except that in two of King's lists, species from several separate localities in the Upton Series were grouped together and true ranges of some species were obscured.

Pohana Zone:

The Pohana Zone is distinguished by the occurrence of Bolivinita pohana Finlay, and the absence of Bolivinita compressa Finlay and Bolivinita pliozea Finlay, and is regarded as Middle Tongaporutuan in age.

Restricted:

Textularia miozea Finlay

Vulvulina pennatula (Batsch)

Martinottiella massami Gibson

Ellipsoglandulina subconica (Kienz)

Hofkeruva rodleyi rodleyi Vella

Bolivina cf. acerosa Cushman

Pullenia quadriloba Reuss

STAGE	MARLBOROUGH ZONES		RANGES OF CHARACTERISTIC ZONE FOSSILS
	Foraminiferal Zones	Molluscan Zones	
Opoitian	Crassaformis	Allani	<div style="display: flex; justify-content: space-between; padding: 0 10px;"> <div style="text-align: center;"> <i>Marama hurupiensis</i> <i>Bolivinita pliozea</i> <i>Bolivinita compressa</i> <i>Globorotalia conomiozea</i> <i>Sectipecten wollastoni</i> <i>Globorotalia crassaformis</i> <i>Austrofusius allani</i> </div> </div>
Kapitean	Conomiozea	Wollastoni	
Up.	Pliozea	-	
Tongaporutuan			
Mid.	Pohana	Hurupiensis	

Table 1 - Biostratigraphic units in Marlborough with their ages and the ranges of the zone name fossils.

Siphonina australis Cushman

Notorotalia cf. depressa Vella

Globigerina nepenthes Todd

Globigerinoides triloba (Reuss)

Limopsis lawsi King

Modiolus altijugates Marwick

Modiolus aff. huttoni Suter

Marana hurupiensis Marwick

Eumarcia aff. atitunula Marwick

Pliozea Zone:

The Pliozea Zone directly overlies the Pohana Zone. The base of the Pliozea Zone is marked by the sudden appearance in both sections of Bolivinita pliozea Finlay, at approximately 1000 ft. above the top of the basal conglomerate. The top of the Pliozea Zone is marked in both sections by the incoming of Globorotalia conomiozea Kennett. The very deep-water foraminifer B. compressa occurs only in the Blind River section and first appears at the same horizon as B. pliozea. Therefore the base of the Pliozea Zone is considered to be equivalent to the base of the Compressa Zone elsewhere in New Zealand, and to mark the base of the Upper Tongaporutuan.

The characteristic Upper Miocene species Plecto-frondicularia pohana Finlay disappears suddenly in the lower part of the Pliozea Zone in both sections, but is known to range higher elsewhere in New Zealand.

Restricted:

Migros medwayensis (Parr)
Quinqueloculina n.sp. (b)
Awhea subtetragona (Finlay)
Parafrondicularia fyfei (Finlay)
Bulimina vellai Gibson - lowermost
Bulimina senta Finlay
Hofkeruva paeniteres (Finlay)
Globobulimina perversa (Cushman)
Bolivinita compressa Finlay
Discorotalia aranea Hornibrook - lowermost
Sphaeroidinella seminulina (Schwager)

First appearances:

Haeuslerella pliocenica (Finlay)
Sigmoilopsis zeaserus Vella - uppermost
Biloculina anomala Schlumberger
Pyrgo tasmanensis Vella
Awhea sinalata (Finlay)
Bulimina aculeata d'Orbigny
Bulimina pupoides d'Orbigny
Virgulina rotundata Parr
Virgulina vellai Kennett
Virgulopsis pustulata Finlay
Bolivinita pliozea Finlay
Gavelinopsis lobatulus (Parr) - rare
Globigerina pachyderma (Ehrenberg)
Globigerina quinqueloba Natland

Last appearances:

Ammodiscus finlayi ParrSiphotextularia ihungia FinlaySiphotextularia subcylindrica FinlaySigmoilopsis schlumbergeri (Silvestri)Bulimina pyrula d'OrbignyNeouvigerina eketahuna VellaNorcottia mioindex (Finlay)Bolivina lapsus Finlay - lowermostPlectofrondicularia pohana FinlayCassidulina cuneata FinlayOsangularia bengalensis (Schwager)Globocadrina dehiscens (Chapman, Parr, & Collins) -
lowermostGloborotalia menardii miotumida Jenkins - lowermostGloborotalia opima continuosa BlowAnomalina aotea FinlayCibicides pseudoungerianus (Cushman)Conomiozea Zone:

The Conomiozea Zone directly overlies the Pliozea Zone. Its base is marked by the incoming of G. conomiozea Kennett but is not clear cut because G. conomiozea is an intermediate form in a gradational bioseries, (Kennett, 1965b, in press) that commenced with G. miozea and ended with G. crassaformis (Galloway & Wissler). For the purpose of defining the zone, the first appearance of G. conomiozea is arbitrarily taken as the lowest sample in which G. conomiozea makes up over 50 per cent of the G. miozea-conomiozea

population. The top of the Conomiozea Zone is marked by the incoming of G. crassaformis. In Taranaki and Wairarapa the lower part of the Conomiozea Zone contain Sectipecten grangei Boreham and is Upper Tongaporutuan in age. In Westland, the strata with S. grangei contain scarcely any planktonic Foraminifera and the Conomiozea Zone can be recognized only from the base of the type Kapitean upwards.

At Blind River Sigmoilopsis schlumbergeri (Silvestri) is replaced by S. zeaserus Vella about 300 ft. below the base of the Conomiozea Zone. The base of the Zeaserus Zone in Wairarapa (Vella, 1963) is the horizon at which S. zeaserus replaces S. schlumbergeri. This was considered to be the base of the Kapitean by Vella, but on evidence from Blind River is within the Upper Tongaporutuan.

At Blind River, as at North Westland, Siphotextularia n.sp. cf. wairoana with less quadrate, more evenly tapering outline and with generally more deeply concave sides than typical S. wairoana, is replaced near the base of the Opoitian by typical S. wairoana. At Blind River however, S. n.sp. cf. wairoana appears in the Upper Tongaporutuan at the base of the Conomiozea Zone, while at North Westland it appears in the Kapitean near the top of the Conomiozea Zone. In the Blind River section, like that at north Westland, the first appearance of Bulimina cf. striata, (small var.) occurs in the Kapitean Stage. The upper boundary of the Conomiozea Zone is taken as the first appearance of Globorotalia crassaformis.

(Galloway & Wissler) and corresponds with the upper boundary of the Kapitean Stage. The first appearance of G. crassaformis is arbitrarily taken as the horizon where forms within the range of variation of G. crassaformis makes up 50 per cent of the G. conomiozea-crassaformis population. This boundary is distinguished with certainty at Blind River where the G. conomiozea-crassaformis bioseries is represented by abundant specimens in most samples. At Upton Brook planktonic Foraminifera are rare, and G. crassaformis was not found in strata considered to be equivalent to the Crassaformis Zone. Here the top of the Conomiozea Zone is inferred from changes in the molluscan faunas shown in the lists below and from a change in depth of deposition which occurs in both sections.

Restricted:

- Siphotextularia awamoana Finlay
- Globorotalia conomiozea Kennett
- Cornuspira cf. corticata Chapman & Parr
- Cornuspira involvens Reuss
- Cucullaea n.sp.
- Sectipecten wollastoni (Finlay)
- Notocallista parki (Marwick)
- Eumarcia n.sp.
- Notocorbula humerosa (Hutton)
- Struthiolaria cf. cingulata Zittel
- Struthiolaria subspinoso Marwick
- Struthiolaria aff. subspinoso Marwick

Maoricrypta radiata (Hutton)

Austrofuscus coerulescens (Finlay)

Dentalium zelandicum Sowerby

First appearances:

Textularia barnwelli Kennett

Textularia kapitea Finlay

Siphotextularia n.sp. cf. wairoana Finlay

Bulimina striata d'Orbigny, (small var.)

Rectobolivina striatula (Cushman)

Pacinonion novozealandicum (Cushman & Edwards)

Notorotalia hurupiensis Vella X finlayi Vella

Anomalinoides spherica (Finlay)

Maorimactra chrydaea Suter

Marama n.sp. aff. hurupiensis Marwick

Nemocardium quinarium Marwick

Struthiolaria (Callusaria) obesa Hutton

Polinella obstructus (Marwick)

Aeneator n.sp.

Austrofuscus pagoda Finlay

Pachymelon uptonensis King

Alcithoe cf. bacchinalia King

Last appearances:

Textularia subrhombica Stache

Gaudryina kingi (Parr)

Karrerella bradyi (Cushman) - lowermost

Karrerella cylindrica Finlay

Sigmoilopsis gavini Gibson

Pyrgo depressa (d'Orbigny)

Bulimina pyrula d'Orbigny var. spinescens Brady

Virgulina schrisbersiana Czjzek

Hofkeruva zeacuminata Vella - lowermost

Bolivina subspinescens Cushman

Bolivinita quadrilatera (Schwager)

Cassidulina cuneata Finlay

Pleurostomella alternans Schwager

Florilus decepatrix (Hornibrook)

Notorotalia taranakia Vella

Globorotalia miozea Finlay

Cucullaea

Wollastoni Zone:

The Wollastoni Zone can be recognised only at Upton Brook. The molluscan species Sectipecten wollastoni (Finlay) occurs sporadically throughout, and the other key Kapitean species Austrofuscus coerulescens (Finlay) occurs at the base. The Wollastoni Zone corresponds with the upper part of the Conomiozea Zone.

Allani Zone:

At Blind River Cucullaea occurs near the middle of the Conomiozea Zone, while Austrofuscus allani King, Xenophallium cf. grangei and Pellicaria aff. canaliculata (Zittel) occurs 500 ft. above the base of the Crassaformis Zone. At Upton Brook Cucullaea occurs persistently through

about 700 ft. of silty and sandy strata with rare G. conomiozea in the lower part. At the top of the sandstone there is a marked lithological change to massive siltstone and about 300 ft. higher occurs a significantly different Molluscan fauna with Pliocene affinities, including Austrofusus allani, Xenophalium cf. grangei, and Pellicaria aff. canaliculata. This fauna marks the Allani Zone.

Immediately above the Conomiozea Zone in both sections, specimens referable to Notorotalia finlayi Vella make up about 50 per cent of the samples of the N. hurupiensis X finlayi plexus. Below the top of the Conomiozea Zone however, at Blind River N. hurupiensis occurs by itself as rare specimens and at Upton Brook N. hurupiensis dominates over N. finlayi.

The change from sandstone to siltstone at Upton Brook represents a change from shallow-water facies to slightly deeper-water facies, and the incoming of abundant Mollusca 300 ft. higher represents shallowing again. At Blind River the Conomiozea Zone is represented by mainly silty mudstone of moderately deep-water facies. Towards the top it passes into distinctly deeper-water mudstone. Above the top of the Conomiozea Zone there is a return to shallow-water facies with abundant macrofossils characteristic of the Allani Zone.

At Upton Brook the Allani Zone contains neither G. crassaformis nor G. conomiozea and the boundary between the Conomiozea Zone and Crassaformis Zone cannot be determined.

At Blind River the base of the Allani Zone cannot be determined with certainty. It is assumed that the facies changes from shallow to deep to shallow indicates equivalent ages in the two sections, and the abrupt lithological change at the top of the sandstone containing Cucullaea is arbitrarily taken as equivalent to the top of the Conomiozea Zone and the Kapitean Stage.

Crassaformis Zone and Allani Zone

Restricted:

Bolivina barnwelli Finlay - upper

Bolivina fyfei Hornibrook

Bolivinita aff. pohana Finlay - uppermost

Cibicides refulgens Montfort

First appearances:

Siphotextularia wairoana Finlay

Notorotalia finlayi Vella X hurupiensis Vella

Notorotalia pliozea Vella

Globigerina dutertrei d'Orbigny

Globorotalia crassaformis (Galloway & Wissler)

Mesopeplum crawfordi (Hutton)

Pleurigens n.sp.

Antisolarium stoliczkai (Zittel)

? Struthiolaria dolorosa King

Pellicaria aff. canaliculata (Zittel)

Xenophalium cf. grangei Marwick

Penion n.sp. aff. aspera Marwick

Austrofuscus allani King

Cominella (Cominella) n.sp.

Coluzea spectabilis Powell

Pachymelon cf. bartrumi King

Olivella (Lamprodomina) neozelanica (Hutton)

Comitas n.sp.

Aoteadrillia cf. waihuaensis Powell

Last appearances:

Cyclammina medwayensis Parr - lower

Siphotextularia n.sp. cf. wairoana Finlay - lowermost

Parafrondicularia awamoana (Finlay)

Bulimina pupoides d'Orbigny - lowermost

Bulimina cf. striata d'Orbigny, (large var.) - rare

PALEOECOLOGY

Depths of deposition are inferred by depth correlation with Upper Miocene and Pliocene Biofacies in Wairarapa (Vella, 1962) and with an additional biofacies recognised in the Kapitean at Cape Foulwind, north Westland (Kennett, 1963).

Lithofacies and Biofacies differ throughout the Upper Miocene and Pliocene sediments of the two sections studied. Lithological changes are shown on the stratigraphic columns (figs. 3 and 5). Sediments of the Blind River section were deposited in much deeper-water at all ages than those of the Upton Brook section. At Blind River, biofacies were more sensitive to depth changes, whereas at Upton Brook the lithofacies, especially in the upper part of the section, were more sensitive to depth changes. At Blind River a change in biofacies inferred to be due to change in depth does not always coincide with an obvious change in lithofacies. At Upton Brook on the other hand, a change in lithofacies suggesting a change in depth of deposition does not always coincide with a distinct change in biofacies.

Biofacies changes in each section are described in ascending order of stages. An attempt is then made to correlate biofacies and lithofacies changes between the two sections.

A summary of the biofacies present in each section and their inferred depth ranges is given in table 2 (Blind

STAGE	ZONE	BIOFACIES	Inferred Depth Range in feet
Opoitian	Crassaformis	Robulus Biofacies	c. 2000
		Haeuslerella Biofacies	c. 800
		Elphidium Biofacies	c. 200
		Haeuslerella Biofacies	c. 400
Kapitean	Conomiozea	Karrierella Biofacies	c. 1000
		Haeuslerella Biofacies	c. 400
		Karrierella Biofacies	c. 1000
Up. Tongaporutuan	Pliozea	Robulus Biofacies	c. 2000
Mid.	Pohana	Haeuslerella Biofacies	c. 400
		Non marine ?	+

Table 2 - Biofacies and inferred depths of deposition in the Blind River section.

STAGE	ZONE	BIOFACIES	Inferred Depth Range in feet
Opoitian	Crassaformis	Haeuslerella Biofacies (Shallow)	c. 400
Kapitean	Conomiozea		
Up. Tongaporutuan	Pliozea	Haeuslerella Biofacies (Deep)	c. 800
Mid.	Pohana		
		Non marine ?	+

Table 3 - Biofacies and inferred depths of deposition in the Upton Brook section.

River) and table 3 (Upton Brook).

Blind River Section

Middle and Upper Tongaporutuan: The basal conglomerate contains no fossils and is possibly non-marine.

In the siltstone and sandstone immediately above the conglomerate, abundant Textularia miozea Finlay, Haeuslerella parri Finlay, Robulus calcar (Linnaeus), Hofkeruva rodleyi rodleyi Vella, Bolivina petiae Gibson and Florilus flemingi (Vella) indicate the Haeuslerella Biofacies. Their association with Notocrotalia cf. depressa Vella probably indicates a depth of deposition in the shallower part of the Haeuslerella Biofacies with an inferred depth close to 300 ft.

In the upper and greater part of the Middle Tongaporutuan and the greatest part of the Upper Tongaporutuan, Mollusca are extremely rare and benthonic and planktonic Foraminifera are very abundant. The occurrence in abundance of deep-water species such as Karrerella cylindrica Finlay, Pullenia bulloides (d'Orbigny), Bolivina affiliata Finlay, Sigmoilopsis schlumbergeri (Silvestri) and the common occurrence of Martinottiella claree Gibson along with the general lack of any shallower-water species indicates the Robulus Biofacies.

From the writer's experience Bolivinita compressa Finlay, Karrerella bradyi Cushman, Osangularia bengalensis (Schwager), Ammodiscus finlayi Parr and Cyclammina medwayensis Parr, which occur in variable abundances at some levels, are restricted to the Robulus and deeper biofacies.

The occurrence of abundant Osangularia bengalensis and Notorotalia taranakia Vella in the Middle Tongaporutuan mudstone and the lower part of the Upper Tongaporutuan mudstone suggests a greater depth of deposition than in the higher part of the Upper Tongaporutuan.

The uppermost part of the Upper Tongaporutuan shows a distinct but gradational shallowing from the Robulus Biofacies to the Karreriella Biofacies. Evidence for the Karreriella Biofacies is a Foraminiferal assemblage containing less abundant Karreriella cylindrica, Bolivina affiliata and Martinottiella clarae, rare Pullenia bulloides and absence of Sigmoilopsis and Bolivinita compressa, and the occurrence of shallower-water species such as Bulimina aculeata d'Orbigny, Bolivina petiae, Pacinonion parki (Hornibrook) and Florilus flemingi.

Kapitean: A change to Haeuslerella Biofacies indicating shallowing, occurs at the base of the Kapitean. Evidence for this is the absence of the deep-water forms Karreriella cylindrica, Bolivina wattii Gibson and Sigmoilopsis, and the occurrence of only rare Martinottiella clarae, Bolivina affiliata and Pullenia bulloides and the abundance of the shallow-water species Bulimina aculeata. The rare occurrence of other shallow-water species, Notorotalia hurupiensis Vella and Anomalinoides spherica (Finlay), is significant.

Karreriella cylindrica seems to be particularly sensitive to depth changes. It is entirely absent in the

Kapitean Haeuslerella Biofacies just described, and from the Kapitean downwards into the Upper Tongaporutuan its abundance progressively increases with the increasing depth of deposition until it is nearly uniformly abundant in samples stratigraphically lower than f658.

Within the Kapitean the Foraminifera show the following fluctuations in depth.

<u>Feet above base of Tk.</u>	<u>Biofacies</u>	<u>Inferred changes</u>
650	Haeuslerella	shallowing
500	Karrerella	deepening
430	Haeuslerella	shallowing
300	Karrerella	deepening
0	Haeuslerella	shallowing

Strata deposited during the second shallowing, associated with the second appearance of the Haeuslerella Biofacies, include the Stace Stream shell bed which contains abundant Mollusca.

Opoitian: Still further shallowing is indicated by a marked facies changes at about 300 ft. above the base of the Opoitian. The biofacies change is accompanied by a marked increase in coarseness of the sediments. Benthonic Foraminifera are fairly abundant but planktonic specimens are significantly less abundant than at lower levels. Mollusca become abundant and form the richly fossiliferous Blind river

shell beds. Characteristic shallow-water species of Foraminifera appear in variable abundance, for example Florilus flemingi, Elphidium charlottensis (Vella), Zeaflorilus parri (Cushman), Notorotalia pliozea Vella and Notorotalia finlayi Vella X hurupiensis Vella. The coarseness of the deposit, abundance of macrofossils, and the species of Foraminifera indicate the Elphidium Biofacies which has an inferred depth range of 10 - 200 ft.

Above the shell beds, biofacies and lithofacies indicate deepening. Mollusca are rare; the sediment is finer; Foraminifera are represented by more abundant species and more abundant specimens; Pullenia bulloides is rare but persistent and Bolivina affiliata occurs in variable abundance; Florilus flemingi and shallower-water species of the Elphidiidae are absent. Most of the section above the shell beds contains a Haeuslerella Biofacies but the highest fauna studied contains abundant Karrerella cylindrica and Bolivina affiliata, and no shallow-water species, suggesting a change to the still deeper Robulus Biofacies.

Upton Brook Section

Middle and Upper Tongaporutuan: The basal conglomerate, like that at Blind River, contains no fossils.

Lithofacies and biofacies above the conglomerate vary only slightly throughout the Middle and Upper Tongaporutuan. Foraminifera are generally sparse in the Middle Tongaporutuan

but become abundant in the Upper Tongaporutuan. Macrofossils and other fossils are very rare throughout, and planktonic Foraminifera are uncommon.

Few shallow-water species of Foraminifera are present but the rareness and the impersistence of deeper-water species such as Karrerella cylindrica, Martinottiella clarae, Bolivina affiliata and Bolivina watti suggest a fairly shallow depth of deposition, in the deeper part of the Haeuslerella Biofacies. In the middle and upper part of the Upper Tongaporutuan, Foraminifera are more abundant, planktonic specimens are somewhat more common and Bolivina watti is abundant and persistent. This appears to be the deepest-water facies of the whole section, but is still not beyond the depth range of the Haeuslerella Biofacies.

Kapitean: Just below the Kapitean - Tongaporutuan boundary a marked but gradual shallowing occurs, which is shown by an increase in the coarseness of sediments to form the Upton lower siltstone and by the change to a shallower biofacies. Higher in the sequence there is a further lithological change from the Upton lower siltstone to the Upton sandstone which consists of 400 ft. of well bedded and concretionary hard medium sandstone.

The Upton lower siltstone and Upton sandstone contain none of the deeper-water species such as Martinottiella clarae, Bolivina affiliata, and Bolivina watti that occur in the underlying Tongaporutuan. Shallow-water species such as Florilus

flemingi, Pacinonion parki, Bolivina petiae, Bulimina aculeata, Notorotalia hurupiensis X finlayi are generally abundant. Anomalinoides spherica, another shallow-water species, occurs in variable abundance. Planktonic Foraminifera are very rare and Mollusca are generally common to abundant throughout. The fauna is a Haeuslerella Biofacies of shallower depth than that of the Tongaporutuan. The fauna of the Upton sandstone is more sparse, but otherwise not significantly different. The sample from high in the Upton sandstone contains many Foraminifera that are broken and worn suggesting, along with the increase in coarseness of the sediments, a still shallower depth of deposition than that of the underlying Upton siltstone.

Opoitian: The biofacies does not differ significantly from that of the Kapitean. At the base of the Opoitian there is a sudden change in lithology from the medium sandstone of the Upton sandstone to the moderately soft massive siltstone of the Upton upper siltstone, and a reduction in the number of macrofossils. Lithofacies therefore suggest a sudden increase in depth of deposition, but this is not supported by the biofacies.

About 300 ft. above the base of the Upton upper siltstone, macrofossils become abundant and the sediments become bedded again, suggesting a change equivalent to the post Kapitean shallowing at Blind River.

Facies Correlation between the Two Sections

To the left of the columnar sections, (figs. 3 and 5)

are shown curves indicating relative depth changes derived from plotting the biofacies for each sample. The range of biofacies differs considerably between both sections; the Upton Brook section includes biofacies that are all shallower than the deeper part of the *Haeuslerella* Biofacies, and the Blind River section includes biofacies mostly deeper than *Haeuslerella* Biofacies and ranging from the *Robulus* Biofacies to the *Elphidium* Biofacies. Despite these differences in range of biofacies, or the overall differences in depths of deposition, most large changes in depth of deposition can be discerned in both sections, and were probably synchronous.

After deposition of the basal conglomerate and immediately overlying sandstone and siltstone, depth increased in both sections to about the middle of the Upper Tongaporutuan Age. Following this, gradual shallowing took place until the Kapitean Age. An increase in depth of deposition occurred in both sections about the beginning of the Opoitian Age. This was followed by shallowing shown by a marked change in biofacies and lithofacies at Blind River where its culmination is represented by the Blind River shell beds. This shallowing is less obvious at Upton Brook but is suggested by a change from massive to poorly bedded sediments and a marked increase in the number of macrofossils. Following this shallowing, a marked increase in depth of deposition occurred at Blind River, and a possible smaller increase in depth at Upton Brook.

CONCLUSIONS

The Upton Brook section consists predominantly of shallower-water facies, while the Blind River section consists predominantly of much deeper-water facies. In the Upton Brook section where Mollusca are abundant and planktonic Foraminifera rare, the base of the Kapitean Stage is taken at the first appearance of the key Kapitean Mollusca Sectipecten wollastoni and Austrofusus coerulescens. In the Blind River section where Mollusca are rare and planktonic Foraminifera are abundant, the base of the Kapitean Stage is determined by a stage in evolution of the Globorotalia crassaformis bioseries (Kennett in press).

The upper boundary of the Kapitean Stage at Blind River is distinguished with certainty at the lowest sample in which typical Globorotalia crassaformis makes up 50 per cent of the G. conomiozea - crassaformis population. The upper boundary of the Kapitean Stage in the Upton Brook section is not well defined because diagnostic Foraminifera are absent. Correlation however is affected with the Opoitian at Blind River by Mollusca and by probably synchronous facies change.

Previous work (Gibson, MS; Kennett, in press) indicated difficulties in correlating deep-water facies and shallow-water facies of Kapitean age. It was not known whether the Kapitean is younger than the Compressa Zone, or equivalent to part or all of it. The first appearance of B.

compressa defining the base of the Upper Tongaporutuan in the deep-water Blind River section occurs about 2000 ft. below the base of the Kapitean Stage. This shows for the first time that the Kapitean Stage is not equivalent to all of the Bolivinita compressa Zone, and is younger than the lower part of the Compressa Zone. The Kapitean Stage is only 700 ft. thick at Blind River and is relatively thin compared with the Upper Tongaporutuan.

At Upton Brook the Wollastoni Zone corresponds with the upper part of the Conomiozea Zone, and the lower part of the Conomiozea Zone of Marlborough appears to be the same age as beds in Taranaki containing both G. conomiozea and S. grangei.

In Westland G. conomiozea does not occur with S. grangei in the Grangei Zone (Kennett, 1963a, in press), because of unfavourable environmental conditions. However as S. grangei seems to be in continuous succession with S. wollastoni, the Grangei Zone can probably be safely correlated with the lower part of the Conomiozea Zone of Marlborough.

At Blind River Sigmoilopsis schlumbergeri is replaced by S. zeaserus just below the first appearance of G. conomiozea and thus the Zeaserus Zone is essentially equivalent to the Conomiozea Zone. The Zeaserus Zone was considered by Vella to be equivalent to the Kapitean Stage but the Conomiozea Zone is equivalent to the upper part of the Upper Tongaporutuan and the Kapitean.

Despite overall differences in facies of the Blind River and Upton Brook sections, most significant changes in depth of deposition appear to occur in both sections and were probably synchronous. One of the most significant depth changes was a marked shallowing of the sea between late Upper Tongaporutuan and early Kapitean times.

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APPENDIX - Index of Fossil Localities

Full locality details are recorded in the Sheet Fossil Master-file for Marlborough region at the Geology Department, Victoria University of Wellington.

Sample numbers are the Sheet Fossil Numbers of the N.Z. Fossil Record system based on sheet districts of the N.Z. map series.

Grid references are the coordinates based on the National Thousand-yard grid.

Lithologies are given in the code of the N.Z. Fossil Record Form (Wellman, 1953:55).

Standard symbols are used for New Zealand stages.

Sheet fossil number	Locality	Grid ref.	Lithology	Age
S29f603	Blind River (Upper part)	300710	7842c0S	M.Tt
f618		301712	9952d	M.Tt
f635		302714	9952d	U.Tt
f636		303718	9952d	U.Tt
f637		310725	9952d	U.Tt
f638		312727	9952d	U.Tt
f639		314728	9952d	U.Tt
f640		317730	9952d	U.Tt
f641		320732	9952d	Tk
f642		321733	9852d	Tk
f643	Stace Stream	322734	9852d	Tk
f644		323734	9852d0S	Tk
f645		324735	9852d	Tk
f646		325736	9952d	Wo
f647		324737	9952d	Wo
f648		324738	8852d	Wo

Sheet fossil number	Locality	Grid ref.	Lithology	Age
f649	Blind River (Middle part)	323739	8852d	Wo
f650		324740	8752d0	Wo
f651		325741	8752d0S	Wo
f652		326742	7852dSS	Wo
f653		327744	9952dS	Wo
f654		328749	9952d	Wo
f655		332754	9952d	Wo
f656		337758	9952d	Wo
S23f561	Upton Brook above Upton Road bridge	204701	9841d	M.Tt
f562		202704	8941e	M.Tt
f563		200708	8941d	M.Tt
f564		198711	8941d	M.Tt
f565		195714	8941d	U.Tt
f566		193716	8941d	U.Tt
f567		192717	9952d	U.Tt
f568		191719	9952d	U.Tt
f569		190720	9952d	U.Tt
f570		189722	9952d	U.Tt
f571		188724	9952d	U.Tt
f572		186725	8952d	U.Tt
f573		185725	9852d	Tk
f574		185726	8842dSS	Tk
f575		182728	7761c00	Tk
f576		181730	7761c00	Tk
f577		180732	8841d	Wo
f578		183736	8841d	Wo
	Awatere River downstream from Upton Brook			

Biostratigraphy and Paleoecology in some
Upper Miocene - Lower Pliocene Sections,
Wairarapa - S. Hawkes Bay, New Zealand.

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ABSTRACT

The faunal succession of six sections through the Upper Miocene - Lower Pliocene is given for Wairarapa and Southern Hawkes Bay. Ranges of Foraminifera and Mollusca are given for each section and lithologies are shown on columnar sections.

For the interval of time from Upper Tongaporutuan to Opoitian, a zonal subdivision consisting of two parallel sets of zones is recognized. One is based on Foraminifera and is applicable mainly to deep-water facies. The other is based on Mollusca and is applicable to shallow-water facies. Diagnostic species for each zone are listed.

The Kapitean Stage is determined in shallow-water facies mainly by the presence of Sectipecten wollastoni. In deep-water facies which lack the key Mollusca, it is determined by means of the Globorotalia crassaformis bioseries. The absence of the Kapitean in two of the sections is shown mainly by the absence of the characteristic Kapitean parts of the G. crassaformis bioseries and of the Siphotextularia wairoana bioseries.

The paleoecology throughout each section is described, and indicates that a shallowing of the sea took place during the Kapitean Age.

INTRODUCTION

Six stratigraphic sections through the Upper Miocene and Pliocene in Wairarapa and Southern Hawkes Bay (fig. 1) were examined to determine the succession of Foraminifera and Mollusca. The main aims were to determine firstly the limits of the Kapitean Stage and secondly, the diagnostic Kapitean fossils in the area. Ancillary to this, a zonal subdivision somewhat different from that of Vella (1962) was established for the interval from Middle Tongaporutuan to Waitotoran. Two parallel sets of zones are recognized, one based on Foraminifera, applicable mainly to deep-water facies, and the other based on Mollusca, applicable only to shallow-water facies. Paleoecology indicates that shallowing of the sea took place during the Kapitean time, and the stratigraphic zonation is partly controlled by the changes in depth of deposition.

The six sections studied are as follows:

Palliser Bay Section

A section from Lower Tongaporutuan to Nukumaruan is well exposed in sea cliffs on the north-east side of Palliser Bay, between Hurupi Creek and Lake Ferry (N.Z.M.S.I. Sheet District NI65). The part of the section east of

Fig. 1 - Map showing location of sections examined.

Whangaimoana (fig. 2) was collected by G.W. Gibson and the writer in 1962, and the Tongaporutuan faunas have been examined by Gibson (1963, MS). The writer however has examined seven samples from the Upper Tongaporutuan to the Waitotaran. Sample localities are shown in fig. 2 and lithologies and sample horizons are shown on a columnar section (fig. 3).

Mangaoranga Section

The Mangaoranga section lies within N.Z.M.S. Sheet District NI53 and extends from one to two miles south-east from Eketahuna township (fig. 4). It is well exposed in the stream flowing alongside the Mangaoranga Road and was sampled at intervals of 100 - 200 ft. Sample locations are shown in fig. 4 and lithologies and sample horizons are shown in a columnar section (fig. 5).

The section has been divided into six formations by Mr. G. Neef (pers. comm.). The six formations are here informally designated as follows:

6. upper mudstone
5. upper siltstone
4. lower mudstone
3. lower siltstone
2. sandstone
1. basal conglomerate

The basal conglomerate lies unconformably on a planed surface of Mesozoic greywacke which forms the basement.

Fig. 2 - Map of the Palliser Bay section
showing location of samples.

Fig 4 - Map of the Mangaoranga section showing location of samples.

Fig. 5 - Stratigraphic column for

THE MANGAORANGA SECTION

Thick- ness (ft.)	Stage	Sample Nos	
2100	Wo	1172	
		1170	Moderately hard, calcareous, blue-grey, massive mudstone with very rare macrofossils.
1800	Tk	1168	Moderately soft, blue-grey muddy siltstone with concretions at one horizon, and brachiopods.
		1166	
1500	U.Tt	1164	
		1162	Moderately hard, calcareous, blue-grey massive mudstone with very rare macrofossils.
1200	M.Tt	1161	
		1160	
900		1159	
		1158	Moderately hard, calcareous, blue- grey, weakly bedded siltstone with uncommon macrofossils.
		1157	
600		1155	
		1154	Weakly to moderately calcareous, blue-grey soft, bedded, fine sandstone with scattered macrofossils.
		1152	
300		1151	Moderately coarse greywacke conglomerate with thin, medium sandstone bands.
0			Greywacke basement.

Molluscan fossils occur in the lower part of the section, and are being listed by Mr. Neef. The six formations were mapped as Tutamoe Series (Lower Miocene) by Ongley (1935), but were found by Neef (pers. comm.) to range from Upper Miocene to Lower Pliocene in age.

Mangatainoka Valley Sections

Two sections were collected in the Mangatainoka Valley (fig. 6) which also lies in N.Z.M.S.I. Sheet District NI53. They are the Ngamaia Stream and Putara sections, and lie about two miles from each other. The Ngamaia Stream section is poorly exposed in the lower reaches of the Ngamaia Stream, $1\frac{1}{2}$ miles south-west of Putara Village. The Putara section is fairly well exposed in cliffs cut by the Mangatainoka River immediately north of Putara, and for $1\frac{1}{2}$ miles n.w. up a stream flowing into the Mangatainoka River.

Sample locations for both sections are shown in fig. 6 and lithologies and sample horizons are shown on columnar sections (fig. 7 - Ngamaia Stream section and fig. 8 - Putara section).

Three formations have been recognized by Neef, and are here informally designated as follows:

3. Mangatainoka upper sandstone
2. Mangatainoka conglomerate
1. Mangatainoka lower sandstone

The lower sandstone rests on a planed basement

Fig 6 - Map of the Mangatainoka Valley sections showing location of samples. (Slightly modified after an unpublished map by Mr. G. Neef.)

Fig. 7 - Stratigraphic column for

THE NGAMAIA STREAM SECTION

Fig. 8 - Stratigraphic column for

THE PUTARA SECTION

surface. The three formations were mapped as Te Aute Series by Ongley (1935) but were considered by Neef to range from Kapitean to Opoitian (Upper Miocene to Lower Pliocene) in age.

Weber Sections

Two sections, 2 miles apart, were collected near Weber township in N.Z.M.S.I. Sheet District NI50. The Waipatiki Stream section is well exposed in a main tributary of the Waipatiki Stream $1\frac{1}{2}$ miles east of Oporae Hill, 5 miles west-north-west of Weber (fig. 9). This section was sampled at intervals of 100 - 200 ft. Sample locations are shown in fig. 9 and sample horizons on a columnar section (fig. 10). The Mangapuka Stream section lies 5 miles north-west of Weber and is moderately well exposed in the upper reaches of the Mangapuka Stream (fig. 11). This section was sampled at intervals of 200 - 300 ft. Sample locations are shown in fig. 11 and sample horizons on a columnar section (fig. 12).

In the Waipatiki Stream section, Taranakian sediments rest with angular unconformity on the Wanstead Formation (Danian or Paleocene), while in the Mangapuka Stream section they lie with angular unconformity on the Whangai Formation (Maestrichtian or Danian). The strata above the unconformity are equivalent to the Mangatoro Formation and Te Aute Limestone mapped by Lillie (1953) in Dannevirke Subdivision. Laing (1964, MS) divided them

Fig. 9 - Map of the Waipatiki Stream section showing location of samples.

Fig. 10 - Stratigraphic column for

THE WAIPATIKI STREAM SECTION

Fig. 11 - Map of the Mangapuka Stream section
showing location of samples.

Fig. 12 - Stratigraphic column for
THE MANGAPUKA STREAM SECTION

Thick- ness (ft.)	Stage	Sample Nos.	
2800	Ww		Coquina limestone containing <u>Neothyris obtusa</u> , <u>Ostrea</u> and <u>Phialopecten triphooki</u>
		1055	Massive, brown, micaceous muddy siltstone with rare concretion bands and Molluscan casts.
2400	Wo?	1054	
		1053	
		1052	Massive, fine, micaceous silty sandstone.
2000	Wo	1051	
1600		1050	Massive, micaceous sandy siltstone with rare Mollusca.
1200		1049	
		1048	
		1047	
800	Tk		Bedded micaceous silty mudstone.
		1046	
			5 ft. concretionary layer
400		1045	
		1044	Hard and soft light blue-grey silty sandstone beds with common Mollusca at some horizons.
		1043	
0	U. Cret.		Contact unexposed Hard green-grey mudstone with concretions.

into three formations which are here designated as follows:

FORMATION	AGE
Te Aute Limestone	Waitotaran
Upper Mangatoro Formation	Opoitian to Waitotaran
Lower Mangatoro Formation	Kapitean

The Lower Mangatoro Formation has blue-grey coarse sand with common molluscan fossils at the base, passing up gradually to blue-grey micaceous silty mudstone with very rare molluscan fossils. The Upper Mangatoro Formation is similar but is generally sandier.

For all sections an index of fossil localities, with lithologies and age determinations is given in Appendix 2.

BIOSTRATIGRAPHY

The distribution of Foraminifera in the sections are shown on range charts (table 13 - Palliser Bay section; table 14 - Mangaoranga section; table 15-Mangatainoka Valley sections and table 16 - Weber sections).

Table 1 shows the zonal classification adopted by the writer compared with that given by Vella for Mauriceville District (1962). Foraminifera can be used to distinguish five zones representing a continuous sequence from Middle Tongaporutuan to Waitotaran. Besides these, three important zones based on Mollusca represent different parts of the same sequence. Selected lists of diagnostic species for each

zone are given in Appendix 1. Ranges of species given by Gibson (1963, MS) have been used to compile parts of the lists for lower zones.

1. Foraminiferal Zones:

Pohana Zone: The Pohana Zone is a foraminiferal zone first distinguished in the Palliser Bay section by Vella (1954). It was recognised by the writer only in the Palliser and Mangaoranga sections, being cut out by unconformity in the other sections examined. It is distinguished by the presence of Bolivinita pohana and absence of Bolivinita compressa and Bolivinita pliozea, and by definition is equivalent to the so-called Middle Tongaporutuan. Bolivina lapsus Finlay and Bulimina vellai Gibson make their last appearances near the top of the Pohana Zone at Palliser Bay and Mangaoranga, and seem to be useful correlation fossils. Bulimina cf. striata d'Orbigny (small var.) makes its first appearance about 200 ft. below the top of the zone at both Palliser Bay and Mangaoranga.

Pliozea Zone: The base of the Pliozea Zone is the top of the Pohana Zone, and is marked by the appearance of Bolivinita pliozea. At Blind River, Marlborough, Bolivinita compressa makes its first appearance at the same horizon as B. pliozea, but in the Wairarapa and southern Hawkes Bay sections examined by the writer it is extremely rare or absent, and probably excluded by facies. By correlation with Blind River, the Pliozea Zone is inferred to be Upper Tongaporutuan in age, but it does not represent the whole

of the Upper Tongaporutuan "substage". The Pliozea Zone is equivalent to the Compressa Zone at Mauriceville (Vella, 1962).

Zeaserus Zone: The Zeaserus Zone was first recognised by Vella (1962). Its base is the top of the Pliozea Zone, and is marked by the first appearance of Sigmoilopsis zeaserus Vella, which replaces Sigmoilopsis schlumbergeri (Silvestri). Sigmoilopsis zeaserus is restricted to relatively deep-water facies, and the zone cannot be recognised in the shallower-water facies representing the late Taranakian in the Mangatainoka Valley.

The Zeaserus Zone was considered by Vella to represent the Kapitean Stage, but correlation by means of the Globorotalia crassaformis bioseries indicates that it represents the Kapitean and part of the Upper Tongaporutuan.

The Globorotalia crassaformis bioseries (Kennett, 1965c, in press) is well defined in the two Weber sections. Sampling intervals were somewhat too wide to show it satisfactorily at Palliser Bay. Parts of the bioseries are missing due to disconformity at Mangatainoka Valley, and specimens are rare in the Mangaoranga section. The early changes from Globorotalia miozea Finlay to G. conomiozea Kennett take place through the Zeaserus Zone. The first appearance of G. conomiozea, arbitrarily defined as the horizon where typical G. conomiozea forms 50 per cent of the population (Kennett, loc. cit.), is near the middle of the

zone. This agrees fairly well with the sequence in Marlborough where the first appearance of G. conomiozea is 300 ft. above that of S. zeaserus. The late Taranakian at Mangatainoka Valley contains G. conomiozea and therefore, although it lacks S. zeaserus it can be correlated with the upper part of the Zeaserus Zone.

Crassaformis Zone: The Crassaformis Zone was previously recognised in Westland and in Marlborough by Kennett (1965a, 1965b, in press). Its base is the top of the Conomiozea Zone in Westland and in Marlborough, and the top of the Zeaserus Zone in Wairarapa and S. Hawkes Bay. Its base is also the base of the Opoitian Stage and the Wanganui Series. Here, for the first time, the Crassaformis Zone is recognised as distinct from an overlying Inflata Zone which contains Globorotalia inflata but G. crassaformis only at its base.

The base of the Crassaformis Zone is marked by the first appearance of the planktonic species Globorotalia crassaformis. This species is the end member of the G. crassaformis bioseries, and its first appearance is arbitrarily taken as where typical G. crassaformis forms 50 per cent of the population. The base of the Crassaformis Zone corresponds to the base of the Inflata Zone of Vella (1962) but this apparent discrepancy is due to incorrect determination of G. crassaformis as G. inflata (Vella, pers. comm.).

At Mangatainoka Valley the upper part of the G. crassaformis bioseries is missing owing to disconformity

between the Crassaformis Zone and the strata equivalent to the Zeaserus Zone.

Inflata Zone: The Inflata Zone of this account is different from the Inflata Zone of Vella (see table 1, and Crassaformis Zone above). Its base is the top of the Crassaformis Zone, and is marked by the first appearance of the planktonic species Globorotalia inflata. Only the Palliser Bay section and the Putara section at Mangatainoka Valley were sampled high enough to reach the Inflata Zone.

The age of the Inflata Zone is uncertain. The lower part is probably late Opoitian or Waipipian. The top has not been determined, and the highest sample in the Palliser Bay section, still in the Inflata Zone, is 500 ft. below the base of the Hautawan Stage (basal Pleistocene), and is either Waipipian or Waitotaran in age.

2. Molluscan Zones:

The two molluscan zones shown in table 1 are based on restricted Pelecypod species that have been important index fossils for many years. Their ages relative to the sequence of Foraminifera can now be set down fairly definitely.

Grangei Zone: The Grangei Zone is the range zone of Sectipecten grangei Boreham. At Callaghans Creek, Westland, S. grangei occurs in the greensand immediately underlying the Kapitean Stage. The species was regarded by Boreham (1961) as the fore-runner of the Kapitean key species S. wollastoni (Finlay) and indicative of a Tongaporutuan age.

Sectipecten grangei was found in the sandstone above the basal conglomerate in the Makakahi River 2 miles s.w. along the strike from the Mangaoranga section (Mr. G. Neef, pers. comm.). The sandstone lies in the Pohana Zone. The species also occurs in the lower sandstone at Mangatainoka Valley, which lies in the Zeaserus Zone. The Grangei Zone therefore is known to range in age from Middle Tongaporutuan to Upper Tongaporutuan. The age of the base is as yet unknown.

Wollastoni Zone: The Wollastoni Zone is the range zone of the Kapitean key species Sectipecten wollastoni (Finlay). Of the sections described herein, the species occurs only at Weber. There Sigmoilopsis zeaserus is rare, and occurs only some 200 ft. below the Crassaformis Zone, but good correlation can be effected by means of the G. crassaformis bioseries. The Wollastoni Zone is equivalent to the upper part (about half, judging from stratigraphic thicknesses) of the Zeaserus Zone. S. wollastoni seems to replace S. grangei abruptly, for S. grangei occurs in the lower part of the Zeaserus Zone.

By combining the sequence of samples from the Grangei Zone at Mangatainoka with those from the Wollastoni Zone at Weber a bioseries of shallow-water benthonic Foraminifera can be recognised. The sequence shows a gradual change from Siphotextularia n.sp. up to Siphotextularia wairoana Finlay. The new species differs from S. wairoana

in having a rhomboid instead of evenly quadrate outline, a more regularly tapering test, and more deeply concave sides. At Maraetotara River, in central Hawkes Bay, 60 miles north of Weber, the same new species extends high into the Opoitian Stage, and no bioserial change can be detected. It is uncertain, therefore, whether the bioserial changes at Mangatainoka and Weber reflect evolution or migration of two interbreeding species due to environmental change (perhaps a change in temperature).

Kapitean Stage in Palliser Bay Section

The key Kapitean Mollusca are lacking and the base of the Kapitean must be determined from the stage of evolution of the Globorotalia crassaformis bioseries (Kennett, 1965c, in press). The Kapitean Stage is very thin at Palliser Bay. The incoming of G. conomiozea is only about 350 ft. below the base of the Opoitian Stage and of this, only the upper 250 ft. are considered to be Kapitean. The Upper Tongaporutuan is correspondingly thin, being only 350 ft. thick, and deposition during late Miocene was evidently slow. By contrast at Blind River, Marlborough, 60 miles to the s.w. the Upper Tongaporutuan is about 2400 ft. thick and the Kapitean Stage is about 600 ft. thick.

Kapitean Stage in Mangaoranga Section

The Upper Tongaporutuan to Opoitian sediments of the Mangaoranga section are similar in facies and thickness

to the Palliser Bay section. The Kapitean Stage, as determined by rare specimens from the G. crassaformis bioseries, is only about 300 ft. thick. The Upper Tongaporutuan is again correspondingly thin, being only about 400 ft. thick.

Kapitean Stage in Mangatainoka Valley Sections

The Mangatainoka lower sandstone which is below the disconformity, contains S. grangei and B. pliozea and is Upper Tongaporutuan in age. A high Upper Tongaporutuan age is suggested by the presence of Siphotextularia n.sp., Patellinella inconspicua (Brady) and Globorotalia conomiozea.

