

Taxonomy and Paleoecology  
of Early Miocene  
Benthic Foraminifera  
of Northern New Zealand  
and the North Tasman Sea

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and Martin A. Buzas*

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## ABSTRACT

Hayward, Bruce W., and Martin A. Buzas. Taxonomy and Paleocology of Early Miocene Benthic Foraminifera of Northern New Zealand and the North Tasman Sea. *Smithsonian Contributions to Paleobiology*, number 36, 154, pages 26 figures, 28 plates, 4 tables, 1979.—Data from 51 samples of early Miocene benthic foraminifera (200–300 individuals per sample) from west Northland, New Zealand (Waitakere and Waitemata Groups), together with those from four samples from the north Tasman sea (Deep Sea Drilling Project 206), are analysed by multidimensional scaling and cluster analysis. The samples are grouped in terms of species abundances into six thanatotoxes, which are interpreted as follows: A, dominated by robust *Amphistegina madagascariensis*, 10%–37% planktonics, inner neritic; B, *Cibicides-Cibicoides* dominant, 10%–55% planktonics, outer neritic; C, *Gyroidina*, *Euvigerina*, *Astrononion*, *Lenticulina* most abundant, 32%–87% planktonics, upper bathyal; D, *Cassidulina-Bolivina-Cibicides* dominant, 16%–99.5% planktonics, upper and midbathyal; E, *Globocassidulina-Epistominella* dominant, 99.5% planktonics, lower bathyal; F, *Quinqueloculina* dominant, 11%–32% planktonics, inner and midneritic.

Using these thanatotope interpretations in conjunction with their stratigraphic and geographic distributions, a model of the early Miocene paleogeography of west Northland is deduced, refining traditional models for the area. A central mid-bathyal basin (Waitemata Basin), bounded in the southwest by a pile of volcanic sediments (Waitakere volcanic pile), built up to an island surrounded by neritic and upper bathyal slopes. In the northwest (Kaipara area) volcanics erupted through a neritic shelf. This shelf became shallower and partly terrestrial during latter parts of the early Miocene. Upper bathyal slopes existed around the southern edge of the northwestern shelf. Submarine canyons cut through these slopes channeling shelf sediment into the bathyal basin. Several ungrouped, greatly mixed samples (interbedded with basin sediments) contain individuals from neritic and bathyal thanatotoxes and are interpreted as having been mixed during transportation down through the canyons into the basin in the form of subaqueous sediment gravity flows.

No change in depth from the present lower bathyal is inferred to have occurred in the vicinity of DSDP 206 (north Tasman Sea) since the early Miocene.

All 378 identified species are listed together with their synonymies; many are described and 194 species are figured. Besides a number of first records for New Zealand, three new species—*Elphidium gibsoni*, *Elphidium kanoum*, and *Eoepionella scotti*—are described.

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# Taxonomy and Paleoecology of Early Miocene Benthic Foraminifera of Northern New Zealand and the North Tasman Sea

*Bruce W. Hayward  
and Martin A. Buzas*

## Introduction

Benthic foraminifera are one of the most important marine groups for paleoecologic and paleogeographic studies. In New Zealand, Vella (1962a, b) was among the first to study benthic foraminiferal paleoecology using upper Miocene and Pliocene faunas. Since then, Scott (1970a, 1971a) has delineated thanatotores of early Miocene foraminiferal faunas. The area of his (1970a) study overlaps with that of the present one, and some of his samples are utilized here.

The purpose of this study is to understand better the changing paleogeography of an early Miocene marine basin. Involved are taxonomic reappraisal of foraminiferal species; grouping of fossil assemblages based on faunal composition, paleoecological interpretation of each grouping; and finally, basin analysis by combining these conclusions with the results of lithostratigraphy and other studies.

Hopefully, this work will provide a basis for future interpretations of this and other early Miocene basins in New Zealand.

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We thank the Deep Sea Drilling Project (DSDP 206) for supplying Tasman Sea samples through the assistance of the National Science Foundation; and Dr. G. H. Scott, New Zealand Geological Survey, for supplying nine samples from the central Kaipara area for use in this study. Dr. R. K. Smith, University of California at Santa Cruz, and Dr.

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This project was completed at the Smithsonian Institution while Bruce Hayward held a post-doctoral fellowship there in 1976.

**EARLY MIOCENE IN NEW ZEALAND.**—By early Miocene times, New Zealand had reached its present-day position with respect to other nearby lands. It consisted then, as it does today, of an elongate slither of continental crust (sial) separated from Australia by the 1500 km wide Tasman Sea (Figure 1). The Tasman Sea is underlain by oceanic crust, formed in the Cretaceous when New Zealand split off from Australia (Hayes and Ringis, 1973). Sedimentation in the Tasman Sea was mainly of coccolith oozes, as it is today.

Geologic evidence indicates that the convergent boundary between the Indian and Pacific Plates passed through New Zealand in the early Miocene, very much as it does today (Ballance, 1976). The land areas, however, were vastly different from the present. One long, narrow island possibly stretched the length of the New Zealand continental crust (Fleming, 1975), with areas of shelf and basinal

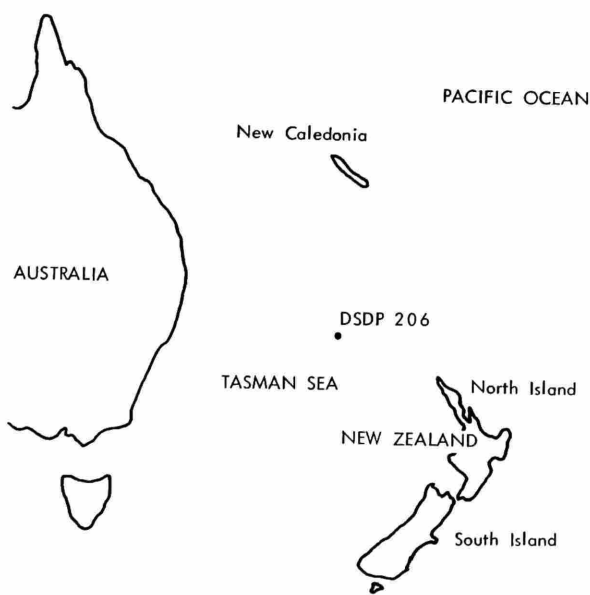


FIGURE 1.—Locality map of the southwest Pacific Ocean. (DSDP 206 = Deep Sea Drilling Program site 206, in the north Tasman Sea.)

sedimentation on either side. These uplifted early Miocene marine sediments crop out today over large portions of both islands. One area of extensive outcrop occurs in the north of the North Island of New Zealand and it is on this “basin” that our study is focussed.

**NORTHERN NEW ZEALAND IN THE EARLY MIOCENE.**—Recent paleogeographic interpretations (Carter, 1974; Hayward, 1975a; Ballance, 1976) of northern New Zealand in the early Miocene have relocated present-day Northland and East Cape regions side by side (Figure 2). Since then, dextral transform displacement along the Alpine Fault (part of the Plate boundary), together with crustal bending of Northland (Ballance, 1976), has moved the two areas apart.

Present geological knowledge suggests that in the early Miocene a trench marked the plate boundary east of the East Cape block and was paralleled by a volcanic arc (Waitakere Arc) along the west side of Northland (Figure 2). The two were separated by a 350–450 km wide arc-trench gap that can be divided into several physiographic parts (Figure 2):

*Eastern Shelf and Slope:* Marine sediments accumulated on a wide eastern shelf and slope (neritic-bathyal) that covered most of the easterly-titled East Cape half of the northern New Zealand sialic block and passed eastwards into the trench.

*Central Basement High:* The central part of the sialic block was uplifted forming an elongate terrestrial high of Permian-Jurassic metagreywackes, metaargillites, and cherts. Minor andesite eruptions occurred along this high in the latter half of the early Miocene (Hayward, 1975a).

*Elongate Basin (Waitemata Basin):* An elongate marine basin existed between the Waitakere Arc and basement high (Ballance, 1965; 1974). This basin can be divided into a central, deeper portion with dominantly flysch sedimentation, margined to the north and south by two areas of marine shelf (Ballance, 1974). The eastern margin of the basin was formed by a rocky greywacke coastline that fluctuated in position in the vicinity of the present Hauraki Gulf (Searle, 1964; Mayer, 1965).

*Northern Landmass:* An area of land composed predominantly of unstable Cretaceous and early Tertiary sediments is thought to have had variable form over much of northern Northland. For a time the sea transgressed over portions of this land in at least two places—Hokianga and North Cape (Har-

rington, 1944; Leitch, 1970). The exact extent of these two basically neritic basins is unknown.

*Waitakere Arc:* Igneous rocks and coarse volcanic sediments produced by the early to mid-Miocene activity of the Waitakere Arc (Hayward, 1974) crop out in three areas of Northland today—Waipoua,

Kaipara, and the Waitakere Hills (Figure 3). Each area is associated with a large positive magnetic anomaly beneath the adjacent west Northland continental shelf (Davey, 1974), which suggests that these were the sites of three major volcanic piles along the Arc (Figure 2). Products from the Waipoua centre occur in the Hokianga basin and over western parts of the northern land mass (Hayward, 1975a). The Kaipara and especially the Waitakere Hills centers built large submarine volcanic piles that formed the western margin of the north and central parts of the Waitemata Basin. It is along this western margin that our foraminiferal studies are centered.

**LITHOSTRATIGRAPHY OF THE WAITAKERE ARC AND WESTERN WAITEMATA BASIN.**—Sediments that accumulated in the Waitemata Basin belong to the Waitemata Group. Igneous rocks and associated volcanoclastic sediments of the Waitakere Arc belong to the Waitakere Group (Ballance et al., 1977).

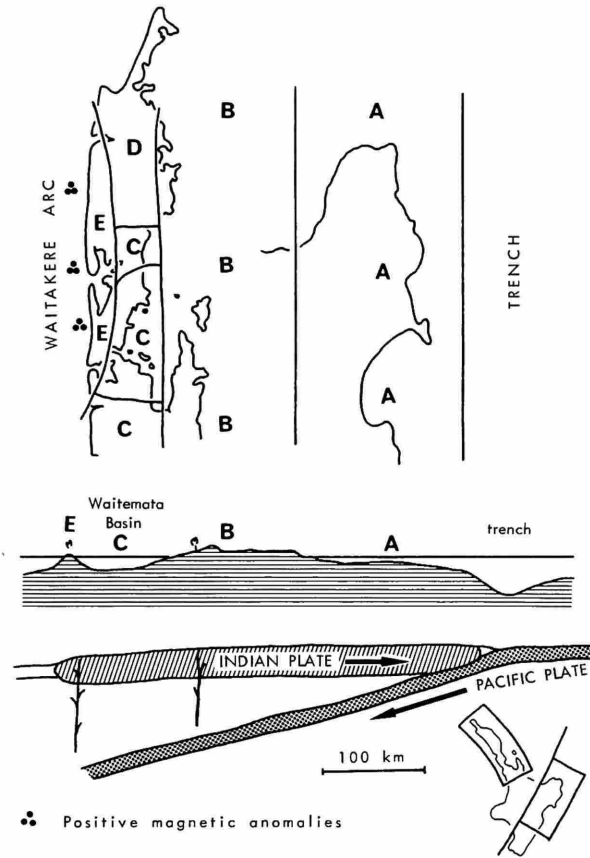


FIGURE 2.—Upper: Map showing the inferred reconstruction of northern New Zealand in the early Miocene and the principal geographic features of that time. The arc-trench gap consists of an eastern marine shelf and slope (A), a central basement high (B), an elongate basin (C), a northern landmass (D), and the Waitakere Arc (E). Middle: Cross-section through northern New Zealand to illustrate the early Miocene paleogeography of the above map (vertical scale exaggerated). Lower: Cross-section (to scale) through northern New Zealand in the early Miocene showing the oceanic crust of the Pacific Plate descending down a low-angle Benioff zone, beneath the New Zealand sialic crust, which lies along the eastern margin of the Indian Plate. Inset map: Map of present-day North Island showing position of the two halves of northern New Zealand's early Miocene sialic block.

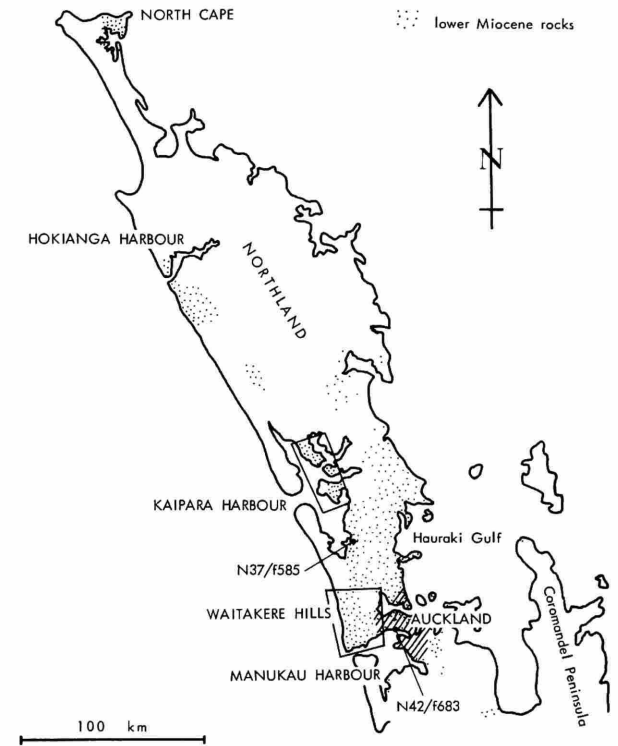


FIGURE 3.—Northern part of the North Island of New Zealand showing present outcrop distribution of lower Miocene rocks, location of South Kaipara (N37/f585) and North Manukau Harbour (N42/f683) samples, and location of maps of central Kaipara and the Waitakere Hills (Figure 4).

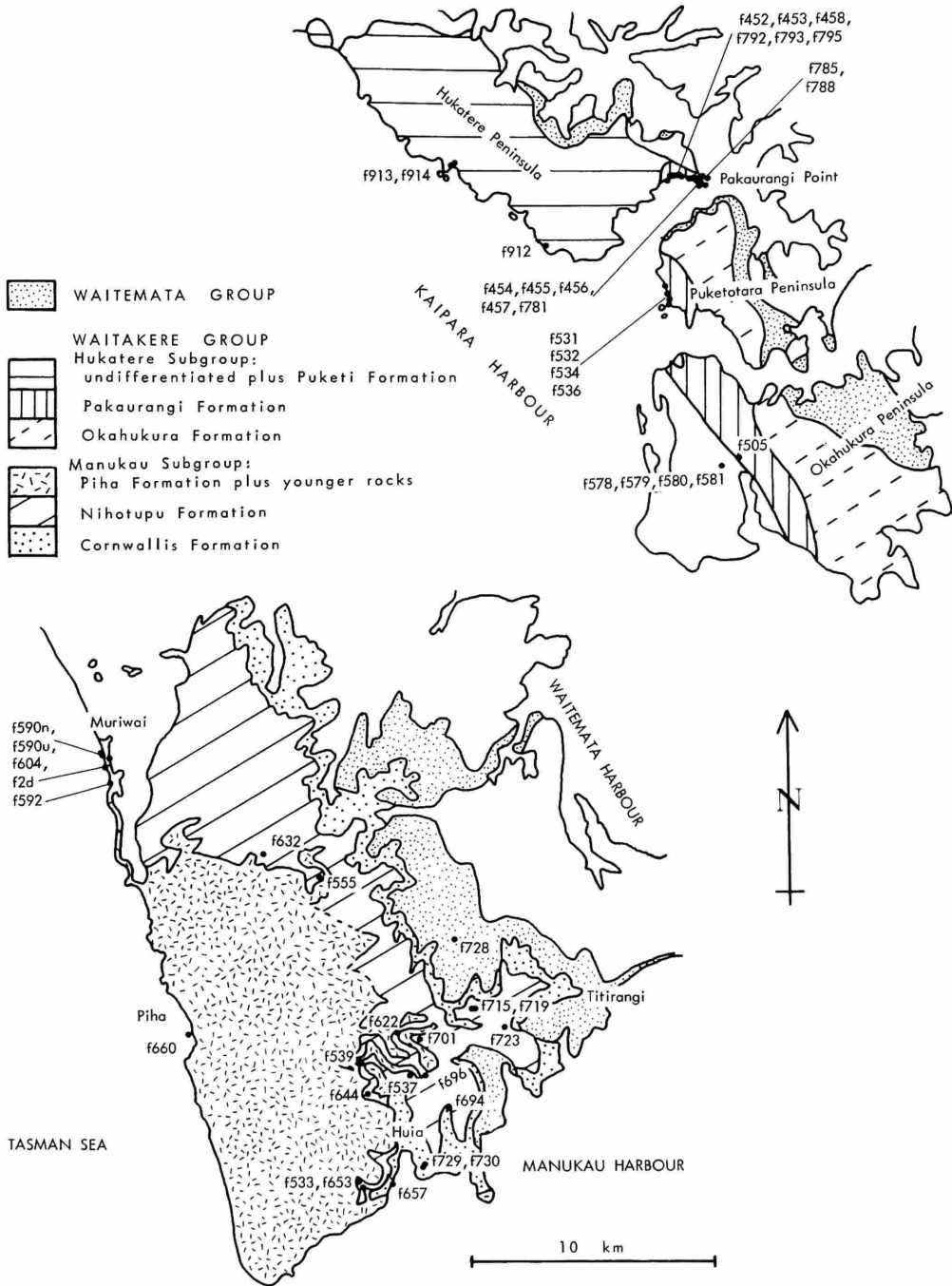


FIGURE 4.—Upper right: Map of central Kaipara area (location shown on Figure 3.) Lower left: Map of Waitakere Hills (location shown in Figure 3). The outcrop of lower Miocene Waitemata Group, and Waitakere Group Formations are shown, together with the location of samples used in the thanatotope analysis.

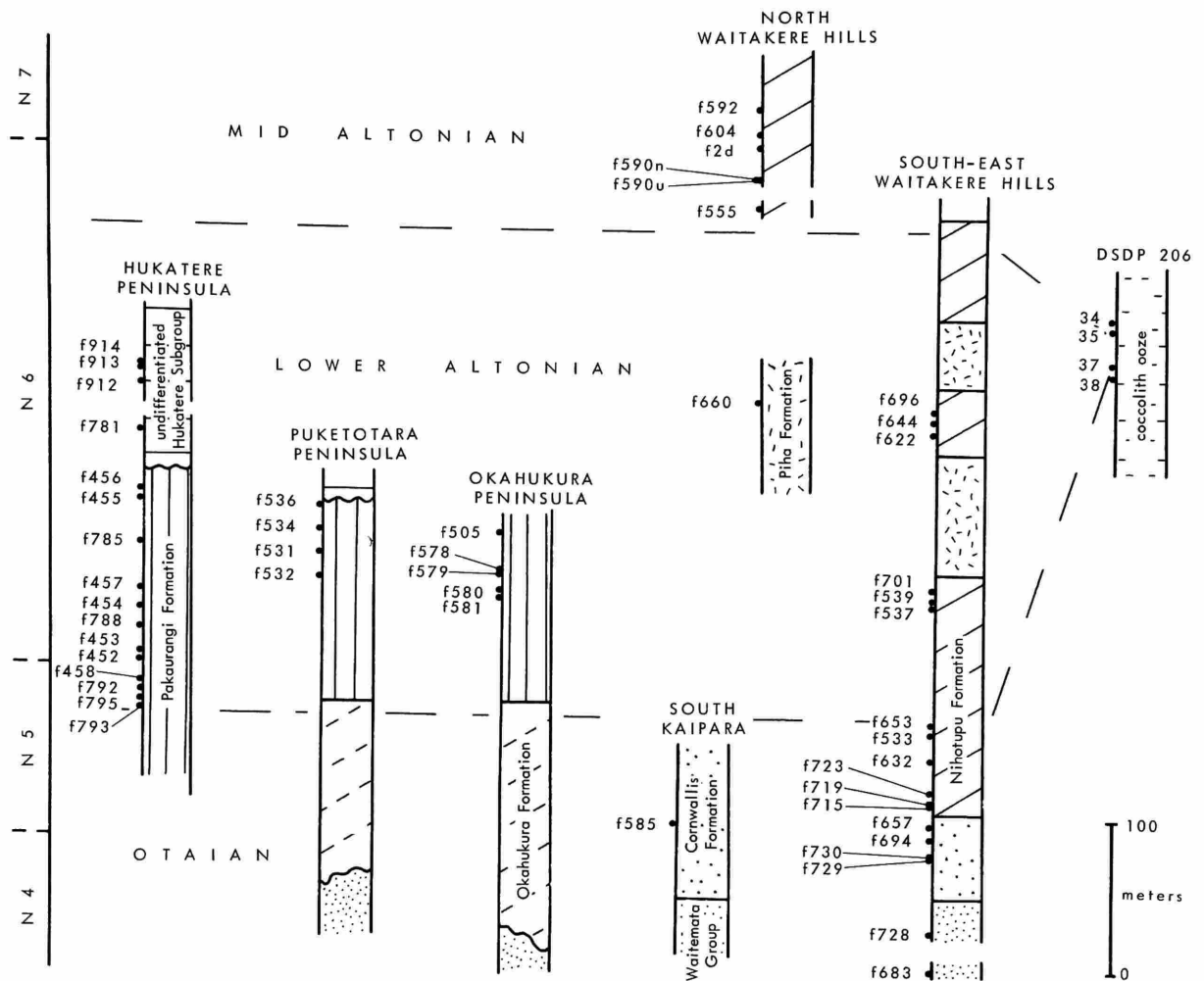


FIGURE 5.—Simplified lithostratigraphic columns of lower Miocene rocks from the west side of the Waitemata Basin and the Waitakere Arc, plus DSDP 206 from the north Tasman Sea. Location of samples used in the thanatotope analysis are shown, together with their approximate age correlation. Blow's (1969) planktonic foraminiferal zones (N4-N7) are indicated on the left.

These rocks are tilted to the west in western Northland. The dividing line between the two Groups is a gradational vertical zone, but for practical mapping purposes an arbitrary horizontal stratum has been selected, below which and crop-

ping out to the east is Waitemata Group, and above which and to the west is Waitakere Group.

The Waitakere Group is divided into the following three subgroups centered on the three volcanic piles (Hayward, 1977b).

1. Waipoua Subgroup in the north is predominantly terrestrial (Hayward 1972, 1973, 1975b) and is not dealt with further in this study.

2. Hukatere Subgroup in the Kaipara area mostly crops out on three peninsulas—Hukatere, Puketotara, and Okahukura (Figure 4). Here the thinly-bedded, Waitemata Group sandstones and siltstones (Timber Bay Formation—Carter, 1971) are unconformably overlain by Hukatere Subgroup. The basal Hukatere Subgroup rocks are diorite-andesite conglomerates and coarse volcanic sandstones (Okahukura Formation—Ballance and McCarthy, 1975) that fill submarine canyons and channels cut in the Waitemata Group. The Okahukura Formation is overlain by macrofossiliferous sandstones with minor pillow lavas and hyaloclastites (Pakaurangi Formation, Figures 4, 5; Jones, 1969; Carter, 1971; Ballance and McCarthy, 1975). The youngest rocks of Hukatere Subgroup crop out on Hukatere Peninsula and consist of volcanic sandstones, lapillistones, tuffaceous breccias, foraminiferal limestones, pillow lava piles and lignites (Puketi Formation—Jones, 1969; undifferentiated Hukatere Subgroup—Brothers, 1954a; Arlidge, 1955).

3. Manukau Subgroup crops out from the Waitakere Hills to south Kaipara Harbour. The oldest rocks are thick, graded, volcanic sandstones and grits (Cornwallis Formation—Jones and Martin, 1965; Hayward, 1977b) that conformably overlie the Waitemata Group flysch (Figure 5). Fine volcanoclastic sediments (sandstones, siltstones, minor pillow lavas, and conglomerates = Niho-tupu Formation, Tirikohua Formation—Hayward, 1976a, 1977a, 1977b) lie conformably upon Cornwallis Formation and crop out around the northern and eastern margins of the Waitakere Hills (Figure 4). These fine volcanoclastic sediments interfinger with and laterally grade southwestwards into coarse volcanoclastic sediments (andesite breccio-conglomerates, slump deposits, lava flows, hyaloclastites, and minor sandstones = Piha Formation—Hayward, 1977b) that form the bulk of this fossil submarine volcanic pile and now outcrop throughout most of the Waitakere Hills (Figure 4).

#### Field Localities

The samples used in this study (Appendix I) are from the Waitemata and Waitakere groups and

were collected from several areas along the west coast of Northland, New Zealand.

The sample numbers are those of the New Zealand Fossil Record File. The prefix (e.g., N28) is the sheet number of the New Zealand Lands and Survey Department 1: 63 360 topographic map series (NZMS 1). The standard notation of the Fossil Record File uses prefixes in the form "N28/f" (f = fossil site), but this is often abbreviated to "f" when there is no confusion as to which sheet number is being referred to. Unabbreviated sample numbers together with sample locations are given in Appendix I. The faunal slides are housed in the Geology Department, University of Auckland.

WAITAKERE HILLS (N41 and N42 samples, Appendix I, Figure 4).—Several hundred lithified sediment samples were collected from finer grained lithologies in the Waitakere Hills during geologic mapping from 1972 to 1974 (Hayward, 1975a). The samples used for this faunal analysis were those containing at least 50 individuals in about 10 trays of washed sediment. Altogether, 24 samples met this criterion and were separated into two groups (Table 1) based on field observations.

The 17 Group 1 samples were collected from well-bedded, thinly laminated volcanic sandstones and siltstones that occasionally contain bathyal macrofaunas (Hayward, 1976a, b).

The seven Group 2 samples were collected from thick, graded or massive beds of pebbly grits and coarse, volcanic sandstones that commonly contain broken shell material and sometimes neritic or mixed neritic-bathyal macrofaunas (Hayward, 1976b).

NORTH MANUKAU HARBOUR (N42/f683, Figure 3).—A single siltstone sample from the Waitemata Group, three km northwest of Onehunga was included.

SOUTH KAIPARA (N37/f585, Figure 5).—A single sandstone sample from the Cornwallis Formation, seven km northwest of Kaukapakapa was included.

CENTRAL KAIPARA (N28 and N33 samples, Appendix I, Figure 4).—Eight processed samples from Pakaurangi Point and five from Okahukura Peninsula, from the collections of the Geology Department, University of Auckland, were selected for use in this study because of their abundant foraminifera, as were a further nine processed sediment samples from Pakaurangi Point and Puketotara Peninsula, from the collections of the New Zealand



TABLE 1.—Samples from the Waitakere Hills containing at least 50 individuals (samples were grouped from field observations)

Group 1 Well-bedded sandstones and siltstones	Group 2 Massive grits and coarse sandstones
N41/f2d	N41/f533
N41/f590n	N41/f537
N41/f590u	N41/f539
N41/f592	N41/f555
N41/f604	N41/f632
N41/f622	N41/f657
N41/f644	N42/f694
N41/f653	
N41/f660	
N42/f696	
N42/f701	
N42/f715	
N42/f719	
N42/f723	
N42/f728	
N42/f729	
N42/f730	

Geological Survey, Lower Hutt (collected by Scott, 1970a). These samples were supplemented by three volcanic sandstones collected from the west coast of Hukatere Peninsula in August 1974. In all, a total of 25 samples were used from the Central Kaipara Area.

NORTH TASMAN SEA (DSDP samples, Figure 1).—Sixteen samples were obtained from the Deep Sea Drilling Project collection to provide an idea of the lower bathyal foraminifera of this region in the early Miocene. Four of these samples (Appendix I) judged to be of equivalent age and containing sufficient benthic foraminifera were selected for use in this study. All samples were from Leg 21, Site 206, between cores 206-32 and 206C-8. The samples were sublithified nannofossil oozes. Site 206 was drilled in the New Caledonia Basin at a present water depth of 3200 m (Burn et al., 1973).

#### Age and Planktonic Foraminiferal Biostratigraphy

The samples used in this study are of early Miocene age and can be assigned to the local New Zealand stages of Otaian, Po (= Aquitanian), and Altonian, Pl (= upper Aquitanian, Burdigalian). These stage determinations have been made using the planktonic foraminiferal stratigraphic frame-

work established by Jenkins (1967, 1971, 1973) and Scott (1971b, 1972).

Detailed planktonic foraminiferal studies have previously assigned the Pakaurangi Point samples to the lower part of the Altonian (Scott, 1969, 1972), and the Waitakere Hills samples to the upper Otaian to middle Altonian (Scott, 1970b; Hayward, 1975a).

The samples here have been assigned to three stages or substages based on the planktonic foraminifera: Otaian, lower Altonian, and middle Altonian (Figure 6).

OTAIAN.—The oldest samples contain typical Otaian faunas (Jenkins, 1971) with abundant large *Globoquadrina dehiscens* (Plate 1: figure 6), *Globigerina bulloides*, *Globigerina woodi woodi*, and *Globigerina woodi connecta*. The boundary between the Otaian and Altonian stages is formally defined using a lineage within populations of the benthic foraminiferid *Haeslerella* (Scott, 1965, 1972). In the absence of *Haeslerella*, a number of planktonic events have been used to indicate proximity to the boundary. The upper limits of *Catapsydrax dissimilis* and *Globorotalia kugleri* (Plate 1: figure 5) in New Zealand are close to this boundary (Jenkins, 1971, 1973). Scott's (1969, 1972) *Globigerinoides trilobus trilobus* datum level, based upon height:width measurements of the primary aperture in populations of *Globigerinoides trilobus*, is just

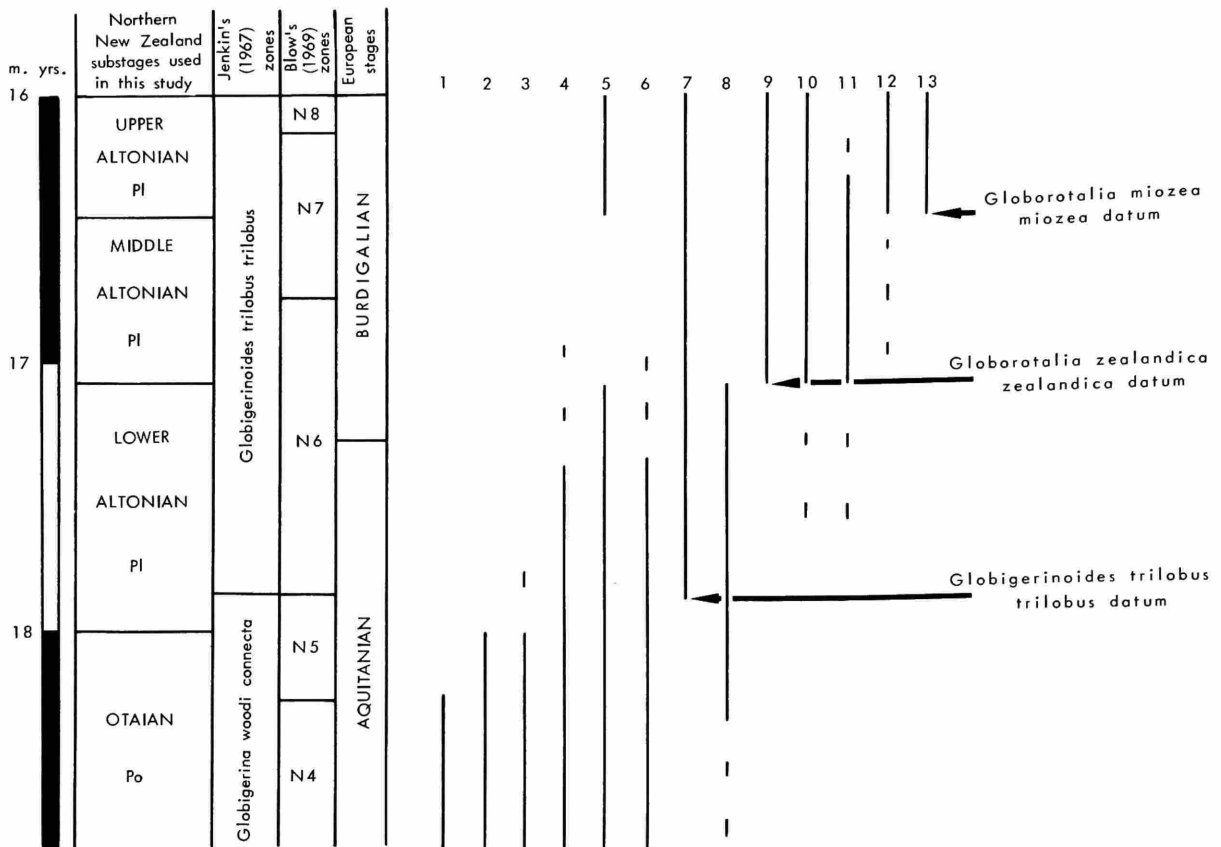


FIGURE 6.—Stratigraphic ranges of key planktonic foraminifera in northern New Zealand, showing important datum levels, appearances and extinctions used in defining the local substages (Otaian, lower Altonian, middle Altonian) applied in this study. The approximate equivalent absolute ages, planktonic zones of Jenkins (1967) and Blow (1969), and European stages are shown. The planktonic foraminifera are: 1, *Globorotalia kugleri* Bolli; 2, *Catapsydrax dissimilis* (Cushman and Bermudez); 3, *Globigerina ciperoensis ciperoensis* Bolli; 4, *Globigerina woodi connecta* Jenkins; 5, *Globoquadrina dehiscens* (Chapman, Parr and Collins); 6, *Globigerinoides trilobus altiapertura* Bolli; 7, *Globigerinoides trilobus trilobus* (Reuss); 8, *Globorotalia zealandica incognita* Walters; 9, *Globorotalia zealandica zealandica* Hornibrook; 10, *Globorotalia bella* Jenkins; 11, *Globorotalia praescitula* Blow; 12, *Sphaeroidinellopsis disjuncta* (Finlay); 13, *Globorotalia miozea miozea* Finlay.

above the Otaian-Altonian boundary (Figure 6; Scott, 1969, 1972; Jenkins, 1973; Hayward, 1975a).

**LOWER ALTONIAN.**—Lower Altonian faunas are dominated by more diverse faunas than the Otaian, with common *Globoquadrina dehiscens*, *Globigerina bulloides*, *G. woodi woodi*, *G. woodi connecta*, *Globigerinoides trilobus trilobus*, *Globorotalia zealandica incognita*, and *Globigerinoides trilobus altiapertura*. The boundary between the lower Altonian and middle Altonian as used in this study, is based predominantly on the *Globorotalia zealandica zealandica* datum in northern New Zealand (Hay-

ward, 1975). Walters (1965) described the apparent lineage in the East Cape area from *G. zealandica incognita* (Plate 1: figures 1, 2), which evolved with increasing ventral inflation and development of a more angular profile (in axial view) into *G. zealandica zealandica* (Plate 1: figure 3, 4). The *G. zealandica zealandica* datum (Figure 6; Walters, 1965; Scott, 1972; Jenkins, 1973) is taken to be the level where individuals having considerable ventral inflation and subangular profile (Walters, 1965, fig. 6κ-z; pl. 1: fig. 3, 4) comprise fifty percent or more of the *G. zealandica* population.

The lower Altonian-middle Altonian boundary is close to the level at which *Globorotalia praescitula* first appears in northern New Zealand (Hayward, 1975a) and at which *Globoquadrina dehiscens* temporarily disappears (Walters 1965; Hayward, 1975a).

MIDDLE ALTONIAN.—The youngest faunas are dominated by *Globigerina bulloides*, *G. woodi woodi* and *Globigerinoides tribolus tribolus*, and characterized by the presence of *Globorotalia zealandica zealandica*, *G. praescitula*, and rare *Sphaeroidinellopsis disjuncta* and by the absence of *Globoquadrina dehiscens* and the upper Altonian form *Globorotalia miozea miozea* and *Globigerinoides tribolus bisphericus* (Figure 6; Jenkins, 1973).

The substages assigned to the various samples on their planktonic content are shown on the lithostratigraphic columns in Figure 5 and listed in Appendix I.

The Waitemata Group, Cornwallis Formation, Okahukura Formation and lower part of the Nihotupu Formation are Otaian. The Pakaurangi Formation, Puketi Formation, Piha Formation, undifferentiated Hukatere Subgroup, and middle part of the Nihotupu Formations are lower Altonian. The upper part of the Nihotupu Formation, cropping out in the northern Waitakere Hills, is middle Altonian.

