Elphidium novozealandicum Cushman, scanning electron micrograph of specimen VF968 from 10 metres in Wellington Harbour, Recent; magnification x130.

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STUDIES IN THE WANGANUI SERIES:

Pliocene Foraminifera from Wanganui Basin

Thesis submitted for the degree of
Doctor of Philosophy
in Geology

Victoria University of Wellington

April, 1972.

71.1185

ABSTRACT

Foraminifera have been examined from seven Pliocene sections in South Wanganui Basin, southern North Island, New Zealand, including the Waipipian and Mangapanian Stratotypes. Lithology, faunal distribution, biostratigraphy and paleoecology are discussed for each section.

The systematics and ecologic and stratigraphic ranges of 193 species are discussed. The new genus Zelamarkina is erected, with Z. excavata n.sp. as type species, and the following five species are also described as new: Bolivina hornibrooki, B. vellai, B. wanganuiensis, Rotalia fastigata and Notorotalia briggsi.

Three biostratigraphic zones based on benthonic foraminifera are recognised. The Hurupiensis Zone, defined by the range of Notorotalia hurupiensis in South Wanganui Basin, is considered equivalent to the Opoitian Stage. The Molestus Zone, defined by the overlapping ranges of Cibicides molestus and Notorotalia finlayi, represents the Waipipian Stage. The Finlayi Zone equals that part of the range of N. finlayi after the extinction of Cibicides molestus, and extends through to the Recent.

Temperatures dropped abruptly and markedly at the time represented by the base of the Molestus Zone, accompanied by a substantial fall in sea level, then rose at the time represented by the end of this zone to a level maintained through the period studied. No marked temperature or sea level change is recorded across the

presumed Pliocene-Pleistocene boundary. The region was covered during late Miocene and early Pliocene times by shallow seas, possibly with land to the west. Rapid subsidence of the centre of the basin during the early Pliocene was followed by gradual shallowing until by the late Pliocene uniformly shallow depths again pertained. The basin was bounded to the east by the emergent Ruahine and Tararua Ranges, and probably to the south and west by shallow bars or islands formed from uplifted basement blocks.

The surface microstructure of nine species of Bolivina and seven species of Notorotalia is described from scanning electron micrographs. Addition of calcite to the test of Notorotalia is progressive and is controlled largely by the positions of sutural and apertural pores.

FOREWORD

The new genus and six new species are described in a paper accepted for publication in the Journal of the Royal Society of New Zealand (Collen, 1972a). The section dealing with test surface structures in Notorotalia has been submitted for publication to the Revista Española de Micropaleontología (Collen, 1972b). A paper, written during the course of this study in collaboration with Professor P. Vella and included in this thesis as Appendix I, has been submitted for publication to the Journal of Foraminiferal Research (Collen and Vella, 1972).

ACKNOWLEDGEMENTS

Sincere thanks are extended to Professor P. Vella for advice and constructive criticism throughout this study and to Professor R. H. Clark for use of the facilities of the Department of Geology, Victoria University of Wellington.

The following are gratefully acknowledged: Professor J. Bradley and my fellow students, for helpful discussion; Dr N. de B. Hornibrook, of N.Z. Geological Survey, for access to literature and collections held in that institution; Mrs D. Seward, for grain-size analyses; Miss T. A. Sledzinska, for X-ray analyses; Mr S. H. Eagar, for field and laboratory assistance throughout this study;

Mr W. M. Briggs, Jr., and Mr R. D. Cooper, for the loan of samples. Comparative material was kindly supplied by Dr R. Todd, of the U.S. National Museum, Professor O. L. Bandy, University of Southern California, and Professor E. Boltovskey, Argentine Museum of Natural Sciences.

Mr W. L. Bertaud, of Physics and Engineering Laboratory, N.Z. D.S.I.R., allotted scanning electron microscope time, and Mrs L. A. Donaldson and Mr G. Walker photographed the specimens. Plates were photographed by the Photographic Laboratory, V.U.W. Mrs M. R. Singleton typed the manuscript.

My gratitude is due to my wife for practical assistance and encouragement throughout the course of this study, and to my parents for assistance in numerous ways.

Financial support is acknowledged from the University Grants Committee, both in the form of a Postgraduate Scholarship, during the tenure of which this study was largely completed, and for assistance with field expenses. Additional financial support for field work was provided by the V.U.W. Internal Research Committee.

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SECTION I

INTRODUCTION

Purpose and Scope of Study

Important advances in Neogene geology have resulted from intensified study during the past decade of sediments from deep-sea cores. Paleomagnetic dating and increased direct radiometric dating of sediments have improved geochronology and tested biostratigraphic zonation. Knowledge of Pliocene and probably Upper Miocene climatic fluctuations allows paleoecological correlation and, together with paleomagnetic reversals, suggests a possible environmental basis for biostratigraphic units. Stratigraphic paleontology now includes detailed studies of such previously neglected fossils as pollens, radiolaria, calcareous nannoplankton and microplankton, and emphasis is on planktonic organisms because of their superiority for inter-continental research.

Progress in integrated interdisciplinary research into New Zealand Cenozoic stratigraphy is shown by recent papers combining foraminiferal biostratigraphy with oxygen isotope studies (Devereux et al, 1970), with calcareous nannoplankton biostratigraphy (Hornibrook and Edwards, 1970) and with paleomagnetic stratigraphy (Kennett et al, 1971; Lienert et al, 1972). Increased interest in the Upper Cenozoic is also shown by controversy over the status of the Hautawan Stage (Beu, 1969, 1970; Vella and Nicol, 1970, 1971; Jenkins, 1971a).

This thesis discusses foraminifera of the Waipipian and Mangapanian Stages (middle and upper Pliocene) in Wanganui Basin.

Three New Zealand stages are currently considered to represent Pliocene time: in order of decreasing age they are the Opoitian, Waipipian and Mangapanian. Type sections of the Waipipian and Mangapanian Stages are in Wanganui Basin, and that of the Opoitian Stage is in northern Hawkes Bay on the North Island east coast. Although New Zealand stages are biostratigraphic and defined by both mollusca and foraminifera, there are no published descriptions of microfaunas from Pliocene type localities.

Foraminifera were examined from the type and other sections of the Waipipian and Mangapanian Stages to try to detect species giving accurate definition of the stage boundaries. It soon became apparent that most foraminiferal changes reflect ecological change and not species extinction, that much of the fauna survived unchanged to the present day (as recognised by Hornibrook, 1968, p.35), and that useful key species tend to be sporadically distributed and facies controlled. The use of key (index) species thus appeared limited even with regard to established stages and could not provide finer divisions necessary for accurate study of the thick Wanganui Series strata in this basin.

The definition of time-stratigraphic boundaries is only one way of measuring meaningful time-planes. When it was realised that standard foraminiferal biostratigraphy is of limited value in Wanganui Basin, paleoecological changes in the fauna denoting climatic change were sought. Many changes in fossil foraminiferal populations result from climatic or tectonic effects. In a large basin such as this, almost astride the most important axis of Upper Cenozoic deformation in New

Zealand, it is unlikely that tectonic effects were equal across the basin floor. Hence, consistent faunal changes may be of climatic origin and useful as stratigraphic time planes.

Climatic events proved difficult to detect because of scarce planktonic foraminifera, and the influence of oceanic currents together with the diachronous effect of changing climate are not fully understood. However, climatic datum planes promise to be nearly as useful as those based on foraminiferal evolution and extinction.

Potentially the most accurate technique is paleomagnetic dating. Paleomagnetic samples were collected in February, 1970, from the Wanganui River section and also from Pleistocene sediments exposed on the Wanganui coast, by Professors N. D. Watkins and J. P. Kennett of the University of Rhode Island. The writer assisted with the collecting, and paleomagnetic sample horizons are given where they correspond to microfossil samples used in this study (Table 2). Very weak permanent remanent magnetism with a relatively strong superimposed viscous component has made measurement of paleomagnetic direction difficult, and results are not yet available.

History and Usage of Stage Names

Pliocene biostratigraphy of Wanganui Basin is discussed in Section IV, but several points need mention here.

Fleming (1953) and Boreham (1963) gave detailed summaries of the history and previous usage of Pliocene and Pleistocene stage names, which will not be repeated. After Fleming (1953), Pliocene time was considered represented by the Waitotaran Stage, with Waipipian and Mangapanian Substages, and the Opoitian Stage. Beu (1969) discussed later developments and formally raised the Waipipian and Mangapanian Substages to full stage rank. Although Waitotaran has priority, to avoid ambiguity and confusion Mangapanian was used for the upper stage, allowing the use of Waitotaran as a "superstage" or where sequences cannot be satisfactorily subdivided. Beu further considered that the Hautawan Stage based on the presence of Chlamys delicatula "is not a chronostratigraphic stage but a biostratigraphic zone" and suggested that it be discarded. This proposal was supported by Jenkins (1971a) and Beu (1971), but contested by Vella and Nicol (1970, 1971).

Data presented here supports the elevation of Waipipian and Mangapanian to stage rank, and this usage is followed. The suggestion of Beu (1969) regarding use of the name Waitotaran is considered sound. The Hautawan Stage as defined by Fleming (1953) is retained in this study because, although foraminiferal evidence in Wanganui Basin is limited, abandonment of the name before complete data (including

paleomagnetic stratigraphy of the type section) is available would be premature.

Detailed lists of mollusca present in the type sections of the Waipipian and younger stages in Wanganui Basin were given by Fleming (1953), who also detailed the contributions of earlier paleontologists. Index mollusca for each stage are well known (Fleming, 1953; 1959, pp. 215, 446, 460-61; Beu, 1969, pp. 645 et seq.). Foraminiferal faunas of Pliocene type sections have not been described, or related to the index mollusca in other sections. However, species considered useful for dividing the Pliocene have been commonly applied by workers throughout New Zealand (see, for example, Hornibrook, 1968, pp. 35-36, 74). The ranges of these species give a biostratigraphic zonation which is used to identify stages in all areas of marine Pliocene in New Zealand but is only approximately related to stages as defined in their type sections by reference to associated index mollusca or by stratigraphic position. Although appearing theoretically unsound, this approach has practical value and was necessary for several sections in Wanganui Basin.

The foraminiferal biostratigraphy of the Wanganui Basin Pliocene sequence and its relation to the New Zealand stage system, and to index species and zones recognised elsewhere in the country, is described in Section IV. Foraminiferal species considered useful for Pliocene biostratigraphy are listed and discussed. They fall into three groups: 1, those that occur in the type sections and have restricted ranges; 2, those whose ranges are determined by relation to the ranges of index mollusca in sections other than the type sections;

and 3, those that do not occur in the type sections and can not be related to index mollusca, but seem to have restricted time ranges. Foraminiferal zones recognised in Wanganui Basin are shown in Table 1.

Table 1. - Biostratigraphic zones of South Wanganui Basin recognised in the present study

AGE	STAGE	FORAMINIFERAL ZONES	MOLLUSCAN ZONES	ZONE FOSSILS
PLEISTOCENE	HAUTAWAN	FINLAYI	-	Euuvigerina zeacuminata Notorotalia hurupiensis Cibicides ihungia Globorotalia puncticulata Cibicides molestus Mesopeplum crawfordi N. finlayi Chlamys delicatula Globorotalia truncatulinoides
			DELICATULA	
PLIOCENE	MANGAPANIAN		MOLESTUS	
	WAIPIPIAN	CRAWFORDI		
	OPOITIAN		HURUPIENSIS	

Biostratigraphic zones erected by Superior (1943) are not followed here, as these are based largely on benthonic foraminifera. Most benthonic faunal change in Wanganui Basin results from local facies change, and tends to be diachronous.

Location and Geological Setting

The area studied is located on the western side of southern North Island, New Zealand (Fig. 1). The term Wanganui Basin is used as defined by Cope and Reed (1967), following Shell, BP and Todd Oil Services practice. In that sense it represents "the entire Tertiary basin east of the Taranaki Fault, from Te Kuiti to Palmerston North". Cope and Reed subdivided the basin into the Patea-Tongaporutu High on the west side, the North Wanganui Basin with basal beds of Oligocene age resting on basement, and the South Wanganui basin with onlap of Pliocene sediments. The present study of Pliocene foraminifera deals mainly with sediments from South Wanganui Basin and the eastern side of the Patea-Tongaporutu High.

The Patea-Tongaporutu High is bounded to the west by a major fault or fault zone, the Taranaki Fault (Cope and Reed, 1967), with a vertical displacement of about 7km (Hunt and Woodward, 1974). Shallow water and possibly estuarine deposits of Waipipian age on the coast near Waverley (Fleming, 1953) and extending northwest to Manaia (Marshall and Murdoch, 1924; Jones, 1965) grade laterally into deeper water facies to the east, and indicate that the high formed the western boundary of the basin when Pliocene subsidence and deposition began. In South Taranaki Bight, basement is now at depths of less than 3km in the Patea-Tongaporutu High, and dips gently eastward towards the axis of the Wanganui Basin (Hunt and Woodward, 1974.)

Fig. 1 Sketch map of the North Island of New Zealand showing location of area studied and position of the axial ranges.

To the east, South Wanganui Basin is bounded by uplifted Mesozoic geosynclinal sediments of the Tararua and Ruahine Ranges. The Tararua Range and, slightly later, the Ruahine Range, began to emerge during the Pliocene and thereafter influenced sedimentation both in Wanganui Basin and in the North Island East Coast basins (Fleming, 1953, pp. 301, 303; Kingma, 1959, 1962, 1967). Shallow water sediments are exposed at Manawatu Gorge and for a short distance to the south on the western flanks of the Tararua Range (the most southerly exposure of Pliocene sediments in Wanganui Basin), on the western flanks of the Ruahine Range (Superior, 1943), and as outliers on ranges to the north (Kingma, 1967).

The oldest beds now exposed in the southern area are Opoitian, with the exception of a small area of Whaingaroan (Oligocene) greensand near Paraparaumu (Macpherson, 1949). Cope and Reed (1967) considered that Oligocene strata may have been deposited over the area, as in North Wanganui Basin, and eroded during Miocene uplift. They concluded that the hinge-line between North and South Wanganui Basins should be relatively high and named it the Pipiriki High, but stated that drilling (Puniwhakau-1, 2113m) had failed to prove shallow basement.

Wanganui Series sediments dip at a shallow angle (usually less than 7°) in the general direction of Cook Strait. To the south, Pliocene beds are concealed beneath progressively younger strata. From west to east across the basin, the direction of dip changes gradually from southeast through south to southwest, and sediments

exposed on land represent only the northeastern quadrant of South Wanganui Basin. Sediments consist largely of rapidly deposited mudstone, siltstone and sandstone, with common shellbeds and occasional limestone and conglomerate. Rapid thickness changes and rapid lateral and vertical facies changes are important.

This basin, with the associated Cook Strait and Taranaki Basin areas, is the largest area of Pliocene-Quaternary sedimentation in New Zealand. It is associated with the highest negative gravity anomaly in the country, the south-western part of the Rangitikei-Waiapu Anomaly (Robertson and Reilly, 1958) with a maximum value of minus 160 milligals near Marton. Robertson and Reilly attributed the anomaly to a crustal downwarp not in isostatic equilibrium, and regarded it as an expression of an active tectonic belt related to the Tonga-Kermadec-Hikurangi Trenches. The anomaly shows no relationship to the trend of the axial ranges, which appear to lack mountain roots.

Cope and Reed (1967) stated that major faults run in a north-south to northeast-southwest direction, are probably transcurrent, and converge southwards. From Eocene to upper Miocene times the trend was mainly north-south to NNE-SSW; from early Pliocene to Recent it has been northeast-southwest. The faults have been shown as forming a splay at the end of the Alpine Fault (Cotton, 1956; Suggate, 1963; Cope and Reed, 1967).

Basement faulting appears to have controlled the formation of northeast-southwest trending folds in late Cenozoic strata. Wells drilled by Superior Oil Company on the Marton Anticline (Stantiall-1)

and Mount Stewart Anticline (Young-1) reached greywacke at 2281m and 1120m respectively, although seismic data indicated 6000m of young sediments within 6.5km south and 4.5km west of the crest of the Marton structure (Superior, 1943). Te Punga (1957b) described evidence that 6 anticlines in the Rangitikei-Manawatu district are still being folded. He considered that they probably all have greywacke cores, and that the folded sediments are draped over the edges of basement scarps at depth. Lensen (1959) considered the basin a complex graben consisting of numerous secondary horsts and grabens.

Previous Geological Work

Mantell (1848) referred to the abundant fossils near Wanganui and most early studies were concentrated on that area. Large collections of molluscan fossils were described and their age debated. These studies were fully reviewed by Fleming (1953, pp. 97-99).

At first less attention was paid to the rest of the basin. Crawford (1869) traversed the Manawatu, Rangitikei and Wanganui Rivers, and divided strata in the Rangitikei and upper Wanganui Rivers into:

- 1) Upper Sandstones,
- 2) Blue Clays, and
- 3) Coal Shales.

He later (1870) described the area as the great Tertiary basin of the country, and Hutton (1886) showed the "Wanganui Series" as two

belts extending one on each side of the North Island. Park (1887a) provided the first geologic sketch map of the Wanganui region and discussed the stratigraphy of the Cenozoic rocks. His sketch map showed Recent and Pleistocene, "Newer Pliocene" and "Older Pliocene", and Upper Miocene beds, overlying older strata. Despite Park's map, Marshall (1905) considered that the Wanganui sediments were not very thick, did not extend far inland, and formed a "Wanganui Coastal Plain".

To the west, Grange (1926) discussed Pliocene strata in the upper Waitotara Valley and noted the similarity of the molluscan fossils with those at Waipipi Beach. Park (1887b) and Fyfe (1946) briefly described the geology of the upper Wanganui River.

To the east of the basin, Cenozoic sediments of the Manawatu Gorge were examined by McKay (1877), Park (1887a), Lillie (1953) and Piyasin (1966), and an occurrence of conglomerate on nearby Wharite Peak was noted by Hill (1893). The origin of the Manawatu Gorge itself has been the subject of papers by Petrie (1908), Hill (1908), Marshall (1908), Morgan (1914), Cotton (1922), Adkin (1930) and Ongley (1935). Speight and Wild (1924) described several sections near Apiti and gave analyses of limestone beds exposed there.

After the survey by Park (1887a), regional mapping of the basin was neglected until serious petroleum exploration began shortly before the Second World War. A gravity survey by V. A. Acheson, of New Zealand Petroleum Company Ltd, first pointed to the existence of the large gravity anomaly of the district (Acheson, 1939). Mason (1939),

of New Zealand Oil Exploration Ltd, made a reconnaissance of the Wanganui River. Between 1939 and 1943, Superior Oil Company geologists completed a map of the area, which they termed the Palmerston-Wanganui Basin. They also carried out a seismic survey and drilled two wells (Stantiall-1, 2063m, and Young-1, 1019m) which were both abandoned as dry. Results of these operations, in manuscript form together with map sheets on a scale of 1:63,360, are filed at N.Z. Geological Survey, Lower Hutt, as reports by Feldmeyer et al (1943), Wheatley (1943) and Ower (1943). The same data forms the content of a manuscript filed, together with copies of the maps, in the Department of Geology, Victoria University of Wellington (Turner, 1944). Following the precedent of Fleming (1953), all references to Superior Oil Company work by the above geologists are denoted in the following text as "Superior (1943)". Superior geologists took microfossil samples at nominal 10 ft stratigraphic intervals in the Rangitikei River and at nominal 50 ft stratigraphic intervals in the Wanganui, Mangawhero and Turakina Rivers. A series of foraminiferal zones were erected and correlated with the standard New Zealand stage system but not with the type sections on the Wanganui coast, which were considered discontinuous and poor in microfossils. Superior's work represented a major advance in Wanganui Basin stratigraphy. Thicknesses were measured carefully, and lithological details are accurate. No major discrepancies in the mapping were found during the present study and Superior's data was used to supplement the writer's data in several of the stratigraphic columns presented below.

Superior's formation names were published by Ongley (1945) in a discussion of the ground-water resources of Wanganui Basin.

Te Punga (1952a) described the geology and macrofossils of Rangitikei Valley and erected a new set of formation names partly defined by paleontology. He later (1952b, 1953a, 1954, 1957a,b, 1962) published papers dealing with various aspects of Pleistocene to Recent geology, and with possible land connections to the South Island (1953b, 1953c).

Between 1943 and 1946, G.A. Fleming mapped N.Z.M.S.1 Sheet Districts N137 and N138 (Wanganui Subdivision), including the important coastal section. In a series of short papers and in N.Z. Geological Survey Bulletin n.s.52, he described lithostratigraphy and macrofossils, and discussed stratigraphic divisions in minute detail (Fleming, 1944, 1946, 1947a, 1949, 1953).

Kingma (1957, 1959) discussed the tectonic setting of the Ruahine-Rimutaka Ranges, and the development of Wanganui Basin (1959, pp. 16-17). McQueen (1953) described upper Pleistocene plant fossils from Rangitikei Valley, and Mildenhall and Harris (1970) described a cool climate pollen assemblage from the type Waipipian section. Cope and Reed (1967) reconstructed Cretaceous paleogeography from a study of basement cores from ten oil exploration wells, and discussed Tertiary tectonic processes. Ker (1970) described slumping in Utiku Sandstone overlying Taihape Mudstone. Unpublished theses have been written on aspects of the geology of the eastern side of the basin by Rich (1959; southern Manawatu Gorge and western side of the

Tararua Range), Piyasin (1966; Woodville and Manawatu Saddle area) and Milne (1968; Apiti District).

The geology of the offshore region has been discussed by Sprigg et al (1965, 1969), Hunt and Woodward (1971) and Woodward and Hunt (1971). Gow (1967) gives references to papers dealing with the origin and distribution of iron sands on west coast beaches.

Apart from Superior's work, Wanganui Basin micropaleontology is known only from an unpublished study of foraminifera from the type sections of the Putikian and Okehuian Stages (Cameron, 1966), a description of sponge sterrasters (Rich, 1958) and occasional references in papers dealing mainly with other areas (Finlay, 1939a,b,c, 1940; Vella, 1957; Hornibrook, 1961, 1968; Hulme, 1964; Jenkins, 1964, 1967a, 1971b; Lewis, 1968; Lewis and Jenkins, 1969).

Since Superior Oil Company ceased work in New Zealand, a further well has been drilled in Wanganui Basin by Champlin Oil and Refining Company and partners. This well (Santoft-1, 2590m) was located on the coast near Bulls, following seismic, gravity and photogeologic surveys, but proved dry. At present, Petroleum Licences 601-632, covering Taranaki and western South Wanganui Basin, are held by Shell, BP and Todd Oil Services and farmed-out to N.Z. Aquitaine Petroleum Ltd. Licences 436-445, for the eastern part of the basin, are held by Hackathorn N.Z. Oil Ltd and farmed-out to Bounty Oil Ltd. The latter company has recently completed a reflection seismic survey of the area west of Palmerston North and proposes further exploratory drilling.

Geological maps on a scale of 1:250,000 covering the area are Sheet 7 - Taranaki (Hay, 1967), Sheet 10 - Wanganui (Lensen, 1959), Sheet 11 - Dannevirke (Kingma, 1962), and Sheet 12 - Wellington (Kingma, 1967).

Methods

Samples were prepared for microscopic examination by drying, disaggregation in water and washing over a 200-mesh (75μ aperture) sieve. A Dawes ultrasonic vibrator was used to aid separation of fossils from matrix. In many instances large samples (2-3 kg) had to be processed because of low foraminiferal numbers and planktonic percentages.

Microfossils were separated from the residue by flotation with CCl_4 where possible. Often this was impracticable because of the presence of large quantities of mica, and the entire residue was searched for foraminifera. When samples needed to be reduced in size a modified Otto microsplitter was used for large volumes and a small, non-laminated sample splitter for lesser volumes (Humphries, 1961).

From each sample, 5g of dry sediment was washed over a 200-mesh sieve, and the residue dried, weighed and calculated as a percentage of the whole. The foraminifera present were counted, and the Foraminiferal Number (number of foraminifera per gram of dry sediment) calculated.

Percentages of arenaceous and planktonic forms, the relative abundance of each planktonic species, and coiling ratios of Globigerina pachyderma were also determined for each sample. From samples in several sections, the mean length of each population of Nonionellina flemingi was measured.

As foraminifera are often rare and sporadic in occurrence in Wanganui Basin sediments, the following tests were made to assess the validity of statistical results:

- a) Test for the minimum number of specimens necessary for reliable results.

The species composition of cumulative counts of 106, 227 and 346 planktonic foraminifera from the same sample were determined (Table 13, appendix). The percentage difference in abundance of each species from one count to the next is small for common species but usually large for rare species. This is because the presence of one extra specimen of a rare species may double the abundance of that species. A more realistic value is obtained by expressing the difference in species abundance from one count to the next as a percentage of the abundance of that species in the fauna. This shows that the abundance of each species varies by 1% or less when 346 rather than 227 specimens are counted.

More than 300 specimens were counted from each sample where present, but counts of 200-300 specimens per sample probably gave results of comparable accuracy. Counts of 100-200 specimens per sample appear accurate to $\pm 5\%$. Phleger (1960, p.35) considers that little accuracy is gained in population studies by counting more than

300 specimens from each sample.

Counts were not made of Globigerina pachyderma to determine the number of individuals necessary for accurate determination of coiling ratios, but extrapolation of the data contained in Table 13 indicates that at least 30 specimens are needed. Ujifé and Miura (1971) also recommend that 30 or more specimens be examined.

Examination of comparative sets of measurements of Nonionellina flemingi (Table 14, appendix) shows that for measurements of more than 100 specimens the mean length varies by less than $\pm 3\%$. Where possible at least 300 specimens from each sample were measured, and only mean values determined from 50 or more measurements are considered reliable.

- b) Test of the consistency of measurements obtained from different fractions of the same sample.

Two equal masses of sediment from the same sample were prepared separately and planktonic species present counted in a split from each. The two counts differed from each other by $\pm 1.6\%$ or less for each species (Table 15, appendix), indicating faunal homogeneity of the sediment within the volume of each sample.

Illustrations of all planktonic species and a number of the more important benthonic species have been drawn by the author using a camera lucida. Twenty species, mainly of Bolivina and Notorotalia, have been photographed with the scanning electron microscope of Physics and Engineering Laboratory, N.Z. Department of Scientific and Industrial Research.

Geographic names used in the text follow the usage of the latest edition of the N.Z.M.S.1, 1:63,360, sheet for each sheet district concerned.

Paleoecological Parameters Measured

Foraminiferal Number

Schott (1935) defined the foraminiferal number of a sample as the number of tests per gram of dry sediment. This parameter can be applied at the population, generic or specific level (Bandy, Ingle and Resig, 1964), and abundance of any constituent of the sediment can be measured in a like manner for comparison between samples (Ingle, 1967). It has been determined for both Recent (Said, 1950) and fossil populations (Ingle, 1967). Walton (1955) considered that available living space is the only natural base to which living populations can be referred. This is not possible with fossil material. Lewis (1972) gives the abundance of foraminifera per unit area for the continental shelf and slope off southern Hawkes Bay, New Zealand, and included data so that foraminiferal numbers could be calculated for comparison with fossil populations.

Foraminiferal number generally increases offshore to maximum values at outer shelf to upper bathyal depths, then decreases to the lower bathyal zone (Bandy and Arnal, 1960). Exceptions occur with the high foraminiferal numbers of sediments composed largely of planktonic foraminifera and on the tops of banks, seamounts and insular shelves (Ingle, 1967), and in areas of upwelling (Phleger, 1964).

In sedimentary sections, most variation in foraminiferal numbers will result from variation in either the rate of sedimentation or the productivity of the foraminiferal fauna.

Planktonic/benthonic Ratio

The ratio of planktonic to benthonic foraminifera as a means of estimating the depth of deposition of sediments (Grimsdale and Van Morkhoven, 1955; Smith, 1955) has been utilised by many authors (for example, Stehli and Creath, 1964; Funnell, 1964; Vella, 1962c; Ingle, 1967). Although fine environmental delineations are not usually possible (Grimsdale and Van Morkhoven, 1955), the ratio of planktonic to benthonic forms increases slowly across the shelf with a sharp increase at the shelf edge. The increase appears due to:

- 1) full salinity of ocean waters (Phleger, 1964);
- 2) upwelling of nutrient waters at the shelf edge, with the resultant increase in phytoplankton (Funnell, 1967; Ingle, 1967);
- 3) a longer water column permitting all species to be present (Ingle, 1967) and possibly allowing the complete life cycle (Funnell, 1967);
- 4) lack of the suspended mineral particles which in shelf waters are inimical to the production of phytoplankton and symbiotic algae (Murray, in Curry et al, 1965).

Phleger (1960, 1964) reported planktonic foraminifera as common in inshore waters and even coastal lagoons where the run-off is low, as in Baja California.

Species Diversity

The number of benthonic species per sample increases offshore to a maximum in outer shelf to middle bathyal depths, then decreases to

deeper environments (Bandy and Arnal, 1960). The reasons for this trend are not clear. Gibson (1966) concluded from a study of benthonic foraminifera in the Gulf of Mexico that species diversity is inversely proportional to environmental variability. Hence, shallow water areas with fluctuating temperatures, salinity and turbidity, and affected strongly by wave and current action, would support less diverse foraminiferal faunas than greater depths with more stable conditions. Ingle (1967) considered the trend a response to optimum conditions for productivity, but did not elaborate.

Abnormally diverse bathyal faunas may result from downslope displacement of shallower water species (Ingle, 1967). Low numbers of species are found in restricted basins (Resig, 1958), although in such environments the foraminiferal number may be high as a result of low sedimentation rates. The sorting effects of currents on shelf sediments may affect both species diversity and foraminiferal numbers, and was important during the deposition of Wanganui Series sediments in Wanganui Basin.

The number of planktonic species present varies as a result of:

- 1) depth of deposition. In deeper water, more species will be present than in shallow water for reasons discussed above under planktonic/benthonic ratio.
- 2) ocean temperature. The number of species of planktonic foraminifera increases in passing from Arctic or Antarctic to temperate to tropical conditions (Phleger, 1960). Jenkins (1968) has used variation in number of planktonic species to investigate New Zealand Tertiary climates.

Determinations of the number of both benthonic and planktonic species present are affected by the taxonomic philosophy of the investigator. However, this should be constant for a particular study and where faunal change with time is examined, relative changes will be valid.

Planktonic Faunal Composition

The planktonic faunal composition has been determined for each sample with sufficient planktonic foraminifera. Many Wanganui Basin samples contain a high proportion of juvenile planktonic specimens. Because of the difficulty of separating such forms, and because their ecologic requirements appear similar, all individuals of Globigerina bulloides d'Orbigny and related species have been included in the G. bulloides Group in the graphs of cumulative planktonic abundance. Species included in this group are: G. bulloides bulloides d'Orbigny, G. bulloides trilocularis Deshayes, G. cf. falconensis Blow and G. foliata Bolli. The species are separated in the range charts for each section.

Coiling Ratios of Globigerina pachyderma (Ehrenberg)

The use of coiling direction in populations of G. pachyderma to determine changes in temperature is now well established. Jenkins (1967a) summarises the literature on this subject. The ratio of sinistral to dextral forms of this species has been determined in all samples with

sufficient specimens. Globorotalia truncatulinoides (d'Orbigny) has been used similarly (Eriksen et al., 1954), but is too rare in Wanganui Basin to be utilised.

Depths of Deposition

Depths of deposition have been inferred from study of the lithology and general faunal composition, combined with correlation with the foraminiferal biofacies established for the New Zealand Tertiary by Vella (1962a,b,c). The Karreriella Biofacies, defined by Kennett (1962) as lying between the Hauserella and Robulus Biofacies (ca. 300m), is not recognised in Wanganui Basin.

Percentage of Sample Coarser than 75 microns

Most foraminifera are found in the sedimentary fraction coarser than 75 microns (200-mesh sieve), and where foraminifera are transported by current action, they behave as sedimentary particles of this size. Carter (1954) has used the abundance of various foraminiferal species coupled with abundances of sedimentary size groups to distinguish between exotic and indigenous species in the English Pliocene Crag deposits. In this study, increase in foraminiferal number paralleling increase in sediment coarser than 75 microns is taken to indicate that the foraminifera may be subject to the same processes of accumulation and sorting as the sedimentary particles (current action and the like), particularly where a corresponding depth increase is not indicated.

Eriksen and Wollin (1956) have made correlations between cores in the equatorial Atlantic and the Caribbean based partly on variations

in sediment coarser than 74 microns.

Although this parameter gives by no means a full grain size analysis, it does give a rapid index of the coarseness of the sediment. Very fine sand contains those particles between 62.5 and 125 μ (Folk, 1968).

Mean Size of Populations of Nonionellina flemingi

Lewis (1968) and Lewis and Jenkins (1969) have shown that Recent specimens of the benthonic foraminifera Nonionellina flemingi (Vella) grow to a larger size in cold waters around New Zealand than in warmer waters, because of delayed maturity, and have applied this knowledge to a study of past climates. This is a potentially valuable means of analysis, especially in shallow water faunas with sparse planktonic foraminifera.

SECTION II

STRATIGRAPHIC SECTIONS

INTRODUCTION

Wanganui Basin localities from which foraminifera have been collected are shown in Fig. 2. Samples have been examined from the type sections of the Waipipian Stage at Waverley Beach, the Mangapanian Stage at Mangapunipuni Stream, and the Waitotaran "Superstage" at Willies Bluff (Fig. 3). Additional samples have been examined from Waitotara Valley and Rangitatau Escarpment to extend the Mangapunipuni Stream section (Fig. 9). These samples, together with a sample from Ohawe Beach, Hawera, are from the Patea-Tongaporutu High as defined by Cope and Reed (1967). The sediments were deposited in shallow water and foraminifera are often rare or absent.

The Wanganui River section below Pipiriki (Fig. 12) was sampled in detail, but foraminifera are sporadic and often absent. The sediments vary considerably in depth of deposition and mostly lack mollusca below the Pleistocene.

Strata sampled in the Mowhango and Rangitikei River valleys (Fig. 16) proved the most useful for biostratigraphy and paleoecology. Beds exposed along Watershed Road, parallel to Rangitikei River and containing the presumed Plio-Pleistocene boundary, were also sampled, and foraminifera from the nearby type locality of the Hautawa Shellbed (stratotype of the Hautawan Stage) have been examined. Pleistocene sediments overlying the Hautawa Shellbed in Turakina Valley mostly lack foraminifera, although one sample (N138f576) contains a rich benthonic fauna from which specimens were selected for stereoscan study.

Fig. 2 Geographic map of Wanganui Basin, showing location of areas mentioned in text.

Sediments from the Manawatu Saddle Road section (Fig. 23) were studied because this is the most southerly area of Waipipian and Mangapanian strata exposed in Wanganui Basin. They provide shallow water foraminifera from the eastern side of the basin to compare with those of the western side and allow examination of the effects of Manawatu Strait on Pliocene ecology.

Details of additional samples collected from various other localities and of a Recent sediment sample from Wellington Harbour which provided useful comparative material are recorded in Tables 16 and 33 (in appendix). Microfaunas mounted by Cameron (1966) and Piyasin (1966) have been re-examined. Superior Oil Company samples, now in the N.Z. Geological Survey collection, were also re-examined, but they proved to be of relatively little value as complete faunas were not mounted and exact locality details are not recorded.

Section II contains the biostratigraphic and paleoecologic data obtained from each section. General interpretations and conclusions based on this data are deferred to Section IV (Biostratigraphy) and Section V (Paleoecology).

Fig. 3 Location of Waipipian, Mangapanian and Waitotaran type sections, and Wanganui River section.

WAVERLEY BEACH, WILKIES BLUFF AND WAITOTARA VALLEY

SECTIONS

Introduction

The history of stage nomenclature for Wanganui Series sediments has already been mentioned. Fleming (1953) nominated type sections for the Waitotaran Stage and Waipipian and Mangapanian Substages (later formally raised to stage rank by Beu, 1969) and gave detailed lists of mollusca present, but the foraminiferal faunas have never been described. Superior (1943) matched their foraminiferal zones with the standard New Zealand stage sequence but did not correlate them with the coastal section, which they considered discontinuous and poor in foraminifera. Species present in the type sections have been mentioned by Vella (1957), Jenkins (1967, 1971), Lewis (1968) and Lewis and Jenkins (1969).

Fleming (1953) designated the Whenuakura Group between Waipipi Point and Waitotara River, Waverley Beach, as stratotype of the Waipipian Substage, and the Wilkies Shellbed at Wilkies Bluff, Waitotara River, as stratotype of the Waitotaran Stage (Fig. 3). Eighteen samples have been examined from Waverley Beach and three from Wilkies Bluff, and the foraminifera present are listed in Table 27 (in appendix). Sample localities are shown in Fig. 4, and stratigraphic horizons and lithologies in Figs. 5 and 7.

The stratigraphy and macropaleontology of both sections were thoroughly described by Fleming (1953), with detailed lists of the

Fig. 4 Sample location map of the type sections of the Waipipian Stage at Waverley Beach and the Waitotaran Stage at Wilkies Bluff. Faults (F) after Fleming (1953).

Fig. 5 Stratigraphic column of the Waverley Beach section, showing sample horizons, lithology and the percentage of each sample coarser than 75 microns. Lithology mainly after Fleming (1953, 1959).

Fig. 6 Foraminiferal trends through the Waverley Beach section. Paleobathymetry is estimated from the conditions of deposition inferred for each formation by Fleming (1953) from molluscan evidence.

molluscan faunas, and summarised by Fleming (in Fleming, ed., 1959, pp. 446-47, 460-61). At the coast, beds are not exposed below those at Waipipi Point, between the top of the Whenuakura Group and the beds at Wilkies Bluff, and immediately above Wilkies Bluff. Coastal formations of the Whenuakura Group cannot be recognised inland (Fleming, 1953).

The Mangapani Shell Conglomerate at Mangapunipuni Stream is the type formation of the Mangapanian Stage. Nine samples were examined from this unit, from underlying Whenuakura Group formations exposed along Waitotara Valley, and from overlying Paparangi and Okiwa Group formations outcropping along Waitotara Valley and Rangitatau escarpment (Figs. 9 and 10). These three localities are here referred to jointly as the Waitotara Valley section. The stratigraphy of the upper part of this section is described by Fleming (1953). The Mangapani Shell Conglomerate is unconformably underlain by a coarse, well sorted, soft brown sandstone passing down into blue-grey sandstones, siltstones and mudstones with occasional mollusca. Fleming assigned these latter beds to the Whenuakura Group, but did not differentiate formations. Lower in the Waitotara Valley section, shelly limestones near Ngamato-pouri contain a molluscan fauna indicating a Waipipian age and considered the same as that at Waipipi Beach (Grange, 1926). These older beds were not sampled for the present study.

Benthonic foraminifera vary considerably in distribution and abundance throughout the three sections. They are absent from a

number of samples (because of unfavorable facies, removal by currents, and/or by post-depositional leaching of calcite), are plentiful and varied in others, and generally indicate shallow water conditions. Planktonic and arenaceous foraminifera are usually rare or absent. The ecologic and sedimentary parameters measured from these three sections are given in Tables 17 and 18 (in appendix).

Biostratigraphy

Waverley Beach (Stratotype of Waipipian Stage)

Foraminifera useful for stratigraphic correlation are rare. Notorotalia finlayi first appears near the base of this section, in N137f684, and is well developed, indicating a horizon above the Hurupiensis-finlayi Datum. Cibicides molestus is represented by a single, damaged specimen in N137f662, and both this and the single specimen of Globorotalia cf. miozea Finlay (from N137f667) may be reworked from older strata. Globorotalia inflata and G. puncticulata are both present in the lower part of this section, but only G. inflata is found above the Lower Waipipi Formation.

The following species, which are important Pliocene index species elsewhere in New Zealand, were found in the Waverley Beach section:

Notorotalia briggsi n.sp., Waipipian to Okehan,

N. finlayi Vella, Waipipian to Recent,

N. kingmai Vella, Opoitian to Mangapanian,

N. olsoni Vella, Kapitean to Recent,

Fig. 7 Stratigraphic column of the Wilkies Bluff section, showing sample horizons, lithology and the percentage of each sample coarser than 75 microns. Lithology after Fleming (1963).

Fig. 8 Foraminiferal trends through the Wilkie Bluff section.

N. pliozea Vella, Kapitean to Waipipian,

N. zelandica mangaoparia Vella, Waipipian to Hautawan,

Globorotalia inflata d'Orbigny, Opoitian to Recent,

G. puncticulata Deshayes, Opoitian to Waipipian,

Globigerina decoraperta Takayanagi & Saito, Lilburnian to Hautawan,

Sphaeroidinella seminulina (Schwager), Tongaporutuan to Waipipian,

Cibicides molestus Hornibrook, Bortonian to Waipipian.

The following are also considered important index species elsewhere in New Zealand but, despite careful search, were not found:

Robulus costatus (Fichtel & Moll), Tongaporutuan to Waipipian,

Lenticulina mammiligera (Karrer), Waitakian to Opoitian,

Rectobolivina maoria Finlay, Upper Altonian to Waipipian,

Euuvigerina zeaeuminata (Vella), Lower Altonian to Opoitian,

Notorotalia hurupiensis Vella, Tongaporutuan to Opoitian,

Cibicides ihungia Finlay, Arnold Series to Opoitian.

Notwithstanding some abundant faunas, the absence of certain species in these shallow water sediments does not necessarily indicate their prior extinction and could be simply the result of unfavorable environmental conditions.

Wilkie's Bluff (Stratotype of Waitotaran "Superstage").

Species of Notorotalia are the most characteristic element of the Wilkie's Bluff faunas, which differ from those of the Waverley Beach section in the presence of N. clathrata (Brady) and the absence of

Fig. 9 Sample location map of the type section of the Mangapuni Stage at Mangapuni Stream, and the Lower Waitotara Valley and Rangitatau Escarpment section. Stage boundaries (dashed lines) after Fleming (1953).

N. kingmai, N. olsoni and N. pliozea. N. finlayi is abundant. Cibicides molestus is absent. Planktonic species are rare; Globorotalia crassaformis is present, but both G. inflata and G. puncticulata are absent.

Waitotara Valley Section (Including Stratotype of Mangapanian Stage)

Foraminifera in this section are similar to those at Wilkies Bluff, although species of Notorotalia are less dominant. N. finlayi is common. N. hurupiensis, Cibicides molestus and large species of Lenticulina were not found. Globorotalia crassaformis is present, but G. inflata and G. puncticulata are both absent.

Paleoecology

Benthonic Faunal Trends

Arenaceous species are small and never form more than 1% of the benthonic population.

1. Waverley Beach Section

Benthonic faunal trends fluctuate widely, but there is general agreement between the foraminiferal number and the number of benthonic species (Fig. 6). Both show peaks at the base of the Rangikura Sandstone, in the vicinity of the Snapper Point Shellbed and at the Lower Waipipi Shellbed. The number of benthonic species present also rises at the Upper Waipipi Shellbed, and shows a slight increase towards the top of the Waverley Formation.

Fig. 10 Stratigraphic column of the Waitotara Valley section, showing sample horizons, lithology and the percentage of each sample coarser than 75 microns.

2. Wilkies Bluff Section

Foraminifera are absent from the Makokako Sand, but abundant in the different members of the Wilkies Shellbed (Fig. 8). The foraminiferal number decreases from N137f629 to N137f630, whereas the number of species present increases.

3. Waitotara Valley Section

The foraminiferal number is small in the lower part of the sampled section, reaching peaks in the Mangapani Shell Conglomerate and Wilkies Shellbed (Fig. 11). The number of benthonic species present is fairly uniform in those samples possessing a foraminiferal fauna.

4. General

Foraminifera are most abundant and most diverse in the shellbeds, and usually absent from coarse sandy sediments. The shellbeds consist of concentrated mollusca in a matrix of muddy sand or silt, and were considered by Fleming (1953, pp. 122, 130, 152, 195) to form in bypassing environments at varying depths (for example, 9-45m for the Wilkies Shellbed). Thus the varied foraminiferal faunas may result from current sorting. However, small specimens are present and the fauna is usually well preserved. The matrix of the shellbeds is often quite muddy, and may have provided suitable environmental conditions for foraminifera. Although Illing (1950) has shown that foraminiferal tests

Fig. 11 Foraminiferal trends through the Waitotara Valley section.
 * = Wilkie's Shellbed.

may be transported for some distance without damage, it is possible that the abundance of foraminifera in the Wanganui Basin shellbeds is due to factors other than current sorting.

Planktonic Faunal Trends

Planktonic specimens are small and rare, usually forming less than 1% of the total foraminiferal population. The number of species present in these sections ranges from 0 to 9 per sample, and varies directly with the number of benthonic species present. This indicates that planktonic and benthonic foraminiferal abundance is controlled by the same factor, probably either change in water depth or the sorting effect of currents.

The following species are present:

Globorotalia crassaformis (Galloway and Wissler)

G. inflata (d'Orbigny)

G. cf. miozea Finlay

G. puncticulata Deshayes

Globigerina bulloides d'Orbigny

G. bulloides var. trilocularis Deshayes

G. decoraperta Takayanagi & Saito

G. dutertrei (d'Orbigny)

G. foliata Bolli

G. pachyderma (Ehrenberg) (thin-shelled forms)

Turborotalita quinqueloba (Natland)

Globigerinita glutinata (Egger)

Globigerinoides ruber (d'Orbigny)

These are all species commonly found in shallow shelf deposits, deeper water species such as Globorotalia scitula (Brady) and heavily encrusted forms of Globigerina pachyderma are absent. Globorotalia cf. miozea may be reworked from older strata.

Paleobathymetry

A paleobathymetric curve has been constructed for the Waverley Beach section (Fig. 5) from data in Fleming (1953, pp. 109-14). Fleming inferred, from lithology and molluscs, conditions prevailing for the deposition of each formation in Wanganui Subdivision. He considered that the Pepper Shell Sand was laid down in shallow, subtidal conditions, followed by the Rangikura Sandstone in an estuarine environment. Subsidence followed, and the succeeding Waipipi Formation contains mollusca indicating normal salinities and depths of 10 to 40m. Little is known of the depth of deposition of the Waverley Formation, but it appears to have been shallower than the Waipipi Formation with possible estuarine conditions in the upper part, returning to shallow, fully marine conditions at the top.

Different microfossil assemblages can be recognised at various horizons, but in such shallow water deposits they do not indicate environments of deposition as accurately as the molluscan fossils, for reasons discussed later. The benthonic fauna in the Waipipi and Waverley Formations at Waverley Beach is dominated by nonionids, such as Astrononion spp., Nonionellina flemingi and Zeafiorilus parri, while that in the Wilkies Shellbed at Wilkies Bluff is dominated by

species of Notorotalia. The nonionid fauna possibly belongs to slightly deeper water with muddier bottom conditions and weaker currents.

Ammonia aoteana (Finlay) is present in only two samples, N137f667 (Snapper Point Conglomerate) and N137f680 (Wilkie's Shellbed at Rangitatau Escarpment) and only as rare, small specimens, despite apparently suitable facies. The rarity of Ammonia in shallow water Pliocene deposits in Wanganui Basin is discussed in Section V.

Paleobathymetric curves have not been constructed for the Wilkie's Bluff and Waitotara Valley sections. Fleming (1953, p.122) considered that the Wilkie's Shellbed formed in depths of 10 to 50m under the influence of strong current action, and discussed problems concerning its origin. From data contained in Fleming (1953) regarding the Waitotara Valley section, it appears that the sea shallowed until sediments were above wave base. The top of the sediment was eroded and the Mangapani Shell Conglomerate was then deposited upon the scoured surface. The succeeding Paparangi Sandstone and lower Makokako Sand were probably deposited above wave base, with a possible slight deepening towards the top of the Makokako Sand that lasted until after deposition of the Wilkie's Shellbed. Further shallowing followed, and the Kuramui Limestone was a shoreline deposit.

Summary

1. Sediments of the type sections of the Waipipian and Mangapanian Stages, and the Waitotaran "Superstage" represent deposition in shallow waters of variable depth. The influence of bottom currents was important throughout.
2. Few of the foraminifera are of use for stratigraphic correlation, but the presence of N. finlayi indicates a stratigraphic position above the Hurupiensis-finlayi Datum for the lowest beds at Waverley Beach.
3. At present, benthonic foraminiferal ecology is insufficiently well known in New Zealand to permit analysis of conditions of deposition in more detail than already inferred from mollusca.
4. Foraminifera are usually most abundant and diverse in the shellbeds, and absent or rare in well sorted sands that contain few mollusca.
5. Paleobathymetric data, though scanty, is consistent. Depths given by Fleming (1953) for the formations of these three sections indicate shallow water conditions at the base of the Waipipian Stage, followed by deepening, then shallowing again in the upper Waipipian. The Mangapanian Stage consists of sediments deposited in shallow conditions, with a deepening at the top during which the Wilkies Shellbed was deposited, followed by shallowing in the Hautawan.

Table 2. - Locality and lithology of microfossil samples examined
from Wilkies Bluff and Waverley Beach Sections.

Sheet No. N137 (Waverley), 2nd Edition, 1965.

Fossil No.	Locality	Grid Ref.	Lithology*
Wilkies Bluff:			
f629	9.5m above base of exposure	254973	661-65S
f630	10.5m above base of exposure	254973	662-65S
f631	2.5m above base of exposure	254973	772-65
Waverley Beach:			
f658	350m SE of Wairoa Stream mouth	169993	884-M82SSS
f659	350m SE of Wairoa Stream mouth	169993	884-M82
f660	W bank of Wairoa Stream mouth	166994	884-M82
f661	130m W of Wairoa Stream mouth	165994	884M82SSS
f662	130m W of Wairoa Stream mouth	165994	884M82
f663	550m W of Wairoa Stream mouth	161995	884D82
f664	550m W of Wairoa Stream mouth	161995	884M82
f665	555m W of Wairoa Stream mouth	161995	884M82
f666	Snapper Point, 1550m W of Wairoa Stream mouth	151994	884-M82
f667	85m W of Snapper Point	150995	384-M82
f668	150m W of Snapper Point	148995	771-M52

* Lithologic code of N.Z.F.R. forms

Table 2. - continued.

Fossil No.	Locality	Grid Ref.	Lithology*
f669	W side of Snapper Point, 1570m W of Wairoa Stream	151994	884-M82
f683	900m E of Waipipi Point, reefs at low tide	127999	5762M2500S
f684	1700m E of Waipipi Point	136000	784-1M82S
f685	800m W of Snapper Point	14997	874-1M82
f686	1500m E of Wairoa Stream mouth	196985	874-1L27
f687	20m W of stream by Waverley Beach motor camp	191982	784-1L27M
f688	50m west of end of cliffs on W of Waitotara River mouth	207978	874-2L2M0SS

* Lithologic code of N.Z.F.R. forms

Table 2a. - Locality and lithology of microfossil samples examined
from Waitotara Valley - Rangitatau Escarpment Section

Sheet No. N130 (Waitotara), 1st Edition, 1962

Fossil No.	Locality	Grid Ref.	Lithology*
f530	Waitotara Valley Rd, 850m S of Orangimeea School	393165	8941L82
f531	Waitotara Valley Rd, 2km S of Orangimeea School	375129	7841L82M

Sheet No. N137 (Waverley), 2nd Edition, 1965

f676	1900m up Mangapunipuni Stn from jcn with Waitotara R.	378098	5330L65MMWW
f677	Same locality as f676	378098	8343L65SSSW
f678	Waitotara Valley Rd, 1.5km S of Mangapunipuni Stn	369085	7931L82
f679	Waitotara Valley Rd, 3km N of jcn with Parekama Rd.	323042	7841L8
f680	Rangitatau West Rd, 1300m N of Te Rama trig	422075	7943L82SSS
f681	Rangitatau West Rd, 200m N of Te Rama trig	415067	9841L82WW
f682	Rangitatau West Rd, quarry near Oamarumui	395051	4654M82SSS

* Lithologic code of N.Z.F.R. forms.

WANGANUI RIVER SECTION

Introduction

Strata of Landon to Castlecliffian age (Oligocene to Pleistocene) outcrop in Wanganui River valley (Lensen, 1959; Hay, 1967). Samples were collected at fairly regular stratigraphic intervals from the lower Pliocene Taihape Mudstone near Ranana up to the Pleistocene Upper Okiwa Group near Pungarehu. They were taken at the same time and same sites as geomagnetic polarity samples collected by Professors N. D. Watkins and J. P. Kennett of the Graduate School of Oceanography, University of Rhode Island. Geomagnetic sample numbers corresponding to microfossil samples used in this study are given in Table 6. Sample locations are shown in Fig. 12, lithologies and sample horizons in the columnar section in Fig. 13.

Park (1887a) described outcrops above the Nukumarua Limestone in lower Wanganui River and discussed in less detail the geology between Parikino and Pipiriki. Park (1887b) and Fyfe (1946) briefly described strata of the upper Wanganui River, outside the area studied in this report.

Superior Oil Company geologists mapped the Wanganui River and in their unpublished report describe a reconnaissance survey of the older rocks of the upper Wanganui River (Superior, 1943). The lithology of younger rocks (from Opoitian upwards) was shown in detail on a stratigraphic column, but not described in the text.

Fig. 12. - Sample locality map of the Wanganui
River section. Partly after Superior
(1943).

Fleming (1953) described strata in Wanganui Valley to about 30 km from the river mouth, and mapped a number of formations (Table 4). Lensen (1959) showed the Opoitian-Waitotaran boundary crossing Wanganui River at the mouth of Ruapirau Stream (approximately 30m stratigraphically below the Opoitian-Waipipian boundary as recognised in this study), and placed the Waitotara-Nukumaruan boundary at the Hautawa Shellbed. The Waitotaran as defined by Lensen is equivalent to Superior's zones TW1, TW2 and lower part of TN2B.

Structure

Strata in Wanganui River dip regularly at 5° or less south-south-west. Fleming (1953) described the Nukumarua Fault zone crossing the coast 6km east of Waitotara River as 600m wide with a total known throw of 150m. He considered this zone could represent the east flank of the Wanganui Anticline in the coastal region, and that the fault was active in later Wanganui times and may then have controlled the western shore of the basin. Fleming showed the Nukumarua Fault Zone extending to the northern edge of N.Z.M.S.1, Sheet District N137, and Lensen (1959) extended it several kilometres to the northeast. Cope and Reed (1967, Fig. 9) extrapolated it into the Taupo Graben as a hypothetical major basement fault, but did not discuss it in the text.

Shattered, massive Taihape Mudstone observed near Ranana may represent the course of the fault zone (Fig. 12), although no

displacements were observed during this study. Faulting may be the cause of large fluctuations in faunal composition in this part of the section (Figs. 14, 15).

Superior (1943), mapped a small fault striking approximately east-west with a displacement of 30m, repeating strata near Koriniti Pa (Fig. 12).

Macpherson (1946) described the Wanganui Anticline in the area west of Lake Taupo. Superior (1943) mapped this feature as a southward plunging fold in the upper reaches of the Wanganui River, but it does not affect strata included in this study, except possibly as the Nukumaru Fault Zone. The Upokongaru Fault (Superior, 1943, p.37, map; Fleming, 1953) passes to the south of the youngest beds sampled and likewise does not affect this study.

Stratigraphy

Introduction

Superior (1943) based their formation names and biostratigraphic zones upon strata exposed in the Rangitikei River and associated valleys. They were reluctant to use the same formation names for strata exposed further west, because of facies change which hindered recognition of marker beds. Names given by Superior in their stratigraphic column, but not in the text, to Pliocene and lower Pleistocene beds in the Wanganui River section are shown in Table 3, together with the appropriate biostratigraphic zones.

Table 3. - Lithostratigraphic units and biostratigraphic zones recognised in Wanganui River by Superior (1943, stratigraphic column [part]).

FORMATIONS	INTERVENING UNNAMED STRATA	FORAM. ZONES
Basal Nukumaruan Sand	Massive mudstone Sandy mudstone Muddy silst. & silty mdst. Massive mudstone Massive mudstone	TN2B
Atene Sand		TW1 ? TW2
Ahuahu Sand		
Koriniti Sands		
Matahiwi Sand		TW3
Jerusalem Sands		
Reef Bearing Sands		TW4

Fleming (1953) named a number of upper Pliocene and Pleistocene formations (Table 4), and introduced the name Mangaweka Mudstone from Superior's Rangitikei River section.

The lithologic classification adopted in this study is shown in Table 5. The divisions recognised by Fleming are followed for the upper part of the section. The remaining formations and member names are based in part on those used by Superior (1943, stratigraphic column). A suggested correlation of formations across Wanganui Basin is shown in Fig. 27.

Taihape Mudstone

Superior (1943) defined this formation in the Rangitikei River valley near Taihape and stated that it "generally loses character between the Turakina and Wangashu Rivers, and is not a mappable unit west of this locality". The Utiku Sand, which overlies the Taihape Mudstone at the Rangitikei River, becomes progressively finer grained and less clearly defined towards the west. Mudstone between Ranana township and Raupirau Stream along the Wanganui River is similar in age and lithology to the Taihape Mudstone at Rangitikei River, and is treated as the same formation.

In Wanganui River, Taihape Mudstone is 675m thick and overlies sands, silts and shellbeds of the Waiouru Sandstone (the Reef-bearing Sands of Superior). It is massive, dark grey mudstone with abundant borings and rare molluscs. Near the base are the 55m thick Jerusalem Sands (not sampled in this study). The top is a sharply defined contact with the overlying Korinititi Sandstone.

Table 4. Lithostratigraphic units and biostratigraphic zones of the Paparangi, Okiwa and Nukumarū Groups in Wanganui River erected by Superior (1943) and Fleming (1953).

FLEMING (1953)		SUPERIOR (1943)	
GROUP	FORMATION	UNIT	ZONE
NUKUMARU	Waipuru Shellbed undiff. shellbed Nukumarū Brown Sand Nukumarū Formation Ohingaiti Sand	Waipuru Sand Ohingaiti Sand	TN1B
OKIWA	UPPER undiff. formations Upokonui Sand Hautawa Shellbed	Hautawa Reef Horizon	TN2A
	LOWER undiff. formations Parihauhau Shellbed undiff. formations Ti Rimu Sand		TN2B
PAPARANGI	Wilkies Shellbed Mangaweka Mudstone	Basal Nukumeruan Sand	TW1

Table 5. - Pliocene and lower Pleistocene lithostratigraphic units and biostratigraphic zones of the Wanganui River section recognised in the present study. Stage abbreviations follow the N.Z. Fossil Record system.

FORMATION	MEMBER	STAGE	ZONES
undiff. fms.		Wh	FINLAYI
Hautawa Shellbed			
undiff. fms.		Wm	
Te Rimu Sand			
Wilkies Shellbed			
Mangaweka Mdst.	Pitangi Mudstone	?	?
	Atene Sand		
	Mangapapa Silstone		
	Ahuahu Sand		
	Raumati Mudstone	Wp	MOLESTUS
Koriniti Sandstone			
Taihape Mudstone	Matahiwi Siltstone Jerusalem Sands	Wo	HURUPIENSIS
Waiouru Sandstone		?	

Matahiwi Siltstone Member:

Type locality: Wanganui River, outcropping for 400m both above and below the township of Matahiwi, Grid ref. N131/677261 to 688257.

A 40m thick bed of hard, grey-brown siltstone 110m below the top of the Taihape Mudstone was termed the Matahiwi Sand by Superior (1943, stratigraphic column, map) but grain size analysis shows it to be a fine silt (Mrs D. Seward, pers. comm.). The member is distinctive and the name Matahiwi Siltstone is proposed.

Koriniti Sandstone

Type locality: Wanganui River, outcropping from a point 400m north of Ruapirau Stream south to Koriniti Pa, Grid ref. N131/693241 to 677204.

The type section is as follows:

Massive blue-grey calcareous mudstone (basal member of Mangaweka Mudstone) grades down to	
Koriniti Sandstone:	m
Medium, yellow-brown unfossiliferous muddy sandstone,	
sharp contact with underlying mudstone	25
Massive, blue-grey calcareous mudstone with sparse molluscs	
and abundant foraminifera, sharp contact with	
underlying sandstone	20
Medium, yellow-brown unfossiliferous sandstone with thin	
mudstone laminae	70

Massive, blue-grey calcareous mudstone as above, with sharp contacts above and beneath	50
Medium, yellow-brown unfossiliferous sandstone with thin mudstone laminae as above, sharp contact with underlying formation	85
Massive, hard, dark grey Taihape Mudstone	675
	925

Each sand body consists of soft, medium to coarse, muddy sandstone weathering yellow-brown and barren of molluscs and foraminifera. The lower two sand units are interbedded with thin mudstone layers. The massive blue-grey mudstone separating the sandstones contains rare molluscs and abundant foraminifera. Occasional concretions are present.

Mangaweka Mudstone

Superior (1943) defined the Mangaweka Mudstone at the Rangitikei River near Mangaweka. They stated that west of the Turakina River "with the underlying Utiku Sand losing character, the Mangaweka Mudstone ceases to be a mappable unit". Although the nature of the lower boundary changes, the Mangaweka Mudstone is still recognisable in Wanganui River (Fleming, 1953). Fleming noted that the proportion of sand relative to silt and mud increases vertically towards the upper part of the formation and laterally towards the west.

The formation is here considered to include all strata between the Wilkies Shellbed and the Koriniti Sandstone. The following five members are distinguished:

Pitangi Mudstone

Atene Sand

Mangapapa Siltstone

Ahuahu Sand

Raumati Mudstone

The mudstone members of this formation are calcareous, moderately soft, blue-grey and silty in places, and are generally coarser, softer and lighter in colour than the Taihape Mudstone below.

Raumati Mudstone:

Type locality: Wanganui River from Koriniti Pa downstream to a point 300m south of Raumati Stream, Grid ref. N131/677204 to 674164.

Raumati Mudstone is 320m thick, micaceous and contains sparse molluscan fossils. A single concretionary band is present 200m above the base, and above it the member becomes increasingly coarser-grained (Fig. 13) and at 320m grades rapidly into the Ahuahu Sand.

Ahuahu Sand:

Type locality: Wanganui River from a point 300m south of Raumati Stream to the mouth of Ahuahu Stream, Grid ref. N131/674164 to 652144.

The Ahuahu Sand is fine to coarse grained, blue-grey muddy sandstone, 170m thick. The lower part is massive, the upper part

Fig. 13 Stratigraphic column of the Wanganui River section showing sample horizons, lithology and the percentage of each sample coarser than 75 microns. Lithology partly after Superior (1943, stratigraphic column).

cross-bedded and concretionary. The sandstone is soft, leached and weathers yellow-brown, with common shell casts at top and bottom, and grades into the overlying siltstone.

Mangapapa Siltstone:

Type locality: Wanganui River from just below the mouth of Ahuahu Stream downstream for 2.3km, Grid ref. N131/652144 to 652118.

Mangapapa Siltstone consists of blue-grey siltstone, 120m thick, and grades up to the Atene Sand. It contains common macrofossils and foraminifera, and is named from Mangapapa Stream which enters Wanganui River at N131/647132.

Atene Sand:

Type locality: Wanganui River from about 1km above to 500m below Atene Pa, Grid ref. N131/652118 to 675114.

The Atene Sand consists of fine sandstone interbedded with siltstone and muddy sands, with abundant borings, rare macrofossil fragments and scarce foraminifera. The top grades up to Pitangi Mudstone.

Pitangi Mudstone:

Type locality: Wanganui River from 500m below Atene Pa downstream to 100m below Whakaihuwhaka, Grid ref. N131/675114 to 672065.

The Pitangi Mudstone is massive and 350m thick. Sand-filled borings are common in the lower part. Foraminifera and mollusca are

rare through most of the member. About 60m below the top, the mudstone grades up into siltstone and fine sandstone with common mollusca and foraminifera. The top is an irregular channelled and current-scoured surface overlain by the Wilkies Shellbed.

Wilkies Shellbed

In the Wanganui River section, the Wilkies Shellbed is a 5 to 9m thick siltstone layer packed with very abundant Crassostrea ingens (Zittel) and Chlamys gemmulata (Reeve).

The strata above the Wilkies Shellbed were described by Fleming (1953). They consist of sands, silts and muds, with common macrofossils and well-developed shellbeds.

Biostratigraphy

Three foraminiferal zones are recognised in the Wanganui River section (Table 5), the Hurupiensis, Molestus and Finlayi Zones. The distribution of foraminifera through the section is given in Tables 28 and 29 (in appendix). Index mollusca are absent from much of the Pliocene of this section, and key foraminifera tend to be sporadic in distribution.

Hurupiensis Zone

Notorotalia hurupiensis vella is present through the Taihape Mudstone and in the lower part of the Koriniti Sandstone. A few

specimens resembling N. finlayi Vella appear 50m lower in the section, but the change to a population which is predominantly N. finlayi occurs over a short stratigraphic interval about 40m above the base of the Korinita Sandstone. Other species restricted to this zone include Karrerella cylindrica Finlay, Lenticulina mammilifera (Karrer), Euuvigerina zeacuminata (Vella), Cibicides ihungia Finley and Cassidulina cuneata Finlay. Common Notorotalia taranaki Vella are restricted to the Hurupiensis Zone, but occasional specimens are found higher in the section.

Molestus Zone

This zone is defined by the overlapping ranges of Notorotalia finlayi Vella and Cibicides molestus Hornibrook. There are no restricted species. N. finlayi arises near the bottom of the Korinita Sandstone and is common in most samples through the rest of the section. C. molestus is uncommon through the Taihape Mudstone, becomes very common through the Korinita Sandstone and disappears 115m above the base of the Raumati Mudstone. Saracenaria spp. and Robulus costatus (Fichtel & Moll) also disappear within this zone.

Finlayi Zone

The Finlayi Zone represents that part of the range of N. finlayi following the extinction of C. molestus, and lasts from the top of the Waipipian to the Recent. Many species make their earliest appearance in the Wanganui River in this zone, but most of them appear earlier

elsewhere in New Zealand and are evidently facies controlled.

Notorotalia zelandica mangaoparia Vella, s.s., appears near the base of the Finlayi Zone, and N. pliozea Vella ranges from the middle of the Molestus Zone through the lower part of the Finlayi Zone.

The Delicatula Zone, based on the presence of the mollusc Chlamys delicatula (Hutton), is represented in this section by the Hautawa Shellbed, 200m above the Wilkies Shellbed. Despite careful search, the important planktonic species Globorotalia truncatulinoides (d'Orbigny) was not found.

Paleoecology

Benthonic Faunal Trends

1) The number of benthonic species present in each sample varies widely through the section (Fig. 14). A diverse foraminiferal fauna is present in the Opoitian Taihape Mudstone and from the mudstone layers of the Korinita Sandstone. The number of species decreases irregularly up to the presumed shallow water Ahuahu Sand (550-1000m), which is barren of foraminifera.

In the middle part of the section (1000-1400m), the number of species present ranges from 30 to 60 species in mudstone samples to nil in sandstone samples.

Fig. 14. - Foraminiferal trends through the
Wanganui River section.

A very striking and abrupt rise in the diversity of the micro-fauna occurs in the sandy formations and shellbeds at the top of the Mangaweka Mudstone (ca. 1400m), and continues through the sampled part of the Pleistocene.

2) The foraminiferal number is highly variable, with less than one specimen per gram in many samples ranging up to a maximum of 915 specimens per gram (Fig. 14). The foraminiferal number curve for the section roughly parallels that of the number of benthonic species per sample.

Foraminifera are moderately abundant in the Taihape Mudstone and reach a peak abundance in the mudstone layers of the Korinititi Sandstone. Foraminifera are completely absent from the sandstones of the Ahuahu and Atene Sands, and are present in low to moderate abundance in the intervening siltstones and mudstones.

In the upper part of the Pitangi Mudstone there is an abrupt increase in the foraminiferal number, comparable to the increase already noted in the number of benthic^{on} species per sample. Through the Pleistocene, the foraminiferal number, although low in several samples, is maintained at a higher average than for the rest of the section.

3) Percentage of arenaceous forms. Arenaceous species are most abundant in the Taihape Mudstone and mudstone layers of the Korinititi Sandstone, reaching a maximum of 26% of the benthonic fauna. Above this, they

form only an insignificant part of the fauna, usually less than 1%, with local and minor increases in abundance at several horizons (Fig. 14). The maximum abundance is in the deepest water facies.

The dominant species, Haeuslerella parri Finlay, is present throughout the Pliocene. In the Taihape Mudstone, Haeuslerella pliocenica (Finlay) and Karrerella cylindrica Finlay are also common.

Siphotextularia wairoana Finlay is uncommon, but present throughout the section. The remaining arenaceous species are sporadic and usually rare. Species of Textularia are very rare.

Planktonic Faunal Trends

The planktonic assemblage generally present is characteristic of temperate regions, with the following common species: Globorotalia crassaformis (Galloway & Wissler), Globorotalia inflata (d'Orbigny), Globigerina bulloides d'Orbigny and related species, G. pachyderma (Ehrenberg), Turborotalita quinqueloba (Natland), Globigerinita glutinata (Egger) and G. uvula (Ehrenberg). Low latitude species such as Globorotalia menardii (Parker, Jones & Brady), Globigerinoides ruber (d'Orbigny), G. siphonifera (d'Orbigny) and Pulleniatina obliquiloculata (Parker & Jones) are rare or absent.

Except in the Taihape Mudstone and parts of the Okiwa Group, planktonic foraminifera are a very minor part of the foraminiferal fauna. There are a number of barren zones in the section, including most of the coarser grained sediments. The mudstone layers between the sand bodies in the Koriniti Sandstone have a good fauna, but the remaining sands and

some of the siltstone in the upper part of the Pitangi Mudstone leave large gaps in the record. Planktonic species reach their greatest abundance in the Taihape Mudstone, are generally sparse through the Koriniti Sandstone and Mangaweka Mudstone, and increase somewhat in abundance higher in the section.

The main trends are as follows (Fig. 15):

- 1) The abundance of the Globigerina bulloides group of species relative to other planktonic species increases upwards, reaching a maximum at the base of the Okiwa Group. Smaller peaks occur in the Taihape Mudstone, lower Koriniti Sandstone, Mangapapa Siltstone and uppermost Pitangi Mudstone.
- 2) There is also a general but less marked increase in the abundance of Globigerina pachyderma (Ehrenberg) through the section, and abundance peaks of this species coincide with those of the G. bulloides group.
- 3) The coiling ratios of G. pachyderma show a general increase of sinistrally coiled forms with time. Sinistral forms are dominant in the Taihape Mudstone, decrease in the Koriniti Sandstone, and show an increase towards the top of the Raumati Mudstone maintained through to, and increased in, the Okiwa Group.
- 4) The ratio of planktonic to benthonic species (Fig. 14; Table 19, in appendix) is generally very low, planktonics usually forming less than 1% of the total population but in one sample reaching 36% and in several others 10-15%.

Fig. 15. - Cumulative abundances and absolute ranges of selected planktonic species, and coiling ratios of Globigerina pachyderma, through the Wanganui River section.

Paleobathymetry

A paleobathymetric curve for the Pliocene and lower Pleistocene of the Wanganui River section is given in Fig. 14, together with the stratigraphic column. The biofacies changes largely parallel the lithologic changes, and clearly indicate a complex shallowing history.

The Taihape Mudstone has abundant foraminifera, including common planktonic specimens, and common radiolaria. Mollusca and ostracoda are rare. The presence in abundance of moderately deep water species, such as Karrerella cylindrica Finlay and Haeuslerella pliocenica (Finlay), with rare to common Pullenia bulloides (d'Orbigny) and Bulimina striata d'Orbigny, rare Astrononion neefi (Vella) and a varied Lagenid fauna, together with shallower water species such as common Bulimina aculeata d'Orbigny and uncommon Nonionellina flemingi (Vella), is typical of a shallow Robulus Biofacies assemblage, indicating depths of probably 370 to 400m. The zone of abundant deep water species 75m below the top of the Taihape Mudstone may represent the greatest depth reached in this part of the basin during the subsidence following deposition of the shallow water Waiouru Sandstone.

The mudstone members of the Koriniti Sandstone contain a well-developed foraminiferal fauna, with abundant Haeuslerella parri Finlay and Melonis zeobesus Vella. Haeuslerella pliocenica (Finlay) is absent, and moderately deep water species such as Bulimina striata d'Orbigny, Notorotalia taranakia Vella and large Lagenids are reduced in abundance. The fauna indicates the deeper part of the Haeuslerella Biofacies, with an inferred depth of deposition of 200 to 300m. Foraminifera are absent

from the sandstone members of the formation, although abundant in the surrounding mudstones. The contacts between the mudstone and sandstone, where exposed, are sharp and non-gradational. Molluscan fossils are present only rarely in the mudstone, and have not been observed in the sand layers. Grain size analysis of sample N131f534, from the lowest sandstone unit of the Koriniti Sandstone, shows it to be a moderately well-sorted, very fine sand (Mrs D. Seward, pers. comm.). These details, together with the fact that the benthonic foraminiferal fauna shows gradually shallowing depths from approximately 300m to 200m, with no abrupt depth changes (Fig. 14), indicates that these sands are displaced and have resulted from the movement of shallow water deposits down-slope.

The Raumati Mudstone member of the Mangaweka Mudstone contains abundant foraminifera, rare mollusca and infrequent ostracoda. The fauna differs markedly from that of the Taihape Mudstone, completely lacking Haeuslerella pliocenica (Finlay), Karrerella cylindrica Finlay, Pullenia bulloides d'Orbigny and Astrononion neefi (Vella). Notorotalia taranakia Vella and Bolivina affiliata Finlay are rare, and the number of species of Lenticulina, Rebulus and Saracenaria reduced. Abundant Haeuslerella parri Finlay, uncommon Bulimina marginata d'Orbigny, Notorotalia finlayi Vella and Siphotextularia wairoana Finlay, and increasing numbers of Nonionellina flemingi (Vella), Criboelphidium charlottensis (Vella), C. simplex (Cushman) and mollusca towards the top of the mudstone indicate the middle Haeuslerella Biofacies at the base,

shallowing to middle Elphidium Biofacies near the top. The inferred depth range is from 200m at the base of the member to 40m or less at the top.

Gradational contacts above and below the Ahuahu Sand, the presence of shell casts near the top and bottom, and the presence of current bedding, indicate deposition in a shallow marine environment. This is supported by the benthonic foraminifera, which show an increase in the rate of shallowing towards the top of the underlying mudstone. No microfossils were recorded from the sand, and molluscan fossils, including casts, are absent from the middle part of the member. The evidence indicates that the Ahuahu Sand was laid down in very shallow water, and may have been above base-level at some stage.

Benthonic foraminifera from the Mangapapa Siltstone, above the Ahuahu Sand, indicate an increase in depth of deposition. A notable feature of the foraminiferal faunas from the shallow water deposits immediately above and below the Ahuahu Sand, from the Atene Sand and from the shallow zone near the middle of the Pitangi Mudstone, is the absence or rarity of Zaeflorilus parri (Gushman), Ammonia aoteanus (Finlay) and certain other shallow water species, especially Discorbids, which are abundant and characteristic in the shallow water deposits higher in the section. Possibly Wanganui Basin was too isolated and the fluctuations in depth too swift for complete shallow-water assemblages to colonise the area at any time before the widespread and permanent shallowing near the end of the Pliocene.