The Mangatainoka upper sandstone contains G. crassaformis and is Opoitian in age. Although the facies is suitable for Sectipecten, S. wollastoni is not known in the area. Furthermore, although G. conomiozea occurs in the Mangatainoka lower sandstone, forms linking it with G. crassaformis characteristic of the Kapitean, are also missing. The conglomerate between the lower and upper Mangatainoka sandstones is assumed to be Opoitian in age and the Kapitean is considered to be represented by disconformity beneath the conglomerate.

Kapitean Stage at Weber

The occurrence of S. wollastoni indicates a Kapitean age near the base of the Mangapuka Stream section. A continuous sequence from the Kapitean to at least the lower Opoitian is indicated by the continuous G. conomiozea - crassaformis bioserial change and by the Siphotextularia n.sp.

- wairoana bioserial change. Assuming a Kapitean age for the base of the section, the Kapitean Stage is about 1300 ft. thick and was deposited rapidly compared with the Kapitean Stage in southern Wairarapa.

PALEOECOLOGY

Palliser Bay Section

The paleoecology of the lower part of the Taranaki Series of the Palliser Bay section has been discussed by Gibson (1963, MS). The following is an account of the paleoecology of the upper part of the Taranaki Series and lower part of the Wanganui Series. A summary of the biofacies present is given in table 2.

Most of the Upper Tongaporutuan massive mudstone contains very rare Mollusca, rare Ostracoda, and at one horizon, abundant Radiolaria. The occurrence in abundance of deep-water species of Foraminifera such as Karreriella bradyi (Cushman), Karreriella cylindrica Finlay, Sigmoilopsis schlumbergeri (Silvestri) - S. zeaserus Vella, Haeuslerella finlayi Vella, Pullenia bulloides (d'Orbigny), Notorotalia taranakia Vella, Bolivina wattii Gibson, Bolivina affiliata Finlay, rare to common Sigmoilopsis gavini Gibson, Bolivinita compressa Finlay, Osangularia bengalensis (Schwager); varied and abundant Lagenidae; and the general lack of any shallower-water species indicates the Robulus Biofacies, or deeper biofacies.

STAGE	WAIRARAPA FORAMINIFERAL ZONES	BIOFACIES
Opoitian ? - Waitotaran	Inflata	Hæuslerella Biofacies
Opoitian	Crassaformis	Robulus Biofacies
Kapitean	Zeaserus	Karrierella Biofacies
Up. Tongaporutuan	Pliozea	Robulus Biofacies
Mid.	Pohana	

Table 2 - Biofacies in the middle part
of the Palliser Bay section.

The uppermost part of the Taranaki Series, (Kapitean and uppermost Tongaporutuan) shows a distinct shallowing of the sea. The foraminiferal assemblage differs from that of the deeper-water facies below, in containing abundant Bulimina aculeata, Pacinoion parki, only rare Sigmoilopsis, and Pullenia, and no Sigmoilopsis gavini, Bolivinita compressa or Osangularia. Moreover the Lagenidae are less abundant and less varied. The assemblage is otherwise similar to that of the deeper-water facies, and is considered to be the Karreriella Biofacies indicating a depth of about 1000 ft.

At the beginning of the Opoitian the sea deepened again, as shown by the occurrence of common S. gavini, rare Sigmoilopsis and O. bengalensis, more varied Lagenidae, and the general lack of any shallower-water species. The assemblage is considered to represent the Robulus Biofacies and to indicate depths of 1500 to 3000 ft.

"Waitotaran" faunas have fewer specimens of Foraminifera than those of the Taranakian and Opoitian. They include common to abundant specimens of shallower-water species such as B. aculeata and Siphotextularia wairoana Finlay. Towards the top they include progressively more common Mollusca and the sediments become coarser. The Foraminifera are diagnostic of the Haeuslerella Biofacies indicating depths from about 400 to 1000 ft.

Mangaoranga Section

The Mangaoranga section shows progressive biofacies and lithofacies changes, indicating a progressive increase in depth of deposition, from the Middle Tongaporutuan beds immediately above the basal unconformity to the Upper Taranakian. Table 3 shows the relationships between the biofacies, informal formations, Wairarapa - S. Hawkes Bay zones and the New Zealand stages.

The basal conglomerate rests unconformably on a planed greywacke basement surface, and its deposition commenced as the sea transgressed over the previous land surface. The change is gradational but rapid from the *Zeaflorilus* Biofacies at the base, through the *Elphidium* Biofacies, *Haeuslerella* Biofacies, and *Karrerella* Biofacies, to the *Robulus* Biofacies. Most appearances and disappearances of species in the section are not time significant but are caused by the gradual facies changes.

Basal conglomerate: The lower part of the basal conglomerate is unfossiliferous, but the upper part contains very rare broken Foraminifera indicative of the *Zeaflorilus* Biofacies. It is assumed that the whole of the conglomerate was deposited in very shallow marine conditions.

Sandstone: The sandstone above the basal conglomerate contains scattered Mollusca, Ostracoda, Bryozoa and Echinoid spines at various levels. In its lower part, sparse foraminiferal faunas consist almost entirely of *Zeaflorilus*

STAGE	INFORMAL FORMATIONS	WAIRARAPA ZONES		BIOFACIES
		Foraminiferal Zones	Molluscan Zones	
Opoitian	upper mudstone	Crassaformis	—	Karreriella Biofacies
Kapitean	upper siltstone	Zeaserus	—	Haeuslerella Biofacies
Up. Tongaporutuan	lower mudstone		Pliozea	Grangei	Robulus Biofacies
		Pohana	Karreriella Biofacies	
lower siltstone	Haeuslerella Biofacies			
sandstone	Elphidium Biofacies			
basal conglomerate	Zeafiorilus Biofacies			

Table 3 - Biofacies in the Mangaoranga section.

parri (Cushman), Elphidium cf. chapmani Cushman, Elphidium cf. depressulum Cushman, and Notorotalia macinnesi Kennett. Foraminifera are often broken and worn, and planktonic species are very rare. They are considered to still represent the Zeaflorilus Biofacies. The coarseness of the deposit condition of the shells, and the biofacies indicates sea depths no greater than 20 ft.

The upper part of the sandstone has a more varied foraminiferal assemblage; specimens are rarely worn or broken and planktonic Foraminifera are rare. The occurrence together of abundant Bulimina aculeata, Sigmoidella elegantissima (Parker & Jones), Notorotalia cf. depressa Vella, Elphidium charlottensis (Vella), Pacinoion parki (Hornibrook) and common Zeaflorilus parri, Guttulina bartschi Cushman & Ozawa, Rectobolivina striatula (Cushman), F. flemingi, and Gavelinopsis lobatulus (Parr), indicate the Elphidium Biofacies.

Lower siltstone: Macrofossils are less common than in the sandstone, while Foraminifera, especially the Lagenidae are more abundant and varied. Ostracoda, Bryozoa and echinoid spines are abundant.

In the lower part of the lower siltstone the common occurrence of the shallow-water species T. barnwelli, T. kapitea, B. aculeata, F. flemingi, G. zelandica, N. hurupiensis and A. spherica, and the general lack of deeper-water species indicate the Haeuslerella Biofacies.

It is worth noting that Cibicides finlayi Gibson

and Bulimina cf. striata (large var.) which extend into much deeper facies first appear in the lower part of the lower siltstone.

The upper part of the lower siltstone contains many of the shallower-water species that occur in the lower part, but the following deeper-water species first appear in abundance: Karreriella cylindrica Finlay, Neouvigerina eketahuna Vella, Bolivina affiliata Finlay, Bolivina watti Gibson. Rare specimens of the deep-water species Pullenia bulloides (d'Orbigny) also appear. The association of these deeper-water species with the typically shallow-water species indicates the Karreriella Biofacies.

Lower mudstone: The lower mudstone consists of massive blue-grey mudstone containing very rare Mollusca. For the most part, lithofacies and biofacies vary only slightly throughout the lower mudstone. The base contains a fauna very similar to the upper part of the lower siltstone and is also indicative of the Karreriella Biofacies. One significant difference however is the first appearance of the deeper-water species Sigmoilopsis schlumbergeri. The highest occurrence of the shallow-water species Notorotalia hurupiensis is at the base of the lower mudstone.

About 170 ft. above the base of the lower mudstone, the following deeper-water forms first appear in variable abundance: Ammodiscus, Karreriella bradyi (Cushman), Awhea sinalata (Finlay), Pacinonion neefi Vella,

and Notorotalia taranakia Vella. Lagenidae and planktonic Foraminifera are more varied and abundant than in the lower biofacies; P. bulloides occurs abundantly for the first time and N. eketahuna is more abundant than lower in the section. The Foraminiferal assemblage is a Robulus Biofacies, indicating depths of probably 1000 to 2000 ft. Rare Osagularia bengalensis (Schwager) and Bolivinita compressa Finlay occurring near the middle of the lower siltstone may indicate even greater depths of deposition.

Upper siltstone: In the uppermost part of the lower mudstone, a facies change due to shallowing culminates in the upper siltstone composed of about 200 ft. of concretionary muddy siltstone containing common Brachiopoda. A corresponding change in biofacies also occurs. The Foraminiferal fauna is relatively depleted in species, partly resulting from the almost complete loss of the deep-water forms such as K. cylindrica, P. neefi, Sigmoilopsis and P. bulloides. Shallow-water species again appeared, such as abundant B. aculeata and B. petiae and more common F. flemingi. The assemblage is a Haeuslerella Biofacies, and the abundance of B. affiliata and B. watti suggests that it is nearer to the moderately deep-water Karreriella Biofacies than to the shallow-water Elphidium Biofacies.

Upper mudstone: Above the upper siltstone a further change in facies due to deepening occurs. Macrofossils and Ostracoda are very rare, Foraminifera are abundant, and

the planktonic and Lagenid Foraminifera are varied and abundant. K. cylindrica, P. bulloides, and P. neefi are generally common, and shallow-water species are generally absent. The assemblage is either the Karreriella Biofacies or the Robulus Biofacies, and indicates deposition slightly deeper than 1000 ft.

Mangatainoka Valley Sections

A summary of the biofacies present is given in table 4.

Mangatainoka lower sandstone: The Mangatainoka lower sandstone consists of sandstone and siltstone containing abundant Mollusca and Ostracoda. The abundant to common occurrence of shallow-water Foraminifera such as T. kapitea, Siphotextularia cf. wairoana Finlay, M. clarae, R. striatula.

Mangatainoka upper sandstone: At Putara the sediments above the Mangatainoka conglomerate becomes progressively finer. The fauna throughout the upper sandstone is typical of the Haeuslerella Biofacies with B. aculeata, B. petiae, P. parki, F. flemingi and A. spherica abundant in most samples and with no trace of deep-water species such as K. cylindrica. The lower part of the Mangatainoka upper sandstone contains abundant G. lobatulus and Elphidium charlottensis and numerous ostracods indicating a shallower phase of the Haeuslerella Biofacies. Towards the middle of the upper sandstone these species disappear and are replaced by B. affiliata, and occasional specimens of Sigmoilopsis, while the ostracod fauna is reduced to only thin-shelled species. Towards the top, B. watti appears, and in the top sample the biofacies approaches the Karreriella Biofacies with abundant H. pliocenica, B. watti, and B. albatrossi, common S. zeaserus and rare S. gavini.

This succession of biofacies changes indicates a gradual increase in depth of deposition from about 200 ft. at the base of the Mangatainoka upper sandstone to nearly 1000 ft. at the top of the sandstone.

The Mangatainoka upper sandstone in Ngamaia Stream two miles to the south-west, is of much shallower-water facies than at Putara. Shallow depth of deposition throughout is shown by coarseness, common current bedding, common Mollusca, and by a foraminiferal fauna almost entirely made

up of abundant Z. parri, F. flemingi and common Quinqueloculina, representing the Zeaflorilus Biofacies. Depth of deposition of the whole of the sandstone at Ngamaia Stream was probably less than 100 feet.

Further south-west from the Ngamaia Stream section the Mangatainoka upper sandstone becomes still coarser and passes into a thick sequence of massive conglomerate (Mr. G. Neef - pers. comm.). Thus lateral deepening of the sandstone occurs from possibly non-marine conglomerate in the south-west, through medium sandstone of the Zeaflorilus Biofacies in the Ngamaia Stream area, to siltstone of the Haeuslerella Biofacies north-east in the Putara area.

Weber Sections

The Waipatiki Stream section and the Mangapuka Stream section, which lie two miles from each other, closely resemble each other in facies. The Lower Mangatoro Formation rests unconformably on either the Wanstead or the Whangai Formations. The base of the Lower Mangatoro Formation is best exposed in Waipatiki Stream and the description of its paleoecology is from this section. A summary of the biofacies present is given in table 5.

Lower Mangatoro Formation

In the lowest 150 ft. comminuted shell fragments, Ostracoda, and Bryozoa are abundant; Foraminifera are relatively sparse and specimens are often broken and worn; planktonic Foraminifera are rare. The association of

STAGE	WAIRARAPA ZONES		BIOFACIES
	Foraminiferal Zones	Molluscan Zones	
Opoitian ? - Waitotaran	Inflata	-	Haeuslerella Biofacies
Opoitian	Crassaformis		Zeaflorilus Biofacies
Upper Tongaporutuan	Zeaserus	Grangei	Haeuslerella Biofacies

Table 4 - Biofacies in the Mangatainoka
Valley sections.

STAGE	FORMATION	WAIRARAPA ZONES		BIOFACIES
		Foraminiferal Zones	Molluscan Zones	
Waitotaran	Te Aute Limestone	-	-	?
Opoitian	Upper Mangatoro Formation	Crassaformis		Haeuslerella Biofacies
Kapitean	Lower Mangatoro Formation	Zeaserus	Wollastoni	Zeaflorilus Biofacies

Table 5 - Biofacies in the Weber sections.

Quinqueloculina incisa Vella, Hofkeruva rodleyi rodleyi, Z. parri, E. charlottensis, N. cf. depressa and N. hurupiensis indicate the Zeaflorilus Biofacies.

Throughout the next 150 ft., the sediment gradually changes from coarse sandstone at the base to silty mudstone, and a more varied and abundant foraminiferal fauna appears. This foraminiferal fauna continues upwards with little change in both sections. The persistent association in abundance of shallower-water species T. barnwelli, B. aculeata, B. numerosa, B. petiae, P. parki, F. flemingi and A. spherica indicates the Haeuslerella Biofacies. Planktonic species and specimens are moderately common. The sporadic and generally uncommon occurrence of Z. parri indicates a fairly shallow phase of the Haeuslerella Biofacies. Depth of deposition was probably about 200 to 400 ft.

Upper Mangatoro Formation

The biofacies of the Upper Mangatoro Formation differs very little from that of the middle to upper part of the Lower Mangatoro Formation.

CONCLUSIONS

This survey of the Kapitean Stage covers a large part of the south-east of the North Island. At only one place in this area could the Kapitean Stage be identified by means of the key molluscan species. That is, in the

two sections 5 miles apart at Weber, southern Hawkes Bay. In the Palliser Bay and Mangaoranga sections, the key Mollusca are absent due to deep-water facies, and the Kapitean Stage must be determined from the stage of evolution of the Globorotalia crassaformis bioseries. In the Mangatainoka Valley the Kapitean Stage is absent due to disconformity between the Opoitian and Upper Tongaporutuan. Disconformity is shown by the occurrence of Sectipecten grangei but the absence of S. wollastoni in the Upper Tongaporutuan immediately beneath the disconformity, and by the absence of characteristic Kapitean parts of the G. crassaformis and Siphotextularia wairoana bioserial changes.

The most useful stratigraphic divisions for deep-water strata are local zones based on Foraminifera. The Kapitean Stage can be correlated with these zones by means of the Globorotalia crassaformis bioseries, and is equivalent to the upper part of the Zeaserus Zone.

Paleoecology indicates that a shallowing of the sea took place during the Kapitean time in the Palliser Bay, Mangaoranga and Mangatainoka Valley areas. At Weber, the Tongaporutuan is absent due to unconformity, and the Kapitean was deposited during or immediately after a transgression of the sea.

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APPENDIX I - Diagnostic species of Wairarapa - S. Hawkes
Bay foraminiferal zones

Pohana Zone

Restricted:

Discorbis cf. dimidiatus (Parker & Jones) - rare, upper

Notorotalia macinnesi Kennett - lower

Globorotalia menardii panda Jenkins - rare, lower

First appearances:

Textularia barnwelli Kennett

Textularia kapitea Finlay

Bulimina cf. striata d'Orbigny, (small var.)

Pacinoion neefi Vella

Elphidium cf. chapmani Cushman

Notorotalia aff. taranakia Vella, (reticulate ornament)

Globigerina pachyderma (Ehrenberg)

Last appearances:

Bulimina mapiria Finlay - rare

Bulimina senta Finlay - rare

Bolivina lapsus Finlay

Discorotalia aranaea Hornibrook

Pliozea Zone

First appearances:

Bolivinita compressa Finlay - uppermost

Bolivinita pliozea Finlay

Last appearances:

Siphotextularia ihungia Finlay

Martinottiella massami Gibson

Sigmoilopsis schlumbergeri (Silvestri)

Bulimina notovata Chapman

Bulimina vellai Gibson

Zeaserus Zone

Restricted:

Siphotextularia n.sp. cf. wairoana Finlay

Quinqueloculina waimea Kennett

Bolivina cf. parri Cushman

Bolivina plicatella Cushman

Virgulopsis turris (Heron-Allen & Earland) - uppermost

Bolivinita elegantissima Boomgaart

Patellinella inconspicua (Brady)

Ammonia aoteanus (Finlay) - rare

Notorotalia pristina Vella

Globorotalia conomiozea Kennett

Sectipecten wollastoni (Finlay)

First appearances:

Sigmoilopsis zeaserus Vella

Bolivina fyfei Hornibrook

Bolivinita n.sp. aff. pohana Finlay - rare

Last appearances:

Haeuslerella finlayi Vella

Siphotextularia awamoana Finlay

Siphotextularia subcylindrica Finlay

Spiroloculina kennetti Gibson

Bulimina pupoides d'Orbigny

Bulimina pyrula d'Orbigny var. spinescens Brady

Bulimina truncanella Finlay - rare

Plectofrondicularia pohana Finlay

Cassidulina cuneata Finlay

Globorotalia miozea Finlay

Anomalina aotea Finlay

Cucullaea

Sectipecten grangei Boreham

Crassaformis Zone

Restricted:

Hofkeruva pliozea Vella

First appearances:

Haeuslerella pliocenica (Finlay)

Siphotextularia cf. subcylindrica Finlay

Siphotextularia wairoana Finlay

Bolivina robusta Brady

Melonis lutorum Vella

Notorotalia pliozea Vella

Globigerina dutertrei d'Orbigny

Globigerinoides obliqua Bolli - upper

Globorotalia crassaformis (Galloway & Wissler)

Globorotalia hirsuta (d'Orbigny)

Last appearances:

Bulimina cf. striata d'Orbigny, (large var.)

Neouvigerina eketahuna Vella

Inflata Zone

First appearance:

Globorotalia inflata (d'Orbigny)

Last appearance:

Globorotalia crassaformis (Galloway & Wissler) - lower

APPENDIX 2 - Index of Fossil Localities.

Sample numbers are the Sheet Fossil Numbers of the N.Z. Fossil Record system based on sheet districts of the N.Z. map series.

Full locality details for sheet districts other than N150, are recorded in the Sheet Fossil Master-file for Wairarapa region at the Geology Department, Victoria University of Wellington. Detailed localities for N150 are held at the N.Z. Geological Survey.

Grid references are the coordinates based on the National Thousand-yard grid.

Lithologies are given in the code of the N.Z. Fossil record form (Wellman, 1953: 55).

Standard symbols are used for New Zealand stages.

Sheet fossil number	Locality	Grid. ref.	Lithology	Age
N165f713	Palliser Bay. Foot of sea cliffs.	727056	9842e	U.Tt
f714	Slip 50 ft. above sea level.	727057	9942h	U.Tt
f715	Cliff 70 ft. above sea level.	726058	9942d	U.Tt
f716	Cliff west of gully above large slip.	725059	9942d	U.Tt
f717	Cliff 150 ft. above sea level.	723060	9942d	Wo
f718	Cliff 100 ft. above sea level.	718064	9942d	Wo
f719	Cliff 50 ft. above sea level.	714066	9942d	Ww?
N153f1151	}	208969	7732d	M.Tt
f1152		206971	7732d	M.Tt
f1154		205972	7732d	M.Tt

Sheet fossil number	Locality	Grid ref.	Lithology	Age
f1155	Stream beside	205973	7732d	M.Tt
f1157	Mangaoranga Road	205974	8852d	M.Tt
f1158	from	205975	8852d	M.Tt
f1159	1 to 2 miles	205976	9952d	M.Tt
f1160	s.e. of Eketahuna	204977	9952d	M.Tt
f1161		203977	9952d	M.Tt
f1162		203978	9952d	U.Tt
f1164		202980	9952d	U.Tt
f1166		202981	9952d	Tk
f1168		201983	8952d	Tk
f1170		198983	9952d	Wo
f1172		195985	9952d	Wo
f1173	Ngamaia Stm.	047964	7742dSO	U.Tt
f1174	Mangatainoka	046966	5531d	U.Tt
f1175	Valley	044970	6752dOS	Wo
f1176	Stream immediately	075987	8852dO	U.Tt
f1177	north of	074987	7852dO	U.Tt
f1178	Putara on	071986	7752dO	Wo
f1179	western side	069987	7752d	Wo
f1180	of Mangatainoka	068987	7752d	Wo
f1181	River	067988	8952d	Wo
f1182		065988	8952d	Wo
f1183		065990	8952d	Wo

Sheet fossil number	Locality	Grid ref.	Lithology	Age
N150f1028	Tributary of Waipatiki Stream 1½ miles east of Oporae Hill.	686327	9952hG	Dt
f1029		685327	5642cS	Tk
f1030		684328	6731c	Tk
f1031		684330	6731c	Tk
f1032		683331	8942dM	Tk
f1033		683332	8942dM	Tk
f1034		683333	8942dM	Tk
f1035		682334	8942dM	Tk
f1036		682335	8842dM	Tk
f1037		682336	8942dM	Tk
f1038		681337	8942dM	Tk
f1039		681338	8842dM	Tk
f1040		680339	8942dM	Wo
f1041		679340	8942dM	Wo
f1042		677341	8942dM	Wo
f1043	Upper Mangapuka Stream,	695364	7842c	Tk
f1044		695363	7742c	Tk
f1045		694363	8842c	Tk
f1046		693364	8942cM	Tk
f1047		690365	9942cM	Tk
f1048		689367	8942cM	Tk
f1049		688367	8942cM	Tk
f1050		687368	7842cM	Wo
f1051		685370	7742cM	Wo
f1052		684371	7842cM	Wo

Sheet fossil number	Locality	Grid ref.	Lithology	Age
f1053	Upper Mangapuka	683373	9842cM	Wo.
f1054	Stream.	683374	9842cM	Wo?
f1055		682377	9842cM	Wo?

Four Upper Miocene to Lower Pliocene Sections,
Hawkes Bay to East Cape, New Zealand.

By J. P. Kennett

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ABSTRACT

Faunal successions through the Upper Miocene and Lower Pliocene were determined in the following four sections: Maraetotara River, central Hawkes Bay; Ruakituri River, northern Hawkes Bay; Waimata River, Gisborne; and near Te Araroa, East Cape. Distribution of Foraminifera is shown on charts, and lithologies are shown on columnar sections. Four well defined biostratigraphic units can be recognised for the Foraminifera, from oldest to youngest; Pohana Zone, Compressa Zone, Conomiozea Zone, and Crassaformis Zone. Diagnostic species are listed for each of these zones.

The Kapitean Stage is determined directly in one section of shallow-water facies by means of the key Kapitean Mollusca, and indirectly in two sections of deep-water facies by means of the Globorotalia crassaformis bioseries. In the fourth section the absence of Upper Tongaporutuan, Kapitean and basal Opoitian is shown by the absence of part of the G. crassaformis bioseries.

The paleoecology throughout each section is described, and indicates that the sea shallowed near the end of the Tongaporutuan Age, remained shallow during the Kapitean Age and deepened again at the beginning of the Opoitian Age.

INTRODUCTION

Four stratigraphic sections through Upper Miocene and Lower Pliocene marine strata in the northern part of the East Coast of the North Island (fig. 1) were examined to determine the succession of Foraminifera and Mollusca. The main aim was to determine the limits of the Kapitean Stage. A zonal scheme based on Foraminifera is established for the interval from Middle Tongaporutuan to Opoitian. Paleoecology indicates a marked decrease in depth of deposition just below the Kapitean Stage, and an increase in depth of deposition near the base of the Opoitian. Vertical ranges of many Foraminifera appear to be controlled by these changes.

Sample localities for all the sections are summarised in Appendix 3. Full locality details are recorded in the Sheet Fossil master-file for the Hawkes Bay region at the N.Z. Geological Survey, Lower Hutt.

The four sections studied are as follows:

Maraetotara River Section

The Maraetotara River section lies within N.Z.M.S. Sheet District N135 and extends along the middle reaches of the Maraetotara River, from 5 to 7 miles s.w. of Cape Kidnappers. The section which ranges in age from Middle Tongaporutuan to Upper Opoitian is fairly well exposed and was sampled at average intervals of 300 ft. Sample localities are shown in fig. 2 and lithologies and sample horizons are shown in a columnar section (fig. 3).

Fig. 1 - Map showing location of
the sections examined.

Fig. 2 - Map of the Maraetotara River section showing location of samples.

Fig. 3 Stratigraphic column for

THE MARAETOTARA RIVER SECTION

The contact between the Taranaki and the Wanganui Series is not exposed, but no more than 150 ft. of strata are covered at this horizon, and the Taranaki Series consists of bathyal massive silty mudstone, while the basal Pliocene consists of shallow-neritic well bedded sandstone. No angular discordance was seen, but it will be shown from paleontology that a disconformity represents the Kapitean Stage and part of the Upper Tongaporutuan.

Ruakituri River Section

The Ruakituri River section lies within N.Z.M.S. Sheet District N106 and extends along the Ruakituri River from 4 to 5 miles n.w. of Te Reinga township, N. Hawkes Bay. The part of the section examined ranges from Middle Tongaporutuan to Opoitian, is moderately well exposed, and was sampled mostly at intervals of 200 - 300 ft.

The lower part of the section consists mainly of massive blue-grey siltstone and mudstone; the middle part is sandier, harder, mostly well bedded and at one horizon contains common macrofossils; the uppermost part consists mainly of massive blue-grey siltstone. The total thickness of strata sampled is about 4000 ft., of which about 2000 ft. is Upper Tongaporutuan in age and 650 ft. is Kapitean in age.

Ongley (1930) mapped the Taranakian part of the section as Mapiri Series and the Opoitian part as the Opoiti Series, and recognised an erosion interval between the two.

Waimata River Section

The Waimata River section lies within N.Z.M.S. Sheet District N98 and extends along the Waimata River from 7 to 9 miles north of Gisborne. The part of the section examined ranges from Upper Tongaporutuan to Opoitian in age, is poorly exposed, and was sampled at intervals averaging about 400 ft.

Sample localities are shown in fig. 4 and lithologies and sample horizons are shown on a columnar section (fig. 5).

The lower part of the section consists predominantly of massive silty mudstone, and includes some graded bedded alternating sandstone and mudstone; the middle part consists mainly of fine to medium silty sandstone; and the upper part consists of massive mudstone.

Henderson & Ongley (1920) mapped all the strata in the section as Tawhiti Series (Upper Miocene). Ridd (1964) mapped the Taranakian part as Tongaporutuan to Kapitean and the Wanganuiian part as Opoitian to Waitotaran.

East Cape Section

The East Cape section lies within N.Z.M.S. Sheet District N63 and is well exposed in cliffs up to 900 ft. high extending for a few miles from Te Araroa towards East Cape. The section was collected immediately east of Awatere River road bridge, Te Araroa. The Kapitean is the only stage represented. Sample localities are shown in fig. 6 and lithologies and sample horizons are shown in a columnar section (fig. 7).

Ongley & Macpherson (1928) mapped the beds in this area as Tokomaru Series (Upper Miocene).

Fig. 4 - Map of the Waimata River section showing location of samples.

Fig. 5 - Stratigraphic column for

THE WAIMATA RIVER SECTION

Thick- ness (ft.)	Stage	Sample Nos.	
5000	Wo	533	
		532	Massive, light blue-grey, calcareous silty mudstone, passing down into siltstone with occasional concretionary layers.
		531	
4000		530	
		529	
3000	Tk	528	Weakly bedded, light blue-grey, fine to medium grained, tuffaceous silty sandstone usually very calcareous when fresh.
		527	
2000			
		526	Massive, medium blue-grey, calcareous, silty mudstone with local turbidites.
1000	U.Tt	525	
		524	
0		523

Fig. 6 - Map of the East Cape section showing location of samples.

Fig. 7 Stratigraphic column for
THE EAST CAPE SECTION

BIOSTRATIGRAPHY

The distribution of Foraminifera in two of the sections is shown on range charts (table 17 - Maraetotara River section; table 18 - Waimata River section). For the East Cape section full faunal lists of Foraminifera and Mollusca are given for the highest and lowest samples and lists of planktonic species, and species not occurring at the top and bottom are given for two intermediate samples (Appendix 2). For the Ruakituri River section, ranges of stratigraphically important species are given in table 1, while the ranges of ecologically important species are discussed in the text.

Foraminifera can be used to distinguish four zones (table 2) representing a continuous sequence from Middle Tongaporutuan to Opoitian.

Lists of diagnostic species for each zone are given in Appendix 1.

Pohana Zone: The Pohana Zone is distinguished by the presence of Bolivinita pohana and the absence of Bolivinita compressa and is equivalent to the so called Middle Tongaporutuan. It was recognized only in the Maraetotara River and Ruakituri River sections as in the other two sections the lowest samples were younger than Middle Tongaporutuan. The type locality of the Pohana Zone is at Maraetotara River, where it is represented by more than 700 ft. of massive mudstone.

STAGE	HAWKES BAY FORAMINIFERAL ZONES	RANGES OF ZONE NAME FOSSILS			
Opoitian	Crassaformis	<i>Bolivinita pohana</i>	<i>Bolivinita compressa</i>	<i>Globorotalia conomiozea</i>	<i>Globorotalia crassaformis</i>
Kapitean	Conomiozea				
Upper Tongaporutuan	Compressa				
	Pohana				
Middle					

Table 2 - Biostratigraphic units in central
Hawkes Bay to East Cape.

Compressa Zone: The base of the Compressa Zone is the top of the Pohana Zone, and is marked by the appearance of Bolivinita compressa. By definition the base of the Compressa Zone is equivalent to the base of the so called Upper Tongaporutuan. The type locality of the Compressa Zone is at Ruakituri River, where it is represented by 1500 ft. of massive mudstone.

Conomiozea Zone: The base of the Conomiozea Zone is the top of the Compressa Zone, and is marked by the appearance of Globorotalia conomiozea. The boundary is not clear cut because G. conomiozea is an intermediate form in a gradational bioseries (Kennett, 1965a, in press). For the purpose of defining the zone, the first appearance of G. conomiozea is arbitrarily taken as the horizon at which forms within the range of variation of G. conomiozea make up 50 per cent of the G. miozea - conomiozea population. The top of the Conomiozea Zone is marked by the incoming of G. crassaformis. The type locality of the Conomiozea Zone is at Ruakituri River, where it is represented by 1000 ft. of well bedded medium sandstone.

At Maraetotara River the Conomiozea Zone is absent due to disconformity. In the East Cape section all the sediments fall within the Conomiozea Zone, and the lowest exposed part contains Sectipecten wollastoni indicating a Kapitean Age. Textularia kapitea occurs at the base of this section. In the Ruakituri River section, the lower part of the Conomiozea

Zone contains Textularia miozea and is uppermost Tongaporutuan in age as in Wairarapa and Marlborough (Kennett, in press).

The Zeaserus Zone which is well defined in Marlborough and Wairarapa (Vella 1962a, Kennett 1965b, Kennett 1965c) could not be recognised in any of the four sections. The base of the Zeaserus Zone is marked by the first appearance of Sigmoilopsis zeaserus Vella, which completely replaces S. schlumbergeri (Silvestri). S. zeaserus occurs but rarely in the Conomiozea Zone at Ruakituri River, and in the Crassaformis Zone at Waimata River, and S. schlumbergeri does not disappear but ranges up into the Crassaformis Zone, and perhaps even higher.

Crassaformis Zone: The Crassaformis Zone directly overlies the Conomiozea Zone. Its base, which is also the base of the Opoitian Stage and the Wanganui Series, is marked by the first appearance of the planktonic species Globorotalia crassaformis. This species is the end member of the gradational G. crassaformis bioseries, and its first appearance is taken as the horizon at which specimens within the range of variation of G. crassaformis make up 50 per cent of the G. conomiozea - crassaformis population. The type locality of the Crassaformis Zone is at Waimata River, where it is represented by more than 2000 ft. of massive siltstone to mudstone.

In the Wairarapa area an Inflata Zone was distinguished

by Kennett (1965c), the base of which is distinguished by the first appearance of G. inflata. Its lower boundary is probably late Opoitian or Waipipian in age. Within the area under review, G. inflata was found only at Ruakituri River where its lowest occurrence is about 300 ft. above the base of the Opoitian Stage, and probably considerably older than in Wairarapa. In the Maraetotara River and Waimata River sections G. inflata was not found and G. conomiozea extends well up into the Opoitian accompanied by G. crassaformis.

At Maraetotara River, G. miozea is abundant in the Tongaporutuan, and G. crassaformis is abundant in the Opoitian, but the gradational bioseries that elsewhere links these species is missing. G. conomiozea occurs through much of the Opoitian but has no gradational relationship with G. crassaformis. The absence of the bioseries linking G. miozea and G. crassaformis indicates that the upper part of the Upper Tongaporutuan, the Kapitean and the lowest part of the Opoitian are absent. The strata immediately below the disconformity represent the Compressa Zone of early Upper Tongaporutuan age, and pass down to the Pohana Zone, of Middle Tongaporutuan age.

In the Waimata River section also, the base of the Kapitean Stage is determined by means of the Globorotalia crassaformis bioseries. Due to the wide sampling interval, the horizon at which G. conomiozea first appears can not be delineated narrowly. The lowest sample of G. conomiozea

obtained is typical of about lowermost Kapitean. The Kapitean Stage is about 900 ft. thick and judging from relative thicknesses elsewhere in New Zealand the Conomiozea Zone should be about 1200 ft. thick. Sampling was not low enough to determine the full thickness of the Upper Tongaporutuan but this unit is more than 2300 ft. thick and is much thicker than the Kapitean.

At the base of the East Cape section the occurrence of Sectipecten wollastoni and Austrofuscus coerulescens indicates a Kapitean Age supported by the occurrence of Textularia kapitea without T. miozea. T. miozea becomes extinct at the top of the Tongaporutuan elsewhere in New Zealand. The stage of development of G. conomiozea indicates a basal Kapitean age, for although a majority of specimens have $4 - 4\frac{1}{4}$ chambers and are strongly conical, a number of specimens have $4\frac{1}{2} - 5$ chambers and have a relatively low "conical angle". More typical G. conomiozea occurs higher in the section.

PALEOECOLOGY

Maraetotara River Section

The sequence of biofacies in the Maraetotara River section is shown in table 3.

Throughout the Middle Tongaporutuan and the lower part of the Upper Tongaporutuan, Mollusca and Ostracoda are very rare, planktonic and benthonic Foraminifera are very abundant and the Lagenidae are particularly well represented. Planktonic Foraminifera constitute about 70 per cent of the specimens. The following deep-water species are generally persistent and abundant:

Karreriella bradyi, Karreriella cylindrica, Textularia subrhombica, Martinottiella massami, Sigmoilopsis schlumbergeri, Pullenia bulloides, Pacinonion neefi, Notorotalia taranakia, Bolivinita compressa, Chilostomella oolina, Cibicides pseudo-ungerianus, Cibicides robertsonianus, Sigmoilopsis gavini, Osangularia bengalensis, Pullenia quadriloba, Massilina subaequalis, Cibicides thiaracuta, Siphotextularia ihungia. No diagnostic shallow-water species were found. Elsewhere in New Zealand many of the above species have been found by the writer in assemblages considered to represent the Robulus Biofacies, but in those assemblages they are relatively uncommon. From the writer's experience, Sigmoilopsis gavini, Osangularia bengalensis, Notorotalia taranakia, and Pullenia quadriloba seem to occur most commonly in the Semipelagic and

STAGE	FORAMINIFERAL ZONES	BIOFACIES
Opoitian	Crassaformis	Haeuslerella Biofacies
Upper	Compressa	Robulus Biofacies
Tongaporutuan		Semipelagic Biofacies or Eupelagic Biofacies
Mid.	Pohana	

Table 3 - Biofacies in the Maraetotara River section.

Eupelagic biofacies, and Cibicides thiaracuta and Massilina subaequalis seem to be restricted to these biofacies. Most of the Tongaporutuan strata at Maraetotara River, therefore are considered to have been deposited in depths well over 2000 ft., perhaps ranging up to 4000 or 5000 ft. (Vella, 1962b).

The uppermost part of the Upper Tongaporutuan shows a distinct gradual shallowing with microfaunas changing to the Robulus Biofacies. The sediment also changes, becoming slightly harder and coarser. Faunas contain generally abundant Bolivinita compressa, Karrerella cylindrica, Pullenia bulloides and uncommon Sigmoilopsis schlumbergeri; they lack many species that occur in the underlying Middle Tongaporutuan and lower part of Upper Tongaporutuan; and they contain a few rare and spasmodic shallower-water species such as Martinottiella clarae and Pacinonion parki.

The disconformity between the Opoitian and the Tongaporutuan represents a period of non-deposition or erosion. The higher part of the Upper Tongaporutuan, the Kapitean and the lowermost Opoitian are missing. Deposition re-commenced on a shallow sea-bed in early Opoitian time.

Of the Opoitian only the lower part was sampled. Macrofossils, Ostracoda and Foraminifera are abundant and planktonic Foraminifera constitute about 40 per cent of the specimens of Foraminifera. The following diagnostic shallow-water species of Foraminifera are present and most are abundant: Siphotextularia n.sp. cf. wairoana, Bulimina

aculeata, Hofkeruva rodleyi tutamoides, Bolivina numerosa, Bolivina petiae, Rectobolivina striatula, Pacinonion parki and Florilus flemingi. No species diagnostic of deep-water were found, and the assemblage is typical of the Haeuslerella Biofacies. The sediments become progressively finer upwards from the base of the Opoitian, suggesting an increase in depth of deposition, but faunas higher in the succession were not examined.

Ruakituri River Section

The Ruakituri River section shows progressive biofacies and lithofacies changes indicating a gradual decrease in depth of deposition from about the middle of the Upper Tongaporutuan to the Kapitean and then an increase in depth of deposition above the Kapitean. The sequence of biofacies is shown in table 4.

The massive mudstone of the Middle Tongaporutuan and the lower part of the Upper Tongaporutuan contains very rare Mollusca and Ostracoda. Planktonic Foraminifera are very abundant, and the following benthonic species are common in many samples and are diagnostic of deep-water biofacies: Karreriella cylindrica, Siphonina australis, Cibicides thiaracuta, C. pseudoungerianus, Sigmoilopsis schlumbergeri, Karreriella bradyi, Notorotalia taranakia, Hofkeruva mioschwageri, Pacinonion neefi, Cibicides robertsonianus, Bolivinita compressa (U.Tt), Pullenia bulloides and Martinottiella massami. No species diagnostic of

STAGE	FORAMINIFERAL ZONES	BIOFACIES
Opoitian	Crassaformis	Haeuslerella Biofacies
Kapitean	Conomiozea	Elphidium Biofacies
Upper		Compressa	Haeuslerella Biofacies
	Karrerella Biofacies	
	Robulus Biofacies	
	Semipelagic Biofacies	
Tongaporutuan		Pohana
Mid.		

Table 4 - Biofacies in the Ruakituri River section.

shallow-water facies were found. The assemblage is considered to indicate the Semipelagic Biofacies, and the depth of deposition was probably greater than 2000 ft.

The Middle part of the Upper Tongaporutuan consists of slightly coarser sediments that are sometimes bedded. The faunas contain generally abundant Bolivinita compressa and Karrerella cylindrica, and more sporadic specimens of Pullenia bulloides and Pacinonion neefi. Many of the deeper-water species occurring in the underlying Middle Tongaporutuan and lower Upper Tongaporutuan are either rare or absent and planktonic specimens are less abundant. A few rare shallower-water species such as Pseudoeponides tenera and Martinottiella clarae, make their appearance. This assemblage is considered to represent the Robulus Biofacies and the depth of deposition was probably between 1000 ft. and 2000 ft.

The higher part of the Upper Tongaporutuan and the Kapitean consists of well bedded sandstone. The lowest 100 ft. of this sandstone contains Karrerella cylindrica with the shallower-water species Martinottiella clarae, Textularia miozea and Rectobolivina striatula in variable abundance. This assemblage is typical of the Karreriella Biofacies, and the depth of deposition was close to 1000 ft.

In the remainder of the Upper Tongaporutuan, Karrerella is no longer present, and the shallower-water species Notorotalia aff. taranakia, Bulimina aculeata and Bolivina numerosa make their appearance in variable abundance.

Foraminifera, especially the planktonic species, are very rare, whereas Mollusca are common. The assemblage is considered to represent the Haeuslerella Biofacies, and the depth of deposition was between 200 feet and 1000 ft.

The sea was at its shallowest during the Kapitean Age. The well bedded sandstone contains numerous macrofossils. The foraminiferal fossils are poorly preserved, are restricted in species, and include only rare planktonic specimens. The most common benthonic Foraminifera are Notorotalia pliozea, Notorotalia hurupiensis, Robulus calcar and Anomalinoides spherica. The assemblage is considered to represent the Elphidium Biofacies and the depth of deposition was probably less than 200 ft.

At the beginning of the Opoitian Age the sea began to deepen again. The lowest Opoitian sample is from well bedded sandstone and contains abundant Rectobolivina striatula, Cassidulinoides orientalis, Notorotalia hurupiensis, Florilus flemingi and fairly common planktonic Foraminifera. This assemblage is considered to represent the shallow phase of the Haeuslerella Biofacies, suggesting depths little more than 200 ft. Higher in the Opoitian the sediment changes to massive siltstone, and the assemblages include abundant Foraminifera with moderately abundant planktonic Foraminifera and Ostracoda. Diagnostic shallow-water benthonic Foraminifera include Anomalinoides spherica, Rectobolivina striatula, Bulimina aculeata, Notorotalia hurupiensis, and Pacinonion

parki. Associated with these in some samples are the deeper-water indicators Haeuslerella pliocenica and Cyclammina.

The assemblage probably indicates the deeper phase of the Haeuslerella Biofacies, and depth of deposition was probably between 500 ft. and 1000 ft.

Waimata River Section

Like the Maraetotara River and Ruakituri River sections, the Waimata River section shows progressive biofacies and lithofacies changes indicating a gradual decrease in depth of deposition towards the top of the Taranaki Series. Above the Kapitean the trend is again reversed indicating increase in depth of deposition again. The sequence of biofacies is shown in table 5.

The Upper Tongaporutuan at the base of the section consists of massive mudstone containing abundant Foraminifera, very rare Mollusca and generally rare Ostracoda. Planktonic Foraminifera constitute about 75 per cent of the fauna. The generally common occurrences of deep-water species such as Sigmoilopsis schlumbergeri, Karrerella cylindrica, Hofkeruva mioschwageri, Bolivinita compressa, Osangularia bengalensis, Notorotalia taranakia and the rare occurrence of Sigmoilopsis gavini and Cibicides thiaracuta, indicates the Semipelagic Biofacies. Depth of deposition was similar to that at Ruakituri River, probably greater than 2000 ft.

The upper part of the Upper Tongaporutuan is mostly massive mudstone which contains persistent Karrerella bradyi,

STAGE	FORAMINIFERAL ZONES	BIOFACIES
Opoitian	Crassaformis	Robulus Biofacies
		Karreriella Biofacies
Kapitean	Conomiozea	Haeuslerella Biofacies
Upper Tongaporutuan	Compressa	Robulus Biofacies
		Semipelagic Biofacies

Table 5 - Biofacies in the Waimata River section.

Karrerella cylindrica, Sigmoilopsis schlumbergeri, Bolivinita compressa, Osangularia bengalensis, Pullenia bulloides, Cibicides pseudoungerianus and Cibicides robertsonianus.

No diagnostic shallow-water species were found and the assemblage is considered to represent the Robulus Biofacies. The depth of deposition was probably between 1000 ft. and 2000 ft.

The uppermost Upper Tongaporutuan from about 200 ft. below the base of the Kapitean Stage, gradually changes from massive mudstone to poorly bedded silty sandstone. The fauna also changes, losing the deep-water indicators of the underlying strata, but gaining diagnostic shallow-water species such as Bolivina petiae, Pacinonion parki, Florilus flemingi, Bulimina aculeata, Rectobolivina striatula, Patellinella inconspicua, Gavelinopsis lobatulus, Robulus calcar, Bolivina numerosa and Notorotalia hurupiensis. This type of fauna represents the Haeuslerella Biofacies and persists from uppermost Tongaporutuan through Kapitean to basal Opoitian. Depth of deposition was probably between 200 ft. and 1000 ft.

Almost immediately after the Kapitean Age the sea began to deepen again. Sandstone at the base of the Opoitian gradually changes upwards to massive silty mudstone which contains Karrerella cylindrica associated with the shallow-water species Robulus calcar and Gyroidinoides zelandica. This association probably indicates the Karreriella Biofacies, indicating a depth of deposition close to 1000 ft. Still

higher in the Opoitian abundant Pullenia bulloides and rare Pacinonion neefi make their appearance indicating further change to the deeper-water Robulus Biofacies.

East Cape Section

Lithologies and faunas are fairly uniform throughout the East Cape section. The sediments are slightly coarser and contain more abundant Mollusca and Ostracoda at the base of the section. These differences suggest that the depth of deposition was slightly less at the base than towards the top. The Foraminifera, however show no significant change. Planktonic species are varied and are represented by abundant specimens throughout the section; the following benthonic species are persistent and abundant: Textularia barnwelli, Bulimina aculeata, Rectobolivina striatula, Pacinonion parki, Florilus flemingi, Gavelinopsis lobatulus, Notorotalia hurupiensis, Robulus calcar and Anomalinoidea spherica. This assemblage is typical of the Haeuslerella Biofacies, and depths of deposition were probably between 200 ft. and 1000 ft.