These local northern New Zealand substages can only be applied with difficulty to the deep-water faunas of the northern Tasman Sea (DSDP 206). The four samples used (DSDP 34, 35, 37, 38) are all early Miocene, being below the *Orbulina* datum and above *Globigerinoides* datum (Burns et al., 1973). Strongly inflated, keeled *Globorotalia* appear above DSDP 34 suggesting that these four samples are age equivalents of the Otaian and lower Altonian.

### Methods

LABORATORY.—The 55 samples chosen for this study were crushed and broken down using a combination of hydrogen peroxide, boiling water and an ultrasonic bath. They were then washed over a sieve with a nominal opening of 0.075 mm. Benthic foraminifera were picked directly from the sediment residue, as infilling of their shells prevented the use of the flotation techniques to concentrate them. For picking, the sediment was spread

evenly over a metal tray with a grid. Each tray of sediment was a microsplit of the entire processed sample and in all cases a complete trayfull or a number of complete traysfull was scanned to obtain individuals. About 200 to 300 individuals were obtained for most samples, but several yielded fewer than this number. A count of the planktonic foraminifera and ostracods was kept during picking.

The picked benthic foraminifera were mounted on slides, identified and counted.

COMPUTER.—The data consist of counts of the number of individuals belonging to 364 species in 55 samples. Because the number of individuals picked was standardized, in so far as possible, at about 200 to 300, the data are more analogous to species proportions than species densities. Initially the data

matrix was standardized by sample,  $|\frac{\chi - \mu}{\sigma}|$ , and the Euclidian distance was calculated between all possible sample pairs resulting in a distance matrix of size  $55 \times 55$ .

One of the techniques used to identify thanatopes was nonmetric multidimensional scaling (Kruskal, 1964). This technique presents a configuration of the  $n=55$  sample points in a  $k$ -dimensional space (two in the present instance). The interpoint distances in the  $k$  space are related monotonically to the original Euclidian distances. The advantage of viewing a configuration in  $k=2$  dimensional rather than  $k=55$  dimensional space is obvious. While other techniques, such as principal component analysis, also present a succinct summarization in a reduced number of dimensions, multidimensional scaling is conceptually and computationally quite distinct.

Initially a random configuration of points is generated from which the distance between all possible pairs are computed. These, in turn, are plotted against the Euclidian distances computed from the standardized data matrix and fitted with a monotonic function. Next a goodness of fit statistic called "stress" (St) is computed by

$$St = \left( \frac{\sum (d_{ij} - \hat{d}_{ij})^2}{\sum d_{ij}^2} \right)^{1/2}$$

wherein  $d_{ij}$  is the original Euclidian distance and  $\hat{d}_{ij}$  is a number computed to minimize the stress. The configuration is then changed slightly so as to improve the stress. Successive iterations are performed until a minimum stress is achieved.

A second technique utilized to identify thanatopes was weighted pair group cluster analysis using arithmetic averages of the Euclidian distance matrix. Discussions of this commonly used technique are given by Sokal and Sneath (1963), Kaesler (1966), and Mello and Buzas (1968). The above techniques were computed using the "NT-SYS" statistical package of Rohlf, Kishpaugh, and Kirk of the State University of New York, Stony Brook, New York.

Three measures of species diversity  $S$ ,  $H$ , and  $E$  were utilized. The first,  $S$ , is simply the number of species observed in the sample. The second is the Shannon-Wiener information function

$$H = -\sum p_i \ln p_i$$

wherein  $p_i$  is the proportion of the  $i$ th species (MacArthur and MacArthur, 1961; Pielou, 1966; and Gibson and Buzas, 1973). Unlike  $S$ , the information function places little weight on the rarer species encountered in the samples. The evenness with which the species proportions are distributed, however, can alter the value of  $H$  considerably. For example, five species each with a species proportion of 0.20 would have a value of  $H=1.60$ , while five species with proportions 0.90, 0.04, 0.03, 0.02, and 0.01 would have a value of  $H=0.45$ . A value of  $H=1.60$  could also be obtained from a sample containing more than five species, but with less evenness in the distribution of species proportions. Consequently, in addition to  $S$  and  $H$  some measures of evenness is required. Now the maximum value of  $H$  for a given  $S$  occurs when all species are equally distributed. In this case  $H=\ln S$ , and from the definition of logarithms of  $e^H=S$ , and  $e^H/S=1$ . Departure from complete evenness results in values of less than 1. Buzas and Gibson (1969) suggested this ratio be used as a measure of evenness and Sheldon (1969) called it  $E$ . For reasons given by Hill (1973) the measure

$$E = \frac{e^H}{S}$$

is more appropriate than some others suggested (see Pielou, 1966) and is used here.

A computer program that ranks the species by abundance, calculates species proportions and cumulative proportions,  $S$ ,  $H$ , and  $E$  was used to evaluate species diversity for each of the 55 samples and the thanatopes defined by multidimensional scaling and cluster analysis.

## Numerical Analyses

The large data matrix ( $364 \times 55$ ) precluded interpretation of the fauna on a sample by sample or species by species basis. Instead two computer techniques, discussed in the previous section, were used to arrange the samples into groups (thanatopes). We now discuss the results of these analyses.

**MULTIDIMENSIONAL SCALING USING EUCLIDIAN DISTANCES.**—After 14 iterations a minimum stress of 43% was achieved. According to Kruskal (1964) a stress of 5%–10% can be considered good. The high stress achieved in the present analysis is analogous to a principal component analysis wherein the first two axes account for a relatively small portion of the total variability. Nevertheless, as the two dimensional configuration shown in Figure 7 shows, there are some clear cut clusters.

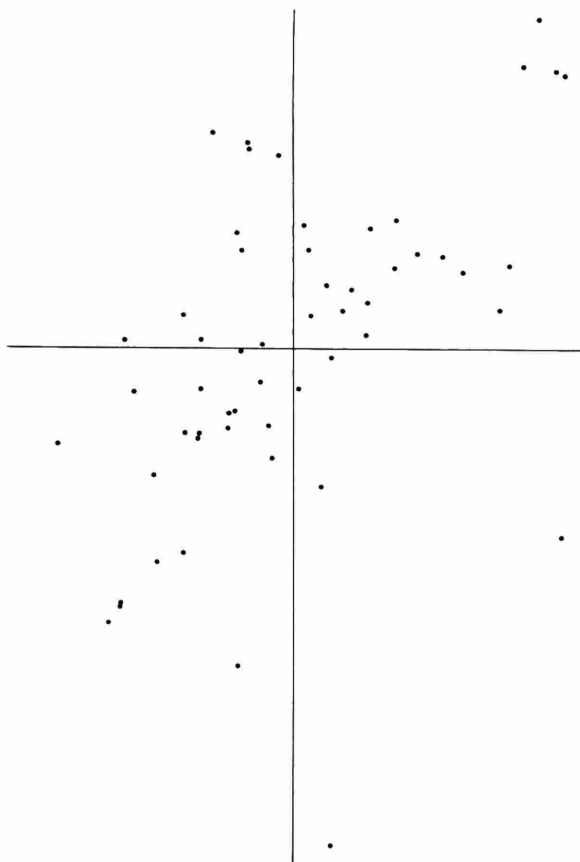


FIGURE 7.—Two-dimensional configuration of samples produced by multidimensional scaling using euclidian distance.

A small cluster (thanatotope) of four samples occurs in the upper right, and a slightly less well-defined thanatotope of five samples occurs in the lower left. Apart from the three scattered samples in the lower right, the remaining samples occur in a diffuse central region. This central configuration represents a natural, gradational change in the fauna, with no rigid boundaries subdividing it into several distinctive thanatotopes. Because of the large faunal change across this central region and the unwieldy number of samples within it, we decided further classification of the samples into thanatotopes was desirable. Consequently, the data were further analyzed through cluster analysis.

**CLUSTER ANALYSIS USING EUCLIDIAN DISTANCE.**—The dendrogram produced using this technique is shown in Figure 8. The two small distinctive thanatotopes from the multidimensional scaling configuration are the two tightest clusters in the dendrogram (thanatotopes A and E, Figures 8, 9). The central region of Figure 7 is divided into three clusters in the dendrogram (thanatotopes B, C, and D, Figure 8). When placed on the multidimensional scaling configuration, these three thanatotopes form three non-overlapping groupings that divide the central region into smaller, more workable units (Figure 9). Four samples around the fringes of the central region did not cluster with thanatotopes B, C, and D (Figure 9). Two of these (N41/f539, f555) cluster on the dendrogram nearest thanatotope A (Figure 8), but have been left ungrouped here for interpretation purposes. The other two samples (N28/f912, f914) cluster in the dendrogram (Figure 8) with the distant sample, N42/f694 (Figure 9) and are given a loose thanatotope status (thanatotope F) for ease of interpretation.

The remaining distant sample in the lower right quadrant (N33/f579, Figure 9) clusters in the dendrogram nearest thanatotope C but has been left ungrouped, as has the distant sample in the lower left (N41/f632, Figure 9).

**Thanatotopes**

Faunal composition of thanatotopes A–F is summarized in Figure 10.

**THANATOTOPE A** (Figure 11).—*Distribution:* Hukatere Peninsula (Puketi Formation: N28/f781; undifferentiated Hukatere Subgroup: N28/f913); Waitakere Hills Group 2 (Cornwallis Formation:

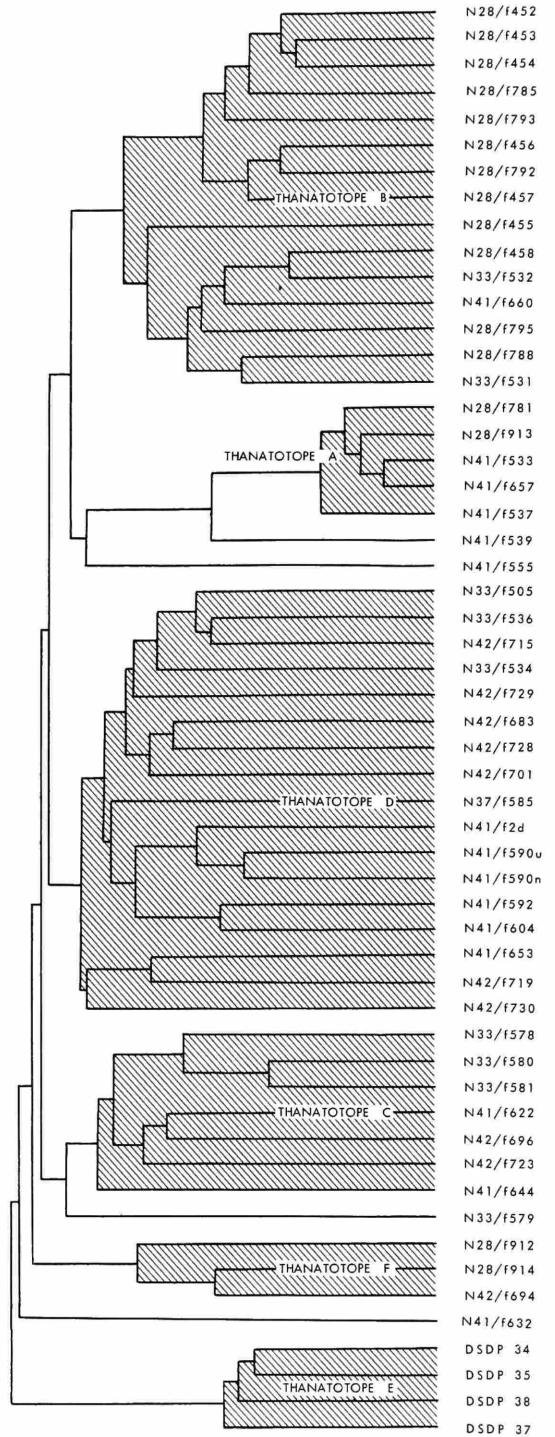


FIGURE 8.—Dendrogram classification of samples produced by cluster analysis using euclidian distance. Thanatotopes A–F were selected by the authors.

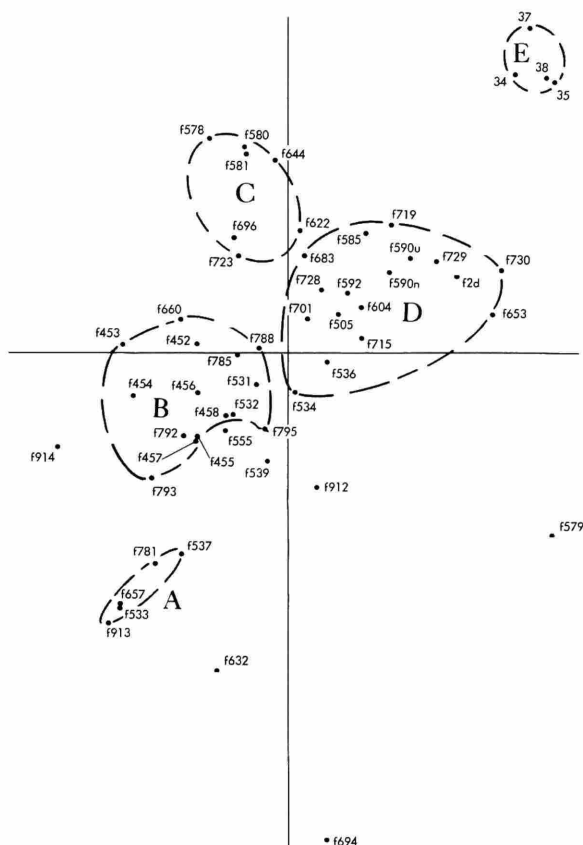


FIGURE 9.—Two-dimensional configuration of samples produced by multidimensional scaling using euclidian distance (as in Figure 7) with thanatotoxes A-E (selected from dendrogram, Figure 8) shown. Thanatotoxe F, consisting of f912, f914 and f694, is not shown because of its very large spread.

N41/f657; Nihotupu Formation: N41/f533, f537).

**Fauna:** Thanatotoxe A samples cluster together because of the dominance of a single species, *Amphistegina madagascariensis* (40%–72%). *Mio-gypsina intermedia* is the second most abundant species with only 5% of the total thanatotoxe fauna. Five further species (three of *Cibicides*, one *Cibicidoides* and *Victoriella*) each comprise 1.5%–3.0% of the total fauna (Figure 10).

**Planktonics:** All five samples (Figure 10) have a low percentage of planktonic foraminifera (10%–37%) compared with other thanatotoxes.

**Species Diversity:** These samples (Table 2) have low diversities of benthic species ( $S=30-51$ ,  $H=1.46-$

2.77) and very low evenness of distribution ( $E=0.14-0.31$ ). This thanatotoxe has distinctly lower species diversity and evenness than all the other thanatotoxes (Figures 12, 13). Only the ungrouped sample N33/f579 has similar low values.

**THANATOTOXE B** (Figure 14).—**Distribution:** Pakaurangi Point (Pakaurangi Formation: N28/f452, f453, f454, f455, f456, f457, f458, f785, f788, f792, f793, f795); Puketotara Peninsula (Pakaurangi Formation: N33/f531, f532); Waitakere Hills Group I (Piha Formation: N41/f660).

**Fauna:** The most abundant species in all samples is either *Cibicides temperatus* or *C. mediocris* and in one instance *C. vortex*. Small fragile individuals of *Amphistegina madagascariensis* are abundant in many samples. Thanatotoxe B samples cluster together because of the dominance of these four most abundant species (Figures 10, 14). Many different species are common in individual samples but none of these occur frequently in all samples.

**Planktonics:** Percentage of planktonics (Figure 14) in the foraminiferal population (10%–55%) is mostly slightly higher than in thanatotoxe A and lower than in thanatotoxes C, D, and E.

**Species Diversity:** Thanatotoxe B has moderately high species diversity ( $S=39-78$ ,  $H=2.63-3.68$ ; N41/f660 cannot be included in these measurements because of the small number of individuals picked). Evenness is moderately low if N41/f660 is not included ( $E=0.36-0.53$ ). Average species diversity in thanatotoxe B is similar to that in thanatotoxes E and F, higher than A and lower than C and D (Figure 12).

**THANATOTOXE C** (Figure 15).—**Distribution:** Okahukura Peninsula (Pakaurangi Formation: N33/f578, f580, f581); Waitakere Hills Group I (Nihotupu Formation: N41/f622, f644; N42/f696, f723).

**Fauna:** Thanatotoxe C is characterized by a group of species that occur in differing combinations as the most abundant constituents in each sample (Figure 15). These common species are *Gyroidina zelandica*, *Euuvigerina miozea*, *Astrononion stelligerum*, *Lenticulina* cf. *nitida*, *Anomalinoidea macraglabra*, *Sphaeroidina bulloides*, *Bolivina punctatostriata*, and *Siphouvirgerina proboscidea*. Other species that comprise over 1.5% of the total thanatotoxe C fauna are shown in Figure 10.

**Planktonics:** Planktonic percentage (Figure 15) ranges from 32%–87%; higher than thanatotoxes A, B, and F, and lower than thanatotoxes D and E.

TABLE 2.—Thanatotope designations and summary of observations by sample

Thanatotope	Sample	Lith.	Indivs.	S	H	E	% Plank.	Ostracods
A	N28/f781	c.s.	271	45	2.34	0.23	10	4
A	N28/f913	c.s.	297	35	1.80	0.17	32	1
A	N41/f533	gr.	144	30	1.50	0.15	26	1
A	N41/f537	gr.	194	51	2.77	0.31	37	5
A	N41/f657	gr.	202	30	1.46	0.14	20	-
B	N28/f452	m.s.	292	67	3.47	0.48	55	3
B	N28/f453	c.s.	298	50	2.92	0.37	17	3
B	N28/f454	c.s.	253	45	2.86	0.39	31	5
B	N28/f455	c.s.	266	58	3.35	0.49	19	19
B	N28/f456	m.s.	279	50	2.98	0.39	18	7
B	N28/f457	m.s.	251	50	3.01	0.40	35	8
B	N28/f458	m.s.	237	39	2.63	0.36	11	10
B	N28/f785	m.s.	216	55	3.37	0.53	46	10
B	N28/f788	gr.	290	78	3.68	0.51	55	2
B	N28/f792	gr.	197	42	2.83	0.40	29	7
B	N28/f793	m.s.	269	53	3.08	0.41	40	6
B	N28/f795	m.s.	289	55	3.26	0.47	15	7
B	N33/f531	f.s.	265	64	3.49	0.51	46	4
B	N33/f532	f.s.	295	64	3.19	0.38	22	5
B	N41/f660	m.s.	49	21	2.64	0.66	26	3
C	N33/f578	f.s.	313	58	3.09	0.38	66	-
C	N33/f580	m.s.	294	55	3.20	0.45	43	11
C	N33/f581	f.s.	297	62	3.31	0.44	32	-
C	N41/f622	m.s.	214	67	3.81	0.67	78	1
C	N41/f644	zst.	200	56	3.66	0.69	75	1
C	N42/f696	zst.	207	84	4.03	0.67	75	7
C	N42/f723	c.s.	194	67	3.83	0.69	87	5
D	N33/f505	m.s.	300	77	3.70	0.52	46	8
D	N33/f534	f.s.	283	64	3.70	0.63	27	2
D	N33/f536	c.s.	268	70	3.66	0.56	16	7
D	N37/f585	f.s.	301	84	4.02	0.66	95	2
D	N41/f2d	zst.	189	51	3.26	0.51	90	7
D	N41/f590n	m.s.	193	57	3.66	0.68	90	-
D	N41/f590u	m.s.	197	61	3.74	0.69	90	-
D	N41/f592	m.s.	168	64	3.74	0.66	87	-
D	N41/f604	c.s.	200	60	3.54	0.58	87	2
D	N41/f653	zst.	202	62	3.66	0.63	94	-
D	N42/f683	zst.	290	73	3.75	0.58	96	-
D	N42/f701	m.s.	201	47	3.42	0.65	71	-
D	N42/f715	m.s.	191	49	3.16	0.48	88	2
D	N42/f719	zst.	198	70	3.83	0.66	72	1
D	N42/f728	f.s.	200	55	3.55	0.63	97	-
D	N42/f729	m.s.	188	39	3.23	0.65	95	-
D	N42/f730	zst.	193	65	3.52	0.52	99.5	2
E	DSDP 34	n.o.	298	56	3.09	0.39	99.5	-
E	DSDP 35	n.o.	296	59	3.25	0.44	99.5	-
E	DSDP 37	n.o.	299	55	3.40	0.55	99.5	-
E	DSDP 38	n.o.	330	57	3.26	0.46	99.5	-
F	N28/f912	f.s.	223	59	3.52	0.57	11	61
F	N28/f914	c.s.	306	62	3.61	0.60	23	34
F	N42/f694	gr.	96	19	2.38	0.57	32	-
ungpd.	N33/f579	f.s.	291	33	2.14	0.26	50	-
ungpd.	N41/f539	gr.	189	70	3.81	0.65	70	17
ungpd.	N41/f555	gr.	188	34	3.06	0.63	47	-
ungpd.	N41/f632	gr.	50	27	3.10	0.82	92	-

ungpd. ungrouped.

Lithologies: gr. grit, c.s. = coarse sandstone, m.s. medium sandstone,

f.s. = fine sandstone, zst. siltstone, n.o. = nannofossil ooze.

Indivs. number of benthic individuals picked.

S = number of benthic species in pick.

H information function (see text).

E evenness (see text).

% Plank. percentage of total foraminifera that are planktonic.

Ostracods : number of ostracods picked.





FIGURE 10.—Histograms of species of benthic foraminifera summarized from all samples in each of thanatotope A to F. Only the most common species (abundance  $\geq 1.5\%$ ) are shown.

*Species Diversity:* Species diversity and evenness (Table 2) are high ( $S=55-84$ ,  $H=3.09-4.03$ ,  $E=0.38-0.69$ ) and about the same as in thanatotope D (Figures 12, 13).

**THANATOTOPE D** (Figure 16).—*Distribution:* Puketotara Peninsula (Pakaurangi Formation: N33/f534, f536); Okahukura Peninsula (Pakaurangi Formation: N33/f505); South Kaipara (Cornwallis Formation: N37/f585); Waitakere Hills Group 1 (Waitemata Group: N42/f728, Cornwallis Formation: N42/f729, f730, Nihotupu Formation: N41/f2d, f590n, f590u, f592, f604, f653; N42/f701, f715, f719); North Manukau Harbour (Waitemata Group: N42/f683).

*Fauna:* Like thanatotope C, there is no single

species that dominates or is even common in all samples. Instead thanatotope D samples are dominated by differing combinations of a group of species belonging to the genera *Cassidulina* (*C. laevigata*), *Bolivina* (*B. finlayi*, *B. reticulata*, *B. silvestrina*, *B. plicatella mera*), *Cibicides* (*C. vortex*, *C. mediocris*), *Globocassidulina* (*G. subglobosa*), *Trifarina* (*T. bradyi*), *Gyroidina* (*G. zelandica*), *Astrononion* (*A. stelligerum*), and *Stilostomella* (*S. pomuligera*).

*Planktonics:* Planktonic percentage ranges from 16%–99.5%, but most samples have over 70% (Figure 5). Only the three northernmost samples have less than 70%.

*Species Diversity:* Species diversity and evenness



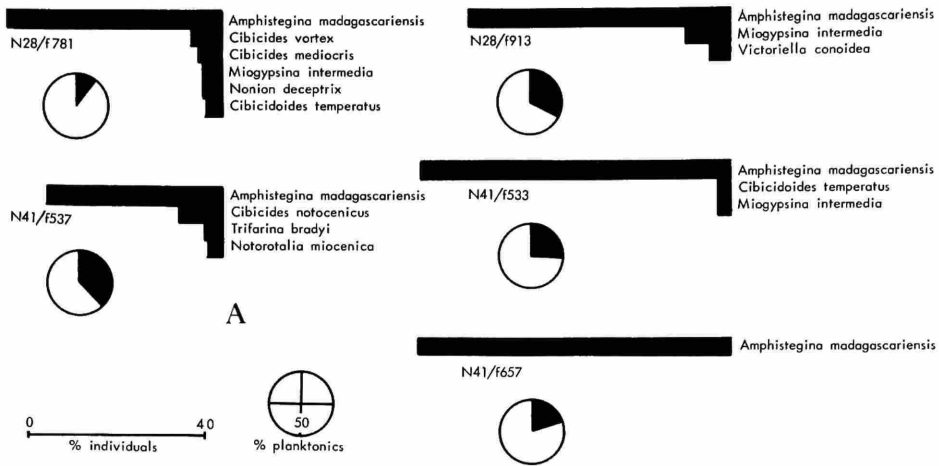


FIGURE 11.—Histograms of common species ( $\geq 3\%$ ) in thanatotope A samples. Percent of foraminifera that are planktonic is shown for each sample.

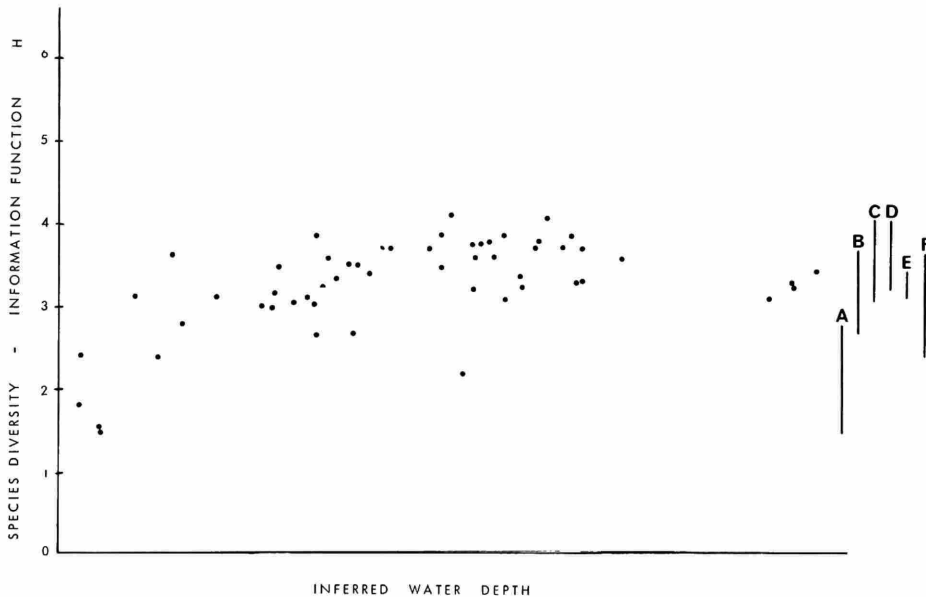


FIGURE 12.—Species diversity ( $H$ ) plotted against a NE-SW axis placed through the multi-dimensional scaling configuration (Figure 9). This axis was selected because it is interpreted to represent increasing depth from left to right. The range of values for samples in each thanatotope is shown on right.

are high ( $S=39-84$ ,  $H=3.23-4.02$ ,  $E=0.48-0.69$ ) and about the same as thanatotope C (Figures 12, 13).

**THANATOTOPE E** (Figure 17).—*Distribution*: North Tasman Sea (DSDP 34, 35, 37, 38).

*Fauna*: The most abundant species in all four samples is *Globocassidulina subglobosa*. *Epistominella exigua* is the next most abundant, occurring

in numbers greater than 8% in all samples. Other common species are *Bolivina aenariensis*, *Oridorsalis tenera*, *Stilostomella pomuligera*, *Melonis simplex*, and *Bulimina semicostata* (Figure 10).

*Planktonics*: Benthic foraminifera are sparse in thanatotope E samples. In all four samples 99.5% of the foraminifera are planktonic.

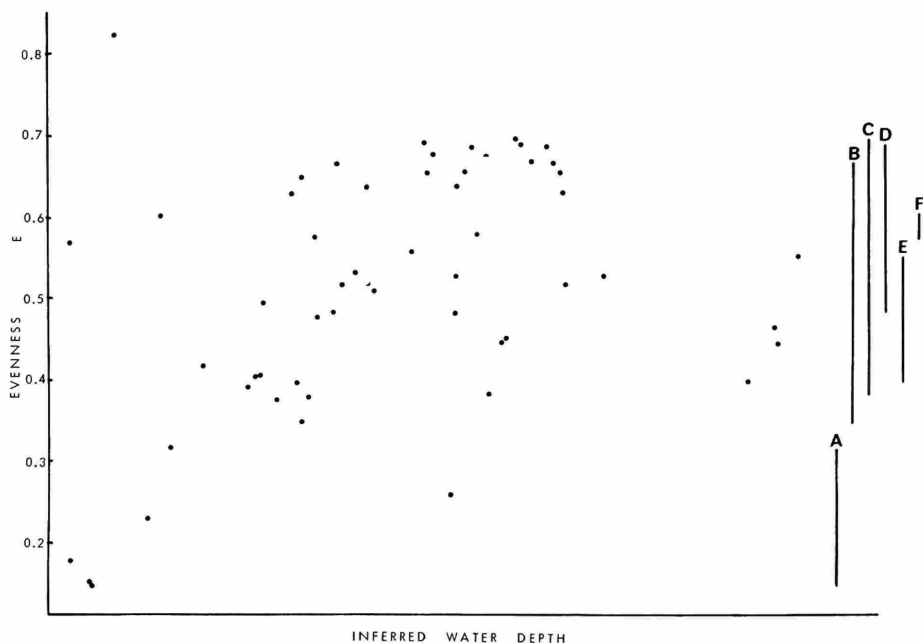


FIGURE 13.—Evenness (E) for species diversity plotted against the same NE-SW axis (in Figure 9) used in Figure 12. Depth increases from left to right. The range of values for samples in each thanatotope is shown on right.

*Species Diversity:* Species diversity is moderately high ( $S=55-59$ ,  $H=3.09-3.40$ ), similar to thanatopes B and F but generally lower than C and D. Evenness is moderately low ( $E=0.39-0.55$ ) similar to B, but lower than C, D, and F (Figures 12, 13).

**THANATOTOPE F** (Figure 18).—*Distribution:* Hukatere Peninsula (Undifferentiated Hukatere Subgroup: N28/f912, f914); Waitakere Hills Group 2 (Cornwallis Formation: N42/f694).

*Fauna:* All three samples are dominated by miliolids, especially *Quinqueloculina angulostriata*, *Q. seminula*, and *Q. plana*. Other common species are *Bulimina pupula*, *Elphidium hornibrooki*, and *E. advenum*.

*Planktonics:* Planktonic percentage is low (11%–32%) similar to thanatopes A and B.

*Species Diversity:* Species diversity is average ( $S=59-62$ ,  $H=3.52-3.61$ ) if N42/f694 is not included because of the small number of individuals in this sample. Evenness is moderately high ( $E=0.59-0.60$ ).

**UNGROUPED SAMPLES:** (Figure 19).—

N33/f579, Okahukura Peninsula  
(Pakaurangi Formation)

*Fauna:* This sample is unusual in the dominance

of *Lenticulina cf. nitida* (43%) and *Bulimina pupula* (18%).

*Planktonics:* 50%.

*Species Diversity:* Species diversity is moderately low ( $S=33$ ,  $H=2.14$ ) and evenness is very low ( $E=0.26$ ).

N41/f539, Waitakere Hills Group 2  
(Nihotupu Formation)

*Fauna:* This sample is dominated by *Amphistegina madagascariensis* (15%) in fewer numbers than in thanatotope A. The other common species—*Cassidulina laevigata*, *Anomalinoidea macraglabra*, and *Bulimina pupula*—are not common in thanatotope A but are in thanatopes C and D (Figure 9).

*Planktonics:* 70%.

*Species Diversity:* Species diversity and evenness are high ( $S=70$ ,  $H=3.81$ ,  $E=0.65$ ).

N41/f555, Waitakere Hills Group 2  
(Nihotupu Formation)

*Fauna:* This sample is dominated by *Cibicides notocenicus*, robust *Amphistegina madagascariensis*

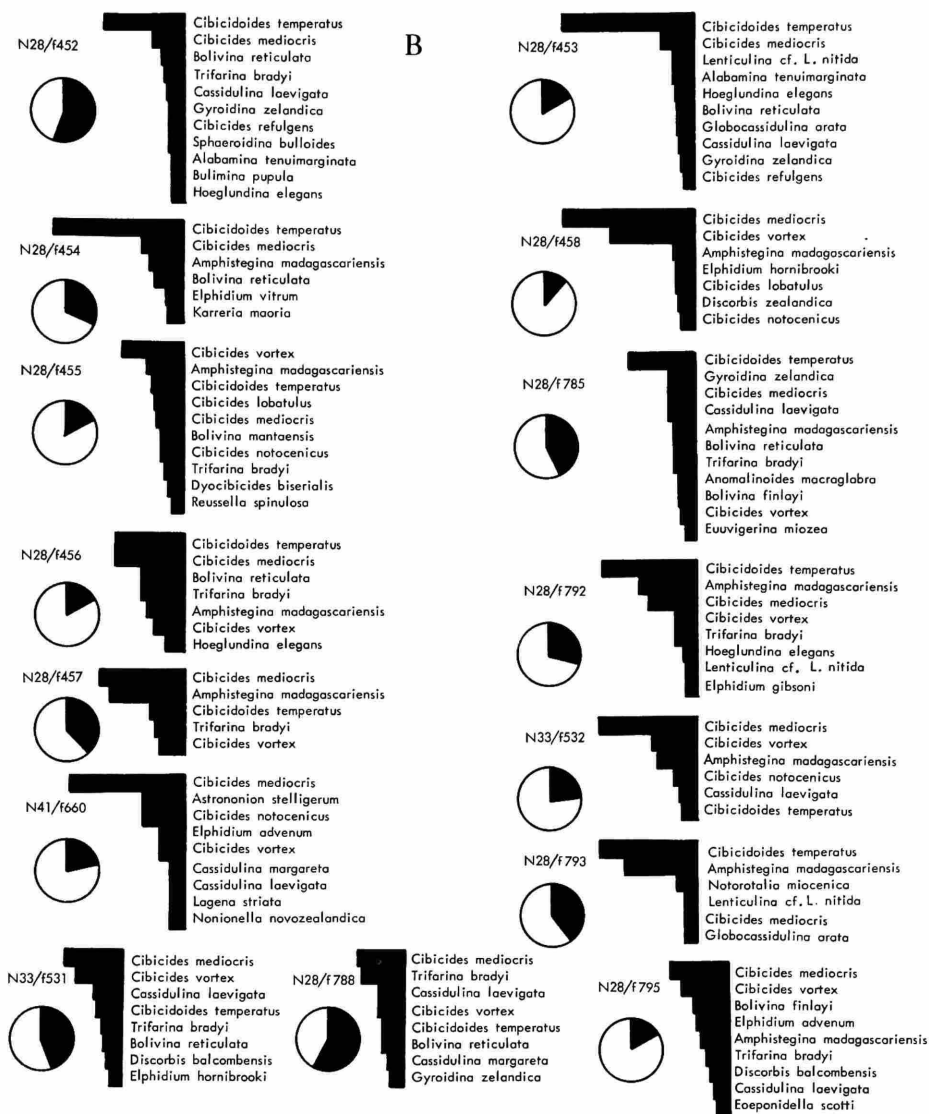


FIGURE 14.—Histograms of common species ( $\geq 3\%$ ) in thanatotope B samples. Percent of foraminifera that are planktonic is shown for each sample.

(both common in thanatotope A), *Cibicides mediocris* (common in thanatotope B), and *Globocassidulina subglobosa* (common in thanatotypes D and E).

*Planktonics*: 47%.

*Species Diversity*: Species diversity is average ( $S=34$ ,  $H=3.06$ ) and evenness is high ( $E=0.63$ ).

#### N41/f632, Waitakere Hills Group 2 (Nihotupu Formation)

*Fauna*: This sample is dominated by *Siphonina*

*australis* with common *Amphistegina madagascariensis*.

*Planktonics*: 92%.

*Species Diversity*: A total of only 50 benthics were obtained from this sample; consequently,  $S$  is low ( $S=27$ ), and  $H$  and  $E$  are high ( $H=3.10$ ,  $E=0.82$ ).