The Mangapapa Siltstone contains a moderate number of species and of specimens per gram. Common Haeuslerella parri Finlay, Bulimina

aculeata d'Orbigny, Nonionellina flemingi (Vella), Criboelphidium charlottensis (Vella), Notorotalia finlayi Vella and Bolivina spp. are characteristic of middle Elphidium to shallow Haeuslerella Biofacies. The foraminifera indicate that after deposition of the Ahuahu Sand, the depth of deposition increased to a maximum of 150 to 200m, then shallowed again.

The siltstones and sandstones of the Atene Sand member were deposited in fairly shallow water. The sandstones are barren of foraminifera, but the interbedded silts contain fairly sparse foraminifera probably representing a middle or shallow Elphidium Biofacies. Many typical shallow water species are absent, as in sediments surrounding the Ahuahu Sand.

The Pitangi Mudstone member, overlying Atene Sand, contains a middle or deep Elphidium Biofacies (ca. 70m) indicating an increase in depth. Several barren zones are present in this member (Fig. 14), but their ecological significance is not known. The upper part of the member contains a middle to shallow Elphidium Biofacies, with an inferred depth range of 7-35m. The number of species and the foraminiferal number increase very rapidly at this level (Fig. 14).

The Wilkie's Shellbed has a rich foraminiferal fauna, including abundant shallow water species which indicate Zeafiorilus to middle Elphidium Biofacies (0-35m).

The sandy formations above the Wilkie's Shellbed all have rich shallow water faunas indicating Zeafiorilus to shallow Elphidium Biofacies (0-15m). Accurate depth zoning of the shallow water deposits

is not possible, but increased abundance of Zeaflorilus parri (Cushman) above the Wilkies Shellbed may indicate that a slight shallowing occurred.

Summary

1. The sampled part of the Wanganui River section represents a series of Lower Pliocene to Pleistocene sediments deposited in depths ranging from 400m to 7m or less.
2. The massive Taihape Mudstone was deposited on the rapidly subsiding basin floor. Foraminifera indicate that the maximum depth reached by this part of the basin during the Pliocene was ca. 400m. The top of the Taihape Mudstone (uppermost Opoitian) contains evidence of significant shallowing.
3. Interbedded sandstones and mudstones of the Korinititi Sandstone appear to have resulted from the movement of well-sorted sands downslope from shallow water into moderately deep water. They contain no typical turbidite features and their mode of downslope movement is uncertain.
4. The sea shallowed steadily and regularly to the time represented by the top of the Raumati Mudstone member of the Mangaweka Mudstone (?early Mangapanian). Rapid shallowing then occurred until the Ahuahu Sand was deposited in shoal water conditions. Lack of abundant and varied shallow water foraminifera indicates some degree of isolation of this area.

5. A series of shallowings and deepenings next occurred, with the water depth alternating between 150 or 200m and less than 7m. An incomplete planktonic foraminiferal record makes determination of a tectonic or climatic cause for these changes difficult.
6. Some stability appears to have been reached by the time the Pitangi Mudstone member of the Mangaweka Mudstone was deposited, when rates of sedimentation and basin floor subsidence (or sea level rise) appear to have become equal. This condition continued through the Hautawan, possibly with a slight shallowing at the beginning of Hautawan time.

Table 6. - Locality and Lithology of the Microfossil Samples
Examined from the Wanganui River Section.

Sheet No. N131 (Kakatahi), 1st Edition, 1969

(Unless otherwise stated, these samples were collected at river level in the Wanganui River.)

Fossil No.	Locality	Grid Ref.	Lithology*	Paleomag. No.
f515	E bank 200 metres up from N end Moutua Island	621292	9942L82B	ZM 1
f516	W bank opposite middle of Moutua Island	623287	9952L82B	ZM 3
f517	W bank 100 metres below S end Moutua Island	625287	9842L82BB	ZM 6
f518	W bank 1000 metres below S end Moutua Island	636286	9842L82BB	ZM 10
f519	W bank opposite and 200 metres below mouth of Whataumu Stream	640285	9842L82BB	ZM 11
f520	E bank 700 metres below mouth of Whataumu Stream	645284	9842L82BB	ZM 13
f521	E bank 850 metres below mouth of Whataumu Stream	645283	9842L82	ZM 14
f522	E bank 200 metres up from junction Mokonui Rd and Pipiriki Rd	646279	9842L82	ZM 15
f523	W bank 300 metres up from Otamakopiri Stream	650276	9842L82	ZM 17
f524	W bank 200 metres up from Otamakopiri Stream	652275	9842L82BBB	ZM 18
f525	E bank opposite mouth Otamakopiri Stream	654277	9842L82BB	ZM 20
f526	W bank opposite mouth Orongaiea Stream	656276	9842L82B	ZM 21
f527	W bank opposite and 150 metres down from Orongaiea Stream	658277	9842L82	ZM 22
f528	E bank by Matahiwi pontoon landing	678258	894125	ZM 24

* Lithologic code of N.Z.F.R. forms.

Table 6. - continued

Fossil No.	Locality	Grid Ref.	Lithology*	Paleomag. No.
f529	E bank 150 metres below S end Moutere Island	686258	984125	ZM 25
f530	W bank 700 metres up from mouth of Ruapirau Stream	689244	894125	ZM 26
f531	Locality as for f530, 3 metres higher stratigraphically	689244	894125	ZM 28
f532	Locality as for f530, 6 metres higher stratigraphically	689244	894125	ZM 30
f533	W bank 700 metres down from Ruapirau Stream	686234	8942L82	ZM 31
f534	W bank 1 km down from mouth Ruapirau Stream	687230	663065W	
f535	W bank 1.4 km down from mouth of Ruapirau Stream	689228	8941L28	ZM 32
f536	W bank 1 km up from mouth of Otuporiki Stn	677204	9842L82	ZM 35
f537	W bank 800 metres up from mouth of Otuporiki Stn	676203	9842L82	ZM 37
f538	W bank 150 metres up from mouth of Otuporiki Stream	675199	9842L82	ZM 40
f539	E bank 300 metres down from Matawhero Stream	678191	9842L82	ZM 42
f540	E bank 900 metres down from Matawhero Stream	675186	9842L82	ZM 44
f541	E bank 950 metres down from Matawhero Stream	675185	9842L82M	ZM 46
f542	W bank 200 metres up from Opoi Stream	675180	9842M82M	ZM 47
f543	W bank 100 metres up from Opoi Stream	675179	9842L8200	ZM 49
f544	E bank 300 metres down from Mangatua Stream	676176	8941M82	ZM 52
f545	W bank 700 metres up from Raumati Stream	676173	8941M82	ZM 54

*Lithologic code of N.Z.F.R. forms

Table 6. - continued

Fossil No.	Locality	Grid Ref.	Lithology*	Paleomag. No.
f546	W bank 600 metres up from Raumati Stream	677172	8941M82	ZM 56
f547	E bank 50 metres up from Raumati Stream	674167	7730M8W	ZM 58
f548	W bank 600 metres down from Raumati Stream	672162	7730M8W	ZM 59
f549	E bank SE of Te Papaku trig	674154	7730M82W	ZM 61
f550	W bank 1.7 km up from Ahuahu Stream	666151	7730M82WW	
f551	W bank on S side of Ahuahu Stream mouth	652144	7730M82WW	ZM 66
f552	W bank 400 metres up from Mangapapa Stream	647136	8942L82	ZM 68
f553	W bank 300 metres up from Mangapapa Stream	647135	8942L82	ZM 70
f554	W bank 20 metres down from Mangapapa Stream	647131	8941M82CS	ZM 73
f555	W bank 1100 metres below Downe's Hut	664113	7941L82	ZM 76
f556	E bank 300 metres below Atene Trig	673118	8942M82BBB	ZM 78
f557	W bank 1 km below Atene Trig	676111	6830M25WW	ZM 80
f558	By Pipiriki Road bridge over Pararoa Stream	694217	9841L82MM	

*Lithologic code of N.Z.F.R. forms.

Table 6. - continued

Sheet No. N138 (Wanganui), 2nd Edition, 1967

(Unless otherwise stated, these samples were collected at river level in the Wanganui River.)

Fossil No.	Locality	Grid Ref.	Lithology*	Paleomag. No.
f548	E bank 500 metres up from bend opposite Otawaki Trig	676099	9842L82	ZM 82
f549	E bank 350 metres up from bend opposite Otawaki Trig	675098	8941L82BB	ZM 84
f550	E bank 100 metres up from bend opposite Otawaki Trig	674096	8941L82BB	ZM 86
f551	W bank 200 metres down from bend opposite Otawaki Trig	673094	8941L82	ZM 88
f552	W bank 500 metres down from bend opposite Otawaki Trig	675092	8941M82	ZM 90
f553	E bank 2.1 kms up from Pitangi Stream	678088	8941M82	ZM 92
f554	W bank 1.8 kms up from Pitangi Stream	677083	8942L82	ZM 94
f555	W bank 1.3 kms up from Pitangi Stream	678077	8941L82	ZM 97
f556	E bank 200 metres up from Pitangi Stream	688072	8941L82W	ZM 99
f557	E bank 200 metres down from Whauteihi Stream	691065	7730M82WS	
f558	W bank 300 metres below bend at Whakaihuwhaka	672065	8742M82SS	ZM 101
f559	W bank 450 metres below bend at Whakaihuwhaka	671064	8842M82SS	ZM 102
f560	W bank opposite Parikino	665036	8742M82	ZM 103
f561	E bank 400 metres down from Parikino School	670029	8841M82	ZM 105
f562	W bank 1.7 kms up from Pungarehu Pt	667023	8841L82	ZM 107

* Lithologic code of N.Z.F.R. forms.

Table 6. - continued

Fossil No.	Locality	Grid Ref.	Lithology*	Paleomag. No.
f563	Locality as for f562 but 6 metres stratigraphically higher	667023	8841L82	ZM 109
f564	Locality as for f562 but 20 metres higher	667023	8841L82	ZM 113
f565	W bank opposite Pungarehu Pt	667009	8841M82S	ZM 114
f566	W bank 500 metres down from Pungarehu Pt	667004	8841M82	ZM 116
f567	E bank 700 metres down from Pungarehu Pt	667001	7840M82	ZM 118
f568	E bank 1.7 kms down from Pungarehu Pt	665992	7740M82	ZM 119
f569	W bank 500 metres down from sharp bend in river	657998	8740M82	ZM 120
f570	E bank 2.1 kms down from sharp bend in river	649006	8740M82	ZM 121

*Lithologic code of N.Z.F.R. forms

RANGITIKEI RIVER AND WATERSHED ROAD SECTIONS

Introduction

Strata ranging in age from Lower Pliocene through to Pleistocene are exposed in the valleys of the Rangitikei River and its tributary, the Moawhango River (Kingma, 1962). Sampling was begun in the Waiouru Sandstone (Opoitian) near Moawhango, and continued up into Okehu Group sediments (Castlecliffian) at Silverhope. Sample locations are shown in Fig. 16, and lithology and sample horizons are given in the columnar section in Fig. 17. Samples collected above N139f549 in the section proved devoid of foraminifera and are not referred to.

Additional samples were collected from the Watershed Road section, paralleling the Rangitikei River section some eight miles to the west and crossing the presumed Pliocene-Pleistocene boundary (Figs. 16, 20).

The early surveys of this area have already been discussed. The first detailed mapping was by Superior Oil Company geologists who described the stratigraphy, collected microfossil samples at nominal 10 foot intervals, and based their standard lithostratigraphic and biostratigraphic sequences on this section (Superior, 1943). Superior's formations, published by Ongley (1945), and their foraminiferal zones are shown in Table 7.

Te Punga (1952a) described and discussed the geology of the Rangitikei Valley. He made no reference to the stratigraphic mapping of the Superior geologists, and erected a different set of lithologic units (Table 7).

Fig. 16. - Sample locality map of the Rangitikei
River and Watershed Road sections.

Fig. 17 - Stratigraphic column of part of the Rangitikei River section, showing sample horizons, a simplified lithology, and the percentage of each sample coarser than 75 microns.

Table 7. - Lithologic units and biostratigraphic zones erected for the Rangitikei River section by Superior (1943) and Te Punga (1952a). Only the more important of Superior's members have been included, and those of Te Punga are omitted.

SUPERIOR (1943)			TE PUNGA (1952a)
FORMATION	MEMBER	FORAM. ZONE	FORMATION
Upper Nukumaruan (Petane)	Waipuru Sand Mangamako Sand Ohingaiti Sand	TN1	Mid Rangitikei
Lower Nukumaruan	Tuha Sand Hautawa Reef Basal Lower Nukumaruan Sand	TN2	
Mangaweka Mudstone		TW1	Lower Rangitikei
Utiku Sand	Conglomeratic Limestone	TW2	
Taihape Mudstone	Taihape Sand	TW3	
Reef-Bearing Sands	No. 1 Reef	TW4	
Hokonui Basement			Ruahine-Kaimanawa Greywacke

Structure

Strata in Rangitikei Valley and along Watershed Road dip regularly south-south-east, at angles ranging from 5° in the Lower Pliocene to 3° or 4° in the Pleistocene. Two major faults, the Rangitikei and Rauoterangi Faults to the west and east of the Rangitikei River respectively, do not intersect the sections sampled in this study, and no faults have been mapped which disturb the strata.

Strata in the lower part of the section form part of an anticlinal fold, the Pokaka Dome, which was mapped in detail by Superior (1943), who also conducted a seismic survey in the area. They concluded that only a thin sedimentary cover (690m) lay above basement in this structure.

Stratigraphy

The formations erected for the Pliocene and lower Pleistocene strata by Superior are adopted, with some modification, in this study (Table 8). Those erected by Te Punga (1952a) were, in his own estimation, not all strictly formations as the final separation of Lower, Middle and Upper Rangitikei Formations was based upon paleontological study.

The International Subcommittee on Stratigraphic Terminology (1960) defined a formation as a body of rock unified with respect to other strata by its lithology or lithologic characters. This definition, and those of succeeding authors, stresses that a formation must be a mappable unit.

Table 8. Pliocene and lower Pleistocene lithostratigraphic units and biostratigraphic zones of the Rangitikei River section recognised in the present study. Stage abbreviations follow the N.Z. Fossil Record system.

FORMATION	MEMBER	STAGE	ZONES
Undifferentiated fms. of Okiwa & Nukumarū Gps.		Wn Wh	FINLAYI
Te Rimu Sand			
Mangaweka Mdst.		Wm	
Utiku Sandstone	Hautapu Shell Limestone	Wp	MOLESTUS
Taihape Mdst.	Taihape Sdst.		HURUPIENSIS
Waiouru Sdst.	No. 1 Reef	Wo	

Most of the units defined by Superior (1943) are true formations in this sense, being based on lithologic characters which can be traced for considerable distances. For this reason, and because they have priority of publication (Ongley, 1946), they are preferred to those of Te Punga (1952).

Superior's terminology is not followed in the case of the "Lower Nukumaruan Formation" which, as noted by Fleming (1953, p.125), confuses biostratigraphic and lithostratigraphic terminology. Fleming introduced the term Okiwa Group, comprising six named formations interbedded with unnamed formations, for strata partly equivalent to the Lower Nukumaruan Formation in map districts N.Z. M.S.1, N137 and N138, and for equivalent strata further east. In this study, no attempt has been made to revise Pleistocene stratigraphic terminology or separate strata, and formations above the Te Rimu Sand (the Basal Lower Nukumaruan Sand of Superior) are referred to the Upper and Lower Okiwa Groups.

The name "Reef-bearing Sands" (Superior, 1943; Ongley, 1945) has been amended by Fleming (in Fleming ed., 1959, pp. 439-40), following recommended stratigraphic practice to include a local geographic name, and is now known as the Waiouru Sandstone.

The lithologies and lateral and vertical changes in thickness and facies of the formations of this section have been described by Superior (1943) and Fleming (in Fleming, ed., 1959) and are not repeated here. Columnar sections showing suggested correlations of the Rangitikei Valley formations with strata in other sections of the

Wanganui Basin are given in Fig. 24.

In the Watershed Road section (Fig. 20) sampling extends upwards from near the top of the Mangaweka Mudstone, which is here a massive, blue-grey calcareous mudstone with occasional mollusca. This passes up into the Te Rimu Sand, a grey-brown, very fine sandstone which in Watershed Road is unfossiliferous, well-sorted and current-bedded. Above the Te Rimu Sand, 250m of massive blue-grey siltstone and silty mudstone with occasional mollusca pass up into massive blue-grey mudstone.

Biostratigraphy

A. Rangitikei River Section

The same three foraminiferal zones are recognised in this section as in the Wanganui River section: the Hurupiensis, Molestus and Finlayi Zones (Table 8). The distribution of foraminifera through the section is given in Table 30 (in appendix).

Hurupiensis Zone

Notorotalia hurupiensis Vella is uncommon but present through the lower half of the Taihape Mudstone. N. finlayi Vella first appears as rare specimens in N132f511 and forms more than 50% of the hurupiensis-finlayi population in N132f514, 250m below the top of the Taihape Mudstone. Lenticulina mammiligera (Karrer) and

Cibicides ihungia Finlay disappear at this level, and Euvigera zeacuminata (Vella) dies out within the next 50m. Karreriella cylindrica Finlay and Cassidulina guncata Finlay have not been found. As in the Wanganui River section, Notorotalia taranakia Vella is abundant only in this zone, but lingers as occasional specimens higher in the section.

Molestus Zone

Cibicides molestus Hornibrook is abundant through the Taihape Mudstone, Utiku Sandstone and lower part of the Mangaweka Mudstone, and Notorotalia finlayi becomes common in the Utiku Sandstone. Cibicides molestus is very abundant in N139f540 but completely absent from N139f541, 80m higher. The only younger record of this species in this section is a single specimen in N139f548 (a very shallow water sediment) which is abraded and probably reworked from older strata. The upper boundary of the Molestus Zone is thus placed 150m above the base of the Mangaweka Mudstone. The index mollusc, Mesopenium crawfordi (Zittel), is present in the upper Taihape Mudstone, through the Utiku Sandstone and last appears in the lower part of the Mangaweka Mudstone, in N139f539. The upper limit of its range is very close to the top of the Molestus Zone.

Finlayi Zone

As in the Wanganui River section, most species making local first appearances in this zone are known to appear earlier elsewhere

in New Zealand, and are evidently facies controlled. Notorotalia finlayi is common in all samples. Rotalia fastigata n.sp. occurs in N139f546. This may be a stratigraphically useful fossil for the Lower Pleistocene, as it appears to give way to a larger, different species in the Castle-cliffian Stage.

A single specimen of Globorotalia truncatulinoides (d'Orbigny) was found in sample N139f546, 180m above the top of the Te Rima Sand. The Hautawa Shellbed is not present in the Rangitikei River section, but is probably represented by a muddy sandstone unit 225m above the top of the Te Rima Sand.

B. Watershed Road Section

All samples collected from the Watershed Road section lie entirely within the Finlayi Zone. No foraminifera characteristic of earlier zones, or of potential use for subdivision of the Finlayi Zone, were found.

Superior (1943) named the Basal Lower Nukumaruan Sand (Te Rima Sand) as the lowest member of the Nukumaruan Stage, but Fleming (in Fleming, ed., 1959) pointed out that mollusca from the Te Rima Sand are similar to those of the type Waitotaran Stage and are of Mangapanian age.

Paleoecology

A. Rangitikei River Section

Benthonic Faunal Trends

- 1) The number of benthonic species per sample is low in the Waiouru Sandstone, rises in the lower part of the Taihape Mudstone, and is fairly constant at 50-70 species per sample through most of the section (Fig. 18). Peaks in the middle Taihape Mudstone and in the bottom part of the Mangaweka Mudstone coincide with the evidence of increased water depth. A third peak in the middle of the Mangaweka Mudstone possibly also signifies slight deepening. The number of species drops away to zero at the top of the Hautawan Stage, where sediments are often pumiceous and sedimentary characters signify very shallow water, possibly even estuarine or terrestrial, conditions.
- 2) The foraminiferal number curve shows less variation than that of the Wanganui River section. The number of foraminifera per gram is low in the Waiouru Sandstone and lower part of the Taihape Mudstone, rises to a fairly high level of around 2000 specimens per gram through most of the Taihape Mudstone, the Utiku Sandstone and the lower part of the Mangaweka Mudstone, then drops to a fairly constant low level which is maintained through the rest of the section sampled (Fig. 18). In general, the curve follows the paleobathymetric curve, with foraminifera becoming less abundant as water depths lessen.

Fig. 18 - Benthonic faunal trends, including absolute ranges of selected foraminifera and the mollusc *Mesopeplum crawfordi*, and estimated paleobathymetry through part of the Rangitikei River section.

The foraminiferal number curve does not closely parallel that for the number of species. In this part of the Wanganui Basin, unlike the Wanganui River area, as the sea shallowed foraminiferal abundance declined although faunal diversity was still maintained at a fairly high level.

3) The percentage of arenaceous forms is low throughout the entire section; only in the upper half of the Mangaweka Mudstone does it rise generally above 1% of the total fauna, with a maximum abundance of 11% in N139f542. The reasons for this may include the relative shallowness of the sea in this area, for the deep water form Karreriella cylindrica Finlay is absent from the section and in the Wanganui River section arenaceous forms are most abundant in the deepest facies. However, moderately deep water conditions (greater than 200m) are inferred for some of the Rangitikei River samples, and the most abundant arenaceous forms in the section are in sediments presumed deposited at shallower depths. The controlling environmental factors evidently do not always correlate directly with depth.

The most common arenaceous species is Haeuslerella morgani (Chapman). H. parri Finlay and Siphotextularia wairoana Finlay are common in many samples throughout the section. Haeuslerella pliocenica (Finlay) is present in only one sample, N132f513, where it is abundant.

Planktonic Faunal Trends

The planktonic assemblage resembles that of present day temperate waters. It is similar to that of the Wanganui River section but generally includes more specimens and species. The main trends are as follows (Fig. 19):

- 1) The Globigerina bulloides Group of species is a dominant part of the planktonic fauna in the Taihape Mudstone. It is less abundant through the Utiku Sandstone and most of the Mangaweka Mudstone, but increases to maximum abundance at the top of the Mangaweka Mudstone and in the basal Lower Okiwa Group. In the latter, it forms up to 80% of the planktonic fauna. The variations in abundance are very similar to those shown in the Wanganui River section.
- 2) Globigerina pachyderma (Ehrenberg) increases sharply in abundance midway through the Taihape Mudstone (at the base of the Molestus Zone). It then decreases in abundance to a level maintained fairly constantly through the Utiku Sandstone and the Mangaweka Mudstone, declines slightly in abundance towards the top of the Mangaweka Mudstone, then becomes more common in the Lower Okiwa Group.
- 3) From predominantly dextral coiling in the lower part of the Taihape Mudstone, Globigerina pachyderma changes abruptly to dominantly sinistral coiling at the base of the Molestus Zone. The coiling ratio stays dominantly sinistral to near the top of the Utiku Sand, then the percentage of dextral forms increases. With minor fluctuations, sinistral and dextral forms are approximately equal through the Mangaweka

Fig. 19 - Cumulative abundances and absolute ranges of selected planktonic species, and coiling ratios of *G. pachyderma* through part of the Rangitikei River section.

Mudstone. Low in the Okiwa Group there is a decrease in sinistral forms, followed by a return to approximately equal proportions.

4) Species of Globorotalia generally form a minor part of the fauna, but for unknown reasons, temporarily increase to nearly 50% of the fauna in sample N139f538.

5) Planktonic foraminifera are rare in the Waiouru Sandstone, and in the Okiwa Group formations at the top of the section, but for most of the rest of the section average 3-8% of the total fauna, reaching a maximum of 21.0% in N139f544 (Fig. 18).

Paleobathymetry

The paleobathymetric curve for the Rangitikei River section is given in Fig. 17. The depth changes are less complex than those of the Wanganui River section.

The Waiouru Sandstone consists of sandstones and sandy siltstones with common, often persistent, shellbeds and poor foraminiferal faunas. Many samples are barren, but the fauna collected includes common Bolivinitidae and Nonionidae, sparse Elphidium spp. and rare planktonic species. It represents a shallow, intertidal or subtidal environment.

Rapid subsidence followed, leading to deposition of the Taihape Mudstone. The lowermost part of this formation contains sparse benthonic and planktonic faunas. Shallow water species, including common Bolivina spp. and uncommon Elphidium spp. and Notorotalia spp., together with uncommon deeper water species such as Bulimina striata d'Orbigny and Haeslerella parri Finlay in a fauna lacking H. pliocenica (Finlay)

and Karrerella cylindrica Finlay, indicate the shallow part of the Haeuslerella Biofacies, with an inferred depth range of 80-150m. A sudden change to an abundant planktonic fauna and common moderately deep water species including Haeuslerella parri Finlay, H. pliocenica (Finlay), large Robulus calcar (Linné), Euvigerina spp., Pullenia bulloides d'Orbigny and Notoretalia taranakia Vella, with less common Lenticulina mammiligera (Karrer), Robulus costatus (Fichtel & Moll), Bulimina striata d'Orbigny and Pullenia quinqueloba (Reuss), indicates the incoming of a shallow Robulus Biofacies, and deepening to ca. 400m, 135m above the base of the Taihape Mudstone. This biofacies is found only in two samples, N132F512 and N132F513, representing about 50m of sediment. Immediately above this level, at the base of the Molestus Zone, the incidence of deep water forms decreases and the remaining fauna represents a middle Haeuslerella Biofacies, indicating an abrupt shallowing to ca. 200m.

The Taihape Sandstone contains a similar fauna to that of the mudstones immediately above and below it, with a similar variety of benthic^{on} and planktonic species, and a slightly higher foraminiferal number. The member is lenticular and thins both towards the Ruahine Range, in the presumed direction of shallowing, and also to the west, towards the Lower Pliocene axis of the basin (Superior, 1943). It grades into the overlying and underlying mudstone and is assumed to have been deposited in similar depths.

The top of the Taihape Mudstone grades up to the Utiku Sandstone. A single sample from muddy sandstone 200m above the base of this

formation contains abundant Haeuslerella morgani (Chapman), Siphotextularia wairoana Finlay and Euvigerina spp., moderately common Bolivina spp., uncommon nonionids, Bulimina aculeata d'Orbigny and B. marginata d'Orbigny, together with a varied and fairly abundant planktonic fauna. Haeuslerella parri Finlay, H. pliocenica (Finlay), Bulimina striata d'Orbigny and common Elphidium spp. and Notorotalia spp. are absent. The fauna is attributed to the middle or deeper part of the Haeuslerella Biofacies, indicating a depth of ca. 200-300m. The Utiku Sandstone thickens towards the Ruahine Range and becomes finer grained and thinner to the west (Superior, 1943), and at Rangitikei appears to have been deposited at the same depth as the underlying mudstone.

The basal part of the Mangaweka Mudstone, immediately above the Hautapu Shell Limestone, consists of siltstone grading rapidly up into mudstone (Fig. 17). The fauna contains abundant Haeuslerella parri Finlay, large Robulus calcar (Linne'), Bolivinina pohana Finlay, large Hoeglundina elegans (d'Orbigny), Anomalinoidea spherica (Finlay) and Cibicides molestus Hornibrook, with rare Bulimina striata d'Orbigny, Pullenia bulloides d'Orbigny, and P. quinqueloba (Reuss). Together with common shallow water forms such as Haeuslerella morgani (Chapman), Siphotextularia wairoana Finlay, Bulimina aculeata d'Orbigny, Notorotalia finlayi Vella and Bolivina spp., and rare Bulimina marginata d'Orbigny and B. elongata subulata Cushman & Parker, it indicates the deep Haeuslerella or shallow Robulus Biofacies, with an inferred depth of 300-400m.

Through the Mangaweka Mudstone the percentage of deeper water forms gradually decreases and miliolids, Nonionellina flemingi (Vella), Zeaflorilus parri (Cushman), Elphidium spp., Notorotalia spp. and associated shallow water foraminifera become important. The depth of deposition decreases regularly from the maximum reached about 50m above the bottom of the formation to a shallow Haeuslerella Biofacies with an inferred depth of 60-100m or less at the top of the formation.

Sediments above the Mangaweka Mudstone contain consistently shallow water faunas representing the Elphidium and Zeaflorilus Biofacies and indicating depths of 60m or less.

B. Watershed Road Section

Benthonic Faunal Trends

The foraminiferal number is fairly low in the upper part of the Mangaweka Mudstone, zero in the Te Rimu Sand, increases into the lower silty part of the overlying Okiwa Group, then decreases markedly in the mudstone. The number of species present varies similarly to the foraminiferal number. Arenaceous forms are rare throughout with a maximum in the Lower Okiwa Group.

Planktonic Faunal Trends

- 1) The planktonic fauna is similar to that of the Rangitikei River section. Planktonic species are a minor part of the total fauna, and decrease gradually in abundance through the section.

Fig. 20 - Stratigraphic column of part of the Watershed Road section, showing lithology, sample horizons and the percentage of each sample coarser than 75 microns.

Fig. 21 - Benthonic faunal trends and estimated paleobathymetry through part of the Watershed Road section.

- 2) The number of planktonic species present varies similarly to the abundance and diversity of benthonic foraminifera, being moderately high in the upper Mangaweka Mudstone, zero in the Te Rimu Sand, rising again in the overlying siltstone and decreasing in the mudstone.
- 3) As in the equivalent part of the Rangitikei River section, the Globigerina bulloides Group of species increases in abundance upwards.
- 4) Globigerina pachyderma (Ehrenberg) becomes slightly less common through the section. Coiling ratios show a gradual increase of dextral specimens, except in the highest sample where sinistral forms increase to 50% of the population.

Paleobathymetry

The upper part of the Mangaweka Mudstone in this section is a grey-blue, silty mudstone with occasional mollusca. The foraminiferal fauna includes common Haeuslerella morgani (Chapman). H. parri Finlay, Bolivina spp., Bulimina aculeata d'Orbigny, Criboelphidium charlottensis (Vella) and Notorotalia finlayi Vella, together with less common Bulimina elongata subulata Cushman & Parker and B. marginata d'Orbigny, and occasional deeper water species such as B. striata d'Orbigny and Robulus calcar (Linné). These species indicate the shallow part of the Haeuslerella Biofacies, and a depth of 150-200m.

The Te Rimu Sand lacks both foraminifera and mollusca in this section. The foraminifera above and below show no sign of abrupt shallowing. The sand is cross-bedded and was probably laid down by currents at some depth on the continental shelf.

Fig. 22 - Cumulative abundances and absolute ranges of selected planktonic species, and coiling ratios of G. pachyderma through part of the Watershed Road section.

Faunas in the overlying siltstone are similar to those immediately below the Te Rimu Sand and indicate similar depths. The proportion of very shallow water species increases gradually upwards, and this trend accelerates in the mudstone above.

Depths of deposition at Watershed Road are slightly greater than for equivalent sediments in the Rangitikei River section.

Summary

1. The Pliocene-Pleistocene section of the Rangitikei and associated valleys contains sediments deposited in depths ranging from intertidal or subtidal to about 400m. The basin floor subsided rapidly from initial shallow conditions, then shallowed gradually until late in the Pliocene deposition and subsidence were approximately equal.
2. The Waiouru Sandstone represents the initial stage and was deposited in a tidal or sub-tidal environment, with rates of subsidence and deposition nearly equal.
3. The massive Taihape Mudstone represents the deepening and early shallowing phases, the maximum depth of about 400m being represented 150m above the base of the formation. Abrupt shallowing to 200m followed, after which conditions remained almost constant during deposition of the remainder of the Taihape Mudstone and most of the Utiku Sandstone.
4. Foraminifera indicate that the Taihape Sandstone was deposited at about 200m.

5. The depth increased during deposition of the upper Utiku Sand and Mangaweka Mudstone, reaching 300-400m. Gradual shallowing then occurred to a depth of less than 60m by the time of deposition of the Lower Okiwa Group. Thereafter the sea remained uniformly shallow.
6. Below-average water temperatures are indicated by planktonic foraminifera from the upper Taihape Mudstone to the base of the Mangaweka Mudstone, a span approximately equal to the Molestus Zone, and possibly also from the lower part of the Lower Okiwa Group. The indicated cooling at the beginning of the time represented by the Molestus Zone coincided with an abrupt shallowing of some 200m. In neither of the sections examined does Globigerina pachyderma (Ehrenberg) indicate marked cooling at the accepted Pliocene-Pleistocene boundary.

Table 9. - Locality and Lithology of the Microfossil Samples Examined
from the Rangitikei River and Watershed Road Sections.

Sheet No. N132 (Taihape), 1st Edition, 1970.

Fossil No.	Locality	Grid Ref.	Lithology*
f507	Napier-Taihape Rd, 5.5km N of Moawhango	279177	7852L820SS
f508	Napier-Taihape Rd, 200m S of Te Riupunga Stream	340300	7852L820SS
f509	Road cutting near Tirianga Stream	343278	8852D820SS
f510	Road cutting 350m at 270° from Pokaka Trig	354268	8852D820SS
f511	Road cutting 8km S of Moawhango	333240	8952D820SS
f512	Road cutting 100m N of Wainui Jcn.	320223	8942M82MOS
f513	Road cutting at Kaiwee Jcn.	294210	9843M82M
f514	Road cutting 400m N of Taihape	289195	8942M82M
f515	Main Rd, 200m N of Taihape College Rd	288165	6830M2000
f516	Main Rd, summit of hill immediately S of Utiku	319101	8741M82SMM

Sheet No. N139 (Mangaweka), unpublished

f538	Main Rd, northern end of Mangaweka Hill		6642L2000S
f539	Main Rd, 14km S of Taihape		9842L82SMM
f540	Main Rd, 800m N of Ruahine Lookout		9942L82MM

* Lithologic code of N.Z.F.R. forms.

Table 9. - continued

114.

Fossil No.	Locality	Grid Ref.	Lithology*
f541	Main Rd, 3.2km S of summit Mangaweka Hill		9942L52MM
f542	Main Rd, below Mangaweka Viaduct		9942L82MM
f543	Main Rd, 150m S of Mangaweka Railway Station		9942L82MM
f544	Main Rd, 1.5km S of Mangaweka		9942L82MMCC
f545	Main Rd, by Makohine Viaduct		9841L82MMS
f546	Main Rd, 1.5km S of Makohine Viaduct		8841L82BSSM
f547	Main Rd, 100m N of summit of Vinegar Hill		8842L82SM
f548	Main Rd, 1.5km S of summit of Vinegar Hill		6620L5MM
f549	Main Rd, 2.4km S of summit of Vinegar Hill		8741M52MS
f550	Watershed Rd, 1.6km S of Te Kumu Station		9842L82SM

SADDLE ROAD SECTION

Introduction

Pliocene and Pleistocene sediments extend across the axial ranges of the North Island in the Manawatu Saddle area (Fig. 2). They lie in an axial sag between the Tararua and Ruahine Ranges which has remained at a relatively low level since at least early Pliocene. For much of the time it was a shallow strait connecting seas to east and west (Lillie, 1953; Neef, 1970).

Ten samples were collected from the Manawatu Saddle Road section, and a further two previously described by Piyasin (1966, unpublished thesis) were re-examined. Sample localities are shown in Fig. 23, lithologies and sample horizons in Fig. 24. The stratigraphic distribution of foraminifera is given in Table 30 (in appendix).

The Tertiary beds form an anticline over uplifted Mesozoic strata, dipping to east and west away from the axis of the ranges at angles ranging from 30° in the oldest beds to 20° or less in Castlecliffian strata. Several major faults with a general north-south trend cut the strata, the two most important being the Ruahine and Wellington Faults (Fig. 23). In the Saddle Road section, conglomerates and grits of the Te Aute Formation rest on a smooth greywacke surface. Close by, as in Hope Stream, the Mangatoro Formation conformably underlies the Te Aute Formation (Piyasin, 1966).

The region has been mapped by Lillie (1953) and in more detail by Piyasin (1966). Lillie (1953, p.57) described a succession of strata

Fig. 23. - Sample locality map of the Saddle
Road section.

Fig. 24 - Stratigraphic column of the Saddle Road section, showing lithology, sample horizons and the percentage of each sample coarser than 75 microns.

to the north of Saddle Road and referred the beds to the Te Aute, Lower and Upper Kumeroa, and Mangatarata Formations. The Saddle Road section is similar to that described by Lillie and the same formations are recognised in this study. A thick mudstone unit placed by Piyasin at the top of the Te Aute Formation was not found. Piyasin mapped the Mangatoro Formation (Opoitian) in Hope Stream, and this has been sampled by the writer to extend the section downwards.

Biostratigraphy

Reliable index foraminifera are rare. Superior (1943) considered that a complete, though compressed, Waitotaran section is present.

Notorotalia hurupiensis Vella occurs in sample N149f592 from near the top of the Mangatoro Formation in Hope Stream, but was not found in the Te Aute Formation. The lowest occurrence of N. finlayi Vella is in N149f594, towards the top of the Te Aute Formation. It is not known what thickness of sediment is missing at the unconformity below the Te Aute Formation in Saddle Road. However, the top of the Hurupiensis Zone is arbitrarily assumed to coincide with the top of the Mangatoro Formation.

Cibicides molestus Hornibrook, which defines the Molestus Zone by the overlap of its range with that of N. finlayi, is completely absent from the section because of unsuitable facies. The highest occurrence of Gleborotalia puncticulata (Deshayes) is in N149f593,

and the Molestus Zone may be represented by that part of the Te Aute Formation below this sample. Sediments above N149f593 are referred to the Finlayi Zone.

On the basis of mollusca and foraminifera, Lillie (1953) considered the Mangatoro Formation to be mostly Opoitian in age, locally Kapitean at the base, and possibly Waitotaran at the top. He restricted the Te Aute Formation to strata of Waitotaran age. In Saddle Road section, the basal grits and conglomerate of the Te Aute Formation contain Crassostrea ingens (Zittel) (Opoitian to Hautawan) and Phialopecten triphooki (Zittel) (Waitotaran to Hautawan). The latter species is also found higher in the Te Aute Formation. Lillie (1953) records Struthiolaria (Pellicaria) aeuminata Marwick (Nukumaruan) and Tawera subsulcata (Suter) (Waitotaran to Hawera Series) from the Lower Kumeroa Formation just north of Saddle Road.

Paleoecology

Benthonic Faunal Trends (Fig. 25)

The foraminiferal number is low, usually less than 1 specimen per gram of dry sediment, in the lower part of the section but reaches a peak of 256 in a muddy shellbed of the Mangatarata Formation. Foraminifera are absent above this level, probably because of leaching.

The number of benthonic species per sample averages 30-40 in the upper Mangatoro and Te Aute Formations, drops to zero in the Lower Kumeroa Formation, then rises again to 60-80 species per sample in the

Fig. 25 - Foraminiferal trends through the Saddle Road section.

Upper Kumeroa and lower Mangatarata Formations, above which foraminifera are absent.

Arenaceous species are uncommon through most of the section but reach 5% of the fauna in N149f599. The most common species are Hauslerella morgani (Chapman) and Siphotextularia wairoana Finlay.

Planktonic Faunal Trends (Fig. 26)

- 1) Planktonic specimens are usually rare, but reach 27% of the total fauna in N149f598 at the top of the Upper Kumeroa Formation (Fig. 25). The number of species present in each sample varies similarly to the number of benthonic species.
- 2) The Globigerina bulloides Group is most abundant in the Te Aute Formation. Higher in the section, the relative abundance of these species is reduced by the increase in abundance of Globigerinita spp. discussed below.
- 3) Globigerina pachyderma (Ehrenberg) is relatively more abundant in this section than in the other sections studied, and reaches its peak in the Te Aute Formation.
- 4) G. pachyderma coils dextrally in the Mangatoro Formation (although very few specimens were found). It changes to dominantly sinistral coiling in the Te Aute Formation and remains so through the remainder of the section, although dextral forms tend to increase upwards.

Fig. 26 - Cumulative abundances and absolute ranges of common planktonic species, and coiling ratios of *Globigerina pachyderma*, through the Saddle Road section.

5) Globigerinita glutinata (Egger) and G. uvula (Ehrenberg) increase abruptly in relative and absolute abundance in sample N149f598, at the top of the Upper Kumeroa Formation. These are both minute forms and their unusual abundance may be the result of selective concentration by currents. The whole planktonic fauna also increases markedly at this level, from an average of less than 1% to 27% of all foraminifera, and the number of planktonic species increases. A likely explanation is that a current carrying a rich planktonic fauna was deflected from the east through Manawatu Strait. The planktonic foraminifera presumably would be killed by unfavourable nearshore conditions, and also would tend to be sorted to some extent by currents in the strait.

Faunal Affinities

Planktonic foraminiferal trends discussed above indicate that oceanic currents flowed through Manawatu Strait. Assuming hydrological conditions similar to those pertaining at present, with cooler water to the east than to the west of southern North Island, the presence of Globigerina pachyderma in greater relative abundances than in sediments in Wanganui Basin proper indicates flow of water from the east. Support to this concept comes from the presence of Struthiolaria (Pellicaria) acuminata in Saddle Road sediments. This mollusc is common in Wairarapa and southern Hawkes Bay, but not known from Wanganui Basin which evolved different lineages of Pellicaria (Beu, 1969; Neef, 1970).

Paleobathymetry

A tentative paleobathymetric curve for this section is given in Fig. 25. Sediments were deposited in shallow water throughout, the faunas representing the shallow part of the *Haeuslerella* Biofacies and shallower biofacies. The rate and amount of shallowing at the top of the Mangatere Formation is unknown, because of the unknown time value of the unconformity at the base of the Te Aute Formation. The depth of deposition increases through the Te Aute Formation, then shallows in the Lower Kumeroa Formation. The thick conglomerate of the Upper Kumeroa Formation lacks fossils, but the coarseness of some beds and the current-bedding of the intercalated sandstones, indicates deposition in very shallow water or non-marine conditions adjacent to a rapidly rising greywacke mass. The overlying limestone indicates a return to a marine environment, and the uniformly fine-grained sediments above this indicate quiescent conditions.

Summary

1. The Saddle Road section contains a sequence of strata with a probable age range of Lower Pliocene to Middle Pleistocene, laid down in a strait connecting the Wanganui and East Coast basins.
2. Because of strong tectonic activity, depth changes cannot be related to climate changes. Tectonic uplift of the adjacent range appears to have reached a maximum during the time of deposition of the Upper Kumeroa conglomerates, and lessened later.

3. Conditions were fully marine, and depths never exceeded 300m. Current action in the strait is indicated, and the abundance of G. pachyderma, together with the presence of Struthiolaria (Pellicaria) acuminata, implies overall water movement from east to west.
4. Coiling ratios of G. pachyderma indicate cooling temperatures at the time represented by the base of the Molestus Zone, followed by gradual and slight warming.

Table 10. - Locality and Lithology of the Microfossil Samples
Examined from the Saddle Road Section.

Sheet No. N149 (Palmerston North), 4th Edition, 1969.

(Except where stated, samples were collected along the Manawatu Saddle Road).

Fossil No.	Locality	Grid Ref.	Lithology*
+ f544	1.7km E from Pohangina River bridge	266433	5542D82M
+ f555	2km E from Pohangina River bridge	263434	9930M82M
f592	S side of road, immediately W of Hope Stream	320406	9842M52
f593	Stream bed 200m S of last farmhouse on Cook Rd	281412	5461M82QS
f594	S side of road, 300m W of side road	300417	8841L82S
f595	S side of road, below woolshed and 800m E of quarry	286423	6650L82S
f596	N side of road, 450m E of quarry	283427	7750L52
f597	S side of road, 1km W of quarry	273433	6554L25WW
f598	S side of road 1.3km W of quarry	272435	9841L82
f599	N side of road, 1.3km E of Pohangina River bridge	257436	9852M82SS
f600	N side of road, 1.2km E of Pohangina River bridge	256437	7930L82WW
f601	E side of road, 200m up hill from Pohangina River bridge	253437	8930L82WW

* Lithologic code of N.Z.F.R. forms.

* Samples collected by Piyasin (1966, MS).

SECTION III

SYSTEMATICS

General

The systematics and distribution of all Wanganui Basin Pliocene species of foraminifera except the Nodosariacea, plus several interesting Pleistocene^{species}/are discussed. The classification adopted is that of Loeblich and Tappan (1964) with minor modifications.

The type reference and a selected synonymy are given for each species. Fuller synonymies for many of the species which occur lower in the Tertiary are given by Hornibrook (1964). Kennett (1966a) and Gibson (1967) give additional references. Many Pliocene species are extant, and Eade (1967a) lists all references to New Zealand foraminifera published prior to the date of his publication.

The "recorded stratigraphic range" gives the published range for the species in New Zealand. The "observed stratigraphic range" is given where the present study extends or clarifies the known range of a species, or records a species for the first time in New Zealand. Complete distributions in the sections examined are given in the range charts in the appendix.

Similarly, the "recorded ecologic range" includes all published limits for the species in New Zealand. The "observed ecologic range" is given where the published limits have been extended or a new record of a species made. Ecologic ranges of fossil species are given in terms of the biofacies erected by Vella (1962a, b, c). The Karreriella Biofacies defined by Kennett (1962), and lying between the Haeuslerella and Robulus Biofacies, has been quoted where appropriate but is not recognised in Wanganui Basin. Ecologic limits for Recent species are

taken from Vella (1957, for Cook Strait), Hulme (1964, for Manukau Harbour), Hedley et al (1967, for intertidal records) and Lewis (1972, for the area off southern Hawkes Bay).

All common planktonic species and a selection of benthonic species have been illustrated by the author, using a camera lucida.

Sample Numbers and Locations

Sample numbers are New Zealand Fossil Record numbers based on sheet districts of New Zealand Map Series 1, 1:63,360. Grid references are co-ordinates based on the National thousand-yard grid.

All types, with the registration numbers prefixed by VF, are lodged in the Department of Geology, Victoria University of Wellington. Unregistered paratypes of all new species except Rotalia fastigata and Zelamarkina excavata, will be presented to the New Zealand Geological Survey, Lower Hutt, and to the Cushman Foundation, U.S. National Museum, Washington.

Details of the type localities for the six new species are as follows:

N137f630, N.Z.M.S.1, Sheet N137 Waverley (2nd Ed., 1965), Grid ref.

254973, Wilkies Bluff, 0.3m below Crassostrea ingens band.

N138f557, N.Z.M.S.1, Sheet N138 Wanganui (2nd Ed., 1967), Grid ref.

691065, east bank of Wanganui River, 200m downstream from Whauteihi Stream, blue-grey sandstone.

N138f558, N.Z.M.S.1, Sheet N138 Wanganui (2nd Ed., 1967), grid ref.

672065, west bank of Wanganui River, 300m downstream from bend of river at Whakaihuwaka, siltstone, 40m stratigraphically above N138f557.

N138f559, N.Z.M.S.1, Sheet N138 Wanganui (2nd Ed., 1967), Grid ref.

671064, west bank of Wanganui River, 450m downstream from bend of river at Whakaihuwaka, siltstone at base of Wilkies Shellbed, 3m stratigraphically above N138f558.

N139f546, N.Z.M.S.1, Sheet N139 Mangaweka (unpublished), roadside

1.5km S.W. of Makohine Viaduct, siltstone.

N143f516, N.Z.M.S.1, Sheet N143 Marton (3rd Ed., 1968), Grid ref.

802791, roadside 500m S.W. of junction of Turakina Valley and Morgans Roads, calcareous mudstone.

Systematic Descriptions

Order FORAMINIFERIDA

Superfamily LITUOLACEA

Family TEXTULARIIDAE

Genus TEXTULARIA DeFrance, 1824

Type Species: Textularia sagittula DeFrance

In Wanganui Basin sediments Textularia is represented only by occasional specimens in a few samples. T. barnwelli Kennett occurs as rare, small specimens in the Taihape Mudstone of the Wanganui River section. Small specimens referred to T. cf. ensis Vella are present in the Mangapani Shell Conglomerate at Mangapunipuni Stream, in the Mangaweka Mudstone of the Rangitikei River section, and in the Mangaweka Mudstone and Lower Okiwa Group of the Wanganui River section. T. goesii Cushman is present in the Hautawa Shellbed and in the Lower Okiwa Group of the nearby Watershed Road section.

Genus HAEUSLERELLA Parr, 1935

Type Species: Haeuslerella pukeuriensis ParrHaeuslerella morgani (Chapman)Spiroplecta morgani Chapman, 1926, p.32, Pl.8, fig.12.Haeuslerella morgani; Kennett, 1966a, pp. 30-31, Pl. 1, fig. 12.Haeuslerella morgani; Gibson, 1967, pp. 8-9, Pl. 1, figs. 12-13.

REMARKS: Characterised by the compressed, biserial initial portion followed by staggered biserial chambers then one to four uniserial, rounded chambers. Many populations grade towards H. parri Finlay through forms with broader, more compressed initial portions and fewer, compressed uniserial chambers. In Wanganui Basin Pliocene sediments, the optimum range of H. morgani (shallow part of Haeuslerella Biofacies) is shallower than that of H. parri (middle part of Haeuslerella Biofacies to shallow Robulus Biofacies). The deeper-water form, H. finlayi Vella, has not been found in Wanganui Basin.

DISTRIBUTION: Present in all except the Wilkies Bluff and Waitotara Valley sections. Usually sporadic, but abundant in the uppermost Opoitian to Mangapanian at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Nukumaruan (Lower Pliocene to Lower Pleistocene).

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies.

Haeuslerella parri Finlay, Pl. 1, figs. 1-3.

Haeuslerella parri Finlay, 1939c, p.340, Pl. 24, fig. 5.

Haeuslerella parri; Kennett, 1966a, pp. 20, 30.

Haeuslerella parri; Hornibrook, 1968, p.94, fig. 18.

REMARKS: Characterised by the broad, compressed test with a single uniserial chamber. The test surface is smooth, with small rounded grains set in a matrix of abundant cement. Commonly mica flakes are incorporated in the test and occasionally sponge spicules and heavy mineral grains.

Dimensions of hypotype (VF1002): length 0.94mm, width 0.36mm, thickness 0.24mm.

DISTRIBUTION: Present in all except the Wilkies Bluff and Waitotara Valley sections. Mostly sporadic, but abundant in the Taihape Mudstone and Koriniti Sandstone at Wanganui River.

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

OBSERVED ECOLOGIC RANGE: Haeuslerella (rarely shallower) to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Haeuslerella pliocenica (Finlay), Pl. 11, fig. 1.Bigenerina pliocenica Finlay, 1939c, p.311, Pl. 24, fig. 15.Haeuslerella pliocenica; Vella, 1963, p.3.Bigenerina pliocenica; Hornibrook, 1968, pp. 74, 94, fig. 14.

REMARKS: Finlay placed this species in Bigenerina because of the central position of the aperture and the sudden transition from biserial juvenile to rectilinear uniserial phase. Vella reclassified it as Haeuslerella because he considered it an end member of the Haeuslerella Bioseries in New Zealand, and this usage, based on a phylogenetic rather than a purely morphologic relationship, is followed here.

Wanganui Basin specimens are large forms closely comparable with the type figure. The test is usually constructed of coarse (up to 0.06mm), sub-angular to sub-rounded quartz grains.

Dimensions of hypotype (VF1003): length 1.06mm, width 0.47mm.

DISTRIBUTION: Common in the Taihape Mudstone at Wanganui River, and in one sample from the Taihape Mudstone at Rangitikei River. A single specimen from the Upper Kumeroa Formation (Nukumaruan) at Saddle Road is probably reworked from older strata. Not found in the other sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Opoitian to Waitotaran (Lower to Middle Pliocene); possibly Upper Tongaporutuan to Hautawan (Upper Miocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Genus SIPHOTEXTULARIA Finlay, 1939

Type Species: Siphotextularia wairoana Finlay

Siphotextularia blacki Vella

Siphotextularia blacki Vella, 1957, pp. 16-17, Pl. 4, figs. 53-54.

REMARKS: Small, compressed specimens with angular peripheries are referred to this species.

DISTRIBUTION: Uncommon in occasional samples from all sections.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies (recorded from Manukau Harbour, and from 89-396m in Cook Strait).

Siphotextularia cf. fretensis Vella

Siphotextularia fretensis Vella, 1957, p. 17, Pl. 4, figs. 58-59.

REMARKS: Differs from the types in being smaller and more compressed, with more oblique sutures.

DISTRIBUTION: Rare in one sample from the Lower Okiwa Group, Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies.

Siphotextularia mestayerae Vella

Siphotextularia mestayerae Vella, 1957, p. 17, Pl. 4, figs. 55-57.

REMARKS: Rare, compressed specimens with the characteristic rhomboid cross-section are referred to this species. A number of the Pliocene specimens show somewhat angular peripheries resembling S. blacki.

DISTRIBUTION: Not found in the Waverley Beach, Wilkies Bluff or Waitotara Valley sections. Present in the other sections in strata ranging in age from uppermost Mangapanian to Castlecliffian, with a single specimen from the Utiku Sand (Waipipian) of the Rangitikei River section.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Castlecliffian (Middle Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeeflorilus to shallow Haeuslerella Biofacies; recorded from intertidal stations around New Zealand, in Manukau Harbour, from 36-315m in Cook Strait and from 142-625m off southern Hawkes Bay.

Siphotextularia wairoana Finlay

Siphotextularia wairoana Finlay, 1939a, p. 511, Pl. 68, fig. 2.

Siphotextularia wairoana; Finlay & Marwick, 1940, p.125.

Siphotextularia wairoana; Fleming, in Fleming ed., 1959, pp. 65, 280-81.

Siphotextularia wairoana; Hornibrook, 1968, p.74, fig. 14.

REMARKS: Abundant S. wairoana is characteristic of Wanganui Series sediments in New Zealand. Kennett (1967) described the Siphotextularia

wairoana Bioseries, with S. wairoana replacing S. dawesi Kennett in the Taranakian and lowermost Opoitian. Specimens referred to S. wairoana from Wanganui Basin sediments all agree with the type description, and forms resembling S. dawesi have not been found.

A single elongate, broken specimen from the Lower Okiwa Group (Hautawan) of the Wanganui River section has been referred to S. cf. wanganuia Finlay.

DISTRIBUTION: Found in varying abundance in all sections; most common in the Wanganui River and Rangitikei River sections.

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

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker & Jones, 1859

Type Species: Nautilus inflatus MontaguTrochammina inflata (Montagu), Pl. 1, figs. 4-6.Nautilus inflatus Montagu, 1808, p. 81, Pl. 18, fig. 3.Trochammina inflata; Brady, 1884, p. 338, Pl. 41, figs. 4a-c.Trochammina inflata; Farr, 1945, p. 194, Pl. 8, figs. 3, 4a, b.Trochammina inflata; Hedley, Hurdle & Burdett, 1967, p. 23, Pl. 6, figs. 3a-c.

REMARKS: Specimens from Wanganui Basin agree closely with those figured by Brady from brackish water, Almouth, England, but are generally more inflated than the specimen figured by Hedley et al from Porirua, New Zealand.

Dimensions of hypotype (VF1004): diameter 0.19mm, thickness 0.12mm.

DISTRIBUTION: Rare in occasional samples from Waverley Beach, Waitotara Valley and Wanganui River. No specimens of Trochammina were found at the centre or eastern side of Wanganui Basin.

OBSERVED ECOLOGIC RANGE: Waipipian to Hautawan (Upper Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies.

RECORDED ECOLOGIC RANGE: Brackish water, England (Brady, 1884); around New Zealand, found intertidally, and living off southern Hawkes Bay from 329-1619m.

Trochammina cf. rotaliformis Wright, Pl. 1, figs. 9-11.

Trochammina rotaliformis Wright, in Heron-Allen & Earland, 1911, p.309.

Trochammina rotaliformis; Cushman & McCulloch, 1939, pp. 107-108,

Pl. 12, fig. 2.

DESCRIPTION: Test small, trochoid, with a low dorsal spire; periphery almost circular in outline, slightly lobulate; dorsal side concave; ventral side convex, excavated at umbilicus. Chambers moderately inflated, becoming progressively more crescentic, about 18 in number; $2\frac{1}{2}$ whorls visible on spiral side with 6-7 chambers per whorl; only the chambers of the final whorl visible on umbilical side, final chamber occupying about one quarter of the umbilical side. Sutures distinct, curved backwards on spiral side, sigmoid and slightly depressed on umbilical side. Wall of small, uniform quartz grains, smoothly finished, reddish-brown in colour. Aperture interio-marginal and extraumbilical-umbilical.

REMARKS: The specimens do not match any described species. They differ from T. rotaliformis in the sigmoid umbilical sutures and greater number of chambers in the final whorl (6-7, cf. 4-5 in T. rotaliformis), and from T. sorosa Parr in being more compressed with fewer chambers and whorls, and more crescentic final chambers.

Heron-Allen and Earland (1922, pp. 111, 114) describe a gradation from T. vesicularis Goës through T. squamata Jones & Parker to T. rotaliformis. Hedley et al (1967) mention a similar plexus comprising T. malovenssis Heron-Allen & Earland, T. sorosa, T. wiesneri Parr and T. rotaliformis.

The Wanganui Basin specimens are probably intermediate between T. rotaliformis and T. sorosa. In view of the known variability of the genus, and the limited material available, no new taxon is erected.

Dimensions of hypotype (VF1005): diameter 0.21mm, thickness 0.08mm.

DISTRIBUTION: Rare in the Lower Okiwa Group, Wanganui River, and in the Snapper Point Conglomerate, Waverley Beach.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Lower Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies.

Trochammina sorosa Parr

Trochammina sorosa Parr, 1950, p.278, Pl. 5, figs. 15-17.

Trochammina sorosa; Hedley, Hurdle & Burdett, 1967, pp. 23-24, Pl. 6, figs. 4a-c, text-figs. 11-15.

REMARKS: Specimens are small, but fall within the range of variation illustrated by Hedley et al.

DISTRIBUTION: Found only in one sample from the Lower Okiwa Group, Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies; recorded living intertidally and from 48-427m off southern Hawkes Bay.

Family ATAXOPHRAGMIIDAE Schwager

Genus GAUDRYINA D'Orbigny, 1839

Type Species: Gaudryina (Pseudogaudryina) atlantica (Bailey)Gaudryina convexa (Karrer)Textilaria convexa Karrer, 1865, p. 78, Pl. 16, figs. 8a-c.Gaudryina convexa; Hedley, Hurdle & Burdett, 1967, p.24, Pl. 6, figs. 5a,b.DISTRIBUTION: Rare in occasional samples from Wanganui River,
Rangitikei River and Saddle Road.RECORDED STRATIGRAPHIC RANGE: Upper Arnold Series (Upper Eocene) to
Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Recorded from 32-317m in Cook Strait (as
G. hastata), and living intertidally at Wellington and New Plymouth.

Genus EGGERELLA Cushman, 1933

Type Species: Verneuilina bradyi CushmanEggerella bradyi (Cushman)Verneuilina pygmaea (Egger); Brady, 1884, Pl. 47, figs. 4-7.Verneuilina bradyi Cushman, 1911, p.54.Eggerella bradyi; Cushman, 1933, p. 30.Eggerella bradyi; Gibson, 1967, p.11, Pl. 2, fig. 21.

DISTRIBUTION: Only two specimens were found, in the Upper Mangaweka

Mudstone and Lower Okiwa Group at Wanganui River.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Living from 625-1419m off southern Hawkes Bay.

Genus KARRERIELLA Cushman, 1933

Type Species: Gaudryina siphonella Reuss

Karrerrella cylindrica Finlay, Pl. 1, Fig. 8.

Karrerrella siphonella (Reuss); Parr, 1935, p. 84, Pl. 20, fig. 3.

Karrerrella cylindrica Finlay, 1940, p. 452, Pl. 63, figs. 43-46.

Karrerrella cylindrica; Kennett, 1966a, pp. 32-33, Pl. 2, fig. 18.

Karrerrella cylindrica; Gibson, 1967, p. 11, Pl. 2, fig. 22.

Karrerrella cylindrica; Hornibrook, 1968, p. 72, fig. 13.

Dimensions of hypotype (VF1006): length 1.07mm, width 0.38mm.

DISTRIBUTION: Common in the Taihape Mudstone at Wanganui River. A single specimen in the Lower Kumeroa Formation at Saddle Road is probably reworked. Not found in the other sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

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

OBSERVED ECOLOGIC RANGE: Deep part of Haeuslerella Biofacies to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Karreriella to Eupelagic Biofacies.

Genus MARTINOTIELLA Cushman, 1933

Type Species: Clavulina communis d'Orbigny

Martinotiella communis (d'Orbigny)

Clavulina communis d'Orbigny, 1826, p. 286, No.4.

Martinotiella communis; Brady, 1884, pp. 91, 394, Pl. 48, figs. 1-13.

Martinotiella communis; Hornibrook, 1952, p. 185.

DISTRIBUTION: Sporadically present through the Rangitikei River and lower part of the Wanganui River section, and as a single specimen in the Wilkies Shellbed at Wilkies Bluff.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

Martinotiella clarae Gibson, Pl. 1, fig.7.

Martinotiella clarae Gibson, 1967, pp. 12-13, Pl. 2, figs. 24, 27-29.

REMARKS: Several damaged specimens from a single Opoitian sample are tentatively referred to M. clarae.

Dimensions of hypotype (VF1007): length 1.49mm, width 0.40mm.

DISTRIBUTION: One sample from the Taihape Mudstone, Wanganui River.

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

OBSERVED ECOLOGIC RANGE: Shallow part of Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Haeslerella to Karreriella Biofacies.

Superfamily MILIOLACEA

Family FISCHERINIDAE

Genus CYCLOGYRA Wood, 1842

Type Species: Cyclogyra multiplex Wood

Cyclogyra sp.

DISTRIBUTION: One poorly preserved specimen from the Lower Okiwa Group, Watershed Road.

Superfamily MILIOLACEA

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

Type Species: Serpula semimulum Linne'Quinqueloculina candeina d'OrbignyQuinqueloculina candeina d'Orbigny, 1839a, p. 199, Pl. 12, figs. 24-26.Quinqueloculina candeina; Cushman, 1929, p.27, Pl. 3, figs. 1a-c.

DISTRIBUTION: Rare in the Snapper Point Conglomerate at Waverley Beach.

OBSERVED STRATIGRAPHIC RANGE: Waipipian (Middle Pliocene); Gibson (1967) records Q. cf. candeina as ranging from Middle to Upper Tongaporutuan (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Zoaflorilus Biofacies.

Quinqueloculina cooki VellaQuinqueloculina cooki Vella, 1957, pp. 9, 13, 25, Pl. 5, figs. 82-83, 87.REMARKS: The Middle Waipipi Shellbed at Waverley Beach contains large, smooth shells with chambers inflated and flat or concave on the sides identical with the Cook Strait form. Specimens from the Snapper Point Shellbed at Waverley Beach are smaller, with narrower chamber sides, and are referred to Q. cf. cooki.

OBSERVED STRATIGRAPHIC RANGE: Waipipian (Middle Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Recorded from 22-76m in Cook Strait and from 40-48m off southern Hawkes Bay.

Quinqueloculina incisa Vella

Quinqueloculina incisa Vella, 1957, p. 24, Pl. 6, figs. 118-21.

Quinqueloculina incisa; Kennett, 1966a, p. 34, Pl. 2, figs. 26-28.

REMARKS: Specimens closely resemble the typical form with the rounded chambers becoming narrower at the apertural end, and the aperture lacking a rim.

DISTRIBUTION: Rare specimens in the Lower Waipipi Formation at Waverley Beach, in the Lower Okiwa Group at Wanganui River and in the Upper Kumeroa Formation at Saddle Road.

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

OBSERVED ECOLOGIC RANGE: Zeafiorilus to Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella Biofacies: 0-400m in Cook Strait, and living in 18-48m off southern Hawkes Bay.

Quinqueloculina kapitiensis Vella

Quinqueloculina kapitiensis Vella, 1957, pp. 9, 13, 26, Pl. 4, figs. 74, 80-81.

Quinqueloculina kapitiensis; Kennett, 1966a, p. 34.

DISTRIBUTION: Ranging from Opoitian to Hautawan in all except the Waverley Beach and Wilkies Bluff sections.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies;

recorded from 18-396m in Cook Strait and living in 18-113m off southern Hawkes Bay.

Quinqueloculina lamarkiana d'Orbigny

Quinqueloculina lamarkiana d'Orbigny, 1839a, p. 189, Pl. 11, figs. 14-15.

Quinqueloculina lamarkiana; Vella, 1957, p. 23, Pl. 6, figs. 105-107.

REMARKS: Typical forms are distinguished by the acute periphery and subcircular outline. Specimens with subacute peripheries and ovate outlines from the Mangaweka Mudstone at Wanganui River are identical to the form figured by Gibson (1967) as Q. cf. lamarkiana, and are so termed in the range charts.

DISTRIBUTION: Sporadic in all sections except Waitotara Valley.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Castlecliffian (Middle Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: (as Q. cf. lamarkiana) Tongaporutuan (Upper Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Recorded in Cook Strait from 45-396m and living at 91m off southern Hawkes Bay.

Quinqueloculina cf. ludwigi Reuss

Quinqueloculina ludwigi Reuss, 1866, p. 126, Pl. 1, figs. 12a-c.

REMARKS: A medium-sized ovate species with inflated, rounded chambers and a round aperture. Wanganui Basin specimens have less inflated and more closely appressed chambers than those of the types.

DISTRIBUTION: Found only in the Snapper Point Shellbed at Waverley Beach.

OBSERVED STRATIGRAPHIC RANGE: Waipipian (Middle Pliocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies.

Quinqueloculina neosigmoilinoidea Kennett

Quinqueloculina sigmoilinoidea Vella, 1957 (not Gianotti), p. 24, Pl. 6, figs. 115-17.

Quinqueloculina neosigmoilinoidea Kennett, 1966a, p. 71.

REMARKS: Characterised by the subangular periphery and sigmoidal transverse profile.

DISTRIBUTION: Found only in the upper Mangaweka Mudstone at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian (Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: From Cook Strait in 2-146m, from Manakau Harbour, and living in 18-427m off southern Hawkes Bay.

Quinqueloculina seminulum (Linnaeus)

Serpula seminulum Linnaeus, 1767, p.1264, No. 791.

Quinqueloculina triangularis; Vella, 1957, pp. 8, 23, Pl. 6, figs. 100-101.

Quinqueloculina seminulum; Hedley, Hurdle and Burdett, 1965, p. 13,
Pl. 2, fig. 8.

DISTRIBUTION: Present in all except the Wilkies Bluff and Saddle Road sections, ranging in age from Opoitian to Castlecliffian.

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

OBSERVED STRATIGRAPHIC RANGE: Zeafflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Karreriella Biofacies; found intertidally and in Manukau Harbour, from 18-189m in Cook Strait and living in 42-329m off southern Hawkes Bay.

Quinqueloculina suborbicularis d'Orbigny

Quinqueloculina suborbicularis d'Orbigny, 1826, p.302, No. 29.

Quinqueloculina suborbicularis; Vella, 1957, pp. 8, 23, Pl. 6, figs.
102-04.

REMARKS: Large, smooth specimens with circular outlines closely resemble the Recent Cook Strait specimens figured by Vella. Occasional specimens from the Middle Waipipi Shellbed at Waverley Beach are longer, with slightly more acute peripheries and are referred to Q. cf. suborbicularis.

DISTRIBUTION: Only in the Mangaweka Mudstone and Lower Okiwa Group, Wangamui River, and Mangatarata Formation, Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian to Castlecliffian (Upper Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Waiauan (Middle Miocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Found in Manukau Harbour, in Cook Strait from 18-164m and off southern Hawkes Bay from 18-48m.

Genus MASSILINA Schlumberger, 1893

Type Species: Quinqueloculina secans d'Orbigny

Massilina brodiei Hedley, Hurdle & Burdett

Massilina brodiei Hedley, Hurdle & Burdett, 1967, pp. 27-28, Pl. 8, figs. 1a-c, text-figs. 17-19.

DISTRIBUTION: Found only in the Lower Okiwa Group at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies.

RECORDED ECOLOGIC RANGE: Recorded from six intertidal localities around New Zealand, and from 18-40m off southern Hawkes Bay.

Genus PYRGO Defrance, 1824

Type Species: Pyrgo laevis Defrance

Pyrgo elongata (d'Orbigny)

Biloculina elongata d'Orbigny, 1826, p. 298, No.4.

Pyrgo elongata; Kennett, 1966a, p. 36.

DISTRIBUTION: One specimen from the Raumati Mudstone, Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian (Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

RECORDED ECOLOGIC RANGE: Haeuslerella Biofacies.

Pyrgo aff. ezo Asano

Pyrgo ezo Asano, 1938, p. 93, Pl. 9, fig. 1.

Pyrgo aff. ezo; Vella, 1957, pp. 9, 29, Pl. 7, figs. 138-39.

DISTRIBUTION: Mangaweka Mudstone and Lower Okiwa Group, Rangitikei River and Watershed Road; Mangatarata Formation at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian to Castlecliffian (Upper Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: 18-189m in Cook Strait.

Pyrgo cf. guerreri (Silvestri)

Biloculina guerreri Silvestri, 1900, p. 22, text-figs. 1-5.

Biloculina? guerreri; Vella, 1957, pp. 9, 29, Pl. 7, figs. 144-45.

REMARKS: Specimens are identical to that figured by Vella.

DISTRIBUTION: Found only in one sample from the Mangaweka Mudstone at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian (Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: 77m in Cook Strait.

Pyrgo pisum (Schlumberger)

Biloculina pisum Schlumberger, 1891, p. 569, Pl. 11, figs. 81-83,
text-figs. 141-42.

Biloculina pisum; Vella, 1957, pp. 9, 29, Pl. 7, figs. 130-31.

Biloculina pisum; Gibson, 1967, p. 19.

DISTRIBUTION: Mangaweka Mudstone, Rangitikei River; Upper Kumeroa Formation, Saddle Road.

RECORDED STRATIGRAPHIC RANGE: Middle Tongaporutuan to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Recorded from 67-155m in Cook Strait and living from 329-375m off southern Hawkes Bay.

Genus SIGMOILOPSIS Finlay, 1947

Type Species: Sigmoilina schlumbergeri SilvestriSigmoilopsis schlumbergeri (Silvestri), Pl. 1, figs. 14, 15.Sigmoilina schlumbergeri Silvestri, 1904, p. 267.Sigmoilopsis schlumbergeri; Gibson, 1967, p. 15, Pl. 2, figs. 30, 37.

REMARKS: Wanganui Basin specimens appear typical. Occasional damaged, compressed specimens from the Waverley Beach section cannot be certainly identified, but are referred to S. cf. wanganuiensis Vella in range charts. Dimensions of hypotype (VF1008): length 1.01mm, width 0.38mm.

DISTRIBUTION: Infrequent and sporadic through all sections except the Wilkies Shellbed and Waverley Beach sections.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies; living off southern Hawkes Bay in 1419m.

Genus SIPHONAPERTA Vella, 1957

Type Species: Siphonaperta macbeathi VellaSiphonaperta macbeathi VellaSiphonaperta macbeathi Vella, 1957, p. 19, Pl. 4, figs. 60-1, 63.

DISTRIBUTION: One specimen from near the top of the Taihape Mudstone at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian (Middle Pliocene).

RECORDED STRATIGRAPHIC RANGE: Lower Nukumaruan (Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

Siphonaperta parvagguta (Vella)

Quinqueloculina parvagguta Vella, 1957, pp. 9, 27, Pl. 4, figs. 71-73.

Siphonaperta parvagguta; Eade, 1967a, p.27.

DISTRIBUTION: Present through all except the Wilkies Bluff and Waitotara Valley sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus (rarely) to shallow Robulus Biofacies.

RECORDED ECOLOGIC RANGE: 45-72m in Cook Strait, and 42-48m off southern Hawkes Bay.

Genus TRILOCULINA d'Orbigny, 1826

Type Species: Miliolites trigonula Lamark

Triloculina chrysostoma (Chapman)

Miliolina chrysostoma Chapman, 1909, p. 322, Pl. 13, figs. 8-10.

Triloculina chrysostoma; Vella, 1957, pp. 9, 14, 28, Pl. 5, figs. 97-99.

DISTRIBUTION: Found only in one sample from the Middle Waipipi Shellbed, Waverley Beach, and in one sample from the Upper Kumeroa Formation at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Nukumaruan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: 45-317m in Cook Strait.

Genus MILIOLINELLA Wiesner, 1931

Type Species: Vermiculum subrotundum MontaguMiliolinella subrotunda (Montagu), Pl. 1, figs. 12, 13Vermiculum subrotundum Montagu, 1803, p. 521.Miliolinella subrotunda; Brady, 1884, Pl. 4, fig. 3; Pl. 5, figs. 10-11,
13-14.

REMARKS: Large, inflated shells, closely resembling the Recent specimens figured by Brady.

Dimensions of hypotype (VF1008): length 0.30mm, width 0.25mm, thickness 0.25mm.

DISTRIBUTION: Found in a single sample from the Raumati Mudstone, Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian (Middle Pliocene).

OBSERVED ECOLOGIC RANGE: Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Living from 42-48m off southern Hawkes Bay.

Miliolinella vigilax Vella, Pl. 1, figs. 16, 17.Miliolinella vigilax Vella, 1957, pp. 9, 13, 21, Pl. 7, figs. 124-26.

REMARKS: Large specimens with more concave sides than the types, but otherwise identical.

Dimensions of hypotype (VF1009): length 0.81mm, width 0.71mm, thickness 0.60mm.

DISTRIBUTION: Present in occasional samples through all except the Waverley Beach and Waitotara Valley sections.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Nukumaruan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: 22-317m in Cook Strait.

Genus SCUTULORIS Loeblich & Tappan, 1953

Type Species: Scutuloris tegminis Loeblich & Tappan

Scutuloris hornibrooki (Vella)

Quinquinella hornibrooki Vella, 1957, pp. 9, 21, Pl. 7, figs. 127-29.

Quinquinella hornibrooki; Hornibrook, 1961, p. 34.

Scutuloris hornibrooki; Kennett, 1966a, p. 36.

Scutuloris hornibrooki; Gibson, 1967, p. 18, Pl. 3, fig. 47.

REMARKS: The specimens are identical with type figures.

DISTRIBUTION: Infrequent in the Lower Okiwa Group, Watershed Road.

RECORDED STRATIGRAPHIC RANGE: Awamoan (Lower Miocene) to Recent.

RECORDED ECOLOGIC RANGE: Haeuslerella Biofacies; 76-189m in Cook Strait, and living in 48-2028m off southern Hawkes Bay.

Superfamily BULIMINACEA

Family TURRILINIDAE

Genus BULIMINELLA Cushman, 1911

Type Species: Bulimina elegantissima d'OrbignyBuliminella elegantissima d'OrbignyBulimina elegantissima d'Orbigny, 1839b, p. 51, Pl. 7, figs. 13-14.

REMARKS: Specimens are rare and poorly preserved.

DISTRIBUTION: Near the top of the Koriniti Sandstone, and in the sandy upper part of the Pitangi Mudstone, Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Mangapanian (Middle to Upper Pliocene).