CONCLUSIONS

1. The Upper Miocene sediments examined are generally of much deeper-water facies than the Upper Miocene sediments elsewhere in New Zealand. Paleoecology indicates that a shallowing of the sea took place during uppermost Tongaporutuan

and Kapitean times and was followed in Opoitian times by a deepening of the sea.

2. Four zones based on Foraminifera are the most useful biostratigraphic divisions of the strata from Middle Tongaporutuan to Opoitian in age.

3. At East Cape, the Kapitean Stage is represented by neritic facies and is identified by the occurrence of Sectipecten wollastoni and Austrofuscus coerulescens and Textularia kapitea (not Textularia miozea). The bottom and top of the Kapitean Stage have not been defined in this area.

At Waimata River and Ruakituri River where the key Kapitean Mollusca were not found, the base and top of the Kapitean Stage are identified by stages in evolution of the Globorotalia crassaformis bioseries.

At Maraetotara River, the Kapitean Stage is represented by disconformity. Evidence for the disconformity is an abrupt lithofacies and biofacies change and the absence of part of the G. crassaformis bioseries.

4. Elsewhere in New Zealand the lower part of the range of Globorotalia conomiozea is late Upper Tongaporutuan in age, and the higher part is Kapitean in age. A similar range at Ruakituri River is substantiated by the occurrence of Textularia miozea in the lower part only of the Conomiozea Zone, because T. miozea is not known to occur above the Tongaporutuan. In the Kapitean of the East Cape section, higher in the Conomiozea Zone, as shown by the stage 1

in evolution of the G. crassaformis bioseries, only T. kapitea occurs. A few occurrences of T. kapitea are known below the Kapitean in some parts of New Zealand, but it appears that T. miozea definitely makes its last appearance at the top of the Tongaporutuan and its place is taken by T. kapitea in all known Kapitean neritic facies.

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APPENDIX 1 - Diagnostic species of central
Hawkes Bay to East Cape foraminiferal zones.

Pohana Zone

Restricted:

Massilina subaequalis (Parr)

First appearance:

Bolivinita pohana Finlay

Compressa Zone

Restricted:

Siphotextularia awamoana Finlay

Siphotextularia kreuzbergi Finlay

Migros medwayensis (Parr)

Clavulinoides instar Finlay

Karrerella n.sp.

Arenodorsaria n.sp.

Cruciloculina ericsoni Loeblich & Tappan

Pseudoeponides umbonatus (Reuss)

First appearances:

Siphotextularia n.sp. cf. wairoana Finlay

Parafrondicularia pellucida (Finlay)

Parafrondicularia wairarapa Vella

Bulimina aculeata d'Orbigny

Bulimina mapiria Finlay

Bulimina cf. striata d'Orbigny, (small var.)

Noviuvula zelandica Vella

Angulogerina n.sp. aff. australis (Heron-Allen & Earland)
Virgulopsis turris (Heron-Allen & Earland)
Bolivina barnwelli Finlay
Bolivina numerosa Vella
Rectobolivina striatula (Cushman)
Bolivinita compressa Finlay
Cassidulina pacifica Cushman
Florilus flemingi (Vella)
Globigerina pachyderma (Ehrenberg)
Globigerina quinqueloba Natland

Last appearances:

Textularia subrhombica Stache
Textularia n.sp. cf. fistulosa Brady
Haeuslerella finlayi Vella
Siphotextularia ihungia Finlay
Vulvulina pennatula (Batsch)
Eggerella bradyi (Cushman)
Martinottiella massami Gibson
 n.gen. (as Ruakituria) n.sp. Kennett, in press
Biloculina murrhina Schwager
Spiroloculina novozealandica Cushman & Todd
Bulimina pyrula d'Orbigny var. spinescens Brady
Bulimina senta Finlay
Virgulina bradyi Cushman
Euuvigerina notohispida (Finlay)
Hofkeruva mioschwageri (Finlay)

Rectuvigerina pohana (Finlay)
Rectobolivina parvula Finlay
Ehrenbergina willetti Finlay
Chilostomella oolina Schwager
Pullenia quadriloba Reuss
Osangularia bengalensis (Schwager)
Buningia creeki Finlay
Siphonina australis Cushman
Ceratobulimina kellumi Finlay
Notorotalia taranakia Vella
Globigerina nepenthes Todd
Globoquadrina dehiscens (Chapman, Parr & Collins)
Globorotalia menardii panda Jenkins
Globorotalia opima continuosa Blow
Anomalinoides vitrinoda (Finlay)
Cibicides pseudoungerianus (Cushman)
Cibicides robertsonianus (Brady)
Cibicides thiaracuta Hornibrook

Conomiozea Zone

Restricted:

Textularia kapitea Finlay - upper part
Quinqueloculina rebecca Vella
Frondicularia longistriata Cushman
Bolivina alata Sequenza
Rectobolivina digitata Parr
Melonis cf. tuberculatum (d'Orbigny)

Florilus decepatrix (Hornibrook)

Florilus olsoni Kennett

Patellinella inconspicua (Brady)

Eponides tuberculatus (Balkwill & Wright)

Elphidium novozealandicum Cushman

First appearances:

Sigmoilopsis zeaserus Vella

Guttulina bartschi Cushman & Ozawa

Angulogerina cf. angulosa (Williamson)

Bolivina petiae Gibson

Bolivinita pliozea Finlay

Astrononion vadorum Vella

Notorotalia hurupiensis Vella

Notorotalia pliozea Vella

Globigerina cf. nepenthes Todd

Globigerinoides obliqua Bolli

Globorotalia conomiozea Kennett

Anomalinoides spherica (Finlay)

Cibicides n.sp. aff. deliquatus Finlay

Cibicides n.sp., (high and conical)

Last appearances:

Textularia miozea Finlay - lower part

Siphotextularia subcylindrica Finlay

Karrerella bradyi (Cushman)

Sigmoilopsis gavini Gibson

Bulimina mapiria Finlay

Bulimina pupoides d'Orbigny

Bulimina truncanella Finlay
Angulogerina n.sp. aff. australis (Heron-Allen & Earland)
Bolivina barnwelli Finlay
Bolivina lapsus Finlay
Bolivina turbiditorum Vella
Bolivinita elegantissima Boomgaart
Cassidulina cuneata Finlay
Melonis maoricum (Stache)
Valvulineria stachei Hornibrook
Alabamina tenuimarginata (Chapman, Parr & Collins)
Globoquadrina altispira globosa Bolli
Globorotalia miozea Finlay

Crassaformis Zone

First appearances:

Haeuslerella pliocenica (Finlay)
Gaudryina convexa (Karrer)
Hofkeruva rodleyi tutamoides Vella
Hofkeruva pliozea Vella
Bolivina silvestrina Cushman
Ehrenbergina mestayeri Cushman
Gavelinopsis hamatus Vella
Rosalina pauperques Vella
Globigerina dutertrei d'Orbigny
Globorotalia crassaformis (Galloway & Wissler)
Globorotalia hirsuta (d'Orbigny)
Globorotalia inflata (d'Orbigny)

Last appearance:

Rectobolivina maoria Finlay

APPENDIX 2 - East Cape Faunas

N63f507 - Lowest sample.

Foraminifera:

<u>Bolivinosia</u> <u>cubensis</u> (Cushman & Bermudez)	1
<u>Textularia</u> <u>barnwelli</u> Kennett	4
<u>Textularia</u> cf. <u>sagittula</u> DeFrance	1
<u>Haeslerella</u> <u>morgani</u> (Chapman)	4
<u>Siphotextularia</u> <u>subcylindrica</u> Finlay	1
n.sp. cf. <u>wairoana</u> Finlay	4
<u>Karrerella</u> <u>bradyi</u> (Cushman)	1
<u>Quinqueloculina</u> <u>lamarckiana</u> d'Orbigny	1
<u>rebecca</u> Vella	1
<u>triangularis</u> d'Orbigny	4
<u>Biloculina</u> <u>pisum</u> Schlumberger	1
<u>Pyrgo</u> <u>tasmanensis</u> Vella	1
<u>Robulus</u> <u>calcar</u> (Linnaeus)	3
<u>Dentalina</u> <u>guttifera</u> (d'Orbigny)	1
<u>substrigata</u> Stache	1
<u>Lagenonodosaria</u> <u>hirsuta</u> (d'Orbigny)	4
<u>scalaris</u> (Batsch)	1
sp., (smooth)	3
<u>Lagena</u> <u>crenata</u> Parker & Jones	1
<u>striata</u> (d'Orbigny)	4
<u>sulcata</u> (Walker & Jacob)	2
<u>Oolina</u> <u>melo</u> d'Orbigny	4
<u>hexagona</u> (Williamson)	1

<u>Fissurina marginata</u> (Walker & Boys)	4
<u>marginato-perforata</u> (Sequenza)	3
<u>orbignyana</u> (Sequenza)	1
<u>Frondicularia longistriata</u> Cushman	1
<u>Parafrondicularia pellucida</u> (Finlay)	1
<u>Guttulina bartschi</u> Cushman & Ozawa	2
<u>yabei</u> Cushman & Ozawa	1
<u>Sigmoidella elegantissima</u> (Parker & Jones)	2
<u>Bulimina aculeata</u> d'Orbigny	4
cf. <u>striata</u> d'Orbigny, (small var.)	4
<u>Neouvigerina eketahuna</u> Vella	3
<u>Hofkeruva lutorum</u> Vella	4
<u>Hofkeruva rodleyi rodleyi</u> Vella	1
<u>Trifarina bradyi</u> Cushman	4
<u>Bolivina affiliata</u> Finlay	4
<u>albatrossi</u> Cushman	1
<u>barnwelli</u> Finlay	1
<u>lapsus</u> Finlay	1
<u>numerosa</u> Vella	1
<u>petiae</u> Gibson	1
<u>plicatella</u> Cushman	2
<u>watti</u> Gibson	1
n.sp.	1
sp.	1
<u>Rectobolivina digitata</u> Parr	1
<u>maoria</u> Finlay	3

<u>Rectobolivina striatula</u> (Cushman)	4
<u>Virgulopsis turris</u> (Heron-Allen & Earland)	1
<u>Bolivinita quadrilatera</u> (Schwager)	1
<u>Plectofrondicularia pohana</u> Finlay	1
<u>Cassidulina laevigata</u> d'Orbigny	1
<u>Cassidulinoides orientalis</u> (Cushman)	4
<u>Pleurostomella alternans</u> Schwager	1
<u>Sphaeroidina bulloides</u> d'Orbigny	1
<u>Pullenia bulloides</u> (d'Orbigny)	1
<u>quinqueloba</u> Reuss	1
<u>Nonion cassidulinoides</u> Hornibrook	1
<u>Astrononion vadorum</u> Vella	1
<u>Pacinonion parki</u> (Hornibrook)	4
<u>Melonis maoricum</u> (Stache)	1
cf. <u>tuberculatum</u> (d'Orbigny)	1
<u>Florilus flemingi</u> (Vella)	4
<u>Zeaflorilus parri</u> (Cushman)	1
<u>Patellinella inconspicua</u> (Brady)	1
<u>Gavelinopsis lobatulus</u> (Parr)	4
<u>Discopulvinulina berthelotti</u> (d'Orbigny)	3
<u>Gyroidinoides zelandica</u> (Finlay)	4
<u>Epistominella iota</u> Hornibrook	2
<u>Alabanina tenuimarginata</u> (Chapman, Parr & Collins)	1
<u>Pseudoeponides prominula</u> (Stache)	1
<u>tenera</u> (Brady)	1
<u>Elphidium charlottensis</u> (Vella)	3

<u>Notorotalia</u> <u>hurupiensis</u> Vella	4
aff. <u>taranakia</u> Vella, (reticulate ornament)	1
<u>Globigerina</u> <u>pachyderma</u> (Ehrenberg)	3
<u>parabulloides</u> Blow	4
<u>praebulloides</u> Blow	1
<u>quincueloba</u> Natland	3
<u>woodi</u> Jenkins	4
<u>zealandica</u> Hornibrook	1
<u>Globigerinoides</u> <u>trilobus</u> <u>trilobus</u> (Reuss)	3
<u>Globigerinita</u> <u>glutinata</u> (Egger)	1
<u>Orbulina</u> <u>universa</u> d'Orbigny	4
<u>Globorotalia</u> <u>conomiozea</u> Kennett	4
<u>scitula</u> (Brady)	1
<u>Anomalinoides</u> <u>parvumbilia</u> (Finlay)	4
<u>spherica</u> (Finlay)	4
<u>Cibicides</u> <u>deliquatus</u> Finlay	4
<u>finlayi</u> Gibson	2
<u>molestus</u> Hornibrook	1
cf. <u>temperata</u> Vella	1
n.sp., (high and conical)	2
n.sp. aff. <u>deliquatus</u> Finlay	2
<u>Dyocibicides</u> <u>biserialis</u> Cushman & Valentine	3

Mollusca:

<u>Cucullaea</u> n.sp.	
<u>Amygalum</u> <u>striatum</u> (Hutton)	
<u>Atrina</u> <u>zelandica</u> (Gray)	

Isognomon zelandicum (Marshall & Murdoch)

Sectipecten wollastoni (Finlay)

Chlamys sp.

Anomia walteri Hector

Ostrea charlottae Finlay

Nemocardium quinarium Marwick

Dosinia cf. greyi Zittel

Notocorbula humerosa (Hutton)

Zeacolpus (Zeacolpus) sp.

Polinices sp.

Xenophalium (Mauicassis) sp.

Argobuccinum (Haurokoa) sp.

Austrofuscus coerulescens (Finlay)

pagoda Finlay

Coluzea sp., (canal only)

Baryspira (Gemaspira) tholiculus Marwick

Alcithoe sp.

Lithoconus cf. hendersoni (Marwick)

Marshallena sp.

Dentalium zelandicum Sowerby

Unidentified fossils:

Ostracoda

spatangid echinoid spines

one otolith

f512 - Highest sample.

Foraminifera:

<u>Bolivinopsis cubensis</u> (Cushman & Bermudez)	1
<u>Textularia barnwelli</u> Kennett	1
<u>Haeuslerella morgani</u> (Chapman)	1
<u>Robulus calcar</u> (Linnaeus)	4
<u>iotus</u> Cushman	1
<u>Dentalina substrigata</u> Stache	2
<u>Nodosaria longiscata</u> d'Orbigny	1
<u>Lagenonodosaria hirsuta</u> (d'Orbigny)	4
sp., (smooth)	1
<u>Stilostomella antipoda</u> (Stache)	4
<u>Lagena crenata</u> Parker & Jones	1
<u>striata</u> (d'Orbigny)	1
<u>sulcata</u> (Walker & Jacob)	1
<u>Oolina hexagona</u> (Williamson)	1
<u>globosa</u> (Montagu)	1
<u>melo</u> d'Orbigny	1
<u>Fissurina marginata</u> (Walker & Boys)	2
<u>marginato-perforata</u> (Sequenza)	1
<u>orbignyana</u> (Sequenza)	1
<u>Frondicularia longistriata</u> Cushman	1
<u>Parafrondicularia pellucida</u> (Finlay)	1
<u>Guttulina yabei</u> Cushman & Ozawa	1
<u>Bulimina aculeata</u> d'Orbigny	4
cf. <u>striata</u> d'Orbigny, (small var.)	3
<u>truncanella</u> Finlay	1

<u>Virgulina schreibersiana</u> Czjzek	1
<u>Neouvigerina vadeszens</u> (Cushman)	4
<u>Hofkeruva lutorum</u> Vella	4
<u>Angulogerina</u> cf. <u>angulosa</u> (Williamson)	1
n.sp. aff. <u>australis</u> (Heron-Allen & Earland)	1
<u>Trifarina bradyi</u> Cushman	4
<u>Bolivina affiliata</u> Finlay	3
<u>albatrossi</u> Cushman	2
<u>barnwelli</u> Finlay	1
<u>lapsus</u> Finlay	1
<u>numerosa</u> Vella	4
<u>plicatella</u> Cushman	3
<u>turbiditorum</u> Vella	3
<u>watti</u> Gibson	4
<u>Rectobolivina digitata</u> Parr	1
<u>striatula</u> (Cushman)	4
<u>maoria</u> Finlay	3
<u>Virgulopsis pustulata</u> Finlay	1
<u>Bolivinita pohana</u> Finlay	2
<u>Plectofrondicularia pohana</u> Finlay	2
<u>Cassidulina laevigata</u> d'Orbigny	1
<u>neocarinata</u> Thalmann	4
<u>Cassidulinoides orientalis</u> (Cushman)	4
<u>Pleurostomella acuminata</u> Cushman	1
<u>Chilostomella ovoidea</u> Reuss	1
<u>Sphaeroidina bulloides</u> d'Orbigny	2

<u>Pullenia bulloides</u> (d'Orbigny)	1
<u>Astrononion vadorum</u> Vella	1
<u>Pacinonion parki</u> (Hornibrook)	4
<u>Melonis</u> cf. <u>tuberculatum</u> (d'Orbigny)	1
<u>Florilus flemingi</u> (Vella)	4
<u>Discorbis</u> n.sp. aff. <u>umbonifer</u> Parr	1
<u>Discopulvinulina berthelotti</u> (d'Orbigny)	1
<u>Gavelinopsis lobatulus</u> (Parr)	3
<u>Laticarinina pauperata</u> (Parker & Jones)	1
<u>Epistominella iota</u> Hornibrook	4
<u>Höglundina elegans</u> (d'Orbigny)	1
<u>Pseudoeponides prominula</u> (Stache)	1
<u>tenera</u> (Brady)	1
<u>Elphidium charlottensis</u> (Vella)	1
<u>Notorotalia hurupiensis</u> Vella	4
<u>Globigerina</u> cf. <u>nepenthes</u> Todd	1
<u>pachyderma</u> (Ehrenberg)	4
<u>praebulloides</u> Blow	3
<u>quinqueloba</u> Natland	4
<u>woodi</u> Jenkins	1
<u>zealandica</u> Hornibrook	4
<u>Globigerinita glutinata</u> (Egger)	1
<u>Globigerinoides obliqua</u> Bolli	2
<u>trilobus trilobus</u> (Reuss)	1
<u>Orbulina universa</u> d'Orbigny	4
<u>Sphaeroidinella seminulina</u> (Schwager)	1

<u>Globorotalia</u> <u>conomiozea</u> Kennett	4
<u>scitula</u> (Brady)	1
<u>Anomalinoides</u> <u>parvumbilia</u> (Finlay)	4
<u>spherica</u> (Finlay)	4
<u>Cibicides</u> <u>deliquatus</u> Finlay	2
<u>finlayi</u> Gibson	1
n.sp. aff. <u>deliquatus</u> Finlay	1
n.sp., (high and conical)	3
<u>Dyocibicides</u> <u>biserialis</u> Cushman & Valentine	2

Unidentified fossils:

Ostracoda

Echinoid spines (spatangid)

Fish otoliths

f508 - Benthonic Foraminifera not represented in f507 and
f512 and planktonic Foraminifera

<u>Eponides tuberculatus</u> (Balkwill & Wright)	1
<u>Valvulineria stachei</u> Hornibrook	1
<u>Globigerina bulloides</u> d'Orbigny	2
<u>duertrei</u> d'Orbigny	1
<u>falconensis</u> Blow	1
<u>praebulloides</u> Blow	4
<u>quinqueloba</u> Natland	4
<u>woodi</u> Jenkins	4
<u>Globigerinita uvula</u> (Ehrenberg)	1
<u>Globigerinoides obliqua</u> Bolli	1
<u>trilobus trilobus</u> (Reuss)	3
<u>Globoquadrina altispira globosa</u> Bolli	1
<u>Sphaeroidinella seminulina</u> (Parker & Jones)	1
<u>Globorotalia conomiozea</u> Kennett	2

f509 - Benthonic Foraminifera not represented in f507,
f512 and f508 and planktonic Foraminifera.

<u>Sigmoilopsis gavini</u> Gibson	1
<u>Vaginulina</u> cf. <u>patens</u> Brady	1
<u>Awhea subtetragona</u> (Finlay)	1
<u>Proxifrons advena</u> (Cushman)	1
<u>Virgulina vellai</u> Kennett	1
<u>Angulogerina esuriens</u> Hornibrook	1

<u>Bolivina alata</u> Sequenza	1
<u>Bolivinita elegantissima</u> Boomgaart	1
<u>Florilus decepatrix</u> (Hornibrook)	1
<u>Parvicarinina altocamerata</u> Finlay	1
<u>Elphidium novozealandicum</u> Cushman	1
<u>Cibicides gibsoni</u> Kennett	1
<u>Globigerina pachyderma</u> (Ehrenberg)	2
<u>parabulloides</u> Blow	4
<u>praebulloides</u> Blow	4
<u>quinqueloba</u> Natland	4
<u>woodi</u> Jenkins	4
<u>Globigerinita glutinata</u> (Egger)	2
<u>Globigerinoides obliqua</u> Bolli	2
<u>Sphaeroidinella seminulina</u> (Schwager)	1
<u>Globorotalia conomiozea</u> Kennett	4

APPENDIX 3- Index of Fossil Localities

Sample numbers are the Sheet Fossil Numbers of the N.Z. Fossil Record system based on sheet districts of the N.Z. map series.

Full locality details for sheet districts ^{are} recorded in the Sheet Fossil Master-file at the N.Z. Geological Survey.

Grid references are the coordinates based on the National Thousand-yard grid.

Lithologies are given in the code of the N.Z. Fossil record form (Wellman, 1953:55).

Standard symbols are used for New Zealand stages.

Sheet fossil number	Locality	Grid ref.	Lithology	Age
N135f563	Middle Maraetotara River, Hawkes Bay	392118	9952a	M.Tt
f564		394122	9952a	M.Tt
f565		395125	9952a	U.Tt
f566		395127	9952a	U.Tt
f567		395133	9952a	U.Tt
f568		396138	9961a	U.Tt
f569		397140	8961a	U.Tt
f570		397142	8961a	U.Tt
f571		395143	9861a	U.Tt
f572		395145	7762a	Wo
f573		395146	7762a	Wo
f574		395149	7762a	Wo
N106f564		837230	9942a	M.Tt
f563		838229	9942a	M.Tt
f562		839228	9942a	U.Tt

Sheet fossil number	Locality	Grid ref.	Lithology	Age
f561	Ruakituri River from 4 to 5 miles n.w. of Te Reinga	841228	9942d	U.Tt
f560		842228	9842d	U.Tt
f559		842227	9842d	U.Tt
f558		848230	9942d	U.Tt
f557		850230	8842d	U.Tt
f556		851230	8842d	U.Tt
f555		851229	8842d	U.Tt
f554		852229	8852d	U.Tt
f553		852228	7852d	U.Tt
f552		852228	7842d	U.Tt
f551		852227	7852d	Tk
f550		852226	7852d	Tk
f549		852225	7852d	Tk
f548		852224	7752c	Wo
f547		852223	7841c	Wo
f546		843219	8842d	Wo
f545		848218	8842d	Wo
f544		849218	8842d	Wo
N98f523	Waimata River 7 to 9 miles north of Gisborne	417547	8942d	U.Tt
f524		415544	8942d	U.Tt
f525		416542	8942d	U.Tt
f526		418539	8942d	U.Tt
f527		420534	7752c	Tk
f528		423530	7752c	Tk
f529		423528	7752c	Wo

Sheet fossil number	Locality	Grid ref.	Lithology	Age
f530	Waimata River	414525	8742c	Wo
f531	7 to 9 miles	412518	8942c	Wo
f532	north of Gisborne	416516	8942c	Wo
f533		416513	8942c	Wo
N 63 f508	Cliff section		9841d	Tk
f509	immediately east		9841d	Tk
f510	of Awatere River		9841d	Tk
f511	road bridge		9841d	Tk
f512	Te Araroa.		9841d	Tk
f507	Road cutting 15 chains n.e. Awatere River Road Bridge.		7841d	Tk

Notes on the Faunal Sequence of the Upper Tongaporutuan
- Kapitean in Inland Taranaki

Inland Taranaki is an important area for the Kapitean Stage because it is the only place besides the standard section of the Kapitean Stage at Callaghans Creek, Westland, where Sectipecten wollastoni is known to occur in sequence with S. grangei. By definition the base of the Kapitean at Kapitea Creek and Callaghans Creek is at the first appearance of S. wollastoni, and S. grangei must be considered to be indicative of a Tongaporutuan age.

A few microsamples from Sectipecten localities were borrowed from the New Zealand Geological Survey and several other microsamples were collected by the writer in order to determine stratigraphic ranges of Foraminifera relative to those of S. grangei and S. wollastoni in Taranaki. The lowest four samples were collected by the writer from strata mapped by Shell, B.P. and Todd Oil Services Ltd. as lowermost Matemateonga Formation. They were collected at stratigraphic intervals of about 50 ft. from the upper reaches of a stream $1\frac{1}{4}$ miles north of Pohokura railway tunnel and $\frac{3}{4}$ mile e.n.e. of Piaka Hill. These strata are below typical S. grangei but above the early form of S. grangei described by Boreham (1961) from the Upper Tongaporutuan of Taranaki. Other samples collected from Sectipecten localities, can not be

placed in sequence by field evidence, but the association of some species in these samples is noted below.

Table 1 shows the occurrences of selected species of Foraminifera in the four samples from the lower Matemateonga Formation at Pohukura, and three samples borrowed from the N.Z. Geological Survey. The latter include two associated with typical S. grangei and one associated with S. wollastoni. Stratigraphic thicknesses between samples above the four collected by the writer are not known, but the total thickness from the horizon of the lower S. grangei samples to that of S. wollastoni sample is probably greater than 2000 ft.

Planktonic Foraminifera are generally rare in the Taranakian of inland Taranaki, and the Globorotalia crassaformis bioseries is represented only by rare specimens. Specimens found throughout all but the highest part of the range of S. grangei are all five chambered, not as conical as typical G. conomiozea and are referable to G. miozea. Typical G. conomiozea occurs in the uppermost part of the range of S. grangei and throughout the range of S. wollastoni.

Two generally persistent and abundant Tongaporutuan species in the Taranaki region, Bolivina barnwelli Finlay and Bulimina vellai Gibson, disappear in the Upper Tongaporutuan about 1500 ft. lower than the lowest known occurrence of S. wollastoni.

In Taranaki the upper limit of Textularia miozea Finlay is not known with certainty but it has not been found

in association with the highest S. grangei or with S. wollastoni. T. miozea is replaced by its descendant T. kapitea in the Kapitean of Taranaki, as judged by its occurrence in one sample (N109f499).. Another Kapitean entrant in inland Taranaki is Siphotextularia n.sp. cf. wairoana Finlay, which was found in three samples associated with S. wollastoni.

Microsamples collected from localities of Phialopecten n.sp. aff. triphooki (Zittel) regarded by Boreham as Opoitian in age, contain no Globorotalia. Thus the relationship between the first appearance of G. crassaformis (Galloway & Wissler), which by definition is the base of the Opoitian Stage, and the first appearance of P. n.sp. aff. triphooki could not be assessed.

Reference

- Boreham, Anne U.E., 1961. The New Zealand Tertiary Genus Sectipecten Marwick (Mollusca). Trans. roy. Soc. N.Z. 88(4): 655-668.

Table 1 - Distribution of some stratigraphically important species in inland Taranaki.

	N110					N109f498	N119f488
	f46	f48	f47	f49	f20		
<u>Sectipecten grangei</u> Boreham	.	.	.	.	X	X	.
<u>Sectipecten wollastoni</u> (Finlay)	.	.	.	.	.	.	X
<u>Textularia barnwelli</u> Kennett	.	2	1	.	.	1	1
<u>Textularia miozea</u> Finlay	1	.	2	.	.	.	.
<u>Siphotextularia awamoana</u> Finlay	.	.	.	.	.	1	.
<u>Siphotextularia</u> n.sp. cf. <u>wairoana</u> Fin.	.	.	.	.	.	.	1
<u>Bulimina vellai</u> Gibson	4	2	4	3	.	.	.
<u>Bolivina barnwelli</u> Finlay	4	4	4	4	.	.	.
<u>Plectofrondicularia pohana</u> Finlay	.	1	.	.	.	.	.
<u>Notorotalia pliozea</u> Vella	.	.	.	4	.	.	4
<u>Globigerina pachyderma</u> (Ehrenberg)	.	.	.	.	.	1	.
<u>Globorotalia conomiozea</u> Kennett	.	.	.	.	.	1	4
<u>Globorotalia miozea</u> Finlay	1	1	.	.	1	.	.
<u>Cibicides</u> n.sp. aff. <u>deliquatus</u> Finlay	.	1	.	.	.	.	4

KEY: X = present; 1 = 1-4 specimens;
 2 = 5-10 specimens; 3 = 10-20 specimens;
 4 = more than 20 specimens.

New Foraminifera from the Upper Miocene
and Lower Pliocene of New Zealand

by J.P. Kennett

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ABSTRACT

The following fourteen new species of fossil Foraminifera are described and illustrated: Textularia crater, Siphotextularia dawesi, Ruakitura pseudorobusta, Karrerella fasigatus, Arenodosaria turris, Vaginulinopsis carinata, Bolivinita finlayi, Brizalina srinivasani, Kolesnikovella zealandica, Discorbinella hamasuturalis, Notorotalia mammiligera, Cibicides porrodeliquatus, Cibicides teararus and Pleurostomella parviapertura. Known stratigraphic ranges and inferred depth ranges are given for each species. The new genus Ruakitura (Ataxophragmiidae) is erected for the species formerly known as Dorothia robusta Keyser.

INTRODUCTION

The Foraminifera described below were collected during examination of late Miocene to early Pliocene sections in the North Island east coast and in Marlborough (Kennett

1965a, 1965b, 1965c).

Holotypes and paratypes are lodged in the Geology Department, Victoria University of Wellington. Catalogue numbers of the foraminiferal holotypes have the prefix F, and paratypes Fp. Paratypes of new species have been presented to the New Zealand Geological Survey.

Sample numbers are the New Zealand Fossil Record Numbers based on sheet districts of the N.Z. map series. Grid references are the coordinates based on the national thousand-yard grid. Details of microfossil localities are recorded in the New Zealand Fossil Record masterfiles, and are summarised in the previous papers (Kennett loc. cit.).

The systematic order closely follows that of Loeblisch and Tappan (1964).

Nearly all the species appear to be useful ecological indicators. Depth ranges of the species given in OBSERVED ECOLOGIC RANGE are inferred from occurrences in biofacies which were defined by Vella (1962a, 1962b) and Kennett (1962).

SYSTEMATIC DESCRIPTIONS

Order	FORAMINIFERIDA
Suborder	TEXTULARIINA
Superfamily	AMMODISCACEA
Family	TEXTULARIIDAE
Subfamily	TEXTULARINAE
Genus	TEXTULARIA Defrance

Textularia crater Kennett, n.sp. Pl. 1, figs. 1 - 4.

DESCRIPTION: Test large, wedge shaped, gently tapering, and fine grained. Initial part broad and spade like. Bluntly rounded edges have projecting tubules arranged in single file, extending almost the entire length of the test, all broken off near the margin. Chambers little inflated, gradually increasing in size, up to 10 on each side. Margins of the terminal face bluntly angled to rounded. Sutures distinct, slightly depressed in upper half of test. Aperture a simple slit at a re-entrant of the inner margin of the last chamber.)

Elongated jagged crater-like depressions immediately above the sutures in the upper half of the test are a distinctive feature. These have been mostly calloused over in the lower half of the test, but sometimes leave residual uncalloused areas.

Dimensions of holotype: length 0.34 mm., breadth 0.23 mm.

Dimensions of figured paratypes: Pl. 1, fig. 2, length 0.30 mm., breadth 0.22 mm.; Pl. 1, figs 3 - 4, breadth 0.27 mm.

TYPES: Holotype (F381) and 4 paratypes (Fp381).

TYPE LOCALITY: N98f524 Waimata River, Poverty Bay, N.Z. grid ref. 415544.

TYPE LEVEL: Upper Tongaporutuan (Upper Miocene), 2500 ft. below the base of the Opoitian Stage (Lower Pliocene).

REMARKS: Distinguished by the lateral tubules and the jagged crater-like depressions above the sutures. Differs

from T. fistulosa Brady in being much broader at the juvenile end and thicker and broader at the adult end, and in having the crater-like depressions. A Pliocene species from Italy, T. cordata has similar crater-like depressions but lacks the lateral tubules.

DISTRIBUTION: Five specimens in the type sample and one specimen 400 ft. stratigraphically lower in the Upper Tongaporutuan of the same section.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Semipelagic Biofacies.

Genus SIPHOTEXTULARIA Finlay

Siphotextularia dawesi Kennett, n.sp. Pl. 1, figs. 5, 6.

1965. Siphotextularia cf. wairoana; Kennett, (in press).

DESCRIPTION: Test small, rhomboid in end view, composed of fine sand grains set in much cement. Widest and thickest at the oral end, tapering regularly to the blunt, small initial end, front moderately deeply concave, sides flat or slightly convex. Peripheral angles sharp to bluntly rounded, often bearing rounded keels. Sutures indistinct, slightly curved, steeply sloping. Up to 7 chambers on each side. Aperture oblique, elongate, surrounded by a thin projecting lip situated near the inner margin of the final chamber.

Dimensions of holotype: length 0.20 mm., breadth 0.13 mm.

Variability: Individuals vary in the degree of development of

the peripheral keel and the depression of the sutures. Some specimens are slightly twisted along the longitudinal axis.

TYPES: Holotype (F382) and 15 paratypes (Fp382).

TYPE LOCALITIES: NI50f1047, Mangapuka Stream, S. Hawkes Bay, N.Z. grid ref. 690365.

TYPE LEVEL: Kapitean Stage, Upper Miocene, 600 ft. below the base of the Opoitian Stage (Lower Pliocene).

REMARKS: The recent species S. mestayerae Vella differs in being compressed and in having its front flattened and its edges rounded. The extremely variable species S. emaciata Hornibrook, includes individuals somewhat similar to S. dawesi, with squarish sides but these differ in having very deeply excavated chambers and coarser grained tests.

In the Taranakian and lowermost Opoitian at Blind River, Marlborough, and in the Waipatiki Stream and Mangapuka Stream sections near Weber, S. Hawkes Bay, S. dawesi gradually changes upwards to S. wairoana Finlay. The vertical sequence of gradually changing tests is here termed the Siphotextularia wairoana Bioseries. The rhomboid outline typical of S. dawesi gradually changes to the evenly quadrate outline typical of S. wairoana. At the same time the regularly tapering test of S. dawesi changes to the blunt-apexed test of S. wairoana. In southern Hawkes Bay, Wairarapa and Marlborough S. dawesi has not been found above the lowermost Opoitian, but in Central Hawkes Bay at Maraetotara River near Cape Kidnappers it extends into the upper part of the Opoitian, and is not replaced by S. wairoana. It is uncertain whether the bioserial change

in the south reflects evolution or migration of two interbreeding species due to environmental change.

DISTRIBUTION: At nth. Westland one specimen of S. dawesi was found near the middle of the type Kapitean and abundant specimens near the top; common from the uppermost Upper Tongaporutuan to the lowermost Opoitian at Blind River, Marlborough; abundant in the Upper Tongaporutuan of the Ngamaia Stream and Putara sections in the Mangatainoka Valley, near Eketahuna, Wairarapa; in variable abundance in the Kapitean of the Waipatiki Stream and Mangapuka Streams near Weber township, S. Hawkes Bay; abundant in the Opoitian of Maraetotara River, near Cape Kidnappers, Hawkes Bay; rare in the Upper Tongaporutuan at Waimata River, Poverty Bay; abundant in the Kapitean east of Te Araroa, East Cape; and in variable abundance in the Kapitean of inland Taranaki.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Mostly associated with the Haeuslerella Biofacies, very rare in deeper biofacies.

Family ATAXOPHRAGMIIDAE

Subfamily GLOBOTEXTULARIINAE

Genus RUAKITURIA Kennett, new genus.

TYPE SPECIES: Dorothia robusta Keyzer, 1953.

DIAGNOSIS: Test in most characters resembles Dorothia.
Early stage trochospiral with 4 or more chambers to whorl,

later stage reduced to biserial. Distinguished from Dorothia by the aperture which instead of being an interiomarginal (basal) slit, is high and narrow. The young triserial tests have an elongated loop shaped aperture, somewhat shorter than in adult specimens.

REMARKS: Keyzer (1953) himself pointed out that the high narrow aperture serves to distinguish R. robusta from other species of Dorothia.

Two other species as interpreted from the type figures (fide Ellis and Messina) appear to be referable to Ruakituria. These are Gaudryina subrotundata Schwager and Ataxophragmium laceratum Schwager both described from the island of Kar Nikobar in the Indian Ocean.

Ruakituria pseudorobusta Kennett, n.sp. Pl. 1, figs 12 - 15.

DESCRIPTION: Test large, stout, coarse grained, oval in section. Initial end bluntly rounded, sides nearly parallel for most of their length. Earliest whorl with 4 or 5 chambers, later triserial, the adult biserial with 4 to 5 pairs of chambers. Sutures indistinct and slightly depressed. In adults the aperture is a vertical or near vertical slit at a re-entrant of the inner margin of the last chamber, widest near the top and with a constriction in the lower half. In the triserial stage there is no constriction; in the young biserial stage the constriction is in the lowermost part of the aperture and in the adult it occurs about $\frac{1}{3}$ of the way up the aperture. In one adult paratype the constriction has been completely

calloused over isolating the upper part of the aperture from the lower.

Dimensions of holotype: length 0.51 mm., breadth 0.22 mm.

Dimensions of figured paratypes: Pl. 1, fig. 14, length 0.50 mm., breadth 0.25 mm.; Pl. 1, fig. 15, length 0.23 mm., breadth 0.21 mm.

Variability: The aperture varies from straight to slightly curved.

TYPES: Holotype (F383) and 18 paratypes (Fp383 and Fp384).

TYPE LOCALITIES: Holotype and 14 paratypes (Fp383) NI06f564, Ruakituri River, n. Hawkes Bay, grid ref. 837230; 4 paratypes (Fp384) N98f524, Waimata River, Poverty Bay grid ref. 415544.

TYPE LEVELS: Middle Tongaporutuan at Ruakituri River; Upper Tongaporutuan at Waimata River (Upper Miocene).

REMARKS: Distinguished from R. robusta (Keyzer), which it closely resembles, by having a longer and thinner aperture and by the distinctive apertural constriction in the adult.

DISTRIBUTION: Found only in the type samples.

OBSERVED STRATIGRAPHIC RANGE: Middle and Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Semipelagic Biofacies.

Genus KARRERIELLA Cushman

Karrerietta fasigatus Kennett, n.sp. Pl. 1, figs. 7 - 9.

DESCRIPTION: Test large, stout, tapering periphery broadly rounded, coarse grained, initial end fairly sharp, greatest breadth at apertural end, earliest whorl with 4 or 5 chambers, most of test triserial, with only 2 biserial chambers at oral end of adult specimens. Chambers distinct, slightly inflated, increasing gradually and uniformly in size, sutures distinct, slightly incised, horizontal in adult. Aperture subrounded in triserial stage, with a distinct lip, well above the base of the last formed chamber.

Dimensions of holotype: length 0.45 mm., breadth 0.24 mm.

Dimensions of figured paratypes: Pl. 1, fig. 8, length 0.29 mm., breadth 0.18 mm.; Pl. 1, fig. 9, breadth 0.26 mm.

TYPES: Holotype (F385) and 8 paratypes (Fp385 and Fp386)

TYPE LOCALITIES: Holotype and 6 paratypes (Fp385), N135f566 Maraetotara River, Hawkes Bay, grid ref. 395127; 2 paratypes (Fp386) from 300 ft. lower in the same section, grid ref. 39125.

TYPE LEVELS: Lower part of Upper Tongaporutuan (Upper Miocene).

REMARKS: Distinguished by the large, tapering subrounded test with chamber arrangement mostly triserial throughout. Differs from K. halkyardi Cushman in having more tapering test and a much longer triserial portion. The very short biserial portion of the test serves to distinguish K. fasigatus from other species of Karrerella.

DISTRIBUTION: Apart from the type samples one specimen

from the Upper Tongaporutuan of Waimata River, Poverty Bay.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan.

OBSERVED ECOLOGIC RANGE: Semipelagic Biofacies.

Subfamily VALVULININAE

Genus ARENODOSARIA Finlay

Loeblich and Tappan (1964) regarded Arenodosaria as a junior synonym of Plectina, arguing that the type species Clavulina robusta Stache is not truly uniserial and rectilinear, but loosely biserial and only nearly uniserial. Stache's type figures and topotypes of A. robusta however show 3 - 4 perfectly rectilinear uniserial adult chambers. Consequently Arenodosaria as defined by Finlay (1939) is retained as a distinct genus.

Arenodosaria turris Kennett, n.sp. Pl. 1, figs. 10, 11.

DESCRIPTION: Test cylindrical, coarsely arenaceous, moderately short; uniserial portion forming about two-thirds of the test; earliest whorl with 4 or 5 chambers rapidly decreasing to 3 chambers and then 2, followed by 4 uniserial chambers. Sutures generally distinct, slightly incised. Terminal face well rounded with an elongate simple terminal aperture.

Dimensions of holotype: length 0.38 mm., breadth 0.18 mm.

Variability: Varies in the degree of incision of the sutures and in the roughness of the test. In some specimens the multiserial portion is relatively bulbous, in others there is little difference in width between the uniserial and multiserial portions.

TYPES: Holotype (F387) and 28 paratypes (Fp387)

TYPE LOCALITY: N135f565 Maraetotara River, Hawkes Bay, N.Z. grid ref. 395125.

TYPE LEVEL: Lowermost Upper Tongaporutuan (Upper Miocene).

REMARKS: Distinguished by the few uniserial chambers, the well rounded oral end and the coarse and often rough test. Differs from A. antipoda (Stache) in smaller size, more sand grains and less cement, shorter and less inflated chambers and the rounded terminal face not drawn out at the aperture.

DISTRIBUTION: Found in the type sample and as rare specimens 300 ft. higher in the Upper Tongaporutuan of the same section.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Semipelagic Biofacies.

Suborder	ROTAIIINA
Superfamily	NODOSARIACEA
Family	NODOSARIIDAE
Subfamily	NODOSARIINAE
Genus	VAGINULINOPSIS Silvestri

Vaginulinopsis carinata Kennett, n.sp. Pl. 2, figs 16 - 18.

1962 Vaginulinopsis n.sp., Kennett, N.Z.J.Geol. Geophys. 5: 620-25.

DESCRIPTION: Test large, thick shelled, moderately compressed, early coiled portion of about 9 chambers, followed by up to 3 chambers in the uncoiled portion. Sutures heavily thickened and raised in central part of test, arcuate and curved strongly downwards from the outer edge of the test towards the proloculum. Remainder of test smooth, without any trace of ornament. Periphery with wide smooth flange, widest around the coiled portion tapering towards the uncoiled portion, around which it is usually absent. Aperture large, radiate, peripheral and directed forward; apertural face smooth, bordered by raised keel.

Dimensions of holotype: length 0.85 mm., breadth 0.42 mm.

Dimensions of figured paratype: length 0.68 mm., breadth 0.48 mm.

Variability: In a few specimens the thickened parts of the sutures are dissected into tubercles.

TYPES: Holotype (F388) and 10 paratypes (Fp388).

TYPE LOCALITY: S24f523 Sea cliffs west of Carters Beach, Cape Foulwind, West Coast, grid ref. 998738.

TYPE LEVEL: Basal Opoitian (Lower Pliocene).

REMARKS: Distinguished by large size, large coiled portion, raised and thickened sutures and wide peripheral flange.

DISTRIBUTION: Common in the Opoitian of Cape Foulwind, rare in the Upper Tongaporutuan of Palliser Bay coastal section, and in the stream flowing alongside Mangaoranga Road $1\frac{1}{2}$ miles s.e. of Eketahuna, in the Kapitean at Ruakituri River, Hawkes Bay and in the Opoitian at Waimata River, Poverty Bay.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies to Robulus Biofacies.

Superfamily BULIMINACEA

Family BOLIVINITIDAE

Genus BOLIVINITA Cushman

Bolivinita finlayi Kennett, n.sp. Pl. 2, figs. 23, 24.

DESCRIPTION: Test of medium size, very compressed, fairly broad, tapering gradually to a rounded initial end. Cross section compressed rhomboid, the acute angles carinate, the obtuse angles gently rounded and non-carinate; the broader faces lightly concave, the narrower faces slightly convex. Sculpture of fine, numerous, irregular, longitudinal costae along most of length of the narrow faces and in most specimens less conspicuously along the broader faces. About 7 chambers on each side, often slightly inflated. Sutures fairly heavily limbate, slightly depressed or flush, very gently curved to straight, and moderately oblique. Aperture large, widest at base.

Dimensions of holotype: length 0.21 mm., breadth 0.11 mm.

Variability: The compression and the development of the lateral keels varies slightly.

TYPES: Holotype (F391) and 13 paratypes (Fp391).

TYPE LOCALITY: N150f1049 Mangapuka Stream, near Weber township, s. Hawkes Bay, N.Z. grid ref. 688367.

TYPE LEVEL: Kapitean Stage (Upper Miocene); 100 ft. below base of Opoitian Stage (Lower Pliocene).

REMARKS: Distinguished by the strong compression, numerous fine costae, acute lateral keels and gently rounded medial angles. Some paratypes of B. pohana Finlay are as compressed as B. finlayi, but the majority are much less compressed, and none have the distinctive sculpture of B. finlayi.

DISTRIBUTION: Sporadic in the Kapitean and Opoitian of the Mangapuka Stream and Waipatiki Stream sections, near Weber township, s. Hawkes Bay, and high in the Opoitian at Maraetotara River, Hawkes Bay.

OBSERVED STRATIGRAPHIC RANGE: Kapitean to Opoitian (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Genus BRIZALINA Costa

Brizalina srinivasani Kennett, n.sp. Pl. 2, figs. 21, 22.

DESCRIPTION: Test of moderate size, moderately compressed with shining surface gradually tapering from bluntly rounded initial end to broad apertural end. Adult test has 7 or 8

pairs of chambers. Periphery narrowly rounded on the early part, subacute on the later part. Sutures flush or slightly raised, thickened, slightly curved. Wall finely perforate, early portion with numerous fine to moderately coarse longitudinal costae which sometimes extend up onto later part of test. Aperture large, wide and lens shaped with slightly thickened rim.

Dimensions of holotype: length 0.27 mm., breadth 0.10 mm.

Variability: Some specimens are slightly twisted, and the thickening of the sutures and strength of ribbing varies somewhat.

TYPES: Holotype (F390) and 31 paratypes (Fp390).

TYPE LOCALITY: N153f1183 half a mile n.w. up stream immediately north of Putara village, Mangatainoka Valley, Wairarapa, N.Z. grid ref. 065990.