#### Interpretation of the Benthic Fauna

**BENTHIC FORAMINIFERA.**—*Thanatotope A*: The dominating form in thanatotope A, *Amphistegina*

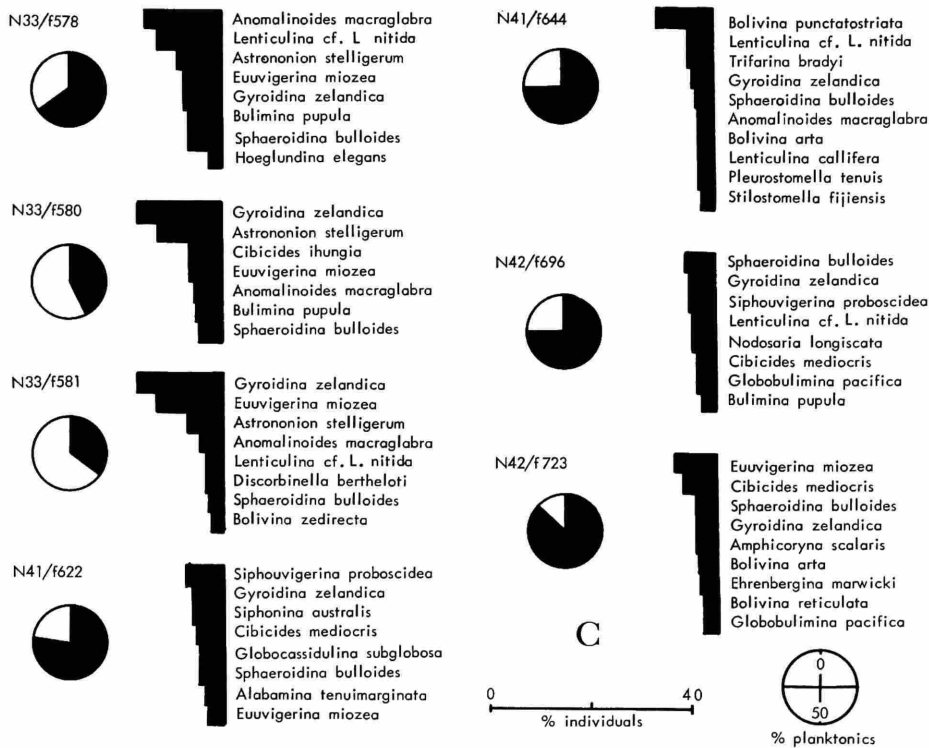


FIGURE 15.—Histograms of common species ( $\geq 3\%$ ) in thanatotope C samples. Percent of foraminifera that are planktonic is shown for each sample.

*madagascariensis*, today is a common, warm-water Indo-Pacific species. Although the precise distribution of this species is not well-documented, it is generally accepted that *Amphistegina* is a shallow, warm-water genus (Scott, 1970a; Murray, 1973; Boltovskoy and Wright, 1976; Todd, 1976). This genus is particularly prone to post-mortem transportation by surf and currents that obscures its living distribution and has prevented accurate determination of its lower depth limit (Todd, 1976). Todd (1965, 1976) recognized several forms of *Amphistegina madagascariensis*. Thick, robust individuals are characteristic of reef-flats, beach sands and near-shore sediments, and small, flatter and more fragile individuals are characteristic of lagoonal and deeper reef-slope environments. In all these environments *Amphistegina madagascariensis* has commonly been recorded comprising up to 25% of the benthic foraminifera. Thanatotope A samples all have over 40% *Amphistegina* (Figures 11, 20). Such a dominance has rarely been recorded, but Cushman, Todd, and Post (1954)

found *A. madagascariensis* comprising up to 80% of the fauna in the lagoons and on the outer reef slopes (about 0–50 m), around the Marshall Islands.

Most *Amphistegina madagascariensis* in thanatotope A are robust individuals supporting in an inferred exposed environment, 5–40 m deep in coarse sands or granular gravels (as indicated by the enclosing sediments.)

Thanatotope A faunas are little mixed as most genera present occur together today in such an environment with frequent *Cibicides*, *Cibicidoides*, *Elphidium*, *Discorbis*, and miliolids (Figures 10, 11, 20). *Cibicides notocenicus* shows its greatest abundance in this shallow thanatotope (Figure 20). A number of extinct, inferred shallow, warm-water, larger foraminifera are common in or restricted to thanatotope A, e.g., *Miogypsina intermedia*, *Victoriella conoidea*, *Eulepidina dilatata dilatata*, *Heterostegina borneensis*, *Hofkerina semiornata*, and *Sherbornina cuneimarginata*.

Foraminifera reworked from Cretaceous and lower Tertiary strata occur in greatest abundance

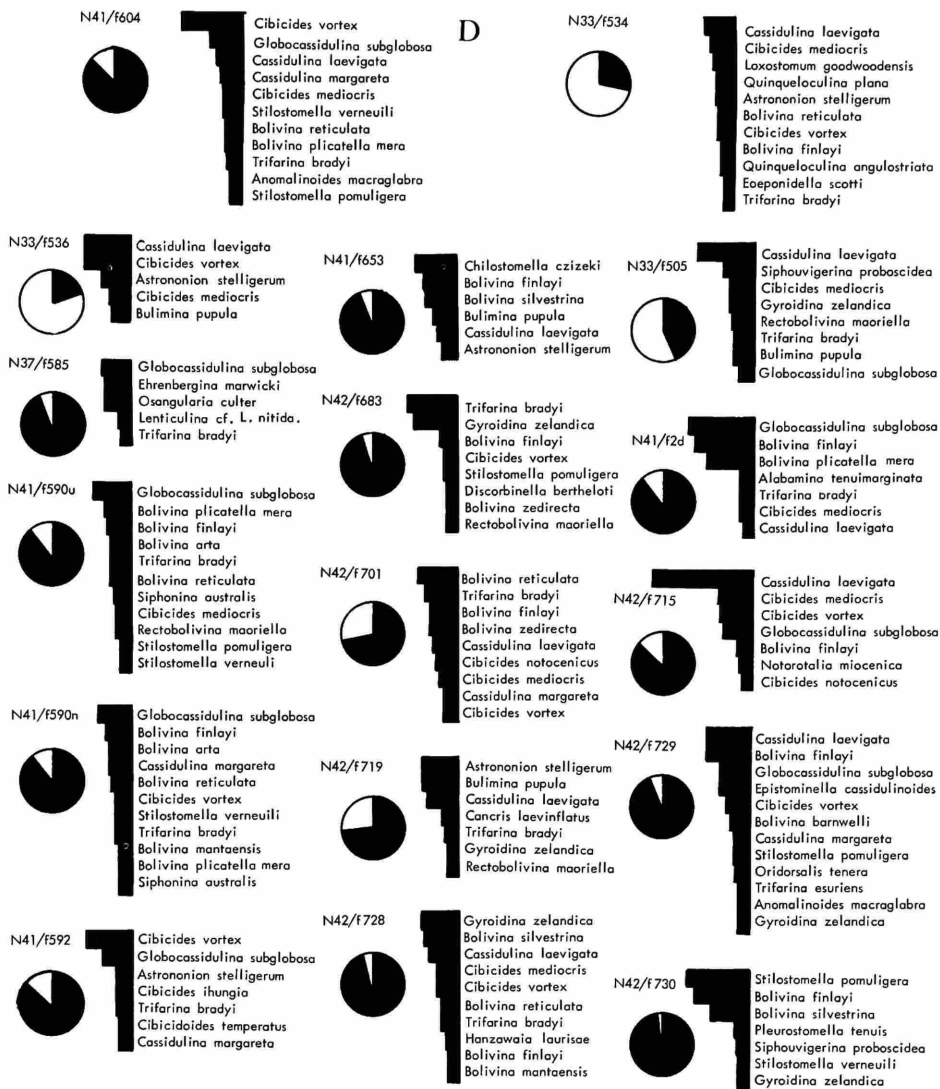


FIGURE 16.—Histogram of common species ( $\geq 3\%$ ) in thanatotope D samples. Percent of foraminifera that are planktonic is shown for each sample.

in this thanatotope (e.g., *Glomospira corona*, *Pelosiina complanata*, *Rzehakina epigona*). A little mixing of the fauna is indicated by the presence of rare individuals of deep-water restricted genera (e.g., *Osangularia*, *Stilostomella*, Figure 20).

*Thanatotope B:* Species of *Cibicides* and *Cibicidoides* (Figure 10, 14, 21) dominate this thanatotope, comprising over 40% of the benthic foraminifera. Such an abundance of these two genera has not often been recorded from modern sediments. Their greatest concentrations, however, are

found today in outer shelf depths (50–200 m) where they are two of the most predominant genera (Boltovskoy and Wright, 1976:119). The four most common species of *Cibicides* and *Cibicidoides* in this thanatotope are extinct, but two living species (*Cibicides lobatulus* and *C. refulgens*) are persistently present and have been recorded as reaching their greatest abundance in the Gulf of Gasconne at outer shelf depths (Pujos-Lamy, 1973).

An outer-shelf environment is supported by other faunal comparisons with present-day distribu-

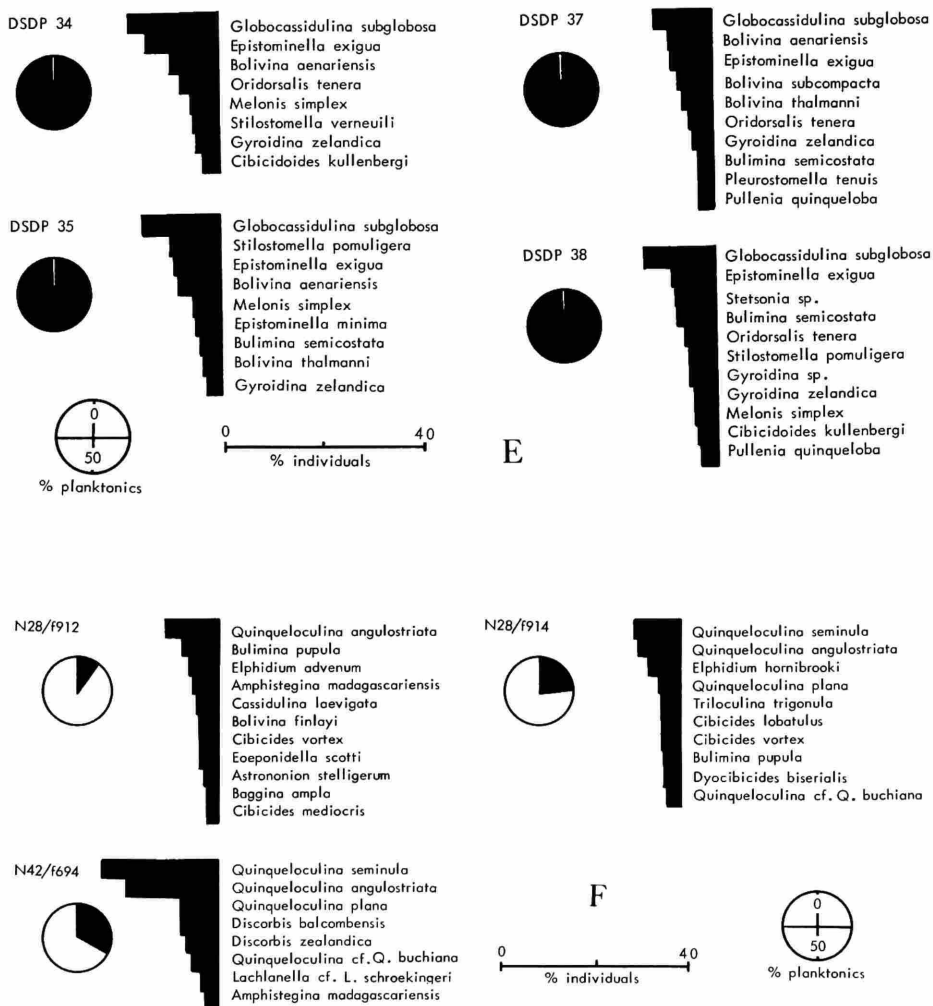


FIGURE 18.—Histogram of common species ( $\geq 3\%$ ) in thanatotope F samples. Percent of foraminifera that are planktonic is shown for each sample.

tions. Thin, fragile individuals of *Amphistegina madagascariensis* are abundant in this thanatotope (Figures 10, 20), and it is this form that Todd (1965, 1976) noted was typical of deeper water situations. She records it in abundance from samples as deep as 300 m.

Thanatotope B faunas are almost entirely autochthonous with few, if any, records of bathyal or deeper water-restricted forms (Figure 21). The samples are almost all sandstones and the dominant faunal elements are typical of modern sandy sediments.

A lower depth limit of approximately 200 m for this thanatotope is indicated by the common

occurrence of a number of shelf-restricted genera (e.g., *Bolivinella*, *Buccella*, *Discorbis*, *Elphidium*, *Glabratalia*, *Notorotalia*, *Pavonina*).

An upper depth limit to thanatotope B may be gauged by the common presence of *Hoeglundina elegans* (shallowest known modern record: 40 m), *Cassidulina laevigata* (almost entirely deeper than 75 m), *Lenticulina* (mostly deeper than 50 m) and *Euvigerina* (predominantly deeper than 100 m).

**Thanatotope C:** Of the nine most abundant genera in this thanatotope (Figure 10), three (*Anomalinoidea*, *Cibicides*, and *Sphaeroidina*) occur commonly in modern outer neritic and bathyal sediments; one (*Astrononion*) is most abundant in

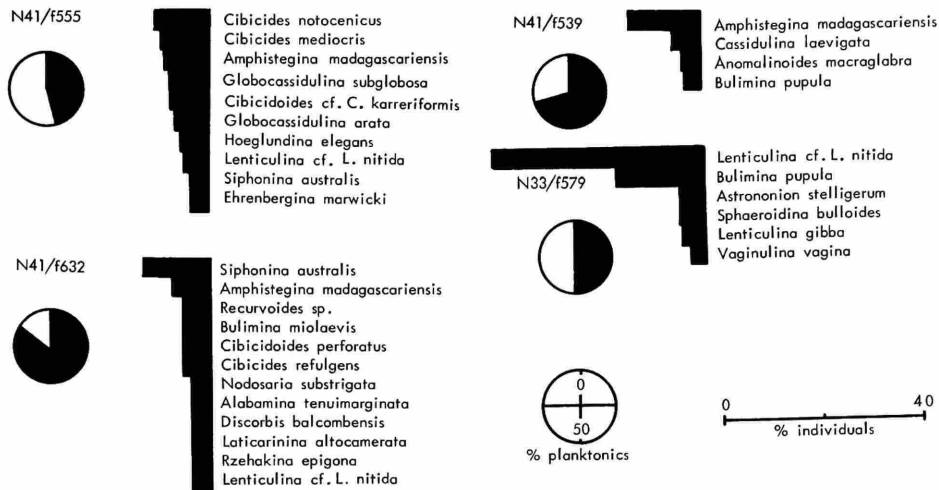


FIGURE 19.—Histogram of common species ( $\geq 3\%$ ) in ungrouped samples. Percent of foraminifera that are planktonic is shown for each sample.

the outer neritic and uppermost bathyal; three are predominant members of modern bathyal faunas (*Bolivina*, *Bulimina*, and *Gyroidina*); and two are most abundant in the upper bathyal (*Euuvigerina* and *Lenticulina*) (Boltovskoy and Wright, 1976; Vella, 1962a; Murray, 1973). From this we conclude that thanatotope C most likely was located at upper bathyal (200–1000 m) depths.

Further support for an upper bathyal environment comes from the most common records in this thanatotope of *Ehrenbergina*, *Globobulimina*, *Saracenaria*, *Siphonina*, and *Siphouvigerina*, all of which are predominantly found today in this zone.

Samples in this thanatotope can probably be divided further into two groups. Those with abundant *Astrononion* and *Lenticulina* (N33/f578, f580, f581; Figure 15) are probably from the uppermost bathyal, as *Astrononion* is not found in abundance at depths greater than 300–400 m (Vella, 1962a; Thompson, 1975) and *Lenticulina* is predominantly found between 200–700 m (Vella, 1962a; Lewis, 1971; Murray, 1973).

The four remaining samples, in the lower right portion of thanatotope C (Figure 9), and lower part of the dendrogram cluster (Figure 8, N41/f622, f644; N42/f696, f723) are probably from the lower upper bathyal. This is suggested by the presence in all four, and not the first three, of two reliable deep-water-restricted taxa: *Osangularia culter* (shallowest known modern record: 700 m; Brady, 1884;

Bandy and Chierici, 1966; Frerichs, 1970; Lewis, 1971; Pflum and Frerichs, 1976) and the genus *Pleurostomella* (predominantly deeper than 1000 m; Brady, 1884; Bandy and Rodolfo, 1964; Frerichs, 1970).

All seven samples contain some allochthonous tests, transported in from shallower depths (e.g., *Elphidium*, *Amphistegina*, Figure 20). The lower four samples appear to be more mixed than the upper three. N41/f644 contains a large number of very battered *Lenticulina* that probably were transported down the slope by currents.

**Thanatotope D:** Thanatotope D samples are dominated by species of *Cassidulina* (*C. laevigata*, *C. margareta*), *Bolivina* (*B. finlayi*, *B. reticulata*, *B. mantaensis*, *B. silvestrina*, *B. plicatella mera*, etc.), *Cibicides* (*C. vortex*, *C. mediocris*) and *Globocassidulina* (*G. subglobosa*) (Figures 10, 16, 20, 21). Assemblages dominated by these genera are typical of outermost neritic and upper half of the bathyal (150–2000 m) in modern sediments (Bandy and Rodolfo, 1964; Betjeman, 1969; Boltovskoy and Wright, 1976; Saidova, 1967). Most of the species are extinct, but the most abundant overall, *Cassidulina laevigata*, is still found commonly (neritic to abyssal) with its greatest abundance in middle latitudes in the upper half of the bathyal (200–1500 m—Brady, 1884; Bandy, 1960). *Globocassidulina subglobosa* is rarely found today above 100 m and is most common in the mid- to

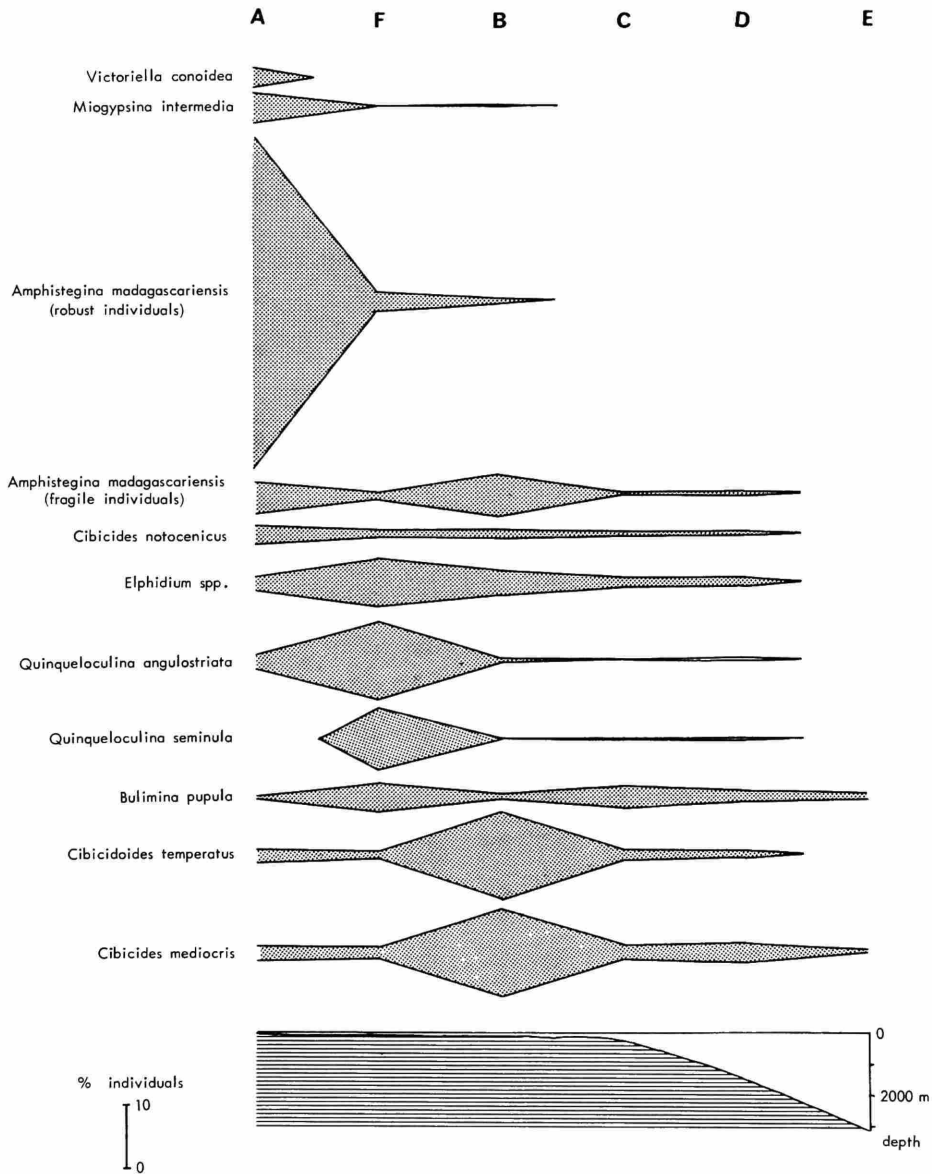


FIGURE 20.—Kite diagrams showing the distribution of common benthic foraminiferal species and genera in thanatotypes A to F. The thanatotypes have been arranged in order of inferred increasing depth as shown by the depth profile at the bottom. The forms in this chart are predominantly neritic species and genera.

lower bathyal (1000–4000 m, Brady 1884; Pflum and Frerichs, 1976).

Other prominent genera in the upper half of the bathyal (200–2000 m) and common in this thanatotype are *Gyroidina*, *Bulimina*, *Siphovigerina*, *Euwigerina*, *Chilostomella*, *Pleurostomella*, *Allo-*

*morphina*, *Pullenia*, and *Nonion* (Boltovsky and Wright, 1976:119).

The benthic composition of thanatotype D is intermediate between C and E (Figures 20, 21), with some of the shallower species of C decreasing in abundance (e.g., *Gyroidina zelandica*, *Euwigerina*



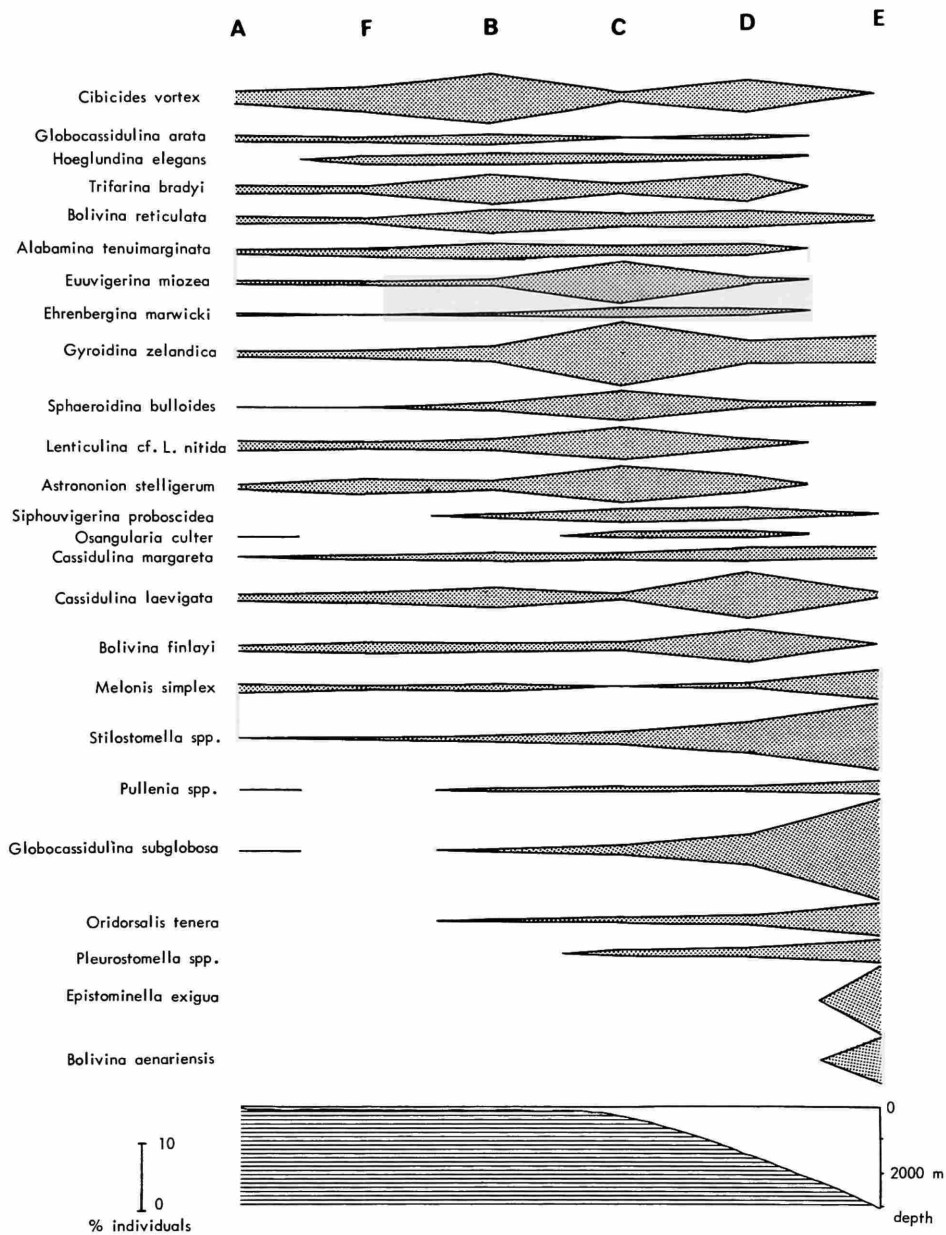


FIGURE 21.—Kite diagrams showing the distribution of common benthic foraminiferal taxa in thanatopes A to F. The thanatopes are arranged in order of inferred increasing depth (left to right) as shown by the depth profile at the bottom. The forms in this chart are predominantly outer neritic and bathyal species and genera.

*miozea*, *Astranonion stelligerum*, *Lenticulina cf. nitida*, *Cibicidoides temperatus*, *Sphaeroidina bulloides*) and many of the deeper forms typical of E, rapidly increasing in abundance (e.g., *Melonis simplex*, *Oridorsalis umbonatus*, *Globocassidulina sub-*

*globosa*, *Bulimina truncana*, *Epistominella spp.*, *Pleurostomella spp.*, *Stilostomella spp.*, *Pullenia spp.*). Several of the dominant species of thanatope E (e.g., *Epistominella exigua*, *Bolivina aenariensis*) are not present in D, suggesting that the lower

depth limit for this thanatotope is somewhat above the 3000 m level of E.

The upper depth limit is best gauged using several deep-water-restricted genera that commonly occur in D. A combination of *Osangularia culter*, *Stilostomella* spp., *Pleurostomella* spp., *Oridorsalis umbonatus*, and several others indicates a depth greater than 1000 m (Brady, 1884; Bandy and Chierici, 1966; Bandy and Rodolfo, 1964; Boltovskoy and Wright, 1976; Frerichs, 1970; Lewis, 1971; Pflum and Frerichs, 1976). This is supported by the common presence of globular Pullenias (*P. bulloides*), small costate Buliminas (*Bulimina striata*, *B. truncana*), small *Eponides* (*Eponides broeckhianus*), and spinose Uvigerinidae (*Siphonuvigerina proboscidea*), which are most abundant in mid-lower bathyal depths (Bandy, 1960).

Some mixing of thanatotope D fauna by down-slope displacement is indicated by the rare occurrences of shelf forms (e.g., *Amphistegina*, *Buccella*, *Elphidium*, *Discorbis*, *Notorotalia*, *Buliminella elegantissima*) and possibly of some upper bathyal forms (e.g., some *Astrononion*, *Lenticulina*, *Saracenaria*).

As in thanatotope C, this thanatotope can be divided into deeper and shallower samples. The bulk of the thanatotope (upper right quadrant in Figure 9) are here considered to be midbathyal (1000–2000 m) assemblages, based on the above data. The two lower left samples (N33/f534, 536) do not contain the deep-water-restricted forms mentioned above and have faunas more compatible with an upper bathyal interpretation. They contain abundant shelf and uppermost bathyal (0–500 m) restricted forms (e.g., *Quinqueloculina*, *Astrononion*, *Elphidium*, *Amphistegina*, *Buliminella elegantissima*), not all of which appear to be displaced.

**Thanatotope E:** The benthic fauna of thanatotope E is typical of a modern lower bathyal (2000–4000 m) assemblage and is consistent with inferred little change in water depth (3000 m) at DSDP 206 between the early Miocene and now (Burns et al., 1973). The two dominant species (*Globocassidulina subglobosa* and *Epistominella exigua*; Figures 10, 17, 21) are both abundant in modern midbathyal to abyssal sediments (Brady, 1884; Pujos-Lamy, 1973). Other distinctively deep-water-restricted living forms that occur in E include *Bolivina decussata*, *Cibicidoides kullenbergi*, *Cibicides wuellerstorfi*, *Eggerella bradyi*, *Laticarinina pauperata*, *Oridorsalis*

*umbonatus*, *Stilostomella antillea*, *Pleurostomella* species, and diverse *Fissurina*, *Lagena*, and *Parafissurina* species (Ingle, 1973; Boltovskoy and Wright, 1976; Brady, 1884; Phleger, 1960).

The fauna appears to be entirely autochthonous with no shallow-restricted forms present at all (Figures 20, 21).

**Thanatotope F:** Thanatope F is dominated by miliolids (*Quinqueloculina angulostriata*, *Q. seminula*, *Q. plana*, *Q. cf. buchiana*, *Triloculina trigonula*, *Lachlanella cf. schroekingeri*; Figures 10, 18, 20). Modern miliolid-dominated faunas are confined to warm water lagoons, estuaries, and inner neritic situations (Murray, 1973; Boltovskoy and Wright, 1976). *Quinqueloculina* seldom occurs living in depths greater than 50 m (Bandy, 1960; Murray, 1973). Both fragile and robust *Amphistegina madagascariensis* occur in all three samples, suggesting some mixing of the faunas with a site of accumulation in the deeper part of the inner neritic (20–50 m). Support for an inferred inner neritic environment, especially for N42/f694, comes from the abundance of *Discorbis*, which is also restricted to water depths shallower than 50 m (Murray, 1973). Other elements common in modern inner neritic sediments and present in E are *Elphidium* and *Cibicides*.

The fauna of N28/f912 is significantly different from the other two samples. It is dominated by *Quinqueloculina angulostriata* but also has a strong mid- to outer neritic representation (Figures 18, 20, 21; e.g., *Cassidulina laevigata*, *Bulimina pupula*, *Hoeglundina elegans*, *Canceris*, *Lenticulina*, *Astrononion*) that suggest that the fauna is considerably mixed. A midneritic depth of accumulation (50–100 m) with a large allochthonous inner neritic component is most consistent with faunal composition for N28/f912.

**Ungrouped Samples:** N33/f579. The four most abundant species in this sample (Figure 19) are among the seven most abundant in thanatotope C (Figure 10). The fauna is consistent with an inferred outermost neritic to uppermost bathyal environment (150–400 m) similar to the shallower samples in thanatopes C and D. In modern sediments, the dominant genera in this sample (*Lenticulina*, *Astrononion*, and large smooth *Bulimina*) are most abundant in this zone.

N41/f539, N41/f555, N41/f632. These three samples appear to contain greatly mixed faunas de-

rived from several of the thanatotores (Figures 20, 21): robust *Amphistegina madagascariensis*, *Cibicides motocenicus* (from A), *Elphidium* (from A, B, or F); *Globocassidulina arata*, *Hoeglundina elegans* (from B or C); *Cassidulina laevigata*, *Cibicides mediocris*, *C. refulgens* (from B, C, or D); *Anomalinoidea macraglabra*, *Bulimina pupula*, *Lenticulina* cf. *nitida*, *Ehrenbergina marwicki* (from C); and *Globocassidulina subglobosa*, *Osangularia culter* (from D). Since all samples are from massive, coarse-grained beds (Waitakere Hills Group 2) and are interbedded with thanatotope D bearing sediments, it is logical to explain these faunas as of subaqueous mass flow origin. The mass flows originating in the inner neritic (A) and passing over and mixing with outer neritic (B) and upper bathyal (C) sediments before coming to rest in the mid-bathyal (D).

**SPECIES DIVERSITY.**—The species diversity of shallow water foraminifera (less than 50 or 100 m) is much lower than in deeper waters (Buzas and Gibson, 1969; Gibson and Buzas, 1973; Sen Gupta and Kilbourne, 1974). In deeper water, species diversity either remains constant, increases, or decreases. On others diversity increases to the edge of the shelf, remains constant thereafter or either increases or decreases at lower bathyal and abyssal depths. The reasons why this is so are not clear, but analyses of hundreds of modern samples from the eastern margin of North America document the pattern.

In the present study the inferred depth ranges from thanatotores A through E increase. Species diversity as measured by the number of species, S, and the information function, H, indicates an increase in diversity from A to B, a slight increase from B to C and D, and a decrease from C and D to E. (Figures 12, 13). Examining the analyses of Gibson and Buzas (1973), one observes a similar pattern for the modern total population in the northeastern Gulf of Mexico (Parker, 1954, traverses VI, VIII, XI). To illustrate the similarities we have tabulated S, H, and E (evenness) from the Gulf of Mexico and the thanatotores described here (Table 3).

The mean number of species in the samples from the Gulf of Mexico and thanatotope A are nearly identical. H is somewhat higher in the Gulf of Mexico because of the relative evenness of species distributions found there. As already pointed out,

thanatotope A is dominated by *Amphistegina*, and, consequently, we observe a low value of E (mean 0.20) resulting in a lower H. Table 3 indicates both the Gulf of Mexico and thanatotope A have much lower species diversities than the other tabulated classes.

In the 50–200 m depth range the samples from the Gulf of Mexico and thanatotope B have very similar species diversity for mean as well as observed ranges.

Thanatotores C and D have inferred overlapping depth ranges and are grouped adjacent to one another by multidimensional scaling (Figure 9). The number of species and the information function for these thanatotores and their modern counterparts are similar. H is slightly higher in the fossil example because of the higher values of E recorded there. Whether or not fossil populations consistently have higher values of E in this depth range poses an intriguing ecological question. If so, then populations in the past would have had much less dominance than modern populations. The mean values of 0.57 and 0.61 for both thanatotores represents a very high value of E; a value of 0.63 would be obtained if individuals were distributed according to MacArthur's broken stick model. The high values of E cannot be due to mixing of different populations unless one of the populations being mixed had even a higher value of E (Gibson and Buzas, 1973).

Thanatotope E has an inferred depth of about 3000 m and the samples from the Gulf of Mexico in the range of 2560 to 3251 m have strikingly similar values.

We conclude that the pattern of species diversity observed for the inferred depth ranges of the thanatotores are entirely in keeping with what one could expect from observations on modern populations.

**PLANKTONIC FORAMINIFERA.**—The percentage of planktonic foraminifera in a sample has been used by many workers as a crude indicator of depth (Grimsdale and Morkhoven, 1955; Phleger, 1960; Vella, 1962a; Boltovskoy and Wright, 1976). In present day oceanic sediments, planktonic foraminifera increase in abundance with distance from shore, and this usually parallels increasing depth.

Lewis (1971) studied present-day sediments off the east coast of the North Island of New Zealand, south of Hawkes Bay. He found 0%–50% plank-

TABLE 3.—Number of species (S), information function (H), and evenness (E) for thanatotoxes A through E, and modern samples from the northeastern Gulf of Mexico (see text for explanation)

	Depth (m)		Thanatotope (inferred depth in m)	
	mean	o.r.	mean	o.r.
	0-50		A 0-50	
S	39.89	27 - 58	38.20	30 - 51
H	2.74	2.06 - 3.18	1.97	1.46 - 2.77
E	.40	.29 - .51	.20	.14 - .31
	50-200		B 50-200	
S	66.82	36 - 79	55.00	39 - 78
H	3.41	2.14 - 3.74	3.15	2.63 - 3.68
E	.46	.23 - .56	.44	.35 - .52
	200-1000		C 200-1000	
S	70.82	64 - 87	64.14	55 - 84
H	3.31	2.86 - 3.75	3.56	3.20 - 4.03
E	.39	.26 - .49	.57	.38 - .69
	150-2000		D 150-2000	
S	73.37	64 - 91	61.65	39 - 84
H	3.40	2.86 - 3.93	3.60	3.60 - 4.02
E	.44	.26 - .71	.61	.48 - .69
	2560-3251		E about 3000	
S	51.33	35 - 88	56.75	55 - 59
H	3.10	2.99 - 3.67	3.25	3.09 - 3.40
E	.45	.35 - .52	.46	.39 - .55

tonics in neritic thanatotoxes and generally 60%–90% planktonics in bathyal thanatotoxes. Thompson (1975) observed a consistent increase in the planktonic percentage in sediments with increasing depth across the continental shelf, east of Northland, New Zealand. Vella (1962a) defined two deep-water biofacies based on their high planktonic content: semipelagic biofacies (600–1200 m), 40%–60% planktonics; eupelagic facies (1200–4000 m), 70%–100% planktonics. Vella noted, however, that high percentages of planktonics sometimes occur in shallow water and may be due to lengthy periods

of onshore winds, such as occur on the west coast of New Zealand. Pflum and Frerichs (1976) summarize data from the Gulf of Mexico that show fewer than 50% planktonics in the neritic, 50% to 90% in the upper bathyal (200–1000 m) and more than 90% in the mid and lower bathyal (1000–4000 m).