RECORDED STRATIGRAPHIC RANGE: Kapitean (Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium to shallow Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: In Manukau Harbour, and from 23m in Foveaux Strait (Hornibrook, in Fleming, 1952).

Family SPHAEROIDINIDAE Cushman

Genus SPHAEROIDINA d'Orbigny, 1826

Type Species: Sphaeroidina bulloides d'OrbignySphaeroidina bulloides d'Orbigny, Pl. 2, fig. 30.Sphaeroidina bulloides d'Orbigny, 1826, p. 267, No. 1.Sphaeroidina bulloides; Hornibrook, 1961, p. 90, Pl. 11, fig. 210.Sphaeroidina bulloides; Kennett, 1966a, p. 51, Pl. 4, fig. 72.

Sphaeroidina bulloides; Gibson, 1967, p. 45, Pl. 10, fig. 167.

Dimensions of hypotype (VF1022): diameter 0.44mm.

DISTRIBUTION: Ubiquitous, in strata ranging in age from Opoitian to Castlecliffian.

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Family BOLIVINITIDAE

Genus BOLIVINITA Cushman, 1927

Type Species: Textilaria quadrilatera Schwager

Bolivinita compressa Finlay

Bolivinita compressa Finlay, 1939c, p. 319, Pl. 27, figs. 101-102.

Bolivinita compressa; Gibson, 1967, p. 40, Pl. 9, figs. 151-52.

Bolivinita compressa; Hornibrook, 1968, pp. 70, 107, fig. 23.

DISTRIBUTION: Rare in the Taihape Mudstone and the lower Mangaweka Mudstone at Pangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to lowermost Mangapanian (Lower to Upper Pliocene).

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

OBSERVED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Bolivinita elegantissima Boomgart

Bolivinita elegantissima Boomgart, 1949, p. 95, Pl. 11, fig. 3.

Bolivinita elegantissima; Hornibrook, 1968, pp. 35, 66, 105, fig. 23.

REMARKS: Rare, small specimens distinguished by rounded cross-section and lobulate outline with common longitudinal ribs are referred to this species.

DISTRIBUTION: Found only in one sample from the Taihape Mudstone at Rangitikei River and in one sample from the Rangikura Sandstone at Waverley Beach.

OBSERVED STRATIGRAPHIC RANGE: Uppermost Opoitian to lower Waipipian (Lower Pliocene to Middle Pliocene).

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

OBSERVED ECOLOGIC RANGE: ?Zeaflorilus to Robulus Biofacies.

Bolivinita cf. finlayi Kennett, Pl. 2, figs. 35, 36.

Bolivinita finlayi Kennett, 1967, pp. 997, 1000, figs. 23-24.

REMARKS: Slightly compressed with carinate acute angles and a sculpture of fine, irregular, longitudinal costae similar to B. finlayi, but more inflated and more rapidly expanding initially.

Dimensions of hypotype (VF1023): length 0.36mm, width 0.21mm.

DISTRIBUTION: Sporadic through the Rangitikei River section, in the Taihape Mudstone at Wanganui River, in the Mangapani Shell

conglomerate at Mangapunipuni Stream, and in the Te Aute Formation at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: (B. finlayi) Kapitean to Opoitian (Upper Miocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: (B. finlayi) Haeuslerella Biofacies.

Bolivinita pliozea Finlay, Pl. 2, figs. 31, 37.

Bolivinita pliozea Finlay, 1939c, p. 319.

Bolivinita pliozea; Vella, 1957, p. 10 (possibly reworked fossil).

Bolivinita pliozea; Hornibrook, 1968, p. 107, fig. 23.

REMARKS: Distinguished by the quadrate section, rounded sides and few, strong longitudinal costae. Some populations show a gradation towards B. pohana, some specimens having more rhomboidal cross-section and reduced ornament.

Dimensions of hypotype (VF1024): length 0.70mm, width 0.25mm.

DISTRIBUTION: Sporadically through all sections.

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

OBSERVED ECOLOGIC RANGE: Zeafiorilus to Haeuslerella Biofacies;

104-396m in Cook Strait, and in Manakau Harbour.

Bolivinita pohana Finlay

Bolivinita pohana Finlay, 1939c, p.319, Pl. 27, figs. 99-100.

Bolivinita pohana; Konnett, 1966a, p. 48, Pl. 4, figs. 61-62.

Bolivinita pohana; Gibson, 1967, pp. 40-41, Pl. 10, figs. 153, 157.

Bolivinita pohana; Hornibrook, 1968, p. 105, fig. 23.

DISTRIBUTION: Present in variable abundance through all sections.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella Biofacies; recorded from 104m in Cook Strait (possibly reworked fossil).

Bolivinita quadrilatera (Schwager)

Textularia quadrilatera Schwager, 1866, p. 253, Pl. 7, fig. 103.

Bolivinita quadrilatera; Gibson, 1967, pp. 39-40, Pl. 10, figs. 155, 159-60.

Bolivinita quadrilatera; Hornibrook, 1968, p. 105, fig. 23.

REMARKS: Characterised by its quadrate cross-section with weak keels and no longitudinal costae.

DISTRIBUTION: Rare and sporadic through the Wanganui River section and in the Waipipian at Waverley Beach, Rangitikei River and Manawatu Saddle Road.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Living in 1419m off southern Hawkes Bay.

Genus BOLIVINA d'Orbigny, 1839

Type Species: Bolivina plicata d'Orbigny

Loeblich and Tappan (1964) revived the genus Brizalina Costa, 1856, to include those species otherwise similar to Bolivina but lacking chamber retral processes or crenulations and often keeled and strongly compressed. Hofman (1971) quoted Gramman (1965, p. 438) and Lindenberg (1966, p.90) as rejecting Brizalina because they considered the diagnostic characters to grade into those of Bolivina. Sliter (1970), however, continued to distinguish the two genera and considered the following surface features to be taxonomically important:

- (1) Bolivina: has chamber retral processes, a varied surface microtopography, and common, coarse, depressed perforations;
- (2) Brizalina: lacks retral processes, has a smooth, glossy surface and numerous fine, flush perforations.

Some of the New Zealand species of Bolivina discussed here show both sets of characteristics, and hence support the suppression of Brizalina as a generic name. Bolivina hornibrooki and B. vellai appear to lack retral processes, but have strong ornamentation, inflated chambers and coarse pores. B. wanganuiensis has coarse pores and resembles B. fyfei Hornibrook, which shows slight chamber overlap on

the sides (Hornibrook, 1958a, fig. 16). However, it lacks retral processes and ornament, and has a compressed early part. Bolivina contains so many species as to be taxonomically unwieldy, and increased use of subgenera (as by Hofman, 1971) may be of practical value.

Differences between species of Bolivina are often subtle, and there has been considerable taxonomic confusion (Sliter, 1969, 1970). The presence of a number of similar forms in Wanganui Series sediments in New Zealand has been recognised previously (Hornibrook, 1961, pp. 73-74; 1968, pp. 76-77), and three new species are described here. Others may become apparent as study progresses.

Bolivina cf. acerosa Cushman

Bolivina acerosa Cushman, 1936a, p. 54, Pl. 8, fig. 1.

Bolivina cf. acerosa; Hornibrook, ^{1961,} p. 73, Pl. 9, fig. 174.

Brizalina cf. acerosa; Kennett, 1966a, pp. 44-45, Pl. 4, figs. 51-52.

REMARKS: Rare specimens of a small, elongate Bolivina with rounded periphery and slightly overlapping chambers are referred to B. cf. acerosa. These forms closely resemble those figured by Hornibrook and by Kennett, and differ from typical B. acerosa in having less oblique sutures and lacking longitudinal costae on the early part of the test.

DISTRIBUTION: Found only in a single sample from the upper Waiouru Sandstone at Rangitikei River.

RECORDED STRATIGRAPHIC RANGE: Waitakian to Opoitian (Upper Oligocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: ?Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Karrerella Biofacies.

Bolivina affiliata Finlay

Bolivina affiliata Finlay, 1939c, p. 320.

Bolivina affiliata; Gibson, 1967, pp. 32-33, Pl. 8, fig. 126.

Bolivina (Latibolivina) affiliata; Hofman, 1971, pp. 311-12, Fig. 13, no. 6, Table 4.

DISTRIBUTION: Present as rare specimens in strata ranging in age from Opoitian to Hautawan, in all except the Waitotara Valley section.

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

OBSERVED ECOLOGIC RANGE: Elphidium (rarely) to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Bolivina alata (Seguenza)

Vulvulina alata Seguenza, 1862, p. 115, Pl. 2, figs. 5, 5a.

Bolivina alata; Cushman, 1937, pp. 106-107, Pl. 13, figs. 3-11.

DISTRIBUTION: Not found in the Waitotara Valley section. Present sporadically in the other sections but nowhere common.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: 97-396m in Cook Strait.

Bolivina albatrossi Cushman

Bolivina albatrossi Cushman, 1922a, P. 31, Pl. 6, fig. 4.

Bolivina albatrossi; Gibson, 1967, p. 33, Pl. 8, fig. 127.

Bolivina albatrossi; Hornibrook, 1968, pp. 35-36, 66, 72, 74, fig. 13.

DISTRIBUTION: Sporadically in the Taihape Mudstone at Wanganui River, through the Rangitikei River section, and in the Mangaweka Mudstone at Watershed Road.

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

RECORDED ECOLOGIC RANGE: *Maeslerella* to *Robulus* Biofacies.

Bolivina compacta Sidebottom, Pl. 13, fig. 1.

Bolivina robusta Brady var. compacta Sidebottom, 1905, p. 15, Pl. 3, fig. 7.

Bolivina compacta; Cushman, 1911, p. 36, fig. 58.

Bolivina compacta; Hedley, Hurdle & Burdett, 1967, pp. 30-31, Pl. 9, figs. 3A, B, text-figs. 20-27.

Bolivina compacta; Sliter, 1970, p. 157, Pl. 1, figs. 105, Pl. 8, figs. 4-5.

REMARKS: A variable, cosmopolitan species distinguished by the elongate, tapering test with rounded periphery and reticulate ornament of coarse pores in irregular polygonal pits.

Hedley et al (1967) considered B. inflata Heron-Allen & Earland synonymous with B. compacta, and illustrated a series of specimens showing gradation between the two forms.

Dimensions of hypotype (VF1025): length 0.17mm, width 0.09mm, thickness 0.06mm.

DISTRIBUTION: Present sporadically through the Wanganui River section. Not found in the other sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal stations around New Zealand, from Manakau Harbour, and from Terra Nova Stations 134 and 144 (as B. inflata) by Heron-Allen and Earland (1922).

Bolivina hornibrooki n.sp., Pl. 2, figs. 41-43;

Pl. 13, fig. 2; Pl. 14, fig. 1.

DESCRIPTION: Test moderately large, twice as long as wide, inflated, periphery broadly rounded, expanding moderately from rounded initial end, sides in adult usually nearly parallel. Chambers distinct, 5-7 on each side, $1\frac{1}{2}$ - 2 times as wide as high throughout; sutures depressed, smooth, fairly straight, at low angle from the horizontal; median line excavated. Chambers covered throughout by strong hispid ornament of large tubercles and rounded, coalescing costae; wall penetrated by numerous coarse, slightly depressed pores. Aperture terminal, elongate, with pronounced, rounded lip, often on extended neck.

Prolocular diameters range from 0.025mm to 0.050mm, but show no obvious dimorphism. Megalospheric and microspheric individuals may be

represented in populations by specimens differing in the rate of enlargement of test.

Microstructure: Surface very finely perforate (perforations 0.2 microns diameter), with microgranular texture; coarse pores (3-4 microns) distributed unevenly over test, in places overgrown by ornament and often covered at apertural end by perforated plate.

Dimensions of holotype: length 0.50mm, breadth 0.23mm, thickness 0.19mm.

Variation: Individuals vary in strength and pattern of ornament, which tends to be reduced on the anterior part of the final one or two chambers.

TYPES: Holotype (VF979) and 47 paratypes (VF980-982).

TYPE LOCALITY: N143f516, Turakina Valley, Grid ref. N143/802791.

TYPE LEVEL: Castlecliffian (Middle Pleistocene).

REMARKS: This is the hispid species described as accompanying B. parri Cushman in Castlecliffian sediments by Hornibrook (1961, 1968). It resembles B. parri but can be consistently separated by the stronger ornament, which is more persistent over the test, and the sutures, which are unobstructed on earlier chambers. The final chambers on B. parri usually lack ornament entirely, and secondary deposition of calcite at the initial end fills the sutures, making them limbate and often overlapping the surrounding chambers.

Some specimens of B. petiae Gibson show areas of surface detail resembling that of B. hornibrooki. B. petiae is considered the ancestral form in a lineage giving rise to B. hornibrooki in the Lower Pleistocene and to B. parri in the Lower Pleistocene.

DISTRIBUTION: Rare to uncommon in the uppermost Opoitian to Mangapanian of the Rangitikei River and Wanganui River sections, becoming more common in the Hautawan and Nukumaruan of these sections and in the Watershed Road and Manawatu Saddle Road sections; common in the Castlecliffian of Turakina Valley.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

Bolivina lapsus Finlay, Pl. 2, figs. 32-38.

Bolivina lapsus Finlay, 1939b, p. 98, Pl. 11, fig. 9.

Bolivina lapsus; Hornibrook, 1961, p. 73, Pl. 10, fig. 184.

Bolivina lapsus; Gibson, 1967, p. 34, Pl. 8, fig. 130.

Dimensions of hypotype (VF1020): length 0.65mm, width 0.22mm, thickness 0.12mm.

DISTRIBUTION: Fleming (in Fleming, ed., 1959) and Hornibrook (ibid) gave the upper stratigraphic limit of B. lapsus as Tongaporutuan. Kennett (1966a) considered the absence of this species above Lower Tongaporutuan in the Greymouth area as possibly due to facies control, and quoted Mr B. A. McInnes (p. 45, pers. comm.) as finding it considerably higher in Hawkes Bay. In Wanganui Basin, typical B. lapsus is occasionally present in all sections except the Waitotara Valley section in strata ranging in age from Opoitian to Castlecliffian.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Elphidium (rarely) to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Bolivina minuta Natland

Bolivina minuta Natland, 1938, p. 146, Pl. 5, fig. 10.

Bolivina minuta; Cushman & McCulloch, 1942, p. 179, Pl. 24, figs. 4-7.

REMARKS: Characterised by the small, palmate test with narrowly rounded periphery and strongly raised median ridge. This species is similar in outline to B. marginata adalaidana Cushman & Kleinpell, but is thicker and lacks raised sutures.

DISTRIBUTION: Present fairly persistently in all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zesflorilus to shallow Robulus Biofacies.

Bolivina petiae Gibson, Pl. 14, fig. 4; Pl. 15, fig. 1.

Bolivina petiae Gibson, 1967, pp. 35-36, Pl. 9, figs. 140-42.

Bolivina n.sp. as petiae Gibson; Kennett, 1966a, p. 46, Pl. 4, figs. 57-58.

REMARKS: Bolivina petiae is distinguished by the ornament of coarse tubercles covering the test and the coarse, irregularly distributed pores, often situated in polygonal pits.

Dimensions of hypotypes: VF1029, length 0.26mm, width 0.14mm, thickness 0.10mm; VF 1030, length 0.23mm, width 0.11mm, thickness 0.08mm.

DISTRIBUTION: Present in all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Middle Pleistocene).

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

RECORDED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Bolivina plicatella Cushman, Pl. 15, fig. 2

Bolivina plicata Brady, Parker & Jones (not d'Orbigny), 1888, p. 221. -
Cushman, 1904, p. 264.

Bolivina plicatella; Cushman & Cahill, 1933, p. 26, Pl. 8, figs. 12a,b.

Bolivina plicatella; Cushman, 1937, p. 89, Pl. 11, figs. 3-4.

REMARKS: A broad, compressed, widely flaring shell with subacute periphery. Wanganui Basin specimens agree well with the type specimens from the Miocene of Florida, except that longitudinal ridges present on either side of the depressed median axis are often less distinct

than in the type figures.

Dimensions of hypotype (VF1034): length 0.23mm, width 0.16mm, thickness 0.06mm.

DISTRIBUTION: Recorded from all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Bolivina pseudoplicata Heron-Allen & Earland, Pl. 16,

fig. 1.

Bolivina pseudoplicata Heron-Allen & Earland, 1930, p. 81, Pl. 3, figs. 36-40.

Bolivina pseudoplicata; Cushman, 1937, pp. 166-68, Pl. 19, figs. 12-20.

Bolivina pseudoplicata; Hedley, Hurdle & Burdett, 1967, p. 30, Pl. 9, figs. 4a, b.

Bolivina pseudoplicata; Sliter, 1970, pp. 160, 162, Pl. 3, figs. 1-6, Pl. 8, figs. 12-13.

REMARKS: Characterised by the compressed test with strong longitudinal ridges on each side of the depressed median area. Wanganui Basin specimens are very similar to the type and other figured specimens.

DISTRIBUTION: Throughout the Wanganui and Rangitikei River sections, in the Wilkies Shellbed at Waitotara Valley, the Lower Kumeroa Formation at Saddle Road and the Lower Okiwa Group at Watershed Road.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Nukumaruan (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeafiorilus to Haeuslerella Biofacies.

Bolivina spathulata (Williamson), Pl. 2, figs. 34, 39.

Textularia variabilis var. spathulata Williamson, 1858, p. 76, Pl. 6, figs. 164-65.

Bolivina numerosa Vella, 1957, p. 33, Pl. 8, figs. 160-61.

Bolivina numerosa; Kennett, 1966a, pp. 45-46, Pl. 4, fig. 60.

Bolivina spathulata; Hedley, Hurdle & Burdett, 1965, p. 21, Pl. 6, figs. 23a, b, text-figs. 60a-g.

REMARKS: Hedley et al (1965) synonymised B. numerosa Vella with B. spathulata (Williamson).

Dimensions of hypotype (VF1033): length 0.35mm, width 0.14mm, thickness 0.07mm.

DISTRIBUTION: Present in variable abundance through all except the Waitotara Valley and Saddle Road sections.

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies; intertidal, in Manukau Harbour, 9-450m in Cook Strait, and living from 48-71m off southern Hawkes Bay.

Bolivina srinivasini (Kennett)

Brizalina srinivasini Kennett, 1967, pp. 1000-1001, figs. 21-22.

DISTRIBUTION: Only in the Utiki Sand and lower Mangaweka Mudstone at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Mangapanian (Middle to Upper Pliocene).

RECORDED STRATIGRAPHIC RANGE: High in the Opoitian Stage (Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Deep Haeuslerella to shallow Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Deeper-water phase of the Haeuslerella Biofacies.

Bolivina subexcavata Cushman & Wickenden, Pl. 16, figs. 2,3.

Bolivina subexcavata Cushman & Wickenden, 1929, p. 9, Pl. 4, fig. 4.

Bolivina subexcavata; Cushman, 1937, pp. 138-39, Pl. 18, fig. 33.

Bolivina subexcavata; Sliter, 1970, pp. 162, 164, Pl. 4, figs. 1-5;

Pl. 8, fig. 14.

REMARKS: The illustrated specimens show the characteristic wedge-shape with subacute periphery and irregular ornament of polygonal pits with coarse pores. Wanganui Basin specimens closely resemble those figured by Sliter.

Dimensions of hypotypes: VF1034, length 0.23mm, width 0.14mm, thickness 0.10mm; VF1035, length 0.25mm, width 0.16mm, thickness 0.12mm.

DISTRIBUTION: Present through all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Bolivina subspinescens Cushman

Bolivina subspinescens Cushman, 1922a, p. 48, Pl. 7, fig. 5.

Bolivina subspinescens; Cushman, 1937, pp. 157-58, Pl. 19, figs. 1-3.

Bolivina subspinescens; Gibson, 1967, pp. 36-37, Pl. 9, fig. 143.

REMARKS: Small, tapered forms exhibiting variable amounts of axial twisting and ornamentation on the lower half of each chamber, but with the top half of each chamber consistently smooth, are referred to this species. Rare, very stout forms from the Middle Siltstone Member of the Mangaweka Mudstone at Wanganui River are referred to B. cf. turbiditorum Vella in range charts.

DISTRIBUTION: Rare in the Waverley Beach and Saddle Road sections; present in variable abundance throughout the Wanganui River and Rangitikei River sections. Not present in the other sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus (rarely) to Robulus Biofacies; Brizalina aff. subspinescens (Cushman) is reported living in 130m off southern Hawkes Bay.

Bolivina variabilis (Williamson)

Textularia variabilis Williamson, 1858, p. 76, Pl. 6, figs. 162-63.

Bolivina variabilis; Cushman, 1922a, p. 49, Pl. 4, figs. 3a, b.

Bolivina variabilis; Cushman, 1937, pp. 158-59, Pl. 16, figs. 6, 12-14.

Bolivina variabilis; Sliter, 1970, p. 166, Pl. 5, fig. 4; Pl. 6, figs. 1-3; Pl. 8, figs. 15-16.

REMARKS: A large, elongate species with distinct retral processes at the base of each chamber. The surface is penetrated by numerous coarse pores, lying in polygonal pits which give a characteristic reticulate pattern to the test surface.

DISTRIBUTION: Only in the Middle Waipipi Shellbed at Waverley Beach and in upper Mangaweka Mudstone at Watershed Road.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Mangapanian (Middle to Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to shallow Haeuslerella Biofacies; Manukau Harbour.

Bolivina vellai n.sp., Pl. 3, figs. 44-47; Pl. 17, figs. 1,2;

Pl. 18, fig. 1.

DESCRIPTION: Test large, $2-2\frac{1}{2}$ times as long as wide, inflated, periphery broadly rounded, tapered, expanding moderately from acute or subacute initial end; microspheric form more tapered than megalospheric. Chambers distinct, 6-8 on each side, $1\frac{1}{2}$ times as wide as high in early part, about as high as wide in adult; sutures incised, straight or slightly curved, at low angle to horizontal, smooth and partially obscured by ornament at initial end, unobstructed and granular towards aperture; strong median depression. Ornament of large tubercles and strong, rounded, coalescing ridges on lower half of test; later chambers smooth. Wall penetrated by numerous very coarse pores. Aperture terminal, large, elongate, with prominent raised, smooth lip.

Dimorphism is limited, but tapered forms, with prolocular diameters averaging 0.032mm, and less tapered, more robust forms with prolocular diameters averaging 0.045mm, are present.

Microstructure: Surface finely perforate, smooth to microgranular, smoothest on early chambers, penetrated by many coarse pores which are most abundant on later chambers, slightly depressed, often with a central plug and may occasionally at any level of the test be covered by a perforated plate; pores often in depressions formed by outgrowth of ornament.

Dimensions: holotype, length 0.38mm, width 0.15mm, thickness 0.12mm;
figured paratype (VF985), length 0.43mm, width 0.18mm,
thickness 0.14mm.

Variation: Specimens vary in the strength and persistence of the ornament on the lower part of the test. The ornament is often more pronounced on the inner part of each chamber, accentuating the median depression. Twisting about the axis of growth is not marked, but some specimens twist up to 45° .

TYPES: Holotype (VF983) and 53 paratypes (VF984-987).

TYPE LOCALITY: N138f559 (VF983, VF985, VF986), Wanganui River, Grid ref. N138/671064; N138f558 (VF987), Wanganui River, Grid ref. N138/672065; N143f516 (VF984), Turakina Valley, Grid ref. N143/802791.

TYPE LEVEL: Uppermost Mangapanian (Upper Pliocene) (VF983, VF985-987); Castlecliffian (Middle Pleistocene) (VF984).

REMARKS: The species differs from B. hornibrooki and B. parri in the rounded, more inflated chambers, tapering shell with coarse pores and stronger, more restricted ornament. It is one of a group of species with similar ornament tending to become reduced towards the aperture, including B. hornibrooki and B. parri on the one hand, and possibly extending to B. wanganuiensis, with the ornament at the prolocular end reduced to a thick calcitic layer, on the other hand.

DISTRIBUTION: Sporadic, rare to abundant, from uppermost Opoitian to Hautawan in all sections studied.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

Bolivina wanganuiensis n.sp., Pl. 3, figs. 51-52, 58-59;

Pl. 18, fig. 2.

Bolivina aff. silvestrina Cushman; Wheatley, 1943, checklist.

Bolivina cf. silvestrina Cushman; Finlay, in Lillie, 1953, p. 146.

Bolivina aff. silvestrina Cushman; Hornibrook, in Wellman, 1954, p. 385.

DESCRIPTION: Test large, $2\frac{1}{2}$ -3 times as long as wide, sides expanding rapidly then becoming subparallel. Chambers 8-9 on each side in adult, about as high as broad throughout, initially slightly compressed with flush sutures, becoming inflated and distinct with depressed sutures. Periphery narrowly rounded on early part, broadly rounded on later part. Sutures curved, at low angle to horizontal, smooth on early part of shell, coarsely granular towards the aperture; slight median depression on later half of test. Surface smooth, glossy, with numerous coarse pores and heavy overlay of secondary calcite deposited on initial part of test. Aperture large, elliptical, with pronounced, rounded lip.

No dimorphic differences of shape of test or prolocular diameters, which average 0.036mm, are apparent.

Microstructure; Wall penetrated by frequent coarse pores, not as large or as numerous as in B. vellai, mostly sealed by calcite on early part; pores slightly depressed.

Dimensions: holotype, length 0.56mm, width 0.19mm, thickness 0.13mm;

figured paratype (VF991), length 0.60mm, width 0.18mm, thickness 0.14mm.

Variation: The secondary calcite layer varies in thickness and extent, and some specimens show slight axial twisting.

TYPES: Holotype (VF988) and 38 paratypes (VF989-991).

TYPE LOCALITY: N138f558 (VF988-990), Wanganui River, Grid ref.

N138/672065; N143f516 (VF991), Turakina Valley, Grid ref. N143/802791.

TYPE LEVEL: Mangapanian (VF988-990) (Upper Pliocene); Castlecliffian (VF991) (Middle Pleistocene).

REMARKS: Distinguished from B. fyfei Hornibrook by its more rapidly expanding, blunt-ended and sub-parallel sided test, with more inflated, less elongate chambers and fewer, coarser perforations. It is larger and less tapered than B. silvestrina Cushman, with straighter sutures and less inflated, more tightly biserial chambers.

B. wanganuiensis and B. fyfei are closely related to B. silvestrina Cushman (Castel'Arquato, Italy) and B. italica Cushman (Sicily). B. fyfei occurs in sediments deposited to the east of the axial ranges (Hornibrook, 1958a), while B. wanganuiensis occurs to the west. The two species probably had a common ancestor and differentiated as a result of geographic isolation.

DISTRIBUTION: Sporadic, rare to common, in Opoitian to Hautawan strata of the sections studied.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to (rarely) shallow part of *Hauserella* Biofacies.

Bolivina watti Gibson

Bolivina watti Gibson, 1967, p. 37, Pl. 9, figs. 144-45.

Brizalina n.sp., as watti (Gibson in press); Kennett, 1966a, p. 46, Pl. 4, figs. 53-54.

REMARKS: Elongate, moderately compressed forms which are smaller but otherwise closely resemble the type specimens.

DISTRIBUTION: Sporadically present in all except the Waverley Beach and Wilkies Bluff sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

OBSERVED ECOLOGIC RANGE: *Zeaflorilus* to *Robulus* Biofacies.

RECORDED ECOLOGIC RANGE: *Haeuslerella* to *Robulus* Biofacies.

Genus RECTOBOLIVINA Cushman, 1927

Type Species: Sagrina bifrons Brady

Rectobolivina maoria Finlay

Rectobolivina maoria Finlay, 1939c, p. 320, Pl. 27, figs. 82-84.

Rectobolivina maoria; Kennett, 1966a, p. 47, Pl. 4, figs. 55-56.

Rectobolivina maoria; Hornibrook, 1968, p. 69, fig. 12.

DISTRIBUTION: Lower Mangaweka Mudstone, Rangitikei River, and upper Taihape Mudstone, Wanganui River.

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

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

RECORDED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies.

Rectobolivina striatula (Cushman), Pl. 3, fig. 50.

Siphogenerina striatula Cushman, 1913, p. 108, Pl. 47, figs. 1a, b.

Rectobolivina striatula; Kennett, 1966a, p. 47, Pl. 4, fig. 59.

Rectobolivina striatula; Hornibrook, 1968, p. 73, fig. 13.

Dimensions of hypotype (VF1037): length 0.60mm, width 0.16mm.

DISTRIBUTION: Present, often in abundance, through all the sections studied.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies.

Family EOUVIGERINIDAE

Genus STILOSTOMELLA Guppy, 1894

Type Species: Stilostomella rugosa Guppy

Stilostomella antipoda (Stache)

Nodosaria antipoda Stache, 1865, p. 194, Pl. 22, fig. 19.

Stilostomella antipoda; Hornibrook, 1961, p. 49, Pl. 6, fig. 98.

DISTRIBUTION: Present in occasional samples in the Wanganui River, Rangitikei River, Watershed Road and Saddle Road sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Runangan to Southland Series (Upper Eocene to Middle Miocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Stilostomella basicarinata Hornibrook

Stilostomella basicarinata Hornibrook, 1961, p. 50, Pl. 6, figs. 104-05.

DISTRIBUTION: Found only in the Taihape Mudstone at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Mangaorapan to Duntroonian (Lower Eocene to Lower Oligocene).

OBSERVED ECOLOGIC RANGE: Robulus Biofacies.

Stilostomella pomuligera (Stache)

Dentalina pomuligera Stache, 1865, p. 204, Pl. 22, fig. 31.

Nodosaria (Dentalina) annulata (Reuss); Chapman, 1926, p. 48, Pl. 3, fig. 31; Pl. 1C, fig. 187

Stilostomella pomuligera; Hornibrook, 1961, p. 49, Pl. 6, fig. 110.

DISTRIBUTION: Found only in a few samples from the Wanganui River, Watershed Road and Saddle Road sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Bertonian to Taranaki Series (Middle Eocene to Upper Miocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Stilostomella verneuillii (d'Orbigny)

Dentalina verneuillii d'Orbigny, 1846, p. 48, Pl. 2, figs. 7-8.

Stilostomella verneuillii; Hornibrook, 1961, p. 50, Pl. 6, fig. 109.

DISTRIBUTION: Present in all sections except the Waverley Beach section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Whaingaroan to Waitotaran (Lower Oligocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Family BULIMINIDAE

Genus BULIMINA d'Orbigny, 1826

Type Species: Bulimina marginata d'Orbigny

In large Pliocene and early Pleistocene populations of Bulimina in Wanganui Basin, continuous morphologic gradation can be observed between forms referred to B. elongata subulata Cushman & Parker, B. aculeata d'Orbigny and B. marginata d'Orbigny (Fig. 27). B. aculeata is most common, and grades towards B. elongata subulata through forms with progressively reduced ornament, more inflated younger chambers and loss of apical spine. It grades to B. marginata through specimens with reduced spines tending to concentrate in fringes along the lower margins of chambers. None of these forms grades towards B. striata d'Orbigny.

These species, including B. striata, have different, though overlapping, ecologic preferences. Fig. 28 shows the estimated relative abundances of the four species through the Wanganui River section compared with the paleobathymetry.

B. striata is most consistently common in the lower part of the section (Opoitian) and became relatively insignificant as the basin shallowed. Peaks of abundance later in the section are anomalous, and possibly related to non-depth controlled environmental factors or reworking of the sediments following uplift.

B. aculeata is common through most of the section, and is especially abundant in the Mangapanian. B. marginata is also present throughout the

Fig. 27 Outline diagrams of Bulimina elongata var. subulata, B. marginata, and B. aculeata from sample N138f558 (Upper Pliocene), to illustrate variation in form and gradation between the three species; all X 70.

a-f, B. elongata var. subulata.

g-o, B. marginata.

p-y, B. aculeata.

Fig. 28. - Variation in abundance of Bulimina elongata
subulata, B. marginata, B. aculeata and B. striata
through the Wanganui River section. A = very
abundant; B = abundant; C = common; D = uncommon;
E = rare; and F = absent. · indicates samples
barren of foraminifera.

section, though in lesser numbers. It increases in abundance in the Mangapanian and Hautawan. Lewis (1972) records B. aculeata as abundant and living at most stations on the continental slope off southern Hawkes Bay, and B. marginata as common on the shelf and upper slope, where the range of the two species overlaps. Parker (1954) showed that in the northeastern Gulf of Mexico, these species have the following depth ranges: B. marginata 0-500m (most abundant from 100-250m); B. aculeata 0-3000m (most abundant from 500-2000m); and B. striata mexicana 200-3000m (most abundant from 220-800m). Phleger (1960, figs. 15, 17) gave fairly similar ranges for the same species in the same region.

B. elongata subulata is present sporadically through the section, and becomes common in the Mangapanian and Hautawan. The only record of this shallow water species around New Zealand is from Manukau Harbour by Hulme (1964). Reasons for the anomalous peaks of abundance in the lower part of the section are not known.

To summarise, depth zones based on dominance of species of Bulimina can be recognised in Wanganui Basin sediments. B. striata is dominant in the Robulus Biofacies, B. aculeata in the Haeuslerella Biofacies, B. marginata from the Elphidium to the shallow Haeuslerella Biofacies, and B. elongata subulata from the Zeaflorilus to the Elphidium Biofacies.

Bulimina aculeata d'Orbigny, Pl. 3, fig. 48; text-
fig. 28p-y

Bulimina aculeata d'Orbigny, 1826, p. 269, No. 7.

Bulimina aculeata; Finlay, 1947, pp. 347-48.

Bulimina aculeata; Kennett, 1966a, p. 38, Pl. 3, figs. 35-36.

Bulimina aculeata; Gibson, 1967, p. 23, Pl. 6, fig. 102.

Bulimina aculeata; Hornibrook, 1968, p. 73, fig. 13.

REMARKS: Specimens vary in the shape and degree of inflation of the chambers, in the amount of ornament, and in the size of the tooth-plate. Some variation in size of the apical spine and in length and abundance of spines on the initial half is due to damage during fossilisation or sample preparation.

Dimensions of hypotype (VF1038): length 0.29mm, width 0.19mm.

DISTRIBUTION: Present, often in abundance, in most samples examined.

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies; recorded living from 276-2469m off southern Hawkes Bay.

Bulimina elongata d'Orbigny var. subulata Cushman & Parker,

Pl. 3, fig. 53; text-fig. 28a-f.

Bulimina elongata d'Orbigny var. subulata Cushman & Parker, 1937, p. 51,

Pl. 7, figs. 6-7.

Bulimina elongata var. subulata; Hulme, 1964, p. 329.

REMARKS: Characterised by its smooth, polished surface, inflated chambers usually lacking ornament and rounded proloculus lacking an apical spine. Specimens show considerable variation in all of these features, and grade towards B. marginata.

A number of forms resembling B. elongata subulata have been described, including B. denudata Cushman & Parker. Shallow water Pliocene and Pleistocene populations of Bulimina show considerable variation, and many of the described species may be synonymous. No attempt to revise these forms has been made here.

Dimensions of hypotype (VF1039): length 0.38mm, width 0.20mm.

DISTRIBUTION: Present through all sections examined.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to (rarely) shallow Robulus Biofacies.

RECORDED ECOLOGIC RANGE: The only New Zealand record of this form is from Manukau Harbour. B. denudata has been recorded from Milford Sound (Kustanovitch, 1965).

Bulimina marginata d'Orbigny, Pl. 3, fig. 54: text-fig. 289g-o.

Bulimina marginata d'Orbigny, 1826, p. 269, No. 4, Pl. 12, figs. 10-12.

Bulimina marginata; Brady, 1884, p. 104, Pl. 51, figs. 3-5.

Bulimina marginata; Hedley, Hurdle & Burdett, 1965, p. 20, Pl. 6, fig. 21; text-fig. 5.

REMARKS: This species exhibits considerable variation both in the degree of inflation of the chambers and in the amount of ornament. A range of specimens figured by Hedley et al shows similar variation.

Dimensions of hypotype (VF1040): length 0.29mm, width 0.18mm.

DISTRIBUTION: Present, usually uncommon, in all sections except the Waitotara Valley section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Nukumaruan (Lower Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Living in 40-427m off southern Hawkes Bay.

Eade (1967) listed other records in the New Zealand Recent.

Bulimina striata d'Orbigny, Pl. 3, fig. 55.

Bulimina striata d'Orbigny, 1826, p. 269.

Bulimina striata; Cushman & Parker, 1947, p. 119, Pl. 28, figs. 1-3.

REMARKS: Medium to small specimens distinguished by the discontinuous costae produced to form spines overlapping the sutures and by the presence of an apical spine.

Dimensions of hypotype (VF1041): length 0.34mm, width 0.21mm.

DISTRIBUTION: Not found in the Waverley Beach or Wilkies Bluff sections; sporadic in the other sections, most abundant in the Taihape Mudstone at Wanganui River.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus (rarely) to Robulus Biofacies.

Genus GLOBOBULIMINA Cushman, 1927

Type Species: Globobulimina pacifica Cushman

Globobulimina pacifica Cushman, Pl. 2, fig. 40.

Globobulimina pacifica Cushman, 1927, p. 67, Pl. 14, fig. 12.

Globobulimina pacifica; Hornibrook, 1961, p. 63.

Globobulimina pacifica; Gibson, 1967, p. 27, Pl. 7, fig. 115.

REMARKS: Large, fragile specimens with transparent walls.

Dimensions of hypotype (VF1042): length 0.48mm, width 0.32mm.

DISTRIBUTION: Not found in the Waverley Beach, Wilkies Bluff or Saddle Road sections. Sporadic but never common in the other sections.

RECORDED STRATIGRAPHIC RANGE: Whaingaroan or Duntroonian (Lower Oligocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Genus VIRGULOPSIS Finlay, 1939

Type Species: Virgulopsis pustulata Finlay

Virgulopsis turris (Heron-Allen & Earland), Pl. 3,
fig. 49.

Verneuillina turris Heron-Allen & Earland, 1922, p. 124, Pl. 4, figs. 8-12.

Virgulopsis turris; Hornibrook, 1968, p. 76, fig. 14.

Dimensions of hypotype (VF1043): length 0.26mm, width 0.15mm.

DISTRIBUTION: Present sporadically, rare to uncommon, in all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Present in Manakau Harbour, in 25-2250m in Cook Strait and living in 18m off southern Hawkes Bay.

Family UVIGERINIDAE

Genus EUUVIGERINA Thalmann, 1952

Type Species: Uvigerina aculeata d'Orbigny

Following the usage of Hornibrook (1968), subgeneric status is retained for the detailed uvigerine species lineages erected by Vella (1961, 1963). The various species of Euuvigerina have been examined in detail, but the only species potentially useful for Lower Wanganui Series biostratigraphy is Euuvigerina zeacuminata Vella, which disappears in Wanganui Basin at about the Hurupiensis-finlayi datum.

Many of the forms show considerable variation, and gradation between several species has been noted. The group of inflated species with continuous ribs resembling E. miozea (Finlay) gradually decreases in abundance through the Pliocene and early Pleistocene. This may be an ecologic change related to the gradually changing conditions, and the relationship of species of this type to Recent species resembling Euuvigerina peregrina (Cushman) is not known. Hornibrook (in Kingma, 1971, p. 102) notes the persistence of Euuvigerina of the miozea line into Middle Castlecliffian sediments in the Clifton-Black Reef section, Hawkes Bay.

Euuvigerina (Hofkeruva) delicatula (Vella)Hofkeruva delicatula Vella, 1961, p. 477, Pl. 2, fig. 5.Hofkeruva delicatula; Vella, 1963, p. 10, Pl. 2, fig. 16.

REMARKS: Rare specimens with undercut chambers and costae produced to form spines at the bases of the juvenile chambers are tentatively

referred to this species.

DISTRIBUTION: Found only in the Snapper Point and Middle Waipipi Shellbeds at Waverley Beach, and in occasional samples through the Pliocene of the Rangitikei River section.

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

RECORDED STRATIGRAPHIC RANGE: Basal Opoitian (Lower Pliocene).

OBSERVED ECOLOGIC RANGE: ?Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Semipelagic Biofacies.

Euuvigerina (Hofkeruva) lutorum (Vella), Pl. 3, fig. 56.

Hofkeruva (Tereuva) lutorum Vella, 1963, pp. 8, 9, Pl. 2, figs. 26-27.

Hofkeruva (Trigonouva) lutorum; Kennett, 1966a, pp. 42-43, Pl. 3, figs. 26-27.

Hofkeruva (Tereuva) lutorum; Gibson, 1967, p. 31, Pl. 7, fig. 124.

REMARKS: Gradation between E. lutorum, with costae produced to form small spines at the blunt apex, and E. pliozea, tapered forms with a large apical spine, as described by Kennett has been noted in Wanganui Basin faunules. Gradation between these forms and E. zeacuminata is not as clearly marked, but a few specimens of E. lutorum from the lowest samples in the Wanganui River sections approach the tapering shape and closely spaced costae of E. zeacuminata.

Dimensions of hypotype (VF1044): length 0.41mm, width 0.28mm.

DISTRIBUTION: Present in all sections examined, except the Wilkies Bluff section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Hauserella to Robulus Biofacies.

Euuvigerina (Hofkeruva) paeniteres (Finlay), Pl. 3,

fig. 62.

Uvigerina paeniteres Finlay, 1939b, p. 103.

Hofkeruva (Tereuva) paeniteres; Vella, 1961, p. 476.

Hofkeruva (Tereuva) paeniteres; Kennett, 1966a, p. 41, Pl. 3, fig. 47.

REMARKS: Kennett considered Hofkeruva euteres Vella to be a junior synonym of Euuvigerina paeniteres (Finlay). Wanganui Basin specimens are smooth, inflated forms, often with very faint costae extending over the initial two-thirds of the test.

Dimensions of hypotype (VF1045): length 0.43mm, width 0.33mm.

DISTRIBUTION: Present in the Taihape Mudstone and Mangaweka Mudstone at Rangitikei River, in the Snapper Point Conglomerate and Lower Waipipi Formation at Waverley Beach, in undifferentiated Hautawan formations at Wanganui River, and in the Upper Kumaroa and Mangatarata Formations at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Castlecliffian (Middle Pliocene to Middle Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella Biofacies.

Euuvigerina peregrina (Cushman), Pl. 3, fig. 57.

Uvigerina peregrina Cushman, 1923, p. 166, Pl. 42, figs. 7-10.

Dimensions of hypotype (VF1046): length 0.38mm, width 0.25mm.

DISTRIBUTION: Found only in one sample from the Matahiwi Silstone member of the Taihape Mudstone at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Living from 276-2329m off southern Hawkes Bay.

Euuvigerina (Hofkeruva) pliozea (Vella), Pl. 3,
figs. 61, 63.

Hofkeruva (Trigonouva) pliozea Vella, 1963, p. 8, Pl. 2, figs. 23, 25.

Hofkeruva (Trigonouva) pliozea; Kennett, 1967, p. 43, Pl. 3, fig. 45.

REMARKS: These are large, variable forms, typically with moderately strong costae and a large apical spine. Large, tapered forms with pointed apices and very strong discontinuous costae dying out on the

final chamber (Pl. 3, fig. 60) are referred to in range charts as E. cf. pliozea. They occur in occasional samples from Opoitian to Hautawan strata in the Wanganui River and Rangitikei River sections, and resemble E. mioschwageri (Finlay) in the strength of the costae. This is probably an extreme variant of E. pliozea, and the specimen figured in Pl. 3, fig. 61 appears intermediate between it and true E. pliozea.

Dimensions of hypotypes: VF1047, length 0.52mm, width 0.35mm;

VF1048, length 0.48mm, width 0.31mm; VF1049, length 0.38mm, width 0.27mm.

DISTRIBUTION: Not found in the Wilkies Bluff section. Present, often in abundance, in all other sections examined.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Uppermost Kapitean to possibly Waipipian (Upper Miocene to Middle Pliocene).

OBSERVED ECOLOGIC RANGE: ?Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Euuvigerina (Hofkeruva) rodleyi (Vella), Pl. 4, fig. 64.

Hofkeruva (Laminiuva) rodleyi Vella, 1963, p. 9, Pl. 2, figs. 28-29.

Hofkeruva (Laminiuva) rodleyi; Kennett, 1966a, p. 41, Pl. 3, fig. 43.

REMARKS: Distinguished by the elongate, fusiform shape and continuous costae. Distinction is made in range charts between specimens referred to E. rodleyi rodleyi, with narrowly rounded costae, and less common specimens with broader, flange-like costae referred to E. rodleyi tutamoides. Specimens in a single sample from the Saddle Road section, with very closely spaced costae, are referred to E. cf. rodleyi.

Dimensions of hypotype (VF1050): length 0.56mm, width 0.22mm.

DISTRIBUTION: Present in all sections examined.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Waiauan to Hautawan (Middle Miocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Euuvigerina (Hofkeruva) zeacuminata (Vella), Pl. 4, fig. 65.

Hofkeruva (Trigonouva) zeacuminata Vella, 1961, p. 476, Pl. 1, figs. 15-16.

Hofkeruva (Trigonouva) zeacuminata; Kennett, 1966a, pp. 43-44, Pl. 3,

fig. 44.

Hofkeruva (Trigonouva) zeacuminata; Gibson, 1967, p. 31, Pl. 7, fig. 125.

REMARKS: Moderately large, tapering forms with pointed apices and costae

dying out on the last chamber. Kennett considered this species ancestral to E. lutorum, and Gibson recorded it as intergrading with E. lutorum in many samples.

Dimensions of hypotype (VF1051): length 0.57mm, width 0.33mm.

DISTRIBUTION: Present in the Taihape Mudstone of the Wanganui River and Rangitikei River sections. A single, stained specimen from the Upper Kumeroa Formation at Saddle Road section is probably reworked from older strata. Not found in the other sections examined.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

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

RECORDED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

Genus SIPHOUVIGERINA Parr, 1950

Type Species: Uvigerina porrecta Brady var. fimbriata Sidebottom

Siphouvigerina bellula (Vella)

Neouvigerina bellula Vella, 1963, p. 11, Pl. 2, figs. 18-19.

REMARKS: Small, elongate, finely hispid forms.

DISTRIBUTION: Present in the Taihape Mudstone at Rangitikei River, in the Taihape Mudstone and the Mangapapa Siltstone at Wanganui River, and in the Mangatarata Formation at Saddle Road. Not found in the other sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

OBSERVED ECOLOGIC RANGE: ?Elphidium to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Robulus to Semipelagic Biofacies.

Siphouvigerina interrupta (Brady), Pl. 4, fig. 66.

Uvigerina interrupta Brady, 1879, p. 274, Pl. 8, figs. 17-18.

Dimensions of hypotype (VF1052): length 0.39mm, width 0.19mm.

DISTRIBUTION: Found only in the Taihape Mudstone of the Rangitikei and Wanganui River sections.

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

OBSERVED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Living off southern Hawkes Bay in 186-375m.

Siphouvigerina vadeszens (Cushman)

Uvigerina proboscides Schwager var. vadeszens Cushman, 1933, p. 85, Pl. 8, figs. 14-15.

Neouvigerina vadeszens; Vella, 1963, p. 11, Pl. 2, fig. 17.

Neouvigerina vadeszens; Kennett, 1966a, p. 40, Pl. 3, fig. 39.

DISTRIBUTION: In all except the Wilkies Bluff and Waitotara Valley sections in Opoitian to Nukumaruan strata.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Nukumaruan (Lower Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Genus TRIFARINA Cushman, 1923

Type Species: Trifarina bradyi Cushman

Trifarina angulosa (Williamson)

Uvigerina angulosa Williamson, 1858, p. 67, Pl. 5, fig. 140.

Uvigerina angulosa; Brady, 1884, Pl. 74, figs. 15-16.

DISTRIBUTION: In all except the Wilkies Bluff section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Living off southern Hawkes Bay in 329-2329m.

Trifarina bradyi Cushman

Trifarina bradyi Cushman, 1923, p. 99, Pl. 22, figs. 3-9.

Trifarina bradyi; Hornibrook, 1961, p. 70, Pl. 9, figs. 163-164.

Trifarina bradyi; Kennett, 1966a, p. 44, Pl. 3, figs. 49-50.

DISTRIBUTION: In all except the Wilkies Bluff section.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies; empty tests found from 18-1240m off southern Hawkes Bay, but not recorded living.

Superfamily DISCORBACEA

Family DISCORBIDAE

Genus DISCORBIS Lamark, 1804

Type Species: Discorbis vesicularis LamarkDiscorbis dimidiatus (Parker & Jones)Discorbina dimidiatus Parker & Jones, 1862, p. 201, text-fig. 32b.Discorbis dimidiatus; Hedley, Hurdle & Burdett, 1967, p. 33, Pl. 1, fig. 4, Pl. 10, figs. 1-3, text-figs. 28-43.Discorbis dimidiatus; Hornibrook, 1968, p. 77, fig. 14.

DISTRIBUTION: Found only in the Snapper Point Conglomerate at Waverley Beach, and in the upper part of the Pitangi Mudstone and overlying undifferentiated Hautawan formations at Wangamui River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Records of live specimens by various authors range from intertidal to 40m.

Genus DISCORBINELLA Cushman & Martin, 1935

Type Species: Discorbinella montereyensis Cushman & MartinDiscorbinella baconica (Hantken)Discorbinella baconica Hantken, 1875, p. 76, Pl. 10, fig. 3.Discorbinella bertheloti var. baconica; Brady, 1884, p. 651, Pl. 90, fig. 1.Discopulvinulina baconica; Hornibrook, 1961, p. 106.DISTRIBUTION: In occasional samples from all sections, usually in association with D. bertheloti.

OBSERVED STRATIGRAPHIC RANGE: Opeitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Hutchinsonian (Lower Miocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Discorbinella bertheloti (d'Orbigny)Rosalina bertheloti d'Orbigny, 1839b, p. 135, Pl. 1, figs. 28-30.Discopulvinulina bertheloti; Hornibrook, 1961, p. 106, Pl. 14, fig. 286.

DISTRIBUTION: Found in all the sections examined.

RECORDED STRATIGRAPHIC RANGE: Landon Series (Oligocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal stations around New Zealand and in Manukau Harbour; from 59-104m in Cook Strait and living from 276-375m off southern Hawkes Bay (as D. cf. bertheloti).

Genus EOEPONIDELLA Wickenden, 1949

Type Species: Eoeponidella linki Wickenden

Eoeponidella cf. zelandica (Hornibrook)

Heminwayina zelandica Hornibrook, 1961, p. 114, Pl. 16, figs. 352, 354-55.

REMARKS: Rare, small specimens with a flatter spire than the types.

DISTRIBUTION: Only in a single sample from the Lower Okiwa Group at Watershed Road.

OBSERVED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene);

Hornibrook (1961) records E. zelandica as ranging from Runangan to Duntroonian (Upper Eocene to Lower Oligocene).

OBSERVED ECOLOGIC RANGE: Shallow part of Haeuslerella Biofacies.

Genus GAVELINOPSIS Hofker, 1951

Type Species: Discorbina praegeri Heron-Allen & Earland

Gavelinopsis hamatus Vella, Pl. 4, figs. 80-82.

Gavelinopsis hamatus Vella, 1957, pp. 35, 36, Pl. 9, figs. 177-180.

REMARKS: A moderately large, plano-convex species with oblique, limbate sutures. Wanganui Basin specimens lack the umbilical plate shown in the type figures, and the umbilical plug characteristic of Gavelinopsis is clearly visible.

Dimensions of hypotype (VF1053): diameter 0.52mm, thickness 0.18mm.

DISTRIBUTION: In the Lower Waipipi Formation at Waverley Beach, the upper part of the Pitangi Mudstone and the Lower Okiwa Group at the Wanganui River, and the Taihape Mudstone at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Manukau Harbour, Cook Strait from 18-396m, and living off southern Hawkes Bay in coarse sediments in 18-42m.

Gavelinopsis lobatulus (Parr), Pl. 4, figs. 69-71.

Discorbis lobatulus Parr, 1950, p. 354, Pl. 13, figs. 23-25.

Gavelinopsis lobatulus; Brady, 1884, p. 182, Pl. 88, fig. 1.

REMARKS: Specimens are small, but otherwise agree closely with those figured by Brady.

Dimensions of hypotype (VF1054): diameter 0.24mm, thickness 0.11mm.

DISTRIBUTION: Not found in the Wilkies Bluff, Waitotara Valley or Wanganui River sections. Present in the other sections as rare specimens in a few samples.

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

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies;
59-85m in Cook Strait; living in 186-1240m off southern Hawkes Bay.

Gavelinopsis pukeuriensis Hornibrook

Gavelinopsis pukeuriensis Hornibrook, 1961, p. 104, Pl. 13, figs. 267,
270-71.

DISTRIBUTION: Sporadic in shallow water sediments through all except the Rangitikei River and Saddle Road sections.

RECORDED STRATIGRAPHIC RANGE: Otaian to Castlecliffian (Lower Miocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies.

Genus LATICARININA Galloway & Wissler, 1927

Type Species: Pulvinulina repanda var. menardii subvar.
pauperata Parker & Jones

Laticarinina altocamerata (Heron-Allen & Earland)

Truncatulina tenuimargo Brady var. alto-camerata Heron-Allen &
Earland, 1922, p. 209, Pl. 7, fig. 24-27.

Parvicarinina altocamerata; Hornibrook, 1961, Pl. 14, figs. 296,
299, 301-02, 305.

DISTRIBUTION: Only in a single sample from the Pitangi Mudstone in the Wanganui River section.

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

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Off southern Hawkes Bay in 329-1649m.

Laticarinina coronata (Heron-Allen & Earland)

Discorbis coronata Heron-Allen & Earland, 1932, p. 416, Pl. 14, figs. 25-30.

Parvicarinina coronata; Hornibrook, 1961, p. 118, Pl. 15, figs. 310-11,
318.

REMARKS: Tiny specimens characterised by the flattened sides, excavated ventral chambers and dorsal peripheral keel.

DISTRIBUTION: Only in one sample from undifferentiated Lower Okiwa Group at Watershed Road.

RECORDED STRATIGRAPHIC RANGE: Lower Eocene to Recent.

OBSERVED ECOLOGIC RANGE: Shallow part of Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Described by Heron-Allen & Earland from the subantarctic Falkland Islands area in 118-304m.

Laticarinina halophora (Stache)

Cristellaria (Robulina) halophora Stache, 1865, p. 248, Pl. 23, fig. 28.

Laticarinina halophora; Finlay, 1940, p. 468, Pl. 62, figs. 27-29.

Laticarinina halophora; Hornibrook, 1961, p. 119, Pl. 14, figs. 300,
303-04.

DISTRIBUTION: Mangaweka Mudstone at Rangitikei River and Watershed Road, and the Lower Okiwa Group at Watershed Road.

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

OBSERVED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Laticarinina pauperata (Parker & Jones)

Pulvinulina pauperata Parker & Jones, 1865, p. 395, Pl. 16, figs. 50, 51.

Laticarinina pauperata; Brady, 1884, pp. 91-92, 696, Pl. 104, figs. 3-11.

Laticarinina pauperata; Eade, 1967a, frontispiece.

DISTRIBUTION: Mangaweka Mudstone at Rangitikei River and Watershed Road, Lower Okiwa Group at Rangitikei River, and Mangatarata Formation at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian to Castlecliffian (Upper Pliocene to Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies; in 1649-2432m off southern Hawkes Bay.

Genus PATELLINELLA Cushman, 1928

Type Species: Textularia inconspicua Brady

Patellinella inconspicua (Brady)

Textularia inconspicua Brady, 1884, p. 357, Pl. 42, fig. 6.

Patellinella inconspicua; Hedley, Hurdle & Burdett, 1967, p. 42, Pl. 9, figs. 7a-c.

DISTRIBUTION: Present, usually uncommon, through all except the Waitotara Valley section.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus (rarely) to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal around New Zealand, in Manukau Harbour, and from 2-207m in Cook Strait.

Genus PLANODISCORBIS Bermudez, 1952

Type Species: Discorbina rarescens Brady

Planodiscorbis rarescens (Brady)

Discorbina rarescens Brady, 1884, p. 651, Pl. 90, figs. 2-3.

Discorbinella rarescens; Hornibrook, 1961, p. 117, Pl. 14, figs. 292-294,
298.

REMARKS: Characterised by the flattened, plano-convex shell with rapidly enlarging chambers and broad peripheral flange.

DISTRIBUTION: Found only in the Middle Waipipi Shellbed at Waverley Beach and in undifferentiated Lower Okiwa Group at Watershed Road.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow part of Haeuslerella Biofacies.

Genus PLANULINOIDES Parr, 1941

Type Species: Discorbina biconcava Jones & ParkerPlanulinoides sp., Pl. 4, figs. 75, 76, 79.

REMARKS: Rare specimens have been found of a moderately large, robust, flattened Planulinoides with 6 chambers in the final whorl. The periphery is sub-rounded and heavily thickened throughout. Sutures are strongly recurved and limbate dorsally. The species has an evolute dorsal side, and a partially involute ventral side with supplementary apertures covered by pointed tooth-plates on the final 3 or 4 chambers. The primary aperture is peripheral and typical of Planulinoides. Differs from P. hamasuturalis Kennett in having fewer chambers and less sinuous sutures. Dimensions of hypotype (VF1055): length 0.33mm, width 0.26mm, thickness 0.09mm.

DISTRIBUTION: Found very occasionally in samples through the Rangitikei River section, and in the Mangatarata Formation at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium (possibly shallower) to Haeuslerella Biofacies.

Genus ROSALINA d'Orbigny, 1826

Type Species: Rosalina globularis d'Orbigny

Rosalina bradyi (Cushman)

Discorbis globularis var. bradyi Cushman, 1915, p. 12, Pl. 8, fig. 1.

Rosalina bradyi; Hedley, Hurdle & Burdett, 1967, pp. 42-43, Pl. 1, fig. 3; Pl. 11, fig. 2, text-figs. 50-55.

DISTRIBUTION: Present in all except the Waverley Beach and Wilkies Bluff sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to (rarely) Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Hedley et al (1967) note that living individuals of this species in intertidal habitats are attached to the stems of coralline algae; it is recorded from 32-86m in Cook Strait and living in 18-130m off southern Hawkes Bay.

Rosalina paupereques Vella, Pl. 4, figs. 73, 74, 77.

Rosalina paupereques Vella, 1957, p. 35, Pl. 9, figs. 181-82.

REMARKS: Wanganui Basin forms appear identical with Vella's species.

Dimensions of hypotype (VF1056): diameter 0.24mm, thickness 0.09mm.

DISTRIBUTION: Found in all sections examined.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Present in Manukau Harbour, and in 18-59m in Cook Strait; found also as rare specimens in 71m off southern Hawkes Bay.

Rosalina vitrevoluta Hornibrook

Rosalina vitrevolute Hornibrook, 1961, p. 102, Pl. 13, figs. 275-77.

DISTRIBUTION: Rare, often damaged, specimens in occasional samples through all sections examined.

RECORDED STRATIGRAPHIC RANGE: Hutchinsonian to Castlecliffian (Lower Miocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to (rarely) Robulus Biofacies.

Rosalina vitrizea Hornibrook, Pl. 4, fig. 78.

Rosaline vitrizea Hornibrook, 1961, p. 101, Pl. 13, figs. 264, 266, 269.

Dimensions of hypotype (VF1057): diameter 0.19mm, thickness 0.07mm.

DISTRIBUTION: Found only in the Pitangi Mudstone and in the Lower Okiwa Group in the Wanganui River section, and in the Mangaweka Mudstone of the Rangitikei River section.

RECORDED STRATIGRAPHIC RANGE: Waitakian (Lower Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Elphidium Biofacies.

RECORDED ECOLOGIC RANGE: Present in Manukau Harbour.

Genus VALVULINERIA Cushman, 1926

Type Species: Valvulineria californica Cushman

Valvulineria sadonica Asano, Pl. 5, figs. 83-85.

Valvulineria sadonica Asano, 1954, p. 8, text-figs. 55-7.

REMARKS: Small, biconvex forms with rounded periphery and aperture a narrow extraumbilical-umbilical slit. Wanganui Basin specimens, with 6 chambers in the final whorl, closely resemble the type specimens from the Japanese Pliocene.

Dimensions of hypotype (VF1059): diameter 0.30mm, thickness 0.15mm.

DISTRIBUTION: Not found in the Wilkies Bluff, Waitotara Valley or Saddle Road sections. Present in the Lower Waipipi Shellbed at Waverley Beach, Lower Okiwa Group at Wanganui River, Rangitikei River and Watershed Road, and Mangaweka Mudstone at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies (also recorded from Manukau Harbour).

Family GLABRATELLIDAE

Genus GLABRATELLA Dorreen, 1948

Type Species: Glabratella crassa DorreenGlabratella zealandica (Vella)Pileolina zealandica Vella, 1957, p. 37, Pl. 8, figs. 175-76.Discorbis zealandica; Hornibrook, 1961, p. 99, Pl. 13, figs. 254-56.

DISTRIBUTION: Rare specimens are present in all sections except the Waitotara Valley and Wanganui River sections.

RECORDED STRATIGRAPHIC RANGE: Awamoan (Lower Miocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal and in Manukau Harbour; from 2-68m in Cook Strait and in 18-71m off southern Hawkes Bay.

Genus HERONALLENIA Chapman & Parr, 1931

Type Species: Discorbina wilsoni Heron-Allen & EarlandHeronallenia wilsoni (Heron-Allen & Earland)

Pl. 4, figs. 67, 68, 72.

Discorbina wilsoni Heron-Allen & Earland, 1922, p. 206, Pl. 7, figs. 17-19.Heronallenia wilsoni; McKnight, 1962, p. 125, Pl. 21, figs. 134a, b.Heronallenia wilsoni; Loeblich & Tappan, 1964, p. C591, fig. 464, 4a-c.

REMARKS: Characterised by the rounded peripheral keel and the limbate sutures. Wanganui Basin specimens agree closely with those figured by

Heron-Allen and Earland from 81-450m around Antarctica and in the Ross Sea. This species has not previously been recorded from New Zealand.

Dimensions of hypotype (VF1058): length 0.37mm, width 0.31mm.
thickness 0.12mm.

DISTRIBUTION: Not found in the Waitotara Valley or Saddle Road sections. Present in the Middle Waipipi Shellbed at Waverley Beach, in the Wilkies Shellbed at Wilkies Bluff, in upper Mangaweka Mudstone at Rangitikei River, Watershed Road and Wanganui River, and in Lower Okiwa Group at Wanganui River and Watershed Road.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies.

Superfamily SPIRILLINACEA

Family SPIRILLINIDAE

Genus PATELLINA Williamson, 1858

Type Species: Patellina corrugata WilliamsonPatellina corrugata WilliamsonPatellina corrugata Williamson, 1858, p. 46, Pl. 3, figs. 86-89.Patellina corrugata; Hornibrook, 1961, p. 97, Pl. 13, fig. 250.

REMARKS: Most specimens agree well with the Recent types. Rare specimens from the Hautawan at Watershed Road referred to as Patellina sp. in the range charts have a very high spire.

DISTRIBUTION: Present in all sections except the Waverley Beach, Wilkies Bluff and Waitotara Valley sections.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal, in Manukau Harbour, and from 18-81m in Cook Strait.

Family ROTALIIDAE

Genus ROTALIA Lamark, 1804

Type Species: Rotalites trochidiformis LamarkRotalia fastigata n.sp., Pl. 5, figs. 86, 89, 90.

DESCRIPTION: Shell small, circular, conical. Dorsal surface conical with slightly convex sides and rounded apex, completely evolute; chambers few, 5-6 in final whorl, with sutures flush, strongly recurved and joining periphery without a perceptible angle. Ventral surface lightly convex, covered with heavy, round pustules, most densely on earliest chambers. Periphery keeled; wall rather thin, dully polished, dorsal surface of chambers with fine pores, sutures smooth. Apertural pores between pustules on ventral surface.

Dimensions of holotype: greatest diameter 0.31mm, thickness 0.18mm.

Variation: Individuals vary in the degree of convexity of the ventral surface.

TYPES: Holotype (VF995) and 6 paratypes (VF996).

TYPE LOCALITY: N139f546, Rangitikei Valley (Sheet N139 unpublished).

TYPE LEVEL: Hautawan (Lower Pleistocene).

REMARKS: A larger species of Rotalia from the Castlecliffian Kupe Formation at Wanganui, described by Cameron (1966), differs in being less conical with sinuous sutures.

DISTRIBUTION: Found only in the type sample.

OBSERVED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Genus AMMONIA Brunnich, 1771

Type Species: Nautilus beccarii Linné

Ammonia aoteana (Finlay)

Streblus aoteanus Finlay, 1940, p. 461.

Ammonia aoteanus; Hedley, Hurdle & Burdett, 1967, p. 47, Pl. 11,
figs. 4a-c, text-figs. 56-60.

Ammonia beccarii aoteana; Hornibrook, 1968, p. 77, fig. 14.

DISTRIBUTION: Present sporadically through all except the Wilkies Bluff and Saddle Road sections.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to (rarely) Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal and in Manukau Harbour; from 2-44m in Cook Strait and living from 18-48m off southern Hawkes Bay.

Family ELPHIDIIDAE

Genus ELPHIDIUM de Montfort, 1808

Type Species: Nautilus macellus Fichtel & Moll

Elphidium crispum (Linnaeus)

Nautilus crispum Linnaeus, 1758, p. 709.

Elphidium crispum; Cushman & Valentine, 1940, pp. 174-76, Pl. 20,
figs. 5a-b.

DISTRIBUTION: In occasional samples from all except the Waitotara Valley section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Elphidium novozealandicum Cushman, Pl. 26, fig. 4;

frontispiece.

Elphidium novozealandicum Cushman, 1936b, p. 85, Pl. 15, fig. 4.

Elphidium novozealandicum; Hedley, Hurdle & Burdett, 1967, pp. 47-48, Pl. 12, fig. 4.

Elphidium novozealandicum; Hornibrook, 1968, p. 77, fig. 14.

Dimensions of hypotype (VF968): diameter 0.71mm, thickness 0.22mm.

DISTRIBUTION: Sporadic, often small, specimens in all except the Waitotara Valley Section.

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

OBSERVED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Elphidium Biofacies; Eade (1967a) lists the many Recent records of this species.

Elphidium spinatum Cushman & Valentine

Elphidium spinatum Cushman & Valentine, 1930, p. 21, Pl. 6, figs. 1-2.

Elphidium spinatum; Cushman, 1939, p. 63, Pl. 18, figs. 3-4.

Elphidium spinatum; Cushman & Valentine, 1940, p. 173, Pl. 19, figs. 10-11.

REMARKS: Occasional specimens with the outline of the final five or six chambers highly lobulate or produced to form spines agree well

with the type specimens from shallow water off the Californian coast.

However, the New Zealand forms may simply be variants of Criboelphidium charlottensis (Vella).

DISTRIBUTION: Only as rare specimens in the Snapper Point Conglomerate at Waverley Beach, in Mangaweka Mudstone at Wanganui River section, and in Lower Okiwa Group at Wanganui River and Watershed Road.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies.

Genus CRIBROELPHIDIUM Cushman & Bronniman, 1948

Type Species: Criboelphidium vadesens Cushman & Bronniman

Criboelphidium argenteum (Parr)

Elphidium argenteum Parr, 1945, p. 216, Pl. 12, fig. 7.

Criboelphidium argenteum; Hedley, Hurdle & Burdett, 1967, p. 48, Pl. 12, fig. 2.

DISTRIBUTION: Present in all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Found intertidally, and living from 48-427m off southern Hawkes Bay.

Criboelphidium charlottensis (Vella)

Elphidiononion charlottensis Vella, 1957, p. 38, Pl. 9, figs. 187-88.

Elphidium charlottensis; Kennett, 1966a, p. 64, Pl. 8, figs. 123-24.

Criboelphidium charlottensis; Hedley, Hurdle & Burdett, 1967, p. 50,
Pl. 12, fig. 3.

DISTRIBUTION: Present in all sections.

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

RECORDED ECOLOGIC RANGE: Zeafloxilus to (rare) Haeslerella Biofacies;
intertidal and in Manukau Harbour, from 7-396m in Cook Strait and living
in 18-130m off southern Hawkes Bay.

Criboelphidium incertum (Williamson), Pl. 11, figs. 2,3.

Polystomella umbilicatula var. incerta Williamson, 1858, p. 44, Pl. 3,
figs. 82, 82a.

Elphidium incertum; Cushman, 1930a, p. 18, Pl. 7, figs. 4-9.

Elphidium incertum; Fujita, 1956, p. 232, Pl. 8, figs. 5a-b.

REMARKS: Moderately large, solid specimens with a broadly rounded
periphery and sutures marked by a single row of relatively coarse
pores separated by solid retral processes. The test is smooth, with
tubercles present inside the sutural pores. C. boscense (Fujita) differs
in the presence of dense tubercles covering the umbonal area and the final
chambers of the final whorl.

Dimensions of hypotypes: VF1000, diameter 0.39mm, thickness 0.21mm;

VF1001, diameter 0.34mm, thickness 0.16mm.

DISTRIBUTION: In occasional samples from all sections except the Waverley Beach and Waitotara Valley sections.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Castlecliffian (Middle Pliocene to Middle Pleistocene). Recorded by Fujita (1956) from the Plio-Pleistocene of Japan.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Cribroelphidium simplex (Cushman)

Elphidium simplex Cushman, 1933, p. 52, Pl. 12, figs. 8-9.

Elphidiononion simplex acceanum Vella, 1957, p. 38, Pl. 9, figs. 185-86.

Cribroelphidium simplex; Hedley, Hurdle & Burdett, 1967, p. 50, Pl. 12, fig. 4.

DISTRIBUTION: Through all sections except the Waitotara Valley section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: This species is common in shallow water throughout the Indo-Pacific region. Eade (1967) lists New Zealand occurrences, to that date, and it has since been found living in 18-48m off southern Hawkes Bay.

Genus NOTOROTALIA Finlay, 1939

Type Species: Notorotalia zelandica Finlay

Loeblich and Tappan (1964) suppressed the genus Notorotalia Finlay as a junior synonym of Polystomellina Yabe and Hanzawa, on the grounds of identical surface, apertural and internal details. Kennett (1967) and Hornibrook (1968) argued for retention of the genus because of the biconvex shape and distinctive sculpture of raised sutures and connecting ribs consistently present in species of Notorotalia, compared with the plano-convex shape and simple, Elphidium-like sculpture of Polystomellina discorbinoides Yabe and Hanzawa (type species of Polystomellina). Both authors pointed out that these features satisfactorily separate a group of species very characteristic of the New Zealand Tertiary and largely endemic to the south-west Pacific region.

Hofker (1969) reviewed the genera Notorotalia, Cribrorotalia, Discorotalia and Parrellina, and described their internal structure. He considered all to be valid genera and retained the Notorotaliinae as a separate subfamily of the Elphidiidae.

Notorotalia briggsi n.sp., Pl. 5, figs. 87,88,91,92; Pl. 19,
figs. 1,2; Pl. 20, fig. 1.

Notorotalia aff. aucklandica Vella; Vella, 1957, pp. 45, 51, 58,
tables 4, 5.

Notorotalia aff. aucklandica Vella; Kennett, 1964, table 3.

DESCRIPTION: Test of moderate size, thin walled, with acute periphery and weak keel. Dorsal side weakly convex to dome-shaped; ventral side moderately convex, with chambers slightly inflated and concave centre. Transverse sutural ribs on dorsal side weak, discontinuous, usually slightly curved; on ventral side continuous and curved. Spiral sutural ribs weak, discontinuous, slightly stronger and often thickened over earlier chambers on dorsal side. Weak sculptural ornament of closely-spaced, usually slightly sinuous ribs, on earlier chambers often continuous from suture to suture, but later much reduced in size and not reaching anterior sutures, sometimes absent on final one or two chambers. Large apertural cribrations visible at base of terminal face; pores present on each side of sutures.

Microstructure: Surface between ribs covered by minute tubercles, most densely on dorsal side, which often obscure sutural pores; tubercles sharply conical on early chambers, decreasing in abundance and becoming low and rounded towards final chambers.

Dimensions: holotype, greatest diameter 0.65mm, thickness 0.28mm; figured paratype (VF880), greatest diameter 0.70mm, thickness 0.28mm.

Variation: In some specimens, secondary deposition of calcite over earlier whorls on the dorsal side forms a small callous and, rarely,

a low callous knob. Individuals vary in the amount of secondary thickening of sculptural ribs, and in the degree of biconvexity, with Pleistocene specimens tending to a more elevated dorsal side.

TYPES: Holotype (VF992) and 26 Paratypes (VF879-881, VF993).

TYPE LOCALITY: N137f630, Wilkies Bluff, 0.3m below Crassostrea ingens band, Grid ref. N137/254973.

TYPE LEVEL: Mangapanian Stage (Upper Pliocene).

REMARKS: The sculpture is typical of the Notorotalia zelandica Group as defined by Vella (1957). N. briggsi is distinguished from N. aucklandica Vella, its probable descendant, by its smaller size, flatter dorsal side and weaker but more extensive sculpture.

DISTRIBUTION: Strongly depth-controlled; sporadic, rare to common in shallow water Waipipian to Hautawan strata of all sections examined; also recorded, as N. aff. aucklandica, from N162f841, Nukumaruan Stage, of Wairarapa (Kennett, 1964).

RECORDED STRATIGRAPHIC RANGE: Waipipian to Okehuan (Middle Pliocene to Middle Castlecliffian), by Vella (1957).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Notorotalia clathrata (Brady)

Rotalia clathrata Brady, 1884, p. 709, Pl. 107, fig. 8.

Notorotalia clathrata; Finlay, 1939a, p. 517.

Notorotalia clathrata; Parr, 1950, p. 374.

Notorotalia clathrata; Boltovskoy, 1954, p. 277, Pl. 25, figs. 8a,b.

Notorotalia clathrata; Vella, 1957, p. 47.

REMARKS: Characterised by the strongly convex dorsal side and the weak spiral ribs. This is the most widespread species of Notorotalia, having been recorded from much of the south-west Pacific region and from the Atlantic coast of South America. Specimens from littoral and sublittoral stations along the Atlantic Coast of Argentina and from south of Tierra de Fuego, presented by Professor E. Boltovskoy, have been examined and found to closely resemble Wanganui Basin specimens.

DISTRIBUTION: Not found in the Waverley Beach, Rangitikei River or Saddle Road sections. Present in occasional samples in the other sections.

RECORDED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zoaflorilus to (rarely) shallow part of Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Present from 77-146m in Cook Strait, and found living in 42m off southern Hawkes Bay.

Notorotalia depressa Vella

Notorotalia depressa Vella, 1957, p. 47, Pl. 1, figs. 13, 19, 20.

REMARKS: Appearing earlier and also associated with N. depressa in a number of samples are specimens with the spiral ribs continuous between sutures, as figured by Vella (1957, Pl. 1, figs. 11, 12, 18) for N. cf. depressa. Vella records these forms from Tongaporutuan to Kapitean, and possibly Opoitian, and Gibson (1967) also records them from the Taranaki Series. N. cf. depressa may be the ancestral form of N. depressa, but sufficiently abundant and well-preserved faunas are not available from Wanganui Basin to clarify the relationship.