TYPE LEVEL: Opoitian Stage (Lower Pliocene).

REMARKS: Distinguished by the moderately compressed glossy test with thickened sutures, ribbing and large aperture. Differs from B. striatula (Cushman) by having thickened, non-depressed sutures, non-inflated and fewer chambers and larger aperture.

Named after Mr. M. S. Srinivasan.

DISTRIBUTION: Found only in the type sample.

OBSERVED STRATIGRAPHIC RANGE: High in the Opoitian Stage (Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Deeper-water phase of the Haeuslerella Biofacies.

Family UVIGERINIDAE

Genus KOLESNIKOVELLA N.K. Bykova

Kolesnikovella zealandica n.sp. Pl. 2, figs. 19, 20.

DESCRIPTION: Test very small, triangular in cross section, slender, about 3 times as long as broad, with sides parallel for most of length. Initial end sharp with a very tiny apical spine. Test regularly triserial for most of length, but tending to become uniserial. Chambers indistinct; sutures mostly indistinct, slightly thickened, flush. Surface distinctly perforated and ornamented with fine close longitudinal costae. Aperture terminal with short neck and very thin lip.

Dimensions of holotype: length 0.13 mm., breadth 0.05 mm.

Variability: The chambers are slightly inflated in some specimens.

TYPES: Holotype (F389) and 20 paratypes (Fp389).

TYPE LOCALITY: N98f525, Waimata River, Poverty Bay, N.Z. grid ref. 416542.

TYPE LEVEL: Upper Tongaporutuan Stage (Upper Miocene).

REMARKS: Distinguished by the very small, slender, regular, obtusely angular test with distinct perforations and fine costae. K. zealandica has probably close affinities with K. australis (Heron-Allen and Earland) but is somewhat narrower and longer, has a shorter apertural neck and has a more distinctly perforate test and costae.

DISTRIBUTION: Apart from the type sample one specimen was found in the Kapitean of East Cape (N63f512).

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan to Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies to Robulus Biofacies.

Superfamily DISCORBACEA

Family DISCORBIDAE

Subfamily DISCORBINAE

Genus DISCORBINELLA Cushman & Martin

Discorbinella hamasuturalis Kennett, n.sp. Pl. 2, figs. 27-29.

DESCRIPTION: Test moderately large, robust, flattened in cross section, nearly planapallel. Final chamber situated well ahead of the penultimate chamber, tending to become detached as a separate lobe. Periphery subrounded, heavily thickened on the final chamber only. Spiral side evolute, umbilical side involute. Up to 18 chambers in the adult whorl with 9 or 10 in the final whorl. Sutures strongly hooked backwards, heavily limbate, and slightly raised. Apertures on ventral side covered by relatively small, pointed tooth plates. A small peripheral aperture situated at the base of the final chamber.

Dimensions of holotype: diameters 0.24 mm., 0.20 mm.

Variability: Both sides are either flat or very gently concave.

TYPES: Holotype (F393) and 17 paratypes (Fp393 and Fp394).

TYPE LOCALITY: Maraetotara River, Hawkes Bay, N.Z.,

Holotype and 4 paratypes (Fp393), N135f565, grid ref. 395125.

Four paratypes (Fp394) - 400 ft. stratigraphically lower in same section, grid ref. 394122.

TYPE LEVELS: Holotype and paratypes - lower part of Upper Tongaporutuan. Additional paratypes - upper part of Middle Tongaporutuan (Upper Miocene).

REMARKS: Distinguished by the moderately large, very compressed test, and strongly hooked heavily limbate sutures. Somewhat resembles Discorbis planulinaformis Keyzer from the Mio-Pliocene of the Celebes, but differs in having the Discorbinella peripheral aperture, less heavily limbate and raised but more strongly curved sutures.

DISTRIBUTION: Found only in the type samples.

OBSERVED STRATIGRAPHIC: Middle and Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Semipelagic Biofacies.

Superfamily ROTALIACEA

Family ELPHIDIIDAE

Subfamily FAUJASININAE

Genus NOTOROTALIA Finlay

Loeblich and Tappan (1964) regarded Notorotalia as a junior synonym of Polystomellina Yabe and Hanzawa.

The writer has examined topotypes of the type species of both genera, and has worked with many Tertiary microfaunas containing different species of Notorotalia. The type of Poly-stomellina, P. discorbinoides Yabe and Hanzawa is plano-convex,

with the ventral (involute) side flat, and has rather simple ornament like that of Elphidium, made up of grooves and ridges parallel to the periphery.

Notorotalia is always biconvex and has a distinctive sculpture of which the primary elements are raised limbate sutures and oblique ribs on the chamber walls extending forwards from the transverse sutural ridges. These ribs over the chambers are rarely parallel to the periphery, often bifurcate, and sometimes are interconnected by a mesh of irregular secondary ribs, giving a reticulate ornament.

Notorotalia has a long Tertiary history in New Zealand, while in Japan there appears to be no forms closer to it than P. discorbinoides. This species almost certainly evolved from Elphidium in or near Japan, independently from Notorotalia. Consequently the writer prefers to retain the genus Notorotalia as distinct from Polystomellina.

Notorotalia mammiligera Kennett, n.sp. Pl. 3, figs. 30-32.

DESCRIPTION: Test of medium size, very depressed with acute periphery surmounted by a thin, flange-like keel. Dorsal surface slightly convex, ventral surface slightly concave or convex at sides, concave in the middle. Spiral sutures and transverse sutures limbate and broken up into small round or elongate isolated papillae. Transverse sutures slightly curved and moderately oblique on the dorsal surface, forming a distinct angle where they meet the periphery. Oblique ribs obsolete occasionally present on the posterior end of chambers,

characteristically replaced by low irregular papillae giving a lumpy texture on the surface of the test.

Dimensions of holotype: diameters 0.18 mm., 0.20 mm.

Variability: On some specimens relatively large papillae are concentrated in the umbilicus.

TYPES: Holotype (F395) and 18 paratypes (Fp395).

TYPE LOCALITY: N153f1176 from cliffs cut by Mangatainoka River immediately north of Putara Village, Wairarapa, N.Z., grid ref. 075987.

TYPE LEVEL: Upper Tongaporutuan Stage (Upper Miocene).

REMARKS: Distinguished by the medium size, strong compression, narrow flange-like keel, and distinctive papillate ornament.

DISTRIBUTION: Found only in the type sample.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Superfamily ORBITOIDACEA

Family CIBICIDAE

Subfamily CIBICIDINAE

Genus CIBICIDES Montfort.

Cibicides porrodeliquatus Kennett, n.sp. Pl. 3, figs. 33-35.

DESCRIPTION: Test relatively large, opaque, often with blotchy, pinkish patches, from 7 - 11 chambers in the final whorl. Dorsal surface flat or slightly concave, coarsely

perforate; ventral surface moderately convex, coarsely perforate but usually less so than dorsal surface. Dorsal sutures often much thickened, moderately curved, flush or slightly depressed. Ventral sutures unthickened, fairly strongly curved, usually depressed. Periphery acute with a much thickened moderately sharp keel. Aperture a small, simple opening at the base of the final chamber extending over the periphery just onto the dorsal surface. A thickened lip surrounds the aperture and can be seen at the base of the 3 previous chambers on the dorsal side of adults.

Dimensions of holotype: diameters 0.23 mm., 0.20 mm.

Variability: Both the amount of depression of the ventral sutures and the number of chambers in the final whorl vary considerably.

TYPES: Holotype (F396) and 53 paratypes (Fp396).

TYPE LOCALITY: N153f1176, from cliffs cut by the Mangatāinoka River immediately north of Putara Village, Wairarapa, N.Z., grid ref. 075987.

TYPE LEVEL: Upper Tongaporutuan Stage (Upper Miocene).

REMARKS: Cibicides porrodeliquatus fairly closely resembles C. deliquatus Finlay which is probably its direct ancestor, but it is less compressed, not convex on the dorsal side, more convex on the ventral side, far more coarsely perforate, and usually is further distinguished by the pinkish blotches.

DISTRIBUTION: Rare in the Middle Tongaporutuan of the

Mangaoranga section 2 miles s.e. of Eketahuna; abundant in the Upper Tongaporutuan near Putara; rare in the Kapitean of Waipatiki Stream near Weber township, s. Hawkes Bay; common in the Kapitean of East Cape; abundant in the Opoitian of the Maraetotara River, near Cape Kidnappers, Hawkes Bay, and in variable abundance in the uppermost Tongaporutuan and Kapitean of inland Taranaki.

OBSERVED STRATIGRAPHIC RANGE: Middle Tongaporutuan to Opoitian (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Cibicides teararus Kennett, n.sp. Pl. 3, figs. 36-38.

DESCRIPTION: Test a small, compact, elevated cone. Dorsal surface flat or slightly concave, fairly coarsely perforate. Ventral surface conical, somewhat less coarsely perforate. Dorsal sutures strongly limbate, moderately curved, usually flush. Ventral sutures slightly limbate, slightly depressed, gently curved. Periphery surrounded by a narrow, blunt keel. Aperture a low to moderately high arched, rimmed slit, extending from about halfway along the base of the terminal face over the periphery and along the full width of the final chamber on the dorsal side. Adults with up to 17 chambers in 2 whorls, 8 or 9 chambers in the final whorl.

Dimensions of holotype: diameters 0.12 mm., 0.10 mm.

Variability: The coarseness and density of the perforations

on the ventral surface vary considerably.

TYPES: Holotype (F397) and 26 paratypes (Fp397).

TYPE LOCALITY: N63f509, 300 ft. above road in cliff section immediately east of Awatere River road bridge, Te Araroa, East Cape, N.Z.

TYPE LEVEL: Kapitean Stage (Upper Miocene).

REMARKS: Distinguished by the small, conical test, with gently curved, little depressed ventral sutures and strongly limbate dorsal sutures. Distinguished from C. westi Howe, by the greater elevation and non-sigmoid ventral sutures, and from C. vortex Dorreen by smaller size, less strongly depressed ventral sutures and absence of the distinctive chevron pattern of the ventral sutures of that species.

DISTRIBUTION: Persistent but in variable abundance throughout the Kapitean section at Te Araroa, East Cape; common in the Upper Tongaporutuan near Putara village, Wairarapa.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan to Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Superfamily	CASSIDULINACEA
Family	PLEUROSTOMELLIDAE
Subfamily	PLEUROSTOMELLINAE
Genus	PLEUROSTOMELLA Reuss.

Pleurostomella parviapertura Kennett, n.sp. Pl. 2, figs. 25, 26.

DESCRIPTION: Test of medium size, swollen, fusiform,

short, about twice as long as wide, circular in cross section. Initial end with short strong spine, apertural end generally pointed. Chambers strongly embracing, the final chamber making up more than half the length of the test. Sutures fairly distinct, slightly depressed. Wall smooth. Aperture small, widest at the top.

Dimensions of holotype: length 0.22 mm., breadth 0.13 mm.

Variability: The greatest width of test may be at the middle or close to the initial end, and the extent to which the final chamber envelops previous chambers varies somewhat.

TYPES: Holotype (F392) and 20 paratypes (Fp392).

TYPE LOCALITY: S29f635 Blind River, Marlborough, N.Z.
grid ref. 302714.

TYPE LEVEL: Near base of Upper Tongaporutuan Stage
(Upper Miocene).

REMARKS: Distinguished by the breadth, apical spine, small aperture, and generally strongly embracing final chamber.

DISTRIBUTION: Found only in the type sample.

OBSERVED STRATIGRAPHIC RANGE: Upper Tongaporutuan
(Upper Miocene).

OBSERVED ECOLOGIC RANGE: Robulus Biofacies.

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Plate 1.

- Figs. 1 - 4 - Textularia crater Kennett, n.sp., 1, holotype; 2, peripheral view of paratype; 3, 4, apertural and side views of another paratype; X50.
- Figs. 5, 6 - Siphotextularia dawesi Kennett, n.sp., 5, holotype; 6, apertural view of holotype; X72.
- Figs. 7 - 9 - Karrerella fasigatus Kennett, n.sp., 7, holotype; 8, juvenile paratype; 9, apertural view of another paratype; X36.
- Figs. 10 - 11 - Arendosaria^o turris Kennett, n.sp. 10, holotype; 11, apertural view of holotype; X50.
- Figs. 12 - 15 - Ruakituria pseudorobusta Kennett, n.gen., n.sp., 12, holotype; 13, transverse section near initial end of paratype; X36; 14, apertural characteristics of another paratype; 15, juvenile paratype; X50.

Plate 2.

- Figs. 16 - 18 - Vaginulinopsis carinata Kennett, n.sp.
16, paratype; 17, holotype; 18, apertural
view of same paratype; X25.
- Figs. 19, 20 - Kolesnikovella zealandica Kennett, n.sp.
19, holotype; 20, apertural view of
holotype; X100.
- Figs. 21, 22 - Brizalina srinivasani Kennett, n.sp.
21, holotype; 22, apertural view of
holotype; X50.
- Figs. 23 - 24 - Bolivinita finlayi Kennett, n.sp.
23, holotype; 24, apertural view of
holotype; X72.
- Figs. 25 - 26 - Pleurostomella parviapertura Kennett, n.sp.
holotype; X50.
- Figs. 27 - 29 - Discorbinella hamasuturalis Kennett, n.sp.
holotype; 27, peripheral view; 28,
dorsal view; 29, ventral view; X50.

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Plate 3.

Figs. 30 - 32 - Notorotalia mammiligera Kennett, n.sp.
holotype, 30, ventral view; 31, dorsal view;
32, peripheral view; X72.

Figs. 33 - 35 - Cibicides porrodeliquatus Kennett, n.sp.
holotype, 33, ventral view; 34, dorsal view;
35, peripheral view; X50.

Figs. 36 - 38 - Cibicides teararus Kennett, n.sp.
36, ventral view; 37, dorsal view;
38, peripheral view; X72.

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Recognition and Correlation of the Kapitean
Stage (Upper Miocene, New Zealand).

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ABSTRACT

The salient features of New Zealand Upper Miocene and Lower Pliocene microfaunas are outlined, and criteria for recognising the Kapitean Stage are summarized. Paleocology suggests that the Kapitean stage represents an interval of time when seas were relatively shallow, that the shallowing took place in the latest part of the Tongaporutuan Age and that subsequent deepening took place in the earliest part of the Opoitian Age. The changes in depth of the sea caused many temporary ("facies") changes in fossil faunas at any particular place, but the Kapitean Stage is soundly based only on relatively few permanent changes of both macrofauna and microfauna. The Kapitean Stage is represented by fairly shallow-water facies at many places but it contains some fairly deep-water facies at other places. These facies contain very few age diagnostic fossils in common, but usually can be correlated by means of a bioseries of planktonic Foraminifera - the Globorotalia crassaformis bioseries.

In nearly all sections the Kapitean Stage is thin compared with the overlying Opoitian and underlying Upper Tongaporutuan, and this is attributed to a decreased rate of

deposition due to shallowing and increased by-passing of sediment. It does not necessarily indicate that the Kapitean Age was briefer than either the Upper Tongaporutuan or the Opoitian Age.

Kapitean microfaunas show a slight but distinct change from north to south, and this is attributed to latitudinal temperature difference.

The previously accepted correlation of the Kapitean Stage with the Pontian Stage of Europe is probably correct. The shallow seas during the Kapitean Age in New Zealand thus appear to have coincided with a regression in Europe and in other parts of the world and are likely to have a eustatic rather than a tectonic cause.

INTRODUCTION

Published work on the Kapitean Stage prior to 1963 was summarized by Kennett (1965a, in press). The following account summarizes the findings of several regional studies of the Upper Miocene to Lower Pliocene succession by the writer (Kennett, 1965a, b, c, d, in press).

The distribution of Kapitean strata was summarized by Finlay & Marwick (1948), and Hornibrook (in Fleming ed., 1959), and is here shown by a map (fig. 1). The intercorrelation of foraminiferal and molluscan zones established for different parts of New Zealand, and their

Fig. 1 - Map of New Zealand with the distribution of sediments of Kapitean Age shown in solid black lines. The thickness of Kapitean sediments is exaggerated.

relationship to the New Zealand stages, are shown in table 1.
Criteria for recognising the Kapitean Stage.

In previous papers (Kennett, loc. cit.) the litho-stratigraphy and biostratigraphy of the Upper Miocene-Lower Pliocene and the evidence for determining the boundaries of the Kapitean Stage, are given for 17 stratigraphic sections between Westland and East Cape. The stage is represented by shallow and deep-water facies and the diagnostic Kapitean fossils are mostly different in the shallow-water facies from those in deep-water facies. The two main facies divisions are therefore discussed separately.

Shallow-water Facies

1. In shallow-water facies the base of the Kapitean Stage is generally marked by the appearance of the key Kapitean Mollusca Sectipecten wollastoni and Austrofuscus coerulescens, and by the absence of the Tongaporutuan species Sectipecten grangei. The top of the stage is usually determined by the appearance of planktonic species as discussed below.

The shallow-water facies at Upton Brook, Marlborough does not contain the critical planktonic species, and the upper boundary there was assumed to be at a horizon where a marked change takes place in the molluscan faunas - immediately above the highest occurrence of Cucullaea.

2. The foraminiferal species Textularia miozea became extinct at the top of the Tongaporutuan, its highest known occurrences being in the uppermost Upper Tongaporutuan at Cape Foulwind on the West Coast and at Ruakituri River in northern

STAGES		NORTH WESTLAND ZONES (Kennett, 1965)		MARLBOROUGH ZONES (Kennett, 1965)		WAIRAPA ZONES			HAWKES BAY FORAMINIFERAL ZONES (Kennett, 1965)	TARANAKI ZONES		
Europe	New Zealand	Foraminiferal Zones	Molluscan Zones	Foraminiferal Zones	Molluscan Zones	Foraminiferal Zones		Molluscan Zones	Informal zones based on present work; Gibson, 1963; and Boreham 1961.	Foraminiferal Zones (Geiger, 1962)		
						Mauriceville (Vello, 1962)	Kennett 1965			Foraminifera	Mollusca	
Aslan - Pleistocene	Waikararan - Opolitan	Finlayi	Chrydæe	-	-	Molestus ?	Inflata	-	-	-	-	Globorotalia Truncatulinoidea Zone
	Opolitan	Crossaformis	-	Crossaformis	Allani	Inflata	Crossaformis	-	Crossaformis	-	Phialopecten aff. triphooki	Globorotalia Inflata Zone
Pleistocene	Kapitean	Conomiozoa	Conulectans Wallastoni	Conomiozoa	Wallastoni	Zosserus	Zosserus	Wallastoni	Conomiozoa	Globorotalia conomiozoa	Sectipecten wallastoni	-
	Upper	Macinnesi	Grangei	Pliozea	-	Compresso	Pliozea	Grangei	Compresso	Bolivinita compressa (rare)	Sectipecten grangei	Globigerina Nepenthes Zone
	Middle Tongaporuan	Quadrilatera	Cliffonensis	Pohana	Hurupiensis ? - - -	-	Pohana	-	Pohana	Bolivinita pohana	-	-
Tertiary	Lower	Quadrilatera	Cliffonensis	-	-	-	-	-	-	Bolivinita quadrilatera	-	-
	Waikararan	Truncatum	-	-	-	-	-	-	-	-	-	-

Table 1 - Chart showing intercorrelation of foraminiferal and molluscan zones for the Upper Miocene to Lower Pliocene of New Zealand.

Hawkes Bay. T. kapitea the derivative of T. miozea, occurs spasmodically in pre-Kapitean sediments at a few localities, but was most widespread during the Kapitean Age.

3. The Siphotextularia wairoana bioseries (Kennett, 1965e) is useful for recognising the Kapitean Stage in shallow-water facies in the South Island and the southern part of the North Island. In these areas, Siphotextularia dawesi Kennett gradually changes from the Upper Tongaporutuan through the Kapitean, to give rise to Siphotextularia wairoana Finlay just above the base of the Opoitian Stage. Absence of much of this bioseries in the Mangatainoka Valley supplies supporting evidence for the disconformity cutting out the Kapitean Stage. In sections where there is a continuous succession of suitable facies from the Upper Tongaporutuan to the Opoitian, the S. wairoana bioseries is unbroken.

The significance of Bulimina aculeata and Textularia kapitea

Until recently the first appearance of the shallow-water species Bulimina aculeata and Textularia kapitea were thought to mark the base of the Kapitean Stage, but these species have recently been found in sediments somewhat older than Kapitean. In the Eketahuna district, Wairarapa, B. aculeata and Textularia kapitea occur in shallow-water sediments of Middle Tongaporutuan Age, are absent for some thousands of feet in deep-water sediments of Middle to Upper Tongaporutuan age, but reappear in abundance in the shallow-water sediments of uppermost Tongaporutuan and Kapitean age.

Similarly in the Palliser Bay section, B. aculeata occurs in shallow-water sediments of Lower Tongaporutuan and upper-most Tongaporutuan - Kapitean age but is absent in the intervening deep-water sediments of Middle Tongaporutuan Age. Thus it is easy to understand how the mistaken impression arose that B. aculeata and T. kapitea make their first appearance at the base of the Kapitean Stage.

Deep-water Facies

Until recently the base of the Kapitean Stage could not be recognised definitely in deep-water facies. The Globorotalia crassaformis bioseries (Kennett, 1965f), a succession of planktonic Foraminifera showing gradual changes in form, has proved to be extremely useful for determining the base and top of the Kapitean Stage in both shallow and deep-water facies. It has been possible to utilise the gradational morphological changes to determine relative stratigraphic ranges of short ranging deep-water and shallow-water benthonic fossils, including the key Kapitean Mollusca.

The base of the Kapitean Stage lies within the range of Globorotalia conomiozea, a member of the Globorotalia crassaformis bioseries, and is distinguished by the following characteristics of the Globorotalia population:

1. a dominance of strong-keeled (somewhat below the appearance in appreciable numbers of non-keeled forms);
2. 85 - 90 per cent of specimens with 4 - 4 $\frac{1}{4}$ chambers;
3. the umbilical side strongly conical (average

"conical angle" between 63° - 68°);

4. the aperture generally narrow and high arched.

Throughout New Zealand the lowermost part of the range of G. conomiozea is uppermost Upper Tongaporutuan in age, and at several places is associated with Sectipecten grangei and Textularia miozea. Most of the range of G. conomiozea overlaps with that of the key Kapitean Mollusca.

The top of the Kapitean Stage is generally easily recognised in all facies as it is, by definition, at the first appearance of the planktonic species G. crassaformis which is found in almost all marine strata. This species is the end member of the G. crassaformis bioseries and its first appearance is arbitrarily taken at the horizon where typical G. crassaformis forms 50 per cent of the G. conomiozea - G. crassaformis sample.

Lists of Species used for Determining the Kapitean

The following lists show those species which at present seem to be useful for recognising the Kapitean Stage. As work proceeds the ranges of many species are bound to be modified. Only the more useful molluscan species are included, as fairly complete lists are given by Marwick (in press). Species marked with an asterisk (*) have been abstracted from literature and have not been found in the sections studied by the writer.

Tongaporutuan Stage:

Last Appearances:

Foraminifera:

- Textularia miozea Finlay
- Textularia crater Kennett
- Siphotextularia kreuzbergi Finlay
- Vulvulina pennatula (Batsch)
- Migros medwayensis (Parr)
- Clavulinoides instar Finlay
- Ruakituria pseudorobusta Kennett
- Karrerella fasigatus Kennett
- Arenodosaria turris Kennett
- Martinottiella massami Gibson
- Massilina subaequalis (Parr)
- Cruciloculina ericsoni Loeblich & Tappan
- Spiroloculina canaliculata d'Orbigny
- Spiroloculina kennetti Gibson
- Parafrondicularia fyfei (Finlay)
- * Bulimina miolaervis Finlay
- Bulimina senta Finlay
- Bulimina vellai Gibson
- Virgulina bramletti Galloway & Motrey
- Euvigerina notohispida (Finlay)
- Hofkeruva mioschwageri (Finlay)
- Rectouvigerina pohana (Finlay)
- * ? Angulogerina australis (Heron-Allen & Earland)

- * Rectobolivina hangaroana Finlay
- * Rectobolivina maoriella Finlay
- Rectobolivina parvula Finlay
- Bolivinita quadrilatera (Schwager)
- Ehrenbergina willetti Finlay
- Pleurostomella parviapertura Kennett
- Nonionella novozealandica Cushman
- Discorbinella hamasuturalis Kennett
- Buningia creeki Finlay
- Ceratobulimina kellumi Finlay
- * Ceratobulimina (Ceratobulimina) clifdenensis Finlay
- Notorotalia cf. depressa Vella
- Notorotalia macinnesi Kennett
- Notorotalia pristina Vella
- Notorotalia mammiligera Kennett
- Discorotalia aranea (Hornibrook)
- Globoquadrina dehiscens (Chapman, Parr & Collins)
- Globorotalia opima continua Blow
- Globorotalia menardii panda Jenkins
- Anomalina aotea Finlay
- Cibicides mediocris Finlay
- Cibicides cf. novozealandicus (Karrer)
- Cibicides thiaracuta Hornibrook
- * Planulina catillus (Finlay)

Mollusca:

Sectipecten grangei Boreham

Kapitean Stage:

Restricted:

Foraminifera:

Quinqueloculina waimea Kennett

Frondricularia longistriata Cushman

Eponides tuberculatus (Balkwill & Wright)

Mollusca:

Sectipecten wollastoni (Finlay)

Struthiolaria cincta Hutton

Austrofusus coerulescens (Finlay)

Alcithoe gravicostata King

First Appearances:

Foraminifera:

Bolivinita finlayi Kennett

Ammonia aoteanus (Finlay)

Elphidium novozealandicum Cushman

Globigerinoides obliqua Bolli

Mollusca:

Marama cf. murdochi Marwick

Nemocardium quinarium Marwick

Dentalium zelandicum Sowerby

Last Appearances:

Foraminifera:

Textularia subrhombica Stache

Siphotextularia awamoana Finlay

Bulimina mapiria Finlay

Bulimina truncanella Finlay
Kolesnikovella zealandica Kennett
Bolivina lapsus Finlay
Bolivina turbiditorum Vella
Bolivinita elegantissima Boomgaart
Cassidulina cuneata Finlay
Melonis maoricum (Stache)
Florilus olsoni Kennett
Valvulineria stachei Hornibrook
Cancris lateralis Finlay
Globoquadrina altispira globosa Bolli
Cibicides teararus Kennett

Mollusca:

Cucullaea n.sp.
Notocorbula humerosa (Hutton)

Opoitian Stage:

First Appearances:

Foraminifera:

Siphotextularia wairoana Finlay
 * Staffia multicostales (Finlay)
Neouvigerina bellula Vella
Hofkeruva delicatula Vella
Hofkeruva rodleyi tutamoides Vella
Hofkeruva pliozea Vella
Bolivina robusta Brady
Bolivina silvestrina Cushman

Ehrenbergina mestayeri Cushman

Melonis lutorum Vella

Rosalina pauperques Vella

Gavelinopsis hamatus Vella

Notorotalia finlayi Vella

Notorotalia kingmai Vella

Notorotalia olsoni Vella

Globigerinoides rubra (d'Orbigny)

Globorotalia crassaformis (Galloway & Wissler)

Globorotalia hirsuta (d'Orbigny)

Globorotalia inflata (d'Orbigny)

Changes in depth of the sea during Late Miocene and Early Pliocene Times.

In most Upper Miocene to Lower Pliocene sections studied by the writer, paleoecology indicates that the sea shallowed appreciably near the end of the Tongaporutuan Age, remained shallow during the Kapitean Age and deepened again about the beginning of the Opoitian Age.

The sections that show this sequence of depth changes are as follows:

Cape Foulwind, West Coast

Upton Brook, Marlborough

Blind River, Marlborough

Palliser Bay coast

Mangaoranga Road, Eketahuna

Putara, Mangatainoka Valley

Ngamaia Stream, Mangatainoka Valley

Maraetotara River, central Hawkes Bay

Ruakituri River, northern Hawkes Bay

Waimata River, Gisborne

Details of lithological and faunal changes which indicate the depth fluctuations are given in previous papers (Kennett, loc. cit.).

No detailed paleoecological analysis of the faunas from Taranaki region was made, but the lithological succession there suggests depth changes similar to those elsewhere. The uppermost Tongaporutuan and Kapitean sediments are generally much coarser than those above and below, and they contain more numerous pebbly shell beds and conglomerate bands.

Sections where the uppermost Miocene shallowing was not recorded are in the Greymouth basin in north Westland and at Weber in southern Hawkes Bay. In these areas much or all of the Tongaporutuan is missing due to unconformity and the sea deepened during Kapitean time due to tectonic downdrop.

Discussion:

The parallel biofacies changes in so many widely distributed sections strongly indicates that the late Tongaporutuan shallowing and the early Opoitian deepening affected a large part of New Zealand. From this it may be inferred that just before the Kapitean, either sea-level fell,

or the lithosphere over almost the entire area rose; and just after the Kapitean either sea-level rose, or the lithosphere over almost the entire area sank.

The tectonic explanation requires synchronous vertical movements of the crust over a highly mobile area in which numerous blocks are known to have been tilting differentially. This explanation is unlikely because the synchronous depth changes occurred in at least two major tectonic units, the East Coast basin and the Wanganui basin and these were probably effected by unrelated tectonic movements.

Changes of sea-level provide a much less complicated mechanism. The chief objection to this mechanism is that the only sea-level changes known to have occurred were glacio-eustatic changes caused by advances and retreats of continental ice-sheets. Suess (1885) and Wells (1960) considered however that such changes of sea-level could have been caused by increase and decrease in the capacity of the ocean basin due to tectonic and sedimentational processes. Even if such processes are considered inadequate, as pointed out by Vella (in press), there is no real evidence that a continental ice-sheet did not exist on Antarctica during the Tertiary, and the possibility of glacio-eustatic changes in other than Pleistocene (or late Paleozoic) times can not be discounted.

Accurate values for the depth changes could not be determined because in each section they are super-imposed on

secular deepening or shallowing caused by a combination of vertical crustal movements, sedimentation and compaction of sediments. For example the sequence of biofacies changes at Palliser Bay is from Robulus Biofacies to Karreriella Biofacies and back to Robulus Biofacies, indicating little secular change in depth; but at Ruakituri River, the sequence is from the Robulus Biofacies through the Karreriella Biofacies to the Elphidium Biofacies, and back to the Karreriella Biofacies indicating a secular shallowing. In general the temporary shallowing effect was of the order of a few hundred feet.

If the shallowing was caused by a lowering of sea-level, evidence for it should be found in uppermost Miocene to Lower Pliocene sediments elsewhere in the world. In Europe and North Africa, the Pontian Stage is considered to be equivalent to the Kapitean (Finlay 1947, Fleming 1959). According to Gignoux (1955) "the Miocene sedimentary cycle always ends in all Western Europe and North Africa with a period of emergence with which we associate the continental formation designated the Pontian."

Shallowing during the late Miocene is seen also in California where littoral and terrestrial deposits were laid down in numerous basins (Kleinpell, 1938, p. 180); in Trinidad where the uppermost Miocene Lengua Formation becomes coarser upwards and planktonic Foraminifera become very rare (Bolli, 1957, p. 102); in the Dominican Republic where

sediments of uppermost Miocene Age are of shallower-water facies than lower in the succession and are overlain by unfossiliferous and possibly non-marine deposits thought to be Pliocene in age (Bermudez, 1949); and in the State of Falcon, Venezuela where the uppermost Miocene Ojo de Agua formation is much coarser than the underlying sediments (Renz, 1948).

The changes in depth of the sea were accompanied by marked changes in marine invertebrate faunas. Hornibrook (1958, p. 31) described the Tongaporutuan microfaunas as very distinctly "Miocene" in character, containing many species that are known in the Southland Series (Lower and Middle Miocene) but not in the Wanganui Series (Pliocene to Pleistocene). At the end of the Tongaporutuan Age and during the Kapitean Age many Miocene species became extinct and many Recent species were introduced. At the end of the Kapitean Age the microfauna was already similar to that of present day New Zealand seas. The most striking and significant changes were in the planktonic Foraminifera. For instance the planktonic species Globigerina pachyderma and Globigerina quinqueloba which are generally regarded as characteristic of temperate and cool seas, and which occur only spasmodically in the Tongaporutuan, are abundant in the Kapitean; and G. crassaformis the immediate ancestor of the Recent G. inflata makes its first appearance and becomes a dominant species immediately above the Kapitean. At the same time keeled Globorotalias became relatively uncommon, though they were

not to disappear until the beginning of the Pleistocene. These changes in the planktonic Foraminifera have generally been regarded as indicating a change from warm subtropical to more temperate sea temperatures (Hornibrook, 1958). This is confirmed by modern oceanographic research, as keeled Globorotalias have been found to be restricted to much warmer waters than are non-keeled Globorotalias (Bandy, 1964). The change in molluscan faunas that took place during Kapitean time, especially the extinction of Cucullaea, supports the suggestion of significant cooling.

Latitudinal variation of Kapitean faunas

Faunas are generally richer in species to the north. Among the planktonic Foraminifera the cool-water species G. pachyderma and G. bulloides increase in abundance towards the south. Planktonic species which occur in variable abundance in the north and which are rarely found in the south are Globigerinoides trilobus, Sphaeroidinella seminulina, Globigerinoides obliqua and Globoquadrina altispira globosa.

The following benthonic species were found in the Kapitean Stage only to the north of Gisborne:

Textularia cf. sagittula Defrance

Frondicularia longistriata Cushman

Bolivina albatrossi Cushman

Bolivina barnwelli Finlay

Bolivina lapsus Finlay

Rectobolivina digitata Parr

Rectobolivina maoria Finlay

Kolesnikovella zealandica Kennett

The following species were found only from Eketa-huna northwards:

Cibicides teararus Kennett

Cibicides porrodeliquatus Kennett

Bolivina plicatella Cushman

The following species are common only south of southern Hawkes Bay:

Sigmoilopsis zeaserus Vella

Virgulina vellai Kennett

Bolivinita pliozea Finlay

Cibicides gibsoni Kennett

The Kapitean microfaunas thus show a slight but distinct latitudinal variation, somewhat more pronounced amongst planktonic species than amongst benthonic species. The latitudinal range of the microfaunas studied, from Westland in the south to East Cape in the north, is approximately five degrees and the faunal differences are almost certainly due to differences in water temperature.

Relative thickness of Kapitean Sediments

The following table shows the thickness in feet of sediments for the Upper Tongaporutuan "substage" and the Kapitean Stage in six sections throughout New Zealand.

	Up. Tongaporutuan	Kapitean
Upton Brook, Marlborough	2200	900
Blind River, Marlborough	2400	600
Palliser Bay	350	250
Mangaoranga Road, Eketahuna	400	300
Ruakituri River, n. Hawkes Bay	2000	650
Waimata River, Gisborne	>2300	900

In all cases the Kapitean Stage is thin compared with the Upper Tongaporutuan. It is likewise usually thin compared with the Opoitian Stage. The Kapitean Stage has generally been considered to represent a relatively short period of time compared with other Tertiary stages (Squires, 1960), but is unlikely to represent a substantially shorter time than the Upper Tongaporutuan "substage". The relative thinness compared with the Upper Tongaporutuan and other units at each area is probably largely due to the decrease in depth of the sea during the Kapitean Age, which almost certainly would have caused a significant increase in by-passing of sediment and consequent decrease in the rate of deposition. It is perhaps significant that at Palliser Bay and Mangaoranga the Kapitean is represented by mudstone deposited in quite deep water, probably an environment where by-passing was not important, and at these localities the Kapitean is comparable in thickness to the Upper Tongaporutuan.

Overseas Correlation of the Kapitean Stage

Finlay (1947) compared the Kapitean faunas with those of

the Californian Repetto Formation. The Repetto was considered to be Pontian in age by Kleinpell (1938, p. 181) who emphasised the good correlation that can be made by means of mammalian faunas between the Sarmatian - Pontian sequence of Europe and the Delmontian - Lower Pliocene sequence of California. Consequently the Kapitean Stage was correlated by Finlay (1947, p. 352) with the Pontian Stage of Europe, the highest stage of the Miocene.

The appearance of a fauna of planktonic Foraminifera substantially like that of the present seas around New Zealand marks the base of the Opoitian Stage, directly above the Kapitean. Hornibrook (1958, p.32) compared this with a similar change at the base of the Pliocene of Italy, and considered that the Kapitean - Opoitian boundary corresponds to the Miocene - Pliocene boundary.

In Taiwan, Chang (1962) likewise placed the Miocene - Pliocene boundary at the first appearance of G. inflata and G. crassaformis (G. punctulata).

In Japan, G. crassaformis appears earlier than G. inflata (Saito, 1963), and sediments containing G. inflata have been assigned to the Pliocene and those containing G. crassaformis to the uppermost Miocene. Takayanaki and Saito (1962) tentatively classed the Nobori Formation which contains G. crassaformis (G. cf. oceanica) as Miocene, but were uncertain whether it is uppermost Miocene or Lower Pliocene in age. If the G. crassaformis bioseries represents evolution, then

the sediments in Japan containing G. crassaformis but below the first appearance of G. inflata would correlate with the lower Opoitian of New Zealand here considered to be lowermost Pliocene.

At southern Iloilo, in the Philippines, Bandy (1963) placed the Miocene - Pliocene boundary at the upper limit of Globoquadrina altispira globosa and Globoquadrina dehiscens dehiscens and the lower limit of Sphaeroidinella dehiscens dehiscens and Globorotalia truncatulinoides. This horizon can not be determined in New Zealand. G. dehiscens dehiscens makes its last appearance near the top of the Tongaporutuan Stage and G. altispira globosa occurs in the Kapitean but probably makes its last appearance below the Opoitian. Neither S. dehiscens nor G. truncatulinoides was found in any of the sections studied by the writer.

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Fig. 2 - Geological map showing the type section of the Kapitean Stage at Kapitea Creek and the standard section at Callaghan's Creek. The clear areas are Upper Pleistocene - Recent gravels. The localities of Austrofuscus coeruleascens (Finlay) are shown by the letter C and of Sectipecten wollastoni (Finlay) by the letter W. (Slightly modified after an unpublished map by H.W. Wellman).

TABLE 6 PART 6

KAPITEA CREEK SECTIONDISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Stage:	Sw	Tk						Wo		
Fossil No.	f642	f643	f644	f645	f646	f647	f648	f649	f650	f651
<i>Dyocibicides biserialis</i> Cushman & Valentine	.	.	.	.	.	.	.	1	.	.
<i>Sectipecten wollastoni</i> (Finlay)	.	4	.	.	.	.	.	.	.	.
SPONGE SPICULES	.	.	.	.	.	.	1	3	.	.
GASTROPODA	.	.	1	.	1	.	.	.	.	.
SCAPHOPODA	.	.	.	.	1	.	.	.	.	.
ECHINOID SPINES, (Spatangid)	.	2	3	4	4	1	3	1	4	.
FISH TEETH & BONES	1	1	1	1	1	.	1	1	1	1
FISH OTOLITHS	.	.	.	.	1	.	.	.	.	.
OSTRACODA	1	.	.	1	1	.	1	.	.	1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;

4 = more than 20 specimens.

TABLE 6, PART 1

KAPITEA CREEK SECTION

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Family TEXTULARIIDAE

Stage:	Sw	Tk						Wo		
Fossil No:	f64.2	f64.3	f64.4	f64.5	f64.6	f64.7	f64.8	f64.9	f65.0	f65.1
<i>Textularia barnwelli</i> Kennett, n.sp.	.	.	1	1	1	.	2	.	1	.
<i>kapitea</i> Finlay	.	3	1	.	.	.	1	.	.	.
<i>Haeuslerella finlayi</i> Vella	.	.	.	.	.	1	1	1	.	.
<i>morgani</i> (Chapman)	2	4	4	4	4	4	4	2	1	2
<i>parri</i> Finlay	.	.	.	.	.	.	.	4	3	4
<i>pliocenica</i> (Finlay)	.	.	.	.	.	.	.	3	1	2
<i>Siphotextularia</i> cf. <i>wairoana</i> Finlay	.	.	.	.	1	.	4	.	.	.

Family VALVULINIDAE

<i>Dorothia</i> aff. <i>minima</i> (Karrer)	1	.	.	.	.	.	.	.	.	.
<i>Karrerella bradyi</i> (Cushman)	3	.	.	.	.	.	.	.	.	.
<i>cushmani</i> Finlay	.	.	.	.	.	.	.	1	.	1
<i>cylindrica</i> Finlay	2	.	.	.	.	.	.	.	.	.
<i>Martinottiella clarae</i> Gibson	.	1	4	.	2	3	2	4	4	4

Family MILIOLIDAE

<i>Sigmoilopsis seaserus</i> Vella	.	.	.	.	.	.	.	.	.	1
<i>Quinqueloculina triangularis</i> d'Orbigny	.	.	.	.	.	.	.	.	.	1
<i>Pyrge depressa</i> (d'Orbigny)	.	.	.	.	.	.	.	1	.	.
<i>Spiroloculina kennetti</i> Gibson	.	.	.	.	.	.	.	.	.	1

Family LAGENIDAE

<i>Robulus calcar</i> (Linnaeus)	.	3	4	4	4	1	2	3	1	4
<i>costatus</i> (Fichtel & Moll)	.	1	.	.	.	.	.	.	.	.
cf. <i>cultratus</i> Montfort	1	.	.	.	.	.	.	.	.	.
<i>gyroscaprus</i> (Stache)	.	.	.	.	.	.	.	2	.	.
cf. <i>gyroscaprus</i> (Stache)	.	.	.	.	.	.	.	2	1	2
<i>limbosus</i> (Reuss)	1	1	.	.	.	.	.	.	.	.
<i>loculosus</i> (Stache)	.	.	.	.	.	1	1	.	1	.
cf. <i>loculosus</i> (Stache)	.	.	.	.	.	.	1	.	.	.
<i>suborbicularis</i> (Parr)	2	.	.	.	.	.	.	.	.	.
<i>Lenticulina gibba</i> (d'Orbigny)	2	.	.	.	.	.	1	.	.	.
<i>peregrina</i> (Schwager)	.	.	.	.	.	.	.	2	.	1
<i>Astaculus</i> cf. <i>crepidulus</i> (Fichtel & Moll)	1	.	.	.	.	.	.	.	.	1
<i>Saracenaria italica</i> DeFrance	.	.	.	.	.	.	.	.	1	.
<i>latifrons</i> (Brady)	1	.	.	.	.	.	.	.	.	.
<i>sehenki</i> Cushman & Hobson	.	.	.	.	.	.	1	.	.	1
<i>Vaginulina elegans</i> d'Orbigny	2	.	.	.	1	1	.	1	1	1
<i>legumen</i> (Linnaeus)	.	.	.	.	.	.	.	.	1	.
<i>vagina</i> (Stache)	2	.	.	.	.	.	.	1	.	.
<i>Marginalina duracina</i> Stache	1	.	.	.	.	.	.	.	.	.
<i>obesa</i> Cushman	1	.	.	.	.	.	.	1	1	.
cf. <i>subbullata</i> Hantken	.	.	.	.	.	.	.	.	.	1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;
4 = more than 20 specimens.

TABLE 6, PART 2.

DISTRIBUTION
OF MICROFOSSILS

KAPITEA CREEK SECTION

(To accompany Thesis by J.P. Kennett)	Stage: Fossil No.	Sw							Tk			Wo		
		f64.2	f64.3	f64.4	f64.5	f64.6	f64.7	f64.8	f64.9	f65.0	f65.1			
<i>Dentalina advena</i> (Cushman)		.	.	.	.	.	.	.	1	.	.			
<i>cf. californica</i> (Cushman & Grey)		1	.	.	.	.	.	.	.	.	.			
<i>communis</i> d'Orbigny		2	.	1	.	.	.	1	1	.	2			
<i>cf. decepta</i> (Bagg)		1	.	.	.	.	.	.	.	.	1			
<i>filiformis</i> (d'Orbigny)		1	.	.	.	.	.	.	.	1	1			
<i>guttifera</i> (d'Orbigny)		1	.	.	.	.	.	.	.	.	3			
<i>guttifera</i> (d'Orbigny) var. <i>semirugosa</i> (d'Orbigny)		.	.	.	.	.	1	.	.	.	2			
<i>obliqua</i> (Linnaeus)		1	.	.	.	.	.	1	.	.	.			
<i>soluta</i> Reuss		.	1	.	.	1	.	.	1	.	.			
<i>cf. subemaciata</i> Parr		1	.	.	.	.	.	.	.	.	.			
<i>subsoluta</i> (Cushman)		1	.	.	.	1	1	1	1	.	.			
spp.		2	.	.	.	.	.	.	1	.	.			
<i>Amphicoryna bradleyi</i> (Silvestri)		1	.	.	.	.	.	.	.	.	.			
<i>Nodosaria affinis</i> Reuss		.	.	.	.	.	.	.	1	.	.			
<i>calomorpha</i> Reuss		1	.	.	.	.	.	.	1	.	.			
<i>holoserica</i> Schwager		1	.	.	.	.	.	.	.	.	.			
<i>lamnifera</i> Boonstra		.	1	1	.	.	1	.	1	.	.			
<i>longiscata</i> d'Orbigny		1	1	.	.	.	.	1	1	3	2			
<i>longiscata</i> d'Orbigny, var.		1	.	.	.	.	.	.	.	.	.			
<i>tosta</i> Schwager		1	.	.	.	.	.	.	.	.	.			
spp.		.	1	.	.	.	.	1	.	.	1			
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)		1	4	4	4	4	4	4	3	1	4			
<i>scalaris</i> (Batsch)		.	.	.	1	.	.	.	.	.	.			
sp., (smooth)		.	2	3	2	2	2	1	1	1	1			
n.sp. (hispid - costate)		3	.	.	.	.	.	.	.	.	.			
<i>Stilostomella abyssorum</i> (Brady)		1	.	.	.	.	.	.	.	.	.			
<i>antillea</i> (Cushman)		2	.	.	.	.	.	.	.	.	.			
<i>antipoda</i> (Stache)		2	.	.	.	.	.	.	.	.	.			
<i>verneuilii</i> (d'Orbigny)		2	.	.	.	.	.	.	.	.	.			
<i>recta</i> (Palmer & Bermudez)		3	.	.	.	.	.	.	.	.	.			
<i>Lagena amphora</i> Reuss		.	.	.	.	.	.	.	.	.	1			
<i>elongata</i> (Ehrenberg)		.	.	.	.	.	1	.	1	.	.			
<i>cf. fornasini</i> Buchner		1	.	.	.	.	.	.	.	.	.			
<i>gracilis</i> Williamson		1	.	.	.	.	.	1	.	.	.			
<i>hispidula</i> Reuss		1	.	.	.	.	.	.	1	.	.			
<i>hispidula</i> Cushman		.	1	1	1	.	1	1	.	1	.			
<i>laevis</i> (Montagu)		1	.	.	.	1	.	1	.	1	.			
<i>nebulosa</i> Cushman		.	...	.	.	.	.	1	1	1	.			
<i>perlucida</i> (Montagu)		.	.	.	.	.	.	.	.	1	.			
<i>striata</i> (d'Orbigny)		1	.	2	.	1	1	2	1	2	1			
<i>striata</i> (d'Orbigny) var. <i>strumosa</i> Reuss		.	.	2	.	.	.	.	.	.	.			
<i>sulcata</i> (Walker & Jacob)		1	.	.	1	.	1	2	1	2	.			