In this study, thanatotope A has the fewest planktonic foraminifera and E the most. If the planktonic percentage of each sample is plotted on the multidimensional scaling configuration (Figure 22), there is a definite overall increase in plank-

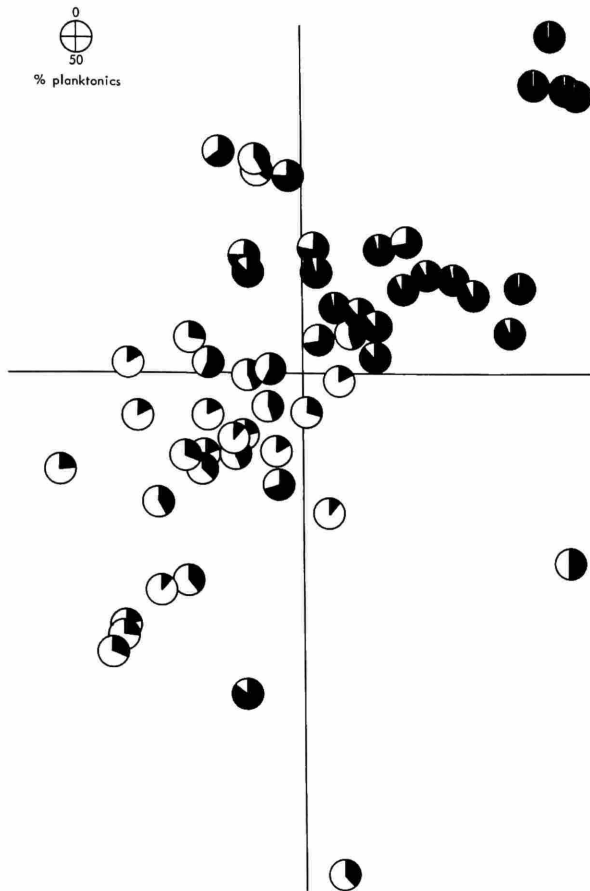


FIGURE 22.—Planktonic percentage of total foraminiferal fauna for each sample plotted on the multidimensional scaling configuration (Figures 7, 9). The inferred shallow water samples in the bottom left quadrant have smaller planktonic percentages than the inferred deepest (lower bathyal) samples in the upper right.

tonics from bottom left to upper right. This "SW-NE" axis is interpreted as one of increasing depth. Thanatotope A is the shallowest thanatotope followed by B and F, then with steadily increasing depth C, D, and lastly E. The average planktonic percentage of samples in A, B, and F is less than 40%. Using the data of Vella (1962a), Lewis (1971), and Thompson (1975), we conclude that these three thanatopes are neritic. The planktonic percentages of samples in C and the lower left (shallower) samples of D are mostly 40%–75%, not inconsistent with a depth interpretation of upper bathyal (200–1000 m). The upper right (deeper) samples in D are mostly 85%–99% planktonics and are possibly midbathyal

(1000–2000 m). The consistent 99.5% planktonics in E is consistent with a depth similar to that at their present position in the New Caledonia basin (3000 m, lower bathyal).

**MACROFAUNA.**—Rich macrofaunas are absent from all thanatotope A, C, E, and F samples, as well as ungrouped samples N33/f579 and N41/f632.

Thanatotope B samples from Pakaurangi Point (Pakaurangi Formation—Figure 5) come from richly microfossiliferous beds, from which Jones (1970) concluded an environment of warm (23°–27° C) marine waters at depths varying from 20 to 250 m (mostly midneritic). These depths are compatible with those we inferred from the foraminifera (50–200 m, Table 4).

Most thanatotope D faunas are from non-microfossiliferous sediments, but four of the samples from the north Waitakere Hills (N41/f2d, f590u, f590n, and f592) come from sediments containing sparse macrofaunas (Hayward, 1976b). These faunas are typical deepwater assemblages and contain several bathyal-restricted genera of gastropod, bivalve, and ahermatypic coral (Hayward, 1976b) and have been interpreted on the basis of these, together with the more definitive benthic foraminifera, as midbathyal (Hayward, 1976a, 1976b).

The two ungrouped samples, N41/f539 and f555, have rich macrofaunas (Hayward, 1976b, 1977c, 1977d). Like the microfaunas, these macrofaunas are greatly mixed and derived from the same wide range of thanatopes, with members from inner neritic hermatypic coral banks and gravels, midneritic sands, and bathyal sands and silts (Hayward, 1976b). These mixed macrofaunas lend support to the subaqueous mass flow origin already proposed for Waitakere Hills Group 2 samples.

**PREVIOUS DEPTH INTERPRETATIONS.**—Depth interpretations for thanatopes based upon their benthic foraminifera and supported by their benthic species diversities and planktonic content are summarised in Table 4 and shown as a general deepening trend towards the upper right on the multidimensional scaling configuration (Figure 23).

Traditional models of the Waitemata Basin (thanatotope D) envisaged it as a shallow basin or lagoon (Bartrum, 1929; Brothers, 1954; Searle, 1964). A limited study of the benthic foraminifera in three samples from Muriwai, north Waitakere Hills (Bandy, et al., 1970), indicated that basin

TABLE 4.—Inferred depth zones for thanatotope A through F and ungrouped samples

Thanatotope	Depth zones	Depth range
A	inner neritic	0 - 50 m
B	outer neritic	50 - 200 m
C	upper bathyal	200 - 1000 m
1. shallow samples (f578, f580, f581)	uppermost bathyal	200 - 400 m
2. deeper samples (f622, f644, f696, f723)	lower upper bathyal	800 - 1000 m
D	upper-mid bathyal	200 - 2000 m
1. shallow samples (f534, f536)	uppermost bathyal	200 - 500 m
2. deeper samples (remainder)	mid-bathyal	1000 - 2000 m
E	lower bathyal	3000 m
F	inner-mid neritic	20 - 100 m
1. shallower samples (f694, f914)	inner neritic	20 - 50 m
2. deeper sample (f912)	mid neritic	50 - 100 m
Ungrouped		
1. f579	uppermost bathyal	150 - 400 m
2. f539, f555, f632	inner neritic - mid bathyal	greatly mixed

depths could have been far greater than originally thought. Bandy, et al., concluded depths of greater than 2000 m for one sample and 200–500 m for the other two. Considering their small faunas, these depths are not substantially different from our 1000–2000 m interpretation for the same sequence (N41/f590n, f590u, f604—thanatotope D). The basin depths of 700–2000 m, deduced from turbidity current models (Ballance, 1974), are extremely close to ours.

Although nine of our samples were splits of Scott's (1970a) processed samples, percentage histograms of the common species differ greatly between the two studies. Undoubtedly this difference can be explained in that Scott's counts are of large individuals ( $\geq 0.152$  mm) and our counts include individuals down to half this size ( $\geq 0.075$  mm). Despite these differences and different methods used in analysis, the two studies concur on a three-fold division of the samples (although Scott's study divided one of these three groupings into four smaller clusters). These divisions are as follows.

1. N28/f781 cluster with our thanatotope A (inner neritic) and Scott's A5 ("near-shoal"). Both interpretations agree upon a coarse sediment, shallow environment.

2. N33/f534 and f536 clustered with our thanatotope D (shallow samples, uppermost bathyal) and Scott's A4 ("back-shoal"). Environmental interpretation of these two samples differs greatly. We consider that a "back-shoal" lagoonal-type of environment is highly unlikely because of their planktonic content, their similarity to our deeper-water thanatotope D samples, and the rarity of the most abundant species (*Cassidulina laevigata*) in such shallow environments today.

3. Six samples (N28/f785, f788, f792, f793; N33/f531, f532) clustered in our thanatotope B (outer neritic) but occur scattered through Scott's A1, A2, A3, and ungrouped ("fore-shoal" and "outer shelf"). Scott's interpretation of these thanatotoxes as down-slope away from his "shoal," and possibly laterally contiguous, is compatible with our broader outer neritic interpretation.

### Paleogeography

The spatial distribution of thanatotoxes (Figure 24) suggests the former presence (during late Otaian–mid-Altonian) of two areas of shelf separated and bounded to the east by a bathyal basin. Both neritic shelf areas (thanatotoxes A, B, and

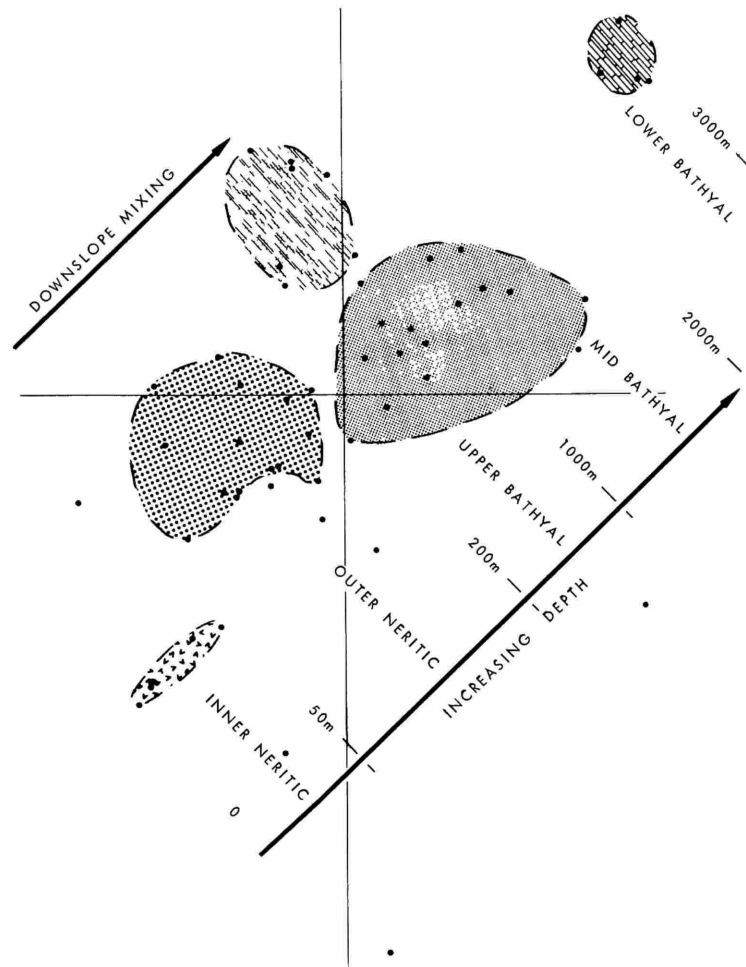


FIGURE 23.—Two-dimensional configuration of samples produced by multidimensional scaling using euclidian distance with thanatotypes A-E shown (as in Figure 9). Paleodepth interpretations based upon the foraminifera are plotted and indicate a general trend of increasing depth towards the upper right. Downslope mixing of the faunas is most noticeable in the outer neritic and upper bathyal zones.

F) are separated from the midbathyal basin (thanatotope D) by an upper bathyal zone (thanatotope C). This distribution pattern is compatible with the traditional paleogeographic model of a flysch basin bounded to the north and west by the Waitakere arc (Searle, 1964; Ballance, 1965, 1974).

Using the depth interpretations of the benthic foraminiferal thanatotypes, together with stratigraphic, lithologic, paleocurrent, and macrofaunal data, a more precise picture of the paleogeography along the western side of the Waitemata Basin can be obtained.

The elongate Waitemata flysch basin was 50–80

km wide and 100–150 km long, bounded to the east by the central basement high (Figures 2, 25) and to the west by the Waitakere volcanic pile. In the north the basin lapped onto the southern end of the northern landmass (Figure 2), forming a marine shelf through which the Kaipara center of the Waitakere Volcanic Arc was erupting (Figure 25). Sediment derived from the basement high and northwestern shelf flowed southeast into the basin via submarine canyons and channels (Ballance, 1974; Hayward, 1975a). This sediment was mostly transported as turbidites, which accumulated in the basin at midbathyal depths of 1000–2000 m (as



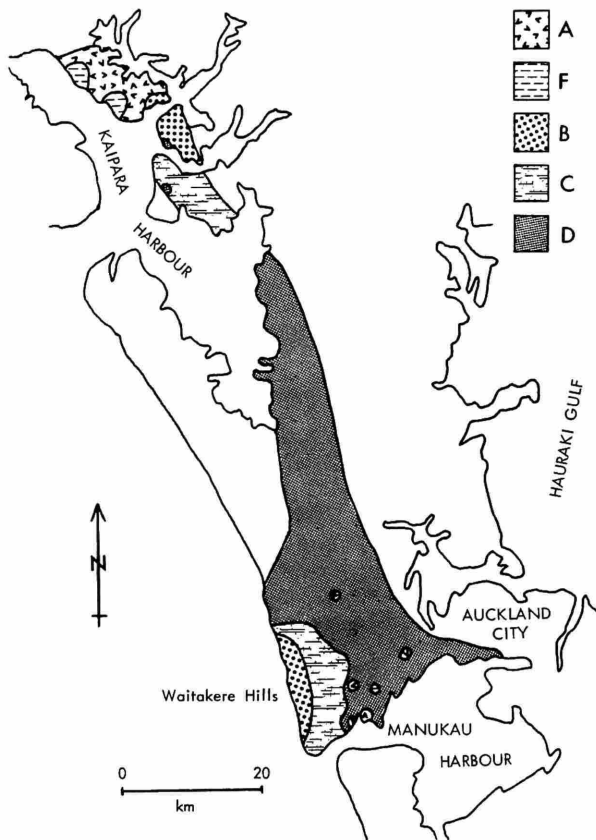


FIGURE 24.—Generalized distribution of thanatotope in southern Northland based upon the sample studies.

indicated by thanatotope D faunas in the interturbidite sediments, e.g., N42/f683), having travelled up to 100 km down an average submarine slope of  $0.6^{\circ}$ – $1.2^{\circ}$ . A fan built up around the base of the canyons that arose on the northwestern shelf, and conglomerates (Albany and Helensville Conglomerates) accumulated in the lower canyons and channels of the upper fan.

Coarse subaqueous sediment gravity flow deposits occur sporadically within the basin flysch sequence, especially in the west and northwest. From the lithologies of the larger clasts it can be deduced that some flowed down the canyons from the northwestern shelf, whereas other (containing solely andesitic material) came down the slopes of the Waitakere volcanic pile. All the Waitakere Hills Group 2 samples have shallow or mixed benthic foraminiferal faunas and were probably displaced downslope in sediment gravity flows. Samples derived from the

northwestern shelf include N42/f694 (thanatotope F) N41/f533, f537, f657 (thanatotope A) and N41/f539, f632 (ungrouped, mixed neritic-bathyal). N41/f555 (ungrouped, mixed neritic-bathyal) probably came from the Waitakere volcanic pile, as it contains andesite boulders up to 2 m across and no Cretaceous or early Tertiary sedimentary clasts typical of the northwestern shelf.

The Waitemata Basin was bordered to the southwest by the submarine pile of the Waitakere volcanic centre. This was composed of coarse volcanoclastic sediments and pillow lavas (Piha Formation) margined by finer grained volcanic sediments (Nihotupu Formation) that graded eastwards into the basin flysch. The presence of aerially erupted tephra and inner neritic hermatypic corals in sediment gravity flows on the pile's flanks (e.g., N41/f555, f567; Hayward, 1977a, 1977c, 1977e) indicate that shallow water and volcanic islands were present (Figure 25). Only a single microfossiliferous sample (N41/f660, thanatotope B) was obtained from the Piha Formation and this is consistent with inferred neritic to upper bathyal (0–800 m) depths of deposition for the pile slopes. Samples from the finer grained sediments of the Nihotupu Formation (Waitakere Hills Group 1) all cluster in the deeper halves of thanatotope C and D (Table 4) and are interpreted as lowermost upper bathyal–midbathyal (800–2000 m). Stratigraphically, a slight shallowing on the eastern flanks of the pile could be inferred to have occurred in early Altonian times, on the basis of the three youngest samples all belonging to thanatotope C (Figure 26). On the northern slopes, however, no shallowing is indicated until later mid-Altonian times, when fault movement, submarine channel erosion and eruption of nearby subaerial vents occurred (Hayward, 1977a). This mid-Altonian shallowing was general over the whole Waitakere Hills area, as the volcanic pile's marine sediments are conformably overlain in many places by terrestrial andesite flows and pyroclastics (Hayward, 1977e).

In the late Otaian–early Altonian times, a northwestern neritic shelf existed in the area of present-day central Kaipara. This shelf was underlain by uplifted Cretaceous–lower Tertiary sediments and some bathyal lower Miocene sediments (Waitemata Group, Puriri and Timber Bay Formations). Samples from the lowest shelf sediments (Okahukura and Pakaurangi Formations) in the outcrop area



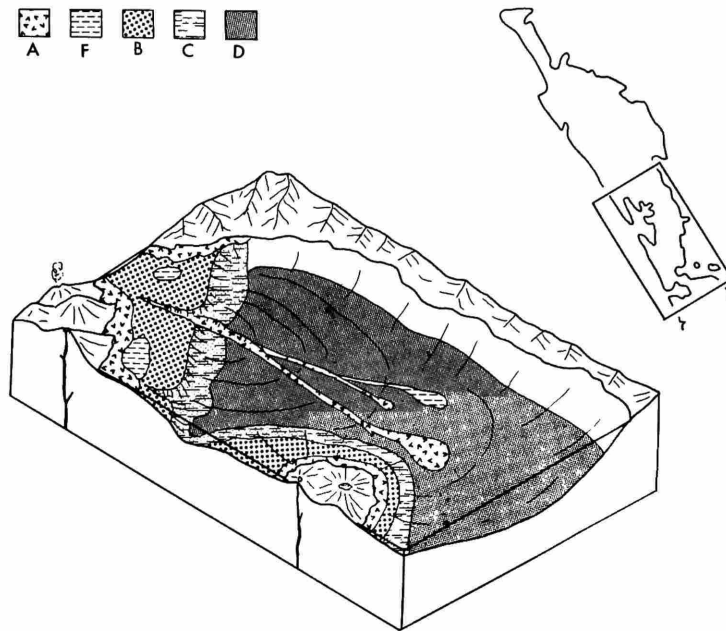


FIGURE 25.—Interpretation of the paleogeography of southern Northland in the late Otaian-early Altonian showing thanatotope distribution. The elongate, bathyal (thanatotope D), Waitemata Basin covered the central area, bounded to the east by a basement high landmass. The basin was bounded in the southwest by the Waitakere volcanic pile (thanatopes A, B, C) and in the northwest by a neritic shelf (thanatopes A, B, F) with associated Kaipara volcanic centre. Submarine canyons channelled subaqueous sediment gravity flows (containing thanatopes A and F) from the north-western shelf down into the Waitemata Basin.

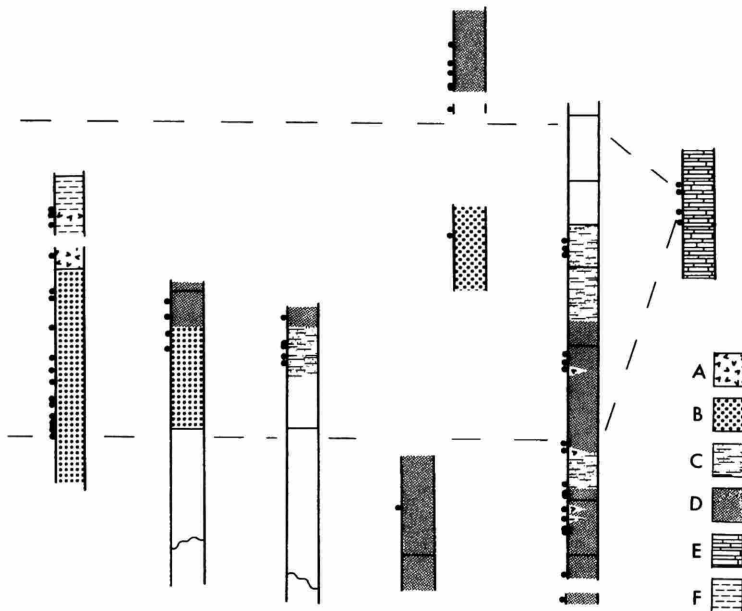


FIGURE 26.—Lithostratigraphic columns (Figure 5), showing distribution of thanatopes, both spatially and temporally.

cluster in thanatopes B, C, and D, indicating uppermost bathyal–outer neritic depths (50–500 m, Table 4). The deeper samples (shallow parts of thanatopes C and D, and ungrouped N33/f579, uppermost bathyal) occur in the southern two peninsulas (Figure 26), with a shallowing towards the north where all the outer neritic thanatope B samples occur. This shelf was not stable, as indicated by numerous sediment wedges, unconformities, and by the changing foraminiferal thanatopes.

Activity of the Kaipara centre of the Waitakere Volcanic Arc advanced eastwards into the outcrop area in late early Altonian period (Figure 25) and may have been associated with the general shallowing indicated by the thanatopes and lithologies of the youngest (lower Altonian) sediments of the Waitakere Group in this area (Puketi Formation, undifferentiated Hukatere Subgroup, Figure 26). The sediments are mostly inner neritic (0–50 m, thanatopes A and F), with some midneritic (50–100 m, thanatope F) and some terrestrial deposits.

### Systematics

This section catalogues all the benthic foraminiferal taxa identified during the faunal analysis of the 55 samples, together with a few extra species identified from less fossiliferous samples from the Waitakere Hills. The location of these additional samples is given in Appendix B.

The holotypes and some paratypes of the three new species described are deposited in the New Zealand Geological Survey, Lower Hutt (TF numbers); paratypes of these three new species are also deposited in the Geology Department, University of Auckland (F numbers), and the National Museum of Natural History, Smithsonian Institution, Washington, D. C. (USNM number = catalog numbers using the abbreviation for the former United States National Museum). All other figured specimens are deposited in the National Museum of Natural History (USNM numbers).

In this section the genera are listed alphabetically under the three suborder headings Textulariina, Miliolina, and Rotaliina.

Taxonomic work on the benthic foraminifera from the Waitemata and Waitakere Groups was initiated by Karrer (1864) using the fauna in a single

sample from the central part of the Waitemata Basin at Orakei Bay, Auckland. Hornibrook (1971) recently revised Karrer's work and reduced the number of recognized species with Orakei Bay type localities to 17. Finlay (1939b, c, 1940) and Hornibrook (1958) described five new species with type-localities at Pakaurangi Point, Pakaurangi Formation (*Bolivina lapsus* Finlay, *Cancris brevior* Finlay, *Cerobertina bartrumi* Finlay, *Discorbis galerus* Finlay, *Loxostomum pakaurangiensis* Hornibrook), and one new species with a type-locality in the Waitemata Group, Waiheke Island (*Notorotalia powelli* Finlay).

Faunas from these two groups have been listed by several workers: Chapman (1926) from Orakei Bay and Titirangi (Waitemata Group) and Pakaurangi Point (Pakaurangi Formation); Finlay (in Searle, 1944) from the north side of Manukau Harbour (Waitemata Group); Hornibrook and Schofield (1963) from the southern part of Waitemata Basin, south of Auckland; Jones (1970) from Pakaurangi Point (Pakaurangi and Puketi Formations).

### Order FORAMINIFERIDA Eichwald, 1830

#### Suborder TEXTULARIINA Delage and Hérouard, 1896

##### *Ammodiscus archimedis* (Stache)

*Cornuspira archimedis* Stache, 1864:180, pl. 22: figs. 1a,b.  
*Ammodiscus archimedis* (Stache).—Hornibrook, 1971:30, pl. 5: figs. 72–74.

DISTRIBUTION.—One specimen in N41/f612. Cornwallis Formation.

##### *Ammodiscus finlayi* Parr

PLATE 1: FIGURE 7

*Ammodiscus finlayi* Parr, 1935:80, pl. 19: figs. 5, 6.

DISTRIBUTION.—Four specimens in N41/f612. Cornwallis Formation.

##### *Arenodosaria antipoda* (Stache)

*Clavulina antipodum* Stache, 1864:161, pl. 21: figs. 3–8.  
*Arenodosaria antipoda* (Stache).—Hornibrook, 1971:32, pl. 5: figs. 77, 78.

DISTRIBUTION.—One specimen in N41/f555, Nihotupu Formation.

***Bathysiphon* species**

PLATE 1: FIGURE 8

DISTRIBUTION.—Rare in thanatotope D. Nihotupu Formation.

***Bolivinopsis compta* Finlay**

*Bolivinopsis compta* Finlay, 1947:262, pl. 1: fig. 8–12.—Hornibrook, 1968:48, fig. 6.

DISTRIBUTION.—Rare in thanatotopes B, D, and E. Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

***Bolivinopsis cubensis* (Cushman and Bermudez)**

*Spiroplectoides cubensis* Cushman and Bermudez, 1937:13, pl. 1: figs. 44, 45.

*Bolivinopsis cubensis* (Cushman and Bermudez).—Hornibrook, 1961:15, pl. 1: fig. 1.

DISTRIBUTION.—Rare in thanatotopes A, B, and F. Cornwallis Formation, Pakaurangi Formation.

***Bolivinopsis* species**

PLATE 1: FIGURE 12

DESCRIPTION.—Early portion planispiral, later uncoiled and biserial; sutures with raised, strong ribs; spiral sutural rib with radial sutural rib branches, continuing as medial rib with alternate sutural ribs in biserial portion; early portion of coil occurs in a wide depression surrounded by spiral rib.

DISCUSSION.—This form differs from all described species in its distinctive sutural ribs. It is represented by four juvenile or broken specimens, insufficient material for a new species.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Cyclammia incisa* (Stache)**

*Haplophragmium incisum* Stache, 1864:165, pl. 21: fig. 1.

*Cyclammia incisa* (Stache).—Hornibrook, 1971:34, pl. 6: figs. 88–91.—Quilty, 1974:33, pl. 1: figs. 1–3.

DISTRIBUTION.—One specimen in N41/f555. Nihotupu Formation.

***Dorothia minima* (Karrer)**

*Textularia minima* Karrer, 1864:79, pl. 16: fig. 9.

*Dorothia minima* (Karrer).—Hornibrook, 1961:28, pl. 2: fig. 27; 1971:16, pl. 1: figs. 16–20.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

***Eggerella bradyi* (Cushman)**

*Verneuilina pygmaea* (Egger).—Brady, 1884:385, pl. 47: figs. 4–7.

*Verneuilina bradyi* Cushman, 1911:54.

*Eggerella bradyi* (Cushman).—Gibson, 1967:11, pl. 2: fig. 21.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Eggerella ihungia* Finlay**

*Eggerella ihungia* Finlay, 1940:450, pl. 62: figs. 11–13.

DISTRIBUTION.—Extremely rare in thanatotope C. Nihotupu Formation.

***Gaudryina convexa* (Karrer)**

*Textularia convexa* Karrer, 1864:78, pl. 16: fig. 8.

*Gaudryina convexa* (Karrer).—Hornibrook, 1971:16, pl. 1: figs. 8–15.—Quilty, 1974: pl. 1, figs. 14, 15.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

***Gaudryina healyi* Finlay**

*Gaudryina healyi* Finlay, 1939c:311, pl. 25: figs. 34, 35.

DISTRIBUTION.—One specimen in N41/f645, Nihotupu Formation. Possibly reworked from Cretaceous strata.

***Gaudryina quadrazea* Hornibrook**

*Gaudryina quadrazea* Hornibrook, 1961:25, pl. 2: figs. 22, 28.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation.

***Gaudryina whangaia* Finlay**

*Gaudryina whangaia* Finlay, 1939:311, pl. 25: figs. 29–31.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation. Possibly reworked from Cretaceous strata.

***Glomospira corona* Cushman and Jarvis**

*Glomospira charoides* var. *corona* Cushman and Jarvis, 1928: 89, pl. 12: figs. 9–11.

*Glomospira corona* Cushman and Jarvis.—Hornibrook, 1968: 42, fig. 4.

DISTRIBUTION.—Rare in thanatopes A and F. Cornwallis Formation. Nihotupu Formation. Probably reworked from Cretaceous and lower Tertiary strata.

***Haeslerella decepta* Hornibrook**

*Haeslerella decepta* Hornibrook, 1961:21, pl. 2: fig. 30.

DISTRIBUTION.—Extremely rare in thanatope C. Nihotupu Formation.

***Haeslerella hectori* Finlay**

*Haeslerella hectori* Finlay, 1939c:310, pl. 24: fig. 11, 12, 20.—Hornibrook, 1961:20, pl. 2: fig. 31; 1968:94, fig. 18.

DISTRIBUTION.—Extremely rare in thanatope D. Cornwallis Formation.

***Haeslerella pukeuriensis* Parr**

*Haeslerella pukeuriensis* Parr, 1935:83, pl. 19: figs. 7a, b.—Hornibrook, 1961:21, pl. 2: figs. 32, 33; 1968:94, fig. 18.

DISTRIBUTION.—Rare in thanatopes B, C, and D. Pakaurangi Formation.

***Karrieriella bradyi* (Cushman)**

*Quadryina pupoides* d'Orbigny.—Brady, 1884:373, pl. 46: figs. 1–4.

*Gaudryina bradyi* Cushman, 1911:67, text fig. 107.

*Karrieriella bradyi* (Cushman).—Hornibrook, 1961:28.

DISTRIBUTION.—Extremely rare in thanatope E. DSDP.

***Martinotiella communis* (d'Orbigny)**

PLATE 1: FIGURE 9, 10

*Clavulina communis* d'Orbigny, 1846:196, pl. 12: figs. 1–2.

*Martinotiella communis* (d'Orbigny).—Hornibrook, 1961:29, pl. 27: fig. 536.

DISTRIBUTION.—Rare in thanatopes B, C, and D. Cornwallis Formation, Pakaurangi Formation.

***Martinotiella* species**

PLATE 1: FIGURE 11

DESCRIPTION.—Test coarsely agglutinated with additional irregularly arranged spicules.

DISTRIBUTION.—Extremely rare in thanatope E. DSDP.

***Pelosina complanata* Franke**

PLATE 2: FIGURE 13

*Pelosina complanata* Franke, 1912:107, pl. 3: fig. 1.

DISTRIBUTION.—Extremely rare in thanatope A. Cornwallis Formation, Nihotupu Formation. Probably reworked from Cretaceous or lower Tertiary strata.

***Recurvoides* species**

PLATE 2: FIGURE 14

DESCRIPTION.—Subglobular test, smoothly arenaceous; streptospiral, with 6–7 chambers per whorl; sutures distinct; flush; small, indistinct areal aperture with lip.

DISTRIBUTION.—Extremely rare. Three specimens in N41/f632, Nihotupu Formation.

***Rzehakina epigona* (Rzehak)**

*Silicina epigona* Rzehak, 1895:214, pl. 6: fig. 1.

*Rzehakina epigona* (Rzehak).—Scott, 1961:21: figs. 10–23.—Hornibrook, 1968:42, fig. 4.

DISTRIBUTION.—Rare in thanatopes A, B, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group. Probably reworked from Cretaceous and lower Tertiary strata.

***Semivulvulina capitata* (Stache)**

PLATE 2: FIGURES 15, 16

*Textilaria capitata* Stache, 1864:270, pl. 24: figs. 19a–c.

*Vulvulina* (*Semivulvulina*) *capitata* (Stache).—Hornibrook, 1971:31, pl. 5: fig. 76.

*Semivulvulina capitata* (Stache).—Quilty, 1974:37, pl. 1: fig. 11.

DISTRIBUTION.—Frequent in thanatope C, extremely rare in thanatope D. Nihotupu Formation, Pakaurangi Formation.

*Siphotextularia awamoana* Finlay

*Siphotextularia awamoana* Finlay, 1939b:91, pl. 14: figs. 89, 90.  
—Hornibrook, 1961:22, pl. 1: figs. 11, 12; 1968:68, fig. 12.—  
Gibson, 1967:9, pl. 1: figs. 14–16.

DISTRIBUTION.—Extremely rare in thanatopes C and F. Nihotupu Formation, undifferentiated Hukatere Subgroup.

*Textularia awamoana* Hornibrook

*Textularia awamoana* Hornibrook, 1961:18, pl. 1: figs. 8, 9.

DISTRIBUTION.—Rare in thanatopes B, C, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, DSDP.

*Textularia hayi* Karrer

*Textularia hayi* Karrer, 1864:78, pl. 16: fig. 7.  
*Textularia hayi* Karrer.—Hornibrook, 1971:15, pl. 1: figs. 1–7.

DISTRIBUTION.—Rare in thanatopes C and D. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Textularia miozea* Finlay

*Textularia miozea* Finlay, 1939a:509; 1947:266, pl. 2: figs. 18–20.—Hornibrook, 1961:17, pl. 1: fig. 15; 1968:72, fig. 13.  
—Gibson, 1967:8, pl. 1: figs. 3, 4.

DISTRIBUTION.—Extremely rare in thanatopes C and D. Nihotupu Formation, Waitemata Group.

*Textularia ototara* Hornibrook

*Textularia ototara* Hornibrook, 1961:17, pl. 1: figs. 6, 10.

DISTRIBUTION.—Extremely rare in thanatope B. Pakaurangi Formation.

*Textularia saggitula* Defrance

*Textularia saggitula* Defrance, 1824:177.—Brady, 1884:361, pl. 17: figs. 17, 18.

DISTRIBUTION.—Extremely rare in thanatope E. DSDP.

*Triplasia marwicki* Loeblich and Tappan

PLATE 2: FIGURE 17

*Triplasia marwicki* Loeblich and Tappan, 1952:46, pl. 8: figs. 2–4.

DISTRIBUTION.—Extremely rare in thanatope C. Nihotupu Formation.

*Tritaxilina languida* Finlay

*Tritaxilina languida* Finlay, 1939b:98, pl. 37: figs. 37–39.

DISTRIBUTION.—One specimen in N42/f733. Cornwallis Formation. Possibly reworked from lower Tertiary strata.

*Trochammina* species

DESCRIPTION.—Test trochospiral, finely agglutinated; 12–13 chambers per whorl; sutures curved, slightly depressed; interiomarginal aperture.

DISTRIBUTION.—Extremely rare in thanatope B. Pakaurangi Formation.

*Vulvulina pennatula* (Batsch)

*Nautilus* (*Orthoceras*) *pennatula* Batsch, 1791:3, 5, pl. 4, figs. 13a–e.

*Bigenenerina pennatula* (Batsch).—Brady, 1884:373, pl. 45, figs. 5–8.

*Vulvulina pennatula* (Batsch).—Hornibrook, 1961:24.

DISTRIBUTION.—Extremely rare in thanatope E. DSDP.

## Suborder MILIOLINA Delage and Hérouard, 1896

*Articulina parri* Cushman

PLATE 2: FIGURES 18–21

*Articulina parri* Cushman, 1944:10, pl. 3: figs. 7–10.

DESCRIPTION.—Early portion quinqueloculine, adult with one and rarely two rectilinear chambers; quinqueloculine chambers slightly elongate with broadly rounded periphery; rectilinear chambers oval in section, compressed towards aperture; ornament of longitudinal costae; aperture terminal, elongate elliptical, with distinct, slightly flaring lip.

DISCUSSION.—This is the first New Zealand record of *Articulina parri* Cushman; previously known only from the Miocene of Australia. The species is distinguished by its elongate aperture, strong costae and broadly rounded early chambers. Unbroken adult specimens are rare; most individuals lack the rectilinear chambers or consist of broken portions.

DISTRIBUTION.—Extremely rare in thanatotoxes B, C, D, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Lachlanella* cf. *L. schroekingeri* (Karrer)

PLATE 2: FIGURES 22, 23

DISCUSSION.—Specimens in this study are similar to those figured as *Quinqueloculina schroekingerii* Karrer (1868:149, pl. 2: fig. 12) and as *Lachlanella schroekingeri* (Karrer) by Luczkowska (1974:94, pl. 10: figs. 4a-c).

DISTRIBUTION.—Frequent in thanatotope F, rare in thanatotoxes A, B, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Pyrgo anomala* (Schlumberger)

PLATE 2: FIGURE 24

*Biloculina anomala* Schlumberger, 1891:182, pl. 11: figs. 84-86.—Vella, 1957:29, pl. 7: figs. 135, 136.—Gibson, 1967:18.

DISTRIBUTION.—Frequent in thanatotope F, rare in thanatotoxes B and D. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Pyrgo depressa* (d'Orbigny)

PLATE 2: FIGURE 25

*Biloculina depressa* d'Orbigny, 1826:298, no. 7, "Modèle, No." 91.