DISTRIBUTION: Present in all sections.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Castlecliffian (Middle Pliocene to Middle Pleistocene). (N. cf. depressa - Opoitian to Castlecliffian).

RECORDED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Present intertidally and in Manukau Harbour, and common from 18-63m in Cook Strait.

Notorotalia finlayi Vella, Pl. 20, fig. 2; Pl. 21,
figs. 1,2; Pl. 22, figs. 1,2.

Notorotalia finlayi Vella, 1957, p. 49, Pl. 1, figs. 4, 5, 9, 10.

Dimensions of hypotypes: VF883, diameter 0.37mm, thickness 0.18mm; VF882, diameter 0.38mm, thickness 0.18mm; VF884, diameter 0.37mm, thickness 0.17mm.

DISTRIBUTION: Common in most Waipipian and younger strata in all sections.

RECORDED STRATIGRAPHIC RANGE: Waipipian to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to (rarely) Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Intertidal and in Manukau Harbour; abundant 6-162m in Cook Strait and living in 48-427m off southern Hawkes Bay.

Notorotalia hurupiensis Vella, Pl. 23, fig. 1.

Notorotalia hurupiensis Vella, 1957, p. 49, Pl. 1, fig. 15.

Notorotalia hurupiensis; Kennett, 1966a, p. 62, Pl. 8, figs. 127-29.

Notorotalia hurupiensis; Gibson, 1967, p. 55, Pl. 13, figs. 206, 212-13.

Notorotalia hurupiensis; Hornibrook, 1968, p. 100, fig. 21.

REMARKS: Usually small specimens, intermediate in shape between N. taranakia and N. finlayi; differing from the former species in the more depressed form, and from the latter species in the spiral ribs continuous across all chambers.

Dimensions of hypotype (VF885): diameter 0.24mm, thickness 0.15mm.

DISTRIBUTION: Present in the Taihape Mudstone and lower Koriniti Sandstone of the Wanganui River section, in the Taihape Mudstone of the Rangitikei River section, and in the Mangatoro Formation of the Saddle Road section.

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

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Notorotalia inornata Vella

Notorotalia inornata Vella, 1957, p. 54, Pl. 2, fig. 29; Pl. 3, figs. 36-38.

REMARKS: Moderately large, biconvex forms with short spiral ribs agree closely with the type specimens.

DISTRIBUTION: Present, usually rarely, in occasional samples from Mangapanian and younger strata in all sections examined.

RECORDED STRATIGRAPHIC RANGE: Mangapanian to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: ?Zeaflorilus to Elphidium Biofacies; found intertidally and in Manukau Harbour, from 7-317m in Cook Strait and 18-479m off southern Hawkes Bay.

Notorotalia kingmai Vella

Notorotalia kingmai Vella, 1957, pp. 50-51, Pl. 2, figs. 21-22.

Notorotalia kingmai; Hornibrook, 1968, p. 100, fig. 21.

DISTRIBUTION: In Taihape Mudstone, Utiku Sand and lower Mangaweka Mudstone at Rangitikei River, and a single specimen from the Snapper Point Shellbed at Waverley Beach.

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

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

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Notorotalia cf. mammiligera Kennett

Notorotalia mammiligera Kennett, 1967, p. 1003, figs. 30-32.

REMARKS: Medium sized, variable but usually moderately compressed specimens with papillate ornament, are referred to N. cf. mammiligera.

They differ from typical N. mammiligera in the better developed spiral ribs. The variable shape suggests that the Wanganui Basin forms are variants of species normally lacking papillate ornament.

DISTRIBUTION: In the Upper Kumeroa and Mangatarata Formations at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Nukumaruan to Castlecliffian (Lower to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: ?Zeaflorilus to Elphidium Biofacies.

Notorotalia olsoni Vella, Pl. 26, figs. 1-3.

Notorotalia olsoni Vella, 1957, p. 50, Pl. 2, figs. 23-24.

REMARKS: Large, plano-convex specimens with the typical fine, dense, slightly reticulated sculpture.

Dimensions of hypotypes: VF961, diameter 0.47mm, thickness 0.22mm; VF962, diameter 0.60mm, thickness 0.26mm; VF963, diameter 0.59mm, thickness 0.25mm.

DISTRIBUTION: In the Middle and Upper Waipipi Formation at Waverley Beach, and the Te Aute Formation at Saddle Road.

RECORDED STRATIGRAPHIC RANGE: Opcitian, and possibly Kapitean, (Lower Pliocene, possibly Upper Miocene) to Recent.

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Notorotalia pliozea Vella, Pl. 24, fig. 1.

Notorotalia pliozea Vella, 1957, p. 54, Pl. 2, figs. 25, 26.

Notorotalia pliozea; Kennett, 1966a, p. 63.

REMARKS: Typically compressed shells with rounded periphery, but a strong, flange-like keel.

Dimensions of hypotype (VF886): diameter 0.56mm, thickness 0.13mm.

DISTRIBUTION: Not found in the Waitotara Valley or Watershed Road sections. Present sporadically, usually rarely, in the other sections.

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

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

RECORDED ECOLOGIC RANGE: Elphidium to Haeuslerella Biofacies.

Notorotalia taranakia Vella, Pl. 24, fig. 2; Pl. 25,
figs. 1-3.

Notorotalia taranakia Vella, 1957, p. 48, Pl. 1, figs. 1-3.

Notorotalia taranakia; Gibson, 1967, pp. 55-56, Pl. 13, figs. 204, 207-08.

Notorotalia taranakia; Hornibrook, 1968, p. 100, fig. 21.

Dimensions of hypotypes: VF887, diameter 0.33mm, thickness 0.18mm;
VF888, diameter 0.33mm, thickness 0.17mm; VF889, diameter 0.35mm,
thickness 0.18mm.

DISTRIBUTION: Only in Taihape Mudstone at Rangitikei River, and in
Taihape Mudstone and sporadically higher at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Waipipian, possibly
lowermost Mangapanian (Lower to Middle Pliocene).

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

OBSERVED ECOLOGIC RANGE: Deep part of Haeuslerella to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Robulus to Eupelagic Biofacies.

Notorotalia zelandica mangaoparia Vella

Notorotalia zelandica mangaoparia Vella, 1957, pp. 55, 57, Pl. 2,
figs. 30, 32, 35, text-fig. 2 f-k.

REMARKS: N. zelandica mangaoparia is distinguished from other subspecies
of N. zelandica by its acute periphery and convex dorsal surface.

Depressed specimens in the Taihape Mudstone are referred to N. zelandica
cf. mangaoparia, and may be related to N. pliozea. N. zelandica rotunda

has not been found in Wanganui Basin, and appears to be a cold-water form which did not extend so far north (Vella, 1957). N. zelandica zelandica (Pl. 27, figs. 1-3) (Pl. 27, figs. 1-3) is common in the Nukumaruan at Rangitikei River.

Dimensions of hypotypes of N. zelandica zelandica: VF965, diameter 0.93mm, thickness 0.43mm; VF966, diameter 1.05mm, thickness 0.43mm; VF967, diameter 0.90mm, thickness 0.33mm.

DISTRIBUTION: Through the Waverley Beach and Wilkies Bluff sections, in Mangaweka Mudstone and a single specimen in Lower Okiwa Group at Wanganui River, and in one sample from Utiku Sand at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Mangapanian to Hautawan (Upper Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Superfamily GLOBIGERINACEA

Family HANTKENINIDAE

Genus GLOBIGERINELLA Cushman, 1927

Type Species: Globigerina aequilateralis Brady

Globigerinella siphonifera (d'Orbigny), Pl. 5, figs. 93,
94, 98.

Globigerina siphonifera d'Orbigny, 1839a, p. 83, Pl. 4, figs. 15-18.

Globigerinella aequilateralis; Jenkins, 1971b, pp. 77-78, Pl. 2,
figs. 47-49.

REMARKS: Wanganui Basin specimens are small and usually immature, showing the characteristic spinose surface and trochospiral coiling. Adult specimens are still slightly trochospiral (Collen and Vella, 1972). Dimensions of hypotype (VF1061): diameter 0.24mm, thickness 0.18mm.

DISTRIBUTION: Restricted to deeper water samples in Taihape Mudstone, Utiku Sand and lower Mangaweka Mudstone at Rangitikei River, and Taihape Mudstone, Koriniti Sandstone and Raumati Mudstone at Wanganui River.

RECORDED STRATIGRAPHIC RANGE: Tongaporutuan to Hawera Series (Upper Miocene to Upper Pleistocene).

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Type Species: Pulvinulina menardii (d'Orbigny) var. tumida

Brady

Globorotalia crassaformis (Galloway & Wissler), Pl. 5,

figs. 99-101.

Globigerina crassaformis Galloway & Wissler, 1927, p. 41, Pl. 50,

fig. 12.

Globorotalia crassaformis; Jenkins, 1971b, pp. 86-88. Pl. 4, figs. 105-07.

REMARKS: Wanganui Basin specimens referred to this species show the characteristic subconical shape with a slit-like aperture, ornament of tubercles covering the test, and four chambers in the final whorl.

Dimensions of hypotype (VF1062): diameter 0.45mm, thickness 0.35mm.

DISTRIBUTION: In most samples from all sections.

RECORDED STRATIGRAPHIC RANGE: Lower part of Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

Globorotalia hirsuta (d'Orbigny)Globigerina hirsuta d'Orbigny, 1839b, p. 131, Pl. 1, figs. 37-39.Globorotalia hirsuta; Parker, 1962, p. 236, Pl. 5, figs. 10-15;

Pl. 6, fig. 1.

Globorotalia hirsuta; Jenkins, 1971b, p. 89, Pl. 4, figs. 111-16.

REMARKS: This species is represented in Wanganui Basin sediments by rare, small, thin-walled specimens with four chambers in the final

whorl and a scattering of tubercles over the test, most densely on the earlier chambers. The specimens resemble G. hirsuta hirsuta rather than G. hirsuta praehirsuta, but the poor material precludes positive identification.

DISTRIBUTION: Very rare specimens present only in occasional deeper water samples from the Wangamui River and Rangitikei River sections.

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

Globoerotalia inflata (d'Orbigny), Pl. 6, figs. 102-104.

Globigerina inflata d'Orbigny, 1839b, p. 134, Pl. 2, figs. 7-9.

Globoerotalia inflata; Parker, 1962, p. 236, Pl. 5, figs. 6-9.

Globoerotalia inflata; Jenkins, 1971b, pp. 116-17, Pl. 11, figs. 282-87.

REMARKS: G. inflata is used here for specimens with inflated chambers and a broadly rounded periphery, with about $3\frac{1}{2}$ chambers in the final whorl. G. puncticulata is restricted to forms with usually four chambers in the final whorl and a subtriangular cross-section. Both species have a high arched aperture and similar sculpture, and appear to intergrade in Opoitian and Waipipian strata. Forms referable to G. puncticulata are lacking from post-Waipipian populations.

Dimensions of hypotype (VF1063): diameter 0.30mm, thickness 0.27mm.

DISTRIBUTION: In most samples from all except the Wilkies Bluff and Waitotara Valley sections.

RECORDED STRATIGRAPHIC RANGE: Opoitian to Recent.

Globorotalia menardii (Parker, Jones & Brady),

Pl. 5, figs. 95-97.

Rotalia (Rotalie) menardii d'Orbigny, 1826, p. 273, No. 10.Rotalia menardii; Banner & Blow, 1960, p. 31, Pl. 6, fig. 2a-c (lectotype).Globorotalia menardii; Jenkins, 1971b, p. 90, Pl. 6, figs. 135-37.

REMARKS: The rare Wanganui Basin specimens exhibit a more domed ventral side than typical specimens, but show the characteristic arched aperture, strong keel, raised dorsal sutures and large pustules developed on the earliest chambers of the final whorl.

Dimensions of hypotype (VF1064): diameter 0.34mm, thickness 0.20mm.

DISTRIBUTION: Single specimens from a sample in Taihape Mudstone at Wanganui River, and two samples in upper Mangaweka Mudstone and Lower Okiwa Group at Watershed Road.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Lillburnian (?) - Waiauan Stages to Opoitian Stage (Middle Miocene to Lower Pliocene).

Globorotalia miozea (Finlay)Globorotalia miozea Finlay, 1939c, p. 326, Pl. 29, figs. 159-161.

REMARKS: Moderately large, thick-walled specimens with $4\frac{1}{2}$ -5 chambers in the final whorl referred to G. miozea s.l. are stained and often abraded, and are believed to be reworked from older strata.

DISTRIBUTION: In Snapper Point Conglomerate at Waverley Beach, and in Upper Kumeroa Formation at Saddle Road.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Nukumaruan (Middle Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: (G. miozea s.l.) Upper Pareora to Lower Wanganui Series (Lower Miocene to Pliocene) by Hornibrook (1968).

Globorotalia puncticulata (Deshayes), Pl. 6,
figs. 107-109, 112-114.

Globigerina punctulata d'Orbigny, 1826, p. 277, no. 8 (nom. nud.).

Globigerina puncticulata Deshayes, 1832, p. 170.

Globigerina punctulata; Fornasini, 1898, p. 210, text-fig. 5

(d'Orbigny's unpublished figure).

Globorotalia puncticulata; Barbieri, 1967, p. 154, Pl. 1.

Globorotalia puncticulata; Kennett, 1970a, p. 126, fig. 2, nos. 1-6.

REMARKS: The distinction between G. puncticulata and G. inflata was discussed above. Collen and Vella (1972) describe and illustrate a lower Pliocene variety having a smaller, smooth, compressed final chamber with subangular periphery and a narrower aperture than typical G. puncticulata. An example of this form from Wanganui Basin lower Pliocene sediments is illustrated here (VF1066).

Dimensions of hypotypes: VF1065, diameter 0.20mm, thickness 0.16mm; VF1066, diameter 0.29mm, thickness 0.19mm.

DISTRIBUTION: Not found at Wilkies Bluff or Watershed Road. Present in all other sections in strata of Opoitian to Waipipian age. A single specimen from the Nukumaruan Upper Kumeroa Formation at Saddle Road is probably reworked from older strata.

RECORDED STRATIGRAPHIC RANGE: Opoitian to Mangapanian (Lower to Upper Pliocene) (Collen and Vella, 1972).

Globorotalia scitula (Brady), Pl. 6, figs. 105, 106,
110, 111.

Pulvinulina scitula Brady, 1882, p. 716.

Globorotalia scitula; Parker, 1962, pp. 238-39, Pl. 6, figs. 4-6.

Globorotalia scitula; Kennett, 1966a, p. 73, Pl. 11, figs. 185-89.

Globorotalia scitula; Gibson, 1967, pp. 64, 65, Pl. 17, figs. 262,
265-66.

Globorotalia scitula; Jenkins, 1971b, pp. 131-32, Pl. 13, figs. 371-73.

REMARKS: Small and relatively uncommon specimens showing the characteristic smooth surface with occasional tubercles and coarse pores on the early chambers, and having $4\frac{1}{2}$ chambers in the final whorl. Dimensions of hypotype (VF1067): diameter 0.23mm, thickness 0.12mm.

DISTRIBUTION: Uncommon, but present in samples through all sections except the Waverley Beach, Wilkies Bluff and Waitotara Valley sections.

RECORDED STRATIGRAPHIC RANGE: Lillburnian-Waiauan to Nukumaruan (Middle Miocene to Lower Pleistocene).

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826

Type Species: Globigerina bulloides d'OrbignyGlobigerina bulloides d'Orbigny, Pl. 6, figs. 119-124.Globigerina bulloides d'Orbigny, 1826, p. 277.Globigerina bulloides; Jenkins, 1971b, pp. 141-43, Pl. 14, figs. 408-10.

REMARKS: Typical G. bulloides is accompanied in many samples by a form with similar shell surface, but a smaller aperture and only $3\frac{1}{2}$ chambers in the final whorl (VF1069). These specimens closely resemble G. bulloides trilocularis Deshayes.

Dimensions of hypotypes: VF1068, diameter 0.35mm, thickness 0.23mm; VF1069, diameter 0.28mm, thickness 0.18mm.

DISTRIBUTION: Usually common in most samples from all sections.

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

Globigerina decoraperta Takayanagi & Saito, Pl. 6,

figs. 116-118.

Globigerina druryi Akers decoraperta Takayanagi & Saito, 1962, p. 85,

Pl. 28, figs. 10a-c.

Globigerina decoraperta; Parker, 1964, p. 629, Pl. 101, figs. 8-10.Globigerina woodi decoraperta; Jenkins, 1971b, pp. 158-59, Pl. 16,

figs. 502-04.

REMARKS: Distinguished by the high spire, and apertural plane approximately normal to the axis of coiling.

Dimensions of hypotype (VF1070): diameter 0.20mm, thickness 0.14mm.

DISTRIBUTION: Scarce but present through all sections except the Waitotara Valley section.

RECORDED STRATIGRAPHIC RANGE: Lillburnian Stage to Hawera Series (Middle Miocene to Upper Pleistocene).

Globigerina dutertrei d'Orbigny, Pl. 7, figs. 128, 129, 133.

Globigerina dutertrei d'Orbigny, 1839a, p. 84, Pl. 4, figs. 19-21.

Gleboquadrina dutertrei; Parker, 1962, pp. 242, 244, Pl. 7, figs. 1-13;
Pl. 8, figs. 1-4.

Globigerina dutertrei; Kennett, 1966a, pp. 64-65, Pl. 11, figs. 173-78.

Gleborotalia dutertrei; Jenkins, 1971b, pp. 114-115, Pl. 11, figs. 273-75.

REMARKS: Wanganui Basin specimens are mostly small. Many populations show a gradation between forms with 5 chambers in the final whorl and those with $4\frac{1}{2}$ or 4 chambers. Similar variation has been noted by Kennett (1970a), Jenkins (1971a) and Collen and Vella (1972). 4-chambered forms are here referred to G. pachyderma.

Stereoscan photographs taken when this study was nearly complete show that G. pachyderma and G. dutertrei have identical test surface structure (Collen and Vella, 1972). Bandy et al (1967) placed G. dutertrei in Neogloboquadrina, and Collen and Vella, because of the close morphological relationship of the two species and because the test surface is distinct from that of the Globigerinacea, referred

G. pachyderma to Neogloboquadrina also and placed the genus in the family Catapsydracidae.

Dimensions of hypotype (VF1071): diameter 0.18mm, thickness 0.13mm.

DISTRIBUTION: In most samples from all sections except the Waverley Beach section.

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

Globigerina eamesi Blow

Globigerina eamesi Blow, 1959, p. 176, Pl. 9, figs. 39a-c.

Globigerina zealandica Hornibrook, 1961, p. 150, Pl. 21, figs. 436-68.

Globigerina eamesi; Jenkins, 1971b, 146, Pl. 15, figs. 454-56.

REMARKS: Damage to the test during deposition and fossilisation tends to remove the characteristic spines of G. eamesi and make recognition difficult. Hence, it may be more common in Wanganui Basin sediments than indicated here.

DISTRIBUTION: Only in samples from the lower part of the Koriniti Sandstone at Wanganui River.

RECORDED STRATIGRAPHIC RANGE: Whaingaroan-Duntroonian to Castlecliffian (Oligocene to Middle Pleistocene).

Globigerina cf. falconensis Blow, Pl. 7, figs. 130-132.

Globigerina falconensis Blow, 1959, p. 177, Pl. 9, figs. 40-41.

Globigerina falconensis; Takayanagi & Saito, 1962, p. 86, Pl. 25,
figs. 1a-c.

Globigerina falconensis; Jenkins, 1971, p. 148, Pl. 16, figs. 463-65.

REMARKS: These forms are very similar to G. bulloides, differing only in the lower aperture with a lip and the more embracing chambers.

Dimensions of hypotype (VF1072): diameter 0.26mm, thickness 0.15mm.

DISTRIBUTION: In most samples through all sections except the Wilkies Bluff section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Altonian to Okshuan (Middle Miocene to Middle Pleistocene) by Jenkins (1971) as G. falconensis.

Globigerina foliata Bolli, Pl. 7, figs. 125-127.

Globigerina foliata Bolli, 1957, p. 111, Pl. 24, figs. 1a-c.

Globigerina foliata; Jenkins, 1971b, pp. 148-49, Pl. 16, figs. 466-68.

REMARKS: Tiny specimens with well separated chambers, subcircular outline and a low, arched aperture with a small lip. Where large numbers of juveniles of various species of Globigerina are present, it is often difficult to separate G. foliata.

Dimensions of hypotype (VF1073): diameter 0.13mm, thickness 0.08mm.

DISTRIBUTION: In most samples from all sections except the Waverley Beach and Wilkies Bluff sections.

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

Globigerina pachyderma (Ehrenberg), Pl. 7, figs. 136, 137,
142.

Aristerspira pachyderma Ehrenberg, 1861, pp. 276-77, 303.

Globigerina pachyderma; Parker, 1962, p. 224, Pl. 1, figs. 26-35; Pl.
2, figs. 1-6.

Globigerina pachyderma; Kennett, 1966a, p. 66, Pl. 9, figs. 139-45.

Globigerina pachyderma; Kennett, 1970a, pp. 47-49, Pls. 8-9.

Globorotalia pachyderma; Jenkins, 1971b, pp. 128-29, Pl. 12, figs. 345-47.

REMARKS: Specimens referred to G. pachyderma in this study vary from compact, heavy-shelled forms with 4 chambers in the final whorl to thinner-walled forms with $4\frac{1}{2}$ chambers in the final whorl. The specimens with thicker walls are normally only present in deeper water samples. Gradation into forms with 5 chambers in the final whorl has been noted under G. dutertrei.

Dimensions of hypotype (VF1074): diameter 0.32mm, thickness 0.22mm.

DISTRIBUTION: Almost ubiquitous, present in nearly all samples with a planktonic fauna.

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

Turborotalita quinqueloba (Natland), Pl. 7, figs. 134, 135,
138, 139-141.

Globigerina quinqueloba Natland, 1938, p. 149, Pl. 6, fig. 7.

Globigerina quinqueloba; Hulme, 1964, p. 335, fig. 5, nos. 1-11;
fig. 6, nos. 1-2.

Globigerina quinqueloba; Kennett, 1966a, pp. 67-68, Pl. 9, figs. 153-54.

Globigerina quinqueloba; Gibson, 1967, pp. 57-58, Pl. 14, figs. 220,
223-24.

Turborotalita quinqueloba; Blow, 1969, p. 373.

Globigerina quinqueloba; Jenkins, 1971b, pp. 155-56, Pl. 18, figs.
539-44.

REMARKS: T. quinqueloba is characterised by 5 chambers in the final whorl, the last chamber being produced as a flap-like extension over the umbilicus. This extension is often more spinose than the rest of the test, though with a smoother underlying surface resembling the smooth surface of the bullae seen in species of Globigerinita. In some specimens this extension of the final chamber is expanded and fused to one or more earlier chambers, and such forms have been separated by Collen and Vella (1972) as T. quinqueloba lingulata. Very occasionally the flap is fused to all four earlier chambers of the final whorl, leaving a number of infralaminar openings (as in the figured specimen, VF1075). These forms resemble T. humilis (Brady), which is distinguished by 6 chambers in the final whorl.

Dimensions of hypotypes: VF1075, diameter 0.18mm, thickness 0.15mm;
VF1080, diameter 0.15mm, thickness 0.11mm.

DISTRIBUTION: In most samples from all sections.

RECORDED STRATIGRAPHIC RANGE: Otaiian Stage (Lower Miocene) to Recent.

Genus GLOBIGERINOIDES Cushman, 1927

Type Species: Globigerina rubra d'Orbigny

Globigerinoides ruber (d'Orbigny)

Globigerina rubra d'Orbigny, 1839a, p. 82, Pl. 4, figs. 12-14.

Globigerinoides ruber; Hornibrook, 1968, p. 89, fig. 17.

Globigerinoides ruber; Jenkins, 1971b, pp. 177-78, Pl. 21, figs. 616-18.

REMARKS: Small, rare, high spired forms with apertures situated symmetrically above sutures are referred to G. ruber. Occasional individuals with less symmetrical apertures may be closer to G. conglobatus (Brady), but adequate material for positive identification is not available.

DISTRIBUTION: Not found in the Waverley Beach or Waitotara Valley sections. Rare specimens in occasional samples through the Wanganui River, Rangitikei River and Watershed Road sections, and as single specimens from the Wilkies Shellbed at Wilkies Bluff and the Upper Kumeroa Formation at Saddle Road.

RECORDED STRATIGRAPHIC RANGE: Awamoan Stage to Hawera Series (Lower Miocene to Upper Pleistocene).

Globigerinoides trilobus trilobus (Reuss), Pl. 8,

figs. 147, 148.

Globigerina triloba Reuss, 1850, p. 374, Pl. 47, figs. 11a-e.

Globigerinoides quadrilobatus trilobus; Gibson, 1967, p. 60, Pl. 15,

fig. 237.

REMARKS: G. trilobus is characterised by the low, slit-like apertures and the circular outline. Jenkins (1971b) mentioned variation in the position and size of the final chamber, and referred specimens with a final chamber larger than the penultimate and slightly enveloping the earlier part of the test to G. trilobus trilobus. Wanganui Basin specimens agree with Jenkin's figures.

Dimensions of hypotype (VF1076): diameter 0.28mm, thickness 0.23mm.

DISTRIBUTION: Found only as occasional specimens in the Wanganui River and Rangitikei River sections. A single specimen from the Lower Okiwa Group at Watershed Road is considered reworked from older strata.

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

Genus SPHAERODINELLA Cushman, 1927

Type Species: Sphaeroidina dehiscens Parker & JonesSphaeroidinella seminulina (Schwager)Globigerina seminulina Schwager, 1866, p. 256, Pl. 7, fig. 112.Sphaeroidinella seminulina; Jenkins, 1971b, pp. 173-74, Pl. 20, figs. 601-03.

REMARKS: Small specimens with three chambers in the final whorl are tentatively referred to this species.

DISTRIBUTION: Rare in the Snapper Point Conglomerate at Waverley Beach and in the lower part of the Rangitikei River section.

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

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

Genus ORBULINA d'Orbigny, 1839

Type Species: Orbulina universa d'OrbignyOrbulina universa d'Orbigny, Pl. 6, fig. 115.Orbulina universa d'Orbigny, 1839a, p. 2, Pl. 1, fig. 1.Orbulina universa; Jenkins, 1971b, pp. 193-94, Pl. 23, fig. 660.

Dimensions of hypotype (VF1077): diameter 0.55mm.

DISTRIBUTION: Usually uncommon, but present in many samples through

all sections except the Waverley Beach, Wilkies Bluff and Saddle Road sections.

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

Genus GLOBIGERINITA Brönniman, 1951

Type Species: Truncatulina humilis Brady

Globigerinita glutinata (Egger), Pl. 7, figs. 143, 144.

Globigerina glutinata Egger, 1893, p. 371, Pl. 13, figs. 19-21.

Globigerinita glutinata; Parker, 1962, pp. 246, 248-49, Pl. 9, figs. 1-16.

Globigerinita glutinata; Kennett, 1966a, pp. 69-70, Pl. 10, figs. 161-65.

Globigerinita incrusta Akers; Jenkins, 1971b, pp. 184-85, Pl. 19, figs. 585-87.

REMARKS: A small percentage of specimens in each population usually lack a bulla, but are otherwise typical.

Dimensions of hypotype (VF1078): diameter 0.22mm, thickness 0.14mm.

DISTRIBUTION: Not found in the Wilkies Bluff or Waitotara Valley sections. Present, often in abundance, in most samples from the other sections examined.

RECORDED STRATIGRAPHIC RANGE: Waiauan to Kapitean; recorded as

G. incrusta by Jenkins (1971b) from Waitakian to Castlecliffian (Oligocene to Middle Pleistocene).

Globigerinita uvula (Ehrenberg), Pl. 7, figs. 145, 146.

Pyrodexia uvula Ehrenberg, 1861, pp. 276, 277, 308.

Globigerina bradyi Wiesner, 1931, p. 133.

Globigerinita uvula; Parker, 1962, pp. 252, 253, Pl. 8, figs. 14-26.

Globigerinita uvula; Kennett, 1966a, p. 70, Pl. 10, figs. 167, 168.

Globigerina bradyi; Jenkins, 1971b, pp. 139-40, Pl. 15, fig. 431-32.

REMARKS: This is a small, high-spined form. In large populations, a few specimens can be found lacking the umbilical bullae and with a small, round aperture.

Dimensions of hypotype (VF1079): diameter 0.11mm, thickness 0.08mm.

DISTRIBUTION: Not found in the Waverley Beach, Wilkies Bluff or Saddle Road sections. Present sporadically through the other sections studied.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Nukumaruan (Lower Pliocene to Lower Pleistocene).

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

Superfamily ORBITOIDACEA

Family EPONIDIDAE

Genus EPONIDES deMontfort, 1808

Type Species: Nautilus repandus Fichtel & MollEponides broekhianus (Karrer)Rotalia broekhiana Karrer, 1878, p. 98, Pl. 5, fig. 26.Eponides broekhianus; Hornibrook, 1961, p. 109, Pl. 15, figs. 321-22.Eponides broekhianus; Kennett, 1966a, p. 57, Pl. 7, fig. 112.

DISTRIBUTION: Present in most samples from all sections studied.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

RECORDED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

Family CIBICIDIDAE

Genus PLANULINA d'Orbigny, 1826

Type Species: Planulina ariminensis Galloway & Wissler?Planulina sp., Pl. 8, figs. 151, 152, 155.

REMARKS: Moderately large, extremely compressed, with a broad keel and limbate, raised sutures; the area between sutures flat, with only limited chamber space present immediately anterior to each suture.

No aperture visible, but hyaline material deposited between whorls on the less evolute side may represent infilled apertures beneath umbilical flaps. These specimens are tentatively included in Planulina because of their superficial resemblance to this genus.

Dimensions of hypotype (VF1081): length 0.38mm, width 0.28mm, thickness 0.07m.

DISTRIBUTION: Rare specimens in occasional samples from the Mangaweka Mudstone of the Wanganui River and Rangitikei River sections and the Lower Okiwa Group of the Rangitikei River and Watershed Road sections.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian to Hautawan (Upper Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: *Haeslerella* Biofacies.

Genus HYALINEA Hofker, 1951

Type Species: *Nautilus balthicus* Schröter

Hyalinea cf. *balthica* (Schröter), Pl. 8, figs. 149, 150.

Nautilus balthicus Schröter, 1783, p. 20, Pl. 1, fig. 2.

Hyalinea balthica; Loeblich & Tappan, 1964, p. C686, fig. 552, 2a-c, 3.

Hyalinea balthica; Matoba, 1967, p. 256, Pl. 28, figs. 2a-b.

Hyalinea balthica; Rouvilleis, 1970, Pl. 3, fig. 1.

Hyalinea balthica; Bock, 1971, p. 187, Pl. 4, figs. 5-6.

REMARKS: These specimens show the diagnostic features of *Hyalinea*.

Both sides are evolute, the primary aperture is a low equatorial interiomarginal arch and supplementary apertures are present beneath umbilical flaps on both sides. They differ from H. balthica in the smaller size and fewer chambers (8-10 in final whorl), inflated juvenile chambers, less incised sutures and broadly rounded periphery.

Supplementary apertures are clearly open for about 6 chambers. True H. balthica has about 11 chambers in the final whorl, supplementary apertures clearly open for about 8 chambers, and a narrowly rounded or subacute periphery. Professor O. L. Bandy has kindly supplied specimens of H. balthica collected by him from the Calabrian section at La Castella

that he has found the species from Upper Miocene to Recent in the Asiatic region. The species has a recorded depth range of from 50 to 800m or deeper, and appears to be a cool-water to cold-water indicator.

Dimensions of hypotypes: H. cf. balthica (VF1082), diameter 0.23mm, thickness 0.08mm; H. balthica (VF1083), diameter 0.43mm, thickness 0.15mm.

DISTRIBUTION: Found only in two samples from the Raumati Mudstone in the Wanganui River section.

-?lower Mangapanian

OBSERVED STRATIGRAPHIC RANGE: Waipipian/(Middle Pliocene).

OBSERVED ECOLOGIC RANGE: Shallow part of Haeuslerella Biofacies.

Genus CIBICIDES de Montfort, 1808

Type Species: Cibicides refulgens de Montfort

Cibicides corticatus Earland

Cibicides refulgens Montfort var. corticatus Earland, 1934, p. 183, Pl. 8, figs. 46-48.

Cibicides (Cibicidoides) corticatus; Vella, 1957, p. 41, Pl. 9, figs. 195-97.

DISTRIBUTION: Sporadically in shallow water samples from all sections except the Waitotara Valley or Saddle Road sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Castlecliffian (Upper Pleistocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to shallow Haeuslerella Biofacies; (recorded from 32-317m in Cook Strait).

Cibicides deliquatus Finlay, Pl. 8, figs. 156, 159, 160.

Cibicides deliquatus Finlay, 1940, p. 465.

Cibicides deliquatus Kennett, 1966a, p. 74, Pl. 12, figs. 196-97, 201.

Cibicides deliquatus; Gibson, 1967, p. 66, Pl. 18, figs. 267-71.

Dimensions of hypotype (VF1084): diameter 0.78mm, thickness, 0.26mm.

DISTRIBUTION: Sporadic in all sections except the Waitotara Valley and Watershed Road sections.

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

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: ?Haeuslerella to Robulus Biofacies.

Cibicides ihungia Finlay

Cibicides ihungia Finlay, 1940, p. 465, Pl. 67, figs. 201-06.

Cibicides ihungia; Hornibrook, 1968, pp. 35-36, 74, fig. 14.

DISTRIBUTION: Present only as occasional specimens in the Taihape Mudstone and lower Korinita Sandstone of the Wanganui River section, and in the Waiouru Sandstone and Taihape Mudstone of the Rangitikei River section.

RECORDED STRATIGRAPHIC RANGE: Arnold Series to Opoitian Stage (Upper Eocene to Lower Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

Cibicides marlboroughensis Vella

Cibicides marlboroughensis Vella, 1957, p. 40, Pl. 9, figs. 189-91.

DISTRIBUTION: Present in occasional samples from all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeafiorilus to Haeuslerella Biofacies; recorded from 22-396m in Cook Strait and living in 18-304m off southern Hawkes Bay.

Cibicides molestus Hornibrook, Pl. 8, figs. 157, 158, 161.

Cibicides n.sp. (sinuous ventral sutures) Hornibrook, in Fleming ed., 1959, p. 404.

Cibicides molestus Hornibrook, 1964, p. 163, Pl. 24, figs. 478-9, 483.

Cibicides molestus; Kennett, 1966a, pp. 74, 75, Pl. 12, figs. 202-4.

Cibicides molestus; Gibson, 1967, p. 67, Pl. 19, figs. 275-6.

Cibicides molestus; Hornibrook, p. 76, fig. 14.

REMARKS: Characterised by the biconvex shape with highly domed dorsal and flatter ventral sides.

Dimensions of hypotype (VF1085): diameter 0.42mm, thickness 0.24mm.

DISTRIBUTION: Not found in the Wilkies Bluff, Waitotara Valley, Watershed Road and Saddle Road sections, and present only as a single, possibly reworked specimen in the Middle Waipipi Shellbed at Waverley Beach. Common in the lower parts of the Wanganui River and Rangitikei River sections. Rare, abraded specimens in the Nukumaruan of the Rangitikei River section are considered to be reworked from older strata.

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

RECORDED STRATIGRAPHIC RANGE: Arnold Series to mid-Waitotaran Stage (Waipipian) (Upper Eocene to Middle Pliocene).

RECORDED ECOLOGIC RANGE: *Haeuslerella* to *Robulus* Biofacies.

Cibicides porrodeliquatus Kennett, Pl. 9, figs. 163-165.

Cibicides porrodeliquatus Kennett, 1967, p. 1006, figs. 33-35.

REMARKS: This species, recorded by Kennett as the probable direct ancestor of *C. deliquatus* Finlay, is almost certainly the species considered by Finlay (1940, p. 465) and Vella (1957, pp. 40-41) to be separable from *C. deliquatus*. Wanganui Basin specimens are variable, but fall within the range exhibited by the types. This species is less coarsely perforate than *C. deliquatus*, with a more domed dorsal side. Dimensions of hypotype (VF1086): diameter 0.46mm, 0.18mm.

DISTRIBUTION: Present in most samples through all the sections examined.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Genus DYOCIBICIDES Cushman & Valentine, 1930

Type Species: Dyocibicides biserialis Cushman & Valentine

Dyocibicides biserialis Cushman & Valentine

Dyocibicides biserialis Cushman & Valentine, 1930, p. 31, Pl. 10,
figs. 1, 2a, b.

Dyocibicides biserialis; Hornibrook, 1961, p. 165, Pl. 26, fig. 516.

DISTRIBUTION: Present in occasional shallow water samples from all sections.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Found in Cook Strait from 18-396m.

Dyocibicides primitiva Vella

Dyocibicides primitiva Vella, 1957, p. 41, Pl. 9, figs. 198-200.

Dyocibicides primitiva; Hornibrook, 1961, p. 165, Pl. 26, fig. 517.

Dyocibicides primitiva; Gibson, 1967, p. 69.

DISTRIBUTION: Occasionally present in shallow water samples from all sections.

RECORDED STRATIGRAPHIC RANGE: Duntroonian (Oligocene) to Recent.

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: 20-225m in Cook Strait, and living in 42m off southern Hawkes Bay.

Family PLANORBULINIDAE

Genus PLANORBULINA d'Orbigny, 1826

Type Species: Planorbulina mediterranensis d'Orbigny

Planorbulina mediterranensis d'Orbigny

Planorbulina mediterranensis d'Orbigny, 1826, p. 280, No. 2, Pl. 14

(5 in text, by error), figs. 4-6.

Planorbulina mediterranensis; Albani, 1968, p. 116, Pl. 10, figs. 12, 16.

REMARKS: The only specimen found is damaged, but agrees closely with the type figures. Recorded from shallow water in New South Wales (Albani, 1968), South Australia and Victoria (Parr, 1943).

DISTRIBUTION: A single specimen in the Lower Okiwa Group at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Hautawan (Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus Biofacies.

Family CAUCASINIDAE

Genus FURSENKOINA Loeblich & Tappan, 1961

Type Species: Virgulina squamosa d'OrbignyFursenkoina vellai Kennett, Pl. 8, fig. 162.Fursenkoina vellai Kennett, 1966a, p. 40, Pl. 3, figs. 40-42.

Dimensions of hypotype (VF1087): length 0.30mm, breadth 0.09mm.

DISTRIBUTION: Rare in two samples from the Mangaweka Mudstone and the Lower Okiwa Group at Wanganui River section; rare specimens present in the Hautawa Shellbed.

OBSERVED STRATIGRAPHIC RANGE: Waipipian to Hautawan (Middle Pliocene to Lower Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826

Type Species: Cassidulina laevigata d'OrbignyCassidulina carinata Silvestri, Pl. 9, fig. 167.Cassidulina laevigata d'Orbigny var. carinata Silvestri, 1896, p. 104, Pl. 2, fig. 10.Cassidulina carinata; Eade, 1967b, pp. 429-30, Fig. 2, nos. 5-9.

REMARKS: Eade placed C. laevigata d'Orbigny and C. neocarinata Thalmann in the synonymy of C. carinata.

Dimensions of hypotype (VF1088): diameter 0.25mm, thickness 0.08mm.

DISTRIBUTION: Present, usually in abundance, in most samples from all sections examined.

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

RECORDED ECOLOGIC RANGE: Zeafleurilus to Robulus Biofacies; widespread off New Zealand in depths of 0 to over 2,000m (Eade, 1967b).

Cassidulina cuneata Finlay

Cassidulina cuneata Finlay, 1940, p. 456, Pl. 63, figs. 62-63.

Cassidulina cuneata; Hornibrook, 1968, p. 61, fig. 9.

DISTRIBUTION: Rare specimens found only in two samples from the Taihape Mudstone of the Wanganui River section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian (Lower Pliocene).

RECORDED STRATIGRAPHIC RANGE: Landon Series to Lower Wanganui Series (Oligocene to Pliocene).

Cassidulina subglobosa Brady, Pl. 9, figs. 168, 169.

Cassidulina subglobosa Brady, 1881, p. 60.

Cassidulina subglobosa; Hornibrook, 1961, p. 85, Pl. 10, fig. 198.

Cassidulina subglobosa; Kennett, 1966a, pp. 49-50, Pl. 4, fig. 66.

Cassidulina subglobosa; Gibson, 1967, p. 42, Pl. 10, fig. 163.

Dimensions of hypotype (VF1089): diameter 0.46mm, thickness 0.19mm.
 DISTRIBUTION: Present sporadically through all the sections examined.
 RECORDED STRATIGRAPHIC RANGE: Porangan (Middle Eocene) to Recent.
 RECORDED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies; here extended to Zeaflorilus Biofacies.

Genus EVOLVOCASSIDULINA Eade, 1967

Type Species: Cassidulina orientalis Cushman

Evolvocassidulina orientalis (Cushman), Pl. 9, fig. 171.

Cassidulina orientalis Cushman, 1922a, p. 129.

Cassidulinoides orientalis; Hornibrook, 1961, p. 86, Pl. 10, fig. 201.

Evolvocassidulina orientalis; Eade, 1967b, pp. 431-32, Fig. 4, nos. 1-2.

REMARKS: A majority of the forms in a 130m section of the upper Taihape Mudstone and lower Koriniti Sands Formation at Wanganui River are larger and much more compressed than normal.

Dimensions of hypotype (VF1090): length 0.35mm, width 0.29mm, thickness 0.13mm.

DISTRIBUTION: In most samples from all sections.

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

RECORDED ECOLOGIC RANGE: Elphidium to Karreriella Biofacies, here extended to Zeaflorilus Biofacies; recorded by Eade (1967b) from 0-400m throughout the southwest Pacific region.

Family NONIONIDAE

Genus CHILOSTOMELLA Reuss, 1849

Type Species: Chilostomella ovoidea ReussChilostomella ovoidea ReussChilostomella ovoidea Reuss, 1850, p. 380, Pl. 48, fig. 12.Chilostomella ovoidea; Hornibrook, 1961, p.89, Pl. 11, fig. 209.

DISTRIBUTION: Only in occasional samples from the Wanganui River section.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Genus NONION de Montfort, 1808

Type Species: Nautilus incrassatus Fichtel & MollNonion cassidulinoides Hornibrook, Pl. 9, figs. 172,173.Nonion cassidulinoides Hornibrook, 1961, pp. 92-3, Pl. 11, figs. 214-15.

REMARKS: Small, planispiral specimens characterised by the sharp periphery and umbonal boss. Wanganui Basin forms are usually more symmetrical than the type figure.

Dimensions of hypotype (VF1091): diameter 0.20mm, thickness 0.13mm.

DISTRIBUTION: Sporadic in samples from all sections except the Wilkies Bluff and Saddle Road sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

RECORDED STRATIGRAPHIC RANGE: Whaingaroan to Waitotaran (Lower Oligocene to Pliocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Genus ASTRONONION Cushman & Edwards, 1937

Type Species: Nonionina stelligera d'Orbigny

Astrononion neefi (Vella)

Pacinonion neefi Vella, 1962b, p. 294, Pl. 1, figs. 6-7.

Pacinonion neefi; Gibson, ¹⁹⁶⁷, p. 47, Pl. 11, fig. 175.

REMARKS: Tiny specimens which are identical with the type figures.

DISTRIBUTION: Only in a single sample from the deepest facies of the Taihape Mudstone at Wanganui River.

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

RECORDED ECOLOGIC RANGE: Robulus to Semipelagic Biofacies.

Astrononion novozealandicum Cushman & Edwards

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

Astrononion novozealandicum; Cushman, 1939, p. 37, Pl. 10, figs. 12a,b.

Pacilonion novozealandicum; Vella, 1962b, p. 290, Pl. 1, figs. 10-11.

REMARKS: Characterised by the moderately large size, inflated chambers and broadly rounded periphery. In many Pliocene faunas, typical A. novozealandicum grades into the smaller form with less rounded periphery referred to A. parki Hornibrook.

DISTRIBUTION: In most samples from all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Castlecliffian (Lower Pliocene to Middle Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Ammonia to Elphidium Biofacies; Eade (1967a) lists the references to this species in New Zealand Recent sediments.

Astrononion parki Hornibrook

Astrononion parki Hornibrook, 1961, p. 95, Pl. 12, figs. 230, 237.

Astrononion cf. parki; Vella, 1962b, pp. 290-91, Pl. 1, figs. 8-9.

Astrononion parki; Kennett, 1966a, pp. 52-53, Pl. 5, figs. 81-82.

Pacilonion parki; Gibson, 1967, p. 47, Pl. 11, fig. 176.

REMARKS: In the original description of this species, Hornibrook discussed the considerable variation shown by individuals in the degree

of inflation, and hence definition of the periphery, and in the development of the umbilical flange, and stated that it was difficult to determine whether more than one species was present. Kennett (1966) considered that the Upper Miocene forms referred by him to A. parki were actually intermediate between that species and A. novozealandicum. Large populations from Wanganui Basin Pliocene sediments exhibit a range of variation similar to that described by the above authors, and it is considered here that A. novozealandicum arose from A. parki in the Upper Miocene, with morphotypes of the latter species lingering on in Pliocene and Lower Pleistocene sediments.

DISTRIBUTION: In all sections, except the Wilkies Bluff section.

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Astrononion poriensis (Vella), Pl. 9, figs. 166, 170.

Pacinonion poriensis Vella, 1962b, p. 294, Pl. 1, figs. 1-3.

Dimensions of hypotype (VF1092): diameter 0.52mm, thickness 0.21mm.

DISTRIBUTION: Sporadic through all sections except the Saddle Road section.

OBSERVED STRATIGRAPHIC RANGE: Opotian to Hautawan (Lower Pliocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Astrononion vadorum Vella

Astrononion vadorum Vella, 1962b, pp. 288-89, Pl. 1, figs. 4-5.

Astrononion vadorum; Kennett, 1966a, p. 52, Pl. 5, figs. 77-78.

REMARKS: Characterised by the lobulate outline, rounded periphery and narrow, subtriangular supplementary chambers with free posterior edges.

DISTRIBUTION: Rare in occasional samples from all sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Hautawan (Lower Pliocene to Lower Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

Genus NONIONELLA Cushman, 1926

Type Species: Nonionella miocenica Cushman

Specimens of Nonionella magnalingua Finlay and N. zenitens Finlay show fine apertural bars connecting the final chamber with the earliest chamber of the final whorl. These have not been figured or mentioned by previous authors. Type specimens of the above two species have been examined at N.Z. Geological Survey, Lower Hutt, and apertural bars are clearly visible on the holotype of N. magnalingua, and less clearly visible but present on a figured paratype. The holotype of N. zenitens

was not examined; apertural bars are obscured but appear to be present on one paratype.

This feature is not mentioned in generic and suprageneric diagnosis, but similar bars are present in other species of the subfamily Nonioninae. Lewis and Jenkins (1969) figure and describe them for Nonionellina flemingi (Vella), and stereoscan photographs of this species taken during the present study confirm their presence (Pl. 12, fig. 1a).

The apertural bars possibly serve to support the greatly enlarged final chamber characteristic of many of these species.

Nonionella magnalingua Finlay, Pl. 9, figs. 174, 179, 180.

Nonionella magnalingua Finlay, 1940, p. 456, Pl. 65, figs. 144, 146.

Nonionella magnalingua; Hornibrook, 1961, p. 94, Pl. 12, figs. 226, 232-33.

Nonionella magnalingua; Kennett, 1966a, p. 55, Pl. 6, figs. 91-92.

Nonionella magnalingua; Gibson, 1967, p. 48, Pl. 11, figs. 181-82.

REMARKS: Most Wanganui Basin specimens agree closely with the type specimens. Occasional forms have a larger, more embracing final chamber. Apertural bars are visible on all well-preserved specimens. Dimensions of hypotype (VF1093): length 0.37mm, width 0.24mm, thickness 0.21mm.

DISTRIBUTION: Only in the Lower Okiwa Group at Wanganui River and Watershed Road, and in the Mangaweka Mudstone at Rangitikei River.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian to Hautawan (Upper Pliocene to Lower Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies.

Nonionella zenitens Finlay

Nonionella zenitens Finlay, 1940, p. 457, Pl. 65, figs. 145, 152-56.

Nonionella zenitens; Hornibrook, 1961, p. 93, Pl. 12, figs. 225, 231.

Nonionella zenitens; Gibson; 1967, pp. 47-8, Pl. 11, figs. 179-80.

DISTRIBUTION: Rare in occasional samples from the Wilkies Bluff, Wanganui River and Rangitikei River sections.

OBSERVED STRATIGRAPHIC RANGE: Opoitian to Nukumaruan (Lower Pliocene to Lower Pleistocene).

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Possible Haeuslerella to Robulus Biofacies.

Genus NONIONELLINA Voloshinova, 1958

Type Species: Nonionina labradorica J. W. Dawson

Nonionellina flemingi (Vella), Pl. 9, figs. 181, 182; Pl. 12,
fig. 1.

Nonion flemingi Vella, 1957, p. 37, Pl. 9, figs. 183-4.

Florilus flemingi; Kennett, 1966a, pp. 53-4, Pl. 5, figs. 83-4.

Florilus flemingi; Gibson, 1967, pp. 48-9, Pl. 11, figs. 183-4.

Florilus flemingi; Hornibrook, 1968, p. 73, fig. 13.

Nonionellina flemingi; Lewis & Jenkins, 1969, Pl. 1, figs. 1-9.

REMARKS: This is a very common Upper Cenozoic and Recent species.

Wanganui Basin specimens are identical with the types. Lewis and Jenkins (1969) have described variation in this species, in particular with response to climatic fluctuations where they showed that an inverse relationship exists between animal size and ocean water temperature. They transferred the species to Nonionellina because the juvenile stage is trochospiral while the adult is planispiral. Very small Pliocene specimens show trochospiral coiling. Apertural bars can be seen in most well preserved specimens.

Dimensions of hypotypes: VF1094, length 0.40mm, width 0.22mm, thickness 0.19mm; VF1095, length 0.26mm, width 0.13mm, thickness 0.11mm.

DISTRIBUTION: In most samples, often abundant, from all sections.

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

RECORDED ECOLOGIC RANGE: Zeaflorilus to Karreriella Biofacies; recorded from intertidal stations, in Manukau Harbour, from 7-396m in Cook Strait and living from 40-625m off southern Hawkes Bay.

Genus PULLENIA Parker & Jones, 1862

Type Species: Nonionina bulloides d'Orbigny

Pullenia bulloides (d'Orbigny), Pl. 9, figs. 184, 185.

Nonionina bulloides d'Orbigny, 1846, p. 107, Pl. 5, figs. 9-10.

Pullenia bulloides; Hornibrook, 1961, p. 90, Pl. 11, figs. 205-06.

Pullenia bulloides; Vella, 1963, pp. 12-13, figs. 7-8.

Dimensions of hypotype (VF1096): diameter 0.22mm, thickness 0.20mm.

DISTRIBUTION: Sporadic through all sections except the Waverley Beach, Wilkies Bluff and Waitotara Valley sections.

RECORDED STRATIGRAPHIC RANGE: Haumurian (Upper Cretaceous) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium (rare) to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Robulus to Semipelagic and possibly Eupelagic Biofacies; from 22-48m in Cook Strait and living in 1419-2432m off southern Hawkes Bay.

Pullenia quinqueloba (Reuss), Pl. 9, figs. 178, 183.

Nonionina quinqueloba Reuss, 1851, p. 71, Pl. 5, fig. 31.

Pullenia quinqueloba; Hornibrook, 1961, p. 90, Pl. 11, figs. 207-08.

Dimensions of hypotype (VF1097): diameter 0.23mm, thickness 0.16mm.

DISTRIBUTION: Sporadic through all sections except the Waverley Beach, Wilkies Bluff and Waitotara Valley sections.

RECORDED STRATIGRAPHIC RANGE: Teurian (Upper Cretaceous) to Recent.

OBSERVED ECOLOGIC RANGE: Elphidium (rare) to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Haeuslerella to Karreriella and possibly Robulus Biofacies; from 77-94m in Cook Strait.

Genus ZEAFLORILUS Vella, 1962

Type Species: Nonionella parri Cushman

Zeaflorilus parri (Cushman), Pl. 9, figs. 175-177.

Nonionella parri Cushman, 1936b, p. 89, Pl. 13, fig. 17.

Zeaflorilus parri; Kennett, 1966a, p. 54, Pl. 6, figs. 89-90.

Florilus parri; Hornibrook, 1968, p. 76, fig. 14.

Dimensions of hypotype (VF1098): length 0.46mm, width 0.24mm, thickness 0.17mm.

DISTRIBUTION: Sporadic through all sections, very abundant in many shallow water samples.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Haeuslerella Biofacies.

RECORDED ECOLOGIC RANGE: Zeaflorilus Biofacies; intertidal, in Manukau Harbour, from 9-386m in Cook Strait and living from 18-48m off southern Hawkes Bay.

Family ALABAMINIDAE Hofker, 1951

Genus ORIDORSALIS Andersen, 1961

Type Species: Oridorsalis westi Andersen

Oridorsalis prominula (Stache)

Rotalia soldani d'Orbigny var. prominula Stache, 1865, p. 274, Pl. 24, fig. 24.

Gyroldina prominula; Hornibrook, 1961, p. 111, Pl. 16, figs. 348-49.

Oridorsalis prominula; Kennett, 1966a, pp. 59-60, Pl. 7, figs. 120-22.

Pseudoeponides prominula; Gibson, 1967, pp. 52-53, Pl. 13, figs. 202-03.

DISTRIBUTION: In occasional samples from all sections except the Waverley Beach, Wilkies Bluff and Waitotara Valley sections.

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

RECORDED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

Oridorsalis tenera (Brady)

Truncatulina tenera Brady, 1884, p. 665, Pl. 95, figs. 11a-c.

Oridorsalis tenera; Kennett, 1966a, p. 60, Pl. 7, figs. 118-19.

Pseudoeponides tenera; Gibson, 1967, p. 52, Pl. 13, figs. 119-201.

DISTRIBUTION: In occasional samples from all sections except the Waverley Beach, Wilkies Bluff and Waitotara Valley sections.

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

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies; from 77-135m in Cook Strait and living from 71-2329m off southern Hawkes Bay.

Family OSANGULARIIDAE

Genus GYROIDINOIDES Brotzen, 1942

Type Species: Rotalina nitida ReussGyroidinoides neosoldanii (Brotzen)Gyroidina neosoldanii Brotzen, 1936, p. 158.Gyroidinoides neosoldanii; Hornibrook, 1961, p. 112, Pl. 16, figs. 338, 343.

DISTRIBUTION: Through all sections except the Wilkies Bluff and Waitotara Valley sections.

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

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: Karreriella to Robulus Biofacies; from 22m in Cook Strait and living at 2329m off southern Hawkes Bay.

Gyroidinoides zelandica (Finlay)Gyroidina zelandica Finlay, 1939c, p. 323, Pl. 28, figs. 138-40.Gyroidinoides zelandica; Hornibrook, 1961, p. 113, Pl. 16, figs. 339, 344.

DISTRIBUTION: Found only in the Taihape Mudstone and Pitangi Mudstone at Wanganui River.

RECORDED STRATIGRAPHIC RANGE: Landon Series to Nukumaruan Stage (Oligocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Elphidium to Robulus Biofacies.

Family ANOMALINIDAE

Genus ANOMALINOIDES Brotzen, 1942

Type Species: Anomalinoides plummerae Brotzen = Anomalina
grosserugosa Plummer (not Gumbel)

Anomalinoides parvumbilia (Finlay), Pl. 10, figs. 188, 189,
 193.

Anomalina parvumbilia Finlay, 1940, p. 461, Pl. 65, figs. 157-59.

Anomalinoides parvumbilia; Hornibrook, 1961, p. 156, Pl. 23, figs. 458-60.

Anomalinoides parvumbilia; Kennett, 1966a, p. 73, Pl. 12, figs. 190-92.

REMARKS: Specimens differ from the types and from those figured by Hornibrook (1961) in being slightly more depressed, with less inflated chambers, and only 11 chambers in the final whorl.

Dimensions of hypotype (VF1099): diameter 0.39mm, thickness 0.16mm.

DISTRIBUTION: Present, usually common, in most samples from all sections except the Wilkies Bluff section.

RECORDED STRATIGRAPHIC RANGE: Whaingaroan to Nukumaruan (Lower Oligocene to Lower Pleistocene).

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

Anomalinoides spherica (Finlay), Pl. 10, figs. 190-192.

Anomalina spherica Finlay, 1940, pp. 460-61, Pl. 66, figs. 166-71.

Anomalinoides spherica; Kennett, 1966a, pp. 73-74, Pl. 12, figs. 193-95.

Anomalinoides spherica; Gibson, 1967, pp. 65-66, Pl. 17, figs. 257, 260.

Dimensions of hypotype (VF1100): diameter 0.46mm, thickness 0.24mm.

DISTRIBUTION: Through all sections except the Wilkies Bluff and Waitotara Valley sections, often abundant.

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

OBSERVED ECOLOGIC RANGE: Zeaflorilus to Robulus Biofacies.

RECORDED ECOLOGIC RANGE: From 20-396m in Cook Strait (as A. spherica frigidex), and living from 40-71m off southern Hawkes Bay.

Genus MELONIS de Montfort, 1808

Type Species: Nautilus pompilioides Fichtel & Moll

Melonis zeobesus Vella, Pl. 10, figs. 186-187.

Melonis zeobesus Vella, 1962b, pp. 292-93, Pl. 1, figs. 14-15.

Melonis zeobesus; Kennett, 1966a, p. 53, Pl. 5, figs. 79-80.

REMARKS: Distinguished from M. lutorum Vella, which inhabited greater depths (Vella, 1962b), by the more inflated chambers, broadly rounded periphery and limbate sutures and umbilical margin.

Dimensions of hypotype (VF1101): diameter 0.48mm, thickness 0.27mm.

DISTRIBUTION: Only in occasional deeper water samples from the Wanganui River and Rangitikei River sections.

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

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

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus and possibly Semipelagic Biofacies.

Superfamily ROBERTINACEA

Family CERATOBULIMINIDAE

Subfamily CERATOBULIMININAE

Genus CERATOBULIMINA Toulou, 1915

Type Species: Rotalina contraria Reuss

Ceratobulimina sp., Pl. 10, figs. 194,

198, 199.

REMARKS: Very rare specimens with an umbilical aperture extending a short distance up the apertural face are closest to C. kellumi Finlay, but distinguished by fewer chambers in the adult whorl and the aperture not extending as far into the final chamber.

Dimensions of hypotype (VF1102): length 0.33mm, width 0.22mm, thickness 0.15mm.

DISTRIBUTION: Only in one sample from upper Mangaweka Mudstone at Wanganui River.

OBSERVED STRATIGRAPHIC RANGE: Mangapanian (Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Genus ZELAMARKINA n. gen.

Type Species: Zelamarkina excavata n.sp. (Upper Pliocene, N.Z.)

DESCRIPTION: Test free, trochospiral, sinistrally coiled, biconvex, chambers increasing gradually in size. Dorsal side roughened, sutures oblique, limbate and strongly raised; ventral side smooth, glossy, deeply umbilicate, chambers inflated, sutures radial, gently depressed. Wall of aragonite (by Feigl's reagent). Aperture umbilical-extraumbilical, extending as slit part way across base of final chamber; septal foramen and internal partition similar to that in Ceratolamarkina.

REMARKS: Zelamarkina is characterised by the slit-like umbilical aperture and strongly raised dorsal sutures. It appears most closely related to Lamarkina, but differs in the much more gradual enlargement of chambers, biconvex shape, sutural and apertural characteristics, and sinistral coiling.

Zelamarkina excavata n.sp., Pl. 10, figs. 195-197, 200.

DESCRIPTION: Test small, subcircular, peripheral edge sub-rounded; 6 chambers in final whorl, increasing in size gradually. Dorsal sutures oblique, raised to form walls with irregular crests surrounding flat chamber surfaces; ventral side smooth, glossy, deeply umbilicate, with nearly straight, gently depressed radial sutures. Aperture a slit at the base of the final chamber, extending from the umbilicus about half way to the periphery.

Dimensions: holotype, greatest diameter 0.36mm, thickness 0.20mm; figured paratype (VF999), greatest diameter 0.23mm, thickness 0.14mm.

TYPES: Holotype (VF997) and three paratypes (VF998, VF999).

TYPE LOCALITY: N138f558 (VF997, VF998), Grid ref. N138/672065; N138f557 (VF999), Grid ref. N138/691065; both localities at Wangamui River.

TYPE LEVEL: Upper part of Mangapanian Stage, N138f558 40m stratigraphically above N138f557.

DISTRIBUTION: Extremely rare, found only in the type samples.

OBSERVED STRATIGRAPHIC RANGE: Upper part of the Mangapanian Stage (Upper Pliocene).

OBSERVED ECOLOGIC RANGE: Elphidium Biofacies.

Subfamily EPISTOMININAE

Genus HOEGLUNDINA Brotzen, 1948

Type Species: Rotalia elegans d'Orbigny

Hoeglundina elegans (d'Orbigny)

Rotalia elegans d'Orbigny, 1826, p. 272, No.6.

Epistomina elegans; Hornibrook, 1961, p. 122, Pl. 17, fig. 367.

Hoeglundina elegans; Kennett, 1966_a, p. 59, Pl. 7, figs. 113-14.

Hoeglundina elegans; Gibson, 1967, pp. 51-2, Pl. 12, fig. 194.

DISTRIBUTION: Only in occasional samples from the Wanganui River, Rangitikei River and Watershed Road sections.

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

RECORDED ECOLOGIC RANGE: Haeuslerella to Robulus Biofacies; from 22-113m in Cook Strait and living off southern Hawkes Bay in 113-375m.

PLATE 1

- Figs. 1-3. Haeuslerella parri Finlay, VF1002, x52.
- Figs. 4-6. Trochammina inflata (Montagu), VF1004, x170.
- Fig. 7. Martinotiella clarae Gibson, VF1007, x40.
- Fig. 8. Karrerella cylindrica Finlay, VF1006, x52.
- Figs. 9-11. Trochammina cf. rotaliformis Wright, VF1005, x160.
- Figs. 12,13. Miliolinella subrotunda (Montagu), VF1009, x105.
- Figs. 14,15. Sigmoilopsis schlumbergeri (Silvestri), VF1008, x52.
- Figs. 16,17. Miliolinella vigilax Vella, VF1010, x42.
- Fig. 18. Amphicoryne hirsuta (d'Orbigny), VF1012, x26.
- Figs. 19,20. Nodosaria lammulifera Boomgart, VF1011, x52.
- Fig. 21. Plectofrondicularia wairarapa (Vella), VF1014, x60.
- Fig. 22. Plectofrondicularia pellucida Finlay, VF1013, x54.

PLATE 1

PLATE 2

- Fig. 23. Lenticulina mammilifera (Karrer), VF1015, x28.
- Fig. 24. Lenticulina peregrina (Schwager), VF1016, x170.
- Fig. 25. Robulus calcar (Linné), VF1019, x36.
- Fig. 26. Robulus costatus (Fichtel and Moll), VF1020, x28.
- Fig. 27. Vaginulina elegans d'Orbigny, VF1021, x51.
- Figs. 28,29. Planularia tricarinnella (Reuss), VF1018, x52.
- Fig. 30. Sphaeroidina bulloides d'Orbigny, VF1022, x52.
- Figs. 31,37. Bolivinita pliozea Finlay, VF1024, x78.
- Figs. 32,38. Bolivina lapsus Finlay, VF1026, x68.
- Fig. 33. Marginulina subbullata Hantken, VF1017, x75.
- Figs. 34,39. Bolivina spathulata (Williamson), VF1033, x115.
- Figs. 35,36. Bolivinita cf. finlayi Kennett, VF1023, x136.
- Fig. 40. Globobulimina pacifica Cushman, VF1042, x56.
- Figs. 41-43. Bolivina hornibrooki n.sp., holotype, VF979, x97:
41, edge view; 42, apertural view; 43, lateral
view.

PLATE 2

PLATE 3

- Figs. 44-47. Bolivina vellai n.sp. 44, 45, 47, holotype, VF983,
x130: 44, edge view; 45, lateral view; 47, apertural
view. 46, paratype, VF985, x100, lateral view.
- Fig. 48. Bulimina aculeata d'Orbigny, VF1038, x105.
- Fig. 49. Virgulopsis turris (Heron-Allen & Earland),
VF1043, x105.
- Fig. 50. Rectobolivina striatula (Cushman), VF1037, x78.
- Figs. 51, 52, 58, 59. Bolivina wanganuiensis n.sp. 51, 58, 59, holotype,
VF988, x100: 51, apertural view; 58, lateral view;
59, edge view. 52, paratype, VF991, x75, lateral view.
- Fig. 53. Bulimina elongata subulata Cushman & Parker, VF1039,
x80.
- Fig. 54. Bulimina marginata d'Orbigny, VF1040, x120.
- Fig. 55. Bulimina striata d'Orbigny, VF1041, x105.
- Fig. 56. Euuvigerina lutorum (Vella), VF1044, x81.
- Fig. 57. Euuvigerina peregrina (Cushman), VF1046, x92.
- Fig. 60. Euuvigerina cf. pliozea (Vella), VF1049, x110.
- Fig. 61. Euuvigerina pliozea (Vella), VF1047, x78.
- Fig. 62. Euuvigerina paeniteres (Finlay), VF1045, x87.
- Fig. 63. Euuvigerina pliozea (Vella), VF1048, x82.

PLATE 3

PLATE 4.

- Fig. 64. Euuvigerina rodleyi rodleyi (Vella), VF1050, x105.
- Fig. 65. Euuvigerina zeacuminata (Vella), VF1051, x80.
- Fig. 66. Siphouvigerina interrupta (Brady), VF1052, x105.
- Figs. 67, 68, Heronallenia wilsoni (Heron-Allen & Earland), VF1058,
72. x105.
- Figs. 69-71. Gavelinopsis lobatulus (Parr), VF1054, x125.
- Figs. 73, 74, Rosalina paupereques Vella, VF1056, x135.
77.
- Figs. 75, 76, Planulinoides sp., VF1055, x105.
79.
- Fig. 78. Rosalina vitrizea Hornibrook, VF1057, x125.
- Figs. 80-82. Gavelinopsis hamatus Vella, VF1053, x80.

PLATE 4

PLATE 5

- Figs. 83-85. Valvulineria sadonica Asano, VF1059, x115.
- Figs. 86, 89, 90. Rotalia fastigata n.sp., holotype, VF995, x100:
86, dorsal view; 89, ventral view; 90, edge view.
- Figs. 87, 88, 91, 92. Notorotalia briggsi n.sp. 87, 91, 92, holotype, VF992, x55: 87, dorsal view; 91, ventral view; 92, peripheral view. 88, paratype, VF880, x55, peripheral view.
- Figs. 93, 94, 98. Globigerinella siphonifera (d'Orbigny), VF1061, x150.
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- Figs. 102-104. Globorotalia inflata (d'Orbigny), VF1063, x93.
- Figs. 105, 106, 110, 111. Globorotalia scitula (Brady). 105, 106, 111, VF1067, x115; 110, VF1103, x105.
- Figs. 107-109. Globorotalia puncticulata (Deshayes), VF1065, x120.
- Figs. 112-114. Globorotalia puncticulata (Deshayes) var., VF1066, x105.
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- Figs. 116-118 Globigerina decoraperta Takayanagi & Saito, VF1070, x140.
- Figs. 119, 120, 124. Globigerina bulloides trilocularis Deshayes, VF1069, x105.
- Figs. 121-123. Globigerina bulloides bulloides d'Orbigny, VF1068, x92.

PLATE 6

PLATE 7

- Figs. 125-127   Globigerina foliata Bolli, VF1073, x170.
- Figs. 128, 129,
133   Globigerina dutertrei d'Orbigny, VF1071, x150.
- Figs. 130-132.   Globigerina cf. falconensis Blow, VF1072, x105.
- Figs. 134, 135,
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VF1075, x150.
- Figs. 136, 137,
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- Figs. 139-141.   Turborotalita quinqueloba (Natland), VF1080,
x125.
- Figs. 143, 144.   Globigerinita glutinata (Egger), VF1078, x125.
- Figs. 145, 146.   Globigerinita uvula (Ehrenberg), VF1079, x185.

PLATE 8

- Figs. 147,148   Globigerinoides trilobus trilobus (Reuss),
VF1076, x110.
- Figs. 149,150.   Hyalinea cf. balthica (Schroeter), VF1082, x165.
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155.
- Figs. 153,154.   Hyalinea balthica (Schroeter), Le Castella,
Italy: Sample 14 of Bandy and Wilcoxon,
1970; x92.
- Figs. 156,159,   Cibicides deliquatus Finlay, VF1084, x52.
160
- Figs. 157,158,   Cibicides molestus Hornibrook, VF1085, x105.
161.
- Fig. 162.   Fursenkoina vellai Kennett, VF1087, x165.

PLATE 8

PLATE 9

- Figs. 163-165. Cibicides porrodeliquatus Kennett, VF1086, x105.
- Figs. 166, 170. Astrononion poriensis (Vella), VF1092, x52.
- Fig. 167. Cassidulina carinata Silvestri, VF1088, x105.
- Fig. 168, 169. Cassidulina subglobosa Brady, VF1089:
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x105.
- Figs. 172, 173. Nonion cassidulinoides Hornibrook, VF1091, x150.
- Figs. 174, 179,
180. Nonionella magnalingua Finlay, VF1093, x78.
- Figs. 175-177. Zeaflorilus parri (Cushman), VF1098, x52.
- Figs. 178, 183. Pullenia quinqueloba (Reuss), VF1097, x100.
- Figs. 184, 185. Pullenia bulloides (d'Orbigny), VF1096, x105.
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PLATE 10

- Figs. 186, 187   Melonis zeobesus Vella, VF1101, x75.
- Figs. 188, 189, 193.   Anomalinoides parvumbilia (Finlay), VF1099, x75.
- Figs. 190-192.   Anomalinoides spherica (Finlay), VF1100, x53.
- Figs. 194, 198, 199.   Ceratobulimina sp., VF1102, x105.
- Figs. 195-197, 200.   Zelamarkina excavata n.gen., n.sp.
195-197, holotype, VF997, x95: 195, ventral view;
196, dorsal view; 197, peripheral view.
200, paratype, VF999, x170, peripheral view of
broken final chamber showing septal foramen
and internal partition.
- Figs. 201-206.   Selachian dermal denticles, x50.

PLATE 10

PLATE 11

Scanning electron micrographs, oblique views.

Fig. 1. Haeuslerella pliocenica (Finlay). VF1003.

1a, lateral view, x83;

1b, details of surface of central region of test, x355.

Fig. 2. Elphidium incertum (Williamson). VF1000.

2a, view of tilted specimen, x170;

2b, surface ornamentation, pore distribution and perforated pore membranes in umbilical region of test, x640;

2c, enlargement of pores from along final and penultimate suture lines; showing perforated pore membrane and open pore, x1115;

2d, further enlargement of above region, showing development of tubercles on walls of pore, x1825.

Fig. 3. Elphidium incertum (Williamson). VF1001.

3a, peripheral view, x190;

3b, enlargement of part of terminal face and surrounding region, x300.

SECTION IV

BIOSTRATIGRAPHY

Wanganui Basin Biostratigraphic Zones

Biostratigraphic zones recognised in the present study, and their relationship to standard New Zealand Pliocene and early Pleistocene stages, are shown in Table 1. Lists of species making first and last appearances in each zone, and those restricted to the Molestus Zone, are given below.

A suggested correlation between Wanganui Basin biostratigraphic zones and those recognised for other areas of New Zealand is given in Table 11. Superior (1943) erected 6 zones and 9 subzones for strata in South Wanganui Basin. Most of the foraminiferal species upon which this system was based are now known to have longer time-ranges elsewhere in New Zealand, and their distribution in Wanganui Basin sediments is facies-dependent. Taxonomic changes since 1943 have further diminished the value of Superior's system, and it is considered to be now obsolete.

Hurupiensis Zone

This zone represents the range of Notorotalia hurupiensis Vella in Wanganui Basin. The top is defined by the evolutionary change of this species to N. finlayi Vella by decrease in length of the spiral ribs so that they no longer extend fully across each chamber. In the sections examined, this change takes place over a short stratigraphic distance. To maintain objectivity, however, the contact between this and the overlying zone is defined as that level where 50% of the

STAGE	Vella 1962a, 1963	Devereux et al, 1970 Kennett et al, 1971	Kennett 1966a	This Study
		Wairarapa	N. Westland	Wanganui
Wh				
	MANGAOPARIA			
Wm	KINGMAI		FINLAYI	FINLAYI
Wp	MOLESTUS	FINLAYI		MOLESTUS
Wo	OLSONI			HORUPIENSIS

Table 11. - Probable correlations of New Zealand Pliocene benthonic foraminiferal zones.

population are referable to N. finlayi. This level is called the Hurupiensis-finlayi Datum. Climatic evidence presented later indicates that this occurs at a very similar stratigraphic position elsewhere in New Zealand.

Last appearances: Textularia barnwelli Kennett, Hauserella pliocenica (Finlay), Karrerella cylindrica Finlay, Martinotiella clarae Gibson, Lenticulina mammiligera (Karrer), Bolivina cf. acerosa Cushman, Stilostomella basicarinata Hornibrook, Euuvigerina peregrina (Cushman), E. zeacuminata (Vella), Notorotalia hurupiensis Vella, Cibicides ihungia Finlay, Cassidulina cuneata Finlay, Astrononion neefi (Vella).

Species not recorded in Wanganui Basin, but which are thought not to range above the Hurupiensis Zone elsewhere in New Zealand include Karrerella cushmani Finlay, Spiroloculina novozealandica Cushman & Todd, Robulus echinatus (d'Orbigny), Staffia multicostales (Finlay), Bulimina bremeri Finlay, Hopkinsina mioindix Finlay, Baggina ampla (Finlay), Anomalinoidea vitrinodus (Finlay) and Cibicides amoenus Finlay (Fleming, in Fleming, ed., 1959, p. 281; Hornibrook, 1968).

Molestus Zone

The Molestus Zone is a concurrent range zone defined by the overlapping parts of the ranges of Notorotalia finlayi Vella and Cibicides molestus Hornibrook.

Special attention was paid to determining the range of C. molestus in all sections. C. molestus is common in moderately deep-water sediments representing the Hauserella to Robulus Biofacies (ca. 60-600m). In the

Rangitikei River section it is very common through the Taihape Mudstone and Utiku Sandstone, becomes abundant in the lower Mangaweka Mudstone up to its final appearance in sample N139f540. Between this and N139f541, 80m higher, there is no discernible lithologic or marked faunal change, and no evidence of significant shallowing (both samples represent deep *Haeuslerella* or shallow *Robulus* Biofacies). In the Wanganui River section, C. molestus is moderately abundant in the Taihape Mudstone and Koriniti Sandstone. It is less abundant in the lower part of the Raumati Mudstone Member of the Mangaweka Mudstone and completely disappears before sample N131f541, 95m above the base of the Mangaweka Mudstone. There is evidence of gradual shallowing through this part of the section but no litho-facies change and the last appearance of C. molestus is in sediment deposited in middle *Haeuslerella* Biofacies, still within the known ecologic range of the species.