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens

4 = more than 20 specimens.

TABLE 6, PART 3

KAPITEA CREEK SECTION

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Stage:	Sw										
Fossil No.	f642	f643	f644	f645	f646	f647	f648	f649	f650	f651	
<i>Colima globosa</i> (Montagu)	.	.	1	.	1	.	2	.	.	.	
<i>hexagona</i> (Williamson)	1	1	2	.	1	1	2	2	2	.	
<i>melo d'Orbigny</i>	.	.	1	.	.	.	.	.	.	.	
<i>Fissurina annectens</i> (Burrows & Holland)	.	1	.	1	.	.	1	.	.	.	
<i>cf. annectens</i> (Burrows & Holland)	.	.	1	.	.	.	.	.	.	.	
<i>laevigata</i> Reuss	.	.	.	.	1	.	2	.	.	.	
<i>lateralis</i> (Cushman)	.	.	.	.	.	.	.	1	1	.	
<i>marginata</i> (Walker & Boys)	1	1	.	.	.	.	.	.	1	1	
<i>aff. marginata-perforata</i> (Sequenza)	.	.	.	.	.	.	.	.	1	.	
<i>submarginata</i> (Boongaart)	1	1	.	1	1	1	1	2	2	2	
<i>wrightiana</i> (Brady)	.	.	.	.	.	.	1	.	.	.	
<i>Parafissurina orbignyana</i> (Sequenza)	1	.	.	.	.	.	1	.	.	.	
<i>cf. quadrata</i> (Williamson)	1	.	.	.	.	.	.	.	.	.	
<i>Proxifrons advena</i> (Cushman)	.	.	.	.	.	.	.	2	1	1	
Family POLYMORPHINIDAE											
<i>Signomorphina lacrimosa</i> Vella	1	.	.	.	.	.	.	.	.	.	
<i>Glandulina symmetrica</i> Stache	1	.	.	1	.	.	1	1	1	.	
<i>Globulina minuta</i> (Roemer)	.	.	.	.	.	.	.	.	1	.	
Family BULIMINIDAE											
<i>Bulimina aculeata</i> d'Orbigny	.	2	.	4	4	1	4	.	.	1	
<i>cf. striata</i> d'Orbigny (large var.)	3	.	.	.	.	.	.	.	.	.	
<i>cf. striata</i> d'Orbigny (small var.)	.	.	.	.	.	.	3	4	3	4	
<i>Globobulimina cf. pacifica</i> Cushman	.	.	.	.	.	.	.	3	.	.	
<i>Virgulina bradyi</i> Cushman	1	.	.	.	.	.	.	.	.	.	
<i>vellai</i> Kennett, n.sp.	.	.	.	.	.	.	1	.	.	.	
n. sp. (long, thin)	4	.	.	.	.	.	.	.	.	.	
<i>Neouvigerina cf. interrupta</i> (Brady)	2	.	.	.	.	.	.	.	.	.	
<i>aff. moorei</i> Vella	4	.	.	.	.	.	.	.	.	.	
<i>vadesceus</i> (Cushman)	.	.	.	.	.	.	1	4	1	.	
<i>Hofkeruva delicatula</i> Vella	.	.	.	.	.	.	.	.	.	4	
<i>paeniteres</i> (Finlay)	.	.	3	.	.	.	.	.	.	.	
<i>lutorum</i> Vella	.	.	.	2	4	4	4	4	4	.	
<i>pliosea</i> Vella	.	.	.	.	.	.	1	4	4	.	
<i>seacuminata</i> Vella	4	2	4	4	2	.	.	.	.	.	
<i>Ruatoria</i> n. sp.	3	.	.	.	.	.	.	.	.	.	
<i>Trifarina bradyi</i> Cushman	.	1	1	.	.	1	1	.	1	.	
<i>Angulogerina esuriens</i> Hornibrook	.	.	.	.	.	.	.	.	.	1	
<i>Bolivina cf. acerosa</i> Cushman	1	.	.	.	.	.	.	.	.	.	
<i>affiliata</i> Finlay	1	.	1	.	1	1	.	1	.	.	
<i>albatrossi</i> Cushman	4	.	.	.	.	.	.	.	.	.	
<i>cf. italica</i> Cushman	1	.	.	.	.	.	.	.	.	.	
<i>lapsus</i> Finlay	2	.	.	.	.	.	.	.	.	.	
<i>numerosa</i> Vella	.	1	2	1	1	.	1	.	.	.	
<i>parri</i> Cushman	.	.	.	.	.	.	.	.	1	.	

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 6 PART 4

KAPITRA CREEK SECTION.

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

OF MICROFOSSILS		Stage:	Sw	Tk						Wo		
(To accompany Thesis by J.P. Kennett)	Fossil No.		f642	f643	f644	f645	f646	f647	f648	f649	f650	f651
	<i>Bolivina petiae</i> Gibson		3	3	.	.	.	1	1	.	.	.
	<i>watti</i> Gibson		1	.	.	.	2	1	3	2	4	3
	<i>Robertinoides cf. pukeuriensis</i> (Hornibrook)		.	.	.	.	1	.	.	.	.	.
Family HETEROCHELICIDAE												
	<i>Bolivinita pliosea</i> Finlay		.	.	.	.	.	.	.	4	4	3
	<i>pohana</i> Finlay		.	4	4	4	4	4	3	.	.	.
Family CASSIDULINIDAE												
	<i>Cassidulina cuneata</i> Finlay		1	.	.	.	.	.	.	.	.	.
	<i>laevigata</i> d'Orbigny		.	1	.	.	1	.	1	.	.	.
	<i>neocarinata</i> Thalmann		4	2	3	1	2	.	4	2	.	3
	<i>subglobosa</i> Brady		.	.	.	.	1	.	.	2	1	1
	<i>Cassidulinoides orientalis</i> (Cushman)		.	1	4	2	1	.	4	2	.	1
	<i>Ehrenbergina osbornei</i> Finlay		4	.	.	.	.	.	.	.	.	.
Family ELLIPSOIDINIDAE												
	<i>Pleurostomella alternans</i> Schwager		4	.	.	.	.	.	.	.	.	.
Family CHILOSTOMELLIDAE												
	<i>Chilostomella ovoides</i> Reuss		.	.	1	.	2	.	.	1	.	.
	<i>Sphaeroidina bulloides</i> d'Orbigny		4	1	4	3	3	1	4	4	4	4
	<i>Pullenia bulloides</i> (d'Orbigny)		1	.	1	.	.	1	1	3	1	2
	<i>quadriloba</i> Reuss		1	.	.	.	.	.	.	.	.	.
	<i>quinqueloba</i> (Reuss)		.	1	1	.	1	.	2	3	2	2
Family NONIONIDAE												
	<i>Pacinoxon neefi</i> Vella		.	.	.	.	.	.	.	3	2	1
	<i>parki</i> (Hornibrook)		.	.	.	.	.	4	4	.	.	3
	<i>Melonis seobesus</i> Vella		.	.	.	.	1	2	1	1	.	2
	<i>Nonionella magnalingua</i> Finlay		.	.	1	.	.	.	1	1	.	2
	<i>Florilus flammigi</i> (Vella)		.	.	1	1	2	2	1	1	1	.
	<i>Zeaflorilus parri</i> (Cushman)		.	.	.	1	.	1	.	.	.	.
Family DISCORBIIDAE												
	<i>Discopulvulina berthelotti</i> (d'Orbigny)		.	.	.	.	.	.	.	1	1	3
	<i>Valvulinaria stachei</i> Hornibrook		1	.	.	.	.	.	.	.	.	.
	<i>Gyroidinoides zelandica</i> (Finlay)		2	.	.	.	.	.	.	2	.	.
	<i>Laticarinina pauperata</i> (Parker & Jones)		1	.	1	.	.	.	1	2	1	1
Family EPISTOMINIDAE												
	<i>Hoglundina elegans</i> (d'Orbigny)		.	.	.	.	.	.	1	1	1	1
	<i>Pseudoepionides prominula</i> (Stache)		.	1	2	1	.	1	4	4	4	4
	<i>tenera</i> (Brady)		1	1	1	.	1	1	2	2	1	1
Family ELPHIDIIDAE												
	<i>Elphidium charlottensis</i> (Vella)		.	.	1	.	.	1	.	.	.	.
	<i>Elphidium cf. chapmani</i> Cushman		.	.	1	.	.	.	.	.	.	.
	<i>Notoretalia hurupiensis</i> Vella		.	1	1	.	1	.	.	.	.	.
	<i>taranakia</i> Vella		.	1	.	.	1	.	4	1	.	.
	<i>aff. taranakia</i> Vella, (reticulate ornament).		.	2	4	3	4	4	1	3	4	2

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;
4 = more than 20 specimens.

TABLE 6, PART 5

KAPITRA CREEK SECTION

DISTRIBUTION
OF MICROFOSSILS

(To accompany Thesis by J.P. Kennett)	Stage:	Sw	Tk						No		
	Fossil No.	f642	f643	f644	f645	f646	f647	f648	f649	f650	f651
Family GLOBIGERINIDAE											
Globigerinella cf. aequilateralis (Brady)		1	.	.	.	.	.	.	.	.	.
Globigerina bulloides d'Orbigny		.	.	.	.	1	.	1	1	.	2
autertrei d'Orbigny		.	1	1	1	1	1	1	1	1	1
cf. falconensis Blow		.	.	.	.	1	.	1	.	.	.
n. sp. cf. nepenthes Todd		3	.	.	.	.	.	.	.	.	.
nepenthes Todd		.	.	.	.	1	.	.	.	.	.
pachyderma (Ehrenberg)		.	2	3	1	3	2	4	4	3	4
parabulloides Blow		.	.	.	.	2	1	1	3	2	.
praebulloides Blow		.	3	4	1	4	2	4	4	4	4
quinqueloba Natland		.	2	.	.	.	1	.	.	.	.
trilocularis d'Orbigny		.	.	.	.	.	1	.	.	.	.
woodi Jenkins		1	1	.	1	2	1	3	.	.	.
zealandica Hornibrook		.	.	.	.	.	.	3	.	.	.
spp.		3	.	.	.	.	.	.	.	.	.
Globigerinita uvula (Ehrenberg)		.	.	.	.	.	.	1	.	.	.
Globigerinoides obliqua Bolli		.	.	.	.	.	.	.	1	.	1
Orbulina suturalis Broodmann		1	.	.	.	.	.	.	.	.	.
universa d'Orbigny		4	.	3	1	3	2	1	4	3	3
universa d'Orbigny (bilobed variety)		3	.	.	.	.	.	.	.	.	.
Globoquadrina dehiscens (Chapman, Parr & Collins)	3	.	.	.	.	.	.	.	.	.	.
Globorotalia barisanensis Le Roy		1	.	.	.	.	.	.	.	.	.
conomiozea Kennett n.sp.		.	2	3	.	4	3	4	.	.	.
crassaformis (Galloway & Wisaler)		.	.	.	.	.	.	.	4	4	4
menardii panda Jenkins		4	.	.	.	.	.	.	.	.	.
menardii cf. miotumida Jenkins, (pustulose)		.	.	.	.	.	.	.	4	.	.
miozea Finlay		4	.	.	.	.	.	.	.	.	.
scitula (Brady)		.	.	2	.	.	1	4	.	.	1
Family ANOMALINIDAE											
Anomalinoides macraglabra (Finlay)		1	.	.	.	.	.	.	.	.	.
miosuturalis (Finlay)		2	.	.	.	.	.	.	.	.	.
parvumbilia (Finlay)		.	1	3	1	.	1	4	4	4	4
pinguiglabra (Finlay)		1	.	.	.	.	.	.	.	.	.
spherica (Finlay)		.	1	1	.	.	.	.	.	.	.
vitrinoda (Finlay)		2	.	.	.	.	.	.	.	.	.
Cibicides amoenis Finlay		3	.	.	.	.	.	.	.	.	.
deliquatus Finlay		.	3	4	3	3	4	4	4	4	4
gibsoni Kennett, n.sp.		.	.	4	2	.	4	4	4	4	4
ihungia Finlay		1	.	.	.	.	.	.	.	.	.
molestus Hornibrook		1	4	4	4	4	2	4	3	4	4
robertsonianus (Brady)		3	.	.	.	.	.	.	.	.	.
n.sp. cf. perforatus (Karrer)		2	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;

4 = more than 20 specimens.

TABLE 7 PART 1

CALLAGHAN CREEK SECTION

DISTRIBUTION
OF MICROFOSSILS

(To accompany Thesis by J.P. Kennett)	Stage:	L.Tt		U.Tt				Tk							
		f52	f53	f54	f55	f56	f57	f58	f59	f61	f62	f63	f64	f65	f66
Family TEXTULARIIDAE	Fossil No.														
Textularia barmwelli Kennett, n.sp.		.	.	.	.	.	.	.	.	1	1	1	.	1	1
kapitea Finlay		.	.	1	.	.	.	.	.	.	1	.	.	.	.
miozea Finlay		.	1	.	.	.	.	.	.	.	.	.	.	.	.
subrhombica Stache		2	3	.	.	.	.	.	.	.	.	.	.	.	.
Haeslerella morgani (Chapman)		4	4	.	.	.	.	.	.	4	4	3	2	4	4
Siphotextularia awamoana Finlay		4	4	.	.	.	.	.	.	1	1	.	.	.	.
subcylindrica Finlay		4	4	.	.	.	.	.	.	.	.	.	.	.	.
n.sp. cf. emaciata Hornibrook		1	.	.	.	.	.	.	.	.	.	.	.	.	.
n.sp. cf. wairoana Finlay		.	1	.	.	.	.	.	.	.	.	.	.	.	.
Family VALVULINIDAE															
Karrerella cylindrica Finlay		.	.	.	.	.	.	.	.	.	.	.	.	1	.
Martinottiella clarae Gibson		.	.	.	.	.	.	.	.	.	.	.	1	.	.
Family MILIOLIDAE															
Quinqueloculina incisa Vella		.	.	.	.	.	.	.	.	1	.	.	.	.	.
kapitiesis Vella		1	.	.	.	.	.	.	.	.	.	.	.	.	.
lamarkiana d'Orbigny		1	.	.	.	.	.	.	.	.	.	.	.	.	.
sp. (low bifid tooth)		.	.	.	.	.	.	1	.	.	.	.	.	.	.
n.sp., (large densely striated)		1	.	.	.	.	.	.	.	.	.	.	.	.	.
sp. indet. juv.		.	.	.	.	.	.	1	.	.	.	.	.	.	.
Scutularis hornibrooki (Vella)		.	.	.	.	.	.	.	.	1	.	.	.	.	.
Miliolinella vigilax Vella		1	.	.	.	.	.	.	.	.	.	.	.	.	.
Biloculina anomala Schlumberger		1	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. anomala Schlumberger		1	.	.	.	.	.	.	.	.	.	.	.	.	.
sp.		1	.	.	.	.	.	.	.	.	.	.	.	.	.
Family LAGENIDAE															
Rebulus antipodus (Stache)		.	.	.	.	.	.	.	.	.	.	1	.	1	1
calcar (Linnaeus)		3	3	1	.	1	.	.	.	3	2	2	4	4	4
cultratus Montfort		1	.	.	.	.	.	.	.	.	.	1	1	.	1
gyroscalprus (Stache)		.	1	.	.	.	.	.	.	.	.	.	.	.	.
iotus Cushman		.	.	.	.	.	.	.	.	.	.	.	.	.	1
loculosus (Stache)		2	.	.	.	.	.	.	.	.	.	.	1	1	.
Lenticulina gibba (d'Orbigny)		1	.	.	.	.	.	.	.	.	.	.	.	.	.
peregrina (Schwager)		1	1	.	.	.	.	.	.	.	.	.	.	.	.
Saracenaria italica DeFrance		.	.	.	.	.	.	.	.	.	.	1	.	.	.
latifrons (Brady)		2	.	.	.	.	.	.	.	.	.	.	.	.	.
Marginulina duracina Stache		2	2	.	.	.	.	.	.	.	.	.	.	.	.
glabra d'Orbigny		.	1	.	.	.	.	.	.	.	.	.	.	.	.
obesa Cushman		1	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. subcrassa Schwager		1	.	.	.	.	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;

4 = more than 20 specimens.

TABLE
SECTION 7 PART 2

CALLAGHANS CREEK SECTION

DISTRIBUTION
OF MICROFOSSILS

	Stage:	L.Tt	U.Tt	Tk											
(To accompany Thesis by J.P. Kennett)	Fossil No.	f652	f653	f654	f655	f656	f657	f658	f659	f661	f662	f663	f664	f665	f666
<i>Dentalina communis</i> d'Orbigny		.	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>decepta</i> (Bagg)		.	1	.	.	.	.	.	.	.	.	.	.	.	1
<i>filiformis</i> (d'Orbigny)		.	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>guttifera</i> d'Orbigny		1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>inornata</i> d'Orbigny, var. <i>bradyensis</i> (Dervilleux)		1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>subsoluta</i> (Cushman)		.	.	.	.	.	.	.	.	.	1	.	.	.	.
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)		3	4	.	.	.	.	.	.	3	4	1	4	4	4
<i>sp.</i> , (smooth)		.	.	.	.	.	.	.	.	2	4	.	.	2	1
<i>Stilostomella antipoda</i> (Stache)		1	2	.	.	.	.	.	.	.	.	.	.	.	.
<i>Rectoglandulina torrida</i> (Cushman)		1	.	.	.	.	.	.	.	.	.	.	.	.	1
<i>Lagena distoma</i> Parker & Jones		1	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>cf. gracilis</i> Williamson		.	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>gracillima</i> (Sequenza)		1	.	.	.	.	.	.	.	.	3	.	.	1	.
<i>heronalleni</i> Earland		.	.	.	.	.	.	1	.	.	.	.	.	.	.
<i>hispidula</i> Reuss		.	.	.	.	.	.	.	.	.	1	.	.	.	1
<i>hispidula</i> Cushman		.	.	.	.	.	.	.	.	1	1	.	.	.	1
<i>laevis</i> (Montagu)		1	1	.	1	1	.	.	.	1	1	.	.	1	1
<i>perlucida</i> (Montagu)		.	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>aff. pliconica</i> Cushman & Gray		3	2	.	.	.	.	.	.	.	.	.	.	.	.
<i>striata</i> (d'Orbigny)		2	2	.	.	1	.	.	.	1	3	.	1	1	1
<i>sulcata</i> (Walker & Jacob)		2	2	.	.	1	.	.	.	1	1	.	1	1	2
<i>sulcata</i> (Walker & Jacob), var. <i>spicata</i> (Cushman & McCulloch)		.	1	.	1	.	.	.	.	.	.	.	.	.	.
<i>Oolina globosa</i> (Montagu)		.	.	.	1	.	.	.	.	.	.	.	1	.	.
<i>hexagona</i> (Williamson)		1	1	.	.	.	.	.	.	1	2	1	.	.	1
<i>Fissurina bicarinata</i> Terquem		1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>marginata</i> (Walker & Boys)		2	.	.	.	.	.	.	.	.	2	.	.	1	.
<i>semicarinata</i> Reuss		1	1	.	.	.	.	.	.	.	1	.	.	.	.
<i>submarginata</i> Boomgaart		.	1	1	.	1	.	.	.	1	.	.	.	.	.
<i>sp.</i> , (spiked keel at base)		.	.	.	.	.	.	.	.	.	1	.	.	.	.
<i>Parafissurina orbignyana</i> (Sequenza)		.	1	.	.	.	.	.	.	.	.	.	.	.	1
<i>Proxifrons advena</i> (Cushman)		1	1	.	.	.	.	.	.	.	.	.	.	.	.
Family POLYMORPHINIDAE															
<i>Sigmonorphina cf. rhomboidalis</i> Vella		.	.	.	1	1	.	.	.	.	.	.	.	.	.
<i>Guttulina bartschi</i> Cushman & Ozawa		.	.	.	.	1	.	.	.	.	.	.	1	.	.
<i>Glandulina symmetrica</i> Stache		.	2	.	.	.	.	.	.	.	.	1	.	.	.
<i>sp. indet.</i>		.	.	.	1	.	.	.	.	.	.	.	.	.	.
Family BULIMINIDAE															
<i>Bulimina aculeata</i> d'Orbigny		.	.	4	2	3	.	.	.	1	1	1	3	3	4
<i>cf. striata</i> d'Orbigny (large var.)		1	4	.	.	.	.	.	.	.	.	.	.	1	.
<i>vellai</i> Gibson		4	4	.	.	.	.	.	.	.	.	.	.	1	.
<i>Virgulina bramlettei</i> Calloway & Morrey		4	4	.	.	.	.	.	.	.	.	.	.	.	.
<i>vellai</i> Kennett, n.sp.		.	1	.	.	.	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;
4 = more than 20 specimens;

TABLE 7 PART 3

CALLAGHANS CREEK SECTION.

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

	Stage:	L.Tt		U.Tt				Tk							
(To accompany Thesis by J.P. Kennett)	Fossil No:	f652	f653	f654	f655	f656	f657	f658	f659	f661	f662	f663	f664	f665	f666
<i>Neouvigerina eketahuna</i> Vella		2	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>Hofkeruva rodleyi rodleyi</i> Vella		2	2	.	.	.	.	.	.	.	.	.	.	.	.
<i>paeniteres</i> Finlay		1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>lutorum</i> Vella		.	.	.	.	.	.	.	.	.	.	1	.	1	1
<i>seacuminata</i> Vella		4	4	2	.	.	.	.	.	.	1	2	1	3	3
<i>Trifarina bradyi</i> Cushman		3	4	1	.	.	.	.	.	.	1	.	.	.	.
<i>Angulogerina esuriens</i> Hornibrook		4	4	.	.	.	.	.	.	.	.	.	.	.	.
<i>Bolivina affiliata</i> Finlay		2	3	.	.	.	.	.	.	.	.	.	.	.	.
<i>albatrossi</i> Cushman		2	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>lapsus</i> Finlay		1	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>numerosa</i> Vella		1	.	.	.	.	.	.	.	.	1	.	.	1	.
<i>petiae</i> Gibson		1	1	2	.	1	.	.	.	1	1	.	.	1	.
<i>watti</i> Gibson		.	2	.	.	.	.	.	.	.	.	.	.	.	.
<i>n.sp. cf. striatula</i> Cushman		2	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Rectobolivina striatula</i> (Cushman)		.	.	.	.	.	.	.	.	.	1	.	.	.	.
Family HETEROHELICIDAE															
<i>Bolivinina pohana</i> Finlay		.	.	.	.	.	.	.	.	4	4	2	3	4	3
<i>quadrilatera</i> (Schwager)		4	4	.	.	.	.	.	.	.	.	.	.	.	.
<i>Plectofrondicularia pohana</i> Finlay		.	1	.	.	.	.	.	.	.	.	.	.	.	.
Family CASSIDULINIDAE															
<i>Cassidulina laevigata</i> d'Orbigny		1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>neocarinata</i> Thalmann		4	3	.	1	.	.	.	.	1	4	1	.	1	2
<i>subglobosa</i> Brady		.	.	2	1	1	.	.	.	.	.	.	.	.	.
<i>Cassidulinoides orientalis</i> (Cushman)		4	4	2	.	1	.	.	.	1	1	1	.	.	1
<i>Ehrenbergina willetti</i> Finlay		1	1	.	.	.	.	.	.	.	.	.	.	.	.
Family ELLIPSOIDINIDAE															
<i>Pleurostomella alternans</i> Schwager		.	1	.	.	.	.	.	.	.	.	.	.	.	.
Family CHILOSTOMELLIDAE															
<i>Chilostomella ovoidea</i> Reuss		1	.	.	.	.	.	.	.	1	2	1	.	3	1
<i>Sphaeroidina bulloides</i> d'Orbigny		4	4	1	.	.	.	.	.	2	4	1	1	3	3
<i>Pullenia quinqueloba</i> (Reuss)		1	1	.	.	.	.	.	.	1	1	1	.	.	.
<i>bulloides</i> (d'Orbigny)		.	.	.	.	.	.	.	.	.	1	.	.	.	.
Family NONIONIDAE															
<i>Nonion cf. cassidulinoides</i> Hornibrook		1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Pacinionion parki</i> (Hornibrook)		1	1	2	1	4	.	.	.	2	1	1	.	2	.
<i>neefi</i> Vella		3	1	.	.	.	.	.	.	.	.	.	.	.	.
<i>n.sp. cf. novozealandicum</i> (Cushman & Edwards)		2	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Melonis zeobesus</i> Vella		1	.	.	.	.	.	.	.	.	.	1	1	3	.
<i>Nonionella novozealandica</i> Cushman		2	2	.	.	.	.	.	.	.	.	.	.	.	.
<i>magnalingua</i> Finlay		.	.	.	.	.	.	.	.	.	.	.	.	1	.
<i>zenitens</i> Finlay		.	.	1	.	.	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;

4 = more than 20 specimens.

TABLE 7 PART 4.

CALLAGHANS CREEK SECTION.

DISTRIBUTION OF MICROFOSSILS	Stage:	L.Tt	U.Tt						Tk							
(To accompany Thesis by J.P. Kennett)	Fossil No.	f652	f653	f654	f655	f656	f657	f658	f659	f661	f662	f663	f664	f665	f666	
<i>Florilus flemingi</i> (Vella)		4	2	3	1	1	.	.	.	4	4	1	3	4	2	
<i>olsoni</i> Kennett, n.sp.		.	.	.	.	3	.	.	.	.	.	.	.	.	.	
<i>Zeafiorilus parri</i> (Cushman)		.	.	.	.	1	.	.	.	.	.	.	.	.	.	
Family DISCORBIIDAE																
<i>Patellinella inconspicua</i> (Brady)		.	.	.	.	.	.	.	.	.	1	.	.	.	.	
<i>Cavelinopsis lobatulus</i> (Parr)		2	3	3	1	1	.	.	.	1	1	1	.	.	1	
<i>Heronallenia</i> n.sp. cf. <i>translucens</i> Parr		.	1	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Gyroidina</i> n.sp. cf. <i>orbicularis</i> d'Orbigny, (compressed, numerous chambers)		4	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Gyroidinoides zelandica</i> Finlay		2	3	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Discorbis</i> cf. <i>dimidiatus</i> (Parker & Jones)		.	.	.	.	.	.	1	.	.	.	.	.	.	.	
<i>subcomplanata</i> Farr		.	.	.	.	.	.	.	.	.	.	.	.	.	1	
<i>Discorbinella rarescens</i> (Brady)		.	1	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Parvicarinina altocamerata</i> (Heron-Allen & Earland)		.	1	.	.	.	.	.	.	.	.	.	.	.	.	
Family EPISTOMINIDAE																
<i>Hoglundina elegans</i> (d'Orbigny)		1	1	.	.	.	.	.	.	.	.	.	.	.	.	
<i>Pseudosponides prominula</i> (Stache)		4	4	.	.	3	.	.	.	.	1	.	.	.	.	
<i>tenera</i> (Brady)		1	3	.	.	.	.	.	.	.	.	.	.	1	1	
<i>Siphonina australis</i> Cushman		.	1	.	.	.	.	.	.	.	.	.	.	.	.	
Family ELPHIDIIDAE																
<i>Elphidium charlottensis</i> (Vella)		.	.	.	2	3	.	.	.	1	.	.	.	.	.	
<i>Notorotalia hurupiensis</i> Vella		.	.	.	.	.	.	.	.	4	4	1	3	.	2	
<i>pliozea</i> Vella		.	.	.	1	.	.	.	.	.	.	.	.	.	.	
<i>taranakia</i> Vella		1	1	.	.	.	.	.	.	1	.	.	.	.	.	
<i>macinnesi</i> Kennett, n.sp.		.	.	3	2	4	.	.	.	.	.	.	.	.	.	
Family GLOBIGERINIDAE																
<i>Globigerina bulloides</i> d'Orbigny		1	1	.	.	.	.	.	.	.	1	1	.	.	1	
<i>autertrei</i> d'Orbigny		.	.	.	.	.	.	.	.	.	1	.	.	.	1	
cf. <i>falconensis</i> Blow		1	.	1	.	.	.	.	.	.	.	.	.	.	.	
<i>foliata</i> Bolli		1	.	.	.	.	.	.	.	.	.	.	.	.	.	
cf. <i>obesa</i> Bolli		.	1	.	.	.	.	.	.	.	.	.	.	.	.	
<i>pachyderma</i> (Ehrenberg)		.	.	1	2	1	.	.	.	1	2	1	.	1	1	
<i>parabulloides</i> Blow		1	1	2	.	.	.	.	.	1	2	.	.	.	.	
<i>praebulloides</i> Blow		3	4	1	.	1	.	.	.	1	2	2	.	1	3	
<i>quinqueloba</i> Natland		.	.	1	.	3	.	.	.	.	.	.	.	.	.	
<i>subcretacea</i> Lomnicki		1	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>woodi</i> Jenkins		1	4	1	.	1	.	.	.	2	1	.	.	1	3	
<i>Globigerinita glutinata</i> (Egger)		.	.	.	.	.	.	.	.	1	1	1	.	4	1	
<i>Orbulina suturalis</i> Bronnimann		2	.	.	.	.	.	.	.	.	.	.	.	.	.	
<i>universa</i> d'Orbigny		1	2	.	.	.	.	.	.	1	2	.	.	1	2	
<i>Globorotalia conomioessa</i> Kennett, n.sp.		.	.	.	.	.	.	.	.	1	2	.	.	2	1	
<i>menardii</i> cf. <i>miotumida</i> Jenkins		4	4	1	.	2	.	.	.	1	1	.	.	.	.	
<i>opima continosa</i> Blow		1	2	.	.	.	.	.	.	.	.	.	.	.	.	
<i>scitula</i> (Brady)		1	2	1	.	1	.	.	.	1	1	1	.	.	.	

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;
4 = more than 20 specimens.

TABLE 7 PART 5

CALLAGHANS CREEK SECTION.

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

OF MICROFOSSILS			Stage:	L.Tt	U.Tt							Tk						
(To accompany Thesis by J.P. Kennett)			Fossil No.	f652	f653	f654	f655	f656	f657	f658	f659	f661	f662	f663	f664	f665	f666	
Family ANOMALINIDAE																		
Anomalinoides parvumbilia (Finlay)				2	3	1	.	.	.	.	.	3	4	1	.	2	4	
pinguiglabra (Finlay)				.	1	.	.	.	.	.	.	.	.	.	.	.	.	
spherica (Finlay)				.	.	.	.	.	.	.	.	2	3	1	.	.	.	
Cibicides deliquatus Finlay				3	1	.	.	.	.	.	.	1	4	1	.	2	3	
gibsoni Kennett, n.sp.				.	.	.	.	.	.	.	.	1	3	.	.	1	.	
ihungia Finlay				.	1	.	.	.	.	.	.	.	.	.	.	.	.	
molestus Hornibrook				2	3	1	.	.	.	.	.	1	.	2	2	3	3	
Dycibicides biserialis Cushman & Valentine				2	3	.	.	.	.	.	.	.	.	.	.	.	.	
RADIOLARIA																		
				.	1	.	.	.	.	.	.	.	.	.	.	.	.	
SPONGE SPICULES																		
				1	.	.	.	.	.	.	.	.	.	.	.	.	.	
PELECYPODA																		
				1	.	.	.	.	.	.	.	.	.	.	.	.	.	
Cucullaea hamptoni n.sp. Marwick (in press)				.	.	.	.	.	.	.	.	3	.	2	.	.	1	
Glymeris callaghani Marwick				.	.	.	.	.	3	.	.	.	.	.	.	.	.	
Limopsis n.sp.				.	.	.	.	.	.	.	.	2	.	.	.	.	.	
Sectipecten grangei Boreham				.	.	.	.	.	1	.	.	.	.	.	.	.	.	
Sectipecten wollastoni (Finlay)				.	.	.	.	.	.	.	.	1	4	2	1	.	.	
Pleuromeris sp.				.	.	.	.	.	.	.	.	1	.	.	.	.	.	
Notocallista n.sp. aff. multistriata (Sowerby)				.	.	.	.	.	.	.	.	1	.	.	.	.	.	
Marama cf. murdochi Marwick				.	.	.	.	.	.	.	.	1	.	3	.	.	.	
Kuia cf. macdowellii Marwick				.	.	.	.	.	4	.	.	.	.	.	.	.	.	
Nemocardium quinarium Marwick				.	.	.	.	.	.	.	.	1	.	.	.	.	.	
GASTROPODA																		
Zeacolpus n.sp. (patagonica of Suter, not Sowerby)				.	.	.	.	.	.	.	.	2	.	.	.	.	.	
Sulconacca vaughani Marwick				.	.	.	.	.	.	.	.	1	.	.	.	.	.	
Polinices cf. propeovatus (Marwick)				.	.	.	.	.	.	.	.	2	.	.	.	.	.	
aff. waipipiensis (Marwick)				.	.	.	.	.	.	.	.	.	.	1	.	.	.	
Xenophalium grangei (Marwick)				.	.	.	.	.	.	.	.	1	.	.	.	.	.	
Austrofusus coerulescens (Finlay)				.	.	.	.	.	.	.	.	1	1	.	1	.	1	
Austrofusus sp.				.	.	.	.	.	1	.	.	.	.	.	.	.	.	
Alcithoe gravicostata King				.	.	.	.	.	.	.	.	1	.	1	.	.	.	
Alcithoe sp.				.	.	.	.	.	1	.	.	.	.	.	.	.	.	
Olivella neozelandica (Hutton)				.	.	.	.	.	1	.	.	1	.	.	.	.	.	
Cylichnina sp.				.	.	.	.	.	.	.	.	1	.	.	.	.	.	
SCAPHOPODA																		
Dentalium zelandicum Sowerby				.	.	.	.	.	.	.	.	2	.	2	.	.	.	
Dentalium spp.				1	.	.	.	.	1	.	.	1	1	.	.	.	.	
OSTRACODA																		
				1	1	1	.	.	.	.	.	3	2	1	1	4	3	
BARNACLES																		
				.	.	.	.	.	.	.	.	1	.	.	.	.	1	
ERYZOA																		
				.	.	.	.	.	.	.	.	2	.	.	.	.	.	
ECHINOID SPINES AND PLATES, (Spatangid)																		
				1	.	.	.	.	.	.	.	2	.	.	.	4	4	
FISH TEETH AND BONES																		
				.	.	1	3	3	.	.	.	2	.	1	.	1	1	
FISH OTOLITHS																		
				1	.	.	.	.	.	.	.	.	.	.	.	.	.	

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;
4 = more than 20 specimens.

TABLE 8 PART 1

COREHOLE D SECTION.

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

(To accompany Thesis by J.P. Kennett)	Stage:	L.Tt	U.Tt	Tk				
Family TEXTULARIIDAE	Fossil No:	f692	f694	f690	f689	f688	f687	f686
Textularia kapitea Finlay		.	.	.	1	.	.	.
subrhombica Stache		1	2	.	.	.	.	.
barnwelli Kennett n.sp.		.	.	.	.	2	3	2
miozea Finlay		1	2	.	.	.	.	.
Hauslerella morgani (Chapman)		4	4	.	1	1	4	3
Siphotextularia awamoana Finlay		1	1	.	.	.	.	.
subcylindrica Finlay		3	2	.	.	.	.	.
n.sp.cf. amaciata Hornibrook		.	1	.	.	.	.	.
n.sp. cf. wairoana Finlay		1	.	.	.	.	.	.
Family VERNEUILINIDAE								
Gaudryina kingi Parr		.	.	.	.	1	.	.
Family VALVULINIDAE								
Karrerella cylindrica Finlay		1	.	.	.	.	.	.
Martinottiella juv.		.	1	.	.	.	.	.
Family MILIOLIDAE								
Quinqueloculina contorta d'Orbigny		.	.	.	.	.	1	.
kapitiensis Vella		1	2	.	.	1	.	.
Spiroloculina canaliculata d'Orbigny		1	1	.	.	.	.	.
Pyrgo murrhyna (Schwager)		.	1	.	.	.	.	.
Family LAGENIDAE								
Rebulus antipodus (Stache)		.	1	.	.	.	.	.
Arcuato-striatus (Hantken) var. carolinianus Cushman		.	1	.	.	.	.	.
calcar (Linnaeus)		2	1	.	2	2	4	1
gyroscaprus (Stache)		.	1	.	.	.	.	.
cf. iotus Cushman		.	1	.	.	.	.	.
loculosus (Stache)		1	.	.	1	.	.	.
orbicularis (d'Orbigny)		1	.	.	.	.	.	.
cf. pliocaenicus (Silvestri)		.	.	.	.	.	1	.
suborbicularis Parr		.	1	.	.	.	.	.
subalata Reuss		1	.	.	.	.	.	.
Lenticulina peregrina (Schwager)		2	1	.	.	.	.	.
Saracenaria latifrons (Brady)		1	1	.	.	.	.	.
Vaginulina elegans d'Orbigny		1	1	.	.	.	.	.
Marginulina duracina Stache		1	1	.	.	.	.	.
cf. obesa (Cushman)		.	1	.	.	.	.	.
Dentalina californica Cushman & Gray		1	1	.	.	.	.	.
communis d'Orbigny		2	2	.	.	.	.	.
decepta (Bagg)		.	1	.	.	.	.	.
filiformis (d'Orbigny)		1	.	.	.	.	.	.
soluta Reuss		1	1	.	.	.	.	.
subsoluta (Cushman)		.	1	.	.	.	.	.
cf. californica (Cushman & Gray)		.	1	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens;

TABLE 8 PART 2

COREHOLE D SECTION

DISTRIBUTION OF MICROFOSSILS	Stage:	L.Tt	U.Tt	Tk
(To accompany Thesis by J.P. Kennett)	Fossil No.	f692 f691	f690 f689	f688 f687 f686
<i>Nodosaria hochstetteri</i> Schwager		1 .	. .	. . .
<i>pyrula</i> (d'Orbigny)		1 2	. .	. . .
<i>vertebralis</i> (Batsch)		1 1	. .	. . .
<i>longiscata</i> d'Orbigny		1 .	. .	. . .
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)		3 2	. .	. 3 2
<i>scalaris</i> (Batsch)		. 1	. .	. . .
<i>sp.</i> , (smooth)		. .	. .	1 1 2
<i>Stilostomella antillea</i> (Cushman)		1 1	. .	. . .
<i>antipeda</i> (Stache)		3 4	. .	. . .
<i>Lagena distoma</i> Parker & Jones		1 1	. .	. . .
<i>cf. gracilis</i> Williamson		. 1	. .	. . .
<i>gracillima</i> (Sequenza)		. 1	. .	. . .
<i>laevis</i> (Montagu)		1 1	. .	. 1 .
<i>aff. pliocenica</i> Cushman & Gray		1 1	. .	. . .
<i>striata</i> (d'Orbigny)		1 1	. .	1 2 .
<i>sulcata</i> (Walker & Jacob)		1 1	. .	. . .
<i>williamsoni</i> (Adcock)		. 1	. .	. . .
<i>Gelina hexagona</i> (Williamson)		1 2	. .	1 1 .
<i>melo</i> d'Orbigny		1 1	. .	. . .
<i>squamosa</i> (Montagu)		. 1	. .	. . .
<i>Fissurina kerguelensis</i> Parr		. 1	. .	. . .
<i>marginata</i> (Walker & Boys)		. 2	. .	. . .
<i>submarginata</i> (Boogaart)		. 1	. .	. . .
<i>Parafissurina orbignyana</i> (Sequenza)		. 1	. .	. 1 .
<i>Parafrendicularia wairarapa</i> Vella		1 .	. .	. . .
<i>Proxifrons advena</i> (Cushman)		2 1	. .	. . .
<i>Amhea sinalata</i> (Finlay)		1 .	. .	. . .
Family BULIMINIDAE				
<i>Bulimina aculeata</i> d'Orbigny		. .	. .	4 4 2
<i>striata</i> , (large var.)		2 3	. .	. . .
<i>vallai</i> Gibson		2 3	. .	. . .
<i>Virgulina bradyi</i> Cushman		1 1	. .	. . .
<i>bramlettei</i> Galloway & Morrey		. 1	. .	. . .
<i>vallai</i> Kennett, n. sp.		. 1	. .	. . .
<i>Neouvigerina eketahuna</i> Vella		2 3	. .	. . .
<i>vadescens</i> (Cushman)		1 1	. .	. . .
<i>Hofkeruva lutorum</i> Vella		3 4	. .	. 1 1
<i>zeacuminata</i> Vella		1 1	. .	1 4 2
<i>Trifarina bradyi</i> Cushman		2 3	. .	. . .
<i>Bolivina affiliata</i> Finlay		2 3	. .	. . .
<i>albatrossi</i> Cushman		2 3	. .	. . .
<i>lapsus</i> Finlay		2 2	1 .	. . .
<i>numerosa</i> Vella		2 2	. .	. . .

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 8 PART 3

CORREOLE D SECTION

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.F. Kennett)

Stage:	L.Tt		U.Tt		Tk	
Fossil No.	f692	f691	f690	f689	f688	f687
<i>Bolivina petiae</i> Gibson	2	2	.	.	2	.
<i>watti</i> Gibson	1	2	.	.	.	.
n.sp. cf. <i>mitcheli</i> Gibson	.	1	.	.	.	.
<i>Rectobolovina maoria</i> Finlay	1	.	.	.	.	.
<i>striatula</i> (Cushman)	.	.	.	.	.	1
<i>Robertinoides</i> cf. <i>pukeuriensis</i> (Hornibrook)	.	1	.	.	.	.
Family HETEROCHELICIDAE						
<i>Bolivinita pohana</i> Finlay	.	.	.	.	2	1
<i>quadrilatera</i> (Schwager)	4	4	.	.	.	.
<i>Plectofrondicularia pohana</i> Finlay	.	1	.	.	.	.
Family CASSIDULINIDAE						
<i>Cassidulina laevigata</i> d'Orbigny	1	2	.	.	.	.
<i>neocarinata</i> Thalmann	1	3	.	.	1	1
<i>Cassidulinoides orientalis</i> (Cushman)	2	2	.	1	2	2
<i>Ehrenbergina willetti</i> Finlay	2	1	.	.	.	.
Family CHILOSTOMELLIDAE						
<i>Chilostomella ovoides</i> Reuss	.	1	.	.	.	.
<i>Sphaeroidina bulloides</i> d'Orbigny	2	3	.	.	.	1
<i>Pullenia bulloides</i> (d'Orbigny)	1	1	.	.	.	.
<i>quingueloba</i> (Reuss)	1	1	.	.	.	.
Family NONIONIDAE						
<i>Pacilonion parki</i> (Hornibrook)	4	4	.	3	3	4
<i>Melonis zeobesus</i> Vella	.	.	.	1	.	1
<i>Florilus flemingi</i> (Vella)	2	2	.	2	3	4
<i>Nonionella magnalingua</i> Finlay	1	1	.	.	.	.
Family DISCORBIIDAE						
<i>Gavelinopsis lobatulus</i> (Parr)	1	2	1	1	3	1
<i>Discopulvinula</i> sp.	.	1	.	.	.	.
<i>Eponides broeckhianus</i> (Karrer)	1	2	.	.	.	.
<i>Gyroidina</i> n.sp. cf. <i>orbicularis</i> (d'Orbigny)	3	3	.	.	.	.
<i>Parvicarinina altocamerata</i> (Heron-Allen & Earland)	1	1	.	.	.	.
<i>Gyroidinoides zelandica</i> (Finlay)	2	4	.	.	.	.
<i>Laticarinina pauperata</i> (Parker & Jones)	2	2	.	.	.	.
Family EPISTOMINIDAE						
<i>Hoglundina elegans</i> (d'Orbigny)	1	1	.	.	.	.
<i>Pseudopponides promimula</i> (Stache)	2	.	.	.	.	1
<i>Pseudopponides tensa</i> (Brady)	1	.	.	.	.	1
Family ROTALIIDAE						
<i>Ammonia aoteanus</i> (Finlay)	.	.	.	.	.	1
Family ELPHIDIIDAE						
<i>Notorotalia hurupiensis</i> Vella	2	3	.	.	4	4
<i>macinnesi</i> Kennett, n.sp.	.	.	3	4	.	.
aff. <i>taranakia</i> Vella (reticulated ornament)	.	.	.	.	.	1
<i>Elphidium charlottensis</i> (Vella)	2	1	.	1	2	1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 8 PART 4

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Stage:	L.Tt		U.Tt		Tk	
	2692	2691	2690	2689	2688	2687
Fossil No.	2692	2691	2690	2689	2688	2687
Family GLOBIGERINIDAE						
<i>Globigerina bulloides</i> d'Orbigny	2	4	.	.	2	.
<i>duertrei</i> (d'Orbigny)	.	.	.	.	1	1
<i>pachyderma</i> (Ehrenberg)	.	.	.	.	2	4
<i>praebulloides</i> Blow	.	.	.	.	1	4
<i>subretacea</i> Lomnicki	2	4	.	.	.	.
<i>woodi</i> Jenkins	1	1	.	.	.	.
<i>Globigerinita uvula</i> (Ehrenberg)	1	3	.	.	.	.
<i>aff. uvula</i> (Ehrenberg)	.	.	.	.	.	1
<i>Orbulina universa</i> d'Orbigny	2	2	.	.	1	1
<i>Globoquadrina altispira globosa</i> Balli	.	.	.	.	.	1
<i>dehiscens</i> (Chapman, Parr & Collins)	.	.	1	.	.	.
<i>Globorotalia miozea</i> Finlay	2	4	.	.	.	.
<i>opima continua</i> Blow	1	.	.	.	.	.
<i>scitula</i> (Brady)	.	2	.	.	.	.
<i>conomiozea</i> Kennett, n.sp.	.	.	.	.	2	4
Family ANOMALINIDAE						
<i>Anomalinoidea parvumbilia</i> (Finlay)	.	2	2	1	1	3
<i>spherica</i> (Finlay)	.	.	.	.	1	1
<i>Cibicides deliquatus</i> Finlay	.	2	3	2	.	3
<i>gibsoni</i> Kennett, n.sp.	.	.	.	.	.	1
<i>ihungia</i> Finlay	2	3	.	.	.	.
<i>mediocris</i> Finlay	2	3	.	.	.	.
<i>molestus</i> Hornibrook	2	3	.	1	2	.
<i>Dycibicides biserialis</i> Cushman & Valentine	2	2	.	.	.	.
PELECYPOD FRAGMENTS	1	4	.	3	1	4
GASTROPODA	.	.	.	.	1	.
SCAPHOPODA	.	.	.	.	.	1
OSTRACODA	.	.	.	.	3	3
ECHINOID SPINES AND PLATES, (Spatangia)	.	.	.	.	3	3
FISH TEETH	.	1	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
 3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 9 PART 1

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Family TEXTULARIIDAE

Stage:

Tk

Wo

Fossil No.