*Pyrgo depressa* (d'Orbigny).—Vella, 1957:29, pl. 7: figs. 137, 140.

DISTRIBUTION.—Extremely rare in thanatotoxes B and D. Pakaurangi Formation.

*Pyrgo* cf. *P. lucernula* (Schwager)

PLATE 3: FIGURE 26

DISCUSSION.—Several specimens of *Pyrgo* are most similar to *Pyrgo lucernula* (Schwager) (as *Biloculina lucernula*, 1866:202, pl. 4: fig. 17a, b; and as *Pyrgo lucernula* (Schwager), Barker, 1960, pl. 3: figs. 6, 14).

DISTRIBUTION.—Extremely rare in thanatotope F. Undifferentiated Hukatere Subgroup.

*Quinqueloculina angulostriata* Cushman and Valentine

PLATE 3: FIGURES 27, 28

*Quinqueloculina angulostriata* Cushman and Valentine, 1930:12, pl. 2: figs. 5a-c.—Quilty, 1974:49, pl. 2: figs. 41, 42.

DISTRIBUTION.—Abundant in thanatotope F, frequent in thanatotoxes A, B and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Quinqueloculina* cf. *Q. buchiana* d'Orbigny

PLATES 3: FIGURES 29-31

DISCUSSION.—Many *Quinqueloculina* specimens are most similar to *Quinqueloculina buchiana* d'Orbigny (1846:289, pl. 18: figs. 10-12).

DISTRIBUTION.—Frequent in thanatotope F, rare in thanatotoxes A, B, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, DSDP.

*Quinqueloculina plana* d'Orbigny

PLATE 3: FIGURES 32, 33

*Quinqueloculina plana* d'Orbigny, 1850:409.—Fornasini, 1905:64, pl. 2: fig. 11.

DISTRIBUTION.—Common in thanatotope F, frequent in thanatotope D, rare in thanatotoxes A and B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Quinqueloculina seminula* (Linnaeus)

PLATE 3: FIGURE 34

*Serpula seminulum* Linnaeus, 1758:786, pl. 2: figs. 1a-c.  
*Miliolina seminulum* (Linnaeus).—Brady, 1884, pl. 5: fig. 6.

*Quinqueloculina seminulum* (Linnaeus).—Quilty, 1974:52, pl. 2: figs. 52, 53.

DISTRIBUTION.—Abundant in thanatotope F, frequent in thanatotope D, rare in thanatotypes B, C, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

### *Quinqueloculina singletoni* Crespin

PLATE 3: FIGURES 35, 36

*Quinqueloculina singletoni* Crespin, 1950:72, pl. 10: fig. 6.

DESCRIPTION.—Test slender, fusiform, about three times longer than broad; periphery rounded; chambers elongate, semicircular in section, covered with strong costae running entire length; aperture circular, terminal on neck.

DISCUSSION.—This is the first New Zealand record of *Quinqueloculina singletoni* Crespin, previously known only from the Eocene of Australia.

### *Sigmoilina victoriensis* Cushman

PLATE 3: FIGURE 37

*Sigmoilina sigmoidea* (Brady) var. *compressa* Cushman, 1946a: 32, pl. 5: figs. 10–12.

*Sigmoilina victoriensis* Cushman, 1946b:103.—Quilty, 1974:55, pl. 2: figs. 65, 66.

*Sigmoilina cushmani* Finlay, 1947:271.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

### *Sigmoilopsis schlumbergeri* (Silvestri)

*Sigmoilina schlumbergeri* Silvestri, 1904:267.

*Sigmoilopsis schlumbergeri* (Silvestri).—Gibson, 1967:15, pl. 2: figs. 30, 37.—Hornibrook, 1968:69, fig. 12.

DISTRIBUTION.—Extremely rare in thanatotypes D and E. Nihotupu Formation, DSDP.

### *Spiroloculina disparilis* Terquem

*Spiroloculina disparilis* Terquem, 1878:85, pl. 5: fig. 12.—Vella, 1957:27, pl. 6: figs. 122, 123.—Hornibrook, 1961:34, pl. 3: fig. 41.

DISTRIBUTION.—Extremely rare in thanatotope F. Undifferentiated Hukatere Subgroup.

### *Spiroloculina excavata* d'Orbigny

PLATE 3: FIGURE 38

*Spiroloculina excavata* d'Orbigny, 1846:271, pl. 16: figs. 19–21.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

### *Spiroloculina torquayensis* Chapman

*Spiroloculina torquayensis* Chapman, 1921:320, pl. 51: figs. 1, 2.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

### *Triloculina oculina* d'Orbigny

*Triloculina oculina* d'Orbigny, 1846:277, pl. 17: figs. 7–9.

DISTRIBUTION.—Extremely rare in thanatotypes B and F. Pakaurangi Formation, undifferentiated Hukatere Subgroup.

### *Triloculina tricarinata* d'Orbigny

*Triloculina tricarinata* d'Orbigny, 1826:299, no. 7, "Modèle No." 94.—Barker, 1960, pl. 3: fig. 17.—Gibson, 1967:18.

DISTRIBUTION.—Rare in thanatotope F, extremely rare in thanatotypes C and E. Cornwallis Formation, Nihotupu Formation, undifferentiated Hukatere Subgroup, DSDP.

### *Triloculina trigonula* (Lamarck)

PLATE 3: FIGURE 39

*Miliolites trigonula* Lamarck, 1804:351, No. 3.

*Triloculina trigonula* (Lamarck).—Barker, 1960, pl. 3: figs. 15, 16.—Hornibrook, 1961, table 6.—Quilty, 1974:59, pl. 2: figs. 80, 81.

DISTRIBUTION.—Frequent in thanatotope F, rare in thanatotope B, extremely rare in thanatotope D. Cornwallis Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

### *Wiesnerella* species

PLATE 3: FIGURE 40

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

**Suborder ROTALIINA**  
**Delage and Hérouard, 1896**

***Alabamina tenuimarginata* (Chapman, Parr  
and Collins)**

PLATE 4: FIGURE 41

*Pulvinulinella tenuimarginata* Chapman, Parr, and Collins, 1934:565, pl. 9: fig. 19.

*Alabamina tenuimarginata* (Chapman, Parr, and Collins, Hornibrook, 1961:123, pl. 17: figs. 365, 366.—Scott, 1970a: fig. 5, no. 4.

DISTRIBUTION.—Common in thanatotypes B and D, frequent in thanatotypes A, C, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

***Allomorphina cubensis* Palmer and Bermudez**

PLATE 4: FIGURE 42

*Allomorphina cubensis* Palmer and Bermudez, 1936:308, pl. 14: figs. 10, 11.—Cushman and Todd, 1949:67, pl. 11: figs. 19, 20.

DESCRIPTION.—Test subglobular to ovoid; three strongly embracing chambers exposed, only small portion of earliest chamber visible; aperture slit with flaring lip.

DISCUSSION.—This is the first New Zealand record of *Allomorphina cubensis* Palmer and Bermudez, previously recorded from the Oligocene of Cuba. This species is very similar to *Chilostomella globata* Gallway and Heminway, from which it differs by its asymmetry and visibility of three instead of two chambers.

DISTRIBUTION.—Extremely rare in thanatotypes A, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Allomorphina pacifica* Cushman and Todd**

PLATE 4: FIGURE 43-45

*Allomorphina pacifica* Cushman and Todd, 1949:68, pl. 12: figs. 6-9.

DESCRIPTION.—Test subtriangular, about two thirds as broad as high; three slightly inflated chambers exposed ventrally; early whorls all visible on flattened dorsal side; walls smooth; aperture a

slit beneath a flap that extends backwards from last chamber towards middle of test on ventral side.

DISCUSSION.—This is the first New Zealand fossil record of *Allomorphina pacifica* Cushman and Todd, previously recorded from the Miocene to Recent of the Indo-Pacific region.

DISTRIBUTION.—Extremely rare in thanatotypes D and E. Nihotupu Formation, DSDP.

***Amphicoryna hirsuta* (d'Orbigny)**

*Nodosaria (Nodosaire) hirsuta* d'Orbigny, 1826:252.

*Nodosaria hirsuta* d'Orbigny.—Brady, 1884:507, pl. 63: fig. 16 [in part.].

*Lagenonodosaria hirsuta* (d'Orbigny).—Hornibrook, 1961:48, pl. 6: fig. 100.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Cornwallis Formation and Nihotupu Formation.

***Amphicoryna nebulosa* (Ishizaki)**

PLATE 4: FIGURE 46

*Lagenonodosaria nebulosa* Ishizaki, 1943:219, pl. 10: figs. 5, 7, 8.

DESCRIPTION.—Test with two to four spherical to slightly elongate chambers; sutures depressed; surface smooth; small lipped aperture on long slender neck.

DISTRIBUTION.—One specimen in N41/f539. Nihotupu Formation.

***Amphicoryna scalaris* (Batsch)**

*Nautilus (Orthoceras) scalaris* Batsch, 1791:4, pl. 2: fig. 4.

*Nodosaria scalaris* (Batsch).—Brady, 1884:510, pl. 63: figs. 28-31.

*Lagenonodosaria scalaris* (Batsch).—Hornibrook, 1961:48, pl. 6: fig. 101.

DISTRIBUTION.—Frequent in thanatotype C, rare in thanatotypes A, B, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, Waitemata Group.

***Amphicoryna scalaris seminuda* (Chapman)**

PLATE 4: FIGURE 47

*Lagenonodosaria scalaris* var. *seminuda* Chapman, 1941:161, pl. 9: fig. 2.



DISCUSSION.—This subspecies differs from typical *Amphicoryna scalaris* in having areas of smooth chamber surface and less distinct costae.

DISTRIBUTION.—Extremely rare in thanatotope A and D. Nihotupu Formation, Puketi Formation.

### *Amphimorphina gagei* Hornibrook

*Amphimorphina gagei* Hornibrook, 1961:83, pl. 12: fig. 249.

DISTRIBUTION.—Extremely rare in thanatotope C and D. Nihotupu Formation.

### *Amphistegina madagascariensis* d'Orbigny

PLATE 4: FIGURES 48, 49

*Amphistegina madagascariensis* d'Orbigny, 1826:304.—Fornasini, 1904:143, pl. 2: fig. 5.—Todd, 1965:34, pl. 11: fig. 3; pl. 12: figs. 1, 2.—Todd, 1976:387.

*Amphistegina aucklandica* Karrer, 1864:85, pl. 16: fig. 19.—Hornibrook, 1971:22, pl. 4: figs. 61–63.

*Amphistegina campbelli* Karrer, 1864, pl. 16: fig. 18.—Hornibrook, 1971:22, pl. 4: figs. 57–60.

DESCRIPTION.—Test involute, compressed to inflated lenticular; raised transparent umbos on both sides; profile symmetric to asymmetric; periphery acutely rounded to slightly keeled; small individuals fragile, commonly with 8–12 chambers per whorl; large individuals robust, commonly with 15–24 chambers per whorl; irregular, radial, limbate lines on both sides; dorsal sutures very strongly recurved; ventral sutures digitate; ventral supplementary chambers slender, curved backward at their outer ends which fail to reach periphery.

DISCUSSION.—*Amphistegina madagascariensis* is a highly variable species (Todd, 1976) characterized by its digitate ventral sutures; slender, curved supplementary chambers; and irregular limbate lines on both sides. Most descriptions attribute this species with an average of 15 chambers per whorl but a study of recent assemblages held in the National Museum of Natural History shows many adults to have 20 or more. The more robust individuals are typical of near-shore sediments (Todd, 1965) and the more fragile individuals are common in present-day deeper environments (Todd, 1976).

*Amphistegina aucklandica* Karrer and *A. campbelli* Karrer are identical to large robust present-day individuals of *A. madagascariensis* and probably

represent Todd's (1965) beach and lagoonal forms respectively.

DISTRIBUTION.—Large, robust individuals: abundant in thanatotope A, rare in thanatotope B and F. Small, fragile individuals: common in thanatotope B, frequent in thanatotope F, extremely rare in thanatotope C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Anomalinoidea alazanensis* (Nuttall)

*Anomalina alazanensis* Nuttall, 1932:32, pl. 8: figs. 5–7.

*Anomalina vitrinoda* Finlay, 1940:458, pl. 65: figs. 120–122.

*Anomalinoidea vitrinoda* (Finlay).—Hornibrook, 1968:70, fig. 12.

*Anomalinoidea alazanensis* (Nuttall).—Douglas, 1973, pl. 19: figs. 6–8; pl. 25: figs. 1, 2.

DISCUSSION.—Examination of the holotype and paratypes of *Anomalina alazanensis* Nuttall (Cushman Collection 16460, 16461) and a paratype of *Anomalina vitrinoda* Finlay (USNM689130) indicates that the two species are conspecific.

DISTRIBUTION.—Extremely rare in thanatotope C and D. Nihotupu Formation.

### *Anomalinoidea awamoana* Hornibrook

*Anomalinoidea awamoana* Hornibrook, 1961:157, pl. 23: figs. 461–463.

DISTRIBUTION.—Rare in thanatotope E, DSDP.

### *Anomalinoidea fasciatus* (Stache)

*Rosalina fasciata* Stache, 1864:281, pl. 24: figs. 31a–c.

*Anomalinoidea fasciatus* (Stache).—Hornibrook, 1961:154, pl. 24: figs. 470–2.—Hornibrook, 1971:50, pl. 11: figs. 194–6.

DISTRIBUTION.—Extremely rare in thanatotope A and B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

### *Anomalinoidea globulosa* (Chapman and Parr)

PLATE 4: FIGURE 50, 51

*Anomalina globulosa* Chapman and Parr, 1937:117, pl. 9: fig. 27.—Barker, 1960, pl. 94: fig. 4.

DESCRIPTION.—Test evolute dorsally, involute ventrally; 6–8 inflated chambers per whorl; sutures

deeply impressed, curved; periphery rounded; ventral side strongly convex; dorsal side flattened; surface deeply pitted on both sides; aperture interiomarginal slit.

DISCUSSION.—This is the first New Zealand fossil record of *Anomalinoidea globulosa* (Chapman and Parr); previously known from Miocene to Recent sediments from various other parts of the world.

DISTRIBUTION.—Extremely rare in thanatotope C. Nihotupu Formation.

### *Anomalinoidea macraglabra* (Finlay)

PLATE 5: FIGURE 52, 53

*Anomalina macraglabra* Finlay, 1940:460, pl. 65: figs. 141–3. *Anomalinoidea macraglabra* (Finlay).—Hornibrook, 1961:155, pl. 24: figs. 473–5.

DISTRIBUTION.—Common in thanatotopes C and D, frequent in thanatotopes B and E, extremely rare in thanatotopes A and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

### *Anomalinoidea parvumbilia* (Finlay)

*Anomalina parvumbilia* Finlay, 1940:461, pl. 65: figs. 157–9. *Anomalinoidea parvumbilia* (Finlay).—Hornibrook, 1961:156, pl. 23: figs. 458–60.

DISTRIBUTION.—Extremely rare in thanatotopes A, B, and D. Cornwallis Formation, Pakaurangi Formation.

### *Anomalinoidea semicibrata* (Beckmann)

PLATE 5: FIGURES 54, 55

*Anomalina pompilioides* var. *semicibrata* Beckmann, 1953:400 pl. 27: fig. 3. *Anomalinoidea semicibrata* (Beckmann).—Douglas, 1973, pl. 14: figs. 1, 2.

DESCRIPTION.—Test involute ventrally, partly evolute dorsally; 5–7 inflated chambers per whorl; sutures slightly depressed, almost radial; periphery broadly rounded; surface smooth on dorsal side, coarsely punctuate on ventral; aperture interiomarginal slit.

DISCUSSION.—This is the first New Zealand fossil record of *Anomalinoidea semicibrata* (Beckmann).

DISTRIBUTION.—Extremely rare in thanatotopes D and E. Cornwallis Formation, Nihotupu Formation, DSDP.

### *Anomalinoidea* species

PLATE 5: FIGURE 56

*Anomalinoidea* sp. 1 Douglas, 1973, pl. 19: figs. 4, 5; pl. 24: figs. 15, 16.

DESCRIPTION.—Test involute ventrally, partly evolute dorsally; 6–8 chambers per whorl sutures slightly depressed, curved; periphery rounded; ventral side greatly inflated, dorsal side flat to concave; early whorls on dorsal side with bead-like pustules; aperture interiomarginal slit with lip on dorsal side.

DISTRIBUTION.—Rare in thanatotope E. DSDP.

### *Astacolus compressus* (Stache)

*Hemirobulina compressa* Stache, 1864:229, pl. 23: figs. 8a, b. *Astacolus compressus* (Stache).—Hornibrook, 1971:41, pl. 8: figs. 132–4.

DISTRIBUTION.—Extremely rare in thanatotopes A, B, and C. Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup.

### *Astacolus insolitus* (Schwager)

PLATE 5: FIGURES 58–60

*Cristellaria insolita* Schwager, 1866:242, pl. 6: fig. 85.

DESCRIPTION.—Test elongate, smooth, consisting of an initial half coil followed by a series of uncoiled, steeply sloping, curved chambers; apertural face about half as high as test; periphery and margins of apertural face acutely rounded; aperture terminal, radiate.

DISCUSSION.—This is the first New Zealand record of *Astacolus insolitus* (Schwager). It differs from other New Zealand species in its more elongate, inflated test.

DISTRIBUTION.—Extremely rare in thanatotopes B, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Astacolus* cf. *A. judyae* Hornibrook

DISCUSSION.—One individual of *Astacolus* is most similar to *Astacolus judyae* Hornibrook (1961:39, pl. 4: figs. 59, 60).

DISTRIBUTION.—Extremely rare in thanatotope A. Undifferentiated Hukatere Subgroup.

*Astacolus neolatus* Vella

*Astacolus neolatus* Vella, 1957:30, pl. 7: figs. 143, 146–8.—Hornibrook, 1961:39, pl. 4: fig. 61.

DISTRIBUTION.—Extremely rare in thanatotypes B, D, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Astrononion fijiensis* Cushman and Edwards

*Astrononion fijiensis* Cushman and Edwards, 1937:35, pl. 3: figs. 15, 16.

*Astrononion (Fijiononion) fijiensis* Cushman and Edwards.—Hornibrook, 1964:338, pl. 1: figs. 1–3.

DISTRIBUTION.—Extremely rare in thanatotypes B and D. Nihotupu Formation, Pakaurangi Formation.

*Astrononion impressum* Hornibrook

*Astrononion impressum* Hornibrook, 1961: 96, pl. 12: figs. 228, 235.

DISTRIBUTION.—Rare in thanatotypes C and D. Cornwallis Formation, Pakaurangi Formation, Nihotupu Formation, Waitemata Group.

*Astrononion parki* Hornibrook

*Astrononion parki* Hornibrook, 1961:95, pl. 12: figs. 230, 237.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Cornwallis Formation, Nihotupu Formation.

*Astrononion pusillum* Hornibrook

*Astrononion pusillum* Hornibrook, 1961:96, pl. 12: figs. 229, 236; 1964:335, pl. 1: fig. 24.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation.

*Astrononion stelligerum* (d'Orbigny)

PLATE 5: FIGURE 57

*Nonionina stelligera* d'Orbigny, 1839c:128, pl. 3: figs. 1, 2.

*Astrononion australe* Cushman and Edwards, 1937:33, pl. 3: figs. 13, 14.

*Astrononion stelligerum* (d'Orbigny).—Cushman and Edwards, 1937:31, pl. 3: fig. 7.—Hornibrook, 1964:334, pl. 1: figs. 5–9, 14–19.—Le Calvez, 1974:37, pl. 9: figs. 1–4.

DESCRIPTION.—Test somewhat compressed, planispiral; periphery broadly rounded, slightly lobulate in adult; 8–10 chambers per whorl; umbilicus distinct, sometimes with slight rim; sutures gently curved, distinctly incised, especially in adult; external tubes, distinct and narrow in early whorls, extending one third of the way along sutures; tubes becoming increasingly plate-like and lance-shaped in adult whorls; tubes having oblique, oval-shaped openings at outer ends, these openings developing into elongate slits along posterior side of plates of adult whorls; primary aperture low arched slit at base of apertural face.

DISCUSSION.—Like most *Astrononion* species, *A. stelligerum* is highly variable in the degree of chamber inflation, test compression, umbilical opening and tube and plate development. Juveniles and adults of this species look distinctly different. In describing *Astrononion australe*, Cushman and Edwards distinguished this species from *A. stelligerum* on the basis of a completely filled umbilical region. Examination of the holotype and paratypes of *A. australe* (Cushman Collection 6653, 23640, 23641) shows the presence of a distinct, depressed umbilicus, and they appear to be identical to Hornibrook's (1964) neotypes of *A. stelligerum* and also to the invalid neotypes of *A. stelligerum* selected by Le Calvez (1974).

This is the first New Zealand Miocene record of *Astrononion stelligerum* (d'Orbigny), it has previously been recorded from Miocene to Recent sediments from many parts of the world.

DISTRIBUTION.—Abundant in thanatotope C, common in thanatotope D, frequent in thanatotope B and F, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

***Astrononion tumidum* Cushman and Edwards**

*Astrononion tumidum* Cushman and Edwards, 1937:33, pl. 3: fig. 17.

*Astrononion (Laminonion) tumidum* (Cushman and Edwards).—Hornibrook, 1964:335, pl. 1: figs. 10–13.

DISTRIBUTION.—Extremely rare in thanatotope D. Cornwallis Formation.

***Bolivina acerosa* Cushman**

PLATE 6: FIGURE 63

*Bolivina acerosa* Cushman, 1936a:54, pl. 8: fig. 1; 1937:94, pl. 12: figs. 11–13.

*Bolivina* cf. *acerosa* Cushman.—Hornibrook, 1961:73, pl. 9: fig. 174.

DISTRIBUTION.—Frequent in thanatotope D, rare in thanatotypes B, C, and E, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, Waitemata Group, DSDP.

***Bolivina aenariensis* (Costa)**

PLATE 6: FIGURES 64, 65

*Brizalina aenariensis* Costa, 1856:297, pl. 15: figs. 1A, B.

*Bolivina aenariensis* (Costa).—Cushman, 1937:105, pl. 12: figs. 21–26.

DISTRIBUTION.—Abundant in thanatotope E. DSDP.

***Bolivina arta* Macfadyen**

*Bolivina arta* Macfadyen, 1931:58, pl. 4: fig. 21.—Cushman, 1937:79, pl. 9: figs. 23–26.

*Bolivina lapsus* Finlay, 1939b:98, pl. 11: fig. 9.—Hornibrook, 1961:73, pl. 10: fig. 184.—Gibson, 1967:34, pl. 8: fig. 130.

DISCUSSION.—Examination of topotypes of *Bolivina arta* Macfadyen (Miocene, Egypt; Cushman Collection 17237, 21792) and a paratype and topotypes of *Bolivina lapsus* Finlay (Miocene, Pakaurangi Point, New Zealand, USNM 689195) indicates that they are conspecific.

DISTRIBUTION.—Frequent in thanatotypes B, C, and D, extremely rare in thanatotope F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

***Bolivina barnwelli* Finlay**

*Bolivina barnwelli* Finlay, 1947:280, pl. 5: figs. 73, 75.—

Gibson, 1967:33, pl. 8: figs. 128, 129, 132, 133, 138.

*Bolivina lutosa* Finlay, 1947:280, pl. 5: figs. 76–79.

DISTRIBUTION.—Rare in thanatotope D, extremely rare in thanatotypes B, C, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Bolivina beyrichi* Reuss**

PLATE 6: FIGURE 66

*Bolivina beyrichi* Reuss, 1851:83, pl. 6: fig. 51.—Cushman, 1937:74, pl. 9: figs. 3–6.—Hornibrook, 1961:72.

DISTRIBUTION.—Extremely rare in thanatotope D. Cornwallis Formation, Nihotupu Formation.

***Bolivina* aff. *B. compacta* Sidebottom**

DISCUSSION.—A number of specimens of *Bolivina* are most similar to *Bolivina robusta* var. *compacta* Sidebottom (1905:15, pl. 3: fig. 7) and *Bolivina compacta* Sidebottom (Cushman, 1937:135, pl. 17: figs. 22–23).

DISTRIBUTION.—Frequent in thanatotope E. DSDP.

***Bolivina decussata* Brady**

*Bolivina decussata* Brady, 1881:58.—1884:423, pl. 53: figs. 12, 13.—Cushman, 1937:125, pl. 16: figs. 7–9.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Bolivina finlayi* Hornibrook**

PLATE 6: FIGURE 67

*Bolivina finlayi* Hornibrook, 1961:75, pl. 9: figs. 169–171.

DISTRIBUTION.—Abundant in thanatotope D, common in thanatotypes B and C, frequent in thanatotope F, extremely rare in thanatotypes A and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

***Bolivina mantaensis* Cushman**

PLATE 6: FIGURES 69, 70

*Bolivina mantaensis* Cushman, 1929b:92, pl. 13: fig. 27; 1937:91, pl. 11: figs. 25, 26.

DESCRIPTION.—Test elongate, somewhat compressed, gently tapered; periphery acutely rounded; sutures strongly oblique, very gently curved, slightly depressed to flush; lower half to two-thirds of test ornamented with distinct longitudinal striae.

DISCUSSION.—This species differs from *Bolivina finlayi* Hornibrook in its almost straight sutures. In form it resembles *Bolivina zedirecta* Finlay, differing by the presence of striae.

DISTRIBUTION.—Frequent in thanatotope B, C, and D, rare in thanatotope A, extremely rare in thanatotope F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemara Group.

***Bolivina* aff. *B. mississippiensis* Cushman**

DISCUSSION.—Several specimens of *Bolivina* are most similar to *Bolivina mississippiensis* Cushman (1922a:92, pl. 15: fig. 5; 1937:69, pl. 8, fig. 16).

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Bolivina mitcheli* Gibson**

PLATE 6: FIGURE 68

*Bolivina mitcheli* Gibson, 1967:34, pl. 8: figs. 136, 137, 139.

DISTRIBUTION.—Rare in N41/f609, N42/f722, N42/f725. Waitemata Group.

***Bolivina plicatella mera* Cushman and Ponton**

PLATE 5: FIGURES 61, 62

*Bolivina plicatella* var. *mera* Cushman and Ponton, 1932:82, pl. 12: fig. 4.—Cushman, 1937:90, pl. 11: figs. 5–8.

DESCRIPTION.—Test small, short, broad, compressed; periphery rounded; sutures sinuate between adult chambers, somewhat obscured by coarse ornamentation; coarsely perforate.

DISCUSSION.—This is the first New Zealand record

of *Bolivina plicatella mera* Cushman and Ponton; it has previously been recorded from the Oligocene and Miocene of the Americas, Europe, North Africa and Guam.

DISTRIBUTION.—Frequent in thanatotope D, extremely rare in thanatotope B and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Bolivina pukeuriensis* Hornibrook**

*Bolivina pukeuriensis* Hornibrook, 1961:76, pl. 9: figs. 172, 173.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

***Bolivina punctatostrata* Kreuzberg**

PLATE 6: FIGURE 71

*Bolivina punctatostrata* Kreuzberg, 1930:278, pl. 20: figs. 5a–c.—Hornibrook, 1968:68, fig. 12.

DISTRIBUTION.—Frequent in thanatotope C, rare in thanatotope D. Nihotupu Formation.

***Bolivina reticulata* Hantken**

PLATE 6: FIGURE 72

*Bolivina reticulata* Hantken, 1875:56, pl. 15: fig. 6.—Cushman, 1937:50, pl. 6: figs. 24–27.

*Bolivina anastomosa* Finlay, 1939c:320, pl. 27: figs. 75–77, 103, 111.—Hornibrook, 1961:72, pl. 10: fig. 188; 1968:63, fig. 10.

*Bolivina anastomosa* Finlay, smooth var.—Hornibrook, 1961:72.

*Bolivina (Latibolivina) reticulata reticulata* Hantken.—Hofmann, 1971:304, fig. 13: nos. 1, 3, 8, 9, 11.

DISCUSSION.—Included here are the typical reticulately ribbed individuals, together with Hornibrook's (1961) smooth variety, which is identical in all respects except for its very reduced ribbing.

DISTRIBUTION.—Common in thanatotope B, C, and D, extremely rare in thanatotope A, E, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

***Bolivina silvestrina* Cushman**

PLATE 6: FIGURES 73, 74

*Bolivina silvestrina* Cushman, 1936a:56, pl. 8: figs. 5a, b.—1937:109, pl. 13: figs. 14–16.

DESCRIPTION.—Test elongate, slender, slightly twisted, gently compressed; periphery broadly rounded; chambers inflated, about as broad as high and of uniform shape throughout; sutures depressed, straight or slightly curved, forming an angle of about 25° with horizontal; surface coarsely perforate.

DISCUSSION.—This is the first New Zealand fossil record of *B. silvestrina* Cushman, previously recorded from the Miocene to Pleistocene of parts of Europe and the Pacific.

DISTRIBUTION.—Frequent in thanatotope D, extremely rare in thanatotypes B and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

***Bolivina subcompacta* Finlay**

PLATE 6: FIGURE 75

*Bolivina subcompacta* Finlay, 1947:278, pl. 5: figs. 64–69.—Hornibrook, 1961:73, pl. 9: fig. 177.

DISTRIBUTION.—Common in thanatotope E, rare in thanatotope D, extremely rare in thanatotypes A, B, and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, DSDP.

***Bolivina thalmani* Renz**

PLATE 6: FIGURES 76, 77

*Bolivina thalmani* Renz, 1948:120, pl. 12: fig. 13.

DISTRIBUTION.—Common in thanatotope E. DSDP.

***Bolivina zedirecta* Finlay**

*Bolivina zedirecta* Finlay, 1947:278, pl. 5: figs. 70–72.—Hornibrook, 1961:73, pl. 9: fig. 176.

DISTRIBUTION.—Frequent in thanatotope D, rare in thanatotypes A, B, C, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

***Bolivinella australis* Cushman**

PLATE 7: FIGURES 78, 79, 82

*Bolivinella australis* Cushman, 1929a:32, pl. 5: figs. 6, 7.—Quilty, 1974:78, pl. 4: fig. 126.

DESCRIPTION.—Test elongate, with rapidly broadening early portion, margins nearly parallel in adult; margins acutely angled, with irregular spines; sutures curved, limbate; median line marked by straight furrow with slightly raised sides.

DISCUSSION.—This is the first record of *Bolivinella australis* Cushman from New Zealand, previously known only from the Oligocene to Miocene of Australia. A study of the type material of the French Miocene species *Bolivinella margaritacea* Cushman suggests that it may be conspecific with *B. australis*.

DISTRIBUTION.—One specimen in N28/f458. Pakaurangi Formation.

***Bolivinella subpectinata* Cushman**

PLATE 7: FIGURES 80, 81

*Bolivinella subpectinata* Cushman, 1929a:34, pl. 5: fig. 8.

DESCRIPTION.—Test flaring, very compressed, of uniform thickness from one margin to opposite margin; margins squarely angled, with irregular spines; chambers numerous, curved; sutures limbate, raised above smooth test surface, irregularly beaded; median line marked by straight, partly beaded rib.

DISCUSSION.—This is the first New Zealand record of *Bolivinella subpectinata* Cushman, previously recorded from the Oligocene of the United States and Oligocene to Miocene of Europe.

DISTRIBUTION.—Two specimens in N28/f458. Pakaurangi Formation.

***Buccella lotella* Hornibrook**

*Buccella lotella* Hornibrook, 1961:110, pl. 15: figs. 314–316; 1968:63, fig. 10.

DISTRIBUTION.—Extremely rare in thanatotope D. Pakaurangi Formation.

***Bueningia creeki* Finlay**

*Bueningia creeki* Finlay, 1939b:123, pl. 14: figs. 82–84.—Hornibrook, 1968:60, fig. 9.

DISTRIBUTION.—Rare in thanatopes B and D, extremely rare in thanatope A. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Bulimina elongata* d'Orbigny

*Bulimina elongata* d'Orbigny, 1826:269, no. 9; 1846:187, pl. 11: figs. 19, 20.—Cushman and Parker, 1947:108, pl. 25: figs. 14–17.—Barker, 1960, pl. 51: figs. 1, 2.

DISTRIBUTION.—Extremely rare in thanatope E. DSDP.

*Bulimina miolaevis* Finlay

*Bulimina miolaevis* Finlay, 1940:454, pl. 64: figs. 70, 71.—Hornibrook, 1961:62.—1968:63, fig. 10.

DISTRIBUTION.—Extremely rare in thanatopes B, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, DSDP.

*Bulimina pupula* Stache sensu lato

PLATE 7: FIGURE 83

*Bulimina pupula* Stache, 1864:265, pl. 24: fig. 13.—Cushman and Parker, 1947:101, pl. 24: figs. 7, 8.—Hornibrook, 1961:63, pl. 8: fig. 141; 1971:48, pl. 10: fig. 180.—Scott, 1970a, fig. 6, no. 10.

DISCUSSION.—Populations referred here to *Bulimina pupula* Stache have a wide range of form, from smooth, oval specimens with flush sutures to more tapering individuals with inflated chambers. The degree of chamber overlap is also extremely variable.

DISTRIBUTION.—Common in thanatope C, frequent in thanatopes D, E, and F, rare in thanatope B. Cornwallis Formation, Nihotupu Formation, Parakaurangi Formation, undifferentiated Hukatere Subgroup.

*Bulimina semicostata* Nuttall

PLATE 7: FIGURES 84, 85

*Bulimina semicostata* Nuttall, 1930:274, pl. 23: figs. 15, 16.—Cushman and Parker, 1947:93, pl. 21: figs. 28, 29.—Douglas, 1973:628, pl. 4: figs. 6, 9.

DISTRIBUTION.—Common in thanatope E. DSDP.

*Bulimina senta* Finlay

*Bulimina senta* Finlay, 1940:454, pl. 64: figs. 73, 74.—Gibson, 1967:25, pl. 6: fig. 105.—Hornibrook, 1968:70, fig. 13.

DISTRIBUTION.—Extremely rare, specimens in N42/f705, N42/f727. Nihotupu Formation, Waitemata Group.

*Bulimina striata* d'Orbigny

PLATE 7: FIGURE 86

*Bulimina striata* d'Orbigny, 1826:269.—Cushman and Parker, 1947:119, pl. 28: figs. 1–3.

*Bulimina* cf. *striata* d'Orbigny.—Gibson, 1967:25, pl. 6: fig. 110.

DISTRIBUTION.—Extremely rare in thanatopes B, C, and D. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Bulimina truncana* Gümbel

PLATE 7: FIGURES 87, 88

*Bulimina truncana* Gümbel, 1868:644, pl. 2: figs. 77a, b.—Cushman and Parker, 1947:89, pl. 21: figs. 7, 8.

*Bulimina rostrata* Brady, 1884:408, pl. 51: figs. 14, 15.—Cushman and Parker, 1947:124, pl. 28: fig. 34.

*Bulimina alazanensis* Cushman, 1927c:161, pl. 25: fig. 4.—Cushman and Parker, 1947:103, pl. 24: figs. 14–16.

*Bulimina bremneri* Finlay, 1940:455, pl. 64: figs. 84–86.

DISCUSSION.—Study of types and topotypic suites of *Bulimina alazanensis* Cushman, *B. bremneri* Finlay, *B. rostrata* Brady and *B. truncana* Gümbel suggests that all belong to one species. Within populations there is considerable variability in test inflation.

DISTRIBUTION.—Rare in thanatopes D and E, extremely rare in thanatopes B and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, DSDP.

*Buliminella elegantissima* (d'Orbigny)

*Buliminella elegantissima* d'Orbigny, 1839b:51, pl. 7: figs. 13, 14.

*Buliminella elegantissima* (d'Orbigny).—Cushman and Parker, 1947:67, pl. 17: figs. 10–12.—Barker, 1960, pl. 50: figs. 20–22.—Vella, 1963:6.

DISTRIBUTION.—Extremely rare in thanatopes B, D, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.



*Buliminella missilis* Vella

PLATE 7: FIGURE 89

*Buliminella missilis* Vella, 1963:6, pl. 1: fig. 3.

DISCUSSION.—These records extend the known time range of *Buliminella missilis* (New Zealand, early Pliocene) back to early Miocene (upper Po—Tk).

DISTRIBUTION.—Extremely rare in thanatopotes B and F. Cornwallis Formation, Pakaurangi Formation.

*Cancris brevior* Finlay*Cancris brevior* Finlay, 1940:463, pl. 64: figs. 95–98.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

*Cancris laevinflatus* Hornibrook*Cancris laevinflatus* Hornibrook, 1961:120, pl. 15: figs. 328, 331, 332.