It is concluded that the disappearance of C. molestus is a true extinction, not facies controlled. The plane defined by the extinction is apparently not diachronous. All records of the species outside the above stratigraphic and ecologic limits (e.g. N139f548, Rangitikei River, Nukumaruan; N137f662, Waverley Beach, Waipipian) refer to single, broken and abraded, often stained, shells. A single specimen from the 1335-1350m sample in Santoft-1a well was considered by Shell, BP and Todd Oil Services micropaleontologists to be reworked (Rowe, 1964). C. molestus is a robust, thick-shelled species which could be expected to withstand reworking and redeposition.

The Molestus Zone of Vella (1962a, 1963), defined as the range of C. molestus in Wairarapa above the disappearance of C. ihungia,

appears the same as the Molestus Zone recognised in this study. The Finlayi Zone of Devereux *et al* (1970) and Kennett *et al* (1971), also for Wairarapa, consists of the range of Notorotalia finlayi below the incoming of Pellicaria mangaoparia Vella. The base of this zone equals the base of the Wanganui Molestus Zone, but correlation of the upper limit is not possible. Kennett (1966a) defined the Finlayi Zone for northern Westland as the strata containing Notorotalia finlayi, thus making its base equal to the base of the Wanganui Molestus Zone, but again leaving correlation of the upper part uncertain.

Restricted species: Quinqueloculina cf. ludwigi Reuss, Hyalinea cf. balthica (Schröter).

Last appearances: Robulus costatus (Fichtel & Moll), Bolivinita elegantissima Boomgart, Rectobolivina maoria Finlay, Siphonigerina interrupta (Brady), Notorotalia taranakia Vella, Globorotalia puncticulata (Deshayes), Sphaeroidinella seminulina (Schwager), Cibicides molestus Hornibrook.

Notorotalia taranakia and Globorotalia puncticulata may extend a short distance into the overlying Finlayi Zone.

First appearances: Siphotextularia blacki Vella, S. mestayerae Vella, Trochammina inflata (Montagu), T. cf. rotaliformis Wright, Quinqueloculina candeina d'Orbigny, Q. cooki Vella, Siphonaperta macbeathi Vella, Triloculina chrysostoma (Chapman), Miliolinella subrotunda (Montagu), M. vigilax Vella, Bolivina alata (Seguenza), B. variabilis (Williamson), Discorbis dimidiatus (Parker & Jones), Heronallenia wilsoni Heron-Allen & Earland, Valvulineria sadonica

Asano, Criboelphidium incertum (Williamson), Notorotalia briggsi n.sp., N. depressa Vella, N. finlayi Vella.

In the Rangitikei River section, the scallop Mesopeplum crawfordi (Zittel) ranges to the top of the Molestus Zone. In the Waverley Beach section it is present in the Waipipi Formation, but not in the Waverley Formation (Fleming, 1953), and has a recorded range in New Zealand of Opoitian to Waipipian (Fleming, 1966; Beu, 1969).

Finlayi Zone

This is an extensive zone from Upper Pliocene to Recent, comprising the range of Notorotalia finlayi above the disappearance of Cibicides molestus. The zone has not been formally subdivided but species are listed below according to whether they appear or disappear in strata attributed to the Mangapanian Stage (lower Finlayi Zone) or in the Hautawan and Nukumaruan Stages (upper Finlayi Zone). A number of species, including Haeuslerella parri Finlay and Notorotalia briggsi n.sp., die out in the Castlecliffian. However, examination of faunal distribution at this level is beyond the scope of this work.

The base of the Finlayi Zone, as here defined, is equivalent to the base of the Kingmai Zone of Wairarapa (Vella, 1962a, 1963).

First appearances: (lower) Textularia cf. ensis Vella, Quinqueloculina neosigmoilinoidea Kennett, Pyrgo aff. ezo Asano, P. cf. guerreri (Silvestri), Notorotalia inornata Vella, Ceratobulimina sp., Zelamarkina excavata n.gen., n.sp; (upper) Textularia goesii Cushman, Siphotextularia cf. fretensis Vella, Trochammina sorosa Parr, Cyclogyra sp.,

Massilina brodiei Hedley, Hurdle & Burdett, Eoeponidella cf. zelandica Hornibrook, Planorbulina mediterraneensis d'Orbigny, Globorotalia truncatulinoides (d'Orbigny).

Last appearances: (lower) Bolivinita compressa Finlay, Euuvigerina delicatula (Vella), Notorotalia kingmai Vella, N. pliozea Vella, ?N. taranakia Vella, ?Globorotalia puncticulata (Deshayes), Melonis zeobesus Vella.

(upper) Haeuslerella morgani (Chapman), Bolivinita cf. finlayi Kennett, B. pohana Finlay, Bolivina affiliata Finlay, B. albatrossi Cushman, B. petiae Gibson, Stilostomella antipoda (Stache), S. verneuilii (d'Orbigny), Siphouvigerina vadesseens (Cushman), Heronallenia wilsoni (Heron-Allen & Earland), Rotalia fastigata n.sp., Notorotalia zelandica mangaoparia Vella, Planulina sp., Fursenkoina vellai Kennett, Nonion cassidulinoides Hornibrook, Asirononion parki Hornibrook, A. poriensis (Vella), A. vadorum Vella, Nonionella magnalingua Finlay, N. zenitens Finlay, Oridorsalis prominula (Stache), Gyroidinoides zelandica (Finlay), Anomalinoidea parvumbilia (Finlay).

Planktonic Foraminiferal Correlation

The zones erected by Vella (1962a, 1963) for Wairarapa included the Inflata Zone between the Molestus and Zeaserus Zones, equivalent to the Opoitian Stage. Kennett (1966c,d) defined Crassaformis and Inflata Zones for eastern North Island. His Inflata Zone was defined by the range of Globorotalia inflata (d'Orbigny) and contained G. crassaformis

(Galloway & Wissler) only in the lower part. Kennett equated the base of his underlying Crassaformis Zone with the base of Vella's Inflata Zone, explaining the discrepancy as resulting from previous misidentification of G. crassaformis as G. inflata (P. Vella, pers. comm. in Kennett, 1966c, p. 90). Jenkins (1971) gives the total New Zealand range of G. crassaformis as lower Opoitian to Castlecliffian, and that of G. inflata as basal Opoitian to Hawera Series. Thus, apart from the base of the Crassaformis Zone, these zones are of local significance only. In Wanganui Basin, both species are present throughout the sections studied, indicating strata younger than lower Opoitian as defined elsewhere in New Zealand.

In Taranaki, Geiger (1962) also considered his Globorotalia inflata Zone as Opoitian and referred all younger beds to the Globorotalia truncatulinoides Zone, which was defined as extending from the last appearance of Globoquadrina dehiscens Chapman, Parr & Collins to Recent. Globorotalia truncatulinoides (d'Orbigny) was considered to range from the base of the Globorotalia inflata Zone to Recent.

Jenkins (1967a, 1971b) divided the Pliocene to Recent Inflata Zone of his New Zealand Cenozoic planktonic zones into subzones based on coiling ratio changes in Globigerina pachyderma (Ehrenberg). Direction of coiling in this species is discussed in more detail under paleoclimates, but in brief the Opoitian and Mangapanian dextral subzones and the Waipipian sinistral subzone can be recognised. The basal Hautawan sinistral subzone has not been found.

Collen and Vella (1972) attempted correlation of New Zealand Upper Miocene and Pliocene strata with the planktonic foraminiferal zones of Banner and Blow (1965) and Blow (1969). The Waipipian, Mangapanian and possibly lower Hautawan were considered equal to Zone N21 (Globorotalia tosaensis tenuitheca Consecutive-range Zone) mainly because of the extinction of Globigerina decoraperta Takayanagi & Saito within the zone, and the presence of Globorotalia truncatulinoides (which defines the base of overlying Zone N22) in slightly younger strata. Upper Opoitian strata were correlated with Zone N20 (Globorotalia multicamerata-Pulleniatina obliquiloculata Partial-range Zone) on the upper limit of Globigerina apertura Cushman, which dies out in the middle of Zone N20, and the presence of rare Globigerina digitata praedigitata Parker and Globorotalia hirsuta praehirsuta Blow, together with the absence of Globorotalia margaritae Bolli.

In Wanganui Basin, Zone N21 is probably represented by the Molestus Zone and lower part of the Finlayi Zone. Globigerina decoraperta is present in the lower part of the Hautawan Stage, where it overlaps in range with Globorotalia truncatulinoides in N139f546. The absence of Globorotalia margaritae and Globigerina apertura indicate that the Hurupiensis Zone represents either lower Zone N21 or upper Zone N20, but poor planktonic faunas make accurate correlation impossible. Zones below N20 are almost certainly not represented in the strata sampled.

Correlation With Type Sections

The biostratigraphic zones defined above cannot be clearly recognised in the Pliocene type sections in Wanganui Basin. The presence of typical Notorotalia finlayi in samples near the base of the type Waipipian section has already been noted, indicating that these beds are stratigraphically above the Hurupiensis-finlayi Datum, and it is possible that the "Waipipian" as commonly recognised throughout New Zealand includes strata older than in the type section. Unfortunately, the foraminiferal fauna of the type section of the Opoitian Stage has not been described, and the position of the Hurupiensis-finlayi Datum with respect to that section is not known.

A single specimen of Cibicides molestus from the type Waipipian, although within its time range, is probably redeposited. However, Globorotalia puncticulata and Mesopeplum crawfordi in the lower part of this section also indicate the Molestus Zone, and published stratigraphic and paleontological data (Fleming, 1953) indicate that the Molestus-Finlayi Zone boundary occurs between the top of the Waipipi Formation and the Wilkies Shellbed. Thus, although the Finlayi Zone is correlated with the Mangapanian Stage and younger strata in this study, it could include Waipipian beds.

The Type Section Concept

The emphasis on type sections and faunal content in the history of New Zealand stage nomenclature has been summarised by Scott (1960).

Scott discussed the composite nature of some stage definitions and pointed out that type localities were not essential to the definitions as they relied on inferences from many sections. He considered the stages to be homotaxial stratigraphic units, distinguished by invariant sequences of fossils, and later (1965) advanced this theme, arguing for the restriction of time-stratigraphic units to those defined by radiometric dating. Jenkins (1971b) also regarded New Zealand stages as biostratigraphic units, and rejected them as time-stratigraphic units because they are not all of equal duration and because he considered that most have diachronous boundaries.

Hornibrook (1971) stressed the instability of zonal schemes based on fossil species, which are subject to changing taxonomic concepts. He considered type sections essential to accurate and objective definition of unit boundaries, particularly with the proliferation of local zonal schemes, and stages based on type sections as essentially time-stratigraphic in intent, not purely biostratigraphic.

The latter view is shared here. Fundamentally, erection of biostratigraphic zones in this study has been an attempt to link the foraminifera commonly used for Pliocene biostratigraphy in New Zealand to the actual type sections, an attempt which has been only partially successful. However, the writer believes that the two important datum planes defined here, the Hurupiensis-finlayi Datum and the extinction of Cibicides molestus, are isochronous in the sense regarded by Hornibrook (1971) as the view of most geologists, "near enough to contemporaneous for the practical purposes of stratigraphy".

The type sections of the Waipipian and Mangapanian Stages are not adequate stratotypes for the following reasons:

1. the sections are incomplete and discontinuous, large parts of the coastal section are not exposed, beds may be absent through faulting, and relationships with the underlying Opoitian stage cannot be established.
2. the foraminiferal fauna is a shallow-water one, with few index species.

The deficiencies of the stratotypes, however, do not invalidate the stages as time-stratigraphic units, and could be largely resolved by the erection of a parastratotype, or standard section, selected for the purpose of defining the stage boundaries. The section in Wanganui Basin most suited to this purpose is that along the Rangitikei and Moawhango Rivers, but more satisfactory sections probably exist in eastern North Island. Establishment of a reliable paleomagnetic stratigraphy, which is probably not possible for the type sections, would greatly increase the value of a parastratotype. Designation of such a parastratotype would be premature before the type Opoitian faunas have been examined. Moreover, agreement as to the location of the parastratotype amongst interested New Zealand stratigraphers would be desirable.

The Pliocene-Pleistocene Boundary

The Pliocene-Pleistocene boundary in New Zealand strata was placed between the Mangapanian and Hautawan stages by Fleming (1953, 1962) on the evidence of the cold-water Hautawan mollusc faunas. The stratigraphic position of this boundary was discussed further by Beu (1969), Vella and Nicol (1970, 1971), Jenkins 1964, 1967a, 1971a,b) and Kennett et al (1971).

The significance of the single specimen of Globorotalia truncatulinoides (d'Orbigny) in sample N139F546 from the Hautawan of the Rangitikei River section, 45m above the Hautawa Shellbed, cannot be fully evaluated at present. G. truncatulinoides is believed to have evolved from G. tosaensis Takayanagi & Saito at or near the base of the type Calabrian sections in Italy (Banner and Blow, 1965; Bayliss, 1969; Bandy and Wilcoxon, 1970), and this event has been used to determine the Pliocene-Pleistocene boundary in deep-sea cores (Ericson et al, 1963; Parker, 1967; Berggren et al, 1967; Glass et al, 1967; and others). Kennett et al (1971) show G. truncatulinoides appearing in Wairarapa, New Zealand, partway through the Hautawan Stage at the base of the Gilsa Geomagnetic Event.

However, G. tosaensis has been reported persisting to the Holocene (Banner and Blow, 1967; Kennett and Geitzenauer, 1969; Bandy and Ingle, 1970), and Kennett and Geitzenauer (1969) suggest that the bioseries may be complicated and controlled at least partially by oceanographic fluctuations. Further complications are introduced by

records of G. truncatulinoides in New Zealand Opoitian (Lower Pliocene) sediments (Hornibrook, 1958b; Fleming, in Fleming, ed., 1959, p. 284; Geiger, 1962; Jenkins, 1964, 1971b). Until the full range of G. truncatulinoides in New Zealand has been clarified, the Wanganui Basin specimen, while suggesting correlation with the base of the Gilsa Event as determined by Kennett et al (1971), is of uncertain stratigraphic value.

Summary

1. The Hurupiensis, Molestus and Finlayi Zones, based on foraminifera commonly used throughout New Zealand for Pliocene biostratigraphy, can be related only approximately to the Waipipian and Mangapanian stratotypes.
2. The evolutionary change of Notorotalia hurupiensis Vella to N. finlayi Vella, marking the Hurupiensis-Molestus Zone boundary, and the extinction of Cibicides molestus Hornibrook, marking the Molestus-Finlayi Zone boundary, are important faunal events recognisable through much of New Zealand and believed to be essentially isochronous.
3. The Waipipian and Mangapanian type sections are incomplete and cannot be related to underlying stages. Erection of a parastratotype to allow the accurate definition of the stage boundaries by both foraminifera and mollusca is recommended.
4. Poor planktonic foraminiferal faunas preclude reliable correlation with overseas planktonic zones.

SECTION V

PALEOECOLOGY, PALEOCLIMATOLOGY AND PALEOGEOGRAPHY

Benthonic Foraminiferal Paleocology

Benthonic Faunal Trends

The similar variation of foraminiferal number and number of benthonic species through each section is in accordance with Recent environmental data, where both parameters increase seawards to maximum values at outer shelf or upper bathyal depths then decrease at greater depths (Bandy and Arnal, 1960). Wanganui Basin sediments were deposited almost entirely in upper bathyal or shallower depths, and the above two measurements vary directly with inferred depth of deposition except in the Wanganui River section where rapid depth and facies changes give a more complicated pattern of faunal distribution.

Several samples (e.g. N131f536, Korinita Sandstone, Wanganui River) have few benthonic species but a high foraminiferal number (Fig. 14). Such abrupt increases in abundance with decrease in number of species may exceptionally result from downslope transport or current sorting, but these processes typically give increased diversity. More likely is that the high foraminiferal numbers result from opportunistic species, species which because of their adaptation to a wide range of environmental fluctuations and potentially high intrinsic rate of reproduction may increase explosively in abundance under suitable conditions (MacArthur, 1960). Such species are normally not resource limited, but are controlled instead by biotic pressure. In Wanganui Basin, temporary restriction of current flow to the basin floor or exceptionally high sedimentation rates may have inhibited most benthonic species and allowed expansion of opportunistic species. Common foraminifera

in such faunas are Bulimina aculeata d'Orbigny, Evolvocassidulina orientalis (Cushman) and Cassidulina carinata Silvestri. These species all have wide geographic and environmental tolerances.

Opportunistic species are usually characteristic of young environments of high physiological stress where animal communities are physically controlled (Levinton, 1970), such as Wanganui Basin undoubtedly was during the Pliocene. Opportunistic species are rare in older communities, where the ecosystem is regulated more by biological factors.

The increase in abundance and variety of benthonic foraminifera at the top of the Mangaweka Mudstone in the Wanganui River section (Fig. 14), when depths remained consistently shallow, probably resulted from a combination of several factors:

1. general shallowing of the basin allowing spread of shallow water forms, as discussed below;
2. despite shallow depths, increased abundance of planktonic foraminifera indicates more "open sea" conditions prevailing, possibly caused by lowering of offshore bars or islands which previously separated the basin from the open ocean; and
3. the presence of hard-bottom biotopes, such as greywacke reefs, diversifies the fauna of a region by increasing the number of ecological niches available. Especially important, such hard bottoms provide a point of attachment for algae, which support many foraminifera, and allow different environments, and hence faunas, to exist in close proximity. Angular greywacke fragments in the Wilkies

Shellbed on Rangitatau Escarpment indicate the presence of basement ridges above sea level at the time of deposition.

Transport by currents is not a satisfactory explanation for the great diversity of the faunas, as foraminifera of all sizes are present in the samples.

Significance of Fauna

Depths of deposition have been determined by reference to the Biofacies Concept developed for the New Zealand Tertiary by Vella (1963a,b,c). Generally, faunas can readily be assigned to a particular biofacies, and often to shallow or deep phases of a biofacies. Large fluctuations in depth are clearly apparent.

Three inner neritic biofacies have been defined (Vella, 1963a,b,c): Ammonia (=Streblus) Biofacies, 0-17m, estaurine; Zeaflorilus (=Pseudononion) Biofacies, 0-7m; and Elphidium Biofacies, 7-ca.70m. Much of the Pliocene and early Pleistocene sedimentation in Wanganui Basin occurred within the depth range of the Elphidium and Zeaflorilus Biofacies. Various different microfossil assemblages can be distinguished within each of these generalised biofacies, and they evidently reflect variations of environmental conditions, including depth. Their significance will not be understood, however, until the ecologies of N.Z. Recent foraminifera have been more fully examined. At present, mollusca allow more reliable and subtle definition of past inner neritic environmental conditions. In deeper water sediments, certain long-ranging but generally rare species show a pattern of occurrence that is exemplified by

Nodosaria lammulifera. This species occurs through 100m of section comprising the top of the Taihape Mudstone and the mudstone layers in the lower Korinita Sandstone at Wanganui River, but not elsewhere in that section. The limits of its occurrence are not marked by any change in lithology or faunal association. As in the shallow water biofacies, study of Recent ecology and a thorough knowledge of the limiting factors is needed before the significance of such species can be evaluated.

Arenaceous foraminifera are generally rare. Comparison of Wanganui Basin faunas with those recorded by Vella (1957) and Lewis (1972) reveals that the fossil faunas lack many genera and species, probably the more fragile forms which readily disintegrate during fossilisation.

High percentages of arenaceous foraminifera are reported in many environments, ranging from brackish water, inhabited by arenaceous species with simple interiors such as Ammobaculites (Bandy, 1956), down to bathyal depths where species such as Cyclammina with complicated interior structure predominate (Akers, 1954). Lowman (1949) considered shallow, stagnant, brackish waters more likely to develop abundant arenaceous populations than well aerated waters. In the Gulf of Mexico, arenaceous foraminifera reach their greatest relative abundance in areas of low CaCO_3 availability, that is, in low temperature, low salinity environments (Greiner, 1969, 1970). The greatest relative abundances of arenaceous forms in Wanganui Basin are in the Opoitian and Waipipian of the Wanganui River section (Fig. 14). The sediments represent the

greatest depths reached in the basin. Calcareous benthonic foraminifera are also abundant and diverse, and do not show the tendency to thin-shelled forms which is a characteristic of species in waters of low oxygen content (Harman, 1964). Abundance peaks of arenaceous species in very shallow water sediments, however, may represent temporarily brackish conditions (Figs. 14, 20).

The alternating estuarine and marine conditions postulated for deposition of the Rangikura Sandstone and probably for much of the Waverley Formation (Fleming, 1953) indicate that the shallow water foraminifer Ammonia aoteana (Finlay) should be common. Other shallow water species such as Zeaflorilus parri (Cushman) are large and abundant through much of the Waverley Beach and Wilkies Bluff sections, but Ammonia is present as rare, small specimens in only two samples from this region, N137f667 (Snapper Point Conglomerate) and N137f680 (Wilkies Shellbed at Rangitatau Escarpment). Similarly, in the Wanganui River section Ammonia and Zeaflorilus are both very rare in sediments immediately above and below the Ahuahu Sandstone, which grade through very shallow water deposits. In all sections, Zeaflorilus, together with discorbids and Dyocibicides spp., does not become common until towards the top of the Mangapanian Stage, and Ammonia is not common until the Hautawan or Nukumaruan.

Reasons for the absence of Ammonia from apparently suitable environments may include:

1. Fully saline, deep water conditions throughout the stratotype sections. This is unlikely and contradicts both the molluscan and lithologic evidence. Transport of mollusca from estuaries elsewhere

would almost certainly be accompanied by transport of Ammonia.

2. Unsuitable lithofacies. The shallow water sediments consist mainly of siltstones and muddy sandstones, often with abundant benthonic foraminifera. Ammonia aoteana has been recorded from Manukau Harbour living commonly on fine sand and mud (Hulme, 1964, tables 1,2: as Streblus) and Hedley et al (1967) describe it as a common shallow water and intertidal species around New Zealand coasts at the present time. It is common as large specimens down to at least 10m in Wellington Harbour (pers. obs.), and Lewis (1972) records it as fairly common on the inner shelf off southern Hawkes Bay, living in 18-48m. Related species in other parts of the world are typical of lagoons and inshore waters (Phleger, 1960). Bottom conditions thus appear to have been suitable for Ammonia, and it became large and common in similar sediments in the area in Castlecliffian time (Cameron, 1966).

3. Isolation of the area from other shallow water areas with populations of Ammonia. Although the A. beccarii group of species achieved world-wide distribution, including migration to New Zealand, in the Upper Miocene (Hornibrook, 1968), details of the rate or mechanism of their spread are not known. Initial subsidence of much of Wanganui Basin may have been too rapid to allow colonisation of the remaining shallow water areas by Ammonia, while still allowing the invasion of certain other shallow water foraminifera and mollusca. Maintenance of the western part of the area as an uplifted tectonic block surrounded by relatively deep water and with currents possibly unfavorable to the spread of shallow water organisms, would have helped to exclude Ammonia.

4. Unfavorable temperature. Bradshaw (1957) has studied the effect of temperature change on laboratory cultures of A. beccarii and found that growth ceases below 10°C . Temperature tolerances of A. aoteana are not known, but the species ranges from Whangaparoa in the north to Portobello in the south (Hedley et al, 1967). Garner (1969) gives bottom temperatures on the continental shelf in the region of Portobello as 10°C in Winter and $12-13^{\circ}\text{C}$ in Summer, and the range of the species further south may be limited by temperature. Cool Waipipian temperatures proposed by Jenkins (1964, 1967a, 1971b), Mildenhall and Harris (1970) and Devereux et al (1970) are supported by the present study. Devereux et al gave oxygen isotope paleotemperatures ranging between 6°C and 10°C for bottom water at Mangaopari Stream, Wairarapa, but depths involved ranged from upper slope to mid shelf. More significant for Ammonia was the near surface water temperature which ranged between 9°C and 14°C .

Associated Microfossils

Together with foraminifera in Wanganui Basin sediments are found radiolarians, diatoms, spicules and sterrasters of sponges, ostracodes, fish teeth and selachian dermal denticles.

Radiolarians and diatoms are sporadic in distribution, though usually more common in deeper water samples. Sponge spicules and sterrasters are common throughout, and the latter are often present in samples of very shallow facies that are barren of other fossils. Ostracodes are rare or absent from the deeper samples, but common in many Elphidium and Zeaflorilus Biofacies samples and abundant in the shellbeds.

Small (0.6-0.8mm) microfossils identified as selachian dermal denticles have been found in sample N132f576 from the Waipipian upper Taihape Mudstone at Rangitikei River. Denticles consist of a basal plate, or root, joined by a pedicel to the anterior part of the crown. Two distinct morphotypes are present in N132f576, in about equal proportions. The first type has a smooth, ovate crown which lacks ornament and thins posteriorly (Pl. 10, figs. 201-203). The other type is basically ovate and smooth, but with from three to five keels projecting posteriorly as short spines (Pl. 10, figs. 204-206). Both forms are amber in colour and translucent, with an inner network of tubules ramifying outwards through the crown from the point of attachment of the pedicel. Denticles in living sharks consist of dentine surrounded by enamel, with an overall composition of apatite plus an unidentified mineral which is probably either whitlockite and/or octocalcium phosphate (Urist, 1961). X-ray analyses of the Pliocene specimens showed apatite to be present (Miss T. Sledzinska, pers. comm.).

Denticles are modifications of the placoid scale, closely related to shark teeth, and have been found in sediments ranging in age from Devonian to Recent (Daniel, 1934; White, 1937). The limits of their variation in each species are not known, and they vary both with position on the body and with the age of the shark (Applegate, 1967). Thus, it is usually necessary that both of these facts are known before precise taxonomic identification is possible. Flattened and smooth denticles are prevalent on the snout, head and anterior parts of the fins, presumably to deflect water, whilst denticles from the sides of the fins and from the body are more often keeled, to aid in directing current

flow (Applegate, 1967). It is therefore probable that both types of denticle figured here are from the same shark. They resemble denticles figured for several species of galeoid sharks (Bigelow and Schroeder, 1948), and sharks of this type are common in New Zealand coastal waters at the present day.

Predation on Benthonic Foraminifera

Several authors have noted the effects of attack on foraminifera by various types of boring predators, which include gastropods (Livan, 1937; Reyment, 1966; Vyalov and Kantolinskaya, 1968), nematodes (Sliter, 1971) and a rotaline foraminifer (Banner, 1971). Borings in a specimen of Nonionellina flemingi (Vella) are illustrated in Pl. 12, figs. 1a-c. Borings have also been observed in specimens of each species of Notorotalia discussed in Section VI, and are visible in the illustrations of N. briggsi n.sp. (Pl. 12, figs. 2a,b), N. finlayi Vella (Pl. 21, figs. 1a,b), N. olsoni Vella (Pl. 26, fig. 1b), N. taranakia Vella (Pl. 24, fig. 2c) and N. zelandica zelandica Finlay (Pl. 27, figs. 103). Sliter (1971) showed that the ecologic rule of predators most commonly attacking the most common organisms was valid for his living foraminiferal populations. A similar predator-prey relationship would explain the widespread borings in specimens of Notorotalia, which are often the dominant foraminifera in Upper Cenozoic shallow water faunas. In faunas where Nonionellina flemingi is very abundant, it too is often extensively bored while related species of the same size which are less common are untouched.

PLATE 12

Scanning electron micrographs, oblique views.

Fig. 1. Nonionellina flemingi (Vella). VF1095.

- 1a, view of tilted specimen, showing holes bored in test, x285;
- 1b, enlargement of borings in early chambers, with the edge of one boring partially bevelled, x425;
- 1c, further enlargement of boring in above area, x2160.

Fig. 2. Notorotalia briggsi n.sp. VF1060.

- 2a, ventral surface, showing bored holes (arrowed), x185;
- 2b, enlargement of borings in final chamber, x870.

1a

1b

1c

2a

2b

The figured specimens of Notorotalia zelandica zelandica show common large borings on the dorsal side (up to 8 per chamber), most of which are located on the sites of sutural pores (Pl. 27, figs. 2a, 3a,b). The borings range in diameter from 11.0 to 14.0 μ and most have a bevelled edge (Pl. 27, fig. 3b,i). Incomplete borings with flat floors (Pl. 27, fig. 3b,ii) and borings where regeneration of the test appears to have commenced (Pl. 27, figs. 3b,iii) are also visible. Smaller borings (1.5 to 4.0 μ in diameter) are randomly distributed over both surfaces of the test (Pl. 27, fig. 1b).

At least two different predator species appear to be responsible for this massive attack upon many tests of N. zelandica zelandica. The large borings are on the upper surface of the test, which is exposed when the Notorotalia is in its aperture-down living position, and the sutural pores on which they are sited represent weak points in the test. The bevelled edge is considered by Jensen (1951), Reymont (1966) and others to be characteristic of gastropod drilling, and the relatively large, flat, exposed and undoubtedly stationary or slow-moving dorsal surface of N. zelandica zelandica would provide a suitable target. However, the size and number of borings do not agree with known instances of gastropod predation (Carriker, 1957; Carriker and Yochelson, 1968).

The smaller holes appear to be due to a different organism or organisms, and their presence on both sides of the test indicates either that the predator inhabited the upper layers of the sediment as well as the surface, or that the borings were made in empty tests subject to current action.

Myers (1943) observed nematodes with larval stages and eggs inside the tests of living specimens of Elphidium crispum (Linné) from Plymouth Sound, England, but did not mention how the nematodes entered the test. Sliter (1971) observed nematodes inside bored chambers of Rosalina globularis d'Orbigny, from southern California, and considered them responsible for the borings. I have observed nematodes to be abundant in association with species of Notorotalia in Recent shallow water sediments from various sites in southern North Island, New Zealand, and these could be the predator in this case. However, little is known of the ecology of living foraminifera, and most phyla include small boring species (Boekschoten, 1966) many of which might be responsible for the borings observed on Notorotalia.

Elongate, narrow sinuous grooves crossing the final chamber of Elphidium novozealandicum (frontispiece) closely resemble the grooves on Dentalium sp. illustrated by Boekschoten (1966), Pl. 1), and attributed by him to the activities of algae.

Planktonic Foraminiferal Paleocology

Pliocene planktonic faunas from Wanganui Basin closely resemble Recent faunas described from the New Zealand Continental shelf by Kustanowich (1963) and Eade (1967a), both in the species present and in their relative abundance.

Kustanowich (1963) described the marked latitudinal variation in planktonic foraminiferal faunas in the south-west Pacific Ocean and

recognised 6 distinct faunal zones, with the number of species present varying from 33 in the north near Fiji to 6 south of New Zealand. Species typical of Kustanowich's Central Zone, which encompasses most of New Zealand except for the far north and south, are common Globigerina bulloides, Globorotalia inflata and G. truncatulinoides, with less abundant Orbulina universa, Globigerina pachyderma and Turborotalita quinqueloba. Globigerina pachyderma and Turborotalita quinqueloba become more abundant to the south. Occasional northern immigrants include Globigerinella siphonifera, Globorotalia crassaformis, Globigerinoides conglobatus and G. ruber.

The Pliocene fauna is similar, except for the extreme rarity of Globorotalia truncatulinoides as a fossil and the presence of the extinct species Globigerina decoraperta, Globorotalia puncticulata and Globigerinoides trilobus.

The poverty of most Pliocene planktonic faunas is attributed to the following factors:

1. turbid water resulting from the high sedimentation rate in the basin;
2. the shallowness of the offshore area, possibly with emergent banks and islands deflecting oceanic water masses; and
3. low salinities caused by fresh-water run-off from the neighbouring land areas.

The shallow basin threshold would have restricted entry of forms known to indicate deeper water, including Globorotalia scitula (Bé and Hamlin, 1967) and heavily calcite-encrusted individuals of various species (Bé and Lott, 1964; Bé, 1965). Present day prevailing winds are moist north-westerlies (Fleming, 1953), and the presence of a similar air-stream during the Pliocene would have given greater run-off into Wanganui Basin than into east coast basins lying in the rain-shadow of the axial ranges.

Because of this sporadic nature of planktonic assemblages, only broad trends on the graphs can be interpreted. The present-day changing relative abundance of species in transects from tropical to colder waters are similar both north and south of the equator (Kustanowich, 1963, fig. 5; Ingle, 1967, fig. 24). However, trends in relative abundance of planktonic species through Wanganui Basin sections resemble more closely the faunal change from deep to shallow water off southern California (Ingle, 1967, fig. 28). The main feature is increasing importance of the Globigerina bulloides group of species, reflecting the overall shallowing of the basin. Turborotalita quinqueloba is common, usually constituting 5-20% of the total faunas. This species is considered to prefer shallow, relatively sheltered coastal waters (Kustanowich, 1963, Ingle, 1967).

Paleoclimates

Inferences from Planktonic Foraminifera

In Wanganui Basin, the clearest paleoclimatic data is obtained from the direction of coiling of Globigerina pachyderma. In both the Rangitikei River and Saddle Road sections, a rapid climatic deterioration is indicated at the base of the Molestus Zone, correlated with the base of the Waipipian Stage (Figs. 19, 26). The cooling appears to have been sudden and to have lasted through most of the time represented by the Molestus Zone. It was followed by warmer conditions beginning in the uppermost Molestus Zone and continuing through the Finlayi Zone. Temperatures do not appear to have regained the high level indicated for the upper part of the Hurupiensis Zone (Opoitian). Similar cold Waipipian climates are reported by Jenkins (1964, 1967a, 1971b), Lewis (1968), Lewis and Jenkins (1969), Devereux et al (1970) and Mildenhall and Harris (1970). From other parts of the world, mid-Pliocene cooling has been reported by Bandy (1960), Ingle (1967) and Frerichs (1971). Correlation with paleomagnetic stratigraphy enabled Kennett et al (1971) to date the duration of the New Zealand mid-Pliocene cooling as from 2.54 to 2.28 million years B.P. In other regions radiometric dates place a cooling at between 5 and 10 million years B.P. (Yeats, 1965; Ingle, 1967). Bandy (1969) and Bandy and Wilcoxon (1970) suggest that some radiometric dates from California may be several times too great, but their correlation may be incorrect.

The sudden onset of the Waipipian cooling in Wanganui Basin parallels that shown by Devereux et al (1970), who place the initial cooling at or near the base of their Finlayi Zone which seems to correspond to the base of the Molestus Zone of this report.

The presence of cold water molluscs led Fleming (1953, 1962) to place the Pliocene-Pleistocene boundary in New Zealand at the base of the Hautawan Stage. Further evidences of cooling at that level have also been recorded by Jenkins (1964, 1967a, 1971b), Beu and Maxwell (1968), and Devereux et al (1970), but in the present study, such evidence was found only in the Saddle Road section (Fig. 26) and even there it was weak. No evidence of marked climatic change is discernible in samples crossing the presumed Pliocene-Pleistocene boundary in Rangitikei River and Watershed Road sections, although most of these samples contain abundant Globigerina pachyderma (Figs. 19, 22).

G. pachyderma constitutes approximately the same percentage of the total fauna throughout each section, with no increase in abundance matching the increase in sinistral forms. The occurrence of G. pachyderma is therefore considered to be controlled by factors other than climate alone.

Subtropical species are present in occasional samples and do not correlate with inferred temperature change. The tropical-warm subtropical species Globorotalia menardii, however, is found only in an Opoitian sample from Wanganui River, representing the time when water temperatures were highest.

Mean Length of Nonionellina flemingi

The mean length of populations of Nonionellina flemingi (Vella) have been measured from 4 sections in all samples where the species is sufficiently common (Fig. 29). Mean size, standard deviation of the mean and number of specimens measured are given in Tables 17, 19, 21 and 25 (in appendix).

Fig. 29 indicates random response to temperature, with populations showing size increases at different levels in each section. Lewis and Jenkins (1969, Fig. 9) show N. flemingi reaching greatest mean size in Waipipian samples from Waverley Beach, results confirmed in the present study (Fig. 29A). Lewis and Jenkins doubted that this increase was the result of current sorting. In the other sections, increase in size in the Waipipian was found only in the Saddle Road section (Fig. 29D). Both Wanganui River and Rangitikei River sections show increase in size in the middle Mangapanian and above, correlating with the decrease in depth of deposition. In the lower parts of these two sections, where depths of deposition are generally below the ecologic range of N. flemingi, only rare, consistently small specimens are present.

Lewis and Jenkins (1969) considered N. flemingi to show no appreciable change of size with depth in any one locality, at least on the upper continental shelf. The small, deeper-water Pliocene specimens found by the writer were possibly transported down the continental shelf from normal populations in shallower water or alternatively represent stunted individuals living at the extreme limit of the range of the species, at greater depths than those sampled in

Fig. 29 - Mean length of Nonionellina flemingi (Vella)
in populations from 4 Wanganui Basin sections.
Sample numbers as in Figs. 5, 7, 13, 17 and 24.
Open circles denote samples with insufficient
specimens for statistical reliability.

WAVERLEY BEACH - WILKIES BLUFF

WANGANUI RIVER

RANGITIKEI RIVER

SADDLE ROAD

Recent sediments by Lewis and Jenkins (1969). Lewis and Jenkins considered that unusually large specimens of N. flemingi from Manukau Harbour samples (Hulme, 1964) might result from low salinities in areas subject to large influxes of freshwater. Populations with large mean size found at various stratigraphic levels in Wanganui Basin, usually in shallow-water sediments, could have resulted from the same cause.

It is concluded that although the inverse relationship between mean population size and temperature has been well documented for Recent populations of N. flemingi, it is only likely to be of paleoclimatic value in sedimentary sections representing deposition in a shallow environment lacking strong current action and sub-saline conditions. In Wanganui Basin, measurement of populations of N. flemingi gives results that vary unsystematically and conflict with other paleoenvironmental data.

Other Benthonic Foraminifera

Recent Antarctic species which are not found living around New Zealand but which are present in Wanganui Basin sediments include Heronallenia wilsoni (Heron-Allen & Earland) and Laticarinina coronata (Heron-Allen & Earland). Heronallenia wilsoni appears first in Waipipian strata, and is present in occasional samples in the Waipipian and Hautawan. Laticarinina coronata, recorded by Hornibrook (1961) as present in New Zealand sediments from Lower Eocene upwards, occurs in Wanganui Basin in the Hautawan. Its possible climatic significance through the rest of the Cenozoic has not been investigated.

Hyalinea balthica, the incoming of which defines the base of the Calabrian Stage in the stratotype at Santa Maria di Catanzaro, Italy, and in the stratotype of the Italian Pleistocene at Le Castella (Gignoux, 1910, 1913), is regarded as a cool-water to cold-water indicator (Emiliani et al, 1961; Flint, 1965; Bock, 1971). A similar form, H. cf. balthica, is recorded in two samples from the Waipipian of Wanganui River.

Discussion

Coiling direction in G. pachyderma perhaps may on occasion vary independently of temperature. At Mangaopari Stream Devereux et al (1970) recorded several anomalous horizons at which coiling ratios disagree with isotopic and relative abundance data. Mayr (1963) considered that direction of coiling of the shell of a mollusc or foraminifer in relation to temperature is a result of versatile pleiotropic manifestations of a single gene or supergene rather than the result of linkage of the coiling allele and the gene giving superior viability at certain temperatures. Such a linkage, he argued, would soon be terminated by crossing over. Pleiotropy is the capacity of a gene to affect several aspects of the phenotype and it is conceivable that occasional hereditary or environmental combinations could result in the coiling direction of G. pachyderma being determined by factors other than temperature.

Data from coiling ratios of G. pachyderma indicates that temperatures were relatively high during Opoitian times, deteriorating

very rapidly at the beginning of Waipipian time with an accompanying rapid and substantial shallowing that may represent a drop in sea level. The following cold period lasted for most of the Waipipian age. Temperatures then increased to a moderate level. No evidence of a temperature change or substantial drop in sea level can be detected across the Mangapanian-Hautawan Stage boundary (the presumed Pliocene-Pleistocene boundary).

The cool Waipipian temperatures, and the rapidity of their onset, are in accordance with data presented by other investigators in New Zealand. This climatic change strengthens correlation of the Molestus Zone with other zones defined on the incoming of Notorotalia finlayi elsewhere in New Zealand, and also with the Waipipian Stratotype. Kennett et al (1971) determined the paleomagnetic stratigraphy of the paleoclimatic trends of Devereux et al (1970), and place the base of their Finlayi Zone (and contemporaneous cooling) 40m below the top of the Gauss Normal Geomagnetic Epoch.

Lack of temperature change across the Pliocene-Pleistocene boundary is in agreement with the concept of a pre-glacial Pleistocene as recognised by Selli (1967) and Bandy and Wilcoxon (1970), but at variance with published New Zealand data. The presence of Chlamys delicatula, an undoubted cold-water mollusc (Pantin, 1963), at this stratigraphic level in the Hautawa Shellbed strongly suggests cool temperatures. It is possible that the coiling ratios of Globigerina pachyderma at this time did not faithfully reflect climate, either because of genetic effects as discussed above or because of the entry

of warm currents into the basin from the Tasman Sea displacing colder currents, but present data is insufficient to resolve this anomalous situation.

Paleogeography

Inferred South Wanganui Basin Paleogeography

Paleogeographic interpretation is limited by the lack of surface geological control in the southern part of the area, and is hindered by the complex tectonic history which has had a marked effect on sedimentation.

The Number 1 Reef of the Waiouru Sandstone persists from Wanganui River east across Wanganui Basin to the west flank of the Ruahine Range (Superior, 1943). This shellbed, and the consistently shallow water nature of the Waiouru Sandstone, indicate that the area was near sea-level with very little relief in earliest Pliocene and possibly late Miocene times. The region that now includes the Wanganui and Rangitikei Rivers subsided rapidly early in the Pliocene, and the Taihape Mudstone was deposited over a wide area (Fig. 30). The axis of this subsidence was near the present site of the Wanganui River, indicated by the deepest facies and greatest thicknesses of sediment, and subsidence at the axis was much faster than deposition. An unnamed sequence of sands in the corresponding part of the Mangawhero River section were not examined during the present study, but may represent either a bank or slumped shallow water deposits. Deposition of mudstone in Wanganui

Fig. 30. - Suggested correlation of Pliocene formations
across South Wanganui Basin. Lithology taken
mainly from Superior (1943, stratigraphic
column).

River was interrupted by a number of sand layers, the Korinita Sandstone, which are inferred to have slumped from a shallow area west of the Wanganui. At an equivalent horizon in the Rangitikei and Turakina Rivers, the Utiku Sandstone is a sand body extending from shallow water sediments on the eastern side of the basin and becoming finer-grained and thinner towards the centre of the basin. These sand units are approximately equal to the Waipipian Stage, and may represent sands displaced during a period of low sea level.

Deposition of the Mangaweka Mudstone occurred across the basin during the late Pliocene. By this time the axis of subsidence had moved eastward to the vicinity of the Mangawhero River. A feature of sedimentation in the western side of the basin was the rapid oscillations of depth and the greater amount of coarse material deposited, while the eastern side was more stable and shallowed regularly both with time and towards the eastern ranges.

Towards the end of Pliocene times, the entire basin shallowed and sediments above the Mangaweka Mudstone show little variation in depth. The greatest depth, and the probable axis of the basin during the early and middle Pleistocene, was in the vicinity of the Turakina River (Fleming, 1953).

During the Pliocene the basin was bounded to the east by the emergent Ruahine Range. It was connected to the sea east of the ranges through the Manawatu Saddle area, and at points further north, as evidenced by the presence of Pliocene marine sediments (Kingma, 1957b, 1962). The facies representing the Waipipian and Mangapanian

in the Waitotara River and coastal sections indicate that shallow water and perhaps sometimes land existed along the site of the Patea-Tongaporutu High. Lack of Opoitian sediments in the coastal sections indicates land in the early Pliocene. As anticlines in South Wanganui Basin appear to have resulted from faulted and uplifted basement blocks (Superior, 1943; Te Punga, 1957b), it is inferred that the seaward edge of the basin was controlled by a similar type of structure. The area to the west and south-west was probably bounded by a series of islands formed by raised NE-SW trending basement blocks, similar to Kapiti Island which is strongly faulted on its eastern margin (Fleming and Hutton, 1949). A granitic landmass west of the present North Island at various times during the Tertiary has been proposed to account for mica (Marshall and Murdoch, 1920) and acid plutonic and metamorphic rocks (Fleming, 1953) in Wanganui Basin sediments. Land connections between the Wellington and Marlborough regions were postulated for the early Pliocene (Grant-Taylor and Hornibrook, 1964) and late Pleistocene (Te Punga, 1953b,c).

Seismic profiles of the southern part of the area (Superior, 1943), together with data from the three wells drilled which all penetrated greywacke at relatively shallow depth, indicate that such raised basement blocks may be common over this part of the basin. Seismic data for the area north of Marton is lacking, but Superior's work suggests that it has less basement relief than further south.

The main area of subsidence of the basin was bounded by a southern line between Manawatu Saddle and Wanganui, by the western flank of the

Ruahine Range, and by a line approximately following the present course of the Waitotara River to the west. The northern limits cannot be determined but lack of Pliocene marine sediments in inland Taranaki suggests the existence of land near Taihape or slightly further north (Fleming, 1953).

At the present time, different current patterns exist on either side of the North Island. To the east, the Subtropical Convergence lying across the Chatham Rise separates the warm East Cape Current from southern subantarctic waters (Garner, 1954, 1959 ; Kustanowich, 1963). Devereux et al (1970) have proposed migration of the convergence zone to the north during cold periods and southwards during warm periods, a mechanism whereby even slight climatic fluctuations might give strong temperature oscillations in the region over which the convergence passed. On the western side of New Zealand, the Subtropical Convergence lies further south, near Stewart Island, and the entire west coast is bathed by the warm Tasman Current, which is part of a major current system flowing south along the east coast of Australia, then passing westwards across the Tasman Sea as several streams at varying depths (Hamon, 1961, 1965; Wyrski, 1962). A similar current pattern during the Pliocene would mean relatively warmer temperatures on the western side compared with the eastern side of the North Island. It is possible that during the Pliocene eastern water flowed into Wanganui Basin through Manawatu Strait and other existing channels. If the Subtropical Convergence were far enough north, subantarctic water could then penetrate the Wanganui Basin. This could account for the cold-water

planktonic foraminiferal faunas in the Waipipian Stage. Towards the end of the Pliocene, restriction of the straits by increased rate of uplift of the axial ranges would have cut off the flow of water from the east. At the same time, lowering of the western island barrier would have allowed warm currents from the Tasman Sea to stabilise the temperature of the basin.

Existing Models for this Concept

Two regions provide models for the Pliocene paleogeography envisaged for Wanganui Basin.

Benthonic foraminifera from the Okhotsk Sea have been studied by Saidova (1957, 1960; English summary in Loeblich and Tappan, 1964, pp. C121-24), and planktonic foraminifera by Lipps and Warne (1966). The Okhotsk Sea is an almost completely enclosed basin bounded by mainland Russia, Kamchatka Peninsular, the islands of Sakhalin and Hokkaido, and the Kurile Islands. The sea has a maximum depth of 3657m, and the Kurile Islands form a barrier between the Okhotsk Sea and the Pacific Ocean, the deepest passage being 2318m. Ways in which the Okhotsk Sea resembles Wanganui Basin are:

1. depths in the shelf area are all less than 75m but the benthonic assemblages vary greatly in species and specimens;
2. coarser bottom sediments have much more abundant faunas than finer bottom sediments at the same depth and temperature;
3. arenaceous species are rare, even in the deeper assemblages;
4. only seven species of planktonic foraminifera are recorded from the sea, and planktonic specimens are usually absent or nearly so

from the nearshore areas;

5. circulation into the sea is restricted by the Kurile Islands, and salinities are reduced by run-off from the adjacent land.

Similar geographically is the Andaman Sea, where an area bounded by the Malay Peninsular, Irrawady Delta and Sumatra is separated from the Bay of Bengal by the island arc chain of the Andaman and Nicobar Islands (Weeks et al., 1967). Planktonic foraminiferal distribution in sediments is controlled by surface salinity, water depth, diagenesis and topography (Frerichs, 1970). Large volumes of fresh water entering the northern Andaman Sea from the Irrawady River result in the exclusion of planktonic foraminifera from this region.

Both these examples are of basins of deposition bounded on three sides by land masses or large islands, and separated from oceans by island chains. Ocean currents passing into the basins are modified in flow by the barriers, and planktonic foraminifera are often sporadic in distribution or absent. Most other aspects of foraminiferal ecology resemble trends observed in Wanganui Basin sediments, except those, such as solution of tests, which are characteristic of deep or tropical waters, and South Wanganui Basin during the Pliocene is considered to have been similar to the Andaman and Okhotsk Seas, but smaller and shallower.

A similar cycle of shelf-type conditions deepening to bathyal facies (1000-2000m), followed by basin filling and transition to paralic facies is recorded in Cenozoic strata in several Philippine basins (Bandy, 1963).

Sedimentation

Table 12 shows comparison of foraminiferal numbers recorded from South Wanganui Basin sediments with those published from other areas.

Table 12. - Comparison of foraminiferal numbers from South Wanganui Basin and other localities.

Locality	Foraminiferal Number
South Wanganui Basin	
Stratotype sections	0-1331
Wanganui River section	0-915
Rangitikei River section	0-2380
Watershed Road section	0-1056
Saddle Road section	0-256
Miocene-Pliocene of S. California (Ingle, 1967)	0-40,000
Southern Hawkes Bay, N.Z., Recent (calculated from Lewis, 1972)	19-800
Laguna Beach outfall area, California (Bandy <u>et al.</u> , 1964).	20-100
West Coast of Central America (Bandy and Arnal, 1957)	0-10,000
Peru-Chile Trench area (Bandy and Rodolfo, 1964)	0-14,000

The foraminiferal number will, of course, depend both on the productivity of the fauna and on the rate of sedimentation. The productivity cannot be estimated for fossil faunas. However, the low Wanganui Basin foraminiferal numbers indicate a high sedimentation

rate. This is supported by the often coarse nature of the sediments, together with thick beds of possibly slumped origin.

Calculations of the rate of sedimentation have been made for the interval between the Hautawa Shellbed and the Hurupiensis-finlayi Datum. Kennett et al (1971), by comparison with the paleomagnetic time scale and established geochronology, place the base of their Finlayi Zone at about 2.54 million years B.P. and the Pliocene-Pleistocene boundary at 1.79 million years B.P. Assuming correlation of the incoming of Notorotalia finlayi and, less certainly, the Hautawa Shellbed with the Pliocene-Pleistocene boundary as recognised in Wairarapa, the interval spans some 0.75 million years. During this time, the following thicknesses of sediment were deposited: Wanganui River section, 1400m, and Rangitikei River section 1260m; giving average sedimentation rates of 1.8m and 1.7m per thousand years respectively. Comparable rates (1-4m per thousand years) have been recorded from the middle part of the continental shelf off southern Hawkes Bay (Lewis, 1972).

Petroleum Exploration

Little further petroleum exploration can be conducted in South Wanganui Basin without detailed geophysical surveys and stratigraphic test drilling in areas lacking Pliocene outcrops. The present study has raised several points, however.

The presence of a possible offshore basement ridge throughout the Pliocene and Pleistocene would hinder migration of petroleum into

Wanganui Basin from source rocks offshore. Within the basin itself, restricted faunas are unfavorable indications of source rocks and only the Taihape Mudstone has potential (Superior, 1943). Most, if not all, anticlines appear to result from rising basement blocks (Te Punga, 1957b) and wells drilled upon them penetrated a shallow water section before reaching greywacke at relatively shallow depth (Superior, 1943; Champlin, 1964; Dunlap, 1964). Further investigation, therefore, should be directed towards very thick sections on the flanks of these structures, and towards the area to the west. Stratigraphic traps may exist against the flanks of the Basement blocks, and the basin may possibly connect with the South Taranaki Bight to the south-west. Complicated distribution can be expected of any petroleum encountered, as freshwater reported at depth in both Stantiall-1 and Young-1 (Superior, 1943) indicates freshwater flushing of the sediments (Katz, 1968). Solution and transportation of hydrocarbons in formation water is considered responsible for the migration and accumulation of crude oil and natural gas in the Surat Basin, Queensland (Conybeare, 1970), and is important in many oilfields in the United States (Beal, 1917; Hubbert, 1940; Goebel, 1950; and others). The uplift and tilting of the northern and eastern perimeters of the basin since the Pliocene is also important.

Summary

1. During the Pliocene, the Wanganui region is inferred to have been a basin of deposition surrounded by major land areas to the north and east, and possibly to the south, and separated from the Tasman Sea by an island chain. It probably resembled the present-day Okhotsk and Andaman Sea areas.
2. Planktonic foraminifera in the basin were restricted by turbid water and low salinities, and their distribution and entry into the basin was controlled by the effect of the surrounding land masses on water movement.
3. Benthonic foraminiferal distribution was affected by the rapid sedimentation rates and depth changes. Many species were opportunistic.
4. Rapid subsidence began in the early Pliocene and reached its maximum by middle Pliocene times. Less rapid shallowing followed, the basin becoming uniformly shallow in the Pleistocene.
5. Currents entering the basin through Manawatu Strait appear to have been important during the early Pliocene, and decreased in importance with time.
6. Coiling ratios of Globigerina pachyderma, with supporting evidence from other species, indicate a cold Waipipian period but no strong climatic change at the Pliocene-Pleistocene boundary.
7. Sedimentation rates were approximately equal to those of Recent sediments off the east coast of the North Island.

SECTION VI

SCANNING ELECTRON MICROSCOPE STUDIES OF THE SHELL SURFACE
STRUCTURE OF SOME SPECIES OF BOLIVINA AND NOTOROTALIA

INTRODUCTION

The scanning electron microscope enables accurate illustration of foraminifera, simplifying comparison of specimens from different areas and the examination of surface detail.

Many species of the genus Bolivina have complex morphology, and a number have cosmopolitan distribution. Nine species, of which three are new, are discussed and illustrated. New Zealand specimens of Bolivina compacta Sidebottom, B. pseudoplicata Heron-Allen and Earland and B. subexcavata Cushman and Wickenden are compared with stereoscan illustrations of the same species from off southern California and northwestern Mexico (Sliter, 1970). Sliter compared his specimens with holotype, paratype and/or plesiotype specimens of each species, which allows indirect comparison of the New Zealand foraminifera with type material.

The genus Notorotalia comprises another group of intricately ornamented foraminifera, which form an important part of the New Zealand Cenozoic benthonic fauna and which are almost endemic to this region (Hornibrook, 1961). A stratigraphically and ecologically important group, their study has been hampered by the difficulties of observing and illustrating the morphology. The present study of seven taxa, including one new species, confirms some previous work and provides several new observations.

Most specimens illustrated are fossils from Pliocene-Pleistocene sediments of Wanganui Basin. Specimens of Bolivina plicatella were selected from Hawkes Bay Pleistocene sediments, and B. compacta,

B. pseudoplicata and Elphidium novozealandicum from Recent sediments in Wellington Harbour, because of their superior state of preservation. Only the type reference is given for each species. Fuller synonymies, distribution, and descriptions of new species are included in the earlier section on systematics of Pliocene foraminifera.

Distinction must be made between openings of two different sizes penetrating the test walls. As used here, perforations are the very fine openings in the walls of most hyaline and some agglutinated foraminifera (Loeblich and Tappan, 1964). The term pore is used to refer to the larger openings adjacent to suture lines in Notorotalia and distributed over chamber surfaces in Bolivina.

Photographs were taken with a Cambridge Instruments Ltd. Stereoscan Mark II, operated by Physical and Engineering Laboratory of the D.S.I.R. Specimens mounted on an aluminium stub were coated in a vacuum chamber with carbon, followed by 200Å of gold-palladium. A standard accelerating voltage of 10KV with a working distance of 11mm. was used, and photographs were recorded on Ilford FP4 35mm. film.

SCANNING ELECTRON MICROSCOPY OF SOME SPECIES OF BOLIVINA

Taxonomy

Differentiation of the genera Bolivina and Brizalina by Loeblich and Tappan (1964) and Sliter (1970) was discussed in Section III. This study follows other authors (Gramman, 1965; Lindenberg, 1966; Hofman, 1971) in rejecting Brizalina because the diagnostic features grade into those of Bolivina.

Under high magnification, all species of Bolivina examined here show a similar test surface that is granular, sometimes with a platy appearance, and finely perforated. The perforations are present even in the walls of pores.

Systematic Descriptions

Order. FORAMINIFERIDA

Superfamily BULIMINACEA Jones, 1876

Family BOLIVINITIDAE Cushman, 1927

Genus Bolivina d'Orbigny, 1839Bolivina compacta Sidebottom, Pl. 13, fig. 1.

Bolivina robusta Brady var. compacta Sidebottom, 1905, p. 15, Pl. 3, fig. 7.

Dimensions: length 0.17mm., width 0.09mm., thickness 0.06mm.

B. compacta is a cosmopolitan species first described from

16-28m in the Aegean Sea (lectotype selected by Hedley et al, 1967), and since recorded from many shallow water localities in the Pacific (6-1530m) and Atlantic Oceans (Cushman, 1937). It has been recorded in New Zealand from Terra Nova Stations 134 and 144 (Heron-Allen and Earland, 1922, as B. inflata), from Manakau Harbour (Hulme, 1964), and as a common intertidal species at a number of other localities (Hedley et al, 1967).

B. compacta is extremely variable, and intertidal specimens from Portobello show continuous gradation to B. inflata which is regarded as a synonym (Hedley et al, loc. cit.). Inner-neritic eastern Pacific populations also exhibit great variation, especially in the strength of surface ornamentation, amount of pore depression and degree of axial twisting (Sliter, 1970).

The specimen illustrated, from 10m in Wellington Harbour, has a less regular and more rugose surface ornamentation than the specimens illustrated with scanning electron micrographs by Sliter (loc.cit.). However, it has the diagnostic characters of an elongate, gradually tapering and nearly parallel-sided test with rounded periphery, and reticulate ornamentation of coarse pores in irregular polygonal pits (Pl. 13, figs. 1b,c).

The ornament on the early part of the test is strong and irregular, obscuring sutures. On later chambers it becomes finer and more regular, with rounded ridges. Retral processes are visible on the last 4 chambers. The surface between ridges is smooth and the test finely perforate overall, with large, evenly-spaced pores in polygonal pits formed between coalescing ridges. Many of the pores at the apertural end are sealed

(Pl. 13, fig. 1b), a feature recorded by Sliter (loc. cit.). The aperture has a well-developed lip. The illustrated specimen, and those figured by Hedley et al (1967) show no axial twisting.

Bolivina hornibrooki n.sp., Pl. 13, fig. 2; Pl. 14,

fig. 1.

Dimensions: length 0.4mm., width 0.21mm., thickness 0.17mm.

Bolivina hornibrooki is often associated with B. parri in Pleistocene sediments, but appears in Wanganui Basin at an earlier horizon (mid-Pliocene rather than Pleistocene) and may be ancestral. The specimen illustrated here is from Castlecliffian mudstone in the Turakina Valley.

Diagnostic features are the elongate, gradually tapering test with rounded periphery and strong ornament. The surface is very finely perforate (0.2μ diameter openings) with a microgranular texture extending into pore canals. Chambers are elongate and inflated, and number 13 in the holotype. Sutures are visible over all of the test, though slightly obscured on early chambers, wide and depressed with a smooth surface lacking ornament. Coarse pores ($3-4\mu$ diameter) are distributed unevenly over the test, including the sutures, and appear to be overgrown in places by ornament. These are open at the prolocular end of the test (Pl. 13, fig. 2c), but towards the apertural end often have a perforated plate (Pl. 14, fig. 1). The feature shown in Plate 13, figure 2d, is unexplained and may be the result either of mounting cement

drying on the specimen (unlikely because of unaffected surrounding surface) or an organic membrane damaged by fossilisation or sample preparation.

The most distinctive feature is the strong, tuberculate ornament present on all chambers, but slightly reduced distally on the last three chambers. The ornament consists of irregular, very high tubercles or short ridges projecting from each chamber. Occasionally these coalesce and rarely form walls around pores, giving deep flaring pits. The proloculus (50μ diameter) in this specimen has a coarsely granular surface without ornament.

This species is related to B. parri Cushman, but differs in the stronger ornament, which is more persistent over the test, and the sutures, which are unobstructed on earlier chambers. No distinct retral processes are visible, but the strong ornament, inflated chambers and coarse pores are characteristic of Bolivina.

Bolivina parri Cushman, Pl. 14, figs. 2,3.

Bolivina parri Cushman, 1936a, p. 57, Pl. 8, figs. 7a,b.

Dimensions: length 0.31-0.35mm., width 0.16-0.19mm., thickness 0.11-0.14mm.

Cushman described Bolivina parri from Castlecliffian sediments at Wanganui. It is common in shallow water, marine Pleistocene sediments, and Vella (1957) listed B. cf. parri as rare and sporadic between 28m. and 182m. in Cook Strait. The illustrated specimens, from the Hautawan

of Wanganui River and the Castlecliffian of Turakina River, are similar to topo-type material at New Zealand Geological Survey, Lower Hutt, but have less limbate and calcite-filled early sutures.

The test is elongate with rounded periphery, gradual taper and strong ornament. The surface between the ornamentation is mostly smooth and finely perforate with occasional small tubercles and scattered large pores ($3-5\mu$ diameter) which are most abundant at the apertural end. There are 11 to 13 elongate, inflated chambers. Sutures are marked by broad, smooth, linear depressions. Secondary calcite often fills the depressions on the early part of the test, making the sutures limbate, and even sometimes overlapping the succeeding chamber. No perforated pore plates have been observed. The aperture has a well-defined lip.

The ornament is strongly tuberculate over the prolocular region, resembling that shown in B. hornibrooki (Pl. 14, fig. 2b), but weaker. Later chambers tend to be strongly arched, and their ornament is often reduced to smooth ridges and furrows.

This species resembles B. hornibrooki but can be consistently distinguished by the infilled early sutures and by the ornament, which is weaker and much reduced on the final chambers and often denser on the prolocular end of the test. True retral processes are not visible, but like B. hornibrooki the affinities are with Bolivina.

Bolivina petiae Gibson, Pl. 14, fig. 4; Pl. 15, fig. 1.

Bolivina petiae Gibson, 1967, pp. 35-36, Pl. 9, figs. 140-42.

Dimensions: length 0.23-0.26mm., width 0.11-0.14mm., thickness 0.08-0.10mm.

Bolivina petiae ranges from Lower Miocene to Pliocene in New Zealand. The illustrated specimens are from Mangapanian siltstone at Wanganui River.

The test is small with a finely perforate, coarsely granular surface. Coarse pores are irregularly distributed over the test, often situated in polygonal pits formed by surrounding ridges of tubercles. On later chambers, pores are often blocked by smooth plates (Pl. 14, fig. 4d).

Two specimens are illustrated: a microspheric form (VF1030), with regular ornament over test; and a megalospheric form (VF1029), showing on the prolocular half of the test ornament similar to that of B. hornibrooki and B. parri.

The megalospheric form (Pl. 14, fig. 4) has an elongate test, rapidly expanding initially then becoming almost parallel-sided. The prolocular diameter is 28μ . Sutures are clear and incised on apertural half of test (they appear less so in Pl. 14, fig. 4 because of the oblique angle of view), but are progressively obscured by secondary deposits towards the proloculus. Ornament on later chambers consists of coarse tubercles, often arranged into irregular polygonal pits (Pl. 14, figs. 4b,d), and is considerably modified on the earlier part of the test by the addition of secondary calcite to give a smoother sculpture of strong ridges. The original granular surface can be seen underlying the smooth

secondary material at many places (Pl. 14, fig. 4c).

The microspheric form (Pl. 15, fig. 1) is tapered, with a prolocular diameter of 18μ . Ornament consists of coarse tubercles evenly covering the entire surface, and often arranged into polygonal pits. All chambers are clearly separated.

The distinctive feature of B. petiae is the tuberculate ornament arranged into polygonal pits. Specimen VF1029 indicates B. petiae may be ancestral to B. hornibrooki and B. parri.

Bolivina plicatella Cushman, Pl. 15, fig. 2.

Bolivina plicatella Cushman, 1930b, p. 46, pl. 8, fig. 10.

Dimensions: length 0.23mm., width 0.16mm., thickness 0.06mm.

Bolivina plicatella was described from the Miocene of Florida, where it also occurs in Pliocene and Pleistocene sediments. Recent records are from the West Indies, Rio de Janeiro Harbour, Argentina and the Falkland Islands (Cushman, 1937). In Wanganui Basin, the species ranges from uppermost Opoitian to Hautawan. The figured specimen is from sample N141f1589, Hautawan, Hawkes Bay.

Characteristic features are the broad, compressed, widely flaring test with subacute periphery. Longitudinal ridges (present but indistinct in the illustrated specimen) occur one on either side of the depressed median axis, connecting with numerous irregular transverse ridges on the chambers. Chamber retral processes are present. Earlier sutures are concealed by ornamentation consisting of coarse

tubercles evenly distributed over the test and surrounding depressed, irregular polygonal pits containing large pores (Pl. 15, fig. 2d). Many pores at all growth levels are blocked by smooth calcite plates. The ornamentation varies little from proloculus to aperture, and under the optical microscope the surface appears smooth and uniform.

The test varies in its width and its degree of axial twisting. B. plicatella resembles B. plicata d'Orbigny, but is distinguished by its flaring test and lack of strong longitudinal costae.

Bolivina pseudoplicata Heron-Allen and Earland, Pl. 16,

fig. 1.

Bolivina pseudoplicata Heron-Allen and Earland, 1930, p. 81, Pl. 3, figs. 36-40.

Dimensions: length 0.34mm., width 0.23mm., thickness 0.14mm.

Bolivina pseudoplicata is a common and distinctive cosmopolitan species, originally described from off Plymouth, England. Cushman (1937) reported it at many sites around the British Isles and in the Mediterranean, and as fossils in the British Pleistocene. Sliter (1970) listed records from the Pacific margin of the United States and Mexico, and credited the species with a latitudinal range from at least 58°N to 40°S. Eade (1967a) listed New Zealand records to that date, and Lewis (1972, in press) recorded it as common from inner shelf to mid-slope off

southern Hawke Bay, with live specimens found from 48-375m. In Wanganui Basin it ranges from Lower Pliocene to Pleistocene.

The illustrated specimen, from 10m in Wellington Harbour, agrees closely with the southern California specimens figured by Sliter (1970). It shows the diagnostic features comprising a somewhat flared, compressed test with subacute periphery and a strong longitudinal ridge on each side of the depressed median area. The surface is finely perforate, and smooth to micro-granular. Coarse pores are distributed over the whole test. None were observed to be closed by perforate or imperforate plates at the surface, but some pores on the final chamber (Pl. 16, fig. 1d) appear to have a perforated plate at a lower level. The longitudinal ribs are strong, rounded and fairly continuous, and connect to transverse ribs on each chamber. The prolocular area is smooth between the ribs (Pl. 16, fig. 1c), but towards the apertural end the surface is covered by a fine, reticulated network of ribs (Pl. 16, fig. 1b).

Bolivina subexcavata Cushman and Wickenden, Pl. 16,

figs. 2, 3.

Bolivina subexcavata Cushman and Wickenden, 1929, p. 9, Pl. 4, fig. 4.

Dimensions: length 0.23-0.25mm., width 0.14-0.16mm., thickness 0.10-0.12mm.

B. subexcavata is a cosmopolitan species, resembling B. pseudoplicata. The holotype is from Juan Fernández Island, Chile, and other records include Norway, the eastern Pacific margin off

California, Ecuador and the Galápagos Islands (Cushman and McCulloch, 1942). The species has not previously been reported from New Zealand, and is rare and sporadic in the Pliocene and Pleistocene of Wanganui Basin. The specimens illustrated are from Manganapanian and Hautawan siltstones in Wanganui River.

The rapidly tapering test with rounded to subacute periphery, irregular longitudinal ridges on each side of a median depression, and strong ornament forming irregular, polygonal pits containing coarse pores are characteristic features. Chambers are slightly inflated, with sutures concealed by sculpture towards the test apex. At high magnification the surface is smooth and finely perforate, with coarse pores. Earlier pores are unobstructed, but several pores near the apertural end show evidence of a damaged covering-plate. The longitudinal ridges are discontinuous, formed from a raised portion of each chamber plus the retral processes, and covered with pore ridges on each chamber. They become less distinct towards the proloculus. Surface ornamentation between ribs varies little along the test.

Tests of specimens examined vary in degree of taper, ornament strength and roundness of periphery, but are considered conspecific with Sliter's (1970) specimens from California. The species is distinguished from B. pseudoplicata by the weaker longitudinal ridges and the stronger polygonal sculpture on each chamber.

Bolivina vellai n.sp., Pl. 17, figs. 1, 2: Pl. 18, fig. 1.

Dimensions: length 0.35-0.52mm., width 0.16-0.22mm., thickness 0.12-0.17mm.

Bolivina vellai is a common species in Lower Pliocene to Pleistocene shallow water faunules in Wanganui Basin. The illustrated specimens are from the Mangapanian of Wanganui River and the Castlecliffian of Turakina River.

The test is tapered with rounded periphery and smooth later chambers, but strongly ornamented early part. Surfaces between pores and ornament have a smooth to microgranular ornament, smoothest on the early chambers, with fine perforations throughout (Pl. 17, figs. 1b,c). Calcite deposition at the prolocular end gives a smoother surface with a sculpture of irregular tubercles and bosses. This weakens about half-way along the test, and later chambers have a granular surface with abundant pores. Perforations are often obscured by the secondary deposits of calcite (Pl. 17, fig. 1e). The surface is penetrated by many coarse pores, which on early chambers are often in depressions formed by outgrowths of ornament. Pores at the apertural end are more common and only slightly depressed, and often show a central plug. Occasional perforated plates are visible in pores on all parts of the test (Pl. 18, fig. 1b). Chambers are inflated, giving a lobulate outline, and number 12-15 in adult specimens. Sutures are distinct and incised, coarsely granular between the final few chambers, and slightly obscured near the proloculus. The test has a depressed median axis, and a well-defined apertural lip. Occasional weak retral processes are visible.

Prolocular diameters range from 38 to 42 μ , and the only obvious dimorphic feature is that the microspheric form (Pl. 17, fig. 1a) is more tapered than the megalospheric form (Pl. 17, fig. 2a).

The species differs from B. parri and B. hornibrooki in having rounded, more inflated chambers, tapering shell and more clearly visible sutures, especially on the early part of the test. It forms part of a group of species with similar ornament which tends to become reduced towards the aperture, including B. hornibrooki and B. parri on the one hand, and possibly extending to B. wanganuiensis, with the ornament at the prolocular end reduced to a thick calcite layer, on the other hand.

Bolivina wanganuiensis n.sp., Pl. 18, fig. 2.

Dimensions: length 0.52mm., width 0.17mm., thickness 0.12mm.

Bolivina wanganuiensis ranges from Lower Pliocene to Pleistocene in Wanganui Basin. It is large and elongate, the test expanding rapidly at first then becoming almost parallel-sided. Adult specimens have about 15 chambers, inflated and clearly separate with a rounded periphery towards the apertural end of the test, but more compressed, with sub-rounded to sub-acute periphery, at the prolocular end. The surface appears smooth and glossy under an optical microscope, but stereoscan photographs show it to be smooth only on later chambers, and coarsely granular at the prolocular end and along the sutures (Pl. 18, figs. 2b,c). Moderately large, slightly depressed pores are scattered over the test,

largest at the prolocular end and becoming smaller, more frequent and more depressed on the final chambers. Pores all open at the surface, but one from the prolocular region (Pl. 18, fig. 2d) appears to contain a damaged plate and another from the apertural region appears blocked at depth (Pl. 18, fig. 2e). The aperture is large with a well-defined lip.

The surface is without ornament. Secondary deposition at the prolocular end gives an even finish obscuring both chambers and sutures. Retral processes are absent, and the depressed initial portion is also indicative of Brizalina. Distinction between Bolivina wangamuiensis and similar species is discussed above.

PLATE 13

Plates 13 to 18 show oblique views.

Fig. 1. Bolivina compacta Sidebottom. VF1025, Recent,
Wellington Harbour.

1a, Lateral view, x590.

1b, Details of surface ornamentation, pore distribution
and smooth surfaces sealing pores of penultimate
chamber, x2060.

1c, Details of surface ornamentation and pore distribution
of chambers in prolocular region, x1400.

Fig. 2. Bolivina hornibrooki n.sp. Paratype, VF980,
Castlecliffian, Turakina Valley.

2a, Lateral view, x260.

2b, Details of pore distribution and surface ornamentation
on central part of test, x435.

2c, Enlargement of pore in central region of test,
showing continuity of surface, x5580.

2d, Enlargement of pore in central region of test,
showing damaged organic? membrane, x5850.

1a

1b

1c

2b

2c

2d

2a

PLATE 14

Fig. 1. Bolivina hornibrooki n.sp. Paratype, VF980.

Enlargement of pore from final chamber, showing perforated pore membrane, x10200.

Fig. 2. Bolivina parri Cushman. VF1027, Castlecliffian, Turakina River.

2a, Lateral view, x250.

2b, Detail of surface ornamentation and pore distribution on central part of test, x430.

Fig. 3. Bolivina parri Cushman. VF1028, Hautawan, Wanganui River. Lateral view, x185.

Fig. 4. Bolivina petiae Gibson. Megalospheric form. VF1029, Mangapanian, Wanganui River.

4a, Lateral view, x250.

4b, Surface detail and pore distribution on final chambers of test, x445.

4c, Surface detail and pore distribution on early portion of test, showing smooth secondary calcite overlying coarsely granular texture, x570.

4d, Enlarged view of central part of test, showing pores, pore membranes, and pore ridges, x1550.

4d, Enlargement of perforation from final chamber, x5900.

1

2b

2a

3

4b

4c

4d

4a

4e

PLATE 15

Fig. 1. Bolivina petiae Gibson. Microspheric form. VF1030,
Mangapamian, Wanganui River.

- 1a, lateral view, x390; (distal smooth areas are adhesive);
- 1b, apical end of test, showing coarsely granular surface ornament, x720;
- 1c, enlargement of pore from apical end, x5600;
- 1d, enlargement of pore from final chamber, x11750.

Fig. 2. Bolivina plicatella Cushman. VF1031, Hautawan, Hawkes Bay.

- 2a, lateral view, x380;
- 2b, details of surface ornamentation on final chamber, x645;
- 2c, details of surface ornamentation on apical part of test, x490;
- 2d, enlargement of surface showing ornamentation, pores and pore ridges on final chamber, x3200.

PLATE 16

Fig. 1. Bolivina pseudoplicata Heron-Allen and Earland. VF1032,
Recent, Wellington Harbour.

1a, lateral view, x295.

1b, details of surface ornamentation at apertural end of
test, showing pore distribution and retral processes,
x550;

1c, test apex, showing surface ornamentation and
longitudinal ridges, x700;

1d, enlargement of pore on final chamber, x4450;

1e, enlargement of pore at apical end of test, x2200.

Fig. 2. Bolivina subexcavata Cushman and Wickenden. VF1034,
Mangapanian, Wanganui River.
Lateral view, x420.