Textularia barmwelli Kennett, n. sp.

kapitea Finlay

Haeusalerella finlayi Vella

morgani (Chapman)

Siphotextularia wairoana Finlay

Family MILIOLIDAE

Quinqueloculina triangularis d'Orbigny

waimea Kennett, n. sp.

pygmaea Reuss

Pyrge elongata (d'Orbigny)

Family LAGENIDAE

Robulus calcar (Linneaus)

cultratus Montfort

loculosus (Stache)

gyroscalprus (Stache)

Vaginulina elegans d'Orbigny

vagina (Stache)

Dentalina communis d'Orbigny

guttifera (d'Orbigny)

Nodosaria lamulifera Boomgaart

longiscata d'Orbigny

Lagenonodosaria hirsuta (d'Orbigny)

sp., (smooth)

Rectoglandulina torrida (Cushman)*Lagena laevis* (Montagu)

striata (d'Orbigny)

sulcata (Walker & Jacob)

Oolina globosa (Montagu)

hexagona (Williamson)

Fissurina marginata (Walker & Boys)

submarginata (Boomgaart)

Family POLYMORPHINIDAE

Glandulina symmetrica Stache

Family BULIMINIDAE

Bulimina aculeata d'Orbigny

inflata Sequenza

cf. striata d'Orbigny, (small var.)

Virgulina vella Kennett, n. sp.*Hofkeruva zeacuminata* Vella

lutorum Vella

Bolivina acerosa Cushman

affiliata Finlay

lapsus Finlay

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens; 4 = more than 20 spe

TABLE 9 PART 2

CORNHOLE F SECTION

DISTRIBUTION OF MICROFOSSILS	Stage:	Tk																No					
(To accompany Thesis by J.P. Kennett)	Fossil No.	f685	f684	f683	f682	f681	f680	f679	f678	f677	f676	f675	f674	f673	f672	f671	f670	f669	f668	f667			
<i>Bolivina numerosa</i> Vella		1	.	1	.	.	1	1	1	1	1	.	1	1	1	.	.	1	.	.	.	.	.
<i>petiae</i> Gibson		.	2	.	2	1	2	1	2	3	1	4	3	2	1	1	.	1	1	2	1	.	.
<i>Rectobolivina striatula</i> (Cushman)		2	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Family HETEROCHELICIDAE																							
<i>Bolivinita pliozea</i> Finlay		.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	4	4	3	1	.	.
<i>pohana</i> Finlay		2	1	3	3	3	4	3	4	4	4	4	4	4	4	.	.	.	.	.	.	.	.
Family CASSIDULINIDAE																							
<i>Cassidulina neocarinata</i> Thalmann		.	.	.	1	1	.	1	2	1	.	2	1	.	1	.	.	2	1	2	.	.	.
<i>subglobosa</i> Brady		.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
<i>Cassidulinoides orientalis</i> (Cushman)		2	1	.	2	2	2	.	1	1	2	1	2	1	3	1	2	1	.	1	.	.	.
Family CHILOSTOMELLIDAE																							
<i>Chilostomella ovoides</i> Reuss		.	.	.	1	.	.	1	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.
<i>Sphaeroidina bulloides</i> d'Orbigny		2	1	1	3	2	2	.	1	2	2	1	.	1	2	.	.	.	1	1	.	.	.
<i>Pullenia bulloides</i> (d'Orbigny)		.	.	.	.	.	.	1	1	1	.	.	.	.	1	.	.	.	.	.	.	.	.
<i>quinqueloba</i> (Reuss)		.	.	.	.	.	.	1	.	.	.	.	1	.	1	1	.	1	.	.	.	.	.
Family NONIONIDAE																							
<i>Pacinnion parki</i> (Hornibrook)		2	3	3	2	2	3	3	3	4	3	4	4	3	3	2	1	3	2	2	1	.	.
<i>Melonis zeobesius</i> Vella		2	.	.	3	1	1	1	1	1	1	.	.	.	.	.	1	.	.	.	.	.	.
<i>Nonionella magnalingua</i> Finlay		.	1	.	2	.	.	1	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.
<i>zenitens</i> Finlay		.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Florilus flamingi</i> (Vella)		1	3	3	2	1	1	3	2	2	.	2	2	3	3	1	1	2	1	3	1	.	.
<i>Zeafloerilus parri</i> (Finlay)		.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family DISCORBIIDAE																							
<i>Gavelinopsis lobatulus</i> (Parr)		3	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	2	1	.	.
<i>Discopulvinulina berthelotti</i> (d'Orbigny)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
<i>Eponides broeckhianus</i> (Karrer)		.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	1	1	.	1	.	.	.
Family EPISTOMINIDAE																							
<i>Hoglundina elegans</i> (d'Orbigny)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.
<i>Pseudoeponides prominula</i> (Stache)		.	.	.	2	1	.	1	1	1	1	.	.	1	1	.	.	1	.	.	.	.	.
<i>tenera</i> (Brady)		.	.	2	1	.	.	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Family ELPHIDIIDAE																							
<i>Notorotalia hurupiensis</i> Vella		.	3	3	3	3	4	3	3	3	4	4	4	4	4	3	3	4	4	4	1	.	.
<i>Elphidium charlottensis</i> (Vella)		.	2	1	.	.	1	.	.	1	1	1	.	3	3	1	1	.	.	.	.	.	.
Family GLOBIGERINIDAE																							
<i>Globigerina bulloides</i> d'Orbigny		.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	2	.	.	.	.	.
<i>duertrei</i> d'Orbigny		1	.	1	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.
<i>pachyderma</i> (Ehrenberg)		2	2	2	1	.	.	.	2	1	1	1	.	.	4	1	.	.	2	1	.	.	.
<i>parabulloides</i> Blow		2	.	.	.	.	1	1	.	1	1	1	3	.	.	1	1	2	1	1	.	.	.
<i>praebulloides</i> Blow		2	.	2	3	2	3	4	.	1	3	.	.	4	.	.	1	1	.	.	.	.	.
<i>quinqueloba</i> Natland		.	.	.	.	.	.	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.
<i>woodi</i> Jenkins		.	.	.	.	1	.	.	1	.	.	.	1	.	.	.	.	1	.	.	.	.	.
<i>zealandica</i> Hornibrook		.	.	.	.	1	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.
<i>Globigerinita uvula</i> (Ehrenberg)		.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
<i>Orbulina universa</i> d'Orbigny		1	2	.	1	1	.	2	1	.	.	.	.	.	1	1	.	1	.	.	.	.	.
<i>Globoquadrina altispira globosa</i> Bolli		.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
<i>Globorotalia conomiozea</i> Kennett, n.sp.		1	1	2	3	2	3	3	4	3	2	3	2	4	4	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens; 4 = more than 20 specimens.

EIGHT MILE CREEK SECTION

TABLE 10 PART 1

DISTRIBUTION
OF MICROFOSSILS

(To accompany Thesis by J.P. Kennett)	Stage:	Sw	U.Tt	Tk	Wo	Ww
Family TEXTULARIIDAE	Fossil No.	f696	f697	f698	f699	f700
<i>Textularia miozea</i> Finlay		4	.	.	.	.
<i>cf. ototara</i> Hornibrook		1	.	.	.	.
<i>Haeslerella morgani</i> (Chapman)		4	1	4	4	1
<i>Siphotextularia ihungia</i> Finlay		1	.	.	.	.
<i>subcylindrica</i> Finlay		1	.	.	.	.
<i>wairoana</i> Finlay		.	.	.	4	.
<i>n. sp. cf. wairoana</i> Finlay		1	.	.	.	.
<i>Vulvulina pennatula</i> (Batsch)		3	.	.	.	.
Family VERNEUILINIDAE						
<i>Gaudryina kingi</i> Parr		1	.	.	.	.
Family VALVULINIDAE						
<i>Martinottiella clarae</i> Gibson		1	.	.	.	.
Family MILIOLIDAE						
<i>Quinqueloculina kapitensis</i> Vella		1	.	.	.	.
<i>suborbicularis</i> d'Orbigny		1	.	.	.	.
<i>Spiroloculina canaliculata</i> d'Orbigny		1	.	.	.	.
<i>novozealandica</i> Cushman & Todd		1	.	.	.	.
Family LAGENIDAE						
<i>Robulus calcar</i> (Linnaeus)		4	2	.	2	1
<i>dicampylus</i> (Franzenau)		1	.	.	.	.
<i>iotus</i> Cushman		1	.	.	.	.
<i>spp.</i>		1	.	.	.	.
<i>Saracenaria italica</i> DeFrance		1	.	.	.	.
<i>latifrons</i> (Brady)		.	.	.	1	.
<i>Vaginulinopsis cliffdenensis</i> Hornibrook		2	.	.	.	.
<i>Vaginulina elegans</i> d'Orbigny		1	.	.	1	.
<i>elegans</i> d'Orbigny, <i>costate</i> var.		1	.	.	.	.
<i>Marginulina duracina</i> Stache		.	1	.	.	.
<i>obesa</i> Cushman		1	.	.	.	.
<i>Dentalina soluta</i> Reuss		1	.	.	.	.
<i>Nodosaria lamulifera</i> Boonagaart		.	.	.	1	.
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)		4	.	.	1	2
<i>pauciloculata</i> (Cushman)		1	.	.	.	.
<i>sp., (smooth)</i>		.	.	.	.	1
<i>Stilostomella antipoda</i> (Stache)		.	1	.	.	.
<i>verneuilii</i> (d'Orbigny)		2	.	.	.	.
<i>Rectoglandulina aperta</i> (Stache)		1	.	.	.	.
<i>Lagena distoma</i> Parker & Jones		1	.	.	.	.
<i>striata</i> (d'Orbigny)		1	1	.	1	.
<i>sulcata</i> (Walker & Jacob)		1	1	.	.	.
<i>Colina hexagona</i> (Williamson)		1	.	.	.	1
<i>Fissurina bicarinata</i> Terquem		1	.	.	.	.
<i>submarginata</i> (Boonagaart)		.	.	.	.	1
Family BULIMINIDAE						
<i>Buliminella missilis</i> Vella		2	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens;
4 = more than 20 specimens.

TABLE 10 PART 2

EIGHT MILE CREEK SECTION.

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Range:	Sw	U.Tt	Tk	Wo	Ww
Fossil No.	f696	f697	f698	f699	f700
<i>Bulimina aculeata</i> d'Orbigny	.	.	.	.	1 4
cf. <i>striata</i> d'Orbigny, (large var.)	2	.	.	.	.
<i>Hofkeruva lutorum</i> Vella	.	.	.	4	.
rodleyi rodleyi Vella	.	4	.	.	.
zeacuminata Vella	4	2	1	.	.
<i>Rectuvigerina vesca</i> (Finlay)	1	.	.	.	.
<i>Trifarina bradyi</i> Cushman	2	2	.	.	.
<i>Bolivina lapsus</i> Finlay	4	.	.	.	.
numerosa Vella	.	1	.	1	1
petiae Gibson	4	3	2	.	4
sedirector Finlay	1	.	.	.	.
sp., (pores along sutures)	2	.	.	.	.
<i>Loxostomum truncatum</i> Finlay	4	.	.	.	.
<i>Rectobolivina maoria</i> Finlay	4	1	.	.	.
striatula (Cushman)	.	.	.	.	1
Family HETEROHELICIDAE					
<i>Bolivinita pliozea</i> Finlay	.	.	.	4	1
pohana Finlay	.	.	3	.	.
Family CASSIDULINIDAE					
<i>Cassidulina neocarinata</i> Thalmann	1	.	.	1	4
subglobosa Brady	.	.	.	1	1
<i>Cassidulinoides orientalis</i> (Cushman)	2	2	1	.	1
Family CHILOSTOMELLIDAE					
<i>Sphaeroidina bulloides</i> d'Orbigny	1	.	.	1	1
<i>Pullenia bulloides</i> (d'Orbigny)	1	.	.	1	.
quinqueloba (Reuss)	.	.	.	1	.
Family NONIONIDAE					
<i>Astrononion vadorum</i> Vella	.	1	.	.	.
<i>Pacinnonion novozelandicum</i> (Cushman & Edwards)	.	.	.	.	4 4
parki (Hornibrook)	3	2	1	.	4 4
<i>Melonis zeobesius</i> Vella	.	2	.	1	.
<i>Florilus flemingi</i> (Vella)	.	4	3	1	4 4
<i>Zeafloerilus parri</i> (Cushman)	.	.	.	.	4 4
Family DISCORBIIDAE					
<i>Gavelinopsis lobatulus</i> (Parr)	.	.	.	1	.
<i>Discopulvulina bertheletti</i> (d'Orbigny)	1	.	.	2	.
<i>Eponides broeckhianus</i> (Karrer)	.	1	.	.	.
<i>Gyroidinoides zelandica</i> (Finlay)	4	.	.	.	1
<i>Discorbinella</i> aff. <i>rarefens</i> (Brady)	.	1	.	.	.
cf. <i>rarefens</i> (Brady)	.	1	.	.	.
<i>Leticarinina pauperata</i> (Parker & Jones)	1	.	.	.	.
<i>Baggina ampla</i> (Finlay)	1	.	.	.	.
Family EPISTOMINIDAE					
<i>Hoglundina elegans</i> (d'Orbigny)	1	.	.	1	.
<i>Pseudoeponides prominula</i> (Stache)	.	1	.	.	.
tenera (Brady)	1	.	.	1	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens; 3 = 10 to 20 specimens; 4 = more than 20 specimens;

TABLE 10 PART 3

EIGHT MILE CREEK SECTION

DISTRIBUTION
OF MICROFOSSILS(To accompany Thesis
by J.P. Kennett)

Stage:	Sw	U.Tt	Tk	Wo	Ww
Fossil No.	f696	f697	f698	f699	f700
<i>Alabamina tenuimarginata</i> (Chapman, Parr & Collins)	1	.	.	.	.
Family ELPHIDIIDAE					
<i>Elphidium charlottensis</i> (Vella)	1	.	4	.	1
<i>oceanicum</i> Cushman	.	1	.	.	.
<i>Notorotalia finlayi</i> Vella	.	.	.	.	4
<i>hurupiensis</i> Vella	.	.	.	3	.
<i>kingmai</i> Vella	.	.	.	4	.
<i>macinnesi</i> Kennett, n.sp.	.	3	4	.	.
<i>pliozea</i> Vella	.	.	.	.	1
aff. <i>taranakia</i> Vella, (reticulate ornament)	.	.	.	.	1
n. sp., (biconvex, reticulate ornament)	4	.	.	.	.
Family GLOBIGERINIDAE					
<i>Globigerina</i> cf. <i>falconensis</i> Blow	.	1	.	1	.
<i>pachyderma</i> (Ehrenberg)	.	.	.	1	.
<i>praebulloides</i> Blow	.	1	.	2	1
<i>quinteloba</i> Natland	.	.	.	1	.
<i>woodi</i> Jenkins	.	3	.	.	1
<i>zealandica</i> Hornibrook	.	.	.	1	.
spp.	.	.	.	.	1
<i>Orbulina universa</i> d'Orbigny	2	.	.	1	.
<i>Globorotalia conomiozea</i> Kennett, n.sp.	.	.	.	1	.
<i>crassaformis</i> (Galloway & Wissler)	.	.	.	3	1
<i>mayeri</i> Cushman & Ellis	3	.	.	.	.
<i>menardii</i> panda Jenkins	2	.	.	.	.
<i>miozea</i> Finlay	2	.	.	.	.
Family ANOMALINIDAE					
<i>Anomalinoides parvumbilia</i> (Finlay)	3	1	.	2	2
<i>spherica</i> (Finlay)	3	2	.	.	1
<i>subnonionoides</i> (Finlay)	4	.	.	.	.
<i>Cibicides deliquatus</i> Finlay	2	.	.	2	2
<i>mediocris</i> Finlay	.	4	.	.	.
<i>molestus</i> Hornibrook	2	3	.	2	.
<i>pseudoungerianus</i> (Cushman)	2	.	.	.	.
<i>gibsoni</i> Kennett, n.sp.	4	1	.	1	.
sp.	.	1	.	.	.
spp.	1	.	.	.	.
<i>Dyocibicides biserialis</i> Cushman & Valentine	1	.	.	.	.
Family AMPHISTEGINIDAE					
<i>Amphistegina</i> sp.	1	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

RIGHT MILE CREEK SECTION

TABLE 10 PART 4

DISTRIBUTION
OF MICROFOSSILS

(To accompany Thesis by J.P. Kennett)	Stage:	Sw	U.Tt	Tk	Wo	Ww
	Fossil No.	f696	f697	f698	f699	f700
OSTRACODA		1	.	.	.	.
FISH TEETH		.	.	4	3	4
PELECYPODA		.	.	1	.	.
<i>Macomona</i> n.sp. cf. <i>liliana</i> (Iredale)		.	.	1	.	.
<i>Maorimacra chrydaca</i> (Suter)		.	.	.	.	4
<i>Zenatia acinaces</i> (Quoy & Gaimard)		.	.	1	.	.
<i>Dosinia cotti</i> Marwick		.	.	3	.	.
<i>Kuia</i> cf. <i>macdowelli</i> Marwick		.	.	4	.	.
<i>Panopea</i> cf. <i>zelandica</i> Quoy & Gaimard		.	.	1	.	.
GASTROPODA						
<i>Struthiolaria</i> cf. <i>praenuntia</i> Marwick		.	.	3	.	.
<i>Struthiolaria</i> (<i>Callosaria</i>) <i>callosa</i> Marwick		.	.	1	.	.
<i>Penion</i> sp.		.	.	1	.	.
<i>Buccinulum</i> n.sp.		.	.	1	.	.
<i>Austrofusus elifdenensis</i> Marwick		.	.	1	.	.
<i>marwicki</i> King		.	.	2	.	.
<i>Cominella hendersoni</i> Marwick		.	.	1	.	.
<i>Baryspira</i> cf. <i>subhebra</i> (Marwick)		.	.	3	.	.
<i>Zeacuminata</i> sp.		.	.	1	.	.
SCAPHOPODA						
<i>Dentalium solidum</i> Hutton		.	.	3	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens;

TABLE 11, PART 1.

BLIND RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt	U.Tt	Tk	Wo
(To accompany Thesis by J.P. Kennett)		Fossil No.	f603 f618	f635 f636 f637 f638 f639 f640	f641 f642 f643 f644 f645	f646 f647 f648 f649 f650 f651 f652 f653 f654 f655
FORAMINIFERA						
Family SACCAMMINIDAE						
Family REOPHACIDAE						
Reophax scorpiurus Montfort				1	1	
Family AMMODISCIDAE						
Ammodiscus finlayi Parr			2	1 1		
Family LITUOLIDAE						
Haplophragmoides subglobosus (Sars)			1	1 1	1	1
Family TEXTULARIIDAE						
Textularia barnwelli Kennett						1 1 4 . 1 1 . . 1 .
X	X miozea Finlay		4 .			
X	subrhombica Stache		2 1 1 (		2 1 3 (	
	cf. subrhombica Stache			1		
Haeslerella finlayi Vella			. 3	2 1 3 2 2 .	2 . 4 2 2 .	4 . 1
morgani (Chapman)			1 4	4 4 4 4 3 4	4 4 4 4 4 .	4 4 4 4 3 4 4 4 .
parri Finlay			4 4 (	. 1 . 1 4 .	2 2 3 . 4 (	. 2 . . 2
pliocenica (Finlay)					3	. . . 1 1 4 4 4 2 4 2
Siphotextularia awamoana Finlay			3 (1	1 . 1 (		
subcylindrica Finlay			. 4	2 (1 (		
wairoana Finlay						. . . 3 1 1 . 4 1 1 .
n.sp. cf. wairoana Finlay				 2 .	. 1 3 2 4 (	1
ihungia Finlay			. 1	1		
Family VERNEUILINIDAE						
Gaudryina kingi Parr			. 1	1 1 (	 1	
Migros medwayensis (Parr)				1		
Family VALVULINIDAE						
Vulvulina pennatula (Batsch)			. 1			
Karrerella bradyi (Cushman)			. 4	. . . 2 1 .		
cylindrica Finlay			. 4	4 4 4 4 4 3 (	. 4 . 3 .	 4
Arenodosaria sp.			. 1			
Martinottiella clarae Gibson			1 1	3 1 2 2 1 1	. 2 4 4 4 2 .	4 . . 1 1 . 1 4 1
massami Gibson			. 1			
Family LITUOLIDAE						
Cyclammina medwayensis Parr			. 1	. 1 1 . . .	. . 1 . . .	. 1
Family OPTHALMIDIIDAE						
Cornuspira cf. corticata Chapman & Parr					1 . 1	
involvens (Reuss)					1 1	 1
Family MILIOLIDAE						
Sigmoilina obesa Heron-Allen & Earland					1	
Sigmoilopsis gavini Gibson			. 1	1 . . 1 . .	. 1 . . .	
schlumbergeri (Silvestri)			. 4	2 3 3 (		
zeaserus Vella					1 2 1 4	. . . 1 1 . . .
Scutuleris hornibrooki (Vella)				1		
Quinqueloculina delicatula Vella			1 .	1 1 . 1 . .	. . 4 3 1 .	. . . 1 1 4 . .
lamarekiana d'Orbigny			. .	1 2 . 3 . .	. . 1 1 . 2 1 1 1 .	. 3
suborbicularis d'Orbigny				1	. 1	
waimoa Kennett						. . . 1 . . .
n.sp., (a)					1	
n.sp., (b)				. 1		
Spiroloculina canaliculata d'Orbigny				. . . 1		
cf. disparilis Terquem						. . . 1 . . .
kennetti Gibson			. 1	2		
Triloculina cf. angustecoralis (Wiesner)						. . . 1 . . .

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

BLIND RIVER SECTION

DISTRIBUTION
OF MICROFOSSILS
(To accompany Thesis
by J.P. Kennett)

Stage:

M.Tt

U.Tt

Tk

Wo

Fossil No.

f603

f618

f635

f636

f637

f638

f639

f640

f641

f642

f643

f644

f645

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f656

Biloculina anomala Schlumberger
cf. *bradyi* Fornasini
guerreri Silvestri
magnacaudata (Smith)
pisum Schlumberger
sp.

Pyrgo depressa (d'Orbigny)
tasmanensis Vella

Family LAGENIDAE

Robulus calcar (Linnaeus)
costatus (Fichtel & Moll)
cultratus Montfort
cf. *cultratus* Montfort
dicampylus (Franzenau)
gyroscapulus (Stache)
lotus Cushman
loculosus (Stache)

Lenticulina gibba (d'Orbigny)
perigrina (Schwager)

Saracenaria ampla Cushman & Todd
italica DeFrance
latifrons (Brady)

Vaginulina elegans d'Orbigny
vagina (Stache)
sp.

Marginulina glabra d'Orbigny

Dentalina emaciata Reuss
filiformis (d'Orbigny)
soluta Reuss
subsoluta (Cushman)
substrigata Stache

Nodosaria hochstetteri Schwager
holoserica Schwager
lammulifera Boonstra
longiscata d'Orbigny
longiscata d'Orbigny, var.
spp.

Lagenonodosaria hirsuta (d'Orbigny)
scalaris (Batsch)
sp. (smooth)

Chrysologonium verticale (Stache)

Stilostomella antipoda (Stache)
globulifera (Kreuz)
sp.

Rectoglandulina cf. *aperta* (Stache)
cf. *rotundata* (Reuss)
torrida (Cushman)

Lagena cf. *amphora* Reuss

crenata Parker & Jones
distoma Parker & Jones
elongata (Kehrenberg)
hispidula Reuss
hispidula Cushman
laevis (Montagu)
striata (d'Orbigny)
sulcata (Walker & Jacob)

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 11, PART 3.

BLIND RIVER SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	M.Tt	U.Tt	Tk	Wo
	Fossil No.		f603 f618	f635 f636 f637 f638 f639 f640	f641 f642 f643 f644 f645	f646 f647 f648 f649 f650 f651 f652 f653 f654 f655 f656
<i>Oolina apiculata</i> Reuss			1			
<i>globosa</i> (Montagu)				1		
<i>hexagona</i> (Williamson)			1	1	1	1
<i>melo d'Orbigny</i>			1			
<i>Fissurina kerguelensis</i> Parr						
<i>marginata</i> (Walker & Boys)			1	2	1	1
<i>orbignyana</i> (Sequenza)			1	1		
<i>submarginata</i> (Boongaart)				1	2	1
<i>tricaudata</i> Silvestri				1	1	1
<i>Parafrondicularia awamoana</i> (Finlay)			1			1
<i>cf. awamoana</i> (Finlay)			1	1		
<i>pellucida</i> (Finlay)			1		4	1 1 3 2 1 3 1
<i>wairarapa</i> Vella			1	1	1	2 1 3
<i>aff. wairarapa</i> Vella				4	1	1
<i>Proxifrons advena</i> (Cushman)			1	1	4	1 4 1 1 1 1 1 1
<i>Awhea sinclata</i> (Finlay)				4	4	2 1 1 1 1 1 1
<i>subtetragona</i> (Finlay)				1	1	1
Family BULIMINIDAE						
<i>Buliminella elegantissima</i> (d'Orbigny)			1			
<i>Bulimina aculeata</i> d'Orbigny			1	3	2 2 4 4 4 4 4	1
<i>inflata</i> Sequenza				2	3 1	1
<i>pupoides</i> d'Orbigny				2	3 1	1
<i>pyrula</i> d'Orbigny			1	1	1	
<i>pyrula</i> d'Orbigny, var. <i>spinescens</i> Brady			1	1	1	
<i>santa</i> Finlay			1			
<i>cf. striata</i> d'Orbigny, (small var.)				3	4 4 4 1 4 1 1 2 1 4 4	
<i>cf. striata</i> d'Orbigny, (large var.)			1	4	2	1
<i>cf. striata</i> d'Orbigny, var. <i>mexicana</i> Cushman			1	1		
<i>vellai</i> Gibson			1			
<i>Globobulimina pacifica</i> Cushman				1	1	1
<i>perversa</i> (Cushman)				1	2	
<i>Virgulina bradyi</i> Cushman			1	1		
<i>rotundata</i> Parr			1	3	1	1
<i>schreibersiana</i> Czjzek			3	1	1	
<i>vellai</i> Kennett			1	1	1 3 1 1 4	3 4 4 4 4 1 4 2 1 1
<i>Neouvigerina sketshuna</i> Vella			4	4	4	
<i>vadescens</i> (Cushman)			3	2	4 4 1	1 4 4 4 3 1 1 2 1 3
<i>Hofkeruva lutorum</i> Vella			2	4	4 4 4 4	4 4 4 4 4 4 4 4 4 4
<i>paeniteres</i> (Finlay)				1		
<i>pliozea</i> Vella						4
<i>zeacuminata</i> Vella			4	1	4 4 4	
<i>zelamina</i> Vella						4
<i>rodleyi</i> rodleyi Vella			4			
<i>Norcottia micindex</i> (Finlay)			4	1		
<i>cf. micindex</i> (Finlay)				1		
<i>Trifarina bradyi</i> Cushman			1	4	2	2 1 2 4
<i>Angulogerina esuriens</i> Hornibrook			4	4	4 4 1	4 3 1 2 1 1 3
<i>Bolivina cf. acerosa</i> Cushman			2			
<i>affiliata</i> Finlay			4	4	1 4 4	1 1 1 4
<i>albatrossi</i> Cushman			4			1
<i>barnwelli</i> Finlay						2 2
<i>fyfei</i> Hornibrook						1 1
<i>lapsus</i> Finlay			3	4		
<i>numerosa</i> Vella			2	4	2	1 1 2 1 2 1 1 1 1
<i>petiae</i> Gibson			4		4 1 4 4	4 3 4 4 1 4 4 4 3 2 1 1 1
<i>aff. petiae</i> Gibson						4
<i>subspinescens</i> Cushman			4			
<i>watti</i> Gibson			1	4	1 4	1 1 4 4 3 1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

BLIND RIVER SECTION

DISTRIBUTION

OF MICROFOSSILS

(To accompany Thesis
by J.P. Kennett)

Stage:

Fossil No.

M.Tt

U.Tt

Tk

Wo

Rectobolivina striatula (Cushman)

Robertinoides cf. pukeuriensis (Hornibrook)

Family HETEROHELICIDAE

Bolivinita compressa Finlay

pliozea Finlay

pohana Finlay

aff. *pohana* Finlay

quadrilatera (Schwager)

sp.

Plectofrondicularia pohana Finlay

Family CASSIDULINIDAE

Cassidulina cuneata Finlay

laevigata d'Orbigny

neocarinata Thalmann

subglobose Brady

Cassidulinoides orientalis (Cushman)

aff. *orientalis* (Cushman),
inflated var.

Family ELLIPSOIDENIDAE

Pleurostomella alternans Schwager

n.sp., (small aperture)

Family CHILOSTOMELLIDAE

Chilostomella oolina Schwager

ovoides Reuss

Sphaeroidina bulloides d'Orbigny

Pullenia bulloides (d'Orbigny)

quadriloba Reuss

quinqueloba (Reuss)

Family NONIONIDAE

Pacinoion neefi Vella

nozoelandicum (Cushman & Edwards)

parki (Hornibrook)

Melonis zeobesius Vella

Nonionella magnalingua Finlay

zenitens Finlay

Florilus deceptrix (Hornibrook)

flemingi (Vella)

Zeafiorilus parri (Cushman)

Family DISCORBIIDAE

Gavelinopsis lobatulus (Parr)

Discopulvinulina bertheleti (d'Orbigny)

Eponides broeckhianus (Karrer)

Osangularia bengalensis (Schwager)

Gyroidinoides neosoldanii (Bretzen)

zelandica (Finlay)

Laticarinina pauperata (Parker & Jones)

Gancris laevinflatus Hornibrook

Family EPISTOMINIDAE

Epistominella iota Hornibrook

Hoglundina elegans (d'Orbigny)

Pseudoeponides prominula (Stache)

tenera (Brady)

cf. *unobovatus* (Reuss)

Family CERATOBULIMINIDAE

Ceratobulimina cf. swamsoni Hornibrook

Family ELPHIDIIDAE

Elphidium charlottensis (Vella)

Notoretalia cf. depressa Vella

finlayi Vella

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 11, PART 5.

BLIND RIVER SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)			Stage:	M.Tt	U.Tt	Tk	Wo																			
	Fossil No.		f603	f618	f635	f636	f637	f638	f639	f640	f641	f642	f643	f644	f645	f646	f647	f648	f649	f650	f651	f652	f653	f654	f655	
	<i>Notoretalia hurupiensis</i> Vella		.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	1	.	1	.	.	.	.	
	<i>pliozea</i> Vella		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	
	<i>taranakia</i> Vella		.	4	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	aff. <i>taranakia</i> Vella, (reticulate ornament)		.	.	4	4	.	4	4	4	4	4	3	4	4	4	4	4	1	4	4	4	4	3	2	4
	sp.		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Discoretalia aranea</i> (Hornibrook)		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	Family GLOBIGERINIDAE		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Globigerina apertura</i> Cushman		.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	1	.	.	.	
	<i>bulloides</i> d'Orbigny		.	.	.	1	.	2	.	.	.	1	1	4	2	2	1	2	1	1	1	.	1	.	.	
	<i>autertrei</i> d'Orbigny		.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	1	.	1	1	1	3	.	.	
	<i>falconensis</i> Blow		.	4	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	1	1	.	.	
	cf. <i>falconensis</i> Blow		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
X	<i>nepenthes</i> Todd		.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
X	<i>pachyderma</i> (Ehrenberg)		.	2	.	2	2	1	3	4	1	2	4	4	4	4	4	4	3	4	4	4	.	3	1	
	<i>parabulloides</i> Blow		2	4	1	1	2	.	1	3	1	1	.	1	.	1	.	1	.	1	.	.	1	4	.	
	<i>praebulloides</i> Blow		1	.	4	1	4	4	4	1	1	.	4	4	2	1	4	1	1	3	4	.	4	.	.	
	<i>quingueloba</i> Natland		.	.	3	.	.	.	3	1	.	4	.	.	.	.	1	.	1	1	1	1	.	3	.	
	<i>woodi</i> Jenkins		1	3	4	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	
	cf. <i>woodi</i> Jenkins		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>zealandica</i> Hornibrook		4	.	1	.	.	.	.	.	.	1	1	.	.	1	1	.	1	.	.	.	.	.	.	
	<i>Globigerinita glutinata</i> (Egger)		.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>uvula</i> (Ehrenberg)		1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Globigerinoides trilobus</i> trilobus (Reuss)		4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>rubra</i> (d'Orbigny)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Orbulina suturalis</i> Bronnimann		1	.	.	1	1	1	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	
	<i>universa</i> d'Orbigny		2	4	1	1	1	2	3	1	.	4	2	4	2	1	2	.	1	1	.	2	1	.	2	
	<i>universa</i> d'Orbigny, (bilobed var.)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Sphaeroidinella seminulina</i> (Schwager)		.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
X	<i>Globoquadrina dehiscens</i> (Chapman, Parr & Collins)		4	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
X	<i>Globoretalia conomiossea</i> Kennett		.	.	.	.	.	.	3	3	1	1	3	4	4	.	.	.	.	.	.	.	.	.	.	
X	<i>crasseiformis</i> (Galloway & Wissler)		.	.	.	.	.	.	.	.	.	.	.	.	.	4	3	2	1	3	3	3	4	1	1	2
X	<i>monardii</i> miotumida Jenkins		2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>miotumida</i> Finlay		.	4	4	2	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>opima</i> continua Blow		1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>scitula</i> (Brady)		.	1	.	1	1	1	.	.	.	1	.	.	.	1	1	.	1	1	1	1	.	.	.	
	Family ANOMALINIDAE		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Anomalina aotea</i> Finlay		.	.	1	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Anomalinoides parvumbilia</i> (Finlay)		4	4	4	4	4	4	4	4	4	2	4	2	2	2	.	3	4	4	4	4	2	1	4	4
	<i>spherica</i> (Finlay)		.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	
	sp.		.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Cibicides deliquatus</i> Finlay		.	3	2	2	2	4	4	4	2	4	4	4	4	4	1	2	1	4	3	3	4	4	3	2
	<i>finlayi</i> Gibson		3	4	4	1	1	4	4	1	1	.	4	2	4	4	3	.	2	.	1	2	.	.	1	
	<i>mediocris</i> Finlay		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>molestus</i> Hornibrook		1	4	4	4	3	4	3	2	4	2	4	4	4	4	.	3	1	.	.	4	.	4	4	.
	<i>pseudoungerianus</i> (Cushman)		.	4	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>refulgens</i> Montfort		.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	
	<i>Dyocibicides biserialis</i> Cushman & Valentine		.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	
	MOLLUSCA		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	PELECYPODA		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	<i>Nuculana</i> sp.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	
	<i>Anomia walteri</i> Hector		X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	
	<i>Cucullaea</i> n.sp.		X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
	sp.		.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	
	<i>Glycymeris tohunga</i> King		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	
	sp.		.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	
	<i>Limopsis lawsi</i> King		X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens; X = present.

TABLE 11, PART 6.

BLIND RIVER SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)	Stage:	M.Tt	U.Tt	Tk	Wo																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens; X = present.

TABLE 12, PART 1

UPTON BROOK SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	M.Tt	U.Tt	Tk	Wo
FORAMINIFERA		Fossil No.	f561 f562 f563 f564 f565 f566 f567 f568 f569 f570 f571 f572 f573 f574 f575 f576 f577 f578 f579 f580			
Family REOPHACIDAE						
<i>Reophax scorpiurus</i> Montfort					1.....	.....
Family LITUOLIDAE						
<i>Haplophragmoides</i> sp.				1.....	11.....	.....
Family TEXTULARIIDAE						
<i>Textularia barnwelli</i> Kennett				)2(.....	)22(.....	.....
<i>kapitea</i> Finlay				1.....	.....	.....
<i>subrhombica</i> Stache				11.....	1.....	.....
<i>Haeslerella morgani</i> (Chapman)			1.....	1.....21311	1(.....)	1111
<i>parri</i> Finlay			3.41	44434443	2.3(.....)	313
<i>Siphotextularia awamoana</i> Finlay				)2.1.12(.....	.....	.....
<i>subcylindrica</i> Finlay				1.....	.....	.....
<i>wairoana</i> Finlay						1
Family VERNEUILINIDAE						
<i>Gaudryina quadrangularis</i> Bagg						1.....
Family VALVULINIDAE						
<i>Karrerella cylindrica</i> Finlay			1.....	.....	.....	.....
<i>Martinottiella clarae</i> Gibson			1.....1.....	1.....	.....	.....
Family MILIOIDAE						
<i>Signolopsis zeaserus</i> Vella				1.....	.....	.....
<i>Quinqueloculina delicatula</i> Vella				1.....	.....	.....
<i>incisa</i> Vella				1.....	.....	.....
<i>lamarckiana</i> d'Orbigny				11.....	1.....	24.1
<i>Biloculina anomala</i> Schlumberger				11.....	1.....	.....
<i>magnacaudata</i> (Smith)				1.....	.....	.....1.....
sp.						1.....
Family LAGENIDAE						
<i>Robulus calcar</i> (Linnaeus)			11.11	1)431144(11.11)	2214	
<i>gyroscaprus</i> (Stache)				1.....	.....	.....
<i>iotus</i> Cushman				1.....	.....	.....1
<i>loculosus</i> (Stache)				1.....11.....	1.....	.....
cf. <i>loculosus</i> (Stache)				1.....	.....	.....
<i>Lenticulina gibba</i> (d'Orbigny)				1.....	.....	.....
sp.				1.....	.....	.....
<i>Saracenaria italica</i> Defrance				1.....	.....	.....
<i>latifrons</i> (Brady)				1.....	.....	.....
<i>Vaginulina elegans</i> d'Orbigny				1.....	.....	.....
<i>Dentalina soluta</i> Reuss				1.....	.....	.....
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)				1.....1.....	4344(1.211111	.....
sp. (smooth)			1.1	1.1121243	3.321211	.....
<i>Stilostomella antipoda</i> (Stache)				31.....	.....	.....
<i>Rectoglandulina</i> cf. <i>rotundata</i> (Reuss)				1.....	.....	.....1.....
<i>torrida</i> (Cushman)			1.1	1.....	1.....	.....
<i>Lagena crenata</i> Parker & Jones				1.....1.....	.....	.....
<i>distoma</i> Parker & Jones					1.....	.....
<i>elongata</i> (Ehrenberg)				1.....1.....	1.....	.....
<i>laevis</i> (Montagu)				1.1.1.1.....	2.1.....	.....
<i>striata</i> (d'Orbigny)				1.....1.....1.....	1.....	11
<i>sulcata</i> (Walker & Jacob)				1.111.....	1.1.....	11
sp.				1.....	.....	.....
<i>Oolina hexagona</i> (Williamson)				1.1112.....	.....	.....111
<i>Fissurina marginata</i> (Walker & Boys)				1.....	.....	.....1.....
<i>orbignyana</i> (Sequenza)					1.....	.....
<i>submarginata</i> (Boonstra)			11.....	111.....	.....	.....1.....
<i>Parafrondicularia fyfei</i> (Finlay)				1.....	.....	.....
<i>pellucida</i> (Finlay)				11.....	.....	.....

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 12, PART 2.

UPTON BROOK SECTION

DISTRIBUTION
OF MICROFOSSILS
(To accompany Thesis
by J.P. Kennett)

Stage:

M.Tt

U.Tt

Tk

Wo

Fossil No.

F561

F562

F563

F564

F565

F566

F567

F568

F569

F570

F571

F572

F573

F574

F575

F576

F577

F578

Family POLYMORPHINIDAE

Ellipsoglandulina subconica (Kienz)

Family BULIMINIDAE

* *Bulimina aculeata* d'Orbignycf. *striata* d'Orbigny, (small var.)cf. *striata* d'Orbigny, (large var.)*Virgulina schrisbersiana* Czjzek

vella Kennett

Neouvigerina eketahuna Vella

vadescons (Cushman)

Hofkeruwa luterum Vella

paeniteres (Finlay)

zeacuminata Vella

Trifarina bradyi Cushman*Bolivina affiliata* Finlay

fyfei Hornibrook

mitchelli Gibson

numerosa Vella

petiae Gibson

subspinescens Cushman

watti Gibson

Rectobolovina striatula (Cushman)

Family HETEROHELICIDAE

Bolivinita pliozea Finlay

pohana Finlay

Plectofrondicularia pohana Finlay

Family CASSIDULINIDAE

Cassidulina cuneata Finlay

laevigata d'Orbigny

neocarinata Thalmann

subglobosa Brady

Cassidulinoides orientalis (Cushman)

Family ELLIPSOIDINIDAE

Pleurostomella alternans Schwager

Family CHILOSTOMELLIDAE

Chilostomella ovoidea Reuss*Sphaeroidina bulloides* d'Orbigny*Pullenia bulloides* (d'Orbigny)

quinqueleba (Reuss)

Family NONIONIDAE

Pacinoion novozealandicum (Cushman & Edwards)

parki (Hornibrook)

Nonionella magnalingua Finlay

zenitens Finlay

Florilus flemingi (Vella)*Zeafiorilus parri* (Cushman)

Family DISCORBIIDAE

Gavelinopsis lobatulus (Parr)*Discopulvinulina berthelotti* (d'Orbigny)*Gyroidinoides neesoldanii* (Bretzen)

Family EPISTOMINIDAE

Siphonina australis Cushman*Epistominella iota* Hornibrook*Höglundina elegans* (d'Orbigny)*Pseudoeponides prominula* (Stache)

tenera (Brady)

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

UPTON BROOK SECTION

OF MICROFOSSILS
(To accompany Thesis
by J.P. Kennett)

Wo

90

aff. taranakia Vella, (reticulate ornament)

miozea Finlay

molestus Hornibrook

Panopea zelandica (Quoy & Gaimard)

Maoricrypta radiata (Hutton)

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens. X = present.

TABLE 12, PART 4.

UPTON BROOK SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	M.Tt			U.Tt			Tk			Wo										
		Fossil No.	f561	f562	f563	f564	f565	f566	f567	f568	f569	f570	f571	f572	f573	f574	f575	f576	f577	f578	f579	f580
Polinices cf. waipipiensis (Marwick)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
Polinella obstructus (Marwick)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
n.sp.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
sp.			.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Xenophalium (Mauicassis) cf. grangei Marwick			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Penion huttoni (King)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
n.sp. aff. aspera Marwick			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
sp.			.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.
Aeneator n.sp.			.	.	.	.	.	.	.	.	.	.	X	X	X	X	.	.	X	X	.	.
Austrofusus cf. allani King			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
* caeruleus (Finlay)			.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
pagoda Finlay			.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X	.	.
Cominella (Cominella) n.sp.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Coluzea spectabilis Powell			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Poirieria zelandica (Gray & Gaimard)			.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	X	.	.
Pachymelon cf. bartrami King			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
uptonensis King			.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	.
Alcithoe cf. bacchinalia King			.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	X	.	.
sp.			.	.	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.
Aoteadrillia cf. waihuensis Powell			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
SCAPHOPODA			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dentalium zelandicum Sowerby			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.
OTHER FOSSILS:			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPONGE SPICULES			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	4
OSTRACODA			.	.	.	.	.	1	.	.	.	.	1	1	1	1	.	.	.	2	1	4
BRYOZOA			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	4
ECHINOID SPINES & PLATES, (spatangid)			.	.	.	.	1	2	1	.	1	4	.	1	.	.	.	.	.	1	1	.
FISH TEETH & BONES			.	.	.	.	.	.	1	.	.	1	2	.	1	1	1	1	.	.	.	.
FISH OTOLITHS			.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	1	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens; X = present.

TABLE 13, PART 1.

PALLISER BAY SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)	Stage:	U.Tt	Wo	Ww?			
Fossil No.	f713	f714	f715	f716	f717	f718	f719
FORAMINIFERA							
Family LITUOLIDAE							
Haplophragmoides sp.	.	.	1	.	.	.	.
Family TEXTULARIIDAE							
Textularia barnwelli Kennett	.	1	.	.	.	.	.
sp.	.	.	.	.	1	.	.
Haeuslerella finlayi Vella	2	4	2	(	.	.	.
morgani (Chapman)	3	.	3	.	.	.	.
parri Finlay	.	2	.	.	.	3	4
pliocenica (Finlay)	.	.	.	.	4	4	3
Siphotextularia awamoana Finlay	.	2	3	.	.	.	.
ihungia Finlay	1	.	.	.	.	.	.
subcylindrica Finlay	3	2	4	.	.	.	.
wairoana Finlay	.	.	.	.	4	2	.
Vulvulina sp.	.	1	.	.	.	.	.
Family VERNEULINIDAE							
Gaudryina kingi Parr	.	1	.	.	.	.	.
Family VALVULINIDAE							
Dorothia sp.	.	.	.	.	1	.	.
Karrerella bradyi (Cushman)	4	.	.	.	.	.	.
cylindrica Finlay	4	2	4	3	4	.	.
Martinettiella clarae Gibson	1	1	3	1	1	.	.
massami Gibson	2	.	.	.	.	.	.
Family MILIOLIDAE							
Sigmoilopsis gavini Gibson	1	1	2	.	2	.	.
schlumbergeri (Silvestri)	3	.	.	.	.	.	.
zeaserus Vella	.	4	1	1	1	.	.
Miliolinella cf. vigilax Vella	.	1	.	.	.	.	.
Spiroloculina canaliculata d'Orbigny	1	.	.	.	.	.	.
novozealandica Cushman & Todd	.	1	.	.	.	.	.
kennetti Gibson	1	1	.	1	.	.	.
Biloculina cf. anomala Schlumberger	.	1	.	.	.	.	.
Pyrgo sp.	.	1	1	.	.	.	.
Family LAGENIDAE							
Robulus calcar (Linnaeus)	1	1	.	.	.	4	.
costatus (Fichtel & Moll)	1	.	1	.	.	.	.
dicampylus (Franzenau)	1	.	.	.	.	.	.
gyroscapulus (Stache)	.	3	4	.	3	.	.
iotus Cushman	1	.	1	.	2	.	.
loculosus (Stache)	.	1	1	.	1	1	.
spp.	1	.	.	.	.	.	.
Lenticulina peregrina (Schwager)	1	2	1	1	.	.	.
Saracenaria ampla Cushman & Todd	1	.	.	.	.	.	.
italica DeFrance	1	.	1	.	.	.	.
latifrons (Brady)	.	.	1	.	.	.	.
Vaginulinopsis n.sp.	.	.	1	.	.	.	.
Vaginulina elegans d'Orbigny	.	1	1	.	1	.	.
vagina (Stache)	1	.	.	.	.	.	.
Marginulina subbullata Hantken	.	2	.	.	.	.	.
sp.	.	.	.	.	1	.	.
Dentalina filiformis (d'Orbigny)	.	.	1	.	.	1	.
guttifera (d'Orbigny)	1	.	1	.	.	.	.
soluta Reuss	.	1	1	.	1	1	.
subsoluta (Cushman)	.	.	1	.	.	.	.
substrigata Stache	.	1	.	.	.	.	.
spp.	.	.	.	.	1	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 13, PART 2.