DISTRIBUTION.—Rare in thanatopotes B and D, extremely rare in thanatotope C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Cassidulina carapitana* Hedberg

PLATE 8: FIGURES 94, 95

*Cassidulina carapitana* Hedberg, 1937:680, pl. 92: fig. 6.

DESCRIPTION.—Test biconvex, close-coiled, involute; periphery sharp, no umbos; chambers long, narrow, sharply curved at inner ends, about five pairs per whorl; sutures distinct, flush with smooth surface; aperture elongate, subparallel to periphery.

DISCUSSION.—This is the first New Zealand record of *Cassidulina carapitana* Hedberg, previously known from the Oligocene and Miocene of Central America, Europe and Guam.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation.

*Cassidulina laevigata* d'Orbigny

PLATE 7: FIGURE 90

*Cassidulina laevigata* d'Orbigny, 1826:282, pl. 15: figs. 4, 5. —Hornibrook, 1961:85, pl. 10: fig. 199.*Cassidulina neocarinata* Thalman.—Hornibrook, 1961:86, pl. 10: fig. 200.

DISCUSSION.—Individuals with a translucent boss, low elongate aperture and sharp periphery (sometimes with a small keel) are here referred to *Cassidulina laevigata*. The species *C. carinata* Silvestri is similar but has a much broader keel.

DISTRIBUTION.—Abundant in thanatotope D, common in thanatotope C, rare in thanatopotes A, C, E, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Cassidulina margareta* Karrer

PLATE 7: FIGURE 91

*Cassidulina margareta* Karrer, 1877:386, pl. 15b: fig. 52.—Asano, 1953:6, pl. 3: fig. 11.

DISCUSSION.—*Cassidulina margareta* Karrer is distinguished by its rounded periphery, somewhat compressed profile, high aperture, lack of a translucent umbo, four pairs of chambers per coil, and very slightly depressed sutures.

DISTRIBUTION.—Common in thanatopotes B and D, rare in thanatopotes C and E, extremely rare in thanatopotes A and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Cassidulina monstrosa* Voloshinova

PLATE 7: FIGURES 92, 93; PLATE 8: FIGURE 96

*Cassidulina limbata* var. *monstrosa* Voloshinova, 1952:94, pl. 3: figs. 5a, b.

DESCRIPTION.—Test biconvex, inflated, close-coiled; periphery rounded; umbos lacking; chambers long, narrow, constricted in central part, with sharply curved inner ends, about five pairs per whorl; sutures limbate, flush or slightly depressed; surface surgary textured; small slit aperture, subparallel to periphery.

DISCUSSION.—This is the first New Zealand record of *Cassidulina monstrosa* Voloshinova, previously recorded from the Miocene of the USSR. This species differs from *C. carapitana* in its rounded



periphery, limbate sutures and sugary texture. *C. monstrosa's* closest relative is probably *Globocassidulina tumida* (Heron-Allen and Earland) (Recent, New Zealand; Eade, 1967:440, fig. 5: nos. 5, 6), which differs in its smoother surface and greater number of chambers.

DISTRIBUTION.—Rare in thanatopes D and E. Cornwallis Formation, DSDP.

### *Ceratobulimina kellumi* Finlay

PLATE 9: FIGURE 112

*Ceratobulimina kellumi* Finlay, 1939b:115, pl. 13: fig. 60.

DISTRIBUTION.—Extremely rare in thanatopes B, C, and D. Cornwallis Formation, Pakaurangi Formation, Nihotupu Formation.

### *Ceratocancris clifdenensis* Finlay

*Ceratobulimina (Ceratocancris) clifdenensis* Finlay, 1939b:117, pl. 13: fig. 62.—Hornibrook, 1961:126, pl. 17: fig. 375.

*Ceratocancris clifdenensis* Finlay.—Hornibrook, 1968:69, fig. 67.

DISTRIBUTION.—Extremely rare in thanatopes B, D, and F. Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Cerobertina bartrumi* Finlay

*Cerobertina bartrumi* Finlay, 1939b:118, pl. 11: figs. 2, 3.—Hornibrook, 1961:127, pl. 17: figs. 379, 380.

DISTRIBUTION.—Extremely rare in thanatopes B, D, and F. Pakaurangi Formation, undifferentiated Hukatere Subgroup.

### *Cerobertina crepidula* Finlay

*Cerobertina crepidula* Finlay, 1939b:121, pl. 11: fig. 1.—Hornibrook, 1961:126, pl. 17: fig. 378.

DISTRIBUTION.—Extremely rare in thanatope D. Nihotupu Formation.

### *Cerobertina mahoenuica* Finlay

*Cerobertina mahoenuica* Finlay, 1939b:119, pl. 13: fig. 58.

DISTRIBUTION.—Extremely rare in thanatopes B and D. Nihotupu Formation, Pakaurangi Formation.

## *Chilostomella czizeki* Reuss

PLATE 9: FIGURES 113, 114

*Chilostomella czizeki* Reuss, 1850:380, pl. 48: fig. 13.—Cushman, 1926:74, pl. 11: figs. 2a-d.

DESCRIPTION.—Test elongate ovoid, circular in section; about twice as long as wide; sides gently convex; wall smooth; aperture a narrow slit of variable length along suture.

DISCUSSION.—This is the first New Zealand record of *Chilostomella czizeki* Reuss, known from Paleocene-Recent sediments from many parts of the world.

DISTRIBUTION.—Rare in thanatope D, extremely rare in thanatope B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

## *Chilostomella globata* Galloway and Heminway

PLATE 9: FIGURES 115, 116

*Chilostomella globata* Galloway and Heminway, 1941:409, pl. 28: fig. 2.

DESCRIPTION.—Test subglobular, subcircular in section, with last chamber forming about two-thirds of test; wall smooth; aperture a narrow slit, with large, everted lip.

DISCUSSION.—This is the first New Zealand record of *Chilostomella globata* Galloway and Heminway, previously known from the Oligocene and lower Miocene of central America.

DISTRIBUTION.—Extremely rare in thanatope D. Cornwallis Formation, Nihotupu Formation.

## *Chilostomella ovoidea* Reuss

PLATE 9: FIGURES 117, 118

*Chilostomella ovoidea* Reuss, 1850:380, pl. 48: fig. 12.—Cushman, 1926:74, pl. 11: figs. 1a-c.—Hornibrook, 1961:89, pl. 11: fig. 209.—Gibson, 1967:45, pl. 10: fig. 166.

DISCUSSION.—*Chilostomella ovoidea* is broader and more inflated than *C. czizeki*. Both these are more inflated than the two parallel-sided species *C. oolina* Schwager and *C. tenuis* Bornemann.

DISTRIBUTION.—Extremely rare in thanatopes A, C, and D. Nihotupu Formation, Pakaurangi Formation.

*Chilostomelloides oviformis* (Sherborn and Chapman)

PLATE 9: FIGURES 119, 120

*Lagena (Obliquina) oviformis* Sherborn and Chapman, 1886: 745, pl. 14: fig. 19.

*Chilostomelloides oviformis* (Sherborn and Chapman).—Cushman, 1926:77, pl. 11: figs. 17, 21.

DESCRIPTION.—Test elongate ovoid, circular in cross-section; last chamber envelopes about four-fifths of test; aperture circular or nearly so, standing out at distinct angle from general contour of test, with thickened lip.

DISCUSSION.—This is the first New Zealand record of *Chilostomelloides oviformis* (Sherborn and Chapman), previously known from the Eocene-Miocene of Europe, North Africa, North and South America, and Taiwan.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Nihotupu Formation.

*Cibicides ihungia* Finlay

*Cibicides ihungia* Finlay, 1940:465, pl. 67: figs. 201–206.—Hornibrook 1961:162, pl. 24: figs. 488–489; 1968:74; fig. 14.

DISTRIBUTION.—Rare in thanatotypes B, C, and D, extremely rare in thanatotypes A and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Cibicides lobatulus* (Walker and Jacob)

PLATE 10: FIGURES 124–126

*Nautilus lobatulus* Walker and Jacob, 1798:642, pl. 14: fig. 36.  
*Cibicides lobatulus* (Walker and Jacob).—Barker, 1960, pl. 92: fig. 10; pl. 93: fig. 1.

DESCRIPTION.—Test trochospiral; involute side convex; spiral side flat; periphery acute, unkeeled, lobulate; 6–8 inflated chambers per whorl; sutures on involute side almost radial, slightly curved, depressed; sutures on spiral side curved, limbate, flush; aperture low, lipped peripheral opening at base of final chamber and extending back along spiral suture a short distance.

DISCUSSION.—This is the first New Zealand record of *Cibicides lobatus* (Walker and Jacob). This universal species is easily recognized by its slightly

lobulate periphery, convex rather than conical ventral profile and lack of a keel or bosses.

DISTRIBUTION.—Frequent in thanatotypes B and F, rare in thanatotypes C and D, extremely rare in thanatotype A. Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Cibicides mediocris* Finlay

PLATE 10: FIGURES 127–129

*Cibicides mediocris* Finlay, 1940:464, pl. 67: figs. 198, 199.—Hornibrook, 1961:160, pl. 25: figs. 499, 500, 502.—Scott, 1970a, fig. 5, no. 1.

DISTRIBUTION.—Abundant in thanatotype B, frequent in thanatotypes A, C, and D, rare in thanatotype F, extremely rare in thanatotype E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Cibicides notocenicus* Dorreen

PLATE 10: FIGURES 132–134

*Cibicides perforatus* var. *notocenicus* Dorreen, 1948:299, pl. 41: fig. 4.

*Cibicides notocenicus* Dorreen.—Hornibrook, 1961:158, pl. 25: figs. 496, 498; 1968:57, fig. 8.

DISTRIBUTION.—Frequent in thanatotypes A, B, and D, rare in thanatotypes C and F, extremely rare in thanatotype E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Cibicides refulgens* de Montfort

PLATE 10: FIGURES 130, 131

*Cibicides refulgens* de Montfort, 1808:123, text-fig. p. 122.—Barker, 1960, pl. 92: figs. 7–9.—Hornibrook and Schofield, 1963:48.—Scott, 1970a, fig. 5, no. 5.

DISTRIBUTION.—Rare in thanatotypes B and D, extremely rare in thanatotypes A, C, and F. Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup.

*Cibicides vortex* Dorreen

PLATE 11: FIGURES 138, 139

*Cibicides vortex* Dorreen, 1948:299, pl. 41: fig. 5.—Hornibrook, 1961:160, pl. 24: figs. 490–492.—Scott, 1970a fig. 6, no. 4.

DISTRIBUTION.—Abundant in thanatotope B, common in thanatotope D, frequent in thanatotypes A and F, rare in thanatotope C, extremely rare in thanatotope E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Cibicides wuellerstorfi* (Schwager)

PLATE 11: FIGURES 140–142

*Anomalina wuellerstorfi* Schwager, 1866:258, pl. 7: figs. 105–107.

*Cibicides wuellerstorfi* (Schwager).—Barker, 1960, pl. 93: fig. 9.

*Cibicoides wuellerstorfi* (Schwager).—Douglas, 1973, pl. 18: figs. 7–9; pl. 25: figs. 15, 16.

DISTRIBUTION.—Frequent in thanatotope E. DSDP.

*Cibicoides brevoralis* (Carter)

*Cibicides brevoralis* Carter, 1958:47, pl. 6: figs. 54–56.

*Cibicides molestus* Hornibrook, 1961:163, pl. 24: figs. 478, 479, 483; 1968:76: fig. 14.—Gibson, 1967:67, pl. 19: figs. 275, 276.

DISCUSSION.—There are no apparent differences between *Cibicoides brevoralis* (Australian Tertiary) and *C. molestus* (New Zealand Tertiary) to justify continued separate recognition.

DISTRIBUTION.—Extremely rare in thanatotypes A, B, C, and D. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Cibicoides karreriformis* (Hornibrook)

PLATE 9: FIGURES 121, 122

*Cibicides karreriformis* Hornibrook, 1961:164, pl. 26: figs. 512–514.

DISTRIBUTION.—Rare in thanatotypes A, B, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Cibicoides kullenbergi* (Parker)

PLATE 10: FIGURE 123

*Cibicides kullenbergi* Parker in Phleger, Parker, and Peirson, 1953:49, pl. 11: figs. 7, 8.

DISCUSSION.—Our material is identical to the holotype and paratype of the recent, deep-water species, *Cibicoides kullenbergi* Parker (USNM 689859, 689860).

DISTRIBUTION.—Frequent in thanatotope E. DSDP.

*Cibicoides perforatus* (Karrer)

*Rotalia perforata* Karrer, 1864:81, pl. 16: fig. 13.

*Cibicides perforatus* (Karrer).—Hornibrook, 1961: 161 [in part]; 1971:21, pl. 4: figs. 69–71.

DISTRIBUTION.—Extremely rare in thanatotypes A, B, D, and E. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, DSDP.

*Cibicoides semiperforatus* (Hornibrook)

*Cibicides semiperforatus* Hornibrook, 1961:162, pl. 25: figs. 506–508.

DISTRIBUTION.—Extremely rare in thanatotypes A, C, and D. Nihotupu Formation, undifferentiated Hukatere Subgroup.

*Cibicoides temperatus* (Vella)

PLATE 11: FIGURES 135–137

*Cibicides temperata* Vella, 1957:40, pl. 9: figs. 201–203.—Hornibrook, 1961:162, pl. 24: figs. 476, 477, 482.—Scott, 1970a, fig. 5, no. 7.

DISTRIBUTION.—Abundant in thanatotope B, frequent in thanatotope A, rare in thanatotypes C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Dentalina* cf. *D. albatrossi* (Cushman)

PLATE 11: FIGURE 143

DISCUSSION.—Several specimens of *Dentalina* are most similar to *Dentalina albatrossi* (Cushman) (as

*Nodosaria vertebralis* var. *albatrossi* Cushman, 1923:87, pl. 15: fig. 1; and as *Dentalina albatrossi* (Cushman), Hornibrook, 1961:46).

DISTRIBUTION.—Extremely rare in thanatopes C, D, and E. Nihotupu Formation, Pakaurangi Formation, DSDP.

### *Dentalina filiformis* (d'Orbigny)

*Nodosaria filiformis* d'Orbigny, 1826:253.—Brady, 1884:500, pl. 63: figs. 3–5.—Hornibrook, 1961:47, pl. 6: fig. 92.

DISTRIBUTION.—Rare in thanatopes B, C, D, and E. Nihotupu Formation, Pakaurangi Formation, DSDP.

### *Dentalina intorta* (Dervieux)

PLATE 11: FIGURE 144

*Nodosaria intorta* Dervieux, 1894:610, pl. 5: figs. 32–34.  
*Dentalina intorta* (Dervieux).—Barker, 1960, pl. 62: figs. 27–31.

DISTRIBUTION.—Extremely rare in thanatope E. DSDP.

### *Dentalina obliquecostata* (Stache)

*Nodosaria obliquecostata* Stache, 1864:197, pl. 22: fig. 24.  
*Dentalina substrigata* (Stache).—Hornibrook, 1961:45, pl. 6: fig. 89.  
*Dentalina obliquecostata* (Stache).—Hornibrook, 1971:38, pl. 7: figs. 100–102.

DISTRIBUTION.—Extremely rare in thanatopes A, B, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, DSDP.

### *Dentalina soluta* Reuss

*Dentalina soluta* Reuss, 1851:60, pl. 3: fig. 4.—Chapman, 1926:50, pl. 3: fig. 29.—Hornibrook, 1961:45, pl. 6: fig. 90.

DISTRIBUTION.—Rare in thanatopes C, D, and E. Cornwallis Formation, Nihotupu Formation, DSDP.

### *Dentalina spirostriolata* (Cushman)

PLATE 11: FIGURE 145

*Nodosaria spirostriolata* Cushman, 1917:656; 1921:212, pl. 38, fig. 4.

DESCRIPTION.—Test elongate, slightly tapering

towards the broadly rounded initial end; chambers numerous, short; sutures slightly depressed; ornamentation numerous, strong, narrow longitudinal costae very gently spiralling over entire test.

DISCUSSION.—Specimens are very similar to Cushman's holotype and paratypes of *Nodosaria spirostriolata* (USNM 9119, 11602).

DISTRIBUTION.—Extremely rare in thanatopes B, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

### *Dentalina subcostata* Chapman

*Nodosaria (Dentalina) obliqua* var. *subcostata* Chapman, 1926:50, pl. 11: fig. 3.  
*Dentalina subcostata* Chapman.—Hornibrook, 1961:45, pl. 6: fig. 88.

DISTRIBUTION.—Extremely rare in thanatopes B and E. Pakaurangi Formation, DSDP.

### *Dentalina subemaciata* Parr

PLATE 11: FIGURE 146

*Dentalina subemaciata* Parr, 1950:329, pl. 12: fig. 1.—Barker, 1960, pl. 62: figs. 25, 26.

DISTRIBUTION.—Rare in thanatopes A, B, C, D, E, and F. Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

### *Discorbinella bertheloti* (d'Orbigny)

PLATE 8: FIGURES 100–102

*Rosalina bertheloti* d'Orbigny, 1839c:135, pl. 1: figs. 28–30.  
*Discorbinella bertheloti* (d'Orbigny).—Brady, 1884:650, pl. 89: figs. 10–12.  
*Discopulvinulina bertheloti* (d'Orbigny).—Hornibrook, 1961:106, pl. 14: fig. 286.

DISTRIBUTION.—Frequent in thanatopes B, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Discorbinella complanata* (Sidebottom)

PLATE 8: FIGURES 103–105; PLATE 12: FIGURES 151, 152

*Discorbinella bertheloti* var. *complanata* Sidebottom, 1918:253, pl. 6: figs. 1–3.

*Discorbinella* cf. *complanata* (Sidebottom).—Hornibrook, 1961:117, pl. 27: fig. 532.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

***Discorbinella galera* (Finlay)**

PLATE 8: FIGURES 106–108

*Discorbis galerus* Finlay, 1940:466.—Dorreen, 1948:293.

DISCUSSION.—This species has never been figured before and has only twice been recorded, originally by Finlay (1940) from the Altonian type locality (Pakaurangi Point) and later by Dorreen (1948) from the Eocene of the South Island. A further three specimens referable to *Discorbinella galera* were found in samples from the type locality during this study.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

***Discorbinella* cf. *D. scopos* (Finlay)**

DISCUSSION.—Several specimens of *Discorbinella* are most similar to *Discorbinella scopos* (Finlay) (as *Discorbis scopos* Finlay, 1940:466, pl. 67: figs. 212, 213; and as *Discopulvinulina scopos* (Finlay), Hornibrook, 1961:105, pl. 14; figs. 284, 285, 290).

DISTRIBUTION.—Extremely rare in thanatopes A, B, C, and F. Nihotupu Formation, Pakaurangi Formation.

***Discorbinella stachi* (Asano)**

PLATE 8: FIGURES 97–99; PLATE 12: FIGURES 153, 154

*Discopulvinulina stachi* Asano, 1951:7, figs. 46–48.

DESCRIPTION.—Test plano-convex, scale-like, sub-circular in outline; periphery acute, slightly rounded; dorsal side evolute, composed of 2–3 whorls of about 6 narrow chambers each; ventral side flat to gently concave, partly involute; short umbilical flaps developing on chambers; aperture on elongate slit along inner umbilical border of last chamber; secondary slit apertures along flap margins.

DISCUSSION.—This is the first New Zealand record of *Discorbinella stachi* (Asano); previously recorded from the Pliocene and Pleistocene of Japan.

DISTRIBUTION.—Rare in thanatotope B, extremely rare in thanatopes D and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

***Discorbinella turgida* (Finlay)**

*Discorbis turgidus* Finlay, 1940:467, pl. 67: figs. 214–216.  
*Discopulvinulina turgida* (Finlay).—Hornibrook, 1961:105, pl. 14: figs. 287, 291, 295.

DISTRIBUTION.—Extremely rare in thanatopes A, B, and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Discorbinella* species**

PLATE 8: FIGURES 109–111

DISCUSSION.—This species belongs to the *Discorbinella bertheloti* group, but differs from the two species recorded here (*D. bertheloti*, *D. complanata*) in being extremely compressed, scale-like, very slightly concavo-convex; in both dorsal and ventral sides being evolute; and having strongly curved limbate sutures with more chambers per whorl (10–12).

DISTRIBUTION.—Extremely rare in thanatopes B and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Discorbis balcombensis* Chapman, Parr and Collins**

PLATE 11: FIGURE 147

*Discorbis balcombensis* Chapman, Parr and Collins, 1934:562, pl. 8: fig. 10.—Hornibrook, 1961:98, pl. 13: fig. 252.  
*Discorbis finlayi* Dorreen, 1948:293, pl. 38, fig. 12a–c.

DISTRIBUTION.—Frequent in thanatopes B and F, rare in thanatopes A and D, extremely rare in thanatotope C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

***Discorbis semiopercularis* Hornibrook**

PLATE 11: FIGURES 148, 149

*Discorbis semiopercularis* Hornibrook, 1961:100, pl. 13: figs. 260–262.

DISTRIBUTION.—Extremely rare in thanatopes

B and F. Cornwallis Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Discorbis zealandica* (Vella)

PLATE 12: FIGURE 150

*Pileolina zealandica* Vella, 1957:37, pl. 8: fig. 175, 176.

*Discorbis zealandica* (Vella).—Hornibrook, 1961:99, pl. 13: figs. 254–256.

DISTRIBUTION.—Frequent in thanatotope F, rare in thanatotope A, B, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Discorotalia aranea* (Hornibrook)

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

*Discorotalia aranea* (Hornibrook).—Hornibrook, 1961:141, pl. 18: fig. 389–91.

DISTRIBUTION.—Extremely rare in thanatotope C. Nihotupu Formation, Pakaurangi Formation.

*Discorotalia tenuissima* (Karrer)

*Polystomella tenuissima* Karrer, 1864:83, pl. 16: fig. 16.

*Discorotalia tenuissima* (Karrer).—Hornibrook, 1961:141, pl. 18: figs. 387, 388; pl. 28: fig. 547; 1968:98, fig. 20; 1971:21, pl. 3: figs. 50–54.—Hofker, 1969:470: figs. 49–56.

DISTRIBUTION.—Rare in thanatopes A and B, extremely rare in thanatopes C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup.

*Dyocibicides biserialis* Cushman and Valentine

PLATE 12: FIGURE 155

*Dyocibicides biserialis* Cushman and Valentine, 1930:31, pl. 10: figs. 1, 2.—Hornibrook, 1961:165, pl. 26: fig. 516.

DISTRIBUTION.—Frequent in thanatotope B, rare in thanatopes C, D, and F, extremely rare in thanatotope F. Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Dyocibicides primitiva* Vella

*Dyocibicides primitiva* Vella, 1957:41, pl. 9: figs. 198–200.—Hornibrook, 1961:165, pl. 26: fig. 517.

DISTRIBUTION.—Extremely rare in thanatopes B, D, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Ehrenbergina marwicki* Finlay

PLATE 12: FIGURE 156

*Ehrenbergina marwicki* Finlay, 1939c:322, pl. 28: figs. 112–118; 1947:283, pl. 7: fig. 118.—Hornibrook, 1961:87, pl. 10: figs. 195–197; 1968:64; fig. 62.—Scott, 1973a:55, figs. 10, 11.

*Ehrenbergina healyi* Finlay, 1947:284, pl. 7: figs. 106–115.—Hornibrook, 1961:87.—Scott, 1973a:55, figs. 7, 9.

*Ehrenbergina willetti* Finlay, 1947:284, pl. 7: figs. 116–117.—Hornibrook, 1961:88.—Scott, 1973a:55, figs. 8, 12.

DISCUSSION.—Scott's (1973a) study on the variability of lower Miocene populations of *Ehrenbergina* led him to conclude that Finlay's three species could be reduced to two subspecies of *Ehrenbergina marwicki*. The subspecies were not separated in this study.

DISTRIBUTION.—Frequent in thanatopes C and D, extremely rare in thanatopes A and B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Elphidium advenum* (Cushman)

PLATE 12: FIGURE 157

*Polystomella advena* Cushman, 1922b:56, pl. 9: figs. 11, 12. *Elphidium advenum* (Cushman).—Cushman, 1939:60, pl. 16: figs. 31–35.—Finlay, 1952:61, 62.

DISTRIBUTION.—Frequent in thanatopes B and F, rare in thanatopes A, C, and D. Nihotupu Formation, Pakaurangi Formation, Piha Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Elphidium gibsoni* Hayward, new species

PLATE 12: FIGURES 158–160; PLATE 15: FIGURE 182

DESCRIPTION.—Test medium to large, lenticular, about 2½ times longer than wide in peripheral view; large, rounded, slightly projecting umbos of semi-opaque shell, ringed by a row of small rounded pores; periphery acutely keeled; 16–22 chambers in adult coil; sutures slightly depressed, radial near umbo but curving backwards toward periphery; retrol processes very short, 7–10 per adult chamber;

aperture a row of small rounded openings along base of apertural face.

DISCUSSION.—This species is distinguished by its large umbos and short retral processes. It differs from *Elphidium chapmani* Cushman (Miocene, Australia) in having fewer chambers and retral processes. It is named for Drs. G. W. Gibson (University of Auckland) and T. G. Gibson (U. S. Geological Survey) both of whom assisted greatly during this study.

HOLOTYPE.—TF 1579/1, New Zealand Geological Survey.

PARATYPES.—USNM 243352 (N28/f781; 4 specimens); USNM 243351 (N28/f792; 1 specimen); TF 1579/2-6, USNM 243349, 243354 (N28/f455; 11 specimens); F83 a-f, USNM 243353 (N28/f457; 15 specimens); USNM 243350 (N42/f709; 1 specimen).

TYPE LOCALITY.—N41/f539, Huia Stream, Waitakere Ranges, Grid. Reference N41/074464. Nihotupu Formation, lower Altonian (P1), early Miocene.

DISTRIBUTION.—Rare in thanatopes A and B, extremely rare in thanatope D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation.

### *Elphidium hornibrooki* Srinivasan

*Elphidium hornibrooki* Srinivasan, 1966:248, pl. 4: figs. 8, 12.

DISTRIBUTION.—Frequent in thanatope B, rare in thanatopes A, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup.

### *Elphidium nigarense* Cushman

PLATE 13: FIGURES 161-165

*Elphidium nigarense* Cushman, 1936c:85, pl. 15: figs. 3a, b; 1939:63, pl. 17: fig. 19.

DESCRIPTION.—Test lenticular,  $2\frac{1}{2}$  times longer than wide in peripheral view; no umbos; umbilical region flat to slightly depressed; periphery acutely keeled; 12-15 chambers in adult coil; anterior rim of chambers thickened and slightly raised, sloping back to suture; sutures depressed, strongly curved; 7-10 retral processes per chamber, extending  $\frac{1}{4}$ - $\frac{2}{3}$  rds distance across adjacent chamber; aperture a

row of rounded openings along base of triangular apertural face.

DISCUSSION.—This is the first New Zealand record of *Elphidium nigarense* Cushman; previously recorded from the Pleistocene to Recent of Europe.

DISTRIBUTION.—Rare in thanatope C, extremely rare in thanatopes A, B, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Elphidium pseudoinflatum* Cushman

PLATE 13: FIGURES 166-168

*Elphidium pseudoinflatum* Cushman, 1936c:80, pl. 14: figs. 5a, b; 1939:41, pl. 11: fig. 8.—Carter, 1964:122, pl. 13: figs. 254, 255.

*Elphidium subinflatum* Cushman, 1936c:84, pl. 15: figs. 1a, b; 1939:48, pl. 12: fig. 20.

DESCRIPTION.—Test inflated; narrow umbilici, often infilled; periphery weakly keeled 8-10 chambers in adult coil; retral processes long, forming narrow, elevated costae that branch from recurved sutural costae; which sutural costae becoming weaker on later adult chambers; aperture a row of rounded openings along base of heart-shaped apertural face.

DISCUSSION.—This is the first New Zealand record of *Elphidium pseudoinflatum* Cushman; previously known from the Miocene of Australia.

DISTRIBUTION.—Rare in thanatope B, extremely rare in thanatopes A and D. Nihotupu Formation, Pakaurangi Formation, Puketi Formation.

### *Elphidium subrotatum* Hornibrook

*Elphidium subrotatum* Hornibrook, 1961:129, pl. 18: figs. 384, 385.

DISTRIBUTION.—One specimen in N28/f458. Pakaurangi Formation.

### *Elphidium kanoum* Hayward, new species

PLATE 13: FIGURES 169, 170; PLATE 15: FIGURES 183, 184

DESCRIPTION.—Test of medium size, about  $2\frac{1}{2}$  to 3 times longer than wide in peripheral view, lenticular; umbos glassy, translucent, pitted; periphery acute, weakly keeled; 17-20 chambers in adult coil; sutures slightly depressed, curved; retral processes



7–10 per chamber, arranged in subannular rows around the umbo; aperture a row of small rounded openings along base of apertural face.

DISCUSSION.—*Elphidium kanoum* is distinguished from the following similar species: *E. subrotatum* Hornibrook (Miocene, New Zealand) by its greater inflation and lack of a spinose keel; *E. parri* Cushman (Miocene, Australia) by its smaller size, glassy umbos and fewer chambers per coil; *E. glabratum* Cushman (Miocene, France) and *E. chipolense* (Cushman) (Miocene, Florida) by its keel and more sharply angled periphery; *E. rolshauseni* Cushman and Ellisor (Miocene, Louisiana) by its greater inflation. Hornibrook (1961:129) refers specimens from the Waitakian and Otaian (Lw, Po) of northern New Zealand “to *subrotatum* although they either lack well developed peripheral spines or are rather more inflated.” These are most likely good specimens of *E. kanoum*.

HOLOTYPE.—TF 1580/1, New Zealand Geological Survey.

PARATYPES.—USNM 243361 (N28/f454, 11 specimens); F 84 a–d (N28/f781, 4 specimens); TF 1580/2–3, USNM 243360 (N28/f792, 3 specimens).

TYPE LOCALITY.—N28/f457, west side of Pakaurangi Point, Grid. Reference N28/811348. Pakaurangi Formation, lower Altonian (P1), early Miocene.

DISTRIBUTION.—Rare in thanatopes A and B, extremely rare in thanatopes C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation.

### *Eoepionidella scotti* Hayward, new species

PLATE 14: FIGURES 171–175; PLATE 15: FIGURES 187–189

DESCRIPTION.—Test small, trochospiral; dorsal side evolute, convex, of 2 to 3 whorls; ventral side involute, flat to concave; periphery broadly rounded, slightly lobulate in outline; chambers 4–6 per whorl, rapidly expanding, with final chamber forming one third of test; dorsal sutures curved, almost flush with smoothly perforate surface; ventral sutures slightly depressed, radial to gently curved; ventral supplementary chambers, rhomboidal, covering inner portions of sutures and partially filling the umbilicus; aperture high and nar-

row, located in infolded depression near base of ventral face of last chamber.

DISCUSSION.—This species most closely resembles *Eoepionidella linki* Wickenden (upper Cretaceous, Canada) from which it differs by its much narrower aperture. A combination of its rhomboidal supplementary chambers, broadly rounded periphery and its high, narrow aperture distinguish *E. scotti* from *E. zealandica* (Hornibrook) (Hornibrook, 1961:114, pl. 16: figs. 352, 354, 355), and other species of this genus. This new species is named for Dr. G. H. Scott (N. Z. Geological Survey), who first recognized *Eoepionidella* in material from Pakaurangi Point (Jones, 1970).

HOLOTYPE.—TF 1581/1, New Zealand Geological Survey.

PARATYPES.—TF 1581/2–4, USNM 243363 (N28/f458, 4 specimens); USNM 243364, 243365 (N28/f795, 7 specimens); USNM 243362, 243366 (N28/f912, 9 specimens); F 85 a–f (N33/f505, 6 specimens); USNM 243367 (N33/f534, 9 specimens).

TYPE LOCALITY.—N28/f457, west side of Pakaurangi Point, Grid. Reference N28/811348. Pakaurangi Formation, lower Altonian (P1), early Miocene.

DISTRIBUTION.—Frequent in thanatopes B, D, and F, extremely rare in thanatopes A, C, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, DSDP.

### *Epistominella cassidulinoides* Hornibrook

*Epistominella cassidulinoides* Hornibrook, 1961:121, pl. 17: figs. 360, 362, 364.

DISTRIBUTION.—Rare in thanatope D, extremely rare in thanatopes B, C, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Epistominella exigua* (Brady)

PLATE 14: FIGURES 176, 177

*Pulvinulina exigua* Brady, 1884:696, pl. 103: figs. 13, 14.

*Epistominella exigua* (Brady).—Barker, 1960, pl. 103: figs. 13, 14.

DISTRIBUTION.—Abundant in thanatope E. DSDP.



*Epistominella iota* Hornibrook

*Epistominella iota* Hornibrook, 1961:122, pl. 17: figs. 359, 361, 363.

DISTRIBUTION.—Extremely rare in thanatopotes B and D. Nihotupu Formation, Pakaurangi Formation.

*Epistominella minima* (Cushman)

*Eponides minima* Cushman, 1933:17, pl. 2: figs. 8a-c.

DISTRIBUTION.—Frequent in thanatotope E. DSDP.

*Eponides broeckhianus* (Karrer)

*Rotalia broeckhiana* Karrer, 1878:98, pl. 5: fig. 26.  
*Gyroidina broeckhiana* (Karrer).—Barker, 1960, pl. 107: fig. 4.  
*Eponides broeckhianus* (Karrer).—Hornibrook, 1961:109, pl. 15: figs. 321-322.

DISTRIBUTION.—Rare in thanatotope D, extremely rare in thanatopotes B, C, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Eponides repandus* (Fichtel and Moll)

*Nautilus repandus* Fichtel and Moll, 1803:35, pl. 3: figs. a-d.  
*Pulvinulina repanda* (Fichtel and Moll).—Chapman, 1926:84, pl. 17: fig. 1.  
*Eponides repandus* (Fichtel and Moll).—Hornibrook, 1961:109, pl. 15: fig. 324.

DISTRIBUTION.—Extremely rare in thanatopotes A, B, and F. Cornwallis Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Eulepidina dilatata dilatata* (Michelotti)

*Orbitoides dilatata* Michelotti, 1861:17, pl. 1: figs. 1, 2.  
*Eulepidina dilatata dilatata* (Michelotti).—Matsumaru, 1971:184, pl. 22: figs. 28-38.

DISTRIBUTION.—Extremely rare in thanatotope A. Nihotupu Formation.

*Euwigerina zelandica* (Finlay)

*Zeauwigerina zelandica* Finlay, 1939a:541, pl. 69: fig. 4—Hornibrook, 1968:84, fig. 16.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP. Possibly reworked from the Paleocene or Eocene.

*Euwigerina* aff. *E. brunnensis* (Karrer)

DISCUSSION.—A single specimen of *Euwigerina* is most similar to *Euwigerina brunnensis* (Karrer) (as *Uvigerina brunnensis* Karrer, 1877:385, pl. 16b:49).

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Euwigerina* aff. *E. cushmani* (Todd)

DISCUSSION.—Several specimens of *Euwigerina* are most similar to *Euwigerina cushmani* (Todd) (as *Uvigerina cushmani* Todd, 1948:257, pl. 33: fig. 1).

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Euwigerina miozea* (Finlay)

PLATE 14: FIGURE 178

*Uvigerina miozea* Finlay, 1939b:102, pl. 12: figs. 12-14.—Hornibrook, 1961:65, pl. 8: fig. 144.  
*Hofkeruwa (Trigonouwa) miozea* (Finlay).—Vella, 1961:477, pl. 1: figs. 5, 8, 9.  
*Euwigerina (Hofkeruwa) miozea* (Finlay).—Hornibrook, 1968:103, fig. 22.

DISTRIBUTION.—Common in thanatotope C, frequent in thanatotope B, rare in thanatotope D, extremely rare in thanatopotes A and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Evolvocassidulina bradyi* (Norman)

PLATE 14: FIGURE 179

*Cassidulina bradyi* Norman.—Brady, 1881:59.  
*Cassidulinoides bradyi* (Norman).—Barker, 1960, pl. 54: figs. 6-9.—Hornibrook, 1961:87.

DISTRIBUTION.—Extremely rare in thanatopotes B, C, and E. Pakaurangi Formation, DSDP.

*Evolvocassidulina* cf. *E. chapmani* Parr

PLATE 15: FIGURE 180

DISCUSSION.—Several specimens of *Evolvocassidu-*

*lina* are most similar to *Evolvocassidulina chapmani* Parr (as *Cassidulinoides chapmani* Parr, 1931:100; figs. a-c).

DISTRIBUTION.—Extremely rare in thanatotoxes B and D. Nihotupu Formation, Pakaurangi Formation.