Fig. 3. Bolivina subexcavata Cushman and Wickenden. VF1035,
Hautawan, Wanganui River.
Lateral view, x315.

1a

1b

1c

1d

1e

2

3

PLATE 17.

Fig. 1. Bolivina vellai n.sp. Paratype, VF984, Castlecliffian,
Turakina River.

1a, Lateral view, x200.

1b, Details of surface ornamentation of final chamber and
apertural region, x340.

1c, Surface ornamentation of test apex, x315.

1d, Enlargement of pore on final chamber, x5000.

1e, Enlargement of pore from central region of test, showing
obstruction by secondary deposition of calcite, x8500.

Fig. 2. Bolivina vellai n.sp. Paratype, VF985, Mangapanian,
Wanganui River.

2a, Lateral view, x280.

2b, Final chamber, showing pore distribution, smooth
surface and deposition of granular secondary material
along line of suture, x580.

2c, Apical region of test, x290.

PLATE 18

Fig. 1. Bolivina vellai n.sp. Paratype, VF984.

- 1a, Enlargement of pore from base of final chamber, showing perforated pore membrane, x6200.
- 1b, Enlargement of pore from lower part of test, showing perforated pore membrane, x9300.

Fig. 2. Bolivina wanganuiensis n.sp. Paratype, VF991, Hautawan, Wanganui River.

- 2a, Lateral view, x235.
- 2b, Details of surface ornamentation, pore distribution and suture line, x760.
- 2c, Details of surface ornamentation and pore distribution on proximal region of test, x705.
- 2d, Enlargement of pore from apical region, showing perforated pore membrane, x5670.

SCANNING ELECTRON MICROSCOPY OF SOME SPECIES OF NOTOROTALIA

INTRODUCTION

Seven species of Notorotalia are discussed. Notorotalia briggsi is described as new, and all other illustrated species have been compared with the holotype specimens filed at New Zealand Geological Survey, Lower Hutt, except N. olsoni, of which paratypes have been examined.

Terms used in discussion of surface morphology are those defined by Vella (1957, p. 44-5, fig. 1). The more complex terminology developed by Hofker (1969) for the internal structure is referred to where necessary. In addition, the term tubercle is used to describe the fine, conical to hemispherical projections which ornament much of the test surface between the ribs. Openings of two different orders of size penetrate the test walls (Pl. 21, fig. 2b). As used here, perforations are the tiny holes (0.4-0.8 μ diameter in Notorotalia) formed during construction of each chamber in calcareous hyaline foraminifera, and allowing egress of pseudopodia (Loeblich and Tappan, 1964). The term pore is used to refer to the larger (3-8 μ diameter) openings present along the suture line (= toothplate foramina of Hofker, 1969), and marking the external openings of an internal canal system (Hornibrook, 1961; Hofker, 1969). Pores and perforations differ in size by approximately one order of magnitude, a feature also noted in many species of planktonic foraminifera (Collen and Vella, 1972) and

probably related to the formation of pseudopodia from a number of finer units as described by Jahn and Rinaldi (1959).

The following features are common to all species examined, and possibly to the entire genus or even a higher taxon:

(1) Foraminifera of the Superfamily Rotaliacea Ehrenberg have a wall that is calcareous, perforate and radial in structure (Loeblich and Tappan, 1964, p. C605). In the species examined, test surfaces between ribs, pores and tubercles are smooth, but high magnification shows a microgranular finish (see, for example, Pl. 25, fig. 1). Ribs, keel and tubercles show a similar but finer texture.

Crushed specimens mounted in immersion oil (R.I. 1.54) were examined with a polarising microscope and showed the black cross mimicking a negative uniaxial interference figure which is characteristic of radial wall structure. Towe and Cifelli (1967) describe a thin granular veneer covering the surface of many calcareous foraminifera. Transmission electron micrographs of the surface and wall sections of Ammonia beccarii (Linné) show this surface to overlies and conceal a basically radial structure, and to line the pore canals penetrating the walls (Towe and Cifelli, loc. cit., Pl. 89, figs. 1-3; Pl. 90, figs. 1-2). The almost identical surface illustrated here (Pl. 25, fig. 1) and extending into pores and perforations (Pl. 19, fig. 2d) is considered to represent a similar microgranular veneer, but was not checked by transmission electron microscopy.

The surface is finely perforate all over, but perforations are less common on the ribs and keel.

(2) The most striking feature revealed by stereoscan photography is the presence of numerous tubercles over much of the test surface between ribs. The tubercles are usually largest and most dense on the earlier chambers of the final whorl and towards the posterior of each chamber. Tubercles tend to decrease in density towards the centre of the test, especially on the dorsal side where they may become obscured by callous deposition. Tubercles have been observed on all the species illustrated here and on the holotypes of N. kingmai Vella and N. zelandica mangaoparia Vella.

The tubercles may be a consistent feature of the entire Subfamily Notorotaliinae Hornibrook. They are present on Discorotalia tenuissima (Karrer) (Hofker, 1969, fig. 49), and are related to the coarser granules which coalesce into ribs on the Lower Tertiary species N. uttleyi Hornibrook and which are present on the other genera of the subfamily. In the genus Cribrorotalia Hornibrook granules have fused to form the umbilical plug, and are aligned and partly coalesced to form incipient ribs (Hornibrook, 1961; Hofker, 1969). Parrelina imperatrix (Brady) has tubercles present on ribs and interspaces (Hofker, 1969, figs. 60, 69), and P. wadeae Hornibrook is described as having a few small isolated tubercles near the centre of the test.

Stereoscan photographs of two species of Elphidium (Subfamily Elphidiinae) show mostly smooth tests, but angular tubercles inside the large sutural pores (E. incertum (Williamson), Pl. 11, figs. 2b,d; E. novozealandicum Cushman, frontispiece). Other scanning electron micrographs (Murray, 1969) show that granular tubercles are present along

the sutures of E. clavatum Cushman and E. subarcticum Cushman, and inside the large sutural pores of E. sp.

(3) The spiral and sutural ribs and the keel are generally slightly smoother than the interspaces, and have fewer perforations, no pores and no tubercles. The ribs and keel in most specimens are thickened on earlier chambers relative to those on later chambers (see especially N. finlayi, Pl. 20, fig. 2a).

(4) Apertural and sutural pores are represented on all specimens, but are often obscured or concealed by secondary calcite deposits. The pores are evidently typical of the family, and of considerable taxonomic importance, contrary to the opinion of Vella (1957).

Cribrate apertural foramina at the base of the terminal face are clear in some species (e.g. N. briggsi, Pl. 20, fig. 1b), but are obscured in most species by thickening of ribs at the base of the terminal face and by unusually dense and coalescent tubercles along the junction of the terminal face with the underlying whorl (e.g. N. finlayi, Pl. 22, fig. 2c).

Sutural pores become obscured by thickening of spiral and sutural ribs, and by increased tubercle density. Where sutural pores are not obscured, two rows can be seen on each chamber. In some species, the rows are situated on opposite sides of the chamber, adjacent to the anterior and posterior sutures (N. finlayi, probably N. hurupiensis), whereas in other species the two rows are close together near the posterior edge of the chamber (N. zealandica zealandica, possibly N. briggsi, N. pliozea). The arrangement is assumed to reflect the

development of the internal tooth-plate canal system described by Hofker (1969).

The species of Notorotalia illustrated here show some obstructed pores (Pl. 22, fig. 1c), but no unambiguously identifiable perforated organic membranes or sieve-plates (Jahn, 1953; Arnold, 1954a, b; Angell, 1967; Sliter, 1970, and others).

Secondary Calcite Deposition

Hyaline calcareous foraminifera add a layer (lamella) of calcite over the entire test each time a new chamber is constructed (Reiss, 1958), and may otherwise secondarily modify the test surface. Functions of the pseudopodia of foraminifera include the deposition of shell material (Hall, 1953; Le Calvez, 1953; Sandon, 1957, 1963). A new chamber wall is formed first as an organic membrane with perforations through which blunt pseudopodia protrude. The organic membrane is subsequently calcified, the perforations remaining open (Loeblich and Tappan, 1964). Describing the continual two-way streaming of granules in foraminiferal cytoplasm, Jahn and Rinaldi (1959) suggested that the fundamental streaming unit is less than 1.0μ in diameter and that all but the finest pseudopodia are bundles of such streaming units. The perforations observed in Notorotalia are of the order of size of Jahn and Rinaldi's fundamental streaming units.

As used in this paper, secondary calcite deposition refers to the addition of calcite to a chamber after its initial formation.

Hofker (1956) observed that calcitic ridges and knobs lie adjacent to the openings of canal systems in a number of genera (including Streblus and Operculina). Later he concluded that pores determine the position of ribs because calcite is deposited from cytoplasm streaming out of them (Hofker, 1969).

The following features indicate progressive addition of secondary calcite to the Notorotalia test during life:

- (1) thickening of spiral and sutural ribs and peripheral keel towards the early chambers (in extreme cases resulting in the formation of a solid callous on the dorsal side);
- (2) increased reticulation of ribs towards earlier chambers;
- (3) increase in size and density of tubercles towards the earliest chambers in the final whorl; and
- (4) partial assimilation of tubercles by ribs (Pl. 20, fig. 1b).

It is postulated that addition of material to the surface of Notorotalia is largely governed by the location and density of pores (Fig. 31). Where the two rows of sutural pores lie on opposite sides of the chamber, the row adjacent to the posterior edge of the rib is most obscured. Pores adjacent to the anterior edge are more clearly and regularly visible, even though closely surrounded by spiral ribs and dense tubercles on early chambers (Pl. 22, figs. 1b,c).

Deposition of calcite occurs normally in the directions shown in Fig. 31-A. Cytoplasm streaming from pores on the posterior side of the suture lays calcite down along the line of the suture and the pores are eventually overgrown by the sutural rib. Cytoplasm streaming

Fig. 31. - Distribution of sutural pores and secondary thickening of ribs around the test of:
A. N. finlayi Vella (x130) and B. N. zelandica zelandica Finlay (x45). Arrows indicate inferred directions of calcite deposition. Explanation in text.

from pores on the anterior side, apparently more strongly calcite-secreting, adds material to the sutural rib and adjoining spiral ribs, and forms tubercles in the interspaces between spiral ribs.

Where a double row of pores occurs towards the posterior of the chamber, calcite deposition is as in Fig. 34-B. Concentration of calcite between two adjacent pores causes a cross-bar to form, giving reticulate sculpture. Probably the relative positions of pores in the two rows in each chamber control the angle and regularity of spiral ribbing.

N. zelandica zelandica, with very regular sculpture, has two identical rows of pores in each chamber (Pl. 27, fig. 1c). Less exact apposition of sutural pores is associated with less regular sculpture e.g.

N. pliozea (Pl. 23, fig. 2a).

It is not certain whether the fine cytoplasmic fibres issuing from perforations contribute to secondary calcite deposition, but they may lay down the microgranular surface of the test (see Pl. 21, fig. 2b).

Relationships within Notorotalia

The present study illustrates the following types of test morphology:

(1) smaller species with sharp peripheries and plano-convex to biconvex shape, fairly sparse tubercles, strongly curved transverse sutural ribs with relatively few spiral ribs;

a. tubercles increase in abundance and ribs thicken towards initial chambers of final whorl:

N. finlayi, N. hurupiensis, N. taranakia.

- b. tubercles fairly even over test, secondary material added mainly at junction of spiral and sutural ribs:

N. olsoni.

- (2) medium to large species, tending to depressed shape, numerous ribs showing little thickening posteriorly, sutural ribs fairly straight, dense ornament of tubercles;

- a. dense, large tubercles evenly over whole of shell;

N. pliozea, N. zelandica zelandica.

- b. fine tubercles, dense on early chambers but much reduced on final ones:

N. briggsi.

The exact position of each row of sutural pores is not at present known for most species, because of concealment by tubercles, and this character is not included in the above classification.

Vella (1957, pp. 45-46, table 4), on the basis of test morphology and stratigraphic range, divided the New Zealand species of Notorotalia into five species groups and a number of lineages. From two of these groups he recognised the following Upper Tertiary to Recent lineages, which contain the species illustrated in this report:

Notorotalia profunda Group:

N. profunda lineage: N. taranakia→N. profunda.

N. finlayi lineage: N. taranakia→N. hurupiensis→N. finlayi

N. olsoni lineage: N. taranakia→N. olsoni.

Notorotalia zelandica Group:

N. inornata lineage: N. pristina-N. inornata.

N. aucklandica lineage: N. pliozea-N. aff. aucklandica
(=N. briggsi)-N. aucklandica

N. zelandica lineage: N. pliozea-N. zelandica mangaoparia-
N. z. rotunda-N. z. zelandica.

High resolution details of surface microstructure discussed on the following pages generally support the relationships proposed by Vella. The N. finlayi lineage with its evolutionary progression from N. taranakia through N. hurupiensis to N. finlayi is substantiated, and N. taranakia also appears closely related to N. olsoni. The three larger species show resemblance to each other. N. pliozea and N. zelandica zelandica have many similar features, but without details of intervening subspecies of N. zelandica the relationship cannot be clarified. N. briggsi is less similar, and its phylogenetic position unclear.

Systematic Descriptions

Order FORAMINIFERIDA

Superfamily ROTALIACEA Ehrenberg, 1839

Family ELPHIDIIDAE Galloway, 1933

Subfamily NOTOROTALIINAE Hornibrook, 1961

Genus Notorotalia Finlay, 1939

(Type species: Notorotalia zelandica Finlay, 1939)

Notorotalia briggsi n.sp., Pl. 19, figs. 1,2: Pl. 20, fig. 1.

Dimensions: diameter 0.54-0.62mm, width 0.21-0.26mm.

Spiral ribs are numerous but weak, sometimes discontinuous, often almost absent from the later chambers and may be slightly thicker on earlier chambers where ribs are weakly reticulated (Pl. 19, figs. 2a,c). The surface between ribs is ornamented with small tubercles, densest on the dorsal side, sharply conical on early chambers (Pl. 20, fig. 1b), decreasing in abundance and becoming low and rounded anteriorly; almost absent from the final two or three chambers on the ventral side, but numerous on the terminal face. Tubercles obscure perforations and pores (Pl. 19, figs. 1b, 2c), and may be incorporated into ribs (Pl. 19, fig. 1b). Large cribrations are visible at the base of the terminal face, each surrounded by a thickened, smooth rim (Pl. 20, figs. 1b,c).

The numerous spiral ribs, the slight curvature of sutural ribs, and the density of tubercles and little thickening of sutural ribs on the early part of the test, are all links with N. pliozea and N. zelandica

zelandica. However, the marked decrease in abundance of tubercles and the reduction of ribs towards the final chamber on the ventral side, and the sharper periphery, distinguish N. briggsi from both these species.

Notorotalia finlayi Vella, Pl. 20, fig. 2; Pl. 21;

Pl. 22.

Notorotalia finlayi Vella, 1957, pp. 49-50, Pl. 1, figs. 4-5, 9-10.

Dimensions: diameter 0.35-0.40mm, width 0.14-0.17mm.

N. finlayi is common in late Pliocene to Recent shelf faunules, and evolved from N. hurupiensis at the end of the Opoitian Stage (Lower Pliocene) by reduction in length of the spiral ribs.

Ribs are smoothly finished. Posteriorly they are broad and flat (Pl. 20, fig. 2b), with the outer part of the sutural ribs tending to fuse with the keel (Pl. 22, figs. 2a,b). Anteriorly, ribs are narrower, rounded, and often discontinuous (Pl. 21, figs. 1b, 2d).

Posterior sutural pores are visible on some areas of the test, mostly on the youngest chambers (Pl. 21, fig. 1b). They lie close to the sutural rib, between spiral ribs, and hence are often concealed by rib and tubercle development (Pl. 22, figs. 1b,c). Anterior sutural pores are less common and have been seen clearly only on the ventral side of the final chamber (Pl. 21, fig. 1b). Apertural cribrations are present, but heavily overgrown (Pl. 22, figs. 2c,d).

Tubercles are hemispherical to conical, and equidimensional to slightly higher than wide. A small callous is present in the centre

of the dorsal side (Pl. 21, figs. 2a,c), consisting of smooth, finely perforate secondary calcite overlying ribs and tubercles.

Notorotalia hurupiensis Vella, Pl. 23, fig. 1.

Notorotalia hurupiensis Vella, 1957, p. 49, Pl. 1, fig. 15.

Dimensions: diameter 0.23mm, thickness 0.11mm.

Sutural ribs on the specimen examined are strongly curved, do not coalesce with keel, only slightly thicken posteriorly, and are slightly irregular on early chambers (Pl. 23, fig. 1b). Spiral ribs are continuous across all chambers, but weaken anteriorly on later chambers (Pl. 23, fig. 1c).

Posterior sutural pores can be seen at various parts of the test, and are less confined by ribs and tubercles than those in N. finlayi. Few anterior sutural pores are visible, and apertural cribrations are obscured. Hemispherical tubercles scattered over the test are largest on earlier chambers and towards the periphery, and are larger and less dense than on N. finlayi.

The illustrated specimen is small for the species, and may not be typical of Opoitian (Lower Pliocene) faunas of N. hurupiensis. It appears to be intermediate between N. taranakia and N. finlayi. It resembles N. taranakia in having sutural ribs which do not join the peripheral keel, slightly irregular spiral ribs continuous across all chambers, and in the size and abundance of tubercles, but is less

strongly biconvex. Affinities with N. finlayi are shown in the similar pattern of tubercle distribution, the tendency to reduction of the spiral ribs on later chambers, and the general shape.

Notorotalia olsoni Vella, Pl. 26, figs. 1-3.

Notorotalia olsoni Vella, 1957, p. 50, Pl. 2, figs. 23-24.

Dimensions: diameter 0.43-0.59mm, thickness 0.22-0.28mm.

N. olsoni is a medium-sized species ranging from Lower Pliocene (and possibly Upper Miocene) to Recent (Vella, 1957).

The complex sculpture consists of fine, dense, slightly reticulated ribs with rounded to triangular cross-section. Keel and ribs are thickened only slightly on early chambers. Secondary calcite added at the junctions of spiral and sutural ribs gives a "scalloped" effect (Pl. 26, fig. 1a).

Many anterior and posterior sutural pores are visible, and several apertural cribrations can be seen at the base of the terminal face. Many of the pores and cribrations are surrounded by raised collars.

Small, hemispherical to conical tubercles scattered over the test and terminal face show a slight tendency to be concentrated at the posterior of each chamber and to be sparser on the final chamber.

N. olsoni resembles N. taranakia, N. hurupiensis and N. finlayi in its general shape and the pattern of tubercular ornament, but is distinguished by its fine, dense, "scalloped" ribs.

Notorotalia pliozea Vella, Pl. 23, fig. 2; Pl. 24,

fig. 1.

Notorotalia pliozea Vella, 1957, p. 54, Pl. 2, figs. 25-26.

Dimensions: diameter 0.58mm, thickness 0.20mm.

Later chambers have a regular, reticulate sculpture of rounded ribs. Early chambers have irregular and discontinuous ribs that are very little thickened posteriorly.

Few sutural pores are visible, the majority being concealed by tubercles. Some very small apertural cribrations can be seen (Pl. 23, figs. 2b,c), but others are concealed by tubercles and by the expanded bases of the 6 or 7 apertural ribs which extend across the full width of the terminal face.

Dense hemispherical to conical tubercles are distributed over all of the test, but are largest and densest on earlier chambers and towards the keel on chambers of the final whorl.

The strongly depressed shape and the dense tubercles are the most distinctive features of this large Kapitean to Waipipian (Upper Miocene to Middle Pliocene) species. N. zelandica zelandica has a similar, but less dense, distribution of tubercles.

Notorotalia taranakia Vella, Pl. 24, fig. 2; Pl. 25,
figs. 1-3.

Notorotalia taranakia Vella, 1957, p. 48, Pl. 1, figs. 1-3.

Dimensions: diameter 0.30-0.36mm, thickness 0.15-0.19mm.

Notorotalia taranakia has a complex reticulate sculpture of rounded ribs and keel which broaden posteriorly. Sutural ribs are strongly curved and occasionally merge with the keel. Some sutural pores are visible, but tend to be obscured by ribs, dorsal callous and tubercles. The terminal face has a reticulate rib pattern with the main ribs continuous across the face, a sparse ornament of tubercles, and several apertural pores visible between the expanded rib bases (Pl. 25, fig. 3b).

Large hemispherical tubercles are distributed over the entire test, but are much sparser anteriorly and towards the centre. They tend to cluster around sutural pores, and in a number of instances very large tubercles form lines parallel to ribs (Pl. 25, fig. 2b), recalling the ornament of Cribrorotalia and of some early species of Notorotalia.

N. taranakia is distinguished by its small size, biconvex shape, reticulate sculpture and large tubercles. Its affinities to N. hurupiensis are discussed above.

Notorotalia zelandica zelandica Finlay, Pl. 27,

figs. 1-3.

Notorotalia zelandica Finlay, 1939a, p. 518.

Dimensions: diameter 0.89-1.23mm, thickness 0.38-0.43mm.

The ribs of Notorotalia zelandica zelandica are rounded and are thickened only slightly on early chambers. Spiral ribs merge into sutural ribs without any break at the posterior side of each chamber and are often continuous across the chamber. Sutural ribs are fairly straight and do not coalesce with the keel. The terminal face is ornamented with a few, scattered conical tubercles and crisp, regular, continuous, slightly reticulating ribs with large, expanded bases.

Two parallel rows of sutural pores, with raised rims of calcite, are regularly developed adjacent to the posterior margins of chambers on the ventral side (Pl. 27, fig. 1c). On the dorsal side they have formed the sites for attack by boring organisms (Pl. 27, figs. 2a, 3a,b). (see discussion in Section VI).

The species is distinguished by its large size and regular sculpture. Tubercle density suggests affinity with N. pliozea, but more specimens including earlier subspecies of N. zelandica must be examined to clarify the relationship.

The fine (0.5-1 μ), irregular, white granules showing on the surface of specimen VF965 (Pl. 27, fig. 1a) are not part of the original ornament, but represent the initial effect of post-mortem calcite solution and redeposition. Other specimens showing more advanced

solution and redeposition have blurred surface features and retain none of the fine detail. If redeposited calcite is removed, the test surface is seen to be coarsely granular, indicating preferential solution along the grains forming the outer lamella of the test, and ribs and tubercles are reduced in size.

Discussion and Conclusions

The species of Notorotalia illustrated here have a finely perforate, microgranular surface (probably a veneer overlying a basically radial wall), covered between ribs by numerous hemispherical to conical tubercles. Examination of the wall with a polarising microscope showed it to be radial in structure. Towe and Cifelli (1967) state that a morphologically granular wall may be optically radial, because rotation of calcite crystals about the c-axis perpendicular to the stage of a polarising microscope does not affect isotropic extinction properties.

Initial wall formation probably involves mineral precipitation onto an organic matrix (Angell, 1967; Towe and Cifelli, 1967). The initial wall acts as a template controlling the structure. Secondary calcite is deposited by cytoplasm streaming from pores and perforations, adding a granular veneer, thickening the initial ornament, and forming tubercles.

Sutural and apertural pores, the large external openings of internal canal systems, are present on all species but tend to be overgrown and obscured by ribs and tubercles. The controlling relationship of pores to ribs and tubercles is quite clear. Calcite deposition is greatest in the vicinity of these openings. Species which progressively form a reticulate sculpture show little thickening of the ribs posteriorly. Other species, generally smaller, which do not develop a reticulate pattern, show progressive thickening of ribs posteriorly.

Species with many pores and perforations tend to have many spiral ribs per chamber and large, densely packed tubercles arranged evenly over the shell. These are the large species, which may be approaching the upper limit of size in an acellular organism for certain organic activities. The more numerous pores allow rapid cytoplasmic flow in and out of the test and, for example, a greater surface area of cytoplasm for gaseous exchange. It is interesting to note, in this connection, the tendency of larger species to a flattened or tubular shape, which reduces the maximum distance of the test from the external environment, while still allowing a large supporting structure. Thus, the sculpture may be intimately related to the organisms' life-processes.

Of the lineages proposed by Vella (1957) which involved species examined here, the N. finlayi lineage is substantiated, N. taranakia, N. hurupiensis and N. finlayi showing gradational variation in surface

morphology. Relationships between N. olsoni and N. taranakia (N. olsoni lineage) and N. pliozea and N. zelandica zelandica (N. zelandica lineage) are likely. The affinity of N. briggsi to N. pliozea (N. aucklandica lineage) is not certain. Study of additional specimens from these last three lineages is required.

Morphologic change in foraminifers may reflect the reversible effect of environment or irreversible effect of genetic change upon the ordering properties of the original organic matrix or upon the calcite-secreting properties of the cytoplasm. In some instances environmental and evolutionary effects may coincide. For example, climatic deterioration in the Middle Pliocene and its effects on protoplasmic function may correlate with the evolutionary progression of N. hurupiensis to N. finlayi by reduction in length of spiral ribs. This change may result from decreasing pseudopodial activity. Verworn (1899) has described how addition of alkali to the water can cause Amoeba limax to alter the shape of its pseudopodia, and discussed the decrease in protoplasmic activity in Amoeba with decreasing temperature. Similar responses to environmental change probably exist in many protozoans.

PLATE 19

Plates 19 to 25 show oblique views.

Fig. 1. Notorotalia briggsi Collen, n.sp. Paratype, VF879,
Mangapanian, Wilkies Bluff.

1a, Dorsal view, x110.

1b, Details of surface ornamentation of centre of dorsal
surface, x1045.

Fig. 2. Notorotalia briggsi Collen, n.sp. Paratype, VF880,
Mangapanian, Wilkies Bluff.

2a, Ventral view, x130.

2b, Details of surface ornamentation and final sutural
rib on ventral side, x775.

2c, Details of surface ornamentation and keel on lower
part of ventral surface, x520.

2d, Enlargement of perforation from above area, showing
texture of surface extending into perforation, x15600.

1a

1b

2b

2a

2c

2d

PLATE 20

Fig. 1. Notorotalia briggsi Collen, n.sp. Paratype, VF881,
Mangapanian, Wilkies Bluff.

1a, Peripheral view, x150.

1b, Details of surface ornamentation on terminal face,
keel and early chamber, x350 (note apertural
cribrations).

1c, Enlargement of most ventral apertural cribration,
x2940.

1d, Enlargement of perforation on early chamber, x12700.

1e, Enlargement of ornamentation on keel, ventral and
dorsal surfaces of early chambers, x525.

Fig. 2. Notorotalia finlayi Vella. VF883, Hautawan, Wanganui
River.

2a, Ventral view, x180.

2b, Details of surface ornamentation on early chambers,
x380.

1a

1c

1d

1b

1e

2b

2a

PLATE 21

Fig. 1. Notorotalia finlayi Vella. VF883.

- 1a, Further enlargement of surface ornamentation on early chambers, x1800.
- 1b, Details of surface ornamentation on final chambers and terminal face, x400.
- 1c, Enlargement of pore from final chamber, x3050.

Fig. 2. Notorotalia finlayi Vella. VF882, Hautawan, Wanganui River.

- 2a, Dorsal view, x175.
- 2b, Enlargement of pore and surrounding perforations from central region of dorsal surface, x6250.
- 2c, Details of surface ornamentation of central part of dorsal surface, x500.
- 2d, Details of surface ornamentation of final chambers, x550.

PLATE 22

Fig. 1. Notorotalia finlayi Vella. VF882.

- 1a, Details of surface ornamentation of lower part of dorsal surface, x410.
- 1b, Further enlargement of surface and spiral rib showing ornament and sutural pore (large hole is boring by predator), x1450.
- 1c, Further enlargement of above area, showing development of tubercles around sutural pore and apparent obstruction of pore, x3800.

Fig. 2. Notorotalia finlayi Vella. VF884, Hautawan, Wangarui River.

- 2a, Peripheral view, x220.
- 2b, Details of keel and surface ornamentation of early part of test, x720.
- 2c, Enlargement of terminal face, showing ornamentation and apertural cribrations, x370.
- 2d, Further enlargement of apertural cribration and ornamentation of terminal face, x1475.

PLATE 23

Fig. 1. Notorotalia hurupiensis Vella. VF885, Opoitian,
Wanganui River.

1a, ventral view, x260;

1b, details of surface ornamentation on early part
of test, x900;

1c, details of surface ornamentation on final chamber
and terminal face, x560.

Fig. 2. Notorotalia pliozea Vella. VF886, Waipipian,
Wanganui River.

2a, ventral view, specimen tilted to show terminal
face and keel, x115;

2b, details of surface ornamentation on terminal face,
final and early chambers, x240;

2c, further enlargement of junction between terminal
face and early chamber, showing details of surface
ornament, pores and perforations, x2270.

1a

1b

1c

2a

2b

2c

PLATE 24

Fig. 1. Notorotalia pliozea Vella. VF886.

- 1a, Enlargement of perforation on apertural face, showing partial obstruction by calcite, x13000.
- 1b, Details of surface ornamentation on lower part of ventral surface (central smooth area is adhesive), x450.
- 1c, Enlargement of pores on final chamber, x3480.
- 1d, Details of surface ornamentation on final chamber.
Note development of rims around pores in 1c and 1d, x400.

Fig. 2. Notorotalia taranakia Vella. VF888, Opoitian, Wanganui River.

- 2a, Dorsal view, x190.
- 2b, Enlargement of central part of Fig. 2a, showing sutural rib, spiral ribs, secondary ribs, and sutural pores, x1150.
- 2c, Details of surface ornamentation on dorsal side of test, x475.

PLATE 25

Fig. 1. Notorotalia taranakia Vella. VF888.

Enlargement of sutural pore and surface texture on dorsal side, x7320.

Fig. 2. Notorotalia taranakia Vella. VF887, Opoitian, Wanganui River.

2a, ventral view, x210;

2b, details of surface ornamentation on ventral side of test, x650;

Fig. 3. Notorotalia taranakia Vella. VF889, Opoitian, Wanganui River.

3a, peripheral view, x225;

3b, enlargement showing terminal face and surface detail of keel and early chamber, x355;

3c, further enlargement of keel and surface detail on dorsal and ventral sides of early chambers, x725.

1

2a

2b

3b

3a

3c

PLATE 26

Fig. 1. Notorotalia olsoni Vella. VF962, ?Mangapanian, Saddle Road.

1a, Enlargement of surface ornamentation along penultimate suture of ventral side, x 495.

1b, Ventral view, x90.

Fig. 2. Notorotalia olsoni Vella. VF963, Mangapanian, Saddle Road.

2a, Enlargement of central part of dorsal surface, x 380.

2b, Dorsal view, x90.

Fig. 3. Notorotalia olsoni Vella. VF964, Mangapanian, Saddle Road.

3a, Peripheral view, x 150.

3b, Enlargement of apertural face, x640.

Fig. 4. Elphidium novozealandicum Cushman. VF968, Recent, Wellington Harbour.

Enlargement of sutural pore from penultimate suture, x 900.

PLATE 27

Fig. 1. Notorotalia zelandica zelandica Finlay. VF966, Hautawan, Rangitikei River.

1a, Further enlargement of part of Fig. 1b, showing perforations, tubercles, a boring and irregular white granules of redeposited calcite, x 1910.

1b, Enlargement of part of the antepenultimate suture on the ventral side, showing sutural pores (a) and small, scattered borings (b), x330.

1c, Ventral view, x 48.

Fig. 2. Notorotalia zelandica zelandica Finlay. VF967, Hautawan, Rangitikei River.

2a, Peripheral view, x80. Note large borings confined to dorsal side.

2b, Enlargement of junction of apertural face with earlier chamber, x 310.

Fig. 3. Notorotalia zelandica zelandica Finlay. VF964, Hautawan, Rangitikei River.

3a, Dorsal view, showing abundant borings sited mainly on sutural pores, x 47.

3b, Enlargement of central part of dorsal surface, showing boring with bevelled edge (a), partial regeneration of shell over boring (b), and abandoned borings (c), x 435.

1a

1b

2a

1c

3a

2b

3b

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APPENDIX I

SUPPORTING PAPER

Pliocene planktonic foraminifera, southern North
Island, New Zealand.

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Submitted for publication in Journal of Foraminiferal
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ABSTRACT

Twenty-five species and subspecies of planktonic foraminifera are described and illustrated with stereoscan photographs, including one new subspecies, Turborotalita quinqueloba lingulata. Minute surface morphology of the test walls suggests certain supraspecific taxonomic revisions: in particular, "Globigerina" pachyderma is referred to Neogloboquadrina, and the name Turborotalia is not used for Pliocene to Recent non-carinate species of Globorotalia. Tentatively the New Zealand stages Mangapanian and Waipipian are correlated with the global biostratigraphic Zone N21, upper Opoitian with N20, lower Opoitian with N19, Kapitean approximately with N18, and Upper Tongaporutuan approximately with N17.

INTRODUCTION

The accompanying stereoscan photographs illustrate all the common species and most of the rarer species of planktonic foraminifera that are found in the extensive Pliocene strata of the southern part of the North Island of New Zealand. The fossils are from two major areas of late Cenozoic marine sedimentation, Wanganui Basin to the west of the axial ranges, and the Wairarapa area to the east (Fig. 1).

Wanganui Basin is thought to have been a partially enclosed embayment during Pliocene times (Collen, 1972 MS), and yields sparse and sometimes impoverished assemblages of planktonic foraminifera. Wairarapa was part of the continental slope east of New Zealand during most of the Pliocene and yields abundant planktonic foraminifera (Vella, 1972, in press).

Morphological detail revealed by the stereoscan photographs throws new light on the taxonomy, especially on the generic and familial relationships of some species. Comments are limited at present by the small number of published stereoscan photographs from elsewhere that are available for comparison.

Until now no attempt has been made to correlate New Zealand Upper Miocene, Pliocene and Quaternary strata with tropical planktonic foraminiferal zones. Southern North Island faunas include subantarctic and cool subtropical assemblages with a maximum of about 20 species and subspecies per sample, offering scant prospect for making such correlations. Nevertheless we consider that an attempt must be made,

Fig. 1 Sketch map of North Island of New Zealand showing areas mentioned in text.

and we propose certain correlations and briefly discuss the extremely tenuous evidence for them.

The main purpose of this paper, however, is to provide the taxonomic foundation for local stratigraphic and paleoclimatic studies, some of which are in preparation, others published or in press (Devereux et al., 1970; Kennett et al., 1971; Vella, 1971, in press; Liener et al., 1972, in prep.).

Registration numbers of figured specimens (prefix VF) are catalogue numbers of the Department of Geology, Victoria University of Wellington. Sample numbers (e.g. N166f884) are Sheet Fossil Numbers of the New Zealand Fossil Record system based on sheet districts of the New Zealand Map Series 1 (1:63,360).

The majority of specimens for illustration were selected from one particularly rich microsample, N166f884, from the upper Opoitian Stage (Lower Pliocene), Hinalura Road, Wairarapa. All other samples, except N139f544 and Galatea Station 626, are from the same section. This is intended to facilitate recollection of reference material.

Apart from the new subspecies, illustrated specimens are identified solely by catalogue numbers (VF-) in the plate captions.

The localities for the catalogued specimens are as follows:-

N139f544 - Rangitikei Valley, Wanganui Basin, Mangapanian Stage

(Upper Pliocene): VF948-950.

N166f880 - Middle Opoitian Stage (Lower Pliocene; Upper Gilbert

Geomagnetic Epoch): VF941.

N166f884 - Upper Opoitian Stage (Lower Pliocene; Upper Gilbert

Geomagnetic Epoch): VF890-936 inclusive, VF944, VF947.

N166f883 - Upper Opoitian Stage (Lower Pliocene; Lower Gauss Geomagnetic Epoch): VF945-946.

N166f885 - Upper Opoitian Stage (Lower Pliocene; Lower Gauss Geomagnetic Epoch): VF942-943, VF951-954.

N166f886 - Upper Opoitian Stage (Lower Pliocene; Gauss Geomagnetic Epoch Mammoth Event): VF939-940.

N166f889 - Top of Opoitian Stage (Lower Pliocene; Upper Gauss Geomagnetic Epoch): VF956, VF978.

N166f893 - Mangapanian Stage (Upper Pliocene; Lower Matuyama Geomagnetic Epoch): VF955.

Recent specimens of 8 species are illustrated for comparison with Pliocene specimens (VF957, VF959, VF969-972, VF974-976). All were taken from Galatea Station 626 in the Tasman Sea west of New Zealand (610m, latitude $42^{\circ} 10'S$, longitude $170^{\circ} 10'E$).

Photographs were taken with a Cambridge Instruments Ltd Stereoscan Mark II, operated by Physics and Engineering Laboratory of the N.Z. Department of Scientific and Industrial Research. Specimens mounted on an aluminium stub were coated in a vacuum chamber with carbon, followed by $200\text{\AA}$ of gold-palladium. A standard accelerating Voltage of 10kV with a working distance of 11 mm was used.

INTERCONTINENTAL BIOSTRATIGRAPHIC CORRELATIONS

The stratigraphic distribution of planktonic foraminifera in the Hinakura Road section (figs. 1,2) is representative for the Upper Miocene and Pliocene of eastern Wairarapa. It differs in minor details

from the Palliser Bay section of south-western Wairarapa (Jenkins, 1971, p. 57, table 44), and more markedly from sequences in the Wanganui Basin. The faunal differences were caused mainly by geographic differences in ocean surface temperatures, and by local fluctuations in these temperatures resulting from episodic changes in the position of the subtropical convergence (Devereux et al., 1970).

The geomagnetic reversal sequence on the left hand side of Table 1 is composed partly from pre-Gilbert to late Gauss polarity determinations on the sediments of Hinakura section itself (Lienert et al., 1972 in prep.), and partly from Gauss to Matuyama polarity determinations published for Mangaopari Stream section 16 km to the south-west (Kennett et al., 1971).

On the right hand side of fig. 2 are shown correlations with New Zealand stages, the New Zealand planktonic foraminiferal zones (Jenkins, 1967a, 1971) and an attempted correlation with the planktonic foraminiferal zones of Banner and Blow (1965) and Blow (1969). The stage correlations are based on all available useful fossils, planktonic and benthonic, and are fairly reliable. In the table, broken lines express uncertainty as to the exact positions of certain stage boundaries. None of Jenkins' zones can be recognised, and they have been correlated with the Hinakura strata solely by reference to the New Zealand stages. Likewise, his subzones based on alternations of sinistral and dextral coiling ratios of Neoglobobadrina pachyderma are not matched in the Hinakura section.

Fig. 2 Chart showing ranges of planktonic foraminifera in Hinakura Section, Wairarapa. Paleomagnetic ages after Kennett et al, 1971 and Lienert et al (in prep.).

The global zones N20 and N21 are correlated with slightly more confidence than N17, N18 and N19. The evidence is as follows:-

N21, Globorotalia tosaensis temuitheca Consecutive-range Zone:

Zone N21 is correlated with the Waipipian and Mangapanian stages and possibly part of the Hautawan stage. The planktonic foraminifera in the zone are nearly all eurythermal species that live in subantarctic waters today, the only important exception being the extinct Globigerina decoraperta which is reported to make its last appearance within Zone N21 (Blow, 1969, p. 266). Definite Globorotalia tosaensis has not been identified. Globorotalia truncatulinoides, which appears at the base of Zone N22, occurs in strata slightly younger than the highest shown in table 1.

N20, Globorotalia multicamerata - Pulleniatina obliqueoloculata

Partial-range Zone:

The strata correlated with Zone N20 form the upper part of the Opoitian Stage. They contain all of the species found in the overlying zone and a further 11 subtropical species and extinct species. The base is placed below the lowest occurrence of Neoglobocadrina dutertrei, which is supposed to make its first appearance low in N20 (Blow, loc. cit. p. 266). The upper limit of Globigerina apertura is in the middle of our zone (upper Opoitian) but is reported to be near the base of N20 (Blow, loc. cit.). Rare occurrences of Globigerina (Beella) digitata praedigitata and Globorotalia hirsuta praehirsuta are consistent with Zone N20 and the lack of Globorotalia margaritae which might be expected to occur in such strongly subtropical

assemblages, indicates an horizon younger than the middle of N19.

N19, Sphaeroidinella dehiscens - Globoquadrina altispira Partial-range
Zone:

The strata correlated with Zone N19 form the lower part of the Opoitian Stage. In eastern Wairarapa the planktonic foraminiferal assemblages of this age are almost entirely subantarctic.

The base of the Opoitian is an important paleontological horizon in New Zealand, marked by substantial changes in molluscan and foraminiferal faunas. The change is reflected in planktonic foraminifera mainly by dominant forms of Globorotalia, which are keeled species (mostly related to G. miozea) below the boundary, and non-keeled species (G. puncticulata, G. crassaformis) above the boundary. Besides being the base of the Opoitian Stage, this surface is the boundary between the Taranaki Series and the Wanganui Series, and has long been regarded as the Miocene-Pliocene boundary (Finlay and Marwick, 1940, 1947; Finlay, 1947).

Important keeled forms of Globorotalia below the boundary are G. miotumida Jenkins and G. miozea conoidea Walters both characterised by heavy incrustation of early chambers, and similar to Globorotalia merotumida Blow and Banner which is supposed to make its last appearance just below Zone N19 (Blow, 1969, p. 276). According to Jenkins (1971, table 11) Globigerina nepenthes makes its last appearance just above the base of the Opoitian Stage, and elsewhere in the world its upper limit is well established near the middle of Zone N19 (Parker, 1967; Hays et al., 1969; Blow, 1969). Globoquadrina dehiscens

disappears considerably below the Opoitian Stage in most parts of New Zealand, but occurs in the Opoitian at Kaawa Creek in the north-west of the North Island. Because the occurrence at Kaawa Creek seems anomalous, the specimens have been suspected to be reworked (e.g. Jenkins, 1971, p. 165). However, the Kaawa beds are the northernmost fossiliferous Opoitian, and the ocean surface water there would have been considerably warmer than in southern North Island, as it is at the present day. There is no doubt that G. dehiscens was a warm-water species (probably tropical to warm subtropical). Cooling ocean surface waters in late Miocene times (Jenkins, 1967b; Kennett, 1968a) may have caused its early disappearance from southern New Zealand. The upper limit of G. dehiscens is near the top of Zone N19 (Blow, 1969, p. 272).

N18, Globorotalia tumida tumida - Sphaeroidinellopsis subdehiscens
paenedehiscens Partial-range Zone:

The strata correlated with Zone N18 correspond roughly to the Kapitean Stage. Planktonic foraminiferal assemblages are depleted in species throughout the country (Jenkins, 1971, table 11), and in southern North Island show characteristics of subantarctic faunas and at some horizons possibly even Antarctic faunas (Kennett, 1968a). There is little prospect of finding any direct evidence within the Kapitean for correlation.

N17, Globorotalia tumida plesiotumida Consecutive-range Zone:

Strata correlated with Zone N17 include the Upper Tongaporutuan Substage and probably part or all of the Middle Tongaporutuan Substage, and correspond to most of the Globorotalia miotumida Zone of Jenkins (1967, 1971). The only direct evidence for correlation with N17 is that Upper and at least part of Middle Tongaporutuan is above the upper limit of Turborotalia continuosa (Jenkins, 1971), and contains specimens resembling Globigerina apertura (fig. 2) which is reported to make its earliest appearance within Zone N16 (Blow, 1969, p. 266).

The weakness of the above overseas correlations results from a scarcity of stratigraphically useful species and is compounded by the effect of local ocean surface temperature changes on local planktonic foraminiferal time ranges. Although magnetic polarities determined at Hinakura Road are not completely reliable and still need considerable checking (Lienert et al., loc. cit.), they can be used as a tentative test of the above correlations. The relationship between paleomagnetic epochs and global planktonic foraminiferal zones shown in fig. 2 compares favourably with that of Hays et al. (1969, Pl. 1).

TAXONOMY

The scanning electron microscope reveals clearly the minute surface detail which has been shown to be important in the generic and suprageneric classification of the planktonic foraminifera (Parker, 1962; Lipps, 1966; Tappan and Lipps, 1966; McGowran, 1968). Lipps (1966)

recognised three main types of sculpture which he considered to be related to the crystalline structure of the test wall:-

Type a: Tubercles and/or secondary crusts of calcite on a basically smooth surface, characteristic of Globorotaliidae and Hantkeninidae.

Type b: A hispid surface formed by subconical spine bases that bear long thin calcitic spines during life of the individual, characteristic of Globigerinidae.

Type c: A regularly pitted (cancellate) surface, lacking tubercles and spine bases, characteristic of Catapsydracidae.

Lipps' observations were based largely on thin sections. Our observations below are based solely on external surface features. To avoid ambiguity it is necessary to restrict and define the usage of certain terms:-

Spines: This term is restricted to the long thin calcitic processes that support the pseudopodia of Globigerinidae during life (Loeblich and Tappan, 1964, p. 667) but are quickly broken off the tests after death.

Spine bases: Short subconical processes formed around the bases of spines, and surviving after death to form the so-called hispid surface.

Tubercles: Short subconical, hemispherical or subcylindrical processes that are not associated with long spines during life.

Crust: More or less amorphous secondary deposit of calcite, usually thickest on early chambers, with a surface either mammilated, or roughened by projecting edges of rhombohedral calcite crystals.

Perforations: Fine holes approximately $0.06\mu - 0.2\mu$ in diameter, penetrating the test walls. Average diameters for each species are mentioned in the taxonomic descriptions.

Pores: Larger holes, $1.0\mu - 3.0\mu$ in diameter, penetrating test walls.

For each species the perforations are one order of magnitude smaller than pores. The supplementary apertures of Orbulina universa are one order of magnitude larger than the pores.

Types of Turborotalita quinqueloba lingulata n. subsp. are deposited in the Department of Geology, Victoria University of Wellington. Unregistered paratypes will be sent to N.Z. Geological Survey, Lower Hutt, and to the Cushman Foundation, U.S. National Museum, Washington.

Family Candeinidae

Genus GLOBIGERINITA Brönnimann, 1951

Type species: Globigerinita naparimaensis Brönnimann
(equals Tinophodella Loeblich and Tappan, 1957).

Spines are not present during life (Parker, 1967, p. 145; Bé et al., 1971, pl. 1, figs. 9a-b). The two species here described have dense subconical tubercles covering the surface. They differ from all other species examined in having no pores. Only very fine perforations penetrate the walls, and they tend to be hidden by the tubercles and show only at very high magnifications or on smooth interspaces where spines are less dense than normal. There is no sign of pits such as those seen in Catapysdracidae and some Globigerinidae, or of conical

depressions such as surround the pores of Globorotaliidae. A bulla covers the umbilicus in both species. In G. glutinata the bulla may be covered by tubercles almost as dense and large as on the normal chambers (pl. 1, fig. 1) or may be comparatively smooth (Bé et al., loc. cit.). In G. uvula the bulla has few tubercles, is densely perforate, seems to be very thin walled, and is often missing from the tests.

Some authors have treated Turborotalita quinqueloba as a species of Globigerinita, but it has spines and pores, and therefore must be classed in Globigerinidae.

Globigerinita glutinata (Egger)

Plate 1, figs. 1, 2.

Globigerina glutinata Egger 1893, p. 371, pl. 13, figs 19-21.

Globigerinita glutinata, Parker, 1962, p. 246, pl. 9, figs 1-16.

Globigerinita incrusta Akers, Jenkins 1971, p. 184, pl. 19, figs 585-7.

Globigerina juvenilis Bolli, Jenkins 1971, p. 149, pl. 16, figs 471-3.

Perforations: 0.29μ (no pores).

Under the optical microscope, Pliocene specimens that lack the bulla and have been identified as G. juvenilis closely resemble G. glutinata in size, gross morphology, thinness of walls, and the exceeding fineness of the surface texture. Stereoscan photographs (Bé et al., 1971, pl. 2, figs. 9a-b) confirm the resemblance and show that the form without a bulla has the characteristic surface features of Globigerinita glutinata.

G. glutinata is a major element in nearly all southern North Island Pliocene faunas. Forms with a bulla usually, but not invariably, outnumber those without.

Globigerinita uvula (Ehrenberg)

Plate 1, figs. 3-6.

Pyrodexia uvula Ehrenberg 1861, p. 276-7, 308; 1873, pl. 2,

Globigerina bradyi Wiesner 1931, p. 133. figs 24-5.

Globigerinita uvula, Parker 1962, p. 252, pl. 8, figs. 14-26.

Perforations: 0.12μ (no pores).

Parker's comments (loc. cit.) on the resemblance between G. glutinata and G. uvula are borne out by the close similarity of the surface detail, characterised by densely packed fine tubercles. Specimens lacking a bulla have been classed previously as Globigerina bradyi (Jenkins, 1971, p. 139, pl. 15, figs. 431-2) but they have the same characteristic surface detail as specimens with a bulla. Specimens with the bulla are relatively uncommon, presumably because the bulla is very thin-walled and easily destroyed.

G. uvula is common in many inner neritic to bathyal Pliocene samples, and is associated with subantarctic and subtropical assemblages. In a few samples it is rare or entirely absent, and a possible reason is that its minute and lightly constructed test may have been very subject to winnowing, even in fairly deep water on the continental slope.

Family Catapsydracidae

Genus NEOGLOBOQUADRINA Bandy, Frerichs and Vincent, 1967

Type species: Globigerina dutertrei d'Orbigny

The lectotype of Globigerina dutertrei (Banner and Blow, 1960a, p. 11, pl. 2, fig. 1) has five chambers in the final whorl and apparently has no apertural plates ("teeth") such as those described by Bandy, Frerichs and Vincent. New Zealand Pliocene and Recent specimens are similar to the lectotype and to the specimens illustrated with stereoscan photographs by Blow (1969, pl. 14, figs. 6,7). They correspond to the form described as N. dutertrei subcretacea (Lomnicki) by Bandy et al (1967).

The surface of the final chamber has deep pits with central pores. The pits are smaller and less regular in shape and arrangement than those found in Globigerinidae such as Globigerina apertura, Globigerina decoraperta and Globigerinoides sacculifer. On earlier chambers some pit walls have been selectively enlarged, and have coalesced to form sinuous ridges, and at places, especially on the umbilical side near the aperture, secondary crust, with a rough surface of rhombohedral calcite crystals, obscures primary sculpture (as in Globorotaliidae). One specimen (pl. 1, fig. 10) shows secondary spike-like tubercles on the penultimate whorl just inside the aperture.

Some Pliocene subtropical assemblages contain intergrading populations of N. dutertrei and "Globigerina" pachyderma. The stereoscan photographs show that these two species have almost identical surface details. They are evidently closely related and are certainly not

generically distinct, and pachyderma must be treated as a member of Neogloboquadrina.

Lipps (1966) stated that N. pachyderma has the kind of wall microstructure characteristic of Globigerinidae, but others have shown that N. pachyderma is non-spinose during life (Be'et al., 1971, pl. 1, figs. 1a-b). Parker (1962, 1967) claimed that all the Recent species included by her in Globoquadrina are non-spinose. We regard pitted primary sculpture and lack of spines as indicative of the family Catapsydracidae, as amended by Lipps (loc. cit.).

Neogloboquadrina dutertrei (d'Orbigny)

Plate 1, figs. 7-10.

Globigerina dutertrei d'Orbigny 1839a, p. 84, pl. 4, figs. 19-21.

Neogloboquadrina dutertrei subcretacea (Lomnicki), Bandy, Frerichs and Vincent 1967, p. 152-6, figs. 3, 7-12.

Globorotalia (Turborotalia) dutertrei, Jenkins 1971, p. 114-115, pl. 11, figs. 173-5.

Pores: $1.7\mu - 7.5\mu$; Perforations: 0.1μ .

In the New Zealand Pliocene N. dutertrei is restricted almost entirely to subtropical assemblages. Jenkins (loc. cit.) gave its stratigraphic range from Tongaporutuan (Upper Miocene) to Castlecliffian (Middle Pleistocene). We have not found it below upper Opoitian (probably Zone N20) in southern North Island.

Neogloboquadrina pachyderma (Ehrenberg)

Plate 1, figs. 7-10.

Aristospira pachyderma Ehrenberg 1864, p. 276-7, 303.*Globigerina bulloides* var. *borealis* Brady 1881, p. 412.*Globigerina pachyderma*, Brady 1884, p. 600, pl. 114, figs. 19-20.*Globigerina pachyderma*, Kennett 1970a, p. 47-9, pls 8-9.Pores: $1.3\mu - 4.0\mu$; Perforations: 0.3μ .

Pliocene subantarctic assemblages contain compactly coiled, thick-shelled *N. pachyderma* with only four chambers in the final whorl. The last chamber is often smaller than the penultimate. The aperture varies from gently arched and low to strongly arched and high, and from strongly asymmetrical to nearly symmetrical with respect to the umbilicus. Secondary crust may be thick. Pores tend to be obscured by crust on early chambers, but may be enlarged adjacent to sutures, a feature seen in *N. dutertrei* also.

Subtropical assemblages contain many specimens with fractionally more than four chambers in the final whorl as in more northerly Recent faunas of the Southwest Pacific (Kennett, 1968b). Some individuals approach the five-chambered form, and are difficult to allocate between *dutertrei* and *pachyderma*. Parker and Berger (1971) suggested that true *N. pachyderma* might be completely sinistral and *N. dutertrei* dextral. However Jenkins (1971) observed that the two forms (distinguished by the number of chambers in the final whorl) generally have the same coiling ratios wherever they occur together, and we have found this to be true in samples examined by us. This correspondence in coiling

ratio suggests a close phylogenetic relationship, and possibly even interbreeding of the two forms. It may be that pachyderma is no more than a subspecies or variety of dutertrei.

N. pachyderma is a dominant form in the antarctic and sub-antarctic water-masses, and overlaps into the southern part of the southern subtropical water-mass (Kustanovich, 1963). It is likewise a dominant species in Pliocene subantarctic assemblages, in some samples forming more than 50 percent of the total population of planktonic foraminifera. It varies in abundance consistently in accordance with temperatures indicated by oxygen isotope ratios but variations in its coiling ratio are occasionally inconsistent with other paleotemperature data (Devereux et al., 1970; Vella, 1972 in press).

Family Globigerinidae

Genus GLOBIGERINA d'Orbigny, 1862

Type species: Globigerina bulloides d'Orbigny

The species of Globigerina that are described below can be divided into two groups according to their surface sculpture:-

1. Globigerina bulloides, G. bulloides trilocularis, G. eamesi, and G. cf. falconensis have the final chamber hispid (with spine bases) and earlier chambers modified by coalescence of spine bases to form irregular ridges. Pores occupy interspaces between spine bases. G. (Beella) praedigitata has similar but finer surface detail.

2. The extinct species Globigerina apertura and G. decoraperta have all chambers covered by regular subhexagonal pits with gently sloping sides, and pores at the centres. The final chamber lacks spine bases, and there is no external evidence that these species were spinose during life. However the surface is very like that of Globigerinoides sacculifer, which is spinose during life (see below), and we consider that G. apertura and G. decoraperta are phylogenetically closely related to G. sacculifer through Globigerina woodi and Globigerinoides trilobus.

Globigerina apertura Cushman

Plate 2, figs. 4-6.

Globigerina apertura Cushman 1918, p. 57, pl. 12, figs. 8a-c.

Pores: $2.0\mu - 5.0\mu$; Perforations: 0.07μ .

In some samples, G. apertura and G. decoraperta tend to intergrade, and are difficult to separate. They have identical sculpture, and both consistently have four slowly increasing chambers in the final whorl. The only useful distinguishing features are that G. decoraperta has a lower spire, and a smaller, more circular, and less inclined aperture.

Jenkins (1971, p. 138, pl. 15, figs. 426-7) recorded G. apertura from the Opoitian Stage and possibly from the overlying Waitotaran Superstage (Waipipian and Mangapanian). In southern North Island it has not been found in the Waitotaran. In Wairarapa it is found in the upper Opoitian Stage, correlated with Zone N20. Specimens that appear to be

intermediate between G. apertura and G. woodi, having the characteristic large aperture of G. apertura, but a relatively low spire, occur in the Tongaporutuan Stage, correlated with Zone N17 (samples N165f961, N166f905). The upper Opoitian and Tongaporutuan occurrences are both in subtropical assemblages.

The distinctive cancellate sculpture indicates that G. apertura is related to G. woodi, and cannot be regarded as a subspecies of G. bulloides, as by Blow (1969).

Globigerina bulloides bulloides d'Orbigny

Plate 2, fig. 7.

Globigerina bulloides d'Orbigny 1862, p. 277, list 1.

Pores: $1.6\mu - 6.0\mu$; Perforations: 0.16μ .

The final chamber has moderately dense coarse spine-bases with pores scattered randomly in interspaces. On earlier chambers the spine-bases tend to be enlarged and coalesced to form irregularly oriented short sinuous ridges. Specimens that have been referred to G. bulloides in New Zealand have between 3 and 4 chambers in the final whorl. The three-chambered form has quite a different outline from the four-chambered form. The two forms vary in relative abundance, and in occasional samples, one form only is represented. We arbitrarily restrict G. bulloides bulloides to those specimens with $3\frac{1}{2}$ to 4 chambers in the final whorl.

G. bulloides bulloides is abundant in the Upper Miocene, Pliocene and Quaternary of southern North Island, and has been recorded in

nearly all samples examined.

Globigerina bulloides trilocularis Deshayes

Plate 2, fig. 8

Globigerina trilocularis d'Orbigny 1826, p. 277, no. 2 (nom. nud.).

Globigerina trilocularis Deshayes 1832, p. 170.

Globigerina trilocularis, Fornasini 1898, pl. 1, figs. 6, 7, 7a; p. 12, text-fig. (three unpublished line drawings by d'Orbigny).

Pores: $1.7\mu - 3.5\mu$; Perforations: not measured.

The final whorl includes less than $3\frac{1}{2}$ chambers. The aperture is somewhat variable in size, and generally smaller than in *G. bulloides bulloides*. Sculpture and average test size are the same as in *G. bulloides bulloides*. New Zealand Pliocene specimens are very similar in outline to the Italian Pliocene specimens illustrated by Fornasini (loc. cit.).

G. bulloides trilocularis is present in nearly all southern North Island Pliocene planktonic faunas. It is sometimes more abundant, sometimes less abundant than *G. bulloides bulloides*, and in one Wairarapa sample has been recorded in the absence of *G. bulloides bulloides*.

Globigerina praebulloides occlusa Blow and Banner (1962, p. 93, pl. 9, figs. u-w) resembles *G. bulloides trilocularis* but seems to have a smaller aperture and is probably distinct.

Globigerina decoraperta Takayanagi and Saito

Plate 2, figs. 9-11.

Globigerina druryi Akers *decoraperta* Takayanagi and Saito 1962,
p. 85, pl. 28, figs. 10a-c.

Globigerina decoraperta, Parker 1964, p. 629, pl. 101, figs. 8-10.

Globigerina (Globigerina) woodi decoraperta, Jenkins 1971, p. 158,
pl. 16, figs. 502-4.

Poros: $1.3\mu - 4.0\mu$; Perforations: 0.13μ .

The pitted surface of *G. decoraperta* is identical to that of *G. apertura* (see above) and probably also to that of *G. woodi* Jenkins. Both *G. apertura* and *G. decoraperta* seem to be more consistent in their gross morphology than *G. woodi*, but the spire height and aperture size of *G. decoraperta* are somewhat variable. In contrast to *G. apertura*, the apertural plane of *G. decoraperta* is generally nearly normal to the axis of coiling, and the apertural margin is almost perfectly circular.

Globigerina rubescens Hofker has a smaller aperture and is not found in the New Zealand Pliocene.

G. decoraperta tends to be restricted to subtropical assemblages, but is represented in some subantarctic assemblages, and evidently was more eurythermal than *G. apertura*. It is abundant in many Upper Miocene and Pliocene samples from southern North Island. Its upper limit is probably in the Mangapanian Stage, and its lower limit is uncertain.

Globigerina eamesi Blow

Plate 3, figs. 1, 2.

Globigerina eamesi Blow 1959, p. 176, pl. 9, figs. 39a-c.*Globigerina zelandica* Hornibrook 1961, p. 150, pl. 21, figs. 436-8.*Globigerina eamesi*, Jenkins 1971, p. 146, pl. 15, figs. 454-6.

Pores: 0.8 - 3.5 ; Perforations: 0.09 .

The surface detail is similar to that of *G. bulloides* except for scattered large spine bases which are particularly prominent on the final chamber.

G. eamesi is always rare, but is very persistent in Upper Miocene and Pliocene faunas, being absent only from the most restricted subantarctic assemblages.

Globigerina cf. *falconensis* Blow

Plate 3, figs. 4, 5.

Globigerina falconensis Parker 1962, p. 224, pl. 1, figs. 14, 16-19 (not *G. falconensis* Blow 1959).

Globigerina falconensis, forma atypica, Blow 1969, p. 266.

Globigerina falconensis, Jenkins 1971, p. 148 (part), pl. 16, figs. 463-5.

Pores: $1.0\mu - 2.5\mu$; Perforations: not measured.

Jenkins (loc. cit.) regarded *G. falconensis* as a close relative of *G. bulloides*, and this is definitely true of the late Cenozoic form here referred to *G. cf. falconensis*. The surface detail is very similar, and the two forms are distinguished only by inconsistent

differences in the gross morphology of the test and the form of the aperture. Ideally the test of G. cf. *falconensis* is flatter than that of *bulloides*, its sutures are less deeply indented, and the aperture is smaller and lower, the rim being more gently arched and always furnished with a lip. Often the chambers are slightly asymmetrical rather than subglobular as in *G. bulloides*. Intermediate forms exist and are difficult to allocate between the two species. Perhaps it would be more appropriate to treat G. cf. *falconensis* as a variety or subspecies of *G. bulloides* than as a separate species.

G. cf. *falconensis* is common in subtropical assemblages, rare or absent in subantarctic assemblages in the Pliocene of southern North Island.

Subgenus BEELLA Banner and Blow, 1960

Type species: *Globigerina digitata* Brady

Globigerina (Beella) *digitata praedigitata* Parker

Plate 3, figs. 3, 6.

Globigerina (Beella) *digitata praedigitata* Parker 1967, p. 151, pl. 19, figs. 5-8.

Pores: 2.5μ ; Perforations 0.25μ .

The surface detail is similar to, but much finer than, that of *G. bulloides*. A stereoscan photograph of a topotype shows the same type of finely textured surface (Blow, 1969, pl. 19, fig. 7; not fig. 9, which has a coarser sculpture and a differently shaped final

chamber and aperture). The final chamber of our figured specimen is abnormally offset towards the umbilical side of the spiral, but is normal in shape.

Only two specimens have been recorded in southern North Island, and one of them has been destroyed. Both specimens are from sample N166f881, Hinakura Road (upper Opoitian, correlated with Zone N20), which represents the Pliocene paleotemperature maximum in eastern Wairarapa.

Genus TURBOROTALITA Blow and Banner, 1962

Type species: Truncatulina humilis Brady

The lectotype of T. humilis (Banner and Blow, 1960a, pl. 8, figs. 1a-c) is similar in gross morphology to our T. quinqueloba lingulata n. subsp., differing in having six chambers in the final whorl, and in having more than two infralaminar openings from the bulla-like final chamber.

The specimens illustrated with stereoscan photographs as T. humilis by Bé et al. (1971, pl. 1, figs. 8a-b) have more numerous chambers, a more depressed spire, and coarser spine-bases (especially near the periphery) than the lectotype, and appear to represent T. cristata Heron-Allen and Earland. Parker (1962, p. 249) synonymised T. cristata with T. humilis, but perhaps it could be retained as a subspecies or variety of T. humilis.

Typical T. quinqueloba has merely a flap-like extension of the final chamber covering the umbilicus, but not attached to the previous

chambers, and has generally been treated as Globigerina. The new subspecies T. quinqueloba lingulata differs in having the leading edge of the flap fused to one or more of the earlier chambers in the final whorl, and confirms the relationship of T. quinqueloba to T. humilis.

On our specimens the final chamber usually has fairly dense well defined spine-bases, and fairly fine pores set in shallow conical depressions. Earlier chambers have either smaller spine-bases (partly buried by secondary deposits) or no trace of spine-bases (completely buried), or spine-bases coalescing into an irregular reticulating ridge pattern; the conical depressions are broader and deeper and the pores are slightly or greatly enlarged. Clefts along sutures may indicate differential solution after death.

Long spines are present during life (Bé et al., 1971, pl. 1, figs. 2a-c). Except for the aperture, gross and detailed morphology indicate relationship to the Globigerinidae, not to the Globorotaliidae or Candelinidae.

Turborotalita quinqueloba quinqueloba (Natland)

Plate 4, figs. 10-12; plate 5, fig. 4

Globigerina quinqueloba Natland 1938, p. 149, pl. 6, fig. 7.

Turborotalita quinqueloba, Blow 1969, p. 373.

Pores: $0.6\mu - 4.0\mu$; Perforations 0.16μ .

New Zealand Pliocene specimens show considerable variation in surface details. Well preserved specimens have spine-bases on all chambers or spine-bases coalesced to form irregular reticulating ridges

on earlier chambers. Other specimens have pits with large pores, which may have been enlarged by solution after death. Those specimens with spine bases on all chambers closely resemble the Recent specimen figured by Bé et al (1971, pl. 1, fig. 2c).

T. quinqueloba is abundant throughout the New Zealand Pliocene, in both subantarctic and subtropical assemblages.

Turborotalita quinqueloba lingulata Collen and Vella,
n. subsp.

Plate 4, fig. 9; plate 5, figs. 1-3.

Turborotalita quinqueloba, Bizon 1971, p. 253, pl. 1, fig. 4c
(not Globigerina quinqueloba Natland 1938).

Pores and perforations, as for the typical subspecies.

A small minority of New Zealand Pliocene and Quaternary specimens of T. quinqueloba have the leading edge of the flap-like extension of the final chamber fused to one or more of the earlier chambers of the final whorl. They seem to belong to the same interbreeding population as the typical G. quinqueloba. Most of the specimens have two openings, one on either side of the soldered down part of the flap; a few specimens have more than two openings as in T. humilis. All specimens have five chambers in the final whorl, and have the same kind of gross and detailed morphology as typical G. quinqueloba. The specimen illustrated by Bizon (loc. cit.) appears to be identical with the New Zealand specimens that have two openings under the apertural flap.

Locality of holotype and figured paratypes:

Holotype and two paratypes VF949, VF950: N139f544,

Rangitikei Valley, 150 m south of Mangaweka Railway
Station;

Paratype VF978: N166f881, Hinakura Road, 100m east of
Mikawera Road junction.

Registration numbers and dimensions:

Holotype: VF948, diameter 0.23 mm; height 0.17 mm.

Paratypes: VF949, diameter 0.17 mm; height 0.12 mm.

VF950, diameter 0.15 mm; height 0.12 mm.

VF978, diameter 0.24 mm; height 0.15 mm.

Genus *GLOBIGERINELLA* Cushman, 1927

Type species: *Globigerina aequilateralis* Brady, equals
Globigerina siphonifera d'Orbigny.

Globigerinella was classified in the Hantkeninidae by Loeblich and Tappan (1964), but we consider that it belongs in the Globigerinidae because of its sculpture and its basically trochospiral coiling. Immature specimens of *G. siphonifera* are trochoid with an umbilical-extraumbilical aperture, and are similar in gross morphology to *Neogloboquadrina dutertrei*. Even the fully mature shell is usually not perfectly planispiral. The sculpture is unlike that of *Hantkenina* or of *Neogloboquadrina*, and is similar to that of *Globigerina bulloides*. Living specimens have long spines (Bé et al., 1971, pl. 2, figs. 4a,b), and dead tests have densely packed spine bases with numerous small

pores in the inter-spaces. On early chambers the spine bases tend to coalesce into irregular ridges.

Globigerinella siphonifera (d'Orbigny)

Plate 3, figs. 7-9, 11, 12.

Globigerina siphonifera d'Orbigny, 1839a, p. 83, pl. 4, figs. 15-18.

Globigerina aequilateralis Brady, 1879, p. 285; 1884, p. 605, pl. 80, figs. 18-21.

Hastigerina (*Hastigerina*) *siphonifera*, Blow, 1960b, p. 22, text-figs. 2a-c, 3a-b.

Globigerinella aequilateralis, Jenkins, 1971, p. 77, pl. 2, figs. 47-49, gives additional references.

Pores: $1.0\mu - 4.0\mu$; Perforations: 0.2μ .

Globigerinella siphonifera ranges from Tongaporutuan (Upper Miocene) to Recent (Jenkins loc. cit.) but is restricted to subtropical and mixed subtropical-subantarctic assemblages (Devereux et al., 1970; Vella, 1972, in press). Asymmetry of the aperture of mature tests and trochoid coiling of immature tests were regarded as diagnostic of *Hastigerina* (H.) *siphonifera praesiphonifera* (Blow 1969, p. 408-9, pl. 54, figs. 7-9). Blow treated this as a chronological subspecies preceding typical *siphonifera*, but the diagnostic characters are normal features of New Zealand Pliocene and Recent specimens. Our cool subtropical populations may be different from the tropical populations and may be more correctly treated as *praesiphonifera*.

Genus GLOBIGERINOIDES Cushman, 1927

Type species: Globigerina rubra d'Orbigny

G. conglobatus, G. ruber and G. sacculifer all have long spines during life (Bé et al., 1971, pl. 2, figs. 103). The final chamber of G. ruber has spine bases like those of Globigerina bulloides. New Zealand specimens here referred to G. obliquus also have spine bases on the final chamber, which are coarse, and some of which have already coalesced to form short sinuous ridges. On earlier chambers the spine bases have all coalesced to surround subhexagonal to irregular pits with central pores, and the earliest part of the test on the spiral side has heavy rugae. The other species illustrated here, G. sacculifer and G. trilobus, differ in having no spine bases on the final chamber, but a regularly reticulating pattern of ridges forming subhexagonal pore pits, and this same pattern persists on most of the earlier chambers.

Globigerinoides obliquus Bolli

Plate 4, figs. 4-6.

Globigerinoides obliquus Bolli 1957, p. 113, pl. 25, figs. 10a-c.Pores: $2.1\mu - 5.4\mu$; Perforations: 0.4μ .

Specimens from Recent bottom sediments in the Tasman Sea (pl. 4, fig. 5) seem identical with the New Zealand Pliocene specimens, suggesting that this species ranges into Zone N23, although previous publications have reported its upper limit as Zone N21 (Parker, 1967) and Zone N22 (Blow, 1969). The type figures and other published figures give no hint as to whether the detailed surface morphology is

like that of our illustrated specimens. Stereoscan photographs attributed to G. obliquus extremus Bolli (Blow, 1969, pl. 21, figs. 2, 3) show slightly different detailed morphology with no distinct spine bases on the final chamber, and smaller pits on earlier chambers.

In the southern North Island Pliocene G. obliquus is rare and restricted to subtropical assemblages in the upper Opoitian and Mangapanian stages.

Globigerinoides saeculifer (Brady)

Plate 4, figs. 7, 8.

Globigerina saeculifera Brady 1877, p. 535; 1884, p. 604, pl. 80, figs. 11-17, pl. 82, fig. 4.

Pores: $2.0\mu - 3.3\mu$; Perforations: 0.2μ .

Nearly all chambers have regular subhexagonal pore pits. Only mature specimens, with the characteristic final chamber, can be distinguished from G. trilobus. Such specimens have been found in only one sample from the southern North Island Pliocene, N166f881, upper Opoitian Stage, Hinakura Road, Wairarapa. It is rare, and is associated with the warmest known paleotemperature in the Wairarapa Pliocene and Quaternary.

Globigerinoides trilobus (Reuss)

Plate 4, figs. 1-3.

Globigerina triloba Reuss 1850, p. 374, pl. 47, figs. 11a-c.

Pores: 2.7μ ; Perforations 0.14μ .

Surface detail is identical to that of G. sacculifer, and all Pliocene specimens referred to trilobus may be immature G. sacculifer. Such specimens are only slightly more frequent than mature sacculifer, and are confined to a few subtropical assemblages.

Genus ORBULINA d'Orbigny, 1839

Type species: Orbulina universa d'Orbigny

Orbulina universa d'Orbigny

Plate 3, fig. 10.

Orbulina universa d'Orbigny, 1839a, p. 2, pl. 1, fig. 1.

Pores: $0.5\mu - 1.0\mu$; Perforations: not measured.

Living Orbulina universa has long spines (Brady, 1884, pl. 78, pl. 81, fig. 24). Our illustrated specimen has small spine bases with wide interspaces. The surface is similar to that of the final chamber of Globigerina bulloides, except for the multiple apertures which measure $7\mu - 9\mu$, one order of magnitude larger than the pores. It does not have the cancellate sculpture mentioned in the generic diagnosis by Blow (1956, p. 66), but stereoscan investigations of specimens of various geological ages would be desirable before any taxonomic conclusions are drawn.

Orbulina universa is persistent but never common in the Pliocene of southern North Island. It is represented in all subtropical and most subantarctic assemblages, and tends to be less frequent when present in the latter.

Family Globorotaliidae

Subfamily Globorotaliinae

Genus GLOBOROTALIA Cushman, 1927

Type species: Pulvinulina menardii (d'Orbigny) var.

tumida Brady

The non-keeled species Globorotalia puncticulata Cushman

In some species, large spike-like tubercles near or in the aperture seem to be secondary structures and not merely enlarged primary tubercles (e.g. plate 6, fig. 1).

The non-keeled species mentioned above are not treated as Turborotalia because the Upper Eocene type species Turborotalia centralis Cushman and Bermudez is reported to have a pitted surface as in Catapsydracidae (Lipps, 1966). Furthermore, in northern New Zealand, keeled Globorotalia miozea Finlay changed progressively with time, through G. sphericomiozea Walters to G. puncticulata (originally identified as G. inflata: McInnes, 1965; Walters, 1965). Whether this bioseries reflects evolution as suggested by McInnes and Walters, or whether it merely reflects ecologically controlled migration (Blow, 1969, p. 350), it indicates a close genetic relationship between the keeled miozea and the non-keeled puncticulata. The development of a non-perforate keel is variable in G. crassaformis, which has been treated as Turborotalia by Blow (1969) and as true Globorotalia by Jenkins (1971) and other authors.

Globorotalia crassaformis (Galloway and Wissler)

Plate 6, figs. 1-6.

Pulvinulina crassa, Brady 1884, p. 694, pl. 103, figs. 11-12.

(not Rotalina crassa d'Orbigny).

Globigerina crassaformis Galloway and Wissler, 1927, p. 41, pl. 7, fig. 12.

Pores: $1.0\mu - 2.5\mu$; Perforations: 0.1μ .

The subconical shape and narrow slit-like aperture are considered to be consistent and diagnostic features. The periphery varies from bluntly rounded to angular. Angular specimens often have a non-perforate keel. The keeled forms may be what Blow (1969) recorded as Pliocene G. conomiozea Kennett, but are closer to G. crassaformis; they possibly represent the forerunners of G. tosaensis Takayanagi and Saito. Specimens reported as possible G. tosaensis by Devereux et al. (1970) are small and very uncertain as to their identity. Kennett et al. (1971) examined a representative collection and rejected the identification of tosaensis, regarding the specimens as variants of G. crassaformis. None of them have more than four chambers in the final whorl.