PALLISER BAY SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	U.1t	Wo	Ww?
	Fossil No.		U.1t	Wo	Ww?
			U.1t	Wo	Ww?
<i>Nodosaria holoserica</i> Schwager			1	1	1
<i>lamnifera</i> Boomgaart			1	1	1
<i>longiscata</i> d'Orbigny			1 1 2 1	2 1	1
<i>longiscata</i> d'Orbigny, var.			1	1	1
<i>pyrula</i> d'Orbigny			1	1	1
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)			3 1 1 1	1 3	1
<i>scalaris</i> (Batsch)			1	1 1	1
sp., (smooth)			1	1	1
<i>Chrysalogonium striatissimum</i> (Stache)			1	1	1
<i>Stilostomella antipoda</i> (Stache)			1	3	1
<i>globulifera</i> (Kreuz)			2 2 1	1	1
sp., (strong spined)			3 4 2 2	2	1
<i>Rectoglandulina</i> cf. <i>aperta</i> (Stache)			1	2	1
<i>rotundata</i> (Reuss)			1 1	1	1
sp.			1	1	1
<i>Lagena crenata</i> Parker & Jones			1	1	1
<i>distoma</i> Parker & Jones			1 2	1	1
<i>hispidula</i> Cushman			1	1	1
<i>laevis</i> (Montagu)			1	1	1
aff. <i>pliocenica</i> Cushman & Gray			1	1	1
<i>striata</i> (d'Orbigny)			1 1 1	1	1
<i>sulcata</i> (Walker & Jacob)			2 1	1 1 1	1
<i>Oolina hexagona</i> (Williamson)			1	1	1
<i>Fissurina laevigata</i> Reuss			1	1	1
<i>marginata</i> (Walker & Boys)			1 1 1	1	1
<i>orbignyana</i> (Sequenza)			1	1	1
<i>tricaudata</i> Silvestri			1	1	1
<i>Parafrondicularia pellucida</i> (Finlay)			1	3	2
<i>wairarapa</i> Vella			3 4	1	1
<i>Proxifrons advena</i> (Cushman)			2 3 4	1 2 1 1	1
<i>Awhea sinalata</i> (Finlay)			2	1 1 1 1	1
<i>subtetragona</i> (Finlay)			1	1	1
Family POLYMORPHINIDAE					
<i>Signomorphina</i> sp.			1	1	1
<i>Globulina minima</i> Bornemann			1	1	1
<i>Glandulina symmetrica</i> Stache			2	1 1	4
<i>Ellipsoglandulina subconica</i> (Kienz)			1 1	1	1
Family BULIMINIDAE					
<i>Bulimina aculeata</i> d'Orbigny			1	4	3 4
<i>notovata</i> Chapman			1	1	1
<i>pupoides</i> d'Orbigny			1	1	1
<i>pyrula</i> d'Orbigny, var. <i>spinescens</i> Brady			2 1 4	1	1
cf. <i>striata</i> d'Orbigny, (small var.)			1	4	4
cf. <i>striata</i> d'Orbigny, (large var.)			4 4 1	4	1
<i>truncanella</i> Finlay			2 1	1	1
<i>Globobulimina pacifica</i> Cushman			1	1 2 1	1
<i>perversa</i> (Cushman)			1	1	1
<i>Virgulina complanata</i> Egger			1	1	1
<i>retundata</i> Parr			1	1	1
<i>schreibersiana</i> Czjzek			1	2	1
<i>vellai</i> Kennett			1	1	1
<i>Neouvigerina eketahuna</i> Vella			4 4 4	2	1
<i>vadescens</i> (Cushman)			1	2	1
<i>Hofkeruwa lutorum</i> Vella			4 4 4 4	1	1
<i>pliozea</i> Vella			1	4	1
<i>redleyi tutamoides</i> Vella			1	4	4
<i>zeacuminata</i> Vella			4	1	1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 13, PART 4.

PALLISER BAY SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	U.Tt				Wo	Ww?	
		Fossil No.	f713	f714	f715	f716	f717	f718	f719
Family GLOBIGERINIDAE									
Globigerinella aequilateralis (Brady)			.	.	.	.	.	1	.
cf. aequilateralis (Brady)			.	1	.	.	.	.	.
Globigerina bulloides d'Orbigny			.	1	.	.	.	4	.
falconensis Blow			1	1	1	.	.	.	.
X	pachyderma (Ehrenberg)		.	2	1	1	4	4	.
parabulloides Blow			2	.	3	.	.	.	.
praebulloides Blow			4	4	4	.	3	3	3
quinqueloba Natland			.	.	.	.	2	.	1
woodi Jenkins			1	1	1	.	.	.	.
zealandica Hornibrook			.	.	.	.	.	1	.
Globigerinita glutinata (Egger)			.	.	2	4	.	.	.
uvula (Ehrenberg)			.	1	.	.	.	.	.
Orbulina suturalis Bronnimann			.	1	.	.	1	.	.
universa d'Orbigny			2	1	4	1	3	1	.
Sphaeroidinella seminulina (Schwager)			.	.	1	.	1	.	.
X	Globoretalia conomiozea Kennett		.	.	.	3	.	.	.
X	crassaformis (Galloway & Wissler)		.	.	.	.	4	4	.
X	inflata (d'Orbigny)		.	.	.	.	.	4	4
X	miozea Finlay		1	4	4	.	.	.	.
	scitula (Brady)		1	1	2	.	1	1	.
Family ANOMALINIDAE									
X?	Anomalina aotea Finlay		1	1	1	.	.	.	.
	Anomalinoides parvumbilica (Finlay)		4	4	4	4	4	2	4
	spherica (Finlay)		.	.	.	.	.	.	1
X	vitrinoda (Finlay)		.	.	.	.	1	.	.
Gibicides deliquatus Finlay			4	3	2	4	4	4	4
finlayi Gibson			4	4	4	4	4	.	.
molestus Hornibrook			4	4	4	1	4	.	.
pseudoungerianus (Cushman)			.	.	.	.	4	.	.
refulgens Montfort			.	.	.	.	1	.	.
robertsonianus (Brady)			.	.	.	.	4	.	.
sp.			.	.	.	1	.	.	.
Dyocibicides biserialis Cushman & Valentine			.	.	1	.	.	.	.
OTHER FOSSILS:									
RADIOLARIA			4	.	.	.	1	.	.
SPONGE SPICULES			4	.	.	.	4	.	.
OSTRACODA			2	1	.	.	.	.	1
ECHINOID SPINES, (spatangid)			.	4	1	.	2	4	1
FISH TEETH			1	1	1	.	.	1	1
FISH OTOLITHS			1	1	.	.	.	.	2

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 14, PART 1.

MANGAORANGA SECTION

DISTRIBUTION

OF MICROFOSSILS

(To accompany Thesis
by J.P. Kennett)

Stage:

Fossil No.

M.Tt
U.Tt
Fk
Wo

f1151
f1152
f1154
f1155
f1157
f1158
f1159
f1160
f1161
f1162
f1164
f1166
f1168
f1170
f1172

FORAMINIFERA

Family AMMODISCIDAE

Ammodiscus finlayi Parr

. 1 . . 1

Family LITUOLIDAE

Haplophragmoides sp.

. 1

Family TEXTULARIIDAE

Textularia barnwelli Kennett

. . . . 1

kapitea Finlay

. . . . 4

Haeslerella finlayi (Vella)

. 1 . 1

morgani (Chapman)

. 1 . 1 . 4 2 . . .

parri Finlay

. . . 1 4 . . 1 . 3 4 . 1 . .

pliocenica (Finlay)

. 4 4

Siphotextularia awamoana Finlay

. . . . 1

subcylindrica Finlay

. . . . 1 2 1 1 2 4 4 4 . . .

Family VERNEUILINIDAE

Gaudryina kingi Parr

. . . . 1

Family VALVULINIDAE

Karrerella bradyi (Cushman)

. 1 3 . . 1 . . .

cylindrica Finlay

. 4 2 4 3 4 4 4 . 4 4

Martinottiella clarae Gibson

. . . . 3 3 2 . . 4 1 4 . .

Family MILIOLIDAE

Sigmoilopsis schlumbergeri (Silvestri)

. 1 1 . 1

zeaserus Vella

. 3

Quinqueloculina sp.

. 1 . 1

Spiroloculina novezealandica Cushman & Todd

. 1

Family LAGENIDAE

Robulus calcar (Linnaeus)

. . . 4 4 . 1 . 1 2 2 1 . . 4

costatus (Fichtel & Moll)

. 1 . 1 .

cultratus Montfort

. . . 4 . . . 1 2 . . 1 .

gyroscaprus (Stache)

. . . . 2 2 3 1 4 3

lotus (Cushman)

. 1 .

loculosus (Stache)

. . . . 1 1 1

Lenticulina gibba (d'Orbigny)

. 1 1 1

cf. mammiligera (Karrer)

. 1

peregrina (Schwager)

. . . . 1 . . 1 . . 1 . .

Saracenaria italica DeFrance

. . . . 1 1 . . . 1 . 1 1

latifrons (Brady)

. 1 . . 1

Vaginulinopsis n.sp.

. 2 . . .

Vaginulina elegans d'Orbigny

. 1 . . 1

sp.

. 1 .

Marginulina duracina Stache

. 1 . . .

subbullata Hantken

. . . . 1 . . . 1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 14, PART 2.

MANGAORANGA SECTION

DISTRIBUTION																	
OF MICROFOSSILS		Stage:	M.Tt								U.Tt	Tt	Wo				
(To accompany Thesis by J.P. Kennett)		Fossil No.	f1151	f1152	f1154	f1155	f1157	f1158	f1159	f1160	f1161	f1162	f1164	f1166	f1168	f1170	f1172
<i>Dentalina communis</i> d'Orbigny			.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
<i>emaciata</i> Reuss			.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
<i>filiformis</i> d'Orbigny			.	.	.	.	.	.	1	.	.	1	.	.	.	.	.
<i>guttifera</i> (d'Orbigny)			.	.	.	.	.	1	1	1	1	1	.	1	.	3	1
<i>soluta</i> Reuss			.	.	.	1	.	.	1	1	2	.	1	.	1	.	.
<i>subsoluta</i> (Cushman)			.	.	.	.	2	.	1	.	.	.	.	.	.	.	1
<i>substrigata</i> Stache			.	.	1	1	1	1	.	.	.	1	.	.	.	1	1
spp.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
<i>Nodosaria affinis</i> Reuss			.	.	.	1	1	.	.	.	.	.	.	1	.	.	.
<i>hochstetteri</i> Schwager			.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
<i>holoserica</i> Schwager			.	.	.	.	.	.	.	.	.	.	3	.	.	3	.
<i>longiscata</i> d'Orbigny			.	.	.	1	.	.	1	1	1	2	1	.	1	2	.
<i>longiscata</i> d'Orbigny, var.			.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
spp.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
<i>Lagenonodosaria hirsuta</i> (d'Orbigny)			.	.	.	3	.	2	.	2	1	1	2	1	1	.	.
cf. <i>scalaris</i> (Batsch)			.	.	.	.	.	.	1	1	.	.	.	2	.	.	.
sp., (smooth)			.	.	.	.	.	.	.	.	.	1	.	.	.	1	.
<i>Stilostomella antipoda</i> (Stache)			.	.	.	.	4	3	4	4	3	2	1	1	1	4	.
<i>globulifera</i> (Kreuz)			.	.	.	.	.	.	1	.	2	.	.	.	.	.	.
sp.			.	.	.	.	.	.	.	.	.	.	.	.	.	3	.
<i>Rectoglandulina aperta</i> (Stache)			.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
cf. <i>rotundata</i> (Reuss)			.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
<i>torrida</i> (Cushman)			.	.	.	.	.	1	.	.	1	1	.	.	.	.	1
<i>Lagena crenata</i> Parker & Jones			.	.	.	1	.	.	1	.	1	1	1	.	.	.	.
<i>distoma</i> Parker & Jones			.	.	.	.	.	.	.	.	.	1	.	.	.	1	.
cf. <i>distoma</i> Parker & Jones			.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
<i>hispida</i> Reuss			.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
<i>hispidula</i> Cushman			.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
<i>laevis</i> (Montagu)			.	.	.	.	.	1	1	1	1	.	.	.	1	1	1
<i>striata</i> (d'Orbigny)			.	.	.	1	.	.	1	.	.	.	.	2	1	.	.
<i>sulcata</i> (Walker & Jacob)			.	.	.	1	.	.	1	.	1	1	.	.	.	3	1
<i>Oolina globosa</i> (Montagu)			.	.	.	1	1	.	.	.	1	.	1	.	.	.	.
<i>hexagona</i> (Williamson)			.	.	.	.	.	.	.	1	1	.	1	4	.	.	.
<i>Fissurina marginata</i> (Walker & Boys)			.	.	.	1	.	.	.	.	.	1	.	.	.	.	1
<i>orbignyana</i> (Sequenza)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
<i>submarginata</i> (Boongaart)			.	.	.	.	.	.	1	1	.	1	1	.	1	2	.
<i>tricaudata</i> Silvestri			.	.	.	.	.	.	.	.	.	1	1	.	.	1	1
<i>Parafrondicularia pellucida</i> (Finlay)			.	.	.	.	.	.	1	1	.	.	.	.	.	4	3
<i>wairarapa</i> Vella			.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
<i>Proxifrons advena</i> (Cushman)			.	.	.	.	.	.	.	.	1	1	2	.	.	2	1
<i>Awhea sinalata</i> (Finlay)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 14, PART 3.

MANGAORANGA SECTION

DISTRIBUTION		Stage:	M.Tt	U.Tt	Tk	Wo												
OF MICROFOSSILS																		
(To accompany Thesis by J.P. Kennett)		Fossil No.	1151	1152	1154	1155	1157	1158	1159	1160	1161	1162	1164	1166	1168	1170	1172	
Family	POLYMORPHINIDAE																	
	Guttulina bartschi Cushman & Ozawa		.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	
	Sigmoidella elegantissima (Parker & Jones)		.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	
Family	BULIMINIDAE																	
	Bulimina aculeata d'Orbigny		.	.	.	4	3	4	4	.	.	.	.	.	4	.	.	
	mapiria Finlay		.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	
	notovata Chapman		.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	
	cf. striata d'Orbigny (small var.)		.	.	.	.	.	.	.	4	1	.	.	4	.	4	4	
	cf. striata d'Orbigny (large var.)		.	.	.	.	.	2	4	4	1	4	2	4	.	1	.	
	truncanella Finlay		.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	
	vellai Gibson		.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	
	Globobulimina pacifica Cushman		.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	
	Virgulina schreibersiana Czek		.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	
	vellai Kennett		.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	
	Neouvigerina eketahuna Vella		.	.	.	.	.	.	3	1	4	4	2	4	1	.	.	
	Hofkeruva lutorum Vella		1	1	.	.	4	4	4	4	4	4	4	4	.	4	.	
	pliozea Vella		.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	
	zeacuminata Vella		.	.	.	1	.	.	.	.	.	.	.	4	4	.	.	
	Trifarina bradyi Cushman		.	.	.	.	.	.	1	.	1	.	.	1	1	3	4	4
	Angulogerina esuriens Hornibrook		.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.
	Bolivina affiliata Finlay		.	.	.	.	.	.	3	2	2	4	1	4	4	4	4	4
	albatrossi Cushman		.	.	.	.	.	.	.	.	.	1	.	4	.	.	4	4
	lapsus Finlay		.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.
	numerosa Vella		.	.	.	.	.	1	.	.	.	1	.	.	1	1	.	.
	petiae Gibson		.	.	.	.	.	.	1	2	.	1	.	2	4	4	.	.
	watti Gibson		.	.	.	.	.	.	4	3	4	4	1	4	4	4	1	.
	Rectobolivina striatula (Cushman)		.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Family	HETEROHELICIDAE																	
	Bolivinita compressa Finlay		.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
	elegantissima Boomgaart		.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.
	pliozea Finlay		.	.	.	.	.	.	.	.	.	.	1	4	4	.	2	1
	pohana Finlay		.	.	.	.	.	2	4	4	4	2	.	1	4	4	4	1
	Plectofrondicularia pohana Finlay		1	.	.	.	1	4	3	4	1	1	4	4	.	.	.	.
Family	CASSIDULINIDAE																	
	Cassidulina cuneata Finlay		.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.
	neocarinata Thalmann		.	.	.	.	.	.	1	.	4	.	.	.	1	.	2	.
	subglobosa Brady		.	.	.	.	.	2	.	1	1	.	1	.	.	.	2	.
	Cassidulinoides orientalis (Cushman)		.	.	.	1	3	1	1	1	.	1	1	1	1	.	1	.
Family	ELLIPSOIDINIDAE																	
	Pleurostomella alternans Schwager		.	.	.	.	.	.	.	1	4	1	1	.	.	.	1	.
Family	CHILOSTOMELLIDAE																	
	Chilostomella colina Schwager		.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 14, PART 4

MANGAORANGA SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt	U.Tt	Tt	Wo
(To accompany Thesis by J.P. Kennett)	Fossil No.					
<i>Chilostomella ovoidea</i> Reuss	21151					
	21152					
	21153					
	21155					
	21157					
	21158					
	21159					
	21160					
	21161					
	21162					
	21164					
	21166					
	21168					
	21170					
	21172					
<i>Sphaeroidina bulloides</i> d'Orbigny	1	1	4	4	4	3
<i>Pullenia bulloides</i> (d'Orbigny)	1	1	4	4	4	3
<i>quinqueloba</i> (Reuss)	2	2	1	1	1	1
Family NONIONIDAE						
<i>Pacinionion neefi</i> Vella	1	2	2	1	1	2
<i>parki</i> (Hornibrook)	4	1	2	1	1	3
<i>Melonis lutorum</i> (Vella)						1
<i>zeobesius</i> Vella					4	
<i>Nonionella magnalingua</i> Finlay	1			1		
<i>zenitens</i> Finlay	1					
<i>Florilus deceptrix</i> (Hornibrook)	1					
<i>flemingi</i> (Vella)	1	1	2	1	1	2
<i>Zeafiorilus parri</i> (Cushman)	2	2	2			
Family DISCORBIIDAE						
<i>Discorbis</i> cf. <i>dimidiatus</i> (Parker & Jones)			1			
<i>Gavelinopsis lobatulus</i> (Parr)	1					
<i>Discopulvinulina berthelotti</i> (d'Orbigny)	2	1	1			1
<i>Osangularia bengalensis</i> (Schwager)				1		
<i>Gyrogonoides neosoldanii</i> (Bretzen)	1	1	4	1	4	4
<i>zelandica</i> (Finlay)	1	4	3	1		4
<i>Laticarinina pauperata</i> (Parker & Jones)	1		2	1	2	1
<i>Cancris laevinflatus</i> Hornibrook	1	1	1			
Family EPISTOMINIDAE						
<i>Epistominella iota</i> Hornibrook				1	1	2
<i>Hoglundina elegans</i> (d'Orbigny)	3			1		4
<i>Pseudoeponides prominula</i> (Stache)	2	2	1	1	1	1
<i>tenera</i> (Brady)	1	1	3	1	2	1
Family ROTALIIDAE						
<i>Ammonia aeteanus</i> (Finlay)				1		
Family ELPHIDIIDAE						
<i>Elphidium</i> cf. <i>chapmani</i> Cushman	1	1				
<i>charlottensis</i> (Vella)	3		1			
cf. <i>depressulum</i> Cushman	1					
<i>Notoretalia</i> cf. <i>depressa</i> Vella	4	1				
<i>hurapiensis</i> Vella	4	4				
<i>macinnesi</i> Kennett	1	1				
<i>taranakia</i> Vella			4	4		
aff. <i>taranakia</i> Vella (reticulate ornament)		4		1	4	4
<i>Discoretalia aranea</i> (Hornibrook)	1					

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 14, PART 5.

MANGAORANGA SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Ft												U.Ft	Tk	Wo
(To accompany Thesis by J.P. Kennett)		Fossil No.	T151	T152	T154	T155	T157	T158	T159	T160	T161	T162	T164	T166	T168	T170	T172
Family GLOBIGERINIDAE																	
	<i>Globigerina bulloides</i> d'Orbigny		.	.	.	1	.	1	.	.	.	.	.	.	.	.	.
	<i>autertrei</i> d'Orbigny		.	.	.	.	.	.	.	.	.	.	.	.	.	.	4 1
	<i>falconensis</i> Blow		.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
	<i>pachyderma</i> (Ehrenberg)		.	.	.	.	.	1	.	1	.	.	1	1	.	4 4	
	<i>parabulloides</i> Blow		.	.	.	1	4	.	1	2	3	4	.	4	1	1	4
	<i>praebulloides</i> Blow		.	.	.	.	.	.	.	1	.	.	.	1	.	1	4
	<i>quinqueloba</i> Natland		.	.	.	.	.	.	.	1	.	.	.	3	.	4	.
	<i>woodi</i> Jenkins		.	.	.	1	1	1	.	2	1	1	1	1	.	.	1
	sp.		.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
	<i>Orbulina suturalis</i> Bronnimann		.	.	.	.	1	.	.	.	.	1	.	1	.	.	.
	<i>universa</i> d'Orbigny		.	.	.	.	1	.	1	1	3	3	2	1	1	2	4
	<i>Globoretalia conomiozea</i> Kennett		.	.	.	.	.	.	.	.	.	.	1	1	.	.	.
	<i>crassaformis</i> (Galloway & Wissler)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	2 4
	<i>menardii</i> panda Jenkins		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
	<i>Globoretalia conomiozea</i> Finlay		.	.	.	.	1	.	.	.	.	1	1	.	.	.	.
	<i>scitula</i> (Brady)		.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Family ANOMALINOIDES																	
	<i>Anomalinoidea parvumbilica</i> (Finlay)		.	.	.	.	3	4	4	4	4	3	4	4	4	4	4
	<i>spherica</i> (Finlay)		.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
	<i>subnonionoides</i> (Finlay)		.	.	.	.	4	4	.	.	.	.	.	.	.	.	.
	<i>Cibicides deliquatus</i> Finlay		.	.	.	.	4	2	1	2	.	2	2	.	4	1	1
	<i>finlayi</i> Gibson		.	.	.	.	4	4	4	2	4	4	4	4	1	4	4
	<i>gibsoni</i> Kennett		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>molestus</i> Hornibrook		1	.	.	.	4	4	4	4	1	1	4	4	4	4	4
	<i>pseudoungerianus</i> (Cushman)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
	<i>refulgens</i> Montfort		.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
	<i>temperata</i> Vella		.	.	.	.	.	.	.	1	.	.	2	.	.	1	.
	n.sp. aff. <i>deliquatus</i> Finlay		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
	<i>Dyocibicides biserialis</i> Cushman & Valentine		.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
OTHER FOSSILS:																	
	OSTRACODA		.	.	.	4	3	.	.	.	.	.	.	.	.	.	1
	BRYOZOA		.	1	1	3	.	.	.	.	.	.	.	.	.	.	.
	ECHINOID SPINES		.	1	.	3	.	.	.	.	.	.	.	.	.	.	.
	ECHINOID SPINES, (spatangid)		.	.	.	.	4	1	1	4	4	2	1	2	.	4	4
	FISH OTOLITHS		.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
	FISH TEETH		.	.	.	1	1	1	1	.	.	1	1	1	.	1	.
	SEEDS		.	.	.	.	1	1	.	.	.	.	.	1	.	.	1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 15 PART 1

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	PITARA SECTION						NOAMATA STREAM SECTION				
		Fossil No.	U.Tt		We				U.Tt		We		
			†1176	†1177	†1178	†1179	†1180	†1181	†1182	†1183	†1173	†1174	†1175
FORAMINIFERA													
Family TEXTULARIIDAE													
Textularia barnwelli Kennett			1	1	.	.	.	.	.	.	3	.	.
kapitea Finlay			4	2	.	.	.	.	.	.	4	.	.
Haeuslerella morgani (Chapman)			.	.	2	4	4	4	4	4	.	.	.
parri Finlay			4	1	.	.	.	.	.	.	4	.	.
pliocenica (Finlay)			.	.	.	.	.	.	.	4	.	.	.
Siphotextularia swamocana Finlay			.	1	.	.	.	.	.	.	4	.	.
subcylindrica Finlay			1	.	.	.	.	.	.	.	.	.	.
cf. subcylindrica Finlay			.	.	.	.	1	1	.	.	.	.	.
n.sp. cf. wairoana Finlay			4	.	.	.	.	.	.	.	4	.	.
wairoana Finlay			.	.	2	4	1	4	4	1	.	.	.
Family VALVULINIDAE													
Martinottiella clarae Gibson			.	4	.	.	.	.	.	4	.	.	.
Family MILIOLIDAE													
Sigmillopsis gavini Gibson			.	.	.	.	.	.	.	1	.	.	.
zeaserus Vella			.	.	.	1	1	.	2	.	.	.	.
Quinqueloculina sp.			.	.	1	.	.	.	.	.	.	2	.
Family LAGENIDAE													
Rebulus calcar (Linnaeus)			.	4	.	4	4	4	4	2	4	.	.
costatus (Fichtel & Moll)			.	.	.	.	.	.	.	1	.	.	.
cultratus Montfort			4	.	4	4	.	.	.	.	.	.	.
gyroscaprus (Stache)			.	4	.	.	.	.	3	.	1	.	.
iotus Cushman			.	.	.	1	1	.	2	.	.	.	.
loculosus (Stache)			1	.	.	1	1	1	1	1	.	.	.
Lenticulina peregrina (Schwager)			.	.	.	.	.	.	.	1	.	.	.
Saracenaria angularis Natland			.	.	.	1	.	.	.	.	.	.	.
italica DeFrance			.	.	.	.	4	1	1	3	.	.	.
latifrons (Brady)			.	.	.	.	.	1	1	1	.	.	.
Vaginulina elegans d'Orbigny			.	1	.	1	1	.	.	1	1	.	.
Marginulina subbullata Hantken			.	.	.	1	.	.	.	.	.	.	.
sp.			.	.	.	.	.	.	1	.	.	.	.
Dentalina guttifera (d'Orbigny)			.	.	.	.	.	.	.	1	.	.	.
soluta Reuss			.	1	.	1	.	.	.	.	.	.	.
subsoluta (Cushman)			.	.	.	.	1	.	1	.	.	.	.
substrigata Stache			.	.	.	1	.	.	.	.	1	.	.
Nodosaria lamulifera Boomgaart			.	2	.	.	.	.	.	.	.	.	.
longiscata d'Orbigny			.	.	.	.	.	.	.	1	1	.	.
Lagenonodosaria hirsuta (d'Orbigny)			2	4	3	4	1	3	1	4	4	.	.
sp., (smooth)			1	3	.	4	.	4	4	1	4	1	.
Stilestomella antipoda (Stache)			.	.	.	.	.	1	4	2	.	.	.
Rectoglandulina torrida (Cushman)			1	.	1	.	.	1	1	1	.	.	.
Lagena laevis (Montagu)			3	.	.	.	.	.	1	1	1	.	.
striata (d'Orbigny)			1	1	1	3	.	1	1	1	1	.	.
sulcata (Walker & Jacob)			1	.	.	1	1	1	1	1	1	.	1
Oolina globosa (Montagu)			1	.	1	2	.	.	.	.	.	.	.
hexagona (Williamson)			2	1	.	4	1	1	1	1	1	.	.
meloe d'Orbigny			4	.	2	.	.	.	.	.	2	2	1
Fissurina marginata (Walker & Boys)			2	.	.	.	1	1	3	2	1	.	.
marginata-perforata (Sequenza)			.	.	.	.	.	.	.	1	.	.	.
orbignyana (Sequenza)			1	.	.	.	.	.	.	.	.	.	.
submarginata (Boomgaart)			.	.	1	1	.	.	.	.	1	.	.
Parafrondicularia pellucida (Finlay)			.	.	.	1	1	3	1	3	.	.	.
wairarapa Vella			.	.	1	.	.	1	1	.	.	.	.
Family POLYMORPHINIDAE													
Guttulina yabei Cushman & Ozawa			1	.	.	.	.	.	.	1	.	.	.
Sigmomorphina lacrimosa Vella			2	.	.	.	.	.	.	.	.	.	.
rhomboidalis Vella			1	.	.	.	.	.	.	.	.	.	.
Globulina cf. guttula Reuss			.	1	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 15, PART 2

TABLE 15, PART 2		PUTARA SECTION							NGAMATA STREAM SECTION				
DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	U.Tt		Wo					U.Tt		Wo	
		Fossil No.	F1176	F1177	F1178	F1179	F1180	F1181	F1182	F1183	F1173	F1174	F1175
Family BULMINIDAE													
Bulimina aculeata d'Orbigny			.	.	1	1	1	1	4		1	1	.
cf. striata d'Orbigny, (small var.)			.	.	2	4	4	4	4		.	.	.
Globobulimina pacifica Cushman			.	.	.	.	.	.	3	.	.	.	.
Virgulina vella Kennett			.	.	.	.	.	4	4	.	.	.	.
rotundata Parr			.	.	.	.	.	.	.	1	.	.	.
Neouvigerina bellula Vella			.	.	.	.	.	.	.	1	.	.	.
Hofkeruva lutorum Vella			.	4	1	4	4	4	4	4	.	.	.
zeacuminata Vella			.	.	.	.	.	.	.	.	4	.	.
sp.			.	.	.	.	.	.	.	.	.	1	.
Trifarina bradyi Cushman			4	4	.	1	.	.	.	2	4	1	.
Bolivina affiliata Finlay			.	.	.	.	1	4	4	.	1	.	.
albatrossi Cushman			.	.	.	.	.	.	.	4	.	.	.
fyfei Hornibrook			1	.	.	.	.	.	.	.	.	.	.
Bolivina numerosa Vella			2	.	.	.	4	1	.	.	1	.	.
petiae Gibson			3	2	1	3	1	4	4	1	4	.	.
plicatella Cushman			2	.	.	.	.	.	.	.	.	.	.
watti Gibson			.	1	.	.	.	2	4	4	.	.	.
n.sp. cf. striatula Cushman			.	.	.	.	.	.	.	4	.	.	.
Rectobolovina striatula (Cushman)			4	1	4	4	.	4	1	1	1	.	.
Virgulopsis sp.			.	.	.	.	1	.	.	.	.	.	.
Family HETEROHELICIDAE													
Bolivinina pliozea Finlay			1	4	.	.	4	4	3	.	1	.	.
pohana Finlay			.	.	.	1	2	4	1	4	.	.	.
Plectofrondicularia pohana Finlay			.	.	.	.	.	.	.	.	1	.	.
Family CASSIDULINIDAE													
Cassidulina laevigata d'Orbigny			1	.	.	.	.	.	.	2	.	4	.
neocarinata Thalmann			4	.	1	4	4	4	4	4	4	.	.
subglobosa Brady			.	1	.	1	.	4	4	1	1	4	.
Cassidulinoides orientalis (Cushman)			4	2	4	.	1	4	3	1	2	.	1
Family ELLIPSOIDINIDAE													
Pleurostomella alternans Schwager			.	.	.	.	.	.	.	1	.	.	.
Family CHILOSTOMELLIDAE													
Chilostomella ovoidea Reuss			.	1	.	1	1	3	4	1	.	.	.
Sphaeroidina bulloides d'Orbigny			.	4	.	4	.	1	1	4	3	.	.
Pullenia bulloides (d'Orbigny)			.	1	.	.	.	.	.	.	.	.	.
quinqueloba (Reuss)			.	1	.	1	1	3	1	1	.	.	.
Family NONIONIDAE													
Astrononion vadorum Vella			1	.	.	.	.	.	.	.	1	.	.
Pacinenion parki (Hornibrook)			4	1	4	4	4	4	4	4	4	1	1
Melonis lutorum Vella			.	.	.	.	.	.	.	4	.	.	.
cf. tuberculatum (d'Orbigny)			.	.	.	.	.	.	.	.	.	1	1
Nonionella magnalingua Finlay			.	.	.	1	.	.	1	.	.	.	.
zenitens Finlay			.	.	.	1	.	.	.	.	.	.	.
Florilus deceptrix (Hornibrook)			.	.	.	1	.	.	.	.	.	.	.
flemingi (Vella)			4	.	3	.	1	4	3	.	4	4	4
Zeafflorilus parri (Cushman)			.	3	.	.	.	.	.	.	.	4	4
cf. stachei (Cushman)			1	.	.	.	.	.	.	.	.	.	.
Family DISCORBIIDAE													
Patellinella inconspicua (Brady)			1	1	.	.	.	.	.	.	.	.	.
Rosalina bradyi (Cushman)			.	.	.	.	.	.	.	.	.	1	.
Gavelinopsis lobatulus (Parr)			4	.	4	.	.	.	.	.	4	1	.
Discopulvinulina bertheletti (d'Orbigny)			1	1	.	1	.	3	4	3	4	1	.
cf. opima Cushman			.	.	.	.	.	1	.	.	.	.	.
sp.			.	.	.	.	.	1	.	.	.	.	.
Gyroidinoides neosoldanii (Bretzen)			.	.	.	.	1	.	3	1	.	.	.
zelandica (Finlay)			4	.	.	.	.	.	.	.	4	.	.
Discorbinella cf. complanata (Sidebottom)			1	.	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 15, PART 3

TABLE 15, PART 3		PUTARA SECTION						NGAMAIA STREAM SECTION					
DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	U.Tt		Wo				U.Tt		Wo		
			f1176	f1177	f1178	f1179	f1180	f1181	f1182	f1183	f1173	f1174	f1175
Laticarinina pauperata (Parker & Jones)			.	1	.	.	.	.	.	1	.	.	.
Canceris laevinflatus Hornibrook			.	.	.	.	.	.	1	1	.	.	.
Family EPISTOMINIDAE													
Epistominella iota Hornibrook			.	.	1	.	.	1	4	4	.	.	.
Höglundina elegans (d'Orbigny)			.	.	.	.	4	4	3	1	.	.	.
Pseudoeponides prominula (Stache)			.	1	.	2	2	4	4	2	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 16, PART 3.

		WAIPIATIKI STREAM SECTION												MANGAPIKA STREAM SECTION																																																
DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	Tk												Wo												Tk												Wo												Wo?											
		Fossil No.	f1029	f1030	f1031	f1032	f1033	f1034	f1035	f1036	f1037	f1038	f1039	f1040	f1041	f1042	f1043	f1044	f1045	f1046	f1047	f1048	f1049	f1050	f1051	f1052	f1053	f1054	f1055																																	
Family ELPHIDIIDAE																																																														
Elphidium cf. chapmani Cushman														1																																																
charlottensis (Vella)			3	1	1	3				1		1	2	1										1	1	2	3	1	1	1																																
Netorotalia cf. depressa Vella			4	4	1		1																																																							
hurapiensis Vella			4		4	4	4							1	1																																															
aff. taranakia Vella, (reticulate ornament)						4	4	4	4	1	4	4	4	4	4	4							1	1	3	4		4	4																																	
Family GLOBIGERINIDAE																																																														
Globigerina bulloides d'Orbigny													1										1																																							
autertrei d'Orbigny															1									1																																						
falconensis Blow							1																						1																																	
pachyderma (Ehrenberg)						1	2	3	4	2	2	1		2	2	4																																														
parabulloides Blow						1	1	3		1	2		2	2	4	3																																														
praebulloides Blow						1																	3						1																																	
quinqueloba Natland						4		2		1			1		3	3																																														
woodi Jenkins																							1	1																																						
zealandica Hornibrook													1										1	4	1	4	1	3		1																																
Orbulina suturalis Bronnimann							1																																																							
universa d'Orbigny						1	1							1	1																																															
universa d'Orbigny, (bilobed var.)																																																														
*	Globorotalia conomiozea Kennett					1	1	1		3			4	2																																																
*	crassaformis (Galloway & Wissler)													4																																																
	hirsuta (d'Orbigny)																																																													
*	miozea Finlay		1																																																											
	scitula (Brady)																																																													
Family ANOMALINIDAE																																																														
Anomalinoidea parvumbilia (Finlay)						1	3	2	1	4	4	4	4	4	4	1																																														
spherica (Finlay)						4	1	4	4	2		4	4	4	4																																															
Cibicides deliquatus Finlay						4	3	4	1	4	3	4	4	4	4	4																																														
finlayi Gibson														1																																																
gibsoni Kennett											2																																																			
molestus Hornibrook			1		1		1		1	2	4	4	3	4																																																
n.sp. aff. deliquatus Finlay			1	1																																																										
sp.							1																																																							
Dyocibicides biserialis Cushman & Valentine																																																														
MOLLUSCA																																																														
Nuculana sp.																		X																																												
Cucullaea n.sp. (as hamptoni Marwick)																		X																																												
Sectipecten wollastoni (Finlay)																		X																																												
Nemocardium quinarium Marwick																		X																																												
Notocorbula humerosa (Hutton)																		X																																												
Zeacolpus (Stiracolpus) sp.																		X																																												
Polinices huttoni Von Ihering																		X																																												
Baryspira sp.																		X																																												
Comitas aff. onokeana King																		X																																												
OTHER FOSSILS:																																																														
SPONGE SPICULES							1																1				4	4	4																																	
BRYOZOA			2		1																																																									
OSTRACODA			2	1		1		2	1	1			1	1	1																																															
ECHINOID SPINES, (spatangid)			1			1		2	1	1	1	1	2	3	1																																															
ECHINOID SPINES, (not spatangid)			1						1																																																					
FISH TEETH			1			2									1																																															
FISH OTOLITHS												1			1																																															
SEEDS															1																																															

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens; X = present.

TABLE 16, PART 1.

FILE 16, PART 1.

		WAIPATIKI STREAM SECTION										MANGAPUKA STREAM SECTION																	
DISTRIBUTION OF MICROFOSSILS		Stage:	Tk										Wo																
(To accompany Thesis by J.P. Kennett)		Fossil No.																											
FORAMINIFERA			f1029	f1030	f1031	f1032	f1033	f1034	f1035	f1036	f1037	f1038	f1039	f1040	f1041	f1042	f1043	f1044	f1045	f1046	f1047	f1048	f1049	f1050	f1051	f1052	f1053	f1054	f1055
Family TEXTULARIIDAE																													
Belivinosia cubensis (Cushman & Bermudez)						1			1																				
Textularia barnwelli Kennett					2	1			4	2	1	2	1	1	1	1		2	4	2	1	3	2	1	2	1		1	
Haeslerella parri Finlay					4	4	4	4	4	3	4	4	4	4	4	4		2	4	4	4	4	4	4	4	3	4	2	
* Siphotextularia wairoana Finlay															2	1								4		1			
* n.sp. cf. wairoana Finlay						1	1				3	3	3				1			3	1	1							
Family VERNEULINIDAE																								1	1				
Gaudryina kingi Parr																													
Family VALVULINIDAE																													
Martinottiella clarae Gibson							3				1	1	4	2				1		2	4								
Family MILIOLIDAE																													
* Sigmoilopsis zeaserus Vella													1																
Quinqueloculina incisa Vella			3																										
lamarckiana d'Orbigny										1	1	2						1	1	1	4								
pygmaea Reuss													1																
waimoa Kennett										1	1																		
Spiroloculina novezealandica Cushman & Todd									1																				
Biloculina pisum Schlumberger																													
sp.			1																										
Triloculina tricarinata d'Orbigny																							1						
Family LAGENIDAE																													
Robulus calcar (Linnaeus)				1	1	2	3	4	4	4	1	1	4	4	4	4			4	4	4	4	4	4	4	1			
costatus (Fichtel & Moll)											1	1																	
cultratus Montfort																													
loculosus (Stache)								1		1	1	1	1	1	1			1	1	1	2	1	1						
iotus Cushman					1	1																							
Saracenaria angularis Natland																													
italica DeFrance							1		1	1	1	1	1																
latifrons (Brady)					1	1																							
Vaginulina elegans d'Orbigny								1	1				1																
Marginulina subbullata Hantken						1																							
sp.																													
Dentalina soluta Reuss														1															
substrigata Stache														1	1														
Lagenonodosaria hirsuta (d'Orbigny)							1	3	1	3	3	1	4	1	2	1			1	1	4	4	2	2	1	1			
sp., (smooth)							4	3	1	4				1	1	1				2	2	2	1	1	1	1			
Stilostomella antipoda (Stache)							1	1	1	1	1	1	1	1	1				1	1	1	2							
globulifera (Kreuz)																													
sp.																													
Rectoglandulina cf. retundata (Reuss)			1																										
torrida (Cushman)														1								1							
Lagena elongata (Ehrenberg)						1																							
laevis (Montagu)						1	1		1	1				1	1														
sulcata (Walker & Jacob)				1	1	1			1	1				1					1	1					1	1	1	1	
striata (d'Orbigny)					1	1	1		1	1	1		1	1	1				1	1		1	1	1	2	1			
Oolina globosa (Montagu)						1			3	1	1				1				2	1			1	1	1				
hexagona (Williamson)						1	2	1		1	1	1	1	1	1				1	1	1	1	3	2	1	4	2	1	
melo d'Orbigny													1																
Fissurina marginata (Walker & Boys)						1	1	1	1	1	1	1	1	1	1	1			1	1	2		1						
orbignyana (Sequenza)																													
Parafrendicularia pellucida (Finlay)									1																				
wairarapa Vella																													
Proxifrons advena (Cushman)												1	1																
Family POLYMORPHINIDAE																													
Glandulina symmetrica Stache						1						1														1			

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 16, PART 2.

WAIKATIKI STREAM SECTION

MANGAPUKA STREAM SECTION

DISTRIBUTION OF MICROFOSSILS (To accompany Thesis by J.P. Kennett)		Stage:	WAIKATIKI STREAM SECTION										MANGAPUKA STREAM SECTION																
		Fossil No.	Fossil No.										Fossil No.																
Family BULIMINIDAE			f1029	f1030	f1031	f1032	f1033	f1034	f1035	f1036	f1037	f1038	f1039	f1040	f1041	f1042	f1043	f1044	f1045	f1046	f1047	f1048	f1049	f1050	f1051	f1052	f1053	f1054	f1055
Bulimina aculeata d'Orbigny			.	.	.	4	4	4	4	4	3	4	4	4	4	1	4	1	4	4	4	(.)	1	1	1	1	1	3	
cf. striata, (small var.)			.	.	.	.	.	.	.	.	.	.	2	1	1	.	.	.	.	1	1	1	4	1	1	1	1	2	
Glebobulimina pacifica Cushman			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Virgulina vellai Kennett			.	.	1	.	.	2	1	.	1	3	(.)	1	1	.	.	.	3	1	1	1	1	1	1	1	1	.	
sp.			.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Neouvirgerina bellula Vella			.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.	.	1	.	.	
Hofkeruva lutorum Vella			.	.	.	.	.	.	.	.	4	4	4	4	4	.	2	4	4	4	3	4	4	4	4	3	4	.	
rodleyi rodleyi Vella			2	1	1	(.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
zeacuminata Vella			.	.	.	4	4	4	4	4	(.)	.	.	.	.	.	4	4	(.)	.	.	.	.	.	.	.	.	.	
zelamina Vella			.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Trifarina bradyi Cushman			.	.	4	1	1	2	4	4	(.)	1	.	1	.	.	4	.	3	3	(.)	.	.	.	.	.	.	.	
Angulogerina esuriens Hornibrook			.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	1	.	.	
Bolivina affiliata Finlay			.	.	.	.	.	.	.	1	1	.	1	.	.	.	1	1	(.)	.	.	1	1	1	1	2	3	.	
fyfei Hornibrook			.	.	.	.	.	.	.	.	1	1	(.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
numerosa Vella			.	.	3	4	3	1	1	3	4	3	3	4	3	.	4	1	3	1	4	4	4	4	1	4	.	1	
cf. parri Cushman			.	.	3	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
petiae Gibson			1	.	4	4	1	3	4	4	3	2	2	1	2	.	4	4	4	4	4	4	2	4	4	3	4	4	
subspinescens Cushman			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	
watti Gibson			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	.	.	
Rectobolivina striatula (Cushman)			.	.	.	.	.	.	.	1	.	.	.	1	.	.	1	.	1	.	1	.	2	3	3	.	1	.	
Virgulopsis turris (Heron-Allen & Earland)			.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family HETEROHELICIDAE																													
Bolivinina pliozea Finlay			.	.	1	4	4	.	1	3	4	4	2	4	2	.	1	1	2	4	4	4	4	4	1	4	4	4	
pohana Finlay			.	.	1	2	.	1	.	.	.	.	1	.	.	.	.	1	.	3	2	(.)	.	.	.	.	.	.	
n.sp. cf. pohana Finlay, (compressed)			.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	4	(1)	.	4	4	4	4	.	
Family CASSIDULINIDAE																													
Cassidulina laevigata d'Orbigny			.	.	1	.	.	.	1	.	1	(.)	.	.	.	.	.	1	1	1	1	.	1	(.)	.	1	.	.	
neocarinata Thalmann			.	.	4	1	.	4	1	1	.	4	2	4	2	.	1	1	4	.	2	.	1	1	1	1	3	4	
subglobosa Brady			.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Cassidulinoides orientalis (Cushman)			.	.	4	2	4	1	3	2	1	3	1	4	2	.	3	1	1	2	.	2	3	1	1	2	3	1	
Family CHILOSTOMELLIDAE																													
Chilostomella ovoidea Reuss			.	.	.	1	1	.	.	1	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	1	
Sphaeroidina bulloides d'Orbigny			.	.	1	.	1	.	1	1	.	1	1	1	.	.	1	1	.	1	1	.	1	.	1	.	1	2	
Pullenia bulloides (d'Orbigny)			.	.	.	.	.	1	.	1	1	(.)	.	.	.	.	.	1	1	2	.	1	.	1	.	.	.	.	
quinqueloba (Reuss)			.	.	1	.	.	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	1	.	2	.	1	1	
Family NONIONIDAE																													
Astrononion vadorum Vella			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Pacinonion parki (Hornibrook)			1	1	1	4	2	3	2	2	4	1	4	3	1	4	4	3	4	4	3	3	4	2	4	4	4	4	
Melonis simplex (Karrer)			1	1	(.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
zeobes Vella			.	.	.	2	.	4	2	4	4	(.)	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	
Nonionella magnalingua Finlay			.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	1	.	.	.	1	.	1	.	.	
zenitens Finlay			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Florilus deceptrix (Hornibrook)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
flemingi (Vella)			1	.	1	3	1	.	4	.	4	4	(1)	.	1	.	2	4	4	4	(.)	1	2	(.)	1	1	1	2	
Zeafloerilus parri (Cushman)			.	4	.	.	1	1	4	.	.	1	3	.	1	.	1	1	.	1	1	.	.	.	.	.	.	.	
Family DISCORBIIDAE																													
Patellinella inconspicua (Brady)			.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	
Gavelinopsis lobatulus (Parr)			.	.	1	2	.	.	.	1	1	.	.	.	.	.	1	4	1	1	.	2	2	1	.	.	1	.	
Discopulvinulina berthelotti (d'Orbigny)			.	.	1	.	.	.	.	1	1	1	.	1	.	.	1	.	1	.	1	1	1	.	.	.	1	.	
Gyroidinoides neosoldanii (Bretzen)			1	1	(.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
zelandica (Finlay)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family EPISTOMINIDAE																													
Epistominella iota Hornibrook			.	1	.	1	4	4	4	4	4	4	4	4	4	.	4	1	4	4	4	4	4	4	4	4	4	4	
Höglundina elegans (d'Orbigny)			.	.	1	1	4	3	.	.	2	4	4	3	.	.	.	1	4	2	1	1	1	1	(.)	.	.	.	
Pseudoeponides prominula (Stache)			.	.	1	.	2	.	1	.	2	4	2	1	.	.	.	1	1	1	.	.	1	1	2	1	4	.	
tenera (Brady)			.	.	.	.	2	.	1	1	1	.	1	2	1	.	1	.	1	3	1	.	.	.	.	.	1	.	