***Evolvocassidulina orientalis* (Cushman)**

PLATE 14: FIGURE 181

*Cassidulina bradyi* Norman.—Brady, 1884, pl. 54: fig. 10 [not of Norman].—Chapman, 1926:42, pl. 9: fig. 11.

*Cassidulina orientalis* Cushman, 1922c:129.

*Cassidulinoides orientalis* (Chapman).—Hornibrook, 1961:86, pl. 10: fig. 201.—Gibson, 1967:43, pl. 10: fig. 162.

*Evolvocassidulina orientalis* (Chapman).—Eade, 1967:431, fig. 4, nos. 1, 2.

DISTRIBUTION.—Frequent in thanatotoxes C and D, extremely rare in thanatotope B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

***Fissurina alveolata* (Brady)**

*Lagena alveolata* Brady, 1884:487, pl. 40: figs. 30–32.—Cushman, 1913:33, pl. 18: fig. 1.

*Fissurina alveolata* (Brady).—Barker, 1960, pl. 60: figs. 30, 32.

DISTRIBUTION.—Extremely rare in thanatotope F. Undifferentiated Hukatere Subgroup.

***Fissurina aperta* Seguenza**

PLATE 16: FIGURES 200, 201

*Fissurina* (*Fissurine*) *aperta* Seguenza, 1862:60, pl. 1: fig. 60.  
*Fissurina aperta* Seguenza.—Parr, 1950:312.

DESCRIPTION.—Test subcircular in side view, moderately compressed; periphery faintly keeled, broadly rounded; apertural edge broadly truncate; test surface smooth; aperture a long narrow fissure, approximately two-thirds width of test; apertural lip distinct, raised.

DISCUSSION.—This is the first New Zealand record of *Fissurina aperta* Seguenza. This species is easily distinguished by its very broad aperture and subcircular test.

DISTRIBUTION.—Rare in thanatotope B, extremely

rare in thanatotope D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

***Fissurina aureoligera* (Buchner)**

PLATE 16: FIGURES 202, 203

*Lagena aureoligera* Buchner, 1940:457, pl. 9: figs. 144–145.

DISTRIBUTION.—Extremely rare in thanatotoxes B and C. Nihotupu Formation, Pakaurangi Formation.

***Fissurina auriculata* (Brady)**

*Lagena auriculata* Brady, 1881:61.—1884:487, pl. 60: fig. 29.  
*Fissurina auriculata* (Brady).—Barker, 1960, pl. 60: fig. 29.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Fissurina basifimbriata* Parr**

PLATE 16: FIGURE 204

*Fissurina basifimbriata* Parr, 1950:312, pl. 9: figs. 6, 7.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Fissurina biancae* Seguenza**

*Fissurina biancae* Seguenza, 1862:57, pl. 1: figs. 48–50.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation, Pakaurangi Formation.

***Fissurina bradii* Silvestri**

*Fissurina bradii* Silvestri, 1902:147.—Barker, 1960, pl. 59: fig. 24.

DISTRIBUTION.—Extremely rare in thanatotoxes B, C, D, and E. Pakaurangi Formation, Piha Formation, Waitemata Group, DSDP.

***Fissurina clypeato-marginata* (Jones)**

*Lagena vulgaris* var. *clypeato-marginata* Jones, 1872:58, pl. 19: fig. 37.

DISTRIBUTION.—Extremely rare in thanatotope D. DSDP.

***Fissurina crenulata* (Cushman)**

*Lagena orbignyana* var. *crenulata* Cushman, 1913:44, pl. 10: fig. 2.

DISTRIBUTION.—Extremely rare in thanatotope D. Waitemata Group.

***Fissurina hartiana* (Earland)**

*Lagena hartiana* Earland, 1933:112, pl. 4: figs. 12–13.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Fissurina kerguelensis* Parr**

PLATE 16: FIGURE 206

*Fissurina kerguelensis* Parr, 1950:305, pl. 8: figs. 7a, b.—Barker, 1960, pl. 59: figs. 8–11.—Kennett, 1966a, table 6.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Fissurina laevigata* Reuss**

*Fissurina laevigata* Reuss, 1850:366, pl. 46: fig. 1.—Barker, 1960, pl. 114: fig. 8.—Kennett, 1966a, table 6.

*Lagena laevigata* (Reuss)—Cushman, 1913:7, pl. 2: fig. 1; 1923:28, pl. 5: figs. 1, 2.

DISTRIBUTION.—Rare in thanatotope D, extremely rare in thanatotypes B, C, and E. Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

***Fissurina lagenoides* (Williamson)**

PLATE 16: FIGURE 205

*Entosolenia marginata* var. *lagenoides* Williamson, 1858:11, pl. 1: figs. 25, 26.

*Lagena lagenoides* (Williamson)—Cushman, 1913:39, pl. 16: fig. 2; 1923:30, pl. 5: figs. 6–8.—Barker, 1960, pl. 60: figs. 6, 9, 12.

*Fissurina lagenoides* (Williamson)—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

***Fissurina marginata* (Walker and Boys)**

PLATE 16: FIGURE 207

*Serpula* (*Lagena*) *marginata* Walker and Boys, 1784:2, pl. 1: fig. 7.

*Lagena marginata* (Walker and Boys)—Cushman, 1923:35, pl. 6: fig. 9.

*Fissurina marginata* (Walker and Boys)—Parr, 1950:305.—Hornibrook, 1961, table 6.—Kennett, 1966a, table 6.

DISTRIBUTION.—Frequent in thanatotope D, extremely rare in thanatotypes B, E, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

***Fissurina* aff. *F. obscurocostata* Galloway and Wissler**

PLATE 16: FIGURE 208

DISCUSSION.—Several specimens of *Fissurina* are most similar to *Fissurina obscurocostata* Galloway and Wissler (1927:52, pl. 9:fig. 1).

DISTRIBUTION.—Rare in thanatotope D, extremely rare in thanatotypes B and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Waitemata Group.

***Fissurina orbignyana* Seguenza**

PLATE 16: FIGURE 210

*Fissurina orbignyana* Seguenza, 1862:66, pl. 2: figs. 25, 26.—Barker, 1960, pl. 59: fig. 26.—Hornibrook, 1961, table 6.

*Lagena orbignyana* (Seguenza)—Cushman, 1923:39.

DISTRIBUTION.—Extremely rare in thanatotypes B, D, E, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, DSDP.

***Fissurina quadrata* (Williamson)**

*Entosolenia marginata* var. *quadrata* Williamson, 1858:11, pl. 1: figs. 27, 28.

*Lagena quadrata* (Williamson)—Cushman, 1913:35, pl. 14: fig. 9; 1923:47, pl. 9: figs. 5, 6.

*Fissurina quadrata* (Williamson)—Barker, 1960, pl. 59: fig. 3.

DISTRIBUTION.—Extremely rare in thanatotypes D and F. Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

***Fissurina radiata* Seguenza**

PLATE 16: FIGURE 209

*Fissurina radiata* Seguenza, 1862:70, pl. 2: figs. 42–43.—Barker, 1960, pl. 60: figs. 13, 14.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Fissurina unguiculata* (Brady)

*Lagena unguiculata* Brady, 1881:61; 1884:474, pl. 59: fig. 12.

—Cushman, 1913:32, pl. 11: fig. 1.

*Fissurina unguiculata* (Brady).—Barker, 1960, pl. 59: fig. 12.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Florilus stachei* (Cushman)

PLATE 17: FIGURE 211

*Nonion stachei* Cushman, 1936b:66, pl. 12: fig. 7a, b; 1939: 16, pl. 3: fig. 18.

*Pseudononion stachei* (Cushman).—Hornibrook, 1961:93, pl. 11: figs. 216, 220.

DISTRIBUTION.—Extremely rare in thanatotypes A, B, and C. Nihotupu Formation, Pakaurangi Formation.

*Fronidularia bassensis* Parr

*Fronidularia bassensis* Parr, 1950:331, pl. 12: fig. 113.

*Fronidularia* cf. *bassensis* Parr.—Hornibrook, 1961:53, pl. 6: fig. 113.

DISTRIBUTION.—Extremely rare in thanatotope D. Pakaurangi Formation.

*Fronidularia tenuissima* Hantken

PLATE 15: FIGURES 185, 186

*Fronidularia tenuissima* Hantken, 1875:43, pl. 13: fig. 11.

DESCRIPTION.—Test compressed, flattened, elongate with both extremities tapered; initial end with stout spine; periphery truncately rounded; chambers narrow, elongate, early ones in loose coil, later ones chevron shaped, partially enveloping early chambers; sutures distinct, slightly depressed; wall smooth; aperture terminal, radiate, on a short neck.

DISCUSSION.—This is the first New Zealand record of *Fronidularia tenuissima* Hantken, previously recorded from the Paleocene to Miocene of the Americas and Europe, Eocene of Pakistan and Australia, and Miocene of Java.

DISTRIBUTION.—Extremely rare in thanatotypes

C and D. Cornwallis Formation, Pakaurangi Formation.

*Fursenkoina bramletti* (Galloway and Morrey)

*Virgulina bramletti* Galloway and Morrey, 1929:37, pl. 5: fig. 14.—Cushman, 1937:19, pl. 3: figs. 6–9.—Hornibrook, 1961:64, pl. 8: fig. 139.

DISTRIBUTION.—Extremely rare in thanatotypes B, D, and E. Nihotupu Formation, Pakaurangi Formation, DSDP.

*Fursenkoina schreibersiana* (Czjzek)

PLATE 17: FIGURE 212

*Virgulina schreibersiana* Czjzek, 1848:147, pl. 13: figs. 18–21.—Cushman, 1937:13, pl. 2: figs. 11–20.—Hornibrook, 1961: 64, pl. 8: fig. 138.

DISTRIBUTION.—Rare in thanatotope D, extremely rare in thanatotypes B, C, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, DSDP.

*Gavelinopsis pukeuriensis* Hornibrook

*Gavelinopsis pukeuriensis* Hornibrook, 1961:104, pl. 13: figs. 267, 270, 271.

DISTRIBUTION.—Extremely rare in thanatotypes B, C, and D. Nihotupu Formation, Pakaurangi Formation.

*Glbratella crassa* Dorreen

*Glbratella crassa* Dorreen, 1948:294, pl. 39: fig. 1.—Hornibrook, 1961:108, pl. 14: fig. 289.—Seiglie and Bermudez, 1965:28.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

*Glbratellina sigali* Seiglie and Bermudez

PLATE 15: FIGURE 190; PLATE 17: FIGURES 213–215

*Glbratellina sigali* Seiglie and Bermudez, 1965:42, pl. 9: figs. 4–7.

DESCRIPTION.—Test trochospiral; dorsal side evolute, conically domed with three to four whorls

visible; ventral side involute, convex around periphery, flat to concave towards open umbilicus; periphery obtusely angled, somewhat rounded; five to six chambers per whorl; sutures slightly limbate, usually flush with surface; dorsal sutures curved backwards; ventral sutures radial; dorsal surface smooth, coarsely perforate; ventral surface with narrow radiating grooves around periphery, centrally papillose; aperture umbilical.

DISCUSSION.—This is the first New Zealand record of *Glabratellina sigali* Seiglie and Bermudez, known from the Miocene of Cuba. This species differs from the New Zealand species *Discorbis patelliformis* (Brady) and *D. zealandica* (Vella) in its higher, more domed dorsal side and less angular periphery. *Glabratellina sigali* is commonly found as plastragamic pairs.

DISTRIBUTION.—Extremely rare in thanatotope B, D, and F. Cornwallis Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

### *Globbulimina pacifica* Cushman

PLATE 17: FIGURES 216, 217

*Globbulimina pacifica* Cushman, 1927a:67, pl. 14: fig. 12.—Cushman and Parker, 1947:134, pl. 29: fig. 37.—Hornibrook, 1961:63.—Gibson, 1967:27, pl. 7: fig. 115.

DISTRIBUTION.—Rare in thanatotope C, extremely rare in thanatotope B and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

### *Globbulimina monteriana* (Kleinpell)

*Bulimina monteriana* Kleinpell, 1938:254, pl. 13: fig. 13.  
*Bulimina (Desinobulimina) monteriana* Kleinpell.—Cushman and Parker, 1947:129, pl. 29: figs. 20, 21.—Gibson, 1967: pl. 7: fig. 114.

DISTRIBUTION.—Extremely rare in thanatotope C. Nihotupu Formation.

### *Globocassidulina arata* (Finlay)

PLATE 17: FIGURE 218

*Cassidulina arata* Finlay, 1939b:112, pl. 14: figs. 74, 75.

DISTRIBUTION.—Frequent in thanatotope B, rare in thanatotope A, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Globocassidulina subglobosa* (Brady)

PLATE 17: FIGURES 219, 220

*Cassidulina subglobosa* Brady, 1881:60; 1884:430, pl. 54: fig. 17.—Hornibrook, 1961:85, pl. 10: fig. 198.—Gibson, 1967:42, pl. 10: fig. 163.

DISTRIBUTION.—Abundant in thanatotope E, common in thanatotope D, frequent in thanatotope C, extremely rare in thanatotope B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

### *Globulina gibba* d'Orbigny

*Globulina gibba* d'Orbigny, 1826:266, "Modèle" 63.—Cushman and Ozawa, 1930:60, pl. 16: figs. 1–4.—Dorreen, 1948: 289, pl. 37: fig. 1.—Hornibrook, 1961:60, pl. 7: fig. 124.

DISTRIBUTION.—Extremely rare in thanatotope C. Pakaurangi Formation.

### *Guttulina austriaca* d'Orbigny

*Guttulina austriaca* d'Orbigny, 1846:223, pl. 12: figs. 23–25.—Cushman and Ozawa, 1930:29, pl. 4: figs. 3–5.—Hornibrook, 1961:55, pl. 7: fig. 120.

DISTRIBUTION.—Extremely rare in thanatotope D and E. Nihotupu Formation, DSDP.

### *Guttulina fissurata* Stache

*Guttulina fissurata* Stache, 1864:263, pl. 24: figs. 10a, b.—Hornibrook, 1961:48, fig. 12, pl. 10: figs. 178, 179.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

### *Guttulina problema* d'Orbigny

*Guttulina problema* d'Orbigny, 1826:266.—Cushman and Ozawa, 1930:19, pl. 2: figs. 1–6; pl. 3: fig. 1.—Hornibrook, 1961:54, pl. 7: fig. 118 [in part].

DISTRIBUTION.—Extremely rare in thanatotope B and E. Pakaurangi Formation, DSDP.

### *Gyroidina danvillensis* Howe and Wallace

PLATE 18: FIGURES 224, 225

*Gyroidina danvillensis* Howe and Wallace, 1932:69, pl. 13: fig. 3.

*Gyroidinoides prominula* (Stache).—Hornibrook, 1961:111, pl. 16: figs. 348, 349.

DESCRIPTION.—Test small, subglobose; ventral side involute, high convex, with small umbilicus; dorsal side evolute, low convex to flat; periphery broadly rounded; 6–7 chambers per whorl; sutures nonlimbate, slightly depressed and radial on both sides; surface smooth; aperture a low slit extending almost from umbilicus to periphery.

DISCUSSION.—This is the first New Zealand record of *Gyroidina danvillensis* Howe and Wallace; previously recorded from the Paleocene to Miocene of the Americas, Europe, and Russia. *G. danvillensis* is distinguished by its small size, rounded periphery, high dorsal side, 6–7 chambers per whorl and radial sutures.

DISTRIBUTION.—Frequent in thanatotope C, rare in thanatotypes B and D. Nihotupu Formation, Pakaurangi Formation.

#### *Gyroidina* cf. *G. orbicularis* d'Orbigny

DISCUSSION.—Several specimens of *Gyroidina* are most similar to *Gyroidina orbicularis* d'Orbigny (1826:278; "Modèle no." 13; Barker, 1960, pl. 115: figs. 6a–c). *Gyroidina* cf. *G. orbicularis* is distinguished from *G. danvillensis* and *G. zelandica* by its more compressed profile, its limbate ventral sutures, angled periphery, 8–10 chambers per whorl and small umbilicus.

DISTRIBUTION.—Rare in thanatotope C. Pakaurangi Formation.

#### *Gyroidina zelandica* Finlay

PLATE 18: FIGURES 221–223

*Gyroidina zelandica* Finlay, 1939c:323, pl. 28: figs. 138–140. —Douglas, 1973, pl. 12: figs. 4–9; pl. 24: figs. 5, 6.

*Gyroidinoides zelandica* (Finlay).—Hornibrook, 1961:113, pl. 16: figs. 339–344; 1968:69, fig. 12.

DISTRIBUTION.—Abundant in thanatotope C, common in thanatotypes B, D, and E, rare in thanatotypes A and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

#### *Gyroidina* species

PLATE 18: FIGURES 226–228

DISCUSSION.—This species occurs commonly with *Gyroidina zelandica* in DSDP samples. It is very distinctive with its strongly tangential dorsal sutures, its angled periphery, closed umbilicus with limbate ventral sutures and its small aperture.

DISTRIBUTION.—Common in thanatotope E. DSDP.

#### *Hanzawaia laurisiae* (Mallory)

PLATE 18: FIGURES 229, 230

*Cibicides laurisiae* Mallory, 1959:267, pl. 24: fig. 8.

DESCRIPTION.—Test plano-convex; periphery angled dorsal side flat, partly involute with flaps on lower margins of chambers overlapping chambers of previous whorl; ventral side high convex, involute, non-umbilicate; 8–10 chambers per whorl; sutures curved, flush or slightly depressed; aperture a peripheral arched opening extending to join supplementary openings beneath dorsal flaps.

DISTRIBUTION.—Rare in thanatotypes C and D, extremely rare in thanatotypes A and B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Waitemata Group.

#### *Hanzawaia* species

DISCUSSION.—This species has a very similar plano-convex profile to *Hanzawaia laurisiae*; it differs in being more involute on the dorsal side, having 10–12 chambers per whorl, sinuously curved ventral sutures and limbate dorsal sutures.

DISTRIBUTION.—Extremely rare in thanatotypes B and D. Pakaurangi Formation.

#### *Heronallenia lingulata* (Burrows and Holland)

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

*Heronallenia lingulata* (Burrows and Holland).—Carter, 1958: 42, pl. 5: figs. 40–42.—Barker, 1960, pl. 91: fig. 3.

DISTRIBUTION.—Rare in thanatotope E. DSDP.

#### *Heterostegina borneensis* van der Vlerk

*Heterostegina borneensis* van der Vlerk, 1930:16, figs. 6, 25. —Hornibrook, 1968:108, fig. 1.

DISTRIBUTION.—Extremely rare in thanatotope A and C. Nihotupu Formation, undifferentiated Hukatere Subgroup.

*Hoeglundina elegans* (d'Orbigny)

PLATE 18: FIGURE 231

*Rotalia* (*Turbinulina*) *elegans* d'Orbigny, 1826:276.

*Pulvinulina elegans* (d'Orbigny).—Chapman, 1926:82, pl. 16: fig. 11.

*Epistomina elgans* (d'Orbigny).—Hornibrook, 1961:122, pl. 17: fig. 367.

*Hoeglundina elegans* (d'Orbigny).—Gibson, 1967:51, pl. 12: fig. 194.—Hornibrook, 1968:52, fig. 7.

DISTRIBUTION.—Frequent in thanatotypes B and C, rare in thanatotypes D and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Hofkerina semiornata* (Howchin)

PLATE 19: FIGURE 232

*Pulvinulina semiornata* Howchin, 1889:14, pl. 1: fig. 12.

*Hofkerina semiornata* (Howchin).—Carter, 1958:58, pl. 9: figs. 88–90.—Hornibrook, 1961:169, pl. 26: figs. 521, 522; 1968:64, fig. 11.

DISTRIBUTION.—Extremely rare in thanatotope A. Undifferentiated Hukatere Subgroup.

*Karrerria maoria* (Finlay)

PLATE 19: FIGURES 233, 234

*Vagocibicides maoria* Finlay, 1939c:326, pl. 29: figs. 148–151, 158.—Hornibrook, 1961:165, pl. 26: fig. 515.

DISTRIBUTION.—Frequent in thanatotope B, rare in thanatotope D, extremely rare in thanatotypes A and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Lagena acuticostata* Reuss

PLATE 19: FIGURE 235

*Lagena acuticostata* Reuss, 1862:305, pl. 1: fig. 4.—Cushman, 1913:23, pl. 8: figs. 9, 10; 1923:5, pl. 1, figs. 1–3.—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation, Waitemata Group.

*Lagena costata* (Williamson)

*Entosolenia costata* Williamson, 1858:9, pl. 1: fig. 18.

*Lagena costata* (Williamson).—Cushman, 1913:21, pl. 9: fig. 6; 1923:12, pl. 1: fig. 16; pl. 2: figs. 1, 2; pl. 3: fig. 8.—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotope C. Pakaurangi Formation.

*Lagena distoma* Parker and Jones

PLATE 19: FIGURE 236

*Lagena distoma* Parker and Jones, in Brady, 1864:467, pl. 48: fig. 6.—Cushman, 1923:14, pl. 3: figs. 2, 3.—Barker, 1960, pl. 58: figs. 11–15.—Hornibrook, 1961, table 6.—Kennett, 1966a, table 6.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Lagena elongata* (Ehrenberg)

PLATE 19: FIGURE 239

*Miliola elongata* Ehrenberg, 1844:274.

*Lagena elongata* (Ehrenberg).—Cushman, 1913:12, pl. 1: fig. 5; 1923:15, pl. 3: fig. 4.—Barker, 1960, pl. 56: figs. 27–29.—Hornibrook, 1961, table 6.—Kennett, 1966a, table 6.

DISTRIBUTION.—Extremely rare in thanatotypes B, C, and D. Nihotupu Formation, Pakaurangi Formation.

*Lagena gracilis* Williamson

PLATE 19: FIGURE 237

*Lagena gracilis* Williamson, 1848:13, pl. 1: figs. 3, 4.—Cushman, 1913:22, pl. 8: figs. 5, 6; 1923:22, pl. 4: figs. 3, 4.—Barker, 1960, pl. 58: figs. 2, 3, 7–10.—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotope B and E. Pakaurangi Formation, DSDP.

*Lagena hispidula* Cushman

*Lagena laevis* Brady, 1884 [in part], pl. 56: figs. 10, 11.

*Lagena hispidula* Cushman, 1913:14, pl. 5: figs. 2, 3.—Barker, 1960, pl. 56: figs. 10, 11.—Kennett, 1966a, table 6.—Quilty, 1974:67, pl. 3: fig. 100.

DISTRIBUTION.—Extremely rare in thanatotypes

C and D. Cornwallis Formation, Pakaurangi Formation.

*Lagena laevis* (Montagu)

*Vermiculum laeve* Montagu, 1803:524.

*Lagena laevis* (Montagu).—Cushman, 1913:5, pl. 1: fig. 3; pl. 38: fig. 5.—Barker, 1960, pl. 56: figs. 7–9; pl. 57: figs. 14, 16, 17.—Hornibrook, 1961, table 6.—Quilty, 1974:68, pl. 3: figs. 101, 102.

DISTRIBUTION.—Extremely rare in thanatopos A, B, C, and D. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Lagena striata* (d'Orbigny)

PLATE 19: FIGURE 240

*Oolina striata* d'Orbigny, 1839b:21, pl. 5: fig. 12.

*Lagena striata* (d'Orbigny).—Cushman, 1913:19, pl. 7: figs. 4, 5; 1923:54, pl. 10: fig. 9.—Hornibrook, 1961, table 6.—Quilty, 1974:69, pl. 3: fig. 105.

DISTRIBUTION.—Frequent in thanatotope C, rare in thanatotope D, extremely rare in thanatotope B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, Waitemata Group.

*Lagena substriata* Williamson

PLATE 19: FIGURE 238

*Lagena substriata* Williamson, 1848:15, pl. 1: fig. 12.—Cushman, 1923:56, pl. 10: fig. 11.

DISTRIBUTION.—Extremely rare in thanatopos C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Lagena sulcata* Walker and Jacob

*Serpula* (*Lagena*) *sulcata* Walker and Jacob, 1798:634, pl. 14: fig. 5.

*Lagena sulcata* Walker and Jacob.—Cushman, 1913:22, pl. 9: fig. 2; 1923:58, pl. 11: fig. 1.—Barker, 1960, pl. 57: figs. 33, 34.—Hornibrook, 1961, table 6.—Quilty, 1974:69, pl. 3: fig. 106.

DISTRIBUTION.—Extremely rare in thanatopos B, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Lagenoglandulina annulata* (Stache)

PLATE 19: FIGURE 241

*Glandulina annulata* Stache, 1864:184, pl. 22: figs. 6a, b.  
*Lagenoglandulina annulata* (Stache).—Hornibrook, 1971:35, pl. 6: figs. 93, 94.

DISTRIBUTION.—Rare in thanatotope C, extremely rare in thanatotope D. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Laticarinina altocamerata* (Heron-Allen and Earland)

PLATE 19: FIGURES 242, 243

*Truncatulina tenuimargo* var. *altocamerata* Heron-Allen and Earland, 1922:209, pl. 7: figs. 24–27.

*Parvicarinina altocamerata* (Heron-Allen and Earland).—Finlay, 1940:467, pl. 62: figs. 30–34.—Hornibrook, 1961:118, pl. 14: figs. 296, 299, 301, 302, 305.

DISTRIBUTION.—Extremely rare in thanatopos B and C. Nihotupu Formation, Pakaurangi Formation.

*Laticarinina pauperata* (Parker and Jones)

*Pulvinulina repanda* var. *menardii* subvar. *pauperata* Parker and Jones, 1865:395, pl. 16: figs. 50, 51.

*Laticarinina halophora* (Stache).—Finlay, 1940:468, pl. 62: figs. 27–29.—Hornibrook, 1961:119, pl. 14: figs. 300, 303–304 [not of Stache].

*Laticarinina pauperata* (Parker and Jones).—Hornibrook, 1968:58; fig. 9; 1971:45.

DISTRIBUTION.—Frequent in thanatotope E. DSDP.

*Lenticulina callifera* (Stache)

PLATE 19: FIGURES 244–246

*Cristellaria callifera* Stache, 1864:236, pl. 23: figs. 15a, b.

*Robulus calliferus* (Stache).—Hornibrook, 1971: 42, pl. 9: figs. 148, 149.

DISTRIBUTION.—Rare in thanatopos B, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Lenticulina colorata* (Stache)

*Cristellaria colorata* Stache, 1864:229, pl. 23: figs. 9a, b.

*Robulus coloratus* (Stache).—Hornibrook, 1971:42, pl. 8: figs. 139–146.



DISTRIBUTION.—Extremely rare in thanatotope C. Pakaurangi Formation.

*Lenticulina dorotheiae* (Finlay)

*Robulus dorotheiae* Finlay, 1939c:314, pl. 27: figs. 107, 108.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Nihotupu Formation, Waitemata Group.

*Lenticulina foliata* (Stache)

*Robulina foliata* Stache, 1864:245, pl. 23: fig. 24.

*Robulus dicampylus* (Franzenau).—Hornibrook, 1961:38, pl. 3: fig. 52.

*Robulus foliatus* (Stache).—Hornibrook, 1961:42, pl. 9: figs. 151, 152.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Cornwallis Formation, Nihotupu Formation.

*Lenticulina formosa* (Cushman)

*Cristellaria formosa* Cushman, 1923:110, pl. 29: fig. 1; pl. 30, fig. 6.

*Lenticulina formosa* (Cushman).—Barker, 1960, pl. 70: figs. 13, 14, 15.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Lenticulina gibba* (d'Orbigny)

*Cristellaria gibba* d'Orbigny, 1839a:40: pl. 7: figs. 20, 21.

*Lenticulina gibba* (d'Orbigny).—Hornibrook, 1961:39, pl. 3: fig. 50.

DISTRIBUTION.—Frequent in thanatotypes C and D, rare in thanatotope B, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup.

*Lenticulina gyrosalpra* (Stache)

*Cristellaria gyrosalprum* Stache, 1864:243, pl. 23: fig. 22.

*Robulus gyrosalprus* (Stache).—Hornibrook, 1961:36, pl. 5: fig. 67; 1971:43, pl. 9: figs. 160, 161.

DISTRIBUTION.—Rare in thanatotope B, extremely rare in thanatotypes A and D. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Lenticulina iota* (Cushman)

*Cristellaria iota* Cushman, 1923:111, pl. 29: fig. 2; pl. 30, fig. 1.

*Robulus iotus* (Cushman).—Hornibrook, 1961:36.—Gibson, 1967, pl. 4: figs. 64, 65.

DISTRIBUTION.—Extremely rare in thanatotope B and E. Pakaurangi Formation, DSDP.

*Lenticulina lenticula* (Stache)

*Robulina lenticula* Stache, 1864:246, pl. 23: fig. 25.

*Robulus lenticulus* (Stache).—Hornibrook, 1971:43, pl. 9: figs. 158, 159.

DISTRIBUTION.—Extremely rare in thanatotypes B, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Lenticulina loculosa* (Stache)

*Robulina loculosa* Stache, 1864:244, pl. 22: fig. 23.

*Robulus loculosus* (Stache).—Hornibrook, 1961:37, pl. 4: fig. 63; 1971:43, pl. 9: fig. 147.

DISTRIBUTION.—Extremely rare in thanatotope A. Undifferentiated Hukatere Subgroup.

*Lenticulina* cf. *L. lucida* (Cushman)

DISCUSSION.—Several specimens of *Lenticulina* are most similar to *Lenticulina lucida* (Cushman) (as *Cristellaria lucida* Cushman, 1923:111, pl. 30: fig. 2; and as *Robulus lucidus* (Cushman), Hornibrook, 1961:36, pl. 3: fig. 51).

DISTRIBUTION.—Extremely rare in thanatotope D. Cornwallis Formation.

*Lenticulina mamilligera* (Karrer)

PLATE 20: FIGURE 247

*Cristellaria mamilligera* Karrer, 1864:76, pl. 16: fig. 5.

*Lenticulina mamilligera* (Karrer).—Hornibrook, 1968:63, fig. 10; 1971:17, pl. 2: fig. 21.—Gibson, 1967, pl. 4: fig. 67.

DISTRIBUTION.—Rare in thanatotope C. Pakaurangi Formation.

*Lenticulina* cf. *L. nitida* (Reuss)

PLATE 20: FIGURES 248, 249

DISCUSSION.—Numerous individuals of *Lenticu-*

*lina* are similar to *Lenticulina nitida* (Reuss) (as *Cristellaria nitida* Reuss, 1863b:54, pl. 6: fig. 66).

**DISTRIBUTION.**—Common in thanatotope C, frequent in thanatotypes B and D, rare in thanatotypes A and F, abundant in ungrouped N33/£579. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Lenticulina planula* (Galloway and Heminway)

PLATE 15: FIGURES 191, 192; PLATE 20: FIGURES 250–252

*Robulus planula* Galloway and Heminway, 1941:350, pl. 11: fig. 14.

**DESCRIPTION.**—Test compressed, glassy, almost flat on both sides, planispiral, evolute; chambers six to seven per whorl, slightly inflated; sutures limbate, gently curved and continuing parallel to periphery on both sides; periphery square-shouldered with narrow flange-like keel; aperture a narrow, elongate slit, situated on peripheral angle; apertural slit surrounded by slim, raised lip that may be slightly crenulated on the sides; aperture joined to the chamber cavity by narrow internal tube clearly visible through translucent shell.

**DISCUSSION.**—*Lenticulina planula* (Galloway and Heminway) has previously only been recorded from its Oligocene type locality in Puerto Rico. This species may belong to a new monotypic genus characterized by its *Lenticulina*-like chamber arrangement, *Fissurina*-like internal tube, and unique slit peripheral aperture.

**DISTRIBUTION.**—Rare in thanatotope C, extremely rare in thanatotope D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Lenticulina pseudocalcarata* (Stache)

*Robulina pseudocalcarata* Stache, 1864:252, pl. 23: fig. 31.  
*Robulus pseudocalcaratus* (Stache).—Hornibrook, 1971:44, pl. 9: figs. 154–157.

**DISTRIBUTION.**—Extremely rare in thanatotypes C and D. Nihotupu Formation.

*Lenticulina pusilla* (Stache)

*Robulina pusilla* Stache, 1864:247, pl. 23: figs. 26a, b.  
*Robulus pusillus* (Stache).—Hornibrook, 1971:44, pl. 9: figs. 150, 153.

**DISTRIBUTION.**—Extremely rare in thanatotope C. Nihotupu Formation.

*Lenticulina vortex* (Fichtel and Moll)

*Nautilus vortex* Fichtel and Moll, 1803:33, pl. 2: figs. d-i.  
*Robulus vortex* (Fichtel and Moll).—Hornibrook, 1961:38, pl. 3: fig. 49.

**DISTRIBUTION.**—Extremely rare in thanatotope C. Nihotupu Formation, Pakaurangi Formation.

*Loxostomum goodwoodensis* Hornibrook

*Loxostomum goodwoodensis* Hornibrook, 1961:76, pl. 10: figs. 185, 186.

**DISTRIBUTION.**—Rare in thanatotypes B, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Loxostomum pakaurangiensis* Hornibrook

PLATE 20: FIGURE 253

*Loxostomum pakaurangiensis* Hornibrook, 1958:659, fig. 17; 1961:76, pl. 10: fig. 187; 1968:66, fig. 12.

**DISTRIBUTION.**—Rare in thanatotope B, extremely rare in thanatotypes A, C, and D. Nihotupu Formation, Pakaurangi Formation, Piha Formation.

*Marginulina angistoma* Stache

*Marginulina angistoma* Stache, 1864:213, pl. 22: figs. 46a, b.  
—Hornibrook, 1971:52, pl. 7: figs. 109–114.

**DISTRIBUTION.**—Extremely rare in thanatotope E. DSDP.

*Marginulina obliquesuturata* (Stache)

*Dentalina obliquesuturata* Stache, 1864:207, pl. 22: fig. 36.  
*Marginulina obliquesuturata* (Stache).—Hornibrook, 1971:38, pl. 7: figs. 115–118.

**DISTRIBUTION.**—Extremely rare in thanatotypes B and C. Pakaurangi Formation.

*Marginulina subbullata* Hantken

*Marginulina subbullata* Hantken, 1875:46, pl. 4: figs. 9, 10; pl. 5: fig. 9.—Dorreen, 1948:288, pl. 37: fig. 2.—Hornibrook, 1961:45, pl. 5: fig. 84.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation.

*Marginulinopsis hydropica* Hornibrook

*Marginulinopsis hydropica* Hornibrook, 1961:43, pl. 5: figs. 74, 75, 79, 80.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

*Melonis affinis* (Reuss)

PLATE 20: FIGURE 256

*Nonionina affinis* Reuss, 1851:49, pl. 5: fig. 32.

*Melonis affinis* (Reuss).—Douglas, 1973, pl. 9: figs. 1, 2.

DISTRIBUTION.—Rare in thanatotope E. DSDP.

*Melonis dorreeni* (Hornibrook)

*Nonion dorreeni* Hornibrook, 1961:91, pl. 11: figs. 212, 213.

DISTRIBUTION.—Extremely rare in thanatotypes C and D. Nihotupu Formation.

*Melonis maorica* (Stache)

*Rosalina maorica* Stache, 1864:282, pl. 24: figs. 32a-c.

*Nonion maoricum* (Stache).—Hornibrook, 1961:91, pl. 11: fig. 211.

*Melonis maorica* (Stache).—Hornibrook, 1971:49, pl. 11: figs. 184, 185.

DISTRIBUTION.—Extremely rare in thanatotypes B, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Melonis pompilioides* (Fichtel and Moll)

*Nautilus pompilioides* Fichtel and Moll, 1803:124, pl. 2: figs. a-c.

*Nonion pompilioides* (Fichtel and Moll).—Barker, 1960, pl. 109: figs. 10, 11.

*Melonis pompilioides* (Fichtel and Moll).—Douglas, 1973, pl. 9: figs. 8, 9.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Melonis simplex* (Karrer)

PLATE 20: FIGURES 254, 257

*Nonionina simplex* Karrer, 1864:82, pl. 16: fig. 17.

*Melonis simplex* (Karrer).—Hornibrook, 1971:19, pl. 2: figs. 43-46.

DISTRIBUTION.—Common in thanatotope E, frequent in thanatotope B, rare in thanatotypes A and D, extremely rare in thanatotypes C and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Miogypsina intermedia* Drooger

PLATE 20: FIGURE 258

*Miogypsina intermedia* Drooger, 1952:35, 36, 54, 55, pl. 2: figs. 30-34; pl. 3: fig. 4.—Hornibrook, 1968:108: figs. 3, 4.

DISTRIBUTION.—Common in thanatotope A, extremely rare in thanatotope B. Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup.

*Neoconorbina terquemi* (Rzehak)

*Discorbina terquemi* Rzehak, 1888:228.

*Rosalina terquemi* (Rzehak).—Hornibrook, 1961:101, pl. 13: fig. 272.

*Neoconorbina terquemi* (Rzehak).—Barker, 1960, pl. 88: figs. 4-8.

DISTRIBUTION.—Extremely rare in thanatotypes B and D. Pakaurangi Formation, Waitemata Group.

*Nephrolepidina orakeiensis* (Karrer)

*Orbitoides orakeiensis* Karrer, 1864:86, pl. 16: fig. 21.

*Lepidocyclus* (*Nephrolepidina*) *orakeiensis* (Karrer).—Hornibrook, 1968:108, fig. 24: nos. 6, 7; fig. 25.—1971:24, pl. 12: figs. 1-5: pl. 13: fig. 1; text-fig. 6.

*Nephrolepidina orakeiensis* (Karrer).—Matsumaru, 1971:185, pl. 22: figs. 1-27.

DISTRIBUTION.—Common in N42/f706. Nihotupu Formation.

*Nodosarella tuberosa* (Gümbel)

PLATE 21: FIGURES 259, 260

*Lingulina tuberosa* Gümbel, 1868:629, pl. 1: figs. 52a, b.

*Nodosarella tuberosa* (Gümbel).—Loeblich and Tappan, 1964, C730: fig. 594, no. 11.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Nodosaria callosa* Stache

*Nodosaria callosa* Stache, 1864:197, pl. 22: fig. 23.—Hornibrook, 1971:37, pl. 7: fig. 99.

DISTRIBUTION.—Extremely rare in thanatotypes A and C. Nihotupu Formation, undifferentiated Hukatere Subgroup.

*Nodosaria hochstetteri* Schwager

*Nodosaria hochstetteri* Schwager, 1866:214, pl. 5: fig. 32.—Hornibrook, 1961:47, pl. 6: fig. 91.

DISTRIBUTION.—Extremely rare in thanatotype D. Nihotupu Formation.

*Nodosaria holoserica* Schwager

PLATE 21: FIGURE 261

*Nodosaria holoserica* Schwager, 1866:221, pl. 5: fig. 49.—Hornibrook, 1961:47, pl. 6: fig. 96.

DISTRIBUTION.—Rare in thanatotype D, extremely rare in thanatotypes B, C, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

*Nodosaria longiscata* d'Orbigny

PLATE 21: FIGURE 262

*Nodosaria longiscata* d'Orbigny, 1846:32, pl. 1: figs. 10–12.—Hornibrook, 1961:46, pl. 6: figs. 93–94.

DISTRIBUTION.—Frequent in thanatotype C, rare in thanatotypes B, D, and E, extremely rare in thanatotype A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, Waitemata Group, DSDP.

*Nodosaria pyrula* d'Orbigny

*Nodosaria pyrula* d'Orbigny, 1826:253.—Brady, 1884:497, pl. 62: figs. 10–12.—Hornibrook, 1961:47, pl. 6: fig. 97.

DISTRIBUTION.—Extremely rare in thanatotypes B, C, D, and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, DSDP.

*Nodosaria substrigata* Stache

PLATE 21: FIGURE 263

*Nodosaria substrigata* Stache, 1864:196, pl. 22: figs. 22a-c.—Hornibrook, 1971:37, pl. 7: fig. 98.

DISTRIBUTION.—Rare in thanatotypes C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Nonion cassidulinoides* Hornibrook

*Nonion cassidulinoides* Hornibrook, 1961:92, pl. 11: figs. 214, 215.

DISTRIBUTION.—Rare in thanatotypes B and D, extremely rare in thanatotypes A, C, E, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Nonion deceptrix* Hornibrook

*Nonion deceptrix* Hornibrook, 1961:92, pl. 11: figs. 218, 219.

DISTRIBUTION.—Rare in thanatotype A, extremely rare in thanatotype F. Puketi Formation, undifferentiated Hukatere Subgroup.

*Nonion* cf. *N. mexicanum* Cole

PLATE 21: FIGURES 264, 265

DISCUSSION.—Several individuals of *Nonion* are most similar to *Nonion mexicanum* Cole, as *Nonion turgidus* var. *mexicanus* Cole, 1927:23, pl. 2: fig. 11; and as *Nonion mexicanus* Cole (Cushman, 1939:6, pl. 1: figs. 23, 24).

DISTRIBUTION.—Extremely rare in thanatotypes B, D, and E. Nihotupu Formation, Pakaurangi Formation, DSDP.

*Nonion tuberculatum* (d'Orbigny)

PLATE 22: FIGURES 272, 273

*Nonionina tuberculatum* d'Orbigny, 1846:108, pl. 5: figs. 13, 14.

*Nonion tuberculatum* (d'Orbigny).—Cushman, 1939:13, pl. 13: figs. 12, 16, 17.

DESCRIPTION.—Test planispiral, compressed, involute; periphery broadly rounded; umbilical regions filled with pustular shell material; 9–12 chambers per whorl; sutures depressed, curved.

DISCUSSION.—This is the first New Zealand record of *Nonion tuberculatum* (d'Orbigny); previously recorded from Oligocene to Pliocene rocks of Europe, Africa, and California.

**DISTRIBUTION.**—Rare in thanatotope D, extremely rare in thanatotypes B, C, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Nonionella novozealandica* Cushman

PLATE 21: FIGURES 266–271

*Nonionella novo-zealandica* Cushman, 1936c:88, pl. 13: fig. 16a–c; 1939:31, pl. 8: fig. 10.—Hornibrook, 1961:94, pl. 11: fig. 217, 221.

**DISCUSSION.**—*Nonionella novozealandica* is more variable in the number of chambers, peripheral outline and development of the chamber extension than Cushman's original description indicates.

**DISTRIBUTION.**—Frequent in thanatotypes B, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Piha Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Nonionella magnalingua* Finlay

*Nonionella magnalingua* Finlay, 1940:456, pl. 65: figs. 144, 146.—Hornibrook, 1961:94, pl. 12: figs. 226, 232–233.—Kennett, 1966a:55, pl. 6: figs. 91–92.

**DISTRIBUTION.**—Rare in thanatotope D. Nihotupu Formation.

### *Nonionella zenitens* Finlay

*Nonionella zenitens* Finlay, 1940:457, pl. 65: figs. 145, 152–156.—Hornibrook, 1961:93, pl. 12: figs. 225, 231.—Kennett, 1966a:55, pl. 6: figs. 93–96.

**DISTRIBUTION.**—Frequent in thanatotope D, extremely rare in thanatotope C, Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

### *Notorotalia miocenica* (Cushman)

PLATE 22: FIGURES 274–278

*Polystomellina miocenica* Cushman, 1936c:87, pl. 15: fig. 8a–c.

**DESCRIPTION.**—Test lenticular, nearly equally bi-convex; periphery acute, weakly keeled; 14–18 chambers per whorl; sutures curved, paralleled by strong ribs, from which branch retral processes; 5–6 retral processes per chamber on dorsal side, 6–9 on ventral side; ventral side involute with solid to

nodulose boss covering umbilical area; dorsal side evolute with early chambers obscured by secondary shell material; aperture a low opening at the base of the apertural face.

**DISCUSSION.**—This is the first New Zealand record of *Notorotalia miocenica* (Cushman), which is known from the early Miocene of south-east Australia. This species is similar to *Notorotalia targetensis* Hornibrook (Miocene, New Zealand) but is distinguished by its ventral boss and dorsal secondary shell material. Comparison of our material with the holotype and seven paratypes of *Notorotalia miocenica* (Cushman Collection Nos. 22726, 23624) confirmed the identification.

**DISTRIBUTION.**—Frequent in thanatotope B, rare in thanatotypes A, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

### *Notorotalia powelli* Finlay

*Notorotalia powelli* Finlay, 1939c:323.—Collen, 1974:113, fig. 1; pl. 1: figs. 1–8.

**DISTRIBUTION.**—Rare in thanatotope C, extremely rare in thanatotypes A, B, and D. Nihotupu Formation, Pakaurangi Formation, Piha Formation, Waitemata Group.

### *Oolina botelliformis* (Brady)

PLATE 23: FIGURE 282

*Lagena botelliformis* Brady, 1881:60; 1884:454, pl. 56: fig. 6.—Cushman, 1923:8, pl. 1: fig. 10.  
*Oolina botelliformis* (Brady).—Hornibrook, 1961, table 6.

**DISTRIBUTION.**—Rare in thanatotope D, extremely rare in thanatotope E. Cornwallis Formation, Nihotupu Formation, DSDP.

### *Oolina* aff. *O. collaris* (Cushman)

PLATE 23: FIGURE 283

**DISCUSSION.**—Several specimens of *Oolina* are most similar to *Oolina collaris* (Cushman) (as *Lagena collaris* Cushman, 1913:10, pl. 1: fig. 2).

**DISTRIBUTION.**—Extremely rare in thanatotypes A, B, C, and D. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Oolina* aff. *O. felsinea* (Fornasini)

DISCUSSION.—Several individuals of *Oolina* are most similar to *Oolina felsinea* (Fornasini) (as *Lagena emaciata* var. *felsinea* Fornasini, 1901:47, fig. 1; and as *Lagena felsinea* Fornasini—Cushman, 1913:10, pl. 4: fig. 1; and as *Oolina felsinea* (Fornasini)—Barker, 1960, pl. 56: fig. 4).

DISTRIBUTION.—Extremely rare in thanatotope D and E. Nihotupu Formation, DSDP.

*Oolina globosa* (Montagu)

PLATE 23: FIGURES 284, 285

*Vermiculum globosum* Montagu, 1803:523.

*Lagena globosa* (Montagu).—Cushman, 1913:3, pl. 4: fig. 2; 1923:20, pl. 4: figs. 1, 2.

*Oolina globosa* (Montagu).—Barker, 1960, pl. 56: figs. 1–3.—Hornibrook, 1961, table 6, part 2.

DISTRIBUTION.—Rare in thanatotypes D and E, extremely rare in thanatotypes B, C, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

*Oolina hexagona* (Williamson)

PLATE 23: FIGURE 286

*Entosolenia squamosa* var. *hexagona* Williamson, 1848:20, pl. 2: fig. 23.

*Lagena hexagona* (Williamson).—Cushman, 1913:17, pl. 6: figs. 2, 3; Cushman, 1923:24, pl. 4: fig. 6.

*Oolina hexagona* (Williamson).—Barker, 1960, pl. 58: figs. 32, 33.—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotope C. Pakaurangi Formation.

*Oolina hispida* (Reuss)

PLATE 23: FIGURE 287

*Lagena hispida* Reuss, 1863a:335, pl. 6: figs. 77–79.—Cushman, 1913:13, pl. 4: figs. 4, 5; pl. 5: fig. 1; 1923:26, pl. 4: figs. 7, 8.

*Oolina hispida* (Reuss).—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotypes B, C, and D. Nihotupu Formation, Pakaurangi Formation.

*Oolina punctulata* (Sidebottom)

PLATE 23: FIGURE 288

*Lagena apiculata* var. *punctulata* Sidebottom, 1912:382, pl. 14: figs. 21–25.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Oolina setosa* (Earland)

PLATE 23: FIGURE 289

*Lagena globosa* var. *setosa* Earland, 1934:150, pl. 6: fig. 52.

*Oolina globosa* var. *setosa* (Earland).—Barker, 1960, pl. 56: figs. 33–35.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Oolina squamosa* (Montagu)

PLATE 23: FIGURE 292

*Vermiculum squamosa* Montagu, 1803:526, pl. 14: fig. 2.

*Lagena squamosa* (Montagu).—Cushman, 1913:16, pl. 6: fig. 1; 1923:51, pl. 10: figs. 3, 4.

*Oolina squamosa* (Montagu).—Hornibrook, 1961, table 6.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation, Waitemata Group.

*Oolina stelligera* (Brady)

*Lagena stelligera* Brady, 1881:60; 1884:466, pl. 57: figs. 35, 36.—Cushman, 1913:26, pl. 12: fig. 3; 1923:53, pl. 10: figs. 5, 6.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Oridorsalis umbonatus* (Reuss)

PLATE 24: FIGURES 295, 296

*Rotalina umbonata* Reuss, 1851:75, pl. 5: fig. 35.

*Eponides umbonatus* (Reuss).—Hornibrook, 1961:109.

*Oridorsalis umbonatus* (Reuss).—Srinivasan, 1966:252, pl. 5: figs. 2, 7, 11.—Douglas, 1973, pl. 13: figs. 1–6; pl. 24: figs. 9–12.

DISTRIBUTION.—Common in thanatotope E, frequent in thanatotope D, rare in thanatotypes B and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

*Orthomorphina challengeriana* (Thalman)

*Nodosaria perversa* Schwager.—Brady, 1884, pl. 64: figs. 25–27 [not of Schwager].

*Nodogenerina challengeriana* Thalman, 1937:341.

*Orthomorphina challengeriana* (Thalman).—Hornibrook, 1961:53.

DISTRIBUTION.—Extremely rare in thanatotypes C, D, and E. Nihotupu Formation, DSDP.

*Osangularia culter* (Parker and Jones)

PLATE 15: FIGURES 163, 164; PLATE 22: FIGURES 279–281

*Planorbulina farcata* var. *ungeriana* subvar. *culter* Parker and Jones. 1865:382, 421, pl. 19: fig. 1.

*Anomalina bengalensis* Schwager, 1866:259, pl. 7: fig. 111.

*Osangularia culter* (Parker and Jones).—Todd, 1965:25, pl. 15: fig. 1.

*Osangularia bengalensis* (Schwager).—Gibson, 1967:53, pl. 12: fig. 197.

DESCRIPTION.—Test strongly convex ventrally, gently convex dorsally; peripheral keel narrow and flange-like, less pronounced in adults; 7–9 chambers per whorl in juveniles, increasing up to 12 in adults; ventral sutures flush to gently depressed, slightly limbate in adults, radial near umbo, slightly kinked and then curving to meet periphery; dorsal sutures limbate, oblique, forming 45° angle with periphery, flush with surface; umbo on ventral side, small, glassy and slightly elevated; surface mostly smooth, with pustular area around umbo on adults; aperture narrow, elongate, rimmed, extending up into apertural face from its base.

DISCUSSION.—As indicated by Todd (1965) there seems to be no specific difference between *Osangularia culter* and *O. bengalensis*.

DISTRIBUTION.—Frequent in thanatotypes C and D, extremely rare in thanatotype A. Cornwallis Formation, Nihotupu Formation, Puketi Formation.

*Parafissurina abnormis* Parr

PLATE 23: FIGURES 290, 291

*Parafissurina abnormis* Parr, 1950:314, pl. 9: figs. 11a-c.

DISTRIBUTION.—Extremely rare in thanatotypes C and E. Nihotupu Formation, DSDP.

*Parafissurina basicarinata* Parr

PLATE 23: FIGURE 293

*Parafissurina basicarinata* Parr, 1950:314, pl. 9: figs. 12, 13.

DISTRIBUTION.—Extremely rare in thanatotype E. DSDP.

*Parafissurina himatiostoma* Loeblich and Tappan

*Parafissurina himatiostoma* Loeblich and Tappan, 1953:80, pl. 14: figs. 12–14.

DISTRIBUTION.—Extremely rare in thanatotype E. DSDP.

*Parafissurina lateralis* (Cushman)

PLATE 23: FIGURE 294

*Lagena lateralis* Cushman, 1913:9, pl. 1: fig. 1.

*Parafissurina lateralis* (Cushman).—Parr, 1950:316.—Barker, 1960, pl. 56: figs. 17, 18.

DISTRIBUTION.—Extremely rare in thanatotype E. DSDP.

*Pararotalia mackayi* (Karrer)

*Rosalina mackayi* Karrer, 1864:82, pl. 16: fig. 14.

*Neorotalia mackayi* (Karrer).—Hornibrook, 1968:63: fig. 10.

*Pararotalia mackayi* (Karrer).—Hornibrook, 1971:19, pl. 3: figs. 55–57; pl. 13: figs. 3–7; text figs. 2a–g.

DISTRIBUTION.—One specimen in N41/f568. Nihotupu Formation.

DISCUSSION.—The rareness of this species in this study is strange, since it occurs in abundance in sediments of Otaian age around Hokianga and Orakei Bay (Hayward, 1972; Hornibrook, 1971).

*Pavonina triformis* Parr

PLATE 24: FIGURE 297

*Pavonina triformis* Parr, 1933:29, pl. 7: figs. 1–3.—Hornibrook, 1968:66, fig. 11.

DISTRIBUTION.—Rare in thanatotype B. Pakaurangi Formation.

*Planodiscorbis rarescens* (Brady)

*Discorbina rarescens* Brady, 1884:651, pl. 90: figs. 2, 3.

*Discorbinella rarescens* (Brady).—Hornibrook, 1961:117, pl. 14: figs. 292–294, 298.

DISTRIBUTION.—Extremely rare in thanatopos B, C, and D. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

***Planodiscorbis timida* (Hornibrook)**

*Discorbinella timida* Hornibrook, 1961:116, pl. 14: figs. 288, 293, 297.

DISTRIBUTION.—Extremely rare in thanatopos B, C, D, and F. Cornwallis Formation, Pakaurangi Formation.

***Planorbulinella plana* (Heron-Allen and Earland)**

*Planorbulina plana* Heron-Allen and Earland, 1924:174, pl. 12: figs. 92–95.

*Planorbulinella plana* (Heron-Allen and Earland).—Hornibrook, 1961:166, pl. 20: fig. 428.

DISTRIBUTION.—Extremely rare in thanatotope D. Nihotupu Formation.

***Planorbulinella zelandica* Finlay**

PLATE 24: FIGURES 298, 299

*Planorbulinella zelandica* Finlay, 1947:290, pl. 8: figs. 119–124.—Hornibrook, 1968:68, fig. 12.

DISTRIBUTION.—Extremely rare in thanatopos B and D. Nihotupu Formation, Pakaurangi Formation.

***Planulina catilla* (Finlay)**

PLATE 24: FIGURE 302

*Cibicides catillus* Finlay, 1940:465, pl. 67: fig. 200.

*Planulina catilla* (Finlay).—Hornibrook, 1968:63, fig. 10.

DISTRIBUTION.—Extremely rare in thanatopos C and D. Cornwallis Formation, Nihotupu Formation.

***Planulina* cf. *P. crassa* Galloway and Heminway**

PLATE 15: FIGURES 195–197

DISCUSSION.—Several specimens of *Planulina* are most similar to *Planulina crassa* Galloway and Heminway (1941:398, pl. 25: figs. 2a–c).

DISTRIBUTION.—Extremely rare in thanatopos B and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Plectofrondicularia awamoana* Finlay**

PLATE 24: FIGURE 301

*Plectofrondicularia awamoana* Finlay, 1939c:319, pl. 27: fig. 109.—Hornibrook, 1961:83, pl. 12: fig. 243.

DISTRIBUTION.—Extremely rare in thanatotope C. Nihotupu Formation.

***Plectofrondicularia fyfei*, Finlay**

*Plectofrondicularia fyfei* Finlay, 1939c:319, pl. 27: fig. 110.

DISTRIBUTION.—Extremely rare in thanatotope C. Nihotupu Formation.

***Plectofrondicularia parri* Finlay**

*Plectofrondicularia parri* Finlay, 1939a:516, pl. 68: fig. 4.—Hornibrook, 1961:82, pl. 12: figs. 244–245; 1968:107, fig. 23.

DISTRIBUTION.—Extremely rare in thanatopos C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

***Plectofrondicularia proparri* Finlay**

PLATE 24: FIGURE 300

*Plectofrondicularia proparri* Finlay, 1947:276, pl. 4: figs. 46–48.—Hornibrook, 1961:81, pl. 12: fig. 246; 1968:107, fig. 23.

DISTRIBUTION.—Extremely rare in thanatopos B and C. Pakaurangi Formation.

***Plectofrondicularia turgida* Hornibrook**

*Plectofrondicularia turgida* Hornibrook, 1961:82, pl. 12: figs. 239, 247, 248.

DISTRIBUTION.—Rare in thanatotope C, extremely rare in thanatopos A, B, and D. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

***Plectofrondicularia (Proxifrons) whaingaroica* (Stache)**

*Fronicularia whaingaroica* Stache, 1864:210, pl. 22: fig. 43.



*Plectofrondicularia whaingaroica* (Stache).—Hornibrook, 1961: 81.

*Plectofrondicularia (Proxifrons) whaingaroica* (Stache).—Hornibrook, 1971:45, fig. 11, pl. 11: figs. 182, 183.

DISTRIBUTION.—Extremely rare in thanatotope D. Cornwallis Formation, Nihotupu Formation.

*Pleurostomella aguafrescaensis* Todd and Kniker

PLATE 25: FIGURES 307, 308

*Pleurostomella aguafrescaensis* Todd and Kniker, 1952:23, pl. 4: fig. 17.

DISTRIBUTION.—Rare in thanatotope E. DSDP.

*Pleurostomella bierigi* Palmer and Bermudez

PLATE 25: FIGURES 309, 310

*Pleurostomella bierigi* Palmer and Bermudez, 1936:294, pl. 17: figs. 7, 8.

DESCRIPTION.—Test oval in outline, apical extremity pointed, maximum breadth at middle of test; chambers strongly embracing, inflated, final chamber occupying over half test; aperture a slit "T" shaped opening.

DISCUSSION.—This is the first New Zealand record of *Pleurostomella bierigi* Palmer and Bermudez, previously recorded from the Eocene to Miocene of central America, Africa, Europe, and Guam.

DISTRIBUTION.—Rare in thanatotope E, extremely rare in thanatotopes C and D. Cornwallis Formation, Nihotupu Formation, DSDP.

*Pleurostomella obtusa* Berthelin

PLATE 25: FIGURES 311, 312

*Pleurostomella obtusa* Berthelin, 1880:29, pl. 1: figs. 9a, b.—Cushman, 1927b:131, pl. 25: fig. 22.

DISCUSSION.—This species is distinguished by its short, slightly inflated chambers and its tendency towards partial uniserial arrangement.

DISTRIBUTION.—Rare in thanatotope E. DSDP.

*Pleurostomella rimosa* Cushman and Bermudez

*Pleurostomella rimosa* Cushman and Bermudez, 1937:17, pl. 1: figs. 62–63.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

*Pleurostomella tenuis* Hantken

PLATE 25: FIGURES 313–317

*Pleurostomella tenuis* Hantken, 1883:25, pl. 1: fig. 5.

DESCRIPTION.—Test small, elongate; chambers elongate, inflated, arranged in a regular alternating series, never becoming uniserial; aperture in an oval depression, two small teeth; some individuals have an incompletely developed final chamber with a small terminal aperture.

DISCUSSION.—This is the first New Zealand record of *Pleurostomella tenuis* Hantken. It is distinguished by its elongate, inflated chambers and lack of any uniserial development.

DISTRIBUTION.—Frequent in thanatotope E, rare in thanatotopes C and D. Cornwallis Formation, Nihotupu Formation, DSDP.

*Pseudonodosaria aperta* (Stache)

*Glandulina aperta* Stache, 1864:188, pl. 22: figs. 11a-c. *Pseudonodosaria aperta* (Stache).—Hornibrook, 1971:36, pl. 7: fig. 95.

DISTRIBUTION.—Rare in thanatotopes B and C, extremely rare in thanatotopes A and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Pseudonodosaria symmetrica* (Stache)

*Glandulina symmetrica* Stache, 1864:187, pl. 22: figs. 9a-b. *Pseudonodosaria symmetrica* (Stache).—Hornibrook, 1971:36, pl. 10: fig. 172.

DISTRIBUTION.—Extremely rare in thanatotopes A, B, and C. Nihotupu Formation, Pakaurangi Formation.

*Pseudopatellinoides* aff. *P. primus* Krashenninnikov

PLATE 25: FIGURES 318, 319

DESCRIPTION.—Test small, trochospiral, conical; periphery sharply angled; dorsal side high, conically convex, evolute; ventral side involute, flat; three chambers per whorl; dorsal sutures limbate, flush,

strongly oblique; ventral sutures radial, slightly depressed; aperture an arched umbilical opening.

DISCUSSION.—This species is represented in our collections by a single specimen. It resembles *Pseudopatellinoides primus* Krasheninnikov (1958:242, pl. 8: figs. 1, 2; Loeblich and Tappan, 1964: fig. 458, nos. 9a–d), of the Russian Miocene, more closely than the other three described species of this genus, but differs in being more highly conical.

DISTRIBUTION.—Extremely rare in thanatotope F. Cornwallis Formation.

### *Pullenia bulloides* (d'Orbigny)

PLATE 24: FIGURES 303, 304

*Nonionina bulloides* d'Orbigny, 1846:107, pl. 5: figs. 9, 10.  
*Pullenia bulloides* (d'Orbigny).—Hornibrook, 1961:90, pl. 11: figs. 205, 206.—Vella, 1963:12, pl. 1: figs. 7, 8.—Kennett, 1966a:51, pl. 5: figs. 73, 74.—Gibson, 1967:45, pl. 10: figs. 168, 169.

DISTRIBUTION.—Rare in thanatotypes C, D, and E, extremely rare in thanatotypes A and B. Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

### *Pullenia quinqueloba* (Reuss)

*Nonionina quinqueloba*, Reuss, 1851:71, pl. 5: fig. 31.  
*Pullenia compressiuscula* var. *quadriloba* Reuss, 1867:55, pl. 3: fig. 8.  
*Pullenia quinqueloba* (Reuss).—Hornibrook, 1961:90, pl. 11: figs. 207, 208.—Vella, 1963:12.—Kennett, 1966a:52, pl. 5: figs. 75, 76.—Gibson, 1967:46, pl. 10: figs. 172, 173.  
*Pullenia quadriloba* Reuss.—Vella, 1963:12, pl. 1: figs. 9, 10.—Gibson, 1967:46, pl. 10: figs. 170–171.

DISTRIBUTION.—Frequent in thanatotope E, rare in thanatotope D, extremely rare in thanatotypes B and C. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

### *Pyrulina acuminata* d'Orbigny

*Pyrulina acuminata* d'Orbigny, 1840:43, pl. 4: figs. 18, 19.—Cushman and Ozawa, 1930:58, pl. 14: figs. 7a–c.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

### *Pyrulina fusiformis* (Roemer)

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

*Pyrulina fusiformis* (Roemer).—Cushman and Ozawa, 1930:54, pl. 13: figs. 3–8.—Hornibrook, 1961:61, pl. 7: fig. 127.

DISTRIBUTION.—Extremely rare in thanatotypes B and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

### *Pyrulina gutta* d'Orbigny

*Pyrulina gutta* d'Orbigny, 1826:267, no. 28, "Modele" 30.—Cushman and Ozawa, 1930:51, pl. 13: figs. 1a–c.

DISTRIBUTION.—Extremely rare in thanatotope E. DSDP.

### *Rumulina* species

PLATE 26: FIGURE 324

DISTRIBUTION.—Extremely rare in thanatotypes B, C, and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

### *Rectobolivina maoriella* Finlay

PLATE 24: FIGURES 305, 306

*Rectobolivina maoriella* Finlay, 1939c:321, pl. 27, figs. 78–81.—Hornibrook, 1961:77, pl. 10: fig. 190; 1968:63, fig. 10.

DISTRIBUTION.—Frequent in thanatotope D, extremely rare in thanatotypes B and C. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

### *Rectobolivina striatula* (Cushman)

PLATE 26: FIGURES 320, 321

*Siphogenerina bifrons* var. *striatula* Cushman, 1917:662.  
*Rectobolivina striatula* (Cushman).—Carter, 1964:69, pl. 2: figs. 35, 36.—Kennett, 1966a:47, pl. 4: fig. 59.—Hornibrook, 1968:73, fig. 13.

DISCUSSION.—A single individual identical to *Rectobolivina striatula* Cushman was found during this study. Hornibrook (1968) cites the stratigraphic range as Tongaporutuan to Recent (upper Miocene to Recent) and this record extends the range. Carter (1964) records *R. striatula* from the lower and mid Miocene of Victoria, Australia.

DISTRIBUTION.—Single specimen in N41/f660. Piha Formation.

*Rectuwigerina rerensis* (Finlay)

*Siphogenerina rerensis* Finlay, 1939b:108, pl. 11: fig. 8.  
*Rectuwigerina rerensis* (Finlay).—Vella, 1961:480, pl. 2: figs. 22, 23.—Hornibrook, 1961:66, pl. 8: fig. 146; 1968:104, fig. 22.

DISTRIBUTION.—Extremely rare in thanatotoxes C and D. Nihotupu Formation.

*Rectuwigerina ruatoria* (Vella)

PLATE 26: FIGURE 322

*Ruatoria ruatoria* Vella, 1961:480, pl. 2: figs. 12, 13.

DISTRIBUTION.—Rare in thanatotoxes C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Rectuwigerina vesca* (Finlay)

PLATE 26: FIGURE 323

*Siphogenerina vesca* Finlay, 1939b:109, pl. 13: figs. 46, 47.  
*Rectuwigerina vesca* (Finlay).—Vella, 1961:481, pl. 2: figs. 24, 25.—Hornibrook, 1968:104, fig. 22.

DISTRIBUTION.—Rare in thanatotoxes C and D. Nihotupu Formation.

*Reussella spinulosa* (Reuss)

PLATE 27: FIGURE 330

*Verneuilina spinulosa* Reuss, 1850:374, pl. 47: fig. 12.  
*Reussella spinulosa* (Reuss).—Cushman, 1945:33, pl. 6: figs. 8, 9.  
*Reussella* aff. *spinulosa* (Reuss).—Hornibrook, 1961:78.

DESCRIPTION.—Test acute triangular pyramid; apertural end convex; edges carinate and spinose; sutures acute, flush or slightly raised.

DISTRIBUTION.—Frequent in thanatotope B, extremely rare in thanatotoxes A, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Rosalina augur* Hornibrook

*Rosalina augur* Hornibrook, 1961:102, pl. 13: figs. 263, 265, 268.

DISTRIBUTION.—Extremely rare is thanatotope B. Pakaurangi Formation.

*Rosalina concinna* (Brady)

PLATE 26: FIGURES 325, 326

*Discorbina concinna* Brady, 1884:646, pl. 90: figs. 7, 8.  
*Rosalina concinna* (Brady).—Hornibrook, 1961:101, pl. 13: figs. 273, 274.

DISTRIBUTION.—Rare in thanatotoxes B and D. Cornwallis Formation, Nihotupu Formation, Waitemata Group.

*Saracenaria arcuatula* (Stache)

*Hemirobulina arcuatula* Stache, 1864:227, pl. 23: figs. 6a, b.  
*Saracenaria arcuatula* (Stache).—Hornibrook, 1961:40, 1971:41, pl. 8: figs. 130, 131.

DISTRIBUTION.—Extremely rare in thanatotoxes C and D. Nihotupu Formation, Pakaurangi Formation.

*Saracenaria kellumi* Dorreen

*Saracenaria kellumi* Dorreen, 1948:289, pl. 37: fig. 4.

DISTRIBUTION.—Extremely rare in thanatotoxes B, C, and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

*Saracenaria latifrons* (Brady)

PLATE 27: FIGURE 331

*Cristellaria latifrons* Brady, 1884:544, pl. 68: fig. 19; pl. 113: fig. 11.  
*Saracenaria latifrons* (Brady).—Kennett, 1966a, table 6.—Gibson, 1967, pl. 4: fig. 69.

DISTRIBUTION.—Extremely rare in thanatotope C. Pakaurangi Formation.

*Saracenaria obesa* Cushman and Todd

PLATE 26: FIGURES 327–329

*Saracenaria obesa* Cushman and Todd, 1945:31, pl. 5: fig. 2.

DESCRIPTION.—Test pyriform; dorsal margin and sides of apertural face bluntly angled; chambers few, 3–5; sutures curved, flush with surface; wall smooth; apertural face broad, somewhat inflated towards its sides; aperture terminal, radiate.

DISCUSSION.—This is the first New Zealand record of *Saracenaria obesa* Cushman and Todd, previ-

ously recorded from the Miocene and Pliocene of Jamaica and Spain, respectively. This species is distinguished by its broad, inflated apertural face, pyriform shape and few chambers.

DISTRIBUTION.—Rare in thanatotope C. Nihotupu Formation, Pakaurangi Formation.

### *Sherbornina cuneimarginata* Wade

*Sherbornina cuneimarginata* Wade, in Wade and Carter, 1957: 158, pl. 1: figs. 6–7.

DISCUSSION.—This species is confined to the lower Miocene of Australia and New Zealand (Hayward, 1978) and is distinguished by its greatly enlarged ventral retral processes and asymmetric profile.

DISTRIBUTION.—Extremely rare in thanatotope A. Nihotupu Formation.

### *Sigmoidella elegantissima* (Parker and Jones)

*Polymorphina elegantissima* Parker and Jones, in Brady, Parker, and Jones, 1870:231, pl. 40: fig. 15.

*Sigmoidella elegantissima* (Parker and Jones).—Cushman and Ozawa, 1930:140, pl. 39: fig. 1.—Hornibrook, 1961:61, pl. 7: fig. 119.

DISTRIBUTION.—Rare in thanatotope B, extremely rare in thanatotope A. Pakaurangi Formation, Puketi Formation.

### *Sigmoidina pacifica* Cushman and Ozawa

PLATE 15: FIGURES 198, 199; PLATE 27: FIGURE 332

*Sigmoidella* (*Sigmoidina*) *pacifica* Cushman and Ozawa, 1928: 19, pl. 2: fig. 13.

*Guttulina* (*Sigmoidina*) *pacifica* (Cushman and Ozawa).—Cushman and Ozawa, 1930:50, pl. 37: figs. 3–5.

*Polymorphina elegantissima* Parker and Jones.—Chapman, 1926:67, pl. 13: fig. 10 [not of Parker and Jones].

*Sigmoidella pacifica* Cushman and Ozawa.—Loeblich and Tappan, 1964:C534, fig. 418, 2a, b.

DESCRIPTION.—Test “tear-drop” shape; walls smooth with flush sutures; chambers elongate in quinqueloculine series; aperture terminal, radiate.

DISCUSSION.—This is the first New Zealand fossil record of *Sigmoidina pacifica* Cushman and Ozawa, previously recorded from the Miocene and Pliocene of Australia, Japan, China, and Russia, and Recent sediments of the West Pacific from New Zealand to Japan.

DISTRIBUTION.—Frequent in thanatotope B, extremely rare in thanatopes A, C, D, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

### *Siphonina australis* Cushman

PLATE 27: FIGURE 333

*Siphonina australis* Cushman, 1927d:8, pl. 2: fig. 6; pl. 3: figs. 7, 8.—Hornibrook, 1961:121, pl. 16: fig. 353; 1968:58, fig. 9.

DISTRIBUTION.—Frequent in thanatopes C and D, extremely rare in thanatotope B. Nihotupu Formation, Pakaurangi Formation, Waitemata Group.

### *Siphowigerina proboscidea* (Schwager)

PLATE 27: FIGURE 334

*Uvigerina proboscidea* Schwager, 1866:250, pl. 7: fig. 96.—Douglas, 1973, pl. 8: fig. 8.

*Neouvigerina plebeja* Vella, 1961:470, figs. 4d-g, pl. 2: fig. 19. *Uvigerina canariensis* d'Orbigny.—Hornibrook, 1961:65, pl. 8: fig. 143

DISTRIBUTION.—Common in thanatopes C and D, rare in thanatotope B, extremely rare in thanatotope E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

### *Sphaeroidina bulloides* d'Orbigny

PLATE 27: FIGURE 335

*Sphaeroidina bulloides* d'Orbigny, 1826:267, “Modèles” 65.—Hornibrook, 1961:90, pl. 11: fig. 210; 1968:58, fig. 9.—Kennett, 1966a:51, pl. 4: fig. 72.

DISTRIBUTION.—Common in thanatotope C, frequent in thanatopes B and D, rare in thanatotope E, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

### *Spirillina* aff. *S. plana* Möller

DISCUSSION.—One specimen of *Spirillina* is most similar to *Spirillina plana* Möller (1879:28).

DISTRIBUTION.—A single specimen in N42/f731. Cornwallis Formation.

*Spirillina vivipara* Ehrenberg

PLATE 27: FIGURE 336

*Spirillina vivipara* Ehrenberg, 1843:323, 422, pl. 3: fig. 41.—  
Barker, 1960, pl. 85: figs. 1–4.

DISTRIBUTION.—Extremely rare in thanatotoxes D and F. Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup.

*Stetsonia* species

PLATE 27: FIGURES 337, 338

DESCRIPTION.