Mature specimens have dense, broad, low, rounded tubercles on the final chamber. Thick crust usually obscures tubercles on earlier chambers. Large, probably secondary tubercles are often developed on the early part of the final whorl adjacent to the aperture.

G. crassaformis first appears at the base of the Opoitian Stage (mid Gilbert geomagnetic Epoch) and is infrequent but fairly persistent throughout the Pliocene, being absent only where paleotemperatures are at their coldest.

Globorotalia hirsuta hirsuta (d'Orbigny)

Plate 7, figs. 6-8.

Rotalina hirsuta d'Orbigny 1839b, p. 131, pl. 1, figs. 37-9.Pores: 0.9μ - 2.7μ ; Perforations 0.16μ .

Recent specimens from the Tasman Sea are figured for comparison with the Pliocene specimens of G. hirsuta praehirsuta described below. The Tasman Sea specimens agree closely with the neotype and topotypes of G. hirsuta figured by Blow (1969, pl. 8, figs. 1-3; pl. 43, figs. 1,2). The surface detail is very similar to that of praehirsuta, has the characteristic features of Globorotalia, and is intermediate in development between very smooth forms like G. scitula, and heavily tuberculate and encrusted forms like G. inflata and G. crassaformis.

Pliocene records of G. hirsuta by Jenkins (1971, p. 89, pl. 4, figs. 111-116) probably represent praehirsuta.

Globorotalia hirsuta praehirsuta Blow

Plate 7, fig. 9.

Globorotalia (Globorotalia) hirsuta praehirsuta Blow, 1969, p. 400, pl. 43, figs. 3-7.

Pores: 1.1μ - 2.6μ ; Perforations: 0.16μ .

Pliocene specimens are smaller than Recent G. hirsuta, have a flatter ventral surface, and lack the small umbilical pit, just as described by Blow. Tubercles increase in size on successively earlier chambers, but show little increase in density. Pores are denser towards

the periphery than near the middle, and tend to be obscured by a light crust on earlier chambers.

In the Pliocene of southern North Island G. praehirsuta is rare and restricted to subtropical assemblages in the Upper Opoitian (here correlated with Zone N20) and possibly in the Mangapanian Stage.

Globorotalia inflata d'Orbigny

Plate 5, figs. 11, 12.

Globigerina inflata d'Orbigny, 1839b, p. 134, pl. 2, figs. 7-9.

Pores 0.8μ - 2.0μ ; Perforations: 0.1μ .

Until very recently (Hornibrook and Edwards, 1970; Vella and Briggs, 1971) New Zealand authors have treated G. inflata and G. puncticulata as one species, under the name of G. inflata. As here interpreted, G. inflata has a test with rounded, inflated chambers, a broadly rounded periphery, and between 3 and 4 chambers in the final whorl (usually about $3\frac{1}{2}$). The final chamber is often relatively small, but when so, it is always rounded and never has the angular periphery that characterises the final chamber of G. puncticulata hinakura n. subsp. Numerous broad, low, rounded tubercles are distributed somewhat irregularly over the final chamber, and a thick crust with rhombohedral surface texture covers earlier chambers (pl. 5, fig. 11). Spike-like tubercles, probably secondary, appear adjacent to the aperture.

The oldest specimens that can be identified confidently as G. inflata are in the Upper Opoitian Stage (Gauss Geomagnetic Epoch) where they are common but still subsidiary to G. puncticulata. In

overlying strata, G. inflata progressively displaces G. puncticulata, becoming dominant in upper Waipipian or lower Mangapanian (early Matuyama). Temporary reversions to puncticulata-dominated populations occur in the Mangapanian Stage.

Holocene and living populations off New Zealand appear to be entirely G. inflata.

Globorotalia puncticulata puncticulata (Deshayes)

Plate 5, figs. 8-10.

Globigerina punctulata d'Orbigny 1826, p. 277, no. 8 (nom. nud.)

Globigerina puncticulata Deshayes 1832, p. 170.

Globigerina punctulata Fornasini 1898b, p. 210, text-fig. 5

(d'Orbigny's unpublished figure).

Globorotalia puncticulata Barbieri 1967, p. 154, pl. 1.

Globorotalia puncticulata Kennett 1970b, p. 126, fig. 2, no. 1-6.

Pores: $0.8\mu - 2.3\mu$; Perforations: 0.2μ .

Barbieri (1969), discussing Italian Pliocene microfaunas, considered that G. puncticulata is closely related to G. crassaformis, but his illustrations show that the aperture is strongly arched as in G. inflata, not slit-like as in G. crassaformis. As recognised in New Zealand, G. puncticulata is close to G. inflata, from which it is distinguished by having a subtriangular cross-section resulting from slight flattening of the ventral flanks of the chambers, and by having not less than four chambers in the final whorl. Its periphery is always rounded, and its sculpture seems to be identical to that of G. inflata.

The base of the Opoitian Stage in southern North Island, and presumably elsewhere in New Zealand, is marked by the earliest occurrence of G. crassaformis and G. puncticulata (not G. inflata as reported by Finlay and Marwick 1940 and many subsequent authors). Representative specimens of the terminal form of the Globorotalia sphericomoidea bioseries (McInnes, 1965; Walters, 1965), lodged by Walters at the New Zealand Geological Survey, were examined by one of the writers. The specimens are small, but appear to be G. puncticulata, not G. inflata. In southern North Island the bioseries is not developed, and G. puncticulata appears suddenly, in fairly small numbers near the top of the stratigraphic range of G. miozea conoidea Walters; above this horizon it quickly increases to become a major element of the lower Opoitian fauna. Higher occurrences are discussed under G. inflata, above.

According to Blow (1969, p. 272) G. inflata appears stratigraphically below G. puncticulata in Europe, but Italian workers report inflata following puncticulata in the Pliocene, as in New Zealand (Follador, 1967, Table 1, facing p. 580).

Globorotalia puncticulata (Deshayes) var.

Plate 6, figs. 7-11.

This variety is characterised by the aberrant form of its final chamber (or rarely the final two chambers) which is more or less compressed, relatively sharply angled at the periphery, may be weakly keeled, and is usually smaller than the preceding chamber. The

aperture may be lower and more slit-like than in typical puncticulata. The surface of the aberrant final chamber is smoother than on typical puncticulata, but the surface of preceding chambers is normal.

Three of the illustrated specimens (figs. 9-11), before coating for stereosean microscopy, appeared to have a keel buried beneath partly transparent crust on the penultimate and antepenultimate chambers. They may be different from the other two illustrated specimens, and possibly are less closely related to G. puncticulata.

G. puncticulata var. is restricted to lower Pliocene faunas.

Globoretalia scitula (Brady)

Plate 5, figs. 5-7.

Pulvinulina scitula Brady 1882, p. 716; 1884, p. 693, pl. 103, figs. 7a-c (as Pulvinulina patagonica (d'Orbigny)).

Pores: $0.8\mu - 2.5\mu$; Perforations: 0.08μ .

Pliocene specimens are very similar to Recent specimens from the Tasman Sea. The surface has sparse tubercles with smooth interspaces and no crust on earlier chambers. On the terminal chamber pores are situated in tiny conical depressions; on earlier chambers the conical depressions are broader and deeper. The periphery is devoid of pores, suggesting an incipient keel. The tests consistently have about $4\frac{1}{2}$ chambers in the final whorl.

The illustrations of the lectotype (Banner and Blow, 1960a, pl. 5, figs. 5a-c) show much fewer tubercles on the ventral surface and a narrower apertural lip than on New Zealand specimens.

G. scitula is always rare, but is persistent in occurrence, being absent only from shallow-water samples or where the coldest paleotemperatures are indicated. In New Zealand it ranges from well below the Pliocene (Jenkins, 1971, p. 131) to the Recent.

Globorotalia truncatulinoides (d'Orbigny)

Plate 7, figs. 1-5.

Rotalina truncatulinoides d'Orbigny 1839b, p. 132, pl. 2, figs. 25-7.

Pores: $0.4\mu - 2.1\mu$; Perforations: 0.1μ .

G. truncatulinoides is not represented in the Pliocene of southern North Island, and the illustrated specimens are from Recent Globigerina ooze in the Tasman Sea. The sculpture is typical of Globorotalia, with unevenly distributed tubercles on late chambers and thick crust on earlier chambers.

The oldest occurrence of G. truncatulinoides in Wairarapa approximately coincides with the base of the Gilsa geomagnetic event (Kennett et al., 1971), which is near the top of the Greycliffs Formation, probably within the Hautawan Stage (Vella and Briggs, 1971). In Wanganui Basin its oldest occurrence is 170 m above the base of the Hautawan Stage (Collen, 1972 MS). In both areas it is extremely rare and represented by small specimens similar to that figured (pl. 7, fig. 4).

The Hautawan Stage is considered to represent the base of the Quaternary in New Zealand, and the above occurrences of G. truncatu-

linoides, in association with the Gilsa event, seem to confirm this. However, G. truncatulinoïdes is reported in some abundance in the Mangapanian Stage, significantly older than the Hautawan, in the northern part of the East Coast district of the North Island (Jenkins, 1971; N. de B. Hornibrook, N.Z. Geological Survey, pers. comm.). Assuming that New Zealand internal correlations of these strata are correct, it follows that the base of Zone N22 (Banner and Blow, 1965) is time-transgressive, and increases in age from basal Quaternary to Upper Pliocene towards the north.

G. truncatulinoïdes is not common in any part of the marine Quaternary of southern North Island. It has been found at two horizons in the Pukenui Limestone (probably Hautawan) of Wairarapa, and in the Upper Kumeroa Formation (Marahauan) of Hawkes Bay. It appears to be missing from all subantarctic assemblages and also from many subtropical assemblages.

ACKNOWLEDGEMENTS

This work was supported by the New Zealand University Grants Committee and the Victoria University Research Committee, and publication was subsidised by the Victoria University Publications Committee. We are indebted to Mr W. S. Bertaud, of the Physics and Engineering Laboratory, New Zealand Department of Scientific and Industrial Research, for use of the scanning electron microscope, and to Mrs L. A. Donaldson and Mr G. D. Walker for photographing the

specimens. We are grateful to have been able to examine specimens at the New Zealand Geological Survey, and we thank Dr N. de B. Hornibrook and Mr G. H. Scott of that institution for critically reading the manuscript.

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PLATE 1

- 1, 2. Globigerinita glutinata (Egger). 1, VF911, ventral view, x285; 2, VF912, dorsal view, x257.
- 3-6. Globigerinita uvula (Ehrenberg). 3, VF941, lateral view, x331; 4, VF940, lateral view, x363; 5, VF939, detail of apertural region of fig. 6, x165; 6, VF939, lateral view of specimen lacking bulla, x359.
- 7-10. Neogloboquadrina dutertrei (d'Orbigny). 7, VF975, ventral view, x153; 8, VF905, ventral view, x147; 9, VF907, dorsal view, x181; 10, VF906, peripheral view, x180.
- 11,12. Neogloboquadrina pachyderma (Ehrenberg). 11, VF918, ventral view, x204; 12, VF920, ventral view, x239.

PLATE 2

- 1-3. Neogloboquadrina pachyderma (Ehrenberg). 1, VF921, ventral view, x176; 2, VF922, dorsal view, x205; 3, VF919, peripheral view, x205.
- 4-6. Globigerina apertura Cushman. 4, VF934, ventral view, x171; 5, VF934, detail of penultimate chamber of fig. 4, x804; 6, VF935, peripheral view, x139.
7. Globigerina bulloides bulloides d'Orbigny, VF974, ventral view, x98.
8. Globigerina bulloides trilocularis Deshayes, VF936, ventral view, x148.
- 9-11. Globigerina decoraperta Takayanagi and Saito. 9, VF951, ventral view, x150; 10, VF953, peripheral view, x171; 11, VF952, dorsal view, x215.

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PLATE 3

- 1,2. Globigerina eamsi Blow. 1, VF890, ventral view, x199;
2, VF890, detail of apertural region of fig. 1, x700.
- 3, 6. Globigerina (Beela) digitata praeditata Parker. 3, VF954,
detail of penultimate chamber of fig. 6, x1042; 6, VF954,
ventral view, x152.
- 4, 5. Globigerina cf. falconensis Blow. 4, VF931, ventral view,
x176; 5, VF932, dorsal view, x176.
- 7-9, 11,12. Globigerinella siphonifera d'Orbigny. 7, VF943,
peripheral view, x288; 8, VF942, dorsal view, x107;
9, VF942, detail of penultimate chamber of fig. 8,
x567; 11, VF971, ventral view, x111; 12, VF971,
detail of penultimate chamber of fig. 11, x304.
10. Orbulina universa d'Orbigny, VF944, x154.

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PLATE 4

- 1-3. Globigerinoides trilobus (Reuss). 1, VF930, peripheral view, x150; 2, VF930, detail of last chamber of fig. 1, x816; 3, VF939, dorsal view, x154.
- 4-6. Globigerinoides obliquus Bolli. 4, VF924, dorsal view, x162; 5, VF976, dorsal view, x163; 6, VF925, peripheral view, x185.
- 7, 8 Globigerinoides saeculifer Brady. 7, VF927, dorsal view, x157; 8, VF927, detail of penultimate chamber of fig. 7, x792.
9. Turborotalita quinqueloba lingulata Collen and Vella, n. subsp. 9, VF950, ventral view, x356.
- 10-12. Turborotalita quinqueloba quinqueloba (Natland). 10, VF914, dorsal view, x271; 11, VF914, enlargement of final chamber of fig. 10, x507; 12, VF913, ventral view, x299.

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PLATE 5

- 1-3 Turborotalita quinqueloba lingulata Collen and Vella,
n. subsp. 1, VF949, ventral view, x272; 2, VF978, ventral
view, x212; 3, VF948, holotype, ventral view, x194.
4. Turborotalita quinqueloba quinqueloba (Natland), VF915,
peripheral view, x270.
- 5-7. Globorotalia scitula (Brady). 5, VF970, ventral view,
x147; 6, VF916; ventral view, x205; 7, VF947, peripheral
view, x171.
- 8-10. Globorotalia puncticulata (Deshayes). 8, VF909,
peripheral view, x148; 9, VF910, dorsal view, x143;
10, VF910, detail of penultimate chamber of fig. 9, x712.
- 11,12 Globorotalia inflata d'Orbigny. 11, VF956, detail of
penultimate chamber of fig. 12, x630; 12, VF956, ventral
view, x116.
13. Globorotalia crassaformis (Galloway & Wissler), VF894,
detail of final chamber, x1092.

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PLATE 6

- 1-6. Globorotalia crassaformis (Galloway and Wissler).
1, VF893, apertural details of fig. 2, x540; 2, VF893,
ventral view, x154; 3, VF895, ventral view, x195;
4, VF946, detail of penultimate chamber of fig. 5, x190;
5, VF946, ventral view, x111; 6, VF945, peripheral
view, x120.
- 7-11. Globorotalia puncticulata (Deshayes) var. 7, VF897,
dorsal view, x119; 8, VF908, ventral view, x164;
9, VF899, ventral view, x167; 10, VF896, ventral view,
x135; 11, VF898, peripheral view, x169.

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PLATE 7

- 1-5. Globorotalia truncatulinoides (d'Orbigny). 1, VF957, ventral view, x93; 2, VF959, detail of penultimate chamber of fig. 3, x610; 3, VF959, dorsal view, x120; 4, VF972, ventral view, x148; 5, VF977, detail of final chamber, x793.
- 6-8. Globorotalia hirsuta hirsuta (d'Orbigny). 6, VF955, ventral view, x90; 7, VF969, dorsal view, x80; 8, VF969, detail of final chamber of fig. 7, x674.
9. Globorotalia hirsuta praehirsuta Blow. VF917, ventral view, x156.

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APPENDIX II

Tables 13-26

Table 13. - Data from cumulative counts of planktonic foraminifera in sample N138f561 to check minimum number of specimens required for reliable statistical counts.

Species	n_1	$\%_1$	n_2	$\%_2$	D_1	P_1	n_3	$\%_3$	D_2	P_2
<i>Globorotalia crassaformis</i>	0	-	1	0.5	-	-	1	0.3	-49.0	-0.1
<i>G. scitula</i>	0	-	0	-	-	-	1	0.3	-	-
<i>Globigerina bulloides</i> Gp.	73	68.9	150	66.1	-4.1	-2.7	232	67.1	+1.5	+1.0
<i>G. dutertrei</i>	19	18.0	33	16.7	-7.2	-1.2	54	15.6	-6.6	-1.0
<i>G. pachyderma</i> -total	6	5.7	19	8.4	+47.4	+4.0	32	9.3	+10.7	+1.0
-dextral	1	16.7	4	21.1	+79.1	+16.7	8	25.0	+18.5	+4.6
<i>Turborotalita quinqueloba</i>	3	2.8	8	3.5	+20.0	+0.7	12	3.5	-	-
<i>Globigerinita glutinata</i>	3	2.8	7	3.1	+9.7	+0.3	10	2.9	-6.5	-0.2
<i>G. uvula</i>	2	1.9	4	1.8	-5.6	-0.1	4	1.2	-50.0	-0.6
No. of specimens	106		227				346			
No. of species	10		11				13			

n_1 etc. = cumulative counts of each species; $\%_1$ etc. = percentage of each species in total fauna; D_1 = percentage difference of count 1 from count 2 for each species; D_2 = percentage difference of count 3 from count 2 for each species; P_1 = difference of $\%_2$ from $\%_1$ expressed as a percentage of the abundance of each species in fauna n_2 ; P_2 = difference of $\%_3$ from $\%_2$ expressed as a percentage of the abundance of each species in fauna n_3 .

Table 14. - Data from measurements of Nonionellina flemingi (Vella) to check minimum number of specimens required for statistical counts.

SAMPLE	COUNT	N	L	S	D
N138f561	1	113	0.205	0.0620	
	2	227	0.207	0.0580	+1.4
	3	348	0.202	0.0610	-2.6
	4	503	0.201	0.0569	-0.3

Calculations are cumulative from counts 1 to 4. N = number of specimens measured; L = mean length in mm; S = standard deviation in mm; D = percentage difference from cumulative mean of previous counts.

Table 18. - Ecologic and sedimentary parameters recorded from the Waitotara Valley section.

Sample Number	% Sample $>75\mu$	Foram. No.	% Plank.	% Aren.	No. Plank. Spp.	No. Benth. Spp.
N130f530	0.1	15	<1	<1	0	16
f531	11.6	<1	-	-	4	29
N137f676	96.7	<1	-	-	0	0
f677	76.8	476	<1	<1	2	42
f678	17.6	<1	-	-	0	0
f679	1.5	<1	-	-	6	35
f680	53.7	998	<1	<1	0	24
f681	23.0	<1	-	-	0	0
f682	93.9	<1	-	-	0	6

Table 15. - Data from counts of planktonic foraminifera in two separate fractions of sample M131f528 to check consistency of results.

Species	n_1	$\%_1$	n_2	$\%_2$	D	F
G. bulloides Group	169	53.0	204	54.0	+1.9	+1.0
G. pachyderma - total	16	5.0	16	4.2	-16.0	-0.7
- dextral	10	62.5	10	62.5	-	-
G. dutertrei	19	6.0	24	6.3	+5.0	+0.3
T. quinqueloba	26	8.2	30	7.9	-3.7	-0.3
G. glutinata	35	10.0	34	9.0	-10.0	-0.9
G. uvula	21	6.6	26	6.9	+4.5	+0.3
G. trilobus	16	5.0	24	6.3	+26.0	+1.6
G. inflata	4	1.3	6	1.6	+23.1	-0.4
G. puncticulata	3	0.9	6	1.6	+77.8	+1.2
G. crassaformis	4	1.3	4	1.1	-15.4	-0.2
G. scitula	3	0.8	2	0.5	-44.5	-0.2
Globigerina sp.	3	0.8	2	0.5	-44.5	-0.2
N	319		378			
No. of Spp.	12		12			

N = total number of specimens counted from each fraction; n_1, n_2 = number of specimens of each species counted from each fraction; $\%_1, \%_2$ = number of specimens of each species expressed as percentages of the total fauna from each fraction; D = percentage difference in abundance of each species in fraction 2 from those in fraction 1; P = difference in abundance of each species in fraction 2 from those in fraction 1 expressed as a percentage of the abundance of each species in fraction 2.

Table 16. - Locality and lithology of miscellaneous samples discussed in text.

Fossil No.	Locality	Grid Ref.	Lithology*
Sheet No. N139 (Mangaweka), Unpublished.			
f557	Cutting on S side of Hautawa Rd 7km N of Kaikarangi Rly Stn. Mudstone 1.2m below base of Hautawa Shellbed. Mangapanian.	094976	9930M2
f558	Locality as for f557. Hautawa Shellbed, 0.3m above base. Hautawan.	094976	9933L5SSS
f559	Locality as for f557. Hautawa Shellbed, 1.8m above base of 3.6m thick shellbed. Hautawan.	095976	9933L5SSS
f560	Locality as for f557. Mudstone 1.2m above top of Hautawa Shellbed. ?Hautawan.	095976	9932M2SS

Sheet No. N141 (Waipawa), 2nd Edition, 1962.

f1589	Ashcott Road, cutting 3km W of jcn with main highway. Nukumaruan.	928808	9842L26S

Sheet No. N143 (Marton), 3rd Edition, 1968.

f516	Roadside 500m SW of jcn of Turakina Valley and Morgans Rds. Calcareous mudstone. Castlecliffian.	802791	9941L83SS

Sheet No. N164 (Wellington), 3rd Edition, 1967.

Wellington Hbr, 500m NE of Ward Island, depth 10m, shell sand.	429215		

*Lithologic code of N.Z.F.R. forms.

Table 17. - Ecologic and sedimentary parameters recorded from Waverley Beach and Wilkies Bluff sections.

Sample Number	% Sample > 75 μ	Foram. No.	% Plank.	% Aren.	No. Plank. Spp.	No. Benth. Spp.	Nonionellina flemingii		
							Mean Size (mm)	S.D. (mm)	No. Measured
N137f629	86.2	191	<1	<1	1	33	0.290	-	5
f630	71.6	79	<1	<1	9	71	0.305	+0.067	107
f631	7.1	<1	-	-	0	0	-	-	-
f658	87.3	25	<1	<1	6	34	0.277	0.0714	36
f659	89.9	<1	-	-	0	0	-	-	-
f660	55.5	<1	-	-	0	2	0.330	-	1
f661	87.8	12	<1	<1	3	67	0.336	0.080	28
f662	57.3	<1	-	-	1	35	0.290	0.064	21
f663	86.0	256	<1	<1	1	42	0.380	0.059	63
f664	63.7	1333	<1	<1	5	78	0.378	0.109	263
f665	88.0	<1	-	-	0	27	0.342	0.060	11
f666	62.8	717	2.0	1.0	5	48	0.299	0.071	204
f667	67.3	62	<1	<1	9	56	0.290	0.0714	49
f668	84.9	<1	-	-	0	0	-	-	-
f669	37.1	230	<1	<1	4	53	0.366	0.158	150
f683	76.8	<1	-	-	0	0	-	-	-
f684	22.6	237	<1	<1	3	28	-	-	-
f685	23.5	51	<1	<1	0	6	-	-	-
f686	80.0	<1	-	-	0	0	-	-	-
f687	23.9	<1	-	-	0	0	-	-	-
f688	43.5	<1	-	-	1	11	-	-	-

Table 19. - Ecologic and sedimentary parameters recorded from Wanganui River section.

Sample Number	% Sample > 75 μ	Foram. No.	% Plankt.	% Aren.	No. Plankt. Spp.	No. Benth. Spp.	Nonionellina flemingii		
							Mean Size (mm)	S.D. (mm)	No. Measured
N131f515	9.5	12	10.2	7.6	14	48	0.164	+0.030	40
f516	0.8	22	3.7	3.8	14	53	0.160	0.029	21
f517	2.4	78	<1	1.5	12	47	0.189	0.015	8
f519	1.0	14	6.9	6.0	16	42	0.168	0.022	5
f520	0.4	35	10.2	13.3	15	76	0.160	0.018	9
f522	0.6	8	<1	12.5	15	56	-	-	-
f523	3.0	13	3.0	1.6	15	56	0.220	0.040	9
f524	1.4	12	3.4	3.4	15	59	0.179	0.038	9
f527	0.3	10	6.0	6.0	13	60	0.173	0.033	15
f528	0.5	62	4.2	8.4	14	37	0.145	-	2
f529	0.4	34	2.4	15.3	12	41	0.145	-	1
f530	0.4	130	36.5	4.4	13	58	-	-	-
f531	0.3	55	5.4	14.0	14	52	0.180	-	2
f532	0.2	44	5.9	11.7	12	50	-	-	-
f533	1.2	26	15.8	26.0	16	53	0.180	-	3
f534	75.6	<1	-	-	0	0	-	-	-
f535	1.0	26	<1	25.4	14	28	-	-	-
f558	6.0	124	3.7	18.0	10	42	-	-	-
f536	4.0	915	12.0	20.0	15	45	0.165	0.020	31
f537	0.4	23	5.5	16.4	12	44	0.165	0.030	13
f538	0.4	10	<1	<1	0	10	-	-	-

Table 19. - Continued.

Sample Number	% Sample > 75 μ	Foram. No.	% Plank.	% Aren.	No. Plank. Spp.	No. Benth. Spp.	Nonionellina flemingii		
							Mean Size (mm)	S.D. (mm)	No. Measured
N131f539	0.4	<1	-	<1	0	3	-	-	-
f540	1.4	18	<1	1.1	15	39	0.160	+0.055	66
f541	5.4	23	2.0	<1	5	26	0.160	0.026	25
f543	3.2	346	<1	<1	11	45	0.170	0.029	66
f544	14.0	<1	-	-	0	4	-	-	-
f545	3.6	46	4.8	<1	11	46	0.153	0.025	97
f546	2.8	<1	-	-	0	2	-	-	-
f547	11.8	<1	-	-	0	0	-	-	-
f548	55.0	<1	-	-	0	0	-	-	-
f549	32.4	<1	-	-	0	0	-	-	-
f550	52.4	<1	-	-	0	0	-	-	-
f551	17.6	<1	-	-	0	0	-	-	-
f552	8.4	15	<1	<1	10	30	0.197	0.053	162
f553	25.0	47	<1	5.0	9	45	0.211	0.047	107
f554	21.4	109	3.0	5.0	13	60	0.178	0.038	331
f555	12.0	35	<1	<1	0	32	0.190	0.043	9
f556	11.5	99	<1	<1	6	36	0.320	0.070	352
f557	61.8	<1	-	-	0	0	-	-	-
N138f548	1.0	37	<1	<1	4	25	0.209	0.090	8
f549	7.6	3	-	-	0	7	-	-	-
f550	14.0	<1	-	-	0	1	-	-	-

Table 19. - Continued.

Sample Number	% Sample > 75 μ	Foram. No.	% Plank.	% Aren.	No. Plank. Spp.	No. Benth. Spp.	Nonionellina flemingi		
							Mean Size (mm)	S.D. (mm)	No. Measured
N138f551	2.0	<1	-	-	0	0	-	-	-
f552	3.8	<1	-	-	0	0	-	-	-
f553	2.4	<1	-	-	0	0	-	-	-
f554	0.2	2	4.7	1.9	4	14	0.260	-	3
f555	1.8	<1	-	-	0	0	-	-	-
f556	21.0	31	<1	<1	6	50	0.229	+0.036	325
f557	83.2	406	<1	<1	8	91	0.286	0.058	176
f558	34.0	326	<1	<1	10	81	0.288	0.065	320
f559	16.2	254	<1	<1	12	63	0.240	0.059	300
f560	39.4	2	1.0	<1	8	41	0.233	0.039	65
f561	2.8	84	7.3	<1	11	43	0.200	0.060	503
f562	2.0	214	13.5	2.0	12	78	0.189	0.042	352
f563	24.0	83	<1	<1	11	54	0.207	0.055	324
f564	48.8	10	<1	<1	9	36	0.230	0.057	383
f565	19.3	100	<1	<1	10	100	0.240	0.061	309
f566	9.0	303	2.2	<1	12	75	0.225	0.041	347
f567	18.2	419	2.0	<1	13	99	0.245	0.092	346
f568	29.2	175	15.0	<1	9	54	0.212	0.049	219
f569	22.6	142	4.5	<1	12	89	0.216	0.056	330
f570	32.4	38	16.0	2.0	12	61	0.293	0.088	263

Table 20. - Relative abundance of planktonic foraminifera in the Wanganui River section, given as percentage of total planktonic fauna. X indicates insufficient specimens for reliable counts.

	N131														
	F515	F516	F517	F519	F520	F522	F523	F524	F527	F528	F529	F530	F531	F532	F533
<i>Globorotalia crassaformis</i>	2	4	7	4	1	4	8	6	3	1	3	4	2	1	2
<i>G. hirsuta</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>G. inflata</i>	3	8	2	2	4	9	2	4	1	1	1	1	2	2	5
<i>G. menardii</i>	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>G. puncticulata</i>	1	2	3	1	5	1	4	1	1	1	1	1	3	2	1
<i>G. scitula</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Orbulina universa</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Globigerina bulloides</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Group															
<i>G. dutertrei</i>	32	31	30	39	25	29	54	24	35	54	41	29	44	42	38
<i>G. pachyderma</i>	7	3	6	4	3	3	1	8	8	7	8	10	8	10	8
% Dextral	21	17	24	12	44	8	12	22	13	6	14	22	14	10	12
<i>Turborotalita quinqueloba</i>	24	76	23	50	45	46	57	68	84	63	37	47	54	74	63
<i>Globigerinita glutinata</i>	21	10	4	27	5	7	3	13	16	8	14	32	21	18	18
<i>G. uvula</i>	7	10	20	8	12	16	8	9	11	12	8	3	1	8	9
<i>Globigerinella siphonifera</i>	4	13	3	3	1	21	3	10	11	7	9	2	4	4	6
<i>Globigerinoides ruber</i>	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>G. trilobus</i>	1	1	1	2	2	1	4	2	2	5	2	1	1	1	1
Total counted	336	321	128	217	281	161	200	383	698	319	309	638	464	177	266

Table 20. - Continued.

	N131										N138									
	F535	F558	F536	F537	F540	F541	F543	F545	F552	F553	F554	F555	F556	F548	F554					
Globorotalia crassaformis	3	2	3	1	6	-	5	3	3	3	2	X	-	-	1					
G. hirsuta	<1	4	<1	-	-	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-
G. inflata	1	3	4	-	-	-	1	-	-	2	2	-	-	-	-	-	-	-	-	-
G. menardii	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. puncticulata	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. scitula	1	1	1	<1	<1	-	1	-	3	-	<1	-	-	-	5					
Orbulina universa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
Globigerina bulloides	49	36	37	26	30	X	31	27	46	62	47	-	29	X	67					
Group	12	3	6	4	19	-	18	2	-	2	2	-	4	-	-					
G. dutertrei	6	26	17	6	14	X	10	46	30	25	22	-	59	X	27					
G. pachyderma	71	65	74	71	63	X	50	44	60	46	60	-	52	X	50					
% Dextral	13	10	12	13	22	X	16	4	9	-	6	-	8	X	-					
Turbototalita quinqueloba	11	8	4	10	6	X	11	13	3	7	9	-	-	-	-					
Globigerinita glutinata	2	2	10	38	-	X	7	5	3	2	7	-	-	-	-					
G. uvula	<1	-	-	-	<1	X	-	-	-	-	-	-	-	-	-					
Globigerinella siphonifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
Globigerinoides ruber	-	-	2	1	<1	-	-	-	3	-	-	-	-	-	-					
G. trilobus	2	-	4	<1	<1	-	-	-	-	-	2	-	-	-	-					
Total counted	238	340	387	329	22	105	109	33	52	204	1	102	10	15						

Table 20. - Continued.

N138		1556	1557	1558	1559	1560	1561	1562	1563	1564	1565	1566	1567	1568	1569	1570
Globovalia crasseformis																
G. hirsuta																
G. inflata																
G. menardii																
G. puncticulata																
G. scitula																
Orbulina universa																
Globigerina bulloides																
Group																
G. dutertrei																
G. pachyderma																
% Dextral																
Turbovalia quinqueloba																
Globigerinita glutinata																
G. uvula																
Globigerinella siphonifera																
Globigerinoides ruber																
G. trilobus																
Total counted		20	134	164	234	80	346	373	293	151	303	274	338	316	320	309

Table 21. - Ecologic and sedimentary parameters recorded from the Rangitikei River section.

Sample Number	% Sample >75 μ	Foram. No.	% Plank.	% Aren.	No. Plank. Spp.	No. Benth. Spp.	Nonionellina flemingi		
							Mean Size (mm)	S.D. (mm)	No. Measured
N132f507	27.5	<1	-	-	0	0	-	-	-
f508	56.0	1220	<1	<1	7	60	-	-	-
f509	2.2	11	14.2	<1	10	23	-	-	-
f510	5.8	<1	<1	<1	13	34	-	-	-
f511	10.0	640	1.0	1.0	13	73	-	-	-
f512	7.5	1747	2.6	<1	16	87	-	-	-
f513	10.7	1881	1.0	1.4	17	74	-	-	-
f514	51.6	1971	6.5	<1	12	51	0.20	0.03	51
f515	55.7	2534	8.1	1.1	15	72	-	-	-
f516	28.8	1472	7.8	<1	15	76	-	-	-
N139f538	46.0	2380	14.0	<1	14	48	-	-	-
f539	30.3	1580	18.6	1.0	15	102	-	-	-
f540	8.6	187	11.0	1.0	16	77	-	-	-
f541	4.5	80	8.0	2.0	16	72	0.17	0.03	52
f542	3.9	65	2.8	11.0	14	63	0.17	0.03	26
f543	10.0	530	3.2	3.7	14	104	0.25	0.04	212
f544	3.5	110	21.0	7.0	13	53	0.25	0.05	314
f545	2.4	29	2.0	<1	11	51	0.25	0.06	311
f546	33.6	99	3.0	<1	16	74	0.28	0.05	308
f547	13.8	115	<1	<1	11	61	0.19	0.05	200
f548	93.4	<1	-	-	0	0	-	-	-
f549	1.4	21	<1	<1	1	14	-	-	-

Table 22. - Relative abundance of planktonic foraminifera in the Rangitikei River section. Abundance given as percentage of total planktonic fauna. X indicates insufficient specimens for reliable counts.

	N132	507	508	509	510	511	512	513	514	515	516
<i>Globorotalia crassaformis</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. hirsuta</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. inflata</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. puncticulata</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. scitula</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. truncatulinoides</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Orbulina univversa</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Globigerina bulloides</i> Group	-	-	-	-	-	-	-	-	-	-	-
<i>G. dutertrei</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. pachyderma</i>	-	-	-	-	-	-	-	-	-	-	-
% Dextral:											
<i>Turborotalita quinqueloba</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Globigerinita glutinata</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. uvula</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Globigerinella siphonifera</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Globigerinoides ruber</i>	-	-	-	-	-	-	-	-	-	-	-
<i>G. trilobus</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Sphaeroidinella seminulina</i>	-	-	-	-	-	-	-	-	-	-	-
Number counted		-	-	-	102	111	306	304	312	308	326

Table 22. - Continued.

	N139													
	F538	F539	F540	F541	F542	F543	F544	F545	F546	F547	F548	F549		
<i>Globorotalia crassaformis</i>	7	12	2	3	2	3	1	1	5	1	-	-		
<i>G. hirsuta</i>	-	-	-	-	-	<1	-	-	-	-	-	-		
<i>G. inflata</i>	12	1	<1	1	<1	<1	-	-	<1	-	-	-		
<i>G. puncticulata</i>	26	3	<1	-	-	-	-	-	-	-	-	-		
<i>G. scitula</i>	-	1	1	<1	<1	1	2	-	<1	-	-	-		
<i>G. truncatulinoides</i>	-	-	-	-	-	-	-	-	<1	-	-	-		
<i>Orbulina univversa</i>	<1	<1	<1	<1	-	-	<1	-	-	-	-	-		
<i>Globigerina bulloides</i> Gp.	31	44	29	42	44	33	55	80	62	44	-	-		
<i>G. dutertrei</i>	1	7	12	8	7	4	10	4	6	13	-	-		
<i>G. pachyderma</i>	14	16	20	20	16	41	13	5	8	20	-	-		
% Dextral	19	32	59	62	40	46	46	46	71	52	-	-		
<i>Turborotalita quinqueloba</i>	3	6	21	8	8	16	12	3	13	6	-	-		
<i>Globigerinita glutinata</i>	4	7	7	8	11	1	3	6	2	10	-	-		
<i>G. uvula</i>	-	2	5	6	10	-	2	<1	1	5	-	-		
<i>Globigerinella siphonifera</i>	<1	-	<1	<1	-	-	-	-	-	-	-	-		
<i>Globigerinoides ruber</i>	<1	-	<1	2	<1	-	-	-	-	-	-	-		
<i>G. trilobus</i>	-	-	-	-	-	-	-	-	-	-	-	-		
<i>Sphaeroidinella seminulina</i>	1	<1	-	-	-	-	-	-	-	-	-	-		
Number counted	312	309	348	334	329	631	315	166	319	312	0	0		

Table 23. - Ecologic and sedimentary parameters recorded from the Watershed Road section.

Sample Number	% Sample > 75 μ	Foram. No.	% Plank.	% Arcn.	No. Plank. Spp.	No. Benth. Spp.	Nonionellina flemingi		
							Mean Size (mm)	S.D. (mm)	No. Measured
N139f550	16.2	333	11.5	<1	14	67	-	-	-
f551	7.6	378	1.7	2.6	14	74	0.21	0.05	331
f552	15.2	<1	-	-	0	0	-	-	-
f553	26.6	<1	-	-	7	41	-	-	-
f554	15.6	1056	3.6	<1	12	91	-	-	-
f555	25.0	845	6.1	16.1	15	117	-	-	-
f556	0.8	<1	-	-	11	50	0.21	0.05	326

Table 24. - Relative abundance of planktonic foraminifera in the Watershed Road section. Abundance given as percentage of total planktonic fauna. X indicates insufficient specimens for reliable counts.

	N139							Number counted
	550	551	552	553	554	555	556	
<i>Globorotalia crassaformis</i>	3	2	-	-	1	2	4	
<i>G. hirsuta</i>	-	-	-	-	-	-	-	
<i>G. inflata</i>	1	-	-	-	-	-	-	
<i>G. menardii</i>	-	-	-	-	-	1	-	
<i>G. puncticulata</i>	-	-	-	-	-	-	-	
<i>G. scitula</i>	1	1	-	-	-	-	-	
<i>Orbulina universa</i>	1	1	-	-	-	1	-	
<i>Globigerina bulloides</i>								
Group	38	46	-	X	64	67	56	
<i>G. dutertrei</i>	5	12	-	X	8	8	20	
<i>G. pachyderma</i>	25	17	-	X	13	14	10	
% Dextral	44	53	-	X	68	70	46	
<i>Turborotalita quinqueloba</i>	10	18	-	-	10	5	4	
<i>Globigerinita glutinata</i>	12	2	-	X	3	2	3	
<i>G. uvula</i>	3	1	-	-	1	1	2	
<i>Globigerinella siphonifera</i>	-	-	-	-	1	1	-	
<i>Globigerinoides ruber</i>	-	1	-	-	1	-	1	
<i>G. trilobus</i>	-	-	-	-	-	1	-	
Number counted	324	552	0	33	323	320	254	

Table 25. - Ecologic and sedimentary parameters recorded from the Saddle Road section.

Sample Number	% Sample > 75 μ	Foram. No.	% Plank.	% Aren.	No. Plank. Spp.	No. Benth. Spp.	Nonionellina flemingi	
							Mean Size (mm)	S.D. (mm) No. Measured
N149f592	26.3	15	-	-	4	32	-	- 85
f593	83.3	<1	-	-	12	34	0.30	0.09 18
f594	18.7	30	-	-	11	41	0.22	0.04 -
f595	30.5	<1	-	-	-	-	-	- -
f596	58.2	<1	-	-	-	-	-	- -
f597	87.2	40	-	-	12	69	0.31	0.09 54
f598	1.1	48	27.4	<1	14	30	0.20	0.04 70
f599	13.9	256	<1	5.0	13	90	0.26	0.06 78
f600	2.2	<1	-	-	-	-	-	- -
f601	0.5	<1	-	-	-	-	-	- -
f544	-	-	-	-	6	45	-	- -
f555	-	-	-	-	3	29	-	- -

Table 26. - Relative abundance of planktonic foraminifera in the Saddle Road section, given as percentage of total planktonic fauna. X indicates presence in unknown abundance.

	N149													Total counted
		f592	f593	f594	f595	f596	f597	f598	f599	f600	f601	f544	f555	
<i>Globorotalia crassaformis</i>		X												
<i>G. hirsuta</i>														
<i>G. inflata</i>			8	1			12	2	1			X		
<i>G. menardii</i>														
<i>G. puncticulata</i>														
<i>G. scitula</i>														
<i>Orbulina universa</i>			1											
<i>Globigerina bulloides</i>														
Group														
<i>G. dutertrei</i>		X	66	48			47	20	46			X	X	
<i>G. pachyderma</i>			1	7			4	9	17			X	X	
% Dextral			3	31			15	17	20			X	X	
<i>Turborotalita quinqueloba</i>			44	23			13	36	41			X	X	
<i>Globigerinita glutinata</i>			2	6			6	18	7					
<i>G. uvula</i>			3	2				31	6					
<i>Globigerinella siphonifera</i>								3						
<i>Globigerinoides ruber</i>														
<i>G. trilobus</i>								1						
Total counted		9	220	137			51	348	246					

APPENDIX III

(in pocket)

Foraminiferal range charts:

Table 27. - Waverley Beach, Wilkies Bluff and Waitotara
Valley sections.

Table 28. - Lower part of Wanganui River section.

Table 29. - Upper part of Wanganui River section.

Table 30. - Rangitikei River section.

Table 31. - Watershed Road section.

Table 32. - Saddle Road section.

TABLE 27, PART 1. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WAVERLEY BEACH (I), MILES BLUFF (II), AND WAITOTARA VALLEY SECTIONS (III). N137, N130.

Samples N137f 631, 659, 668, 676, 678, 681, 683, 686 and 687 are barren of foraminifera.

Section:	I														II		III				
	Stage:	W ₀														W _{1m}	W _{0p}	W _{1m}	W _{1n}		
Fossil No.:	f684	f685	f667	f666	f669	f665	f663	f664	f661	f662	f660	f658	f688	f629	f630	f530	f531	f677	f679	f680	f682
FORAMINIFERIDA																					
Family TEXTUARIIDAE																					
Textularia cf. ensis Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.
Itaeniderella morgani (Chapman)	.	d	e	d	c	.	e	.	.	.	.	d	.	.	.	.	.	.	.	.	.
parri Finlay	.	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Siphonotextularia blacki Vella	.	.	.	.	.	.	e	e	.	.	.	.	.	.	e	.	.	d	.	.	.
waitoana Finlay	.	.	.	.	.	.	e	e	.	.	.	.	.	.	d	.	.	.	.	e	.
Family TROCHAMMINIDAE																					
Trochammina inflata (Montagu)	.	.	d	.	.	.	.	c	.	.	.	.	.	.	.	.	e	.	d	.	.
cf. rotaliformis Wright	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family AMMONIATIDAE																					
Martinoiella communis d'Orbigny	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.
Family MILIOLIDAE																					
Quinqueloculina canedina d'Orbigny	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cooki Vella	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
cf. cooki Vella	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
incisa Vella	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
kapitiensis Vella	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.
lamarckiana d'Orbigny	.	.	d	.	.	.	.	.	d	.	.	e	.	.	.	.	.	.	.	.	.
aff. lata Terquem (of Vella, 1957)	.	.	.	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.
cf. ludwigi d'Orbigny	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
parvaggluta Vella	.	.	.	.	.	.	.	.	d	.	.	d	.	.	.	.	.	.	.	.	.
cf. suborbicularis d'Orbigny	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
triangularis d'Orbigny	.	.	.	.	.	.	d	.	b	.	.	.	.	.	.	.	.	.	.	.	.
sp. (elongate)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.
Sigmoliopsis schlumbergeri (Silvestri)	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. wanganuiensis Vella	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Triloculina chrysastoma (Chapman)	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
Miliolinella vigilax Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.
Family NODOSARITIDAE																					
Nodosaria longiscata d'Orbigny	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
pyrula (d'Orbigny)	.	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Amphicoryna hirsuta (d'Orbigny)	.	.	.	.	d	.	.	.	.	e	.	e	.	.	.	.	.	.	.	.	.
Chrysalogonium verticale Reuss	.	.	.	d	.	.	e	e	.	.	.	.	.	.	.	.	e	.	.	.	.
Dentalina emaciata Reuss	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.
soluta Reuss	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lagena albopunctata Matthes	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.
cf. bella Matthes	.	.	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.
distoma Parker & Jones	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.
gracilis Williamson	.	.	.	.	.	e	e	.	.	.	.	.	.	.	e	.	.	e	d	.	.
hispidia Reuss	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. hispidia Reuss	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.
pliocenica Cushman & Gray	.	.	e	.	.	.	.	.	.	.	.	.	.	.	e	.	.	e	.	.	.
stelligera Brady	e	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	e	d	e	.	.
striata (d'Orbigny)	e	d	e	d	.	.	e	d	.	.	.	.	.	.	.	d	.	.	c	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare. All samples from N137, except N137f530 & f531.

TABLE 27, PART 2. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF MICROFOSSILS IN WAVERLEY BEACH (I), WILKES BLUFF (II) AND WAITOTARA VALLEY (III) SECTIONS.

Samples N137f 631, 659, 668, 676, 678, 681, 683, 686 and 687 are barren of foraminifera.

Section:	I										II		III			
	Stage:										Fossil No.:		Fossil No.:			
Fossil No.:	Fossil No.:										Fossil No.:		Fossil No.:			
	Fossil No.:										Fossil No.:		Fossil No.:			
Lagena sp.																
Lenticulina peregrina (Schwager)																
Planularia tricarlinella (Reuss)																
Robulus cultratus Montfort																
plioaenicum (Silvestri)																
Vaginulina vagina (Stache)																
Family POLYORPHINIDAE																
Guttulina bartschii Cushman & Ozawa																
Sigmomorphina lacrimosa Vella																
rhomboidalis Vella																
cf. rhomboidalis Vella																
sp. (striate)																
Family GLAUDULINIDAE																
Oolina globosa (Montagu)																
hexagona (Williamson)																
melod'Orbigny																
Fissurina bassensis Parr																
concurbitasema Loeblich & Tappan																
curvifuba Parr																
deltoides Seguenza																
earlandi Parr																
cf. formosa (Schwager)																
oblonga Reuss																
orbignyana Seguenza																
quadriscopulata (Reuss) var. sexcostulata Silvestri																
siciliensis Loeblich & Tappan																
submarginata (Boongart)																
tricostulata Pierce																
yokoyamae (Millet)																
Parafissurina subulata Parr																
Family SPHAERODINIDAE																
Sphaeroidina bulloides d'Orbigny																
Family BOLIVININIDAE																
Bolivinita pliozea Finlay																
cf. finlayi Kennett																
pohana Finlay																
elegantissima Boongart																
quadrilatera (Schwager)																
Bolivina affiliata Finlay																
alata (Seguenza)																
barnwelli Finlay																
lapsus Finlay																
minuta Nettland																
petiae Gibson																

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare. All samples are from N137, except N131f530 & 531.

TABLE 27, PART 3. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF MICROFOSSILS IN Waverley Beach (I), Wilkes Bluff (II) AND Waitotara Valley (III) SECTIONS.

Samples N137f 631, 659, 668, 676, 678, 683, 686 and 687 are barren of foraminifera.

	Section:										II		III	
	Stage:										Wp		Wm	
	Fossil No.:										f629	f630	f530	f531
Bolivina plicatella Cushman	pseudoplicata Heron-Allen & Earland spatulata (Williamson) subexcavata Cushman & Wicikenden subspinescens Cushman variabilis (Williamson) watti Gibson vellai n.sp. wanganuiensis n.sp.	f684	e	o	c	e	d	e	o	c	e	e	o	o
		f685	o	o	o	o	o	o	o	o	o	o	o	o
		f667	o	o	o	o	o	o	o	o	o	o	o	o
		f666	e	o	o	e	o	e	d	o	e	e	o	o
		f669	o	o	o	e	o	o	o	o	o	o	o	o
		f665	o	o	o	o	o	o	o	o	o	o	o	o
		f663	o	o	o	o	o	o	o	o	o	o	o	o
		f664	o	o	o	o	o	o	o	o	o	o	o	o
		f661	o	o	o	o	o	o	o	o	o	o	o	o
		f662	o	o	o	o	o	o	o	o	o	o	o	o
Family EOVIGERINIDAE	Stilostomella verneuilli (d'Orbigny)	f658	o	o	o	o	o	o	o	o	o	o	o	o
		f688	o	o	o	o	o	o	o	o	o	o	o	o
		f629	e	o	o	o	o	o	o	o	o	o	o	o
		f630	e	o	o	o	o	o	o	o	o	o	o	o
		f530	o	o	o	o	o	o	o	o	o	o	o	o
		f531	o	o	o	o	o	o	o	o	o	o	o	o
		f677	d	o	o	o	o	o	o	o	o	o	o	o
		f679	o	o	o	o	o	o	o	o	o	o	o	o
		f680	o	o	o	o	o	o	o	o	o	o	o	o
		f682	o	o	o	o	o	o	o	o	o	o	o	o
Family BULMINIDAE	Bulimina aculeata d'Orbigny elongata d'Orb. var. subulata Cushman & Parker marginata d'Orbigny striata d'Orbigny Virgulopsis turris Heron-Allen & Earland Globobulimina pacifica Cushman	b	o	d	c	c	e	d	c	d	b	o	d	o
		d	o	o	o	o	o	o	c	e	o	o	o	o
		e	o	d	d	o	e	o	d	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		e	o	d	e	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
Family WIGERINIDAE	Euwigierina lutorum (Vella) paeniteres (Finlay) plicosa (Vella) rodleyi rodleyi(Vella) rodleyi (Vella) var. tutamoides (Vella) delicatula (Vella) Siphonvigerina vadeszens (Vella) Trifarina angulosa (Williamson) bradyi Cushman	o	o	o	c	o	o	o	d	c	d	o	o	o
		o	o	e	o	e	o	o	o	o	o	o	o	o
		c	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	e	c	d	o	e	d	e	o	e	o	o
		o	o	o	o	c	d	o	o	b	o	o	o	o
		o	o	e	o	o	o	o	o	e	o	o	o	o
		o	o	e	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
Family DISCORBIDAE	Discorbis dimidiatus (Parker & Jones) Discorbinella baconica (Hantken) bertheloti (d'Orbigny) rarescens (Brady) Gavellinopsis nematus Vella lobatulus (Parr) pukauriensis Hornibrook sp. Rosalina bradyi (Cushman) paupereques Vella vitrevoluta Hornibrook sp. (elongate)	o	o	d	o	o	o	o	o	o	o	o	o	o
		o	o	e	o	o	o	e	o	o	o	o	o	o
		o	o	d	e	o	e	c	o	o	d	o	o	o
		o	o	o	o	o	o	o	e	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	e	o	c	d	o	d	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
Family GLABRATULIDAE	Glabratella zelandica Vella	o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o
		o	o	o	o	o	o	o	o	o	o	o	o	o

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare. All samples are from N137, except N131f530 & 531.

TABLE 27, PART 4. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF MICROFOSSILS IN WAVERLEY BEACH (I), WILKIES BLUFF (II) AND WAITOTARA VALLEY (III) SECTIONS.

Samples N137f 634, 659, 668, 676, 678, 683, 686 and 687 are barren of foraminifera.

	Section:		I								II		III				
	Stage:	Fossil No.:	Wp								Wm	Wp	Wm	Wm	Wm	Wm	Wm
Heronallenia wilsoni (Heron-Allen & Earland)			e	e	e	e	e	e	e	e	e	e	e	e	e	e	e
Family SPIRILLINIDAE																	
Patellina corrugata Williamson																	
Family ROTALIIDAE																	
Ammonia aoteana (Finlay)			d														e
Family ELPHIDIIDAE																	
Elphidium crispum (Linnaeus)				c	e					d		e					
novozelandicum Cushman				e	e							e					
spinatum Cushman & Valentine				e													
Cribroelphidium charlottensis (Vella)			d	b	d	c	d	d	b	b	d	e	e				e
argenteum (Parr)										d							
incertum (Williamson)												e					
simplex (Cushman)			e	d	e	c				d		d					
Notorotalia briggsi n. sp.										d	e						
clathrata (Brady)												c	c				
depressa Vella				d	e	d				d			e				
cf. depressa Vella (of Vella, 1957)				b		e	c		a			b	d				e
finlayi Vella			e	d	b	a	e	d	b	d	c	b	c				
inornata Vella				e	c	d	e	e		d							
kingmai Vella					e												
olsoni Vella										d							
pliozea Vella				e	d		c	c	d	c	c	e	d				
zelandica Finlay var. mangaparia Vella						e	b	c	c	b		d	c				
sp. (stellate)										e							
Family GLOBOROTALIIDAE																	
Globorotalia crassaformis (Galloway & Wissler)				e	e	e						d					
inflata (d'Orbigny)				e						e							
miozea Finlay s.l.				e													
puncticulata (Deshayes)				d						e							
Family GLOBIGERINIDAE																	
Globigerina bulloides d'Orbigny			e									d					
decoraperta Takayanagi & Saito					e							d					
duterrei d'Orbigny													d				
cf. falconensis Blow				d	e	e			d	e							
foliata Bolli			e		e		e		d			e	c				
pachyderma (Furberg)			e		e	e	e		e			c					
Globigerinoides ruber (d'Orbigny)													e				
Globigerinita glutinata (Egger)				e					e								
Turborotalita quinqueloba (Netland)									e								
Sphaeroidinella seminulina (Shwager)													d				
Family EPONIDIDAE				e													
Eponides broekianus (Karrer)			d		d	d	e		c	d	d		d	c			
Family CIBICIDIDAE					e				e	d							
Cibicides corticatus Earland													d				

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare. All samples are from N137, except N131f530 & 531.

TABLE 27, PART 5. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WAVERLEY BEACH (I), WILKIES BLUFF (II) AND WAITOTARA VALLEY (III) SECTIONS.

Samples N137f 631, 659, 668, 676, 678, 683, 686 and 687 are barren of foraminifera.

Section:	I												II		III						
Stage:	Vhp												Wm		Vhp	Wm	Wh				
Fossil No.:	f684	f685	f667	f666	f669	f665	f663	f664	f661	f662	f660	f658	f688	f629	f630	f530	f531	f677	f679	f680	f682
Cibicides deliquatus Finlay	.	.	.	d	e	.	d	e	.	.	.	.	.	.	d	.	.	.	.	.	.
marlboroughensis Vella	.	.	e	.	.	e	e	d	e	.	.	.	.	.	.	.	.	e	.	e	.
molestus Hornibrook	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.
porrodeliquatus Kennett	.	.	d	e	.	e	e	d	d	.	.	d	.	d	.	.	.	.	.	e	.
Dyocibicides biserialis Cushman & Valentine	.	.	.	.	.	.	c	.	c	.	.	d	.	c	d	.	.	e	e	.	.
primitiva Vella	.	.	e	.	.	.	.	e	e	.	.	.	.	.	e	.	.	.	e	.	.
Family CAUCASINIDAE																					
Fursenkoina vellai Kennett	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.
Family CASSIDULINIDAE																					
Cassidulina carinata Silvestri	d	.	b	b	b	c	d	c	b	d	.	d	d	e	d	a	b	c	b	d	.
subglobosa Brady	.	.	e	e	.	e	e	c	.	e	.	.	.	.	.	.	.	.	.	.	e
Evolvocassidulina orientalis (Cushman)	e	.	.	c	d	.	d	c	d	.	.	c	e	.	d	c	d	d	.	d	.
Family NONIONIDAE																					
Astrononion novozealandicum Cushman & Edwards	d	.	.	b	c	.	d	b	c	d	.	.	.	e	d	d	e	e	e	e	.
parki Hornibrook	e	.	d	e	b	e	.	.	.	.	.	e	.	.	.	c	.	.	.	.	.
poriensis (Vella)	.	.	.	c	d	d	c	c	c	c	.	b	.	e	d	.	.	e	.	.	.
vadorum Vella	.	.	e	.	e	.	.	d	d	e	.	d	.	e	d	.	.	e	.	.	.
Nonion cassidulinoides Hornibrook	e	.	e	.	.	.	.	c	.	.	.	.	.	.	.	.	.	d	.	.	.
Nonionellina flemingi (Vella)	c	e	d	b	a	e	d	b	c	c	e	d	d	d	c	c	c	d	b	e	e
Zeaflorilus parri (Cushman)	e	.	a	c	.	.	e	d	b	.	.	.	.	e	e	.	.	e	.	.	.
cf. parri (Cushman)(limbate sutures)	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
Family ANOMALINIDAE																					
Anomalinoides parvumbilia (Finlay)	.	.	e	d	b	.	.	.	.	.	.	.	.	.	.	b	.	.	.	.	.
spherica (Finlay)	.	.	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

All samples are from N137, except N131f530 & 531.

TABLE 28, PART 1. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

Samples N131f 534, 547, 549 and 551 are barren of foraminifera.

Stage:	Wo																				Wp						Wm						
Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f558	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556	
FORAMINIFERIDA																																	
Family TEXTULARIIDAE																																	
Textularia cf. barnwelli Kennett	.	.	.	.	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. ensis Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	c	e	.	.
Haeuslerella morgani (Chapman)	e	.	.	.	e	.	.	.	.	.	.	.	c	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
parri Finlay	c	c	c	c	c	b	c	e	e	c	c	b	b	c	a	a	a	a	a	.	e	d	.	c	e	e	.	.	b	c	e	.	
pliocenica (Finlay)	d	d	d	d	c	c	d	c	c	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Siphotextularia wairoana Finlay	e	e	c	e	e	e	c	e	.	.	.	.	.	e	.	.	e	.	d	.	.	.	.	e	.	e	.	.	.	d	.	.	
Family TROCHAMMINIDAE																																	
Trochammina inflata (Montagu)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	
Family ATAXOPHRAGMIIDAE																																	
Eggerella bradyi (Cushman)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	
Karrerella cylindrica Finlay	.	.	.	.	c	d	d	d	c	c	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Martinotiella clarae Gibson	.	.	.	e	.	e	.	d	.	c	.	.	.	c	.	.	d	c	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.
communis d'Orbigny	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family MILIOLIDAE																																	
Quinqueloculina cf. lamarkiana d'Orbigny	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	e	.	.	.	.	.	.	
aff. lata Terquem (of Vella,1957)	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
parvaglutta Vella	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.
Pyrgo elongata (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sigmoilopsis sp.	e	.	.	.	.	e	e	.	.	e	d	e	.	e	.	e	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Miliolinella subrotunda (Montagu)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
vigilax Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.
Family NODOSARIIDAE																																	
Nodosaria calomorpha Reuss	.	.	.	.	.	.	.	.	.	.	.	d	.	e	.	.	.	d	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
holoserica Schwager	.	.	.	.	e	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
lamulifera Boomgart	.	.	.	.	.	.	.	.	.	.	.	.	e	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
longiscata d'Orbigny	.	.	.	.	e	.	.	d	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
pyrula (d'Orbigny)	.	.	.	.	d	.	.	d	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Amphicoryna hirsuta (d'Orbigny)	d	d	c	e	b	c	d	d	e	c	e	c	c	c	b	c	c	b	c	c	.	e	.	.	.	e	.	.	.	e	.	.	
Chrysalogonium verticale Reuss	.	e	.	e	e	.	.	.	.	.	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dentalina emaciata Reuss	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
filiformis (d'Orbigny)	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
soluta Reuss	e	e	d	.	e	e	e	e	e	.	e	.	.	.	d	.	d	d	e	.	.	e	d	e	.	.	.	.	.	c	.	.	

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 28, PART 2. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

Samples N131f 534, 547, 549 and 551 are barren of foraminifera.

Stage:	Wo														Wp											Wm						
Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f558	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556
Dentalina substrigata (Stache)	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
vertebralis (Batsch)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	c	p	.	.	.	.	.	.	.	.	.	.	.	.	
Lagena albopunctata Matthes	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e
distoma Parker & Jones	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
favoso-punctata Brady	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
hispidia Reuss	e	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
cf. hispidia Reuss	.	.	e	.	e	d	.	.	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
laevis (Montagu)	e	e	e	e	.	e	e	c	.	d	d	d	e	e	e	e	e	.	e	.	.	.	c	d	.	.	.	.	b	.	c	.
pliocenica Cushman & Gray	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	d	.	e
stelligera Brady	.	.	.	e	e	d	d	d	c	d	c	c	c	c	e	.	.	e	e	.	.	d	.	.	.	.	.	.	.	.	e	d
striata (d'Orbigny)	.	e	e	e	e	d	.	d	c	.	.	d	e	.	d	e	d	e	.	.	d	b	c	.	d	.	.	c	b	d	.	.
sulcata (Walker & Jacob)	.	.	.	.	.	.	.	e	e	.	.	.	e	.	.	.	e	e	e	.	.	.	c	d	.	.	.	.	c	c	.	.
Lenticulina mammiligera (Karrer)	.	.	e	e	e	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
peregrina (Schwager)	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marginulina subbulata Hantken	.	e	e	.	d	d	.	.	.	.	.	e	e	.	.	.	.	.	d	.	.	e	.	.	.	.	.	.	.	.	.	.
Planularia tricarinaella (Reuss)	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Robulus calcar (Défrance)	c	c	c	c	c	c	b	b	b	c	d	b	b	c	b	a	b	a	c	.	.	.	.	c	d	c	.	e	c	c	d	.
costatus (Fichtel & Moll)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	d	d	d	.	.	.	.	.	.	.	.	.	.	.	.	.
cultratus Montfort	.	c	c	c	c	c	d	c	c	.	.	.	.	c	c	c	c	b	b	.	.	.	.	.	d	d	.	e	c	.	c	.
dicampylus (Franzenau)	.	d	c	.	e	.	.	c	e	.	.	.	.	.	.	.	e	d	e	.	e	.	.	.	.	.	.	.	.	.	.	.
gyroscalprus (Stache)	.	.	.	.	.	.	.	.	.	.	.	.	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
iotus (Cushman)	c	c	c	c	.	.	d	.	e	.	.	e	c	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
loculosus (Stache)	.	.	.	.	.	.	.	.	.	.	.	c	.	c	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.	.	.	.
orbicularis (d'Orbigny)	.	.	.	.	.	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.
sp. (stellate)	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saracenaria ampla Cushman & Todd	.	.	.	c	d	d	d	.	.	.	.	.	.	.	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
italica DeFrance	d	d	d	c	e	d	e	.	d	.	.	.	e	e	e	d	d	c	d	.	e	.	e	.	.	.	.	.	.	.	.	
latifrons (Brady)	.	.	.	.	e	.	e	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vaginulina elegans d'Orbigny	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
vagina (Stache)	e	e	e	d	c	e	e	e	.	e	.	.	.	d	e	c	e	.	d	e	.	.	.	.	.	.	.	.	.	e	.	.
Plectofrondicularia pellucida Finlay	.	.	e	.	e	d	d	d	d	e	d	e	.	e	c	.	e	.	c	c	.	.	.	.	.	.	.	.	.	.	.	.
wairarapa Vella	e	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.
Family POLYMORPHINIDAE																																
Guttulina bartschi Cushman & Ozawa	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sigmomorphina lacrimosa Vella	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 28, PART 3. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

WANGANUI RIVER SECTION, Lower Part.

Samples N131f 534, 547, 549 and 551 are barren of foraminifera.

	Stage:	W ₀													W _p										W _m								
	Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f538	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556
Family GLANDULINIDAE																																	
Oolina globosa (Montagu)		.	.	.	e	.	.	.	.	.	.	a	e	.	.	.	.	.	.	e	.	.	.	a	e	a	a	.	.	a	e	e	a
hexagona (Williamson)		.	.	.	e	.	.	.	a	.	.	.	e	.	.	.	.	.	a	e	.	.	.	e	.	.	a	.	.	a	e	e	a
mele d'Orbigny		.	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	e	.	.	a	.	.	e	a	e	.
Fissurina bicarinata Seguenza		.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
concurbitasema Loeblich & Tappan		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
curvita Parr		.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
deltoides Seguenza		.	.	.	.	d	.	e	e	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
earlandi Parr		.	.	.	.	.	.	e	e	e	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	a	.	.	.	.	e	
formosa (Schwager) var. angusticarinata Parr		.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
cf. formosa (Schwager)		.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
keruelensis Parr		e	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
orbignyana Seguenza		.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
quadricostulata (Reuss) var. sexcostulata Silvestri		.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
siciliensis Loeblich & Tappan		e	e	.	.	e	e	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
submarginata (Boegart)		e	e	d	.	.	.	.	e	.	.	.	.	.	.	.	.	e	d	.	e	.	d	d	d	.	b	.	e	d	d	e	
Parafissurina sublata Parr		.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
tectulostoma Loeblich & Tappan		.	.	.	.	.	.	.	.	e	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
tricarinata Parr		.	.	.	.	.	.	.	e	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family TURRILINIDAE																																	
Buliminella elegantissima d'Orbigny		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family SPHAERODINIDAE																																	
Sphaeroidina bulloides d'Orbigny		e	d	e	e	b	e	.	e	e	e	d	e	.	e	d	e	e	.	.	.	d	e	d	.	e	.	.	e	e	e	.	
Family BOLIVINITIDAE																																	
Bolivinita cf. finlayi Kennett		.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
plicosa Finlay		d	e	.	e	e	d	e	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
pohana Finlay		e	d	.	.	e	.	e	e	.	e	e	e	d	d	.	.	.	.	.	.	.	e	b	e	.	e	.	.	e	e	.	
quadrilatera (Schwager)		.	.	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Bolivina affiliata Finlay		.	.	.	.	d	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	
alata (Seguenza)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
albatrossi Cushman		.	b	d	d	.	e	d	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
compacta (Sidebottom)		.	.	d	.	d	.	.	.	.	e	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
minuta Natland		.	.	.	.	.	.	.	.	e	e	e	e	e	e	e	e	e	e	e	.	.	.	.	.	.	.	.	.	.	.		
petiae Gibson		.	d	e	.	d	d	.	e	d	.	.	.	.	e	d	.	.	.	.	.	.	e	b	b	.	e	.	e	d	b	e	
plicatella Cushman		.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 28, PART 4. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

Samples N131f 534, 547, 549 and 551 are barren of foraminifera.

Stage:	Wo													Wp										Wm									
Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f558	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556	
Bolivina pseudoplicata Heron-Allen & Earland	e	.	e	.	.	e	.	.	d	.	.	c	c	.	d	.	.	.	e	.	.	d	c	d	.	e	.	c	d	c	e	c	
spathulata (Williamson)	e	.	.	.	c	e	.	.	.	.	.	e	.	.	d	.	.	e	.	.	.	.	e	.	e	.	.	e	.	e	.	.	
subexcavata Cushman & Wickenden	.	.	.	e	d	e	.	.	e	.	e	.	d	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.	.	.	.	.	
subspinescens Cushman	e	d	d	e	d	d	e	c	c	c	d	.	.	c	d	.	.	.	.	.	.	d	.	e	.	e	.	c	c	c	.	c	
cf. turbiditorum Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	
vellai n.sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	d	.	.	.	.	.	.	.	.	.	e	d	c	d	e	
wanganuiensis n.sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	c	.	.	.	c	.	.	.	.	.	.	d	.	c	e	
watti Gibson	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	c	.	.	.	.	c	.	.	.	.	.	d	.	c	e	.	.	
Rectobolivina maoria Finlay	.	.	.	.	e	.	.	e	d	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
striatula (Cushman)	.	e	.	e	e	d	d	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	
Family EOUVIGERINIDAE																																	
Stilostomella basicarinata Hornibrook	.	.	.	.	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
pomuligera (Stache)	b	.	.	.	.	.	e	e	d	.	.	.	.	.	e	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	
verneulli (d'Orbigny)	.	.	.	.	.	.	e	e	e	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
sp. (striate)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family BULIMINIDAE																																	
Bulimina aculeata d'Orbigny	c	d	d	d	e	e	c	c	d	d	.	d	e	d	d	e	d	d	e	.	c	b	d	.	c	e	b	b	b	a	b		
elongata d'Orb. var. subulata Cush. & Parker	e	.	.	.	.	.	.	.	.	e	d	.	.	.	.	d	.	.	.	.	.	d	c	e	.	.	.	d	e	e	.	d	
marginata d'Orbigny	.	c	d	c	b	e	e	d	d	d	d	d	e	d	.	e	e	.	d	.	.	d	.	.	d	.	d	.	.	.	.	.	
striata d'Orbigny	c	d	c	c	c	c	d	c	e	d	d	e	e	e	d	.	.	e	.	.	.	.	.	e	.	.	.	.	.	.	.	.	
Virgulopsis turris Heron-Allen & Earland	.	.	.	.	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	c	e	d	.	e	
Family UVIGERINIDAE																																	
Euvigerina lutorum (Vella)	e	c	c	c	c	c	d	d	d	c	b	d	.	b	d	.	d	.	b	e	e	e	d	.	b	.	d	b	a	d	.		
paeniteres (Finlay)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	
peregrina (Cushman)	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
pliozea (Vella)	.	b	c	c	c	b	b	b	c	e	c	b	b	b	d	d	d	b	b	.	.	d	.	c	.	d	.	d	.	c	b	e	
cf. pliozea (Vella)(strongly costate)	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	
rodleyi (Vella) var. rodleyi (Vella)	.	.	.	.	.	e	.	.	.	.	e	.	.	.	d	.	e	d	.	.	.	.	.	.	.	.	.	c	b	a	e	.	
rodleyi (Vella) var. tutamoides (Vella)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	
zeacuminata (Vella)	c	c	c	c	c	d	d	c	b	e	d	.	b	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Siphouvigerina bellula (Vella)	.	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	
interrupta (Brady)	.	.	.	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
vadescens (Vella)	.	e	.	.	e	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	e	
Trifarina angulosa (Williamson)	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
bradyi Cushman	.	e	.	.	.	.	.	.	e	.	.	.	.	d	d	e	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	
spp.	.	.	.	.	.	e	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

Samples N131f 534, 547, 549, and 551 are barren of foraminifera.

Stage:	Wg														Ng										Nm							
Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556	
Family DISCORIDAE																																
Discorbinella bertheloti (d'Orbigny)	e	d	.	e	d	e	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Patellinella inconspicua (Brady)	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	
Rosalina vitrevoluta Hornibrook	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	
sp.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family ROTALIIDAE																																
Ammonia aoteana (Finlay)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	e	.	.	.	
Family ELPHIDIIDAE																																
Elphidium crispum (Linnaeus)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
novosealandicum Cushman	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	e	.	.	.	.	.	.	
Critroelphidium charlottensis (Vella)	e	.	.	.	.	.	e	.	.	.	.	d	e	.	e	.	e	.	.	.	.	e	e	.	b	.	c	d	e	e	a	
cf. charlottensis (Vella)(scalloped)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
argenteum (Parr)	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	e	.	.	e	
simplex (Cushman)	.	.	.	.	.	e	.	.	.	.	.	e	.	.	.	.	.	.	.	e	d	e	.	e	.	e	.	.	.	.	.	
Notarotalia briggsi n.sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
cf. depressa Vella (cf Vella, 1957)	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	e	.	.	.	.	.	.	.	.	.	d	.	.	d	
finlayi Vella	.	.	.	.	.	.	.	.	e	.	.	d	d	d	d	d	d	d	e	e	.	d	e	d	e	e	e	a	d	e	a	
hurapiensis Vella	d	d	d	d	e	e	d	e	d	e	d	d	d	d	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
pliosea Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	d	e	.	.	
taranakia Vella	.	d	d	d	d	e	d	d	d	d	d	d	d	e	d	.	.	.	.	.	.	d	.	.	.	.	.	.	.	e	.	
selandica Finlay var. mangaoparia Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	d	.	.	
Family HANTKENINIDAE																																
Globigerinella siphonifera (d'Orbigny)	e	.	.	e	e	.	e	.	.	.	.	.	.	.	.	e	e	.	.	e	.	.	.	.	.	.	.	.	.	.	.	
Family GLOBOROTALIIDAE																																
Globorotalia crassaformis (Galloway & Wissler)	d	d	e	e	d	d	e	e	d	d	d	e	e	d	d	d	e	d	.	.	e	.	d	.	d	.	d	.	d	.	.	
hirsuta (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
inflata (d'Orbigny)	d	e	d	d	d	e	d	d	e	d	.	.	d	d	d	e	e	d	.	.	.	.	e	.	.	.	d	a	.	.	.	
menardii (Parker, Jones & Brady)	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
puncticulata (Deshayes)	d	d	d	d	d	e	d	e	e	e	.	.	d	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
scitula (Brady)	.	e	.	e	e	d	.	e	.	e	.	e	.	.	e	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	
Family GLOBIGERINIDAE																																
Globigerina bulloides d'Orbigny	e	d	e	d	e	d	e	e	d	e	e	e	d	e	e	b	e	e	.	.	e	e	e	.	e	.	d	e	b	.	e	
decoraperta Takayanagi & Saito	e	e	e	e	e	d	d	e	d	d	.	e	d	.	d	e	.	d	.	.	e	.	.	.	e	.	.	e	.	.	.	
dutertrei d'Orbigny	e	d	e	d	d	d	e	e	e	e	e	e	e	e	e	e	d	e	.	.	e	.	e	.	d	.	.	e	e	.	e	
canesi Blow	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
cf. falconensis Blow	.	d	d	e	d	d	e	e	d	e	e	e	e	d	e	e	d	e	.	.	e	e	e	.	e	.	d	e	e	.	e	
foliata Bolli	e	e	e	b	.	e	b	e	b	e	b	e	b	b	e	e	b	e	b	.	b	.	e	.	e	.	d	e	d	.	d	
pachyderma (Ehrenberg)	b	e	b	e	b	e	e	b	e	d	e	b	e	e	e	e	d	e	e	.	e	e	e	.	b	.	e	b	e	.	e	
Globigerinoides triloba (Reuss)	d	e	.	e	e	d	d	d	d	d	e	e	e	e	d	d	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	

KEY: a = very abundant; b = abundant; e = common; d = uncommon; e = rare.

TABLE 28, PART 6. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

Samples N131f 534, 547, 549 and 551 are barren of foraminifera.

Stage:	Wo														Wp										Wm							
Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f558	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556
Globigerinoides ruber (d'Orbigny)	.	.	.	d	.	e	.	e	.	.	.	.	.	.	.	.	.	e	e	.	.	e	.	.	.	.	.	e	.	.	.	.
Orbulina universa d'Orbigny	e	.	.	.	e	.	e	.	.	.	e	e	.	.	e	.	.	d	.	.	.	e	.	e	.	.	.	d	.	e	.	.
Globigerinita glutinata (Egger)	c	c	b	c	c	c	c	c	c	c	c	d	c	c	c	c	c	d	c	.	.	c	e	c	.	c	.	e	c	c	.	.
uvula (Elrenberg)	d	c	d	d	.	b	d	c	c	c	c	d	d	d	c	e	e	c	b	.	.	d	e	c	.	d	.	e	e	c	.	.
Turborotalita quinqueloba (Natland)	b	c	d	b	d	c	d	c	c	c	c	b	c	c	c	c	d	c	c	.	.	b	.	c	.	d	.	d	.	c	.	c
Family EPONIDIDAE																																
Eponides broekhianus (Karrer)	.	c	b	b	b	b	.	d	.	.	.	e	e	e	.	.	e	e	e	.	e	d	b	e	.	c	.	e	d	d	d	a
Family CIBICIDIDAE																																
Hyalinea cf. balthica (Schubert)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	d	.	.	.	.	.	.	.	.
Cibicides deliquatus Finlay	c	.	c	d	.	c	.	.	e	b	.	c	c	c	c	d	d	c	c	.	.	e	.	d	.	.	.	.	.	c	.	.
ihungia Finlay	.	d	e	.	c	.	c	.	.	.	e	e	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
marlboroughensis Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	.	.	d	c	.
molestus Hornibrook	d	d	c	d	d	c	d	.	e	d	c	c	c	c	c	c	c	c	b	.	.	d	.	.	.	.	.	.	.	.	.	.
porrodeliquatus Kennett	.	.	c	c	c	c	c	c	c	c	c	c	c	d	c	c	.	.	a	.	d	.	d	.	.	.	.	d	c	.	e	.
Dyocibicides biserialis Cushman & Valentine	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e
primitiva Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e
Family CAUCASINIDAE																																
Fursenkoina vellai Kennett	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.
Family CASSIDULINIDAE																																
Cassidulina carinata Silvestri	d	e	c	c	d	e	e	d	e	d	e	d	e	.	e	.	d	c	e	.	.	c	c	a	.	b	.	c	c	c	e	c
cuneata Finlay	.	.	.	.	e	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
subglobosa Brady	e	d	e	e	c	e	.	.	.	.	e	e	e	.	e	e	e	e	.	.	.	.	.	.	.	e	.	.	.	.	.	.
Ehrenbergina mestayerae Cushman	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Evolvocassidulina orientalis (Cushman)	.	e	e	.	.	.	e	e	e	e	e	d	e	.	d	.	d	d	e	.	.	b	.	a	.	c	.	c	c	b	.	d
cf. orientalis (Cushman)(compressed).	.	.	.	.	.	.	.	.	.	.	.	c	c	d	d	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family NONIONIDAE																																
Chilostomella ovoidea Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e
Astrononion neefi Vella	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
novozealandicum Cushman & Edwards	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	a	c	e
parki Hornibrook	c	d	d	e	c	e	d	.	e	d	c	c	d	.	.	.	e	.	e	d	.	e	b	d	e	d	.	c	a	c	b	e
poriensis (Vella)	.	.	.	.	.	.	.	.	.	d	.	c	c	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.
Nonionella zenitens Finlay	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.
Pullenia bulloides d'Orbigny	.	.	.	.	c	.	e	e	.	c	c	d	e	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.
quinqueloba (Reuss)	e	e	.	.	d	e	.	e	.	d	e	d	e	e	e	e	e	.	.	.	.	.	e	.	.	.	.	.	.	e	.	.
Nonionellina flemingi (Vella)	d	d	.	.	e	.	e	e	.	e	e	e	e	.	e	e	e	d	e	.	.	d	.	c	.	d	.	c	c	b	d	a
Zeaflorilus parri (Cushman)	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	e	.	.	.	.	.	.	.	.	e	.	.	.	e	.	.
Family ALABAMINIDAE																																
Oridorsalis prominula (Stache)	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
tenera (Brady)	d	b	c	.	c	c	d	d	d	e	d	d	d	d	.	.	e	e	.	.	.	.	.	c	.	c	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 28, PART 7. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Lower Part, N131.

Samples N131f 534, 547, 549 and 551 are barren of foraminifera.

Stage:	T ₀														T ₁										T ₂						
Fossil No.:	f515	f516	f517	f519	f520	f522	f523	f524	f527	f528	f529	f530	f531	f532	f533	f535	f536	f537	f538	f539	f540	f541	f543	f544	f545	f546	f552	f553	f554	f555	f556
Family GARTULARIIDAE																															
Gyroidinoides neosoldanii (Drotzen)	c	c	c	d	.	d	d	c	e	.	.	.	.	.	e	.	.	.	.	.	a	.	c	.	.	.	.	.	.	.	.
zealandica (Finley)	.	.	.	.	e	.	d	d	d	.	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family ANOMALINIDAE																															
Anomalinaoides parvumbilica (Finley)	e	d	e	.	c	e	e	d	d	.	.	e	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
spherica (Finley)	.	.	.	.	e	.	.	.	.	.	.	.	d	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Melonia zeobasus Vella	.	e	.	.	c	e	d	e	e	.	.	d	c	d	c	c	c	d	b	.	.	.	.	.	.	.	.	.	.	.	.
Family CERATONULINIDAE																															
Hoeglundina elegans (d'Orbigny)	.	.	.	.	.	.	e	c	d	.	.	d	c	d	c	.	c	c	.	.	.	e	e	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 29, PART 3. (To accompany thesis by J.D. Colten).

DISTRIBUTION OF FORAMINIFERALS IN WANGANUI RIVER SECTION, Upper Part, M138.

Samples M138f 551, 552, 553 and 555 are barren of foraminifera.

	Stage:		Mn										Mh									
	Fossil No.:		f548	f549	f550	f554	f556	f557	f558	f559	f560	e	f561	f562	f563	f564	f565	f566	f567	f568	f569	f570
<i>Fissurina</i>	<i>lacunata</i> (Burrows & Holland)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>oblonga</i> Reuss		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>orbignyana</i> Seguenza		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>quadriconstulata</i> (Reuss) var. <i>sexcostulata</i> Parr		.	.	.	.	.	e	.	c	.	.	.	.	.	.	.	e	.	.	.	.
	<i>semimarginata</i> Reuss		.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>siciliensis</i> Loeblich & Tappan		.	.	.	.	e	.	.	c	.	.	.	d	.	.	.	c	.	e	.	.
	<i>subcircularis</i> Parr		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	.
	<i>submarginata</i> (Boonpart)		d	e	.	e	c	c	.	d	d	.	e	b	b	c	c	b	e	c	c	e
	<i>subquadrata</i> Parr		.	.	.	.	.	.	e	.	e	.	.	.	.	.	.	e	.	e	.	.
	<i>triconstulata</i> Pierce		.	.	.	.	.	.	.	e	.	.	.	d	.	.	.	.	.	.	d	e
	<i>trigono-oblonga</i> (Seguenza & Siddall)		.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
	<i>wiesneri</i> Brady		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	e	.	.	.
	<i>wrightiana</i> (Brady)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Parafissurina</i>	<i>sublata</i> Parr		.	.	.	.	.	.	.	d	e	.	.	.	.	.	.	.	.	.	.	.
	<i>teetulostrona</i> Loeblich & Tappan		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>tricarinata</i> Parr		.	.	.	.	.	.	.	c	.	.	.	e	.	.	.	d	c	.	e	.
<i>Family TURRITIDAE</i>			.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Orlininella</i>	<i>elegantissima</i> d'Orbigny		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Family SPIAERIODINIDAE</i>			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Spiæroidina</i>	<i>bulloides</i> d'Orbigny		.	.	.	.	.	d	d	d	.	e	c	d	e	c	e	d	.	.	e	d
<i>Family BOLIVINIDAE</i>			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Bolivinita</i>	<i>pliozea</i> Finlay		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>pohana</i> Finlay		.	.	.	.	.	.	e	.	.	.	d	.	.	.	.	.	.	.	.	.
	<i>quadrilatera</i> (Schwager)		.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	e	.
<i>Bolivina</i>	<i>aenariensis</i> (Costa)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>affiliata</i> Finlay		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>alata</i> (Seguenza)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>cacozela</i> Vella		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>compacta</i> (Sidebottom)		.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.
	<i>hornibrooki</i> n.sp.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>lapsus</i> Finlay		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>minuta</i> Matland		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>petiae</i> Gibson		b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>pseudoplicata</i> Heron-Allen & Earland		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>spatulata</i> (Williamson)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>subexcavata</i> Cushman & Wickenburg		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>subspinescens</i> Cushman		e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>vellai</i> n.sp.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>wanganuiensis</i> n.sp.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	<i>watti</i> Gibson		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Reotobolivina</i>	<i>striatula</i> (Cushman)		.	.	.	.	e	b	b	d	e	.	.	.	.	.	.	.	.	.	.	.
<i>Family BOVIGERINIDAE</i>			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Stilosomella</i>	<i>antipoda</i> (Stache)		.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.
	<i>verneuili</i> (d'Orbigny)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Family BULMINIDAE</i>			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Bulimina</i>	<i>aculeata</i> d'Orbigny		c	d	.	c	c	c	d	d	c	.	d	c	c	b	c	b	c	d	c	c

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 29, PART 4. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Upper Part, M38.

Samples M38f 551, 552, 553 and 555 are barren of foraminifera.

	Stage:	M38										M39									
		Fossil No.:	f548	f549	f550	f554	f556	f557	f558	f559	f560	f561	f562	f563	f564	f565	f566	f567	f568	f569	f570
<i>Bulinna elongata</i> d'Orb. var. <i>subulata</i> Cushman & Parker			.	.	.	d	e	c	e	d	d	d	.	b	c	c	a	d	e	c	c
<i>marginata</i> d'Orbigny			b	.	.	.	.	.	e	d	.	e	e	.	.	.	.	.	.	.	d
<i>striata</i> d'Orbigny			e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	d	.
<i>Virgulopsis turris</i> Heron-Allen & Barland			.	.	.	.	e	d	.	.	b	e	e	b	b	c	a	b	d	b	d
<i>Globobulimina pacifica</i> Cushman			.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	d	.	.	.
Family URGERIIDAE																					
<i>Euviglerina tutorum</i> (Vella)			e	.	.	c	e	.	.	.	.	d	e	d	.	d	d	d	d	e	e
<i>paeniteres</i> (Finlay)			.	.	.	.	.	.	.	.	.	.	.	.	.	e	c	.	.	.	e
<i>pliozea</i> (Vella)			.	.	.	.	.	.	.	e	d	.	c	.	d	d	.	e	c	.	c
cf. <i>pliozea</i> (Vella) (strongly costate)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.
<i>rodleyi rodleyi</i> (Vella)			.	.	.	.	e	d	c	c	e	.	b	c	.	d	.	d	d	.	d
<i>rodleyi</i> (Vella) var. <i>tutamoidea</i> (Vella)			.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.
<i>Siphoviglerina vadeszens</i> (Vella)			.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.
<i>Trifarina angulosa</i> (Williamson)			.	.	.	.	.	.	.	.	.	.	d	.	.	.	.	d	e	.	.
sp.			.	.	.	.	.	.	d	.	.	.	.	.	.	.	e	d	e	e	.
Family DISCORIIDAE																					
<i>Discorbis dimidiatus</i> (Parker & Jones)			.	.	.	.	.	.	b	c	c	.	.	c	.	.	.	.	.	.	.
sp.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e
<i>Discorbinella baconica</i> (Hantken)			.	.	.	.	.	.	e	.	.	.	.	.	.	e	d	.	.	e	e
<i>bertheloti</i> (d'Orbigny)			.	.	.	.	.	.	c	c	e	.	c	d	d	c	c	c	d	.	d
sp. (limbate sutures)			.	.	.	.	.	.	d	.	d	.	e	.	.	e	.	d	.	.	.
<i>Epistominellaiota</i> Hornibrook			.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	e	e
<i>Gavelinopsis hamatus</i> Vella			.	.	.	.	.	.	d	d	.	.	.	.	.	.	.	.	b	.	.
<i>pukeruiensis</i> Hornibrook			.	.	.	.	.	.	.	.	.	.	.	.	.	c	.	.	.	b	.
<i>Laticarinina altocamerata</i> (Heron-Allen & Barland)			.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Patellinella incenspicua</i> (Brady)			.	.	.	.	.	c	c	.	.	.	.	.	.	.	.	.	.	.	.
<i>Rosalina bradyi</i> (Cushman)			.	.	.	.	.	c	c	d	e	d	e	c	c	d	c	c	.	c	e
<i>pauperesques</i> Vella			.	.	.	.	.	d	d	e	.	d	e	.	.	e	d	e	.	d	.
<i>vitricza</i> Hornibrook			.	.	.	.	.	e	d	.	.	.	.	.	.	e	e	.	.	e	.
Family GLABRATULIIDAE																					
<i>Heronallenia wilsoni</i> (Heron-Allen & Barland)			.	.	.	.	.	c	.	.	.	.	.	.	.	e	d	.	.	e	.
<i>Valvulineria saeonica</i> Asano			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.
Family SPIRILLINIDAE																					
<i>Patellina corrugata</i> Williamson			.	.	.	.	.	.	e	.	.	.	.	.	e	.	.	.	.	.	.
Family ROTALIIDAE																					
<i>Ammonia aoteana</i> (Finlay)			.	e	.	.	b	d	c	e	e	d	.	d	c	c	d	.	c	d	c
Family ELPHIDIIDAE																					
<i>Elphidium crispum</i> (Linnaeus)			.	.	.	.	.	.	e	.	.	.	.	.	.	b	.	.	e	c	b
<i>novozealandicum</i> Cushman			.	.	.	.	.	d	b	.	.	.	.	.	.	.	.	.	.	.	.
<i>Oribroidelphidium argenteum</i> (Parr)			.	.	.	.	e	d	a	.	e	e	d	c	.	b	.	b	.	.	.
<i>charlottensis</i> (Vella)			c	e	.	e	b	a	a	c	d	.	a	d	d	c	b	a	c	c	c
cf. <i>charlottensis</i> (Vella) (scalloped)			.	.	.	.	.	.	.	.	e	.	.	.	.	.	e	c	e	.	.
<i>incertum</i> (Williamson)			.	.	.	.	.	e	.	.	.	.	.	.	d	d	.	d	.	e	d
<i>simplex</i> (Cushman)			e	.	.	.	b	a	e	c	d	d	c	b	c	a	b	a	c	b	b
<i>Notorotalia briggsi</i> n.sp.			.	.	.	.	.	e	d	d	.	.	.	.	.	.	.	.	.	.	.
<i>clathrata</i> (Brady)			.	.	.	.	.	.	.	.	c	.	.	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 29, PART 5. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF MICROFOSSILS IN MANGATU RIVER SECTION, Upper Part, N138.

Samples N138f 551, 552, 553 and 555 are barren of foraminifera.

	Stage:																			
	Fossil No.:		m										n							
	f548	f549	f550	f554	f556	f557	f558	f559	f560	f561	f562	f563	f564	f565	f566	f567	f568	f569	f570	
Family NOTOROTALIIDA																				
cf. depressa Vella (cf Vella, 1957)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
finlayi Vella	d	.	.	c	c	a	a	c	.	.	.	.	b	.	.	.	c	e	.	.
inornata Vella	.	.	.	.	.	e	d	.	.	.	.	d	.	d	d	c	.	e	e	.
pliozea Vella	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
zelandica Finlay var. mangaparia Vella	.	.	.	.	e	.	.	e	.	.	.	.	.	.	.	.	d	.	.	.
Family GLOBOROTALIIDA																				
Globorotalia crassaformis (Galloway & Wissler)	.	.	.	.	.	d	d	e	d	e	.	e	.	d	d	d	d	d	e	.
hirsuta (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
inflata (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	e	.	e	.	.
scitula (Brady)	.	.	.	.	.	.	.	e	.	e	.	.	.	.	e	.	.	e	.	.
Family GLOBIGERINIDA																				
Globigerina bulloides d'Orbigny	e	.	.	e	d	c	d	c	b	b	b	b	b	b	c	b	c	c	b	.
Georoperta Takayanagi & Saito	.	.	.	e	.	e	.	e	.	e	e	e	e	d	d	.	.	e	.	.
auterrei d'Orbigny	.	.	.	.	e	c	c	c	d	c	d	d	d	d	d	c	d	c	d	.
cf. falconensis Blow	e	.	.	.	e	e	e	e	e	c	b	c	c	c	c	c	c	c	c	.
foliata Bolli	.	.	.	.	e	e	d	b	d	c	b	c	d	c	c	c	c	c	c	.
paocyderma (Ehrenberg)	e	.	.	e	d	c	b	c	c	c	b	b	b	b	b	c	b	c	c	.
Globigerinoides ruber (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.
triloba (Reuss)	.	.	.	.	.	.	d	.	.	.	d	.	d	.	d	.	.	.	d	.
Orbulina universa d'Orbigny	.	.	.	e	.	.	.	e	.	.	e	.	.	.	.	e	.	.	e	.
Globigerinita glutinata (Egger)	e	.	.	.	e	.	d	e	e	d	c	d	d	c	c	d	c	c	d	.
uvula (Ehrenberg)	.	.	.	.	.	e	d	d	.	d	d	d	.	d	d	d	c	d	d	.
Turborotalita quinqueloba (Natland)	.	.	.	.	.	.	d	c	.	d	d	d	c	c	d	e	d	d	d	.
Family EPONIDIDAE																				
Eponides broeckianus (Karrer)	c	.	.	.	e	d	.	e	d	.	e	d	c	d	c	e	c	c	d	.
Family CIBICIDIDAE																				
Planulina sp.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.
Cibicides corticatus Earland	.	.	.	.	.	c	.	.	.	.	e	.	.	c	d	e	.	d	d	.
deliquatus Finlay	.	.	.	e	.	.	.	e	.	.	c	.	.	.	.	d	.	.	.	.
marboroughensis Vella	.	.	.	.	.	c	c	e	.	e	e	.	.	.	.	e	e	d	e	.
porrodeliquatus Kennett	.	.	.	.	.	d	d	.	.	.	.	.	.	.	.	d	.	.	c	.
temperata Vella	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.
sp. (coarsely perforate)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.	.
Lyocibicides biserialis Cushman & Valentine	.	.	.	.	.	d	c	e	.	e	.	.	.	.	c	b	.	d	c	.
primitiva Vella	.	.	.	.	.	d	.	e	.	.	.	.	.	e	e	e	.	d	e	.
Family PLANORBULINIDA																				
Planorbulina mediterraneensis d'Orbigny	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.
Family CAUDASINIDA																				
Pursenkoina vella Kennett	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.
Family CASSIDULINIDA																				
Cassidulina carinata Silvestri	a	.	.	d	c	c	c	d	d	e	b	c	c	d	b	c	c	b	c	.
subglobosa Brady	.	.	.	.	.	b	c	d	.	.	c	.	.	e	c	d	d	.	.	.
Ehrenbergina westayerae Cushman	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.
Evolocassidulina orientalis (Cushman)	b	.	.	.	.	c	d	d	e	e	e	c	d	d	c	c	d	c	d	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 29, PART 6. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF MICROFOSSILS IN WANGANUI RIVER SECTION, Upper Part, N138.

Samples N138f 551, 552, 553 and 555 are barren of foraminifera.

Stage:	Wm										Wh									
Fossil No.:	f548	f549	f550	f554	f556	f557	f558	f559	f560	f561	f562	f563	f564	f565	f566	f567	f568	f569	f570	
Family NONIONIDAE																				
Chilostomella ovoidea Reuss	.	.	.	.	.	.	.	.	e	e	d	.	.	e	.	d	.	.	.	
Astrononion novozealandicum Cushman & Edwards	.	.	.	.	e	b	b	d	d	.	a	c	e	c	d	c	.	e	e	
parki Hornibrook	c	.	.	c	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
poriensis (Vella)	.	.	.	.	e	.	d	.	.	.	e	.	.	b	e	c	d	.	d	
vadorum Vella	.	.	.	.	e	.	.	c	.	.	.	.	.	e	.	e	.	.	.	
Nonionella magnalingua Finlay	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	
turgida (Williamson)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	
zenitens Finlay	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	e	.	.	.	
Pullenia bulloides d'Orbigny	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	e	.	
quingeloba (Reuss)	.	.	.	.	.	.	.	.	.	.	.	.	e	e	.	.	e	.	.	
Nonionellina flemingi (Vella)	.	.	.	.	a	c	a	b	c	c	a	a	a	a	a	a	b	b	b	
Zeafiorilus parri (Cushman)	.	.	.	.	d	c	d	e	.	d	.	c	c	a	b	c	c	c	b	
Family ALABAMINIDAE																				
Oridorsalis prominula (Stache)	.	.	.	.	.	e	.	.	.	e	.	.	.	.	.	.	.	.	.	
Family OSANGULARIIDAE																				
Gyroidinoides neosoldanii (Brotzen)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.	.	
zealandica (Finlay)	.	.	.	.	.	c	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family ANOMALINIDAE																				
Anomalinoides parvumbilica (Finlay)	.	.	.	.	.	.	.	.	.	.	a	d	.	e	d	c	.	e	e	
spherica (Finlay)	.	.	.	.	.	.	.	.	.	.	a	e	.	e	d	c	e	.	e	
Melonis sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	
Family CERATOBULLINIDAE																				
Ceratobulimina sp.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	
Zelamarkina excavata n.gen., n.sp.	.	.	.	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	
Hoeglundina elegans (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 30, PART 1. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN RANGITIKEI RIVER SECTION.

Stage:	M132							M139				M139										
Fossil No.:	M132							M139				M139										
	F507	F508	F509	F510	F511	F512	F513	F514	F515	F516	F538	F539	F540	F541	F542	F543	F544	F545	F546	F547	F548	F549
FORAMINIFERIDA																						
Family TEXTULARITIDAE																						
<i>Textularia</i> cf. <i>ensis</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Heuserella mergui</i> (Chapman)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>perti</i> Pinley	.	d	e	e	e	d	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>plicosepta</i> (Pinley)	.	.	.	.	.	b	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Siphotextularia blacki</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. <i>blacki</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>nestoyana</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>waipoua</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family AMMONIATIDAE																						
<i>Gastryina convexa</i> (Karrer)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Hertiniella communis</i> d'Orbigny	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family Miliolidae																						
<i>Quinqueloculina legitimensis</i> Vella	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>laurentiana</i> d'Orbigny	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>parvopagula</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>triangularis</i> d'Orbigny	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
sp. (compressed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Pyrgo</i> aff. <i>exo</i> Asano (cf Vella, 1957)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. <i>guerreri</i> Silvestri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>plum</i> (Schlumberger)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Sigmoilopsis schlumbergeri</i> (Silvestri)	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Sphenoperta mabeathi</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Miliolinella vigilax</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. <i>vigilax</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family NODOSARITIDAE																						
<i>Nodosaria holoserica</i> Sinuiger	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>longicosta</i> d'Orbigny	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>pyrula</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Amphioecyna hirsuta</i> (d'Orbigny)	.	.	.	.	.	d	.	.	c	b	b	.	.	.	.	.	.	.	.	.	.	.
<i>Chrysologonina verticale</i> Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Dentalina vertebialis</i> (Batsch)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Legum albuginata</i> Matthes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>amplora</i> Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. <i>belli</i> Matthes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. <i>corumbiensis</i> Millett	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>distans</i> Parker & Jones	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>gracilis</i> Williamson	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>gracillima</i> (Seguenza)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. <i>hiapida</i> Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>laevis</i> (Montagu)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>legumoides</i> (Williamson) var. <i>trigonotenui-</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>striata</i> Bellwilt & Millett	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>plicosepta</i> Cushman & Gray	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 30, PART 2. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN RANGITIKEI RIVER SECTION.

Stage:	M132					M139					M139											
Fossil No.:	M132					M139					M139											
	f507	f508	f509	f510	f511	f512	f513	f514	f515	f516	f538	f539	f540	f541	f542	f543	f544	f545	f546	f547	f548	f549
<i>Lagena stelligera</i> Brady	.	.	.	e	.	e	e	.	.	.	e	e	d	.	.	e	.	.	.	.	d	.
<i>striata</i> (d'Orbigny)	.	.	.	e	d	d	d	.	d	d	e	d	c	.	e	c	c	.	d	d	.	.
<i>striatopunctata</i> Parker & Jones var. <i>cista</i> Cushman & McCulloch	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.
<i>sulcata</i> (Walker & Jacob)	.	d	.	e	.	.	.	.	.	e	e	d	e	e	c	.	.	e	e	e	.	.
sp. (spiral ornament)	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	.	.	.	.	.	.
<i>Lenticulina mammiliger</i> (Karrer)	.	.	.	.	.	e	c	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Margiulina subbullata</i> Hantken	.	.	.	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Planularia tricarlinella</i> (Reuss)	.	.	.	.	.	.	.	e	.	e	.	.	.	.	.	.	.	.	.	e	.	.
<i>Robulus calcar</i> (Défrance)	.	.	.	.	.	e	b	c	e	c	.	a	b	c	c	b	b	.	.	.	.	.
<i>costatus</i> (Nichtel & Moll)	.	.	.	.	.	e	.	.	.	.	.	.	c	.	.	.	.	.	.	.	.	.
<i>cultratus</i> (Nichtel & Moll)	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>dicampylus</i> (Frauzenau)	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>gyroscaepus</i> (Stache)	.	d	.	.	e	d	d	d	e	.	e	e	e	d	e	e	d	.	e	e	e	.
<i>iotus</i> (Cushman)	.	.	.	.	.	e	d	e	.	.	.	e	.	d	e	.	.	d	.	.	.	.
<i>orbicularis</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	.	.	.	.	.	.
<i>pliocenicus</i> (Silvestri)	.	.	.	.	.	.	e	.	e	.	.	.	.	e	e	e	.	.	.	.	.	.
<i>Saracenaria ampla</i> Cushman & Todd	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>italica</i> DeFrance	.	.	.	.	.	c	d	d	e	e	e	e	d	.	.	.	.	e	.	.	.	.
<i>latifrons</i> (Brady)	.	.	.	.	.	.	.	.	.	.	e	e	e	.	.	.	.	.	.	.	.	.
<i>Vaginulina vagina</i> (Stache)	.	.	.	.	.	c	d	.	.	e	.	e	d	.	.	e	.	.	.	.	.	.
sp. (tiny, curved)	.	.	.	e	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.
<i>Plectofrondicularia pellucida</i> Finlay vairarapa Vella	.	e	.	.	.	.	.	.	.	.	.	.	e	.	.	.	e	.	.	.	.	.
Family POLYMORPHINIDAE	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Guttulina bartschi</i> Cushman & Ozawa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Sigmomorphina laetrimosa</i> Vella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	d
<i>rhomboidalis</i> Vella	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family GLANDULINIDAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Glandulina symmetrica</i> Stache	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.
<i>Oolina globosa</i> (Montagu)	.	.	.	e	e	d	e	d	.	e	c	.	d	.	e	d	.	.	.	d	.	.
<i>hexagona</i> (Williamson)	.	c	.	d	c	d	e	d	d	c	d	d	c	d	d	.	.	.	e	d	.	.
<i>melo</i> d'Orbigny	.	b	.	e	d	d	d	.	c	c	b	d	.	e	.	d	.	e	c	c	.	.
<i>Fissurina basicarinata</i> Seguenza	.	.	.	.	.	.	.	.	.	.	.	e	.	.	d	.	.	.	.	.	.	.
<i>bassensis</i> Parr	.	.	.	.	.	.	.	.	.	.	e	.	.	.	d	.	.	.	.	.	.	.
<i>biconica</i> Silvestri	.	.	.	.	.	.	.	.	.	.	c	e	e	e	d	.	.	.	.	.	.	.
cf. <i>concurbitasema</i> Loeblich & Tappan	.	d	.	.	d	d	.	.	.	.	.	e	e	e	e	d	.	e	.	.	.	.
<i>curvifuba</i> Parr	.	.	.	.	.	.	.	.	e	.	.	.	.	.	e	d	.	.	.	.	.	.
<i>deltoides</i> Seguenza	.	b	.	.	e	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.
<i>earlandi</i> Parr	.	.	.	.	.	.	c	.	.	.	.	e	e	c	d	e	.	d	.	.	.	.
<i>colunga</i> Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>orbignyana</i> Seguenza	.	.	.	.	e	e	.	d	e	.	d	e	.	.	.	.	.	.	.	.	.	.
<i>quadrata</i> (Williamson)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>quadriscostulata</i> (Reuss) var. <i>sexcostulata</i> Parr	.	.	.	.	.	.	.	e	e	e	.	.	.	.	c	.	e	d	.	.	.	.
<i>semimarginata</i> Reuss	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 30, PAGE 3. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN RAINYRIVER RIVER SECTION.

Stage:	M32										M39				M39							
Possil No.:	F507	F508	F509	F510	F511	F512	F513	F514	F515	F516	F538	F539	F540	F541	F542	F543	F544	F545	F546	F547	F548	F549
Family SPHAERODINIDAE																						
<i>Sphaeroidina bulloides</i> d'Orbigny																						
.																						
Family BOLIVINIDAE																						
<i>Bolivinita compressa</i> Finlay																						
.																						
<i>elegantissima</i> Boungart																						
.																						
<i>cf. finlayi</i> Kennett																						
.																						
<i>pliozea</i> Finlay																						
.																						
<i>cf. pliozea</i> Finlay																						
.																						
<i>poiana</i> Finlay																						
.																						
<i>quadrilatera</i> (Schwager)																						
.																						
<i>Bolivina affilata</i> Finlay																						
.																						
<i>cf. acerosa</i> Cushman (<i>cf. Kennett, 1966a</i>)																						
.																						
<i>albatrossi</i> Cushman																						
.																						
<i>alata</i> (Seguenza)																						
.																						
<i>hornibrooki</i> n.sp.																						
.																						
<i>lapseus</i> Finlay																						
.																						
<i>minuta</i> Wetland																						
.																						
<i>perrini</i> Cushman																						
.																						
<i>petinae</i> Gibson																						
.																						
<i>cf. petinae</i> Gibson																						
.																						
<i>plicatella</i> Cushman																						
.																						
<i>pseudoplicata</i> Heron-Allen & Earland																						
.																						
<i>spatulata</i> (Williamson)																						
.																						
<i>srinivasini</i> (Kennett)																						
.																						
<i>subcompressa</i> Cushman & Wickenburg																						
.																						
<i>subopalescens</i> Cushman																						
.																						
<i>vellai</i> n.sp.																						
.																						
<i>wanganniensis</i> n.sp.																						
.																						
<i>watti</i> Gibson																						
.																						
Family BOVIGERINIDAE																						
<i>Rectobolivina striatula</i> (Cushman)																						
.																						
<i>Stilostomella antipoda</i> (Stacho)																						
.																						
<i>vermilla</i> (d'Orbigny)																						
.																						

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 30, PART 4. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN RANGITIKEI RIVER SECTION.

	Stage:		T10					T11					T12				T13				T14			
	Fossil No.:		I1132					I1139					I1139				I1139				I1139			
			f507	f508	f509	f510	f511	f512	f513	f514	f515	f516	f538	f539	f540	f541	f542	f543	f544	f545	f546	f547	f548	f549
Stilostomella sp. (finely striate) sp. (smooth)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family BULMINIDAE			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bulimina aculeata d'Orbigny			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
elongata d'Orb. var. subulata Cushman & Parker			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
marginata d'Orbigny			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
striata d'Orbigny			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Globobulimina pacifica Cushman			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Virgulopsis turris Heron-Allen & Earland			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family UVIGERINIDAE			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euuvigerina tutorum (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
delicatula (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
paeniteres (Finlay)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
pliozea (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
cf. pliozea (Vella) (strongly costate)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
rodleyi rodleyi (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
rodleyi (Vella) var. tutamoides (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
zeacuminata (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Siphonvigerina bellula (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
interrupta (Brady)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
vadesceus (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trifarina angulosa (Williamson)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
bradyi Cushman			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family DISCORBINIDAE			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discorbinella baconica (Fantken)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
berthelotti (d'Orbigny)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gavelinopsis namatus Vella			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
pukeuriensis Hornibrook			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Laticarinina halophora (Stache)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
pauperata Parr & Jones			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Patellinella inconspicua (Brady)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Planulinoides sp.			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rosalina bradyi (Cushman)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
paupereques Vella			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
vitrevoluta Hornibrook			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
vitrevoluta Hornibrook			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
sp. (flat)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family CLABRATULIDAE			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Clabratella zelandica (Vella)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Heronallenia wilsoni (Heron-Allen & Earland)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Valvulineria sadonica Asano			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family SPIRILLINIDAE			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Patellina corrugata Williamson			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Family ROTALIIDAE			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ammonia aoteana (Finlay)			.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 30, PART 5. (To accompany thesis by J.D. Colten).

DISTRIBUTION OF FORAMINIFERA IN MANGITKEI RIVER SECTION.

Stage:	M132					M139			
Fossil No.:	M132					M139			
	F507	F508	F509	F510	F511	F512	F513	F514	F515
	F514	F515	F516	F538	F539	F540	F541	F542	F543
	F544	F545	F546	F547	F548	F549	F550	F551	F552
<i>Notella fastigata</i> n.sp.	.	.	.	.	.	.	.	.	.
Family EPHIDIDAE	.	.	.	.	.	.	.	.	.
<i>Ephidium erlapum</i> (Linneus)	.	.	.	.	.	.	.	.	.
<i>Novaezelandicum</i> Cushman	.	.	.	.	.	.	.	.	.
<i>Orthocephidium argenteum</i> (Parr)	.	.	.	.	.	.	.	.	.
<i>charlottensis</i> (Vella)	.	.	.	.	.	.	.	.	.
<i>incertum</i> (Williamson)	.	.	.	.	.	.	.	.	.
<i>simplex</i> (Cushman)	.	.	.	.	.	.	.	.	.
<i>Notototalia briggsi</i> n.sp.	.	.	.	.	.	.	.	.	.
<i>depressa</i> Vella	.	.	.	.	.	.	.	.	.
<i>cf. depressa</i> Vella (cf Vella, 1957)	.	.	.	.	.	.	.	.	.
<i>Finlayi</i> Vella	.	.	.	.	.	.	.	.	.
<i>huxleyensis</i> Vella	.	.	.	.	.	.	.	.	.
<i>incunata</i> Vella	.	.	.	.	.	.	.	.	.
<i>kingi</i> Vella	.	.	.	.	.	.	.	.	.
<i>plicosa</i> Vella	.	.	.	.	.	.	.	.	.
<i>cf. plicosa</i> Vella	.	.	.	.	.	.	.	.	.
<i>olsoni</i> Vella	.	.	.	.	.	.	.	.	.
<i>taranaki</i> Vella	.	.	.	.	.	.	.	.	.
<i>zealandica</i> zealandica Finlay	.	.	.	.	.	.	.	.	.
<i>zealandica</i> Finlay var. <i>mangoporia</i> Vella	.	.	.	.	.	.	.	.	.
<i>zealandica</i> Finlay cf. <i>mangoporia</i> Vella	.	.	.	.	.	.	.	.	.
Family HAMMILLINIDAE	.	.	.	.	.	.	.	.	.
<i>Globigerinella siphonifera</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.
Family GLOBOROTALITIDAE	.	.	.	.	.	.	.	.	.
<i>Globorotalia crassaformis</i> (Galloway & Wissler)	.	.	.	.	.	.	.	.	.
<i>inflata</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.
<i>hiirsuta</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.
<i>puncticulata</i> (Deshayes)	.	.	.	.	.	.	.	.	.
<i>scitula</i> (Brady)	.	.	.	.	.	.	.	.	.
<i>truncatulinoides</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.
Family GLOBIGERINIDAE	.	.	.	.	.	.	.	.	.
<i>Globigerina bulloides</i> d'Orbigny	.	.	.	.	.	.	.	.	.
<i>aeooperata</i> Takayanagi & Saito	.	.	.	.	.	.	.	.	.
<i>interret</i> d'Orbigny	.	.	.	.	.	.	.	.	.
<i>cf. palmonensis</i> Blow	.	.	.	.	.	.	.	.	.
<i>foliata</i> Blow	.	.	.	.	.	.	.	.	.
<i>pachyderma</i> (Munro)	.	.	.	.	.	.	.	.	.
<i>Globigerinoides ruber</i> (d'Orbigny)	.	.	.	.	.	.	.	.	.
<i>trilobus</i> (Reuss)	.	.	.	.	.	.	.	.	.
<i>Orbulina univerrsa</i> d'Orbigny	.	.	.	.	.	.	.	.	.
<i>Globigerinita glutinata</i> (Egger)	.	.	.	.	.	.	.	.	.
<i>uvula</i> (Munro)	.	.	.	.	.	.	.	.	.
<i>Turbototalita quinqueloba</i> (Matland)	.	.	.	.	.	.	.	.	.
<i>Sphaeroidinella semnulina</i> (Schmager)	.	.	.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 30, Part 6. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF FORAMINIFERA IN RANGITIKEI RIVER SECTION.

Stage:	W0					Wb				Wm				Wm-Wn								
Fossil No.:	M32									M39												
	f507	f508	f509	f510	f511	f512	f513	f514	f515	f516	f538	f539	f540	f541	f542	f543	f544	f545	f546	f547	f548	f549
Family EPONIDIDAE																						
Eponides broekianus (Karrer)	.	.	.	.	c	e	.	e	.	d	.	e	.	e	d	e	e	.	d	.	.	.
Family CIBICIDIDAE																						
Planulina sp. (raised sutures)	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	e	e	.	e	.	.	.
Cibicides corticatus Earland	.	.	.	.	.	e	.	.	.	.	e	.	.	.	.	e	e	.	e	.	.	.
deliquatus Finlay	.	e	.	.	e	d	d	c	c	d	.	c	c	c	c	.	e	.	.	.	.	.
ihungia Finlay	.	d	d	.	e	e	e	.	.	.	.	.	.	.	.	.	.	.	d	e	.	.
marlboroughensis Vella	.	.	.	.	.	.	.	e	e	.	.	.	.	.	.	.	.	.	.	.	.	.
moléstus Hornibrook	.	.	e	.	.	c	c	.	e	d	.	c	b	.	.	.	.	.	.	.	.	.
porrodeliquatus Kennett	.	d	.	.	.	d	d	c	d	c	c	c	d	c	d	.	d	.	.	e	.	.
sp. (flat)	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.
Dyocibicides biserialis Cushman & Valentine	.	.	.	.	d	.	.	.	.	c	.	.	.	.	.	.	.	.	e	e	.	.
primitiva Vella	.	.	.	.	.	.	.	.	e	d	.	.	.	.	.	.	.	.	.	.	.	.
Family CASSIDULINIDAE																						
Cassidulina carinata Silvestri	.	c	c	c	c	c	a	c	c	c	b	c	b	c	c	b	c	d	b	d	c	.
subglobosa Brady	.	c	e	.	e	c	d	e	d	d	e	e	e	d	e	d	.	.	c	e	.	.
Evolvocassidulina orientalis (Cushman)	.	b	c	c	e	e	b	b	e	d	d	c	c	c	e	c	c	c	b	d	.	.
Family NONIONIDAE																						
Chilostomella ovoides Reuss	.	.	.	.	.	.	e	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.
Nonion cassidulinoides Hornibrook	.	d	.	.	.	.	e	e	c	c	d	.	.	.	e	.	.	.	e	.	.	.
Astrononion novozelandicum Cushman & Edwards	.	c	d	e	b	c	c	d	c	e	.	d	.	d	.	b	d	b	b	d	e	e
parki Hornibrook	.	d	.	.	.	.	.	d	d	d	.	e	.	e	.	e	.	.	.	.	d	e
poriensis (Vella)	.	d	.	.	e	.	.	.	e	.	.	d	e	e	b	.	d	.	.	.	.	.
vadorum Vella	.	.	.	e	.	.	.	d	.	.	.	d	.	d	.	e	.	.	.	.	.	.
Nonionella magnalingua Finlay	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	.	.	.
zenitens Finlay	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	e	.
Nonionellina flemingii(Vella)	.	c	d	d	c	e	e	d	c	d	d	d	e	d	e	a	b	c	b	c	.	e
Pullenia bulboides d'Orbigny	.	.	.	.	.	c	e	.	.	.	.	e	e	d	.	.	.	.	.	.	.	.
quinqueloba (Reuss)	.	.	e	.	.	e	e	.	e	a	.	d	a	d	e	c	c	.	.	.	.	.
Zeefflorilus parri (Cushman)	.	.	.	.	d	e	.	.	.	e	.	e	.	.	.	e	e	.	c	e	.	.
Family ALABAMINIDAE																						
Oridorsalis prominula (Stache)	.	.	.	d	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
tenera (Brady)	.	.	e	.	.	e	e	d	.	.	.	d	e	.	.	.	e	d	.	.	.	.
Family OSANGULARIIDAE																						
Gyroldinoides neosolanii (Brotzen)	.	.	.	.	.	.	.	.	.	e	.	.	.	.	d	.	.	.	.	.	.	.
Family ANOMALINIDAE																						
Anomalinoidea parvumbilica (Finlay)	.	d	d	d	d	c	d	d	e	c	d	b	c	c	d	b	.	.	d	.	d	.
sphaerica (Finlay)	.	e	.	.	e	d	e	e	c	c	b	b	d	b	e	d	.	.	e	e	.	.
sp. (deep umbilicus)	.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Melonis zeobesius Vella	.	.	.	.	.	.	.	e	e	.	.	d	c	.	.	.	.	.	.	.	.	.
Family GERATOBULMINIDAE																						
Hoeglundina elegans (d'Orbigny)	.	.	.	.	.	.	.	.	e	.	c	c	c	d	e	c	d	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 31, PART 1. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN WATERSHED ROAD SECTION, M39.

	Stage:		Wm		Wn	
	Fossil No.:					
	f550	f551	f552	f553	f554	f555
						f556
FORAMINIFERIDA						
Family TEXTULARIIDAE						
Textularia goeisi Cushman	.	.	.	.	.	.
Hauserella morgani (Chapman)	.	c	.	.	e	b
parri Pinlay	b	c	.	e	c	.
Siphotextularia bleeki Vella	.	.	.	.	e	d
mestayerae Vella	.	.	.	.	.	d
wairoana Pinlay	d	d	.	.	d	d
cf. wanganua Pinlay	.	.	.	.	.	d
Family MILIOLIDAE						
Quinqueloculina delicatula Vella	.	.	.	.	d	.
kapitiensis Vella	.	.	.	.	.	e
lamarckiana d'Orbigny	.	.	.	.	.	b
aff. lata Verquem (of Vella, 1957)	.	.	.	.	.	e
parvaglutta Vella	.	.	.	.	c	.
rebeccae Vella	.	.	.	.	d	.
triangularis d'Orbigny	.	.	.	.	d	.
Pyrgo anomala (Schlumberger)	.	.	.	.	e	.
depressa (d'Orbigny)	.	.	.	.	.	e
aff. ezo Asano (of Vella, 1957)	.	.	.	.	d	.
Sigmoilopsis schlumbergeri (Silvestri)	.	.	.	.	e	d
Miliolinella vigilax Vella	.	.	.	.	.	d
Scutuleris hornibrooki (Vella)	.	.	.	.	e	d
Family NODOSARITIDAE						
Amphicoryna hirsuta (d'Orbigny)	d	.	.	.	.	.
Chrysalogonium verticale Reuss	d	.	.	e	d	.
Lagena albopunctata Matthes	e	c	.	.	e	.
cf. bella Matthes	.	e	.	.	.	.
cf. cornubiensis Millett	.	.	.	.	.	e
distoma Parker & Jones	.	e	.	c	.	.
gracilis Williamson	.	.	.	d	e	.
hispidia Reuss	.	e	.	.	e	e
cf. hispidia Reuss	.	.	.	d	.	.
legnoides (Williamson) var. trigonoten-	.	.	.	.	e	.
uistriata Balgwilli & Millett	.	.	.	.	.	.
laevis (Montagu)	c	d	.	c	c	.
pliocenica Cushman & Gray	.	e	.	.	d	e
stelligera Brady	e	e	.	e	e	.
striata (d'Orbigny)	b	d	.	d	c	e
striatopunctata Parker & Jones var. cista	.	d	.	.	.	d
Cushman & McCulloch	.	.	.	.	.	.
sulcata (Walker & Jacob)	c	b	.	d	c	c
Margulinulina subbullata Hantken	.	.	.	.	e	.
Planularia tricarlinella (Reuss)	.	.	.	.	e	e
tricarlinella (Reuss) var. spinipes	e	.	.	.	e	.
(Cushman)	.	.	.	.	.	.
Robulus calcar (Défrance)	c	b	.	e	d	.
EYROSALPRUS (Stache)	c	e	.	e	e	d
pliocenicum (Silvestri)	.	d	.	.	.	e

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 31, PART 2. (To accompany thesis by J.D. Colten).

DISTRIBUTION OF FORAMINIFERA IN WATERBED ROAD SECTION, M139.

Stage:	Fossil No.:	fm	fm
	f550		f553
	f551		f554
	f552		f555
			f556
Saracenaria italica Defrance			
	e	•	•
Vaginulina vagina (Stache)			
	d	•	•
Plectofrondicularia pellicula Finlay			
	d	•	•
waiparepa Vella			
	e	•	•
Family POLYMORPHINIDAE			
Sigmonorphina laevis Vella			
	e	e	•
rhomboidalis Vella			
	•	•	•
sp. (striate)			
	•	•	e
Family GLANDULINIDAE			
Glandulina symmetrica Stache			
	•	•	•
Colina globosa (Montagu)			
	e	e	d
desmophora (Jones)			
	•	•	•
hexagona (Williamson)			
	d	d	d
melo d'Orbigny			
	•	e	c
Fissurina biconica Silvestri			
	d	•	c
bicaudata Seguenza			
	•	e	•
curviflata Parr			
	•	•	c
deltoides Seguenza			
	e	•	•
earlandi Parr			
	•	c	b
orbignyana Seguenza			
	c	e	c
quadrata (Williamson)			
	•	•	e
quadriricostulata (Reuss) var. sexcostulata Parr			
	•	d	•
siciliensis Loeblich & Tappan			
	•	e	c
cf. siciliensis Loeblich & Tappan			
	•	e	•
siciliensis Loeblich & Tappan var. angust-ecarinata Parr			
	e	•	•
subformosa Parr			
	•	•	e
submarginata (Boongart)			
	b	c	d
subquadrata Parr			
	•	e	d
tricostulata Pierce			
	e	•	e
yokoyamae Asano			
	•	•	c
wiesneri Brady			
	•	d	e
Parafissurina subulata Parr			
	•	•	c
spp.			
	d	•	e
Family SPHAERODINIDAE			
Sphaeroidina bulloides d'Orbigny			
	e	d	d
Family BOLIVINITIDAE			
Bolivinina pliozea Finlay			
	e	e	d
pohana Finlay			
	c	c	c
Bolivina alata (Seguenza)			
	•	d	•
albatrossi Cushman			
	•	d	•
affiliata Finlay			
	•	•	•
oacozela Vella			
	•	•	•
cf. lyfei Hornibrook			
	•	e	•
hornibrooki n.sp.			
	e	•	c
lapsus Finlay			
	•	•	d

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 31, PART 3. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN WATERFORD ROAD SECTION, M139.

	Stage:							
	Fossil No.:		Mm			Mn		
		F550	F551	F552	F553	F554	F555	F556
<i>Bolivina minuta</i> Matland		c	c	.	.	b	.	c
<i>parri</i> Cushman		.	.	.	.	.	e	e
<i>petiae</i> Gibson		e	c	.	d	.	.	.
<i>placatella</i> Cushman		c	c	.	.	c	c	c
<i>pseudoplicata</i> Heron-Allen & Earland		.	.	.	.	.	e	d
<i>spatulata</i> (Williamson)		e	.	.	e	c	d	e
<i>srinivasini</i> Kennett		.	e	.	e	.	.	.
<i>subexcavata</i> Cushman & Wickenburg		c	e	.	.	.	e	.
<i>veribilis</i> (Williamson)		e	.	.	.	.	.	.
<i>vella</i> n.sp.		.	.	.	c	c	.	e
<i>watti</i> Gibson		e	.	.	.	.	e	.
<i>wangeniensis</i> n.sp.		.	.	.	c	.	d	c
<i>Rectobolivina striatula</i> (Cushman)		e	e	.	d	c	e	.
Family BOUVIERINIDAE								
<i>Stilostomella antipoda</i> (Stache)		.	.	.	.	.	.	e
<i>pomuligera</i> (Stache)		e	.	.	d	.	.	.
<i>verneuilli</i> (d'Orbigny)		e	.	.	.	c	.	.
sp. (smooth)		e	.	.	.	d	.	.
sp. (striate)		.	.	.	e	.	.	.
Family BULMINIDAE								
<i>Bulimina aculeata</i> d'Orbigny		b	c	.	c	b	b	c
<i>elongata</i> d'Orb. var. <i>subulata</i> Cushman & Parker		d	e	.	.	c	d	c
<i>marginata</i> d'Orbigny		e	e	.	e	d	.	d
<i>striata</i> d'Orbigny		c	.	.	.	.	.	.
<i>Globobulimina pacifica</i> Cushman		.	d	.	.	d	.	.
<i>Virgulopsis turris</i> Heron-Allen & Earland		.	.	.	e	d	d	e
Family UVIGERINIDAE								
<i>Euvigenerina lutorum</i> (Vella)		b	c	.	c	.	.	d
<i>pliozea</i> (Vella)		e	.	.	e	.	e	.
<i>rodleyi</i> rodleyi (Vella)		e	b	.	c	c	b	e
<i>rodleyi</i> (Vella) var. <i>tutamooides</i> (Vella)		.	.	.	.	e	.	.
<i>Siphovigenerina vadesceus</i> (Vella)		e	.	.	.	.	e	.
<i>Trifarina angulosa</i> (Williamson)		.	.	.	e	d	d	.
<i>bradyi</i> Cushman		e	.	.	.	e	.	.
Family DISCORBIDAE								
<i>Discorbinella baconica</i> (Hantken)		.	.	.	.	e	e	.
<i>bertheloti</i> (d'Orbigny)		e	.	.	.	c	c	.
<i>rareseus</i> (Brady)		.	.	.	.	.	e	.
sp. (flat)		.	e	.	.	.	e	.
<i>Gavelinopsis lobatulus</i> (Parr)		.	.	.	.	.	e	.
<i>pukeuriensis</i> Hornibrook		.	.	.	.	.	c	.
<i>laticarinina coronata</i> (Hornibrook)		.	.	.	.	.	d	.
<i>halophora</i> (Stache)		e	.	.	.	.	e	.
<i>pauperata</i> Parr & Jones		e	e	.	.	.	.	.
<i>Boeponidella</i> cf. <i>zelandica</i> (Hornibrook) (flat top)		.	.	.	.	.	e	.
<i>Patellinella inconspicua</i> (Brady)		.	.	.	.	.	e	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 31, PART 4. (To accompany thesis by J.D. Cullen).

DISTRIBUTION OF FORAMINIFERA IN INTERSHOAL ROAD SECTION, M39.

Stage: Fossil No.:	Wn			Wn				
	f550	f551	f552	f553	f554	f555	f556	
Planulinoides sp. (curved sutures)	.	.	.	.	c	.	.	.
Rosalina bradyi (Cushman)	.	.	.	.	c	.	d	.
paupereques Vella	.	d	.	.	c	.	.	.
vitrevoluta Hornibrook	.	d	.	.	.	c	.	.
Family GLABRATELLIDAE								
Glabratella zelandica (Vella)	.	.	.	.	.	c	.	.
Heronallenia wilsoni (Heron-Allen & Earland)	.	e	.	.	d	e	.	.
Valvulineria sadonica Asano	.	.	.	.	.	e	.	.
Family SPIRILLINIDAE								
Patellina corrugata Williamson	.	e	.	.	e	d	.	.
Family ROTALIIDAE								
Ammonia aoteana (Finlay)	.	.	.	.	.	e	e	.
Family ELPHIDIIDAE								
Elphidium crispum (Linnaeus)	.	.	.	.	.	d	e	.
novozealandicum Cushman	.	.	.	.	e	.	.	.
Griboeulophidium argenteum (Parr)	e	.	.	.	.	.	.	.
charlottensis (Vella)	c	c	.	d	b	b	c	.
incertum (Williamson)	e	.	.	.	.	e	.	.
spinatum Cushman & Valentine	.	.	.	.	e	.	e	.
Noterotalia briggsi n.sp.	.	d	.	.	.	e	e	.
clathrata (Brady)	.	.	.	.	.	e	.	.
depressa Vella	.	.	.	.	.	e	.	.
finleyi Vella	d	c	.	c	b	b	b	.
inornata Vella	.	.	.	.	d	d	.	.
Family GLOBOROTALIIDAE								
Globorotalia crassaformis (Galloway & Wissler)	d	d	.	.	e	d	d	.
inflata (d'Orbigny)	.	.	.	.	.	e	.	.
menardii (Parker, Jones & Brady)	e	.	.	.	.	e	.	.
scitula (Brady)	e	e	.	.	.	.	.	.
Family GLOBIGERINIDAE								
Globigerina bulloides d'Orbigny	c	c	.	c	a	c	c	.
decoraperta Takayanagi & Saito	d	d	.	e	e	e	e	.
autertrei d'Orbigny	d	c	.	d	c	c	c	.
cf. falconensis Blow	b	c	.	d	c	b	c	.
foliata Bolli	b	c	.	d	c	b	b	.
pachyderma (Ehrenberg)	b	c	.	e	c	c	c	.
Globigerinoides ruber (d'Orbigny)	.	e	.	.	e	.	e	.
trilobus (Reuss)	.	.	.	.	.	e	.	.
Orbulina universa d'Orbigny	e	e	.	.	.	e	.	.
Globigerinita glutinata (Egger)	c	d	.	e	d	d	d	.
uvula (Ehrenberg)	d	d	.	.	e	e	d	.
Turborotalita quinqueloba (Mottland)	c	c	.	.	c	c	d	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 31, PART 5. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN WATERSHED ROAD SECTION, N139.

	Stage:		Tm		Tm				
	Fossil No.:		f550	f551	f552	f553	f554	f555	f556
Family EPONIDIDAE									
Eponides broekianus (Karrer)			e	d	.	d	e	e	c
Family CIBICIDIDAE									
Planulina sp.			.	.	.	.	e	.	.
Cibicides corticatus Barland			.	.	.	.	.	d	e
marlboroughensis Vella			.	.	.	.	d	.	.
porrodeliquatus Kennett			e	e	.	.	e	c	.
Dyocibicides biserialis Cushman & Valentine			.	.	.	.	e	d	.
primitiva Vella			.	e	.	.	e	d	.
Family CASSIDULINIDAE									
Cassidulina cerinata Silvestri			c	a	.	d	c	c	b
subglobosa Brady			e	.	.	e	d	d	d
Evolvoceassidulina orientalis (Cushman)			d	b	.	d	d	d	b
Family NONIONIDAE									
Nonion cassidulinoides Hornibrook			.	e	.	.	.	e	.
Astrononion parvi Hornibrook			e	d	.	d	.	e	d
novozelandicum Cushman & Edwards			.	c	.	e	c	c	c
poriensis (Vella)			.	.	.	.	e	c	e
vadorum Vella			.	e	.	.	.	.	.
Nonionella magnalingua Finlay			.	.	.	.	.	c	.
Nonionellina flemingi (Vella)			d	b	.	c	b	a	c
Pullenia bulloides d'Orbigny			.	e	.	.	.	.	.
quingueloba (Reuss)			c	.	.	.	.	d	e
Zeeflorilus parvi (Cushman)			.	.	.	.	d	e	e
Family ALABAMINIDAE									
Oridorsalis prominula (Stache)			.	.	.	.	.	.	e
tenera (Brady)			.	d	.	.	.	.	.
Family OSANGULARIDAE									
Gyroldinoides neosoldani (Brotzen)			e	.	.	.	.	e	.
Family ANOMALINIDAE									
Anomalinoides parvumbilica (Finlay)			.	d	.	.	d	c	c
sphaerica (Finlay)			.	.	.	.	e	a	d
Family CERATOBULLINIDAE									
Meglundina elegans (d'Orbigny)			.	d	.	.	.	.	.
ADDITIONAL:									
Family FISCHERINIDAE			.	.	.	.	.	e	.
Cyclogyra sp.			.	.	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 32, PART 1. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN SADDLE ROAD SECTION, N142.

Samples N142, 595, 596, 600 & 601 are barren of foraminifera.

Stage:	W0	W1	W2	W3	W4			
Fossil No.:	f592	f593	f594	f597	f598	f544	f555	f599
FORAMINIFERIDA								
Family TEXTUARIIDAE								
Maeslerella morgani (Chapman)	o	c	c	d	.	.	.	e
parri Finlay	.	.	.	d	.	.	.	e
pliocenica (Finlay)	.	.	.	e	.	.	.	.
Siphotextularia blacki Vella	.	.	e	.	.	.	.	.
westayerae Vella	.	.	.	e	.	/	.	d
wairoana Finlay	d	c	b	e	.	.	.	e
cf. wairoana Finlay	.	d	.	.	.	.	.	.
Family AMMONITIDAE								
Gaudryina convexa (Karrer)	.	.	e	.	.	.	.	.
Family MIIOLIDAE								
Quinqueloculina incisa Vella	.	.	.	d	.	.	.	.
kapitiensis Vella	.	.	.	.	.	/	.	.
Lamarckiana d'Orbigny	.	.	.	e	.	.	/	e
miles Vella	.	.	.	.	.	.	.	e
parvoglutta Vella	.	.	.	.	.	.	.	c
rebeccae Vella	.	.	.	d	.	.	.	.
suborbicularis d'Orbigny	.	.	.	.	.	.	.	e
triangularis d'Orbigny	.	.	.	d	.	/	.	.
sp. (elongate)	.	.	.	.	.	.	/	.
Pyrgo depressa (d'Orbigny)	.	.	.	.	.	/	/	.
aff. ezo Asano (cf Vella, 1957)	.	.	.	.	.	.	.	e
pisum (Schlumberger)	.	.	.	d	.	.	.	.
tasmanensis Vella	e	.	d	.	/	.	.	.
Sigmoilopsis schlumbergeri (Silvestri)	.	.	e	.	.	.	.	e
Triloculina chrysastoma (Chapman)	.	.	.	.	/	.	.	.
Miliolinella vigilax Vella	.	.	.	.	/	.	.	.
Family NODOSARITIDAE								
Nodosaria longiscata d'Orbigny	.	.	.	.	.	.	.	e
pyrula (d'Orbigny)	.	.	.	.	e	.	.	.
Amphicoryna hirsuta (d'Orbigny)	c	d	d	.	.	.	.	e
scalaris (Batsch)	.	d	.	*e	.	.	.	.
Chrysalogonium verticale Reuss	.	.	.	e	.	.	.	.
Dentalina emaciata Reuss	.	.	.	e	.	.	.	.
Lagena cf. cornubiensis Millett	.	.	.	.	.	.	.	e
gracilis Williamson	.	.	.	e	.	.	.	e
stelligera Brady	e	.	e	.	.	.	.	e
striata (d'Orbigny)	d	e	d	.	e	/	/	d
striatopunctata Parker & Jones var. cista	.	.	.	.	.	.	.	c
Cushman & McCulloch	.	.	.	.	.	.	.	.
sulcata (Walker & Jacob)	.	.	.	.	.	.	.	e
Lenticulina peregrina (Schwager)	.	.	.	.	.	.	.	e
Planularia tricarinella (Reuss)	.	.	.	.	.	.	.	e
Robulus celcar (Linnaeus)	e	.	c	.	.	.	.	.
cultratus (Montfort)	.	.	.	e	.	/	/	d
Vaginulina vagina (Stache)	.	.	.	.	.	.	.	d
Plectrotrondicularia pellucida Finlay	.	.	d	.	.	.	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare; / = present in unknown abundance;

* = apparently reworked (stained and pyritised).

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 32, PART 2. (To accompany thesis by J.D. Colleen).

DISTRIBUTION OF FORAMINIFERA IN SADDLE ROAD SECTION, N149.

Stage:	Wb	Wc	Wa	Wb
Fossil No.:	F592	F593 F594	F597 F598 F544	F555 F599
Family POLYMERINIDAE				
Guttulina bartschi Cushman & Ozawa	.	.	d	d
Pseudopolymorphina tortuosa Vella	.	.	.	e
Sigmomorphina lacrimosa Vella	e	e	d	/
rhomboidalis Vella	.	.	e	.
Family GLANDULINIDAE				
Oolina globosa (Montagu)	.	.	.	.
hexagona (Williamson)	.	d	.	c
melo d'Orbigny	.	e	c	/
Fissurina bassensis Farr	.	.	.	d
curvifurca Farr	.	.	.	d
earlandi Farr	.	e	.	/
cf. formosa (Schwager)	.	.	e	.
formosa (Schwager) var. angusticarinata Parr	.	.	.	e
oblonga Reuss	.	.	e	e
orbignyana Seguenza	.	.	e	.
siciliensis Loeblich & Tappan	.	.	e	e
subcircularis Farr	.	e	.	.
submarginata (Boongart)	.	e	e	e
tricoostulata Pierce	.	.	e	.
wiesneri Brady	.	c	.	e
yokoyamae Asano	.	.	e	/
spp.	.	.	e	d
Family BULIMINIDAE				
Bulimina exuleata d'Orbigny	d	e	e	c
elongata d'Orbigny var. subulata Cushman & Parker	.	.	d	/
marginata d'Orbigny	.	.	.	/
striata d'Orbigny	d	.	d	d
Virgulopsis turris Heron-Allen & Earland	.	.	e	e
Family EOVIGERINIDAE				
Stilostomella antipoda (Stache)	.	.	.	/
ponuligera (Stache)	.	.	.	e
vernemilli (d'Orbigny)	d	e	.	.
sp. (smooth)	.	e	.	.
Family SPHAERODINIDAE				
Sphaeroidina bulloides d'Orbigny	d	e	e	e
Family BOLIVINITIDAE				
Bolivinita cf. finlayi Kennett	.	e	.	.
pliozea Finlay	.	.	.	/
potana Finlay	.	.	e	/
quadrilatera (Schwager)	.	d	.	d
Bolivina affiliata Finlay	.	e	e	.
elata (Seguenza)	.	.	e	.
cacozela Vella	.	.	e	e
hornibrooki n.sp.	.	e	.	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare; / = present in unknown abundance; * = apparently reworked (stained & pyritised).

TABLE 32, PART 3. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF FORAMINIFERA IN SADDIE ROAD SECTION, M149.

Samples M149f 595, 596, 600 & 601 are barren of foraminifera.

Stage:	W0	W1	W2	W3
Fossil No.:	F592	F593 F594	F597 F598 F544	F555 F599
<i>Bolivina</i> <i>lapsus</i> Finlay	e	.	.	/ d
<i>minuta</i> Natland	.	.	.	d
<i>parri</i> Cushman	.	.	e	.
<i>petiae</i> Gibson	.	.	e	.
<i>plicatella</i> Cushman	.	c	e	d
<i>pseudoplicata</i> Heron-Allen & Earland	.	.	e	.
<i>subexcavata</i> Cushman & Wickenden	.	.	.	d
<i>subspinescens</i> Cushman	.	.	e	.
<i>vella</i> n.sp.	.	d	.	d
<i>wanganuiensis</i> n.sp.	.	e	d	.
<i>watti</i> Gibson	.	.	d	d
<i>Rectobolivina striatula</i> (Cushman)	c	c	d	.
Family <i>UVIGERINIDAE</i>				
<i>Emuigerina lutorum</i> (Vell a)	.	.	c	/ d
<i>paeniteres</i> (Finlay)	.	.	*e	/
<i>pliozea</i> (Vella)	.	.	d	/ d
<i>rodleyi rodleyi</i> (Vella)	e	c	d	/ e
<i>rodleyi</i> (Vella) var. <i>tutanooides</i> (Vella)	e	.	d	.
cf. <i>rodleyi</i> (Vella) (very fine costae)	.	.	.	/
<i>zeacuminata</i> (Vella)	.	.	*e	.
<i>Siphonovigerina bellula</i> (Vella)	.	.	.	d
<i>vadesceus</i> (Vella)	.	d	d	.
<i>Trifarina angulosa</i> (Williamson)	.	.	d	/ e
<i>bradyi</i> Cushman	.	.	.	/
Family <i>DISCORBIDAE</i>				
<i>Discorbinella baconica</i> (Hantken)	e	e	.	.
<i>bertheloti</i> (d'Orbigny)	d	c	.	.
<i>Gavelinopsis lobatulus</i> (Parr)	.	e	.	d
<i>Iaticarinina pauperata</i> (Parr & Hones)	.	.	.	e
<i>Petellinella inconspicua</i> (Brady)	.	e	.	/ d
<i>Planulinoides</i> sp. (curved sutures)	.	.	.	/ e
<i>Rosalina bradyi</i> (Cushman)	.	.	e	/
<i>paupereques</i> Vella	.	.	e	/ d
<i>vitrevoluta</i> Hornibrook	.	.	d	.
Family <i>GLABRATELLIDAE</i>				
<i>Glabratella zelandica</i> (Vella)	.	.	d	/
Family <i>SPIRILLINIDAE</i>				
<i>Patellina corrugata</i> Williamson	.	.	.	/ d
Family <i>ROTALIIDAE</i>				
<i>Rotalia fastigata</i> n.sp.	.	.	.	/
Family <i>ELPHIDIIDAE</i>				
<i>Elphidium crispum</i> (Linnaeus)	.	e	e	/ d
<i>novozelandicum</i> Cushman	.	.	.	/
<i>Cribroelphidium argenteum</i> (Parr)	.	e	e	.
<i>charlottensis</i> (Vella)	.	d	d	/ d
<i>incertum</i> (Williamson)	.	.	e	.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare; / = present in unknown abundance; * = apparently reworked (stained & pyritised)

TABLE 32, PART 4. (To accompany thesis by J.D. Colten).

DISTRIBUTION OF FORAMINIFERA IN SADDLE ROAD SECTION, M149. Samples M149f 595, 596, 600 & 601 are barren of foraminifera.

Stage:	W0	W1	W2	W3	W4			
Fossil No.:	F592	F593	F594	F597	F598	F544	F555	F599
Orbocelphidium simplex (Cushman)								
Notarotalia briggsi n.sp.	.	.	.	.	.	/	/	.
depressa Vella	.	d	.	c	.	/	.	d
cf. depressa Vella (cf Vella, 1957)	.	d	.	d	.	/	.	.
finlayi Vella	.	.	d	d	d	/	/	c
hurupiensis Vella	d	.	.	.	.	.	.	.
inornata Vella	.	.	.	d	.	.	.	.
olsoni Vella	.	.	c	.	.	.	.	.
pliozea Vella	.	e	.	.	.	.	.	.
cf. mammiligera Kennett	.	.	.	d	.	.	.	e
Family GLOBOROTALIIDAE								
Globorotalia crassaformis (Calloway & Wissler)	e	c	e	d	e	.	.	e
inflata (d'Orbigny)	.	d	e	d	e	/	.	e
miozea Finlay s.l.	.	.	.	.	.	*	/	.
puncticulata (Deshayes)	e	e	.	*e	.	.	.	.
scitula (Brady)	.	.	e	.	e	.	.	e
Family GLOBIGERINIDAE								
Globigerina bulloides d'Orbigny	e	c	c	d	c	/	/	c
decoregera Takayanagi & Saito	.	e	e	e	.	.	.	.
auterrei d'Orbigny	.	e	e	e	d	/	.	d
cf. falconensis Blow	.	.	.	e	e	.	.	e
foliata Bolli	.	.	d	d	d	.	.	c
pechyderma (Ehrenberg)	e	e	d	e	c	/	/	c
Orbulina universa d'Orbigny	.	e	.	.	.	/	.	.
Globigerinoides ruber (d'Orbigny)	.	.	.	.	e	.	.	.
Globigerinita glutinata (Egger)	.	e	e	.	c	.	.	d
uvula (Ehrenberg)	.	.	.	.	e	.	.	.
Turbototalia quinqueloba (Holland)	.	e	e	d	c	.	/	e
Family EPOINIDAE								
Eponides broelchianus (Karrer)	.	e	.	.	e	.	.	e
Family CIBICIDIDAE								
Cibicides deliquatus Finlay	d	.	.	.	.	/	.	.
marboroughensis Vella	.	.	.	.	.	.	/	d
porrodeliquatus Kennett	d	d	d	d	.	/	.	d
Dyocibicides biserialis Cushman & Valentine	.	.	.	.	.	/	.	e
primitiva Vella	.	.	.	d	.	/	.	.
Family CASSIDULINIDAE								
Cassidulina carinata Silvestri	d	.	d	d	e	.	/	d
subglobosa Brady	.	.	.	e	.	.	.	d
Evolvocassidulina orientalis (Cushman)	.	d	.	e	d	.	.	d
Family NONIONIDAE								
Astrononion novozelandicum Cushman & Bowers	c	d	d	d	e	/	/	d
Parai Nonion rock	e	.	.	.	.	.	.	.
poriensis (Vella)	e	.	.	.	.	.	.	.
vadorum Vella	.	.	.	.	.	.	.	e

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare; / = present in unknown abundance; * = apparently reworked (stained and pyritised).

TABLE 32, PART 5. (To accompany thesis by J.D. Collen).

DISTRIBUTION OF FORAMINIFERA IN SANDIE ROAD SECTION, M149. Samples M149f 595, 596, 600 & 601 are barren of foraminifera.

Stage:	Wo	Ww	Wn	Wc
Fossil No.:	f592	f593 f594	f597 f598 f594	f555 f599
<i>Nonionellina flemingi</i> (Vella)	.	c .	c c /	/ d
<i>Pullenia bulloides</i> d'Orbigny	.	. .	. e .	. .
<i>quinqueloba</i> (Reuss)	.	. e	. . .	. .
<i>Zeaflorilus parri</i> (Cushman)	.	e .	d . /	. d
Family ALABAMINIDAE				
<i>Oridorsalis prominula</i> (Stache)	d	e c	. . .	. .
<i>tenera</i> (Brady)	.	. e	. . .	. .
Family CERATULARIIDAE				
<i>Gyroidinoides neosoldanii</i> (Brotzen)	d	d .	c . .	. .
Family ANOMALINIDAE				
<i>Anomalinoidea parvumbilica</i> (Finlay)	e	. .	e . .	. .
<i>spherica</i> (Finlay)	d	e c	d e .	. d
Family CERATOBULMINIDAE				
<i>Ceratobulimina</i> sp.	.	e .	. . .	. .

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare; / = present in unknown abundance; * = apparently reworked (stained & pyritised).

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.

TABLE 29, PART 2. (To accompany thesis by J.D. Colten).

DISTRIBUTION OF MICROFOSSILS IN WAMMANUI RIVER SECTION, Upper Part, M138.

Samples M138f 551, 552, 553 and 555 are barren of foraminifera.

	Stage:	Mm										Mm									
	Fossil No.:	f548	f549	f550	f554	f556	f557	f558	f559	f560	f561	f562	f563	f564	f565	f566	f567	f568	f569	f570	
Lagena distoma Parker & Jones		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
gracilis Williamson		e	.	.	.	.	.	.	e	.	d	d	.	.	.	.	e	.	.	.	
gracillima (Seguenza)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
hispidia Reuss		.	.	.	.	.	.	.	.	.	e	d	.	.	.	.	.	.	.	.	
cf. hispidia Reuss		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
laevis (Montagu)		d	.	.	.	e	.	e	d	d	d	c	d	c	e	d	c	e	.	c	
Lagenoides (Williamson) var. trigono-		.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	
tenuistriata Balgwilli & Millett		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
cf. multicostrata (Karrer)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	d	.	.	.	.	
pliocenica Cushman & Gray		.	.	.	.	.	e	.	.	.	e	d	d	e	.	.	d	.	.	.	
stelligera Brady		.	.	.	.	c	.	d	d	d	.	.	.	.	.	.	.	.	.	.	
striata (d'Orbigny)		d	.	.	e	.	.	d	e	c	e	d	c	.	c	d	d	c	d	d	
striatopunctata Parker & Jones var. cista		.	.	.	.	.	.	.	.	.	.	c	d	.	.	.	e	.	.	.	
Cushman & McCulloch		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
sulcata (Walker & Jacob)		d	.	.	.	.	.	.	d	d	.	c	d	.	e	.	d	.	.	.	
Lenticulina peregrina (Schwager)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Planularia tricarinella (Reuss)		.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	
tricarinella (Reuss) var. spinipes		.	.	.	.	.	.	d	c	.	.	.	.	.	d	d	.	.	.	.	
Cushman		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Sarcenaria ampla Cushman & Todd		.	.	.	.	.	.	e	.	.	.	.	.	.	.	e	e	.	.	.	
Vaginulina elegans d'Orbigny		.	.	.	.	.	.	.	.	.	.	.	.	e	.	e	.	.	e	.	
vagina (Stache)		.	.	.	.	e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	
Robulus calcar (Défrance)		d	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
culturatus (Nichtel & Holi)		e	.	e	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
dicaeumulus (Mrazencu)		.	.	.	.	.	e	.	.	.	.	.	.	.	e	.	.	.	.	.	
gyrosculptus (Stache)		.	.	.	.	.	d	.	.	.	.	.	.	.	.	.	e	.	.	.	
loculosus (Stache)		.	.	.	.	.	.	.	e	.	.	c	.	.	e	.	.	.	e	.	
Plectofrondicularia wirarapa Vella		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Family POLYORPHINIDAE		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Guttulina bartschi Cushman & Ozawa		.	.	.	.	.	d	.	.	.	e	.	.	.	.	.	.	.	.	.	
Sigamorphina laevis Vella		.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	
rhomboidalis Vella		.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	.	
spp.		.	.	.	.	.	.	d	.	.	.	.	.	.	d	.	e	.	.	.	
Family GLANDULINIDAE		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Oolina globosa (Montagu)		e	d	.	.	e	e	d	d	.	e	c	d	.	.	c	e	e	.	d	
hexagona (Williamson)		.	.	.	.	d	.	e	e	d	.	c	e	c	d	c	c	d	e	.	
melo d'Orbigny		.	e	.	.	c	b	c	b	d	d	b	b	b	b	a	b	a	b	a	
Pissurina bassensis Parr		.	.	.	.	.	.	e	.	.	.	c	.	.	.	.	.	.	.	e	
basicarinata Seguenza		.	.	.	.	.	.	e	.	.	.	.	.	.	.	.	.	.	.	e	
bicaudata Seguenza		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
biconica Silvestri		.	.	.	.	.	.	.	.	.	.	.	.	.	e	.	.	.	.	.	
concurbitasema Loeblich & Tappan		.	.	.	.	d	.	.	d	.	e	.	d	.	.	e	e	.	.	.	
cucullata Silvestri		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
curvifurca Parr		.	.	.	.	.	.	.	.	.	.	.	.	.	c	.	.	.	.	.	
deltoides Seguenza		.	.	.	.	e	.	d	.	.	.	.	.	.	.	.	c	e	e	d	
earlandi Parr		.	.	.	.	.	.	c	c	e	d	.	d	.	.	.	.	.	.	.	
cf. formosa (Schwager)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
keruelensis Parr		.	.	.	.	e	.	d	.	.	c	.	.	.	.	d	.	.	.	.	

KEY: a = very abundant; b = abundant; c = common; d = uncommon; e = rare.