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 17, PART 2

MARATOTARA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt	U.Tt	Wo											
(To accompany Thesis by J.P. Kennett)		Fossil No.	1561	1562	1563	1564	1565	1566	1567	1568	1569	1570	1571	1572	1573	1574
Family LAGENIDAE																
Rebulus calcar (Linnaeus)			.	.	.	.	.	.	.	.	.	2	1	4	2	4
aff. calcar (Linnaeus)			1	.	.	.	.	.	.	.	.	.	.	.	.	.
cultratus Montfort			1	.	2	.	.	1	1	.	.	.	.	.	.	.
dicampylus (Franzenau)			3	1	1	.	.	.	.	.	.	.	.	.	.	.
gyroscalprus (Stache)			.	.	.	2	.	.	.	.	.	.	.	.	.	.
iotus Cushman			1	.	1	.	.	.	.	.	.	.	.	.	.	.
loculosus (Stache)			.	1	1	1	.	.	.	1	1	.	.	.	1	.
orbicularis (d'Orbigny)			.	.	2	.	.	.	.	.	.	.	.	.	.	.
sp.			.	.	.	1	1	.	.	.	.	.	.	.	.	1
Lenticulina cf. gibba (d'Orbigny)			.	.	1	.	.	.	.	.	.	.	.	.	.	.
mammiligera (Karrer)			.	.	.	1	.	.	.	.	.	.	.	.	.	.
peregrina (Schwager)			.	.	1	1	.	.	.	.	.	.	.	.	.	.
Saracenaria italica DeFrance			1	.	1	1	.	.	.	.	.	.	.	.	.	.
latifrons (Brady)			.	.	1	.	.	.	.	.	.	.	.	.	.	1
Marginulinopsis sp.			.	.	1	.	.	.	.	.	.	.	.	.	.	.
Vaginulina elegans d'Orbigny			.	.	.	.	1	1	.	1	.	.	.	.	.	1
cf. patens Brady			.	.	.	.	.	.	.	.	.	.	.	.	1	1
vagina (Stache)			.	.	1	.	.	.	.	.	.	.	.	.	.	.
sp.			.	.	.	.	.	1	1	1	1	.	.	.	.	.
Marginulina subbullata Hantken			.	1	.	.	.	.	.	.	.	.	.	.	.	.
Dentalina guttifera (d'Orbigny)			.	.	.	.	.	.	.	.	.	.	.	.	.	1
soluta Reuss			1	.	1	.	.	1	.	.	.	.	.	.	.	1
substrigata Stache			.	.	.	.	.	.	.	.	.	.	.	.	.	1
sp.			1	.	.	.	.	.	.	.	.	.	.	.	.	.
Nodosaria holoserica Schwager			.	1	.	.	1	.	1	1	.	.	.	.	.	1
longiscata d'Orbigny			1	4	1	1	4	1	2	3	4	.	.	.	.	1
Lagenonodosaria hirsuta (d'Orbigny)			1	.	.	1	1	1	1	.	1	1	.	.	.	2
scalaris (Batsch)			.	.	.	.	.	1	1	1	.	1	1	.	.	.
sp., (smooth)			.	.	.	1	.	1	.	.	.	.	2	1	2	.
Chrysologonium striatissimum (Stache)			.	1	.	.	.	.	.	.	.	.	.	.	.	.
Stilestomella antipoda (Stache)			1	.	4	4	.	1	.	.	1	.	.	.	.	.
globulifera (Kreuz)			1	3	1	1	1	.	.	.	.	.	.	.	.	.
spp.			.	.	.	1	4	.	2	.	.	.	.	.	.	1
Rectoglandulina cf. rotundata (Reuss)			1	1	1	.	.	.	.	.	.	.	.	.	.	.
Lagena distoma Parker & Jones			.	1	1	.	1	.	.	.	.	.	.	.	1	.
hispidula Cushman			.	.	.	.	.	.	.	.	.	.	.	.	.	1
laevis (Montagu)			.	.	.	.	.	1	1	.	.	.	3	.	1	.
striata (d'Orbigny)			.	.	.	.	.	1	.	.	1	.	1	1	.	.
sulcata (Walker & Jacob)			.	1	1	1	1	1	.	1	.	4	3	.	.	.
Oolina globosa (Montagu)			.	.	.	1	.	.	.	.	.	.	.	.	.	.
hexagona (Williamson)			.	.	.	.	.	.	.	.	.	.	1	1	2	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 17, PART 1

MARAEOTOTARA RIVER SECTION

DISTRIBUTION		Stage:	M.Tt	U.Tt	Wo									
(To accompany Thesis by J.P. Kennett)		Fossil No.	1563	1564	1565	1566	1567	1568	1569	1570	1571	1572	1573	1574
FORAMINIFERA														
Family REOPHACIDAE														
Reophax aff. cylindricus Brady			.	.	2	.	.	.	.	.	.	.	.	.
Family TEXTULARIIDAE														
Bolivinopsis cubensis (Cushman & Bermudez)			.	.	.	1	.	1	.	.	1	.	.	.
Textularia barnwelli Kennett			.	.	.	.	.	.	.	.	.	.	1	.
subrhombica Stache			2	1	1	1	1	.	.	.	.	.	.	.
cf. sagittula DeFrance			.	.	.	.	.	.	.	.	.	3	.	.
sp.			1	.	.	.	.	.	.	.	.	.	.	.
Haeslerella finlayi Vella			2	1	4	.	.	.	.	.	.	.	.	.
morgani (Chapman)			.	4	4	4	4	2	.	.	.	3	2	.
parri Finlay			4	.	.	.	.	3	.	1	1	.	.	4
Siphonotextularia awamoana Finlay			.	.	1	.	.	.	.	.	.	.	.	.
ihungia Finlay			2	2	4	1	1	.	.	.	1	.	.	.
subcylindrica Finlay			.	1	1	2	4	.	.	.	.	.	.	.
n.sp. cf. wairoana Finlay			.	.	.	.	.	.	.	.	.	4	4	3
Vulvulina pennatula (Batsch)			.	1	.	1	.	.	.	.	1	.	.	.
Family VERNEUILINIDAE														
Gaudryina convexa (Karrer)			.	.	.	.	.	.	.	.	.	4	.	.
kingi Parr			1	.	1	2	1	.	.	.	.	.	.	.
Family VALVULINIDAE														
Eggerella bradyi (Cushman)			.	.	4	.	.	.	.	.	.	.	.	.
Karrerella bradyi (Cushman)			4	3	4	4	.	1	.	.	.	.	.	.
cylindrica Finlay			4	4	4	4	4	4	1	2	4	.	.	.
n.sp.			.	.	1	2	.	.	.	.	.	.	.	.
Arenodosaria n.sp.			.	.	2	1	.	.	.	.	.	.	.	.
Martinottiella clarae Gibson			.	.	.	.	.	3	.	1	1	.	.	1
massami Gibson			2	4	1	1	4	1	.	.	.	.	.	.
Family LITUOLIDAE														
Haplophragmoides cf. canariensis (d'Orbigny)			.	.	3	.	.	.	.	.	.	.	.	.
Cyclammina medwayensis Parr			.	.	1	.	.	.	.	.	.	.	.	.
Family MILIOLIDAE														
Sigmoilopsis gavini Gibson			.	3	3	3	2	.	.	.	.	.	.	.
schlumbergeri (Silvestri)			4	4	4	4	4	.	1	2	1	1	.	1
Quinqueloculina kapitensis Vella			1	1	.	1	1	.	.	.	.	.	.	.
triangularis d'Orbigny			.	.	.	1	.	.	.	.	.	.	.	.
Massilina subaequalis (Parr)			.	2	1	.	.	.	.	.	.	.	.	.
Spiroloculina canaliculata d'Orbigny			.	.	1	.	.	.	.	.	.	.	.	.
kennetti Gibson			.	1	1	.	.	.	.	.	.	.	.	.
novezealandica Cushman & Todd			1	.	.	.	1	.	.	.	.	.	.	.
Biloculina cf. anomala Schlumberger			.	.	.	1	.	.	.	.	.	.	.	.
Pyrgo murrhyna (Schwager)			1	1	1	2	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 17, PART 6.

MARATOTARA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt		U.Tt						Wo			
(To accompany Thesis by J.P. Kennett)		Fossil No.	f563	f564	f565	f566	f567	f568	f569	f570	f571	f572	f573	f574
Globigerina woodi Jenkins			2	1	1	.	2	1	1	2	.	2	3	4
sealandica Hornibrook			.	.	.	.	.	1	.	.	.	.	4	.
app. indet.			.	4	4	.	.	.	.	.	.	2	.	.
Globigerinoides obliqua Bolli			.	.	.	.	.	.	.	.	.	1	1	3
trilobus immaturis Le Roy			.	.	2	1	.	.	.	.	.	.	.	.
trilobus sacculifera (Brady)			.	.	.	.	1	.	.	.	.	.	1	.
trilobus trilobus (Rouss)			1	4	4	2	1	.	.	.	.	1	.	2
Orbulina suturalis Bronnimann			.	.	.	.	.	1	1	.	.	.	.	1
universa d'Orbigny			4	4	4	4	4	2	1	1	1	1	1	1
Sphaerodinaella seminulina (Schwager)			.	1	1	2	.	.	.	.	.	.	.	1
Globoquadrina altispira globosa Bolli			.	.	.	.	.	1	.	.	.	.	.	.
Globorotalia conomiozea Kennett			.	.	.	.	.	.	.	.	.	4	4	4
crassaformis (Galloway & Wissler)			.	.	.	.	.	.	.	.	.	4	4	4
inflata (d'Orbigny)			.	.	.	.	.	.	.	.	.	.	4	.
menardii panda Jenkins			1	.	.	.	.	.	.	.	.	.	.	.
miozea Finlay			4	4	4	4	4	4	4	4	4	.	.	.
scitula (Brady)			2	1	1	1	.	4	1	.	4	1	1	1
Family ANOMALINIDAE														
Anomalinoidea parvumbilica (Finlay)			4	.	4	4	4	1	1	1	1	1	2	4
Cibicides deliquatus Finlay			1	2	.	4	4	4	4	4	4	.	4	4
finlayi Gibson			1	2	3	1	1	2	2	2	.	.	1	.
molestus Hornibrook			3	4	4	4	4	2	1	4	4	.	1	4
praecinctus (Karrer)			.	.	.	.	.	.	.	.	.	.	1	.
pseudoeungarianus (Cushman)			4	4	4	4	4	.	.	.	.	.	.	.
refulgens Montfort			.	.	.	.	.	.	.	.	.	1	.	.
robertsonianus (Brady)			.	1	4	1	.	.	.	.	.	.	.	.
thiaraeuta Hornibrook			.	4	4	.	.	.	.	.	.	.	.	.
n.sp. aff. deliquatus Finlay			.	.	.	.	.	.	.	.	.	4	4	3
Dycibicides biserialis Cushman & Valentine			.	.	1	.	.	.	.	.	.	3	3	2
Panulina cf. ariminensis d'Orbigny			1	.	.	.	.	.	.	.	.	.	.	.
OTHER FOSSILS:														
RADIOLARIA			.	.	.	.	.	4	4	4	4	.	.	.
SPONGE SPICULES			.	.	.	.	.	3	4	4	4	.	.	1
"LEPTODERMELLA"			.	.	.	.	.	4	4	4	4	.	.	.
ECHINOID SPINES, (spatangid)			1	.	1	.	.	.	.	1	.	.	4	4
BRYOZOA			.	.	.	.	.	.	.	.	.	1	.	.
OSTRACODA			.	1	1	.	.	1	.	.	.	4	4	4
FISH OTOLITHS			1	.	1	1	.	.	.	1	.	.	.	.
FISH TEETH			1	1	.	1	1	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 17, PART 4.

MARATOTARA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt		U.Tt							Wo		
(To accompany Thesis by J.P. Kennett)		Fossil No.	f563	f564	f565	f566	f567	f568	f569	f570	f571	f572	f573	f574
Bolivina numerosa Vella			.	.	.	.	.	.	.	1	.	.	4	4
petiae Gibson			.	.	.	.	.	.	.	.	.	.	4	4
plicatella Cushman			.	.	.	.	.	.	.	.	.	1	4	4
silvestrina Cushman			.	.	.	.	.	.	.	.	.	3	2	3
watti Gibson			.	.	1	2	3	.	.	1	.	1	.	.
sp.			.	.	.	.	.	.	.	.	.	.	.	1
Rectobolivina maoria Finlay			.	.	.	1	.	.	.	.	.	.	1	.
striatula (Cushman)			.	.	.	.	.	.	.	.	.	3	2	4
Family HETEROHELICIDAE														
Bolivinina compressa Finlay			.	.	4	4	2	1	4	4	2	.	.	.
elegantissima Boomgaart			1	.	.	4	.	.	.	.	.	.	.	.
pohana Finlay			4	4	4	4	4	4	4	1	4	1	.	4
Plectofrondicularia pohana Finlay			4	4	2	4	2	1	2	1	1	.	1	1
Family CASSIDULINIDAE														
Cassidulina neocarinata Thalmann			.	.	.	.	.	1	.	.	.	3	1	4
pacifica Cushman			.	.	.	.	.	.	.	.	.	.	.	1
subglobosa Brady			.	.	.	.	.	.	.	.	.	.	.	1
Cassidulinoides orientalis (Cushman)			.	.	.	1	.	.	.	.	.	4	4	4
Ehrenbergina mestayeri Cushman			.	.	.	.	.	.	.	.	.	2	1	1
Family ELLIPSOIDINIDAE														
Pleurestomella acuminata Cushman			.	.	4	.	.	.	2	1	2	.	.	.
cf. acuminata Cushman			.	1	.	.	.	.	.	.	.	.	.	.
alternans Schwager			4	4	.	4	1	.	.	.	.	.	1	1
Family CHILOSTOMELLIDAE														
Chilostomella colina Schwager			.	1	1	3	1	.	.	.	.	.	.	.
ovoidea Reuss			.	.	.	.	.	.	.	.	.	.	.	1
Sphaeroidina bulloides d'Orbigny			4	.	2	4	4	2	1	2	1	.	1	1
Pullenia bulloides (d'Orbigny)			4	2	4	1	1	1	3	2	1	.	.	1
cf. multilobata Chapman			.	.	1	.	.	.	.	.	.	.	.	.
quadriloba Reuss			2	1	1	1	.	.	.	.	.	.	.	.
quinqueloba (d'Orbigny)			.	.	.	.	.	1	.	.	.	1	1	1
Family NONIONIDAE														
Astrononion vadorum Vella			.	.	.	.	.	.	.	.	.	.	.	1
Pacilonion neefi Vella			1	1	4	4	1	1	.	.	1	.	.	.
parki (Hornibrook)			.	.	.	1	1	.	.	2	4	4	4	.
Melonis zeobesus Vella			1	.	.	.	.	.	.	.	.	.	.	.
Nonionella magnalingua Finlay			.	.	.	2	1	.	.	.	.	.	.	.
zenitens Finlay			.	1	1	1	.	.	.	.	.	.	.	.
Florilus flemingi (Vella)			.	.	.	.	1	.	.	.	.	4	4	1
Zeafiorilus parri (Cushman)			.	.	.	.	.	.	.	.	.	1	.	1
Family DISCORBIIDAE														
Spirillina denticulata Brady			1	.	.	.	.	.	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 17, PART 3.

MARATOTARA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt	U.Tt	Wo
(To accompany Thesis by J.P. Kennett)	Fossil No.		1563 1564	1565 1566 1567 1568 1569 1570 1571	1572 1573 1574
<i>Oolina mele</i> d'Orbigny			..	..	1 4
<i>Fissurina marginata</i> (Walker & Boys)			4 3	2 3 4 1 1 1 1	.. 4 .
<i>tricaudata</i> Silvestri			..	.. 1 ..	.. ..
<i>sp.</i>			.. 4	.. ..	4 4 4
<i>Parafrondicularia pellucida</i> (Finlay)			..		1 1 2
<i>wairarapa</i> Vella			..	 1 . 1	.. 1 1
<i>Proxifrons advena</i> (Cushman)			3 2	4 4 3 . . 1	.. ..
<i>Awhea sinalata</i> (Finlay)			.. 1	1 1	.. ..
<i>subtetragona</i> (Finlay)			1 1	1 1	.. ..
Family POLYMRPHINIDAE					
<i>Guttulina bartschi</i> Cushman & Ozawa			..		1 1
<i>Glandulina symmetrica</i> Stache			..	1 1 . . . .	.. ..
<i>Ellipsoglandulina subconica</i> (Kienz)			1 1	1 1 1 . 1 1	.. ..
<i>Sigmoidella elegantissima</i> (Parker & Jones)			..		.. 1 .
Family BULIMINIDAE					
<i>Bulimina aculeata</i> d'Orbigny			..		1 2 4
<i>mapiria</i> Finlay			..	 4 2	.. ..
<i>pupoides</i> d'Orbigny			.. 3	2 . . . . .	.. ..
<i>pyrula</i> d'Orbigny, var. <i>spinescens</i> Brady			1 2	4 . . . . .	.. ..
<i>senta</i> Finlay			2 2	.. ..	.. ..
<i>cf. striata</i> d'Orbigny, (large var.)			4 4	4 4 4 1 3 2 2	.. ..
<i>cf. striata</i> d'Orbigny, (small var.)			..	.. 1 1	.. 4
<i>truncanella</i> Finlay			.. 1	.. ..	.. ..
<i>Globobulimina pacifica</i> Cushman			..	1 1 . . . .	.. ..
<i>Virgulina bradyi</i> Cushman			.. 2	1 1 1 . . . .	.. ..
<i>vellai</i> Kennett			..	 1 . . 1	.. ..
<i>Neouvigerina ekotahuna</i> Vella			4 4	4 4 4 4 1 4 4	1 3 .
<i>vadescens</i> (Cushman)			.. 4	3 2 4	1 1 4
<i>Hofkeruva lutorum</i> Vella			4 4	3 1 4 4 4 4 4	.. ..
<i>mioschwageri</i> (Finlay)			4 .	1 . . . . .	.. ..
<i>rodleyi tubemoides</i> Vella			..		4 4 4
<i>zeacuminata</i> Vella			2 4	2 4 4 . . . .	.. ..
<i>Rectuvigerina pohana</i> (Finlay)			.. 1	.. 1 2 . . . .	.. ..
<i>sp.</i>			..		1 . .
<i>Trifarina bradyi</i> Cushman			..	 1 . . .	4 4 4
<i>Angulogerina cf. angulosa</i> (Williamson)			..		.. 1 .
<i>esuriens</i> Hornibrook			..	4 . . 1 . . 1	.. ..
<i>Bolivina cf. acerosa</i> Cushman			..		.. 1 .
<i>affiliata</i> Finlay			4 1	4 . 2 1 . . .	.. 1 4
<i>albatrossi</i> Cushman			4 4	.. 4 4 . . . 1	.. ..
<i>barnwelli</i> Finlay			..	 1 1 . .	.. 4
<i>lapseus</i> Finlay			4 .	4 4 4 . . . 1	.. ..

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 17, PART 5.

MARATOTARA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	M.Tt										U.Tt	Wo		
(To accompany Thesis by J.P. Kennett)	Fossil No.		f563	f564	f565	f566	f567	f568	f569	f570	f571	f572	f573	f574		
<i>Discorbis</i> n.sp. aff. <i>umbonifer</i> Parr			1	1	1	1	1	1	1	1	1	1	1	1		
<i>Rosalina bradyi</i> (Cushman)			..	..	..	..	..	..	..	..	..	..	..	1	..	
<i>pauperques</i> Vella			..	..	..	..	..	..	..	..	..	..	..	1	1	
<i>Gavelinopsis hamatus</i> Vella			..	..	..	..	..	..	..	..	..	..	..	2	1	..
<i>Discopulvinulina bertheletti</i> (d'Orbigny)			..	..	..	..	..	..	..	..	..	..	..	1	3	4
<i>Valvulineria stachei</i> Hornibrook			..	..	2	1	..	..	..	..	..	..	..	..	..	..
<i>Osangularia bengalensis</i> (Schwager)			4	4	4	4	1	..	..	..	..	..	..	..	..	..
<i>Gyroldinoides neosoldanii</i> (Brotzen)			1	4	4	4	3	1	1	1	2	..	..	..	..	..
<i>zelandica</i> (Finlay)			..	..	..	1	..	..	..	1	4	4	4	..	..	..
<i>Discorbinella</i> cf. <i>complanata</i> (Sidebottom)			..	..	..	..	..	..	..	..	..	1	1	..	..	..
<i>rarescens</i> (Brady)			..	..	..	..	..	..	..	..	..	1	..	..	..	..
n.sp.			..	3	2	..	..	..	..	..	..	..	..	..	..	..
<i>Parvicarinina altocamerata</i> (Heron-Allan & Earland)			1	1	..	1	..	..	..	..	..	..	..	..	..	..
<i>Laticarinina pauperata</i> (Parker & Jones)			2	3	4	3	4	2	3	2	1	1	1	..	..	..
<i>Baggina</i> n.sp. cf. <i>amplus</i> (Finlay), (smaller, 4 chambers in adult whorl)			..	..	..	..	..	..	..	..	..	..	..	..	1	..
Family EPISTOMINIDAE																
<i>Hoglundina elegans</i> (d'Orbigny)			1	3	3	2	..	1	..	..	..	..	..	..	..	..
<i>Alabamina tenuimarginata</i> (Chapman, Parr & Collins)			..	..	1	1	..	..	..	..	..	..	..	..	..	..
<i>Pseudoeponides prominula</i> (Stache)			..	..	..	1	..	..	..	1	..	..	..	..	..	..
<i>tenera</i> (Brady)			1	1	..	1	..	..	1	1	..	..	1	..	..	..
cf. <i>umbonatus</i> (Reuss)			..	..	2	..	..	..	..	..	..	..	..	..	..	..
Family GERATOBULIMINIDAE																
<i>Ceratobulimina kellumi</i> Finlay			2	..	3	..	..	..	..	..	..	..	..	..	..	..
Family ELPHIDIIDAE																
<i>Elphidium</i> cf. <i>advenum</i> (Cushman)			..	..	..	..	..	..	..	..	..	..	..	1	..	..
<i>charlottensis</i> (Vella)			..	..	..	..	..	..	..	1	..	..	1	..	..	..
<i>crispum</i> (Linnaeus)			..	..	..	..	..	..	..	..	..	..	..	..	1	..
<i>Notoretalia hurupiensis</i> Vella X <i>finlayi</i> Vella			..	..	..	..	..	..	..	..	..	..	..	4	4	4
<i>olsoni</i> Vella			..	..	..	..	..	..	..	..	..	..	..	1	1	..
<i>pliozea</i> Vella			..	..	..	..	..	..	..	..	..	..	..	..	4	..
<i>taranakia</i> Vella			4	4	4	4	..	..	..	..	..	..	..	..	..	..
aff. <i>taranakia</i> Vella, (reticulate ornament)			1	..	4	4	4	2	2	3	3	..	..	..	..	..
Family GLOBIGERINIDAE																
<i>Globigerinella</i> cf. <i>aequilateralis</i> (Brady)			..	..	..	1	..	..	..	..	..	..	..	..	..	..
sp.			..	1	..	..	..	..	..	..	..	..	..	..	..	..
<i>Globigerina bulloides</i> d'Orbigny			1	..	..	1	..	..	..	..	..	..	..	..	..	..
<i>falconensis</i> Blow			..	..	..	1	3	..	..	..	..	2	..	..	..	..
<i>nepenthes</i> Todd			2	1	..	1	2	..	..	..	..	..	..	..	..	..
<i>pachyderma</i> (Ehrenberg)			1	1	..	..	2	2	2	1	4	4	4	..	..	..
<i>parabulloides</i> Blow			..	4	4	4	4	4	4	..	2	4	4	4	..	..
<i>praebulloides</i> Blow			4	4	..	4	4	1	1	..	2	4	3	..	..	..
<i>quinqueloba</i> Natland			..	..	2	..	4	4	1	1	3	..	2	..	..	..

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 18, PART 1

WAIMATA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS	Stage:	U.Tt	TK	Wo								
(To accompany Thesis by J.P. Kennett)	Fossil No.	f523	f524	f525	f526	f527	f528	f529	f530	f531	f532	f533
FORAMINIFERA												
Family RHIZAMMINIDAE												
Rhizammina sp.		.	.	.	.	1	.	.	.	.	.	.
Family LITUOLIDAE												
Haplophramoides cf. canariensis (d'Orbigny)		.	.	.	.	4	.	4	2	.	.	.
Family TEXTULARIIDAE												
Bolivinaopsis cubensis (Cushman & Bermudez)		.	1	1	.	.	.	.	.	.	1	1
Textularia subrhombica Stache		.	1	.	.	.	.	.	.	.	.	.
n.sp. cf. fistulosa Brady		1	1	.	.	.	.	.	.	.	.	.
cf. sagittula DeFrance		1	2	.	.	.	.	.	.	.	.	.
Haeslerella morgani (Chapman)		4	4	3	.	1	.	4	.	3	.	.
parri Finlay		.	.	.	.	4	.	4	.	.	3	.
pliocenica (Finlay)		.	.	.	.	.	.	.	.	4	.	.
Siphotextularia ihungia Finlay		1	.	.	.	.	.	.	.	.	.	.
kreuzbergi Finlay		.	.	1	.	.	.	.	.	.	.	.
subcylindrica Finlay		.	3	3	.	.	.	.	.	.	.	.
n.sp. cf. wairoana Finlay		1	2	1	.	.	.	.	.	.	.	.
Vulvulina pennatula (Batsch)		1	.	1	.	.	.	.	.	.	.	.
Family VERNEUILINIDAE												
Migros medwayensis (Parr)		.	.	1	.	.	.	.	.	.	.	.
Clavulinoides instar Finlay		1	1	.	.	.	.	.	.	.	.	.
Family VALVULINIDAE												
new genus, n.sp. (as Ruakituria pseudorobusta Kennett in press)		.	1	.	.	.	.	.	.	.	.	.
Karrerella bradyi (Cushman)		1	2	3	1	1	.	.	.	.	.	.
cylindrica Finlay		1	2	3	2	1	.	.	2	3	4	.
n.sp.		.	1	.	.	.	.	.	.	.	.	.
Martinottiella clarae Gibson		.	1	1	.	1	.	1	1	3	.	.
massami Gibson		.	.	1	.	.	.	.	.	.	.	.
Family MILIOLIDAE												
Sigmillopsis gavini Gibson		1	.	.	.	.	.	.	.	.	.	.
schlumbergeri (Silvestri)		2	1	1	2	.	.	.	.	.	.	.
zeaserus Vella		.	.	.	.	.	.	.	.	1	.	.
Miliolinella cf. vigilax Vella		.	1	.	.	.	.	.	.	.	.	.
Quinqueloculina delicatula Vella		.	1	1	.	.	.	.	.	.	.	.
sp.		.	.	1	.	.	.	.	.	.	.	.
Cruciloculina ericsoni Loeblich & Tappan		.	2	.	.	.	.	.	.	.	.	.
Spiroloculina novezealandica Cushman & Todd		.	2	1	.	.	.	.	.	.	.	.
Triloculina trigonula (Lamarck)		.	.	.	.	1	.	.	.	.	.	.
Biloculina cf. anomala Schlumberger		.	1	.	.	.	.	.	.	.	.	.
Family LAGENIDAE												
Rebulus calcar (Linnaeus)		.	1	1	.	.	1	4	2	4	2	3
costatus (Fichtel & Moll)		.	.	.	.	.	.	.	.	.	1	.
cf. cultratus Montfort		.	.	.	.	.	3	.	.	.	.	.
dicampylus (Franzenau)		3	1	2	2	3	.	.	.	.	1	.
gyroscaprus (Stache)		.	.	.	.	1	.	.	2	.	.	.
iotus Cushman		.	.	1	.	1	.	1	.	.	.	.
loculosus (Stache)		.	.	.	.	.	.	1	.	2	1	.
spp.		.	1	1	.	.	.	.	.	.	.	.
Lenticulina mammiligera (Karrer)		.	.	1	.	.	.	.	.	.	.	.
Saracenaria ampla Cushman & Todd		.	1	1	.	.	.	.	.	.	.	.
italica DeFrance		.	.	1	.	.	.	.	1	1	2	.
latifrons (Brady)		1	.	.	.	.	.	1	.	.	.	.
Vaginulinopsis n.sp., (striated)		.	.	2	.	.	.	.	.	.	.	.
n.sp.		.	.	.	.	.	.	1	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 18, PART 2

WAIMATA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	U, Tt	Tk	Wo
(To accompany Thesis by J. P. Kennett)	Fossil No.		f523 f524 f525 f526 f527 f528	f529 f530 f531 f532 f533	
<i>Vaginulina elegans</i> d'Orbigny				1 2 2 3 1	
<i>vagina</i> (Stache)			. 1		
sp.			. . 1 . . .		1
<i>Marginulina</i> sp.					1
<i>Dentalina guttifera</i> (d'Orbigny)			. . 1 1 1 .	. . 1 2 1	
<i>soluta</i> Reuss			. . 1 1 . .	. 1 . 1 .	
<i>substrigata</i> Stache			. 1 1 . . .	. . . 1 1	
cf. <i>substrigata</i> Stache			. . . 1 . .		
spp.			. . 1 . 1 .	. 1	
<i>Nodosaria holoserica</i> Schwager				. . . 1 3	
<i>longiscata</i> d'Orbigny			. 1 1 1 1 .		
spp.			1 1		
<i>Lagenonodosaria hirsuta</i> d'Orbigny			1 1 . . . 1	1 1 1 2 1 1	
<i>scalaris</i> (Batsch)			1 1 1 . . 1	. . . 3 3	
spp.			 1 .		
<i>Stilostomella antipoda</i> (Stache)			. . 1 . . 2	. 3	
<i>globulifera</i> (Kreus)			. . . 1 2 .	. 1	
sp.			. 1 1 . . .	. 1	
<i>Rectoglandulina</i> cf. <i>retundata</i> (Reuss)				. . . 1 .	
<i>Lagena crenata</i> Parker & Jones			1 . 1 . . 1	. . . 1 .	
<i>distoma</i> Parker & Jones			. 1		
<i>hexagona</i> Williamson			1 1 1 . . 1		
<i>laevis</i> (Montagu)			. . 1 1 1 .	. 1	
<i>striata</i> (d'Orbigny)			1 1 1 . 1 1	. 1 . 1 . .	
<i>sulcata</i> (Walker & Jacob)			1 . . . 2 .	2 1 1 . 1	
sp.			1		
<i>Oolina globosa</i> (Montagu)			1		
<i>hexagona</i> (Williamson)			 1 .	. 1 . 1 .	
<i>malo</i> d'Orbigny			 1 1	. 1	
<i>Fissurina marginata</i> (Walker & Jacob)			2 . 1 1 1 1	1 1 . 2 1	
<i>orbignyana</i> (Sequenza)			1 1 . . . 1		
<i>submarginata</i> (Boonstra)			. 1 . 1 . .		
<i>tricaudata</i> Silvestri			. 1		
<i>Parafrondicularia pellucida</i> (Finlay)			. . . 1 . .	. 1 1 . . .	
<i>wairarapa</i> Vella			. 1 1 . . .	. 1 . . 1 1	
<i>Proxifrons advena</i> (Cushman)			. 1 1 . . .	. 1 1 . 2 1	
<i>Awhea sinalata</i> (Finlay)			. 2 1 . 1 .		
Family POLMORPHINIDAE					
<i>Glandulina symmetrica</i> Stache			. . 1 . . .	. . . 1 1	
Family BULMININIDAE					
<i>Buliminella elegantissima</i> (d'Orbigny)			. 1		
<i>Bulimina aculeata</i> d'Orbigny			. 1 . . . 1	. 1	
<i>mapiria</i> Finlay			2 2 2 . 1 .		
<i>pupoides</i> d'Orbigny			 1 .		
<i>senta</i> Finlay			. . 1 . . .		
cf. <i>striata</i> d'Orbigny, (small var.)			3 2 . . . 4	1 4 . 4 3	
cf. <i>striata</i> d'Orbigny, (large var.)			. . 4 1 4 .	. 1 . . . 1	
<i>truncanella</i> Finlay			. 1 1 . . .		
sp.				. . 1 1 .	
<i>Neouvigerina eketahuna</i> Vella			4 4 4 2 . .	. 1	
<i>vadescens</i> (Cushman)			. . 1 . 1 4		
cf. <i>vadescens</i> (Cushman)			. 1		
sp.				. . 1 . .	
<i>Euvigerina notehispida</i> (Finlay)			. . . 3 . .		
<i>Hofkeruwa luterum</i> Vella			. . 1 . . 4	2 1 1 4 4	

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 18, PART 3.

WAIMATA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS		Stage:	U.Tt				Tk		Wo				
(To accompany Thesis by J.F. Kennett)	Fossil No.		f523	f524	f525	f526	f527	f528	f529	f530	f531	f532	f533
<i>Hofkeruva mieschwageri</i> (Finlay)			4	.	.	.	.	.	.	.	.	.	.
<i>pliozea</i> Vella			.	.	.	.	.	.	.	.	3	3	2
<i>zeacuminata</i> Vella			4	4	1	.	2	.	.	.	.	.	.
<i>Noviuvu zelandica</i> Vella			.	.	.	4	.	.	2	.	.	.	.
<i>Rectuvigerina pohana</i> (Finlay)			1	2	.	.	.	.	.	.	.	.	.
<i>Trifarina bradyi</i> Cushman			4	1	1	.	4	1	.	.	1	1	.
<i>Angulogerina esuriens</i> Hornibrook			.	.	1	.	1	1	1	4	.	3	2
<i>n.sp. aff. australis</i> (Heron- Allen & Earland)			.	.	4	.	.	.	.	.	.	.	.
<i>sp.</i>			1	.	.	.	.	.	.	.	.	.	.
<i>Bolivina affiliata</i> Finlay			2	3	3	.	4	1	1	1	1	1	2
<i>albatrossi</i> Cushman			1	.	4	.	.	.	.	.	.	.	.
<i>barnwelli</i> Finlay			.	.	1	.	1	.	.	.	.	.	.
<i>lapseus</i> Finlay			1	4	4	.	.	.	.	.	.	.	.
<i>numerosa</i> Vella			.	.	.	.	1	1	.	1	.	.	.
<i>petiae</i> Gibson			.	.	.	.	.	2	.	.	.	.	.
<i>plicatella</i> Cushman			.	.	2	.	.	.	.	.	.	.	.
<i>cf. striatula</i> Cushman			.	.	1	.	.	.	.	.	.	.	.
<i>turbiditorum</i> Vella			.	.	1	.	.	.	.	.	.	.	.
<i>watti</i> Gibson			.	.	1	.	.	.	.	.	.	.	.
<i>sp.</i>			.	1	.	.	.	.	.	.	.	.	.
<i>Rectebolivina maoria</i> Finlay			4	4	1	.	.	.	.	.	.	.	.
<i>parvula</i> Finlay			.	.	1	.	.	.	.	.	.	.	.
<i>striatula</i> (Cushman)			.	.	.	.	1	1	.	.	.	.	.
<i>Virgulopsis turris</i> (Heron-Allen & Earland)			.	.	1	.	1	.	.	.	.	.	.
Family HETEROHELICIDAE													
<i>Bolivinita compressa</i> Finlay			4	4	3	.	1	.	.	.	.	.	.
<i>pliozea</i> Finlay			.	.	.	.	1	1	1	.	1	1	.
<i>pohana</i> Finlay			3	1	.	1	2	1	1	1	.	2	.
<i>quadrilatera</i> (Schwager)			1	.	.	.	.	.	.	.	.	.	.
<i>Plectofrondicularia pohana</i> Finlay			.	1	1	.	.	.	.	.	.	.	.
Family CASSIDULINIDAE													
<i>Cassidulina cuneata</i> Finlay			4	3	.	.	1	.	.	.	.	.	.
<i>laevigata</i> d'Orbigny			1	.	.	.	.	.	1	.	.	.	.
<i>neocarinata</i> Thalmann			1	1	1	.	1	.	1	.	.	.	.
<i>pacifica</i> Cushman			.	1	.	.	.	.	.	.	.	.	.
<i>subglobosa</i> Brady			1	.	1	.	1	.	.	.	.	1	.
<i>Cassidulinoides orientalis</i> (Cushman)			1	1	1	.	1	4	.	.	.	.	.
<i>Ehrenbergina willetti</i> Finlay			.	1	.	.	.	.	.	.	.	.	.
Family ELLIPSOIDINIDAE													
<i>Pleurostomella alternans</i> Schwager			1	1	1	.	1	.	1	.	.	.	.
Family CHILOSTOMELLIDAE													
<i>Chilostomella ovoides</i> Reuss			.	.	.	.	.	.	1	.	.	.	.
<i>Sphaeroidina bulloides</i> d'Orbigny			1	4	4	1	.	.	.	.	.	1	.
<i>Pullenia bulloides</i> (d'Orbigny)			1	1	1	1	1	1	1	1	1	1	3
<i>quinqueloba</i> (Reuss)			.	.	.	.	.	.	1	.	.	.	.
Family NONIONIDAE													
<i>Pacinnion neefi</i> Vella			.	.	1	.	.	.	.	.	.	1	.
<i>parki</i> (Hornibrook)			.	4	.	.	2	.	1	.	.	1	.
<i>cf. parki</i> (Hornibrook)			4	.	.	.	.	.	.	.	.	.	.
<i>Melonis zeobesius</i> Vella			2	1	.	1	.	.	.	.	.	.	.
<i>Nonionella magnalingua</i> Finlay			.	.	.	.	1	.	.	.	.	.	.
<i>Florilus flemingi</i> (Vella)			.	.	.	.	2	.	.	.	.	.	.
<i>olsoni</i> Kennett			.	.	.	.	1	.	.	.	.	.	.

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 18, PART 4.

WAIMATA RIVER SECTION

DISTRIBUTION OF MICROFOSSILS	Stage:	U.Tt	Tk	Wo								
(To accompany Thesis by J.P. Kennett)	Fossil No.	f523	f524	f525	f526	f527	f528	f529	f530	f531	f532	f533
Family DISCORBIIDAE												
Patellinella inconspicua (Brady)		.	.	.	.	.	.	1	.	.	.	.
Gavelinopsis lobatulus (Parr)		.	.	.	.	.	.	1	.	.	.	.
Discopulvinulina berthelotti (d'Orbigny)		.	1	.	.	.	1	1	.	.	.	.
Osangularia bengalensis (Schwager)		2	3	1	1	1	.	.	.	.	.	.
Gyroidinoides neosoldanii (Bretzen)		4	2	2	.	.	1	.	1	1	.	4
zealandica (Finlay)		.	.	.	.	.	.	.	.	.	4	.
Discorbinella cf. complanata (Sidebottom)		1	1	.	.	.	.	.	.	.	.	.
rarefscens (Brady)		.	.	.	.	.	.	.	1	.	.	.
Parvicarinina altocamerata (Heron-Allon & Earland)		.	1	.	.	.	.	.	.	.	.	.
Laticarinina pauperata (Parker & Jones)		1	3	2	.	.	.	.	.	.	1	.
Cancris laevinflatus Hornibrook		1	.	.	.	.	.	.	.	.	.	.
Buningia creeki Finlay		1	.	.	.	.	.	.	.	.	.	.
Family EPISTOMINIDAE												
Siphonina australis Cushman		1	4	2	.	.	.	.	.	.	.	.
Epistominella iota Hornibrook		.	.	1	.	.	.	.	1	.	.	.
Hoglundina elegans d'Orbigny		.	3	1	.	1	1	1	.	.	1	.
Alabama tenuimarginata (Chapman, Parr & Collins)		.	1	.	.	.	.	.	.	.	.	.
Pseudoeponides prominula (Stache)		.	.	.	.	.	.	.	1	.	.	.
tenera (Brady)		1	.	.	.	.	.	.	1	.	.	1
Family CERATOBULIMINIDAE												
Ceratobulimina kellumi Finlay		.	.	1	.	.	.	.	.	.	.	.
Family ELPHIDIIDAE												
Elphidium charlottensis (Vella)		.	.	.	.	.	.	1	.	.	.	.
Notoretalia hurupiensis Vella		.	.	.	.	.	.	2	.	.	.	.
taranakia Vella		2	1	.	.	.	.	.	.	.	.	.
aff. taranakia Vella, (reticulate ornament)		.	.	.	1	5	2	2	3	1	2	4
Family GLOBIGERINIDAE												
Globigerinella siphonifera (d'Orbigny)		.	.	1	.	.	.	.	.	.	.	.
Globigerina bulloides d'Orbigny		.	1	.	.	.	.	.	.	.	.	.
dutertrei d'Orbigny		.	.	.	.	.	.	.	.	.	2	.
falconensis Blow		3	4	2	1	.	.	.	.	.	.	.
nepenthes Todd		1	3	1	4	.	.	.	.	.	.	.
cf. nepenthes Todd		.	.	.	.	.	.	.	.	.	1	2
pachyderma (Ehrenberg)		.	1	.	.	1	4	1	4	.	1	4
parabulloides Blow		2	1	2	.	4	4	2	2	.	.	.
praebulloides Blow		1	.	.	.	.	.	.	.	.	.	.
quinqueloba Natland		.	.	4	.	.	4	.	.	1	4	1
woodi Jenkins		4	4	4	1	.	1	.	.	.	.	2
zealandica Hornibrook		.	1	4	.	.	.	.	.	.	.	.
app. indet.		.	.	.	.	4	.	4	.	.	.	.
Globigerinita glutinata (Egger)		.	.	1	.	.	1	.	.	.	.	.
uvula (Ehrenberg)		.	1	.	.	.	2	.	.	.	.	.
Globigerinoides obliqua Bolli		.	.	.	.	.	.	.	.	.	.	1
trilobus trilobus (Reuss)		4	4	4	1	.	1	.	.	.	.	.
Orbulina suturalis Bronnimann		.	.	1	1	.	.	.	.	.	.	1
universa d'Orbigny		4	4	4	4	4	4	4	2	3	1	4
universa d'Orbigny, (bilobed var.)		.	.	.	.	.	.	.	.	.	.	1
Sphaeroidinella seminulina (Schwager)		.	.	.	.	.	.	.	1	1	1	1
Globoquadrina dehiscens (Chapman, Parr & Collins)		4	4	1	.	.	.	.	.	.	.	.
Globoretalia conomiozea Kennett		.	.	.	.	4	4	.	.	.	.	.
crassaformis (Galloway & Wissler)		.	.	.	.	.	.	.	4	4	4	3
menardii cf. mictumida Jenkins		.	.	.	.	.	.	.	.	.	.	1

KEY: 1 = less than 5 specimens; 2 = 5 to 10 specimens;
3 = 10 to 20 specimens; 4 = more than 20 specimens.

TABLE 18, PART 5

WAIMATA RIVER SECTIONDISTRIBUTION
OF MICROFOSSILS

Stage:

U, Tt

Tk

Wo

(To accompany Thesis
by J.P. Kennett)

Fossil No.

f523 f524 f525 f526 f527 f528 f529 f530 f531 f532 f533

Globoretalia menardii panda Jenkins

. 1 3

miozea Finlay

4 4 4 4 1

opima continosa Blow

. 1

scitula (Brady)

1 2 1 . 1 2

off. hirsuta (d'Orbigny)

. 3 .

Family ANOMALINIDAE

Anomalinoides parvumbilia (Finlay)

2 4 4 . 1 1 . . 4 . 4

vitrinoda (Finlay)

1 3 3

Cibicides deliquatus Finlay

3 2 3 2 4 2 1 1 4 2 .

finlayi Gibson

3 2 3 1 2 . . . 1 . 2

molestus Hornibrook

2 4 3 1 3 . 1 2 4 1 4

cf. novozelandicus (Karrer)

. . 1

pseudoungerianus (Cushman)

1 1 4

robertsonianus (Brady)

1 . 1 1

thiaracuta Hornibrook

1

Dycibicides biserialis Cushman & Valentine

1 . 1 . . 1

OTHER FOSSILS:

RADIOLARIA

. 4 4

"LEPTODERMELLA"

. . . 4 4 . 2 . 4 4

SPONGE SPICULES

. . . 1 4 4

ECHINOID SPINES, (spatangid)

1 1 1 . 1 1 2 4 4 . 1

OSTRACODA

1 2 1 . 1 2 3 1 . . .

FISH TEETH

. . 1 . . . 1

FISH OTOLITHS

1 1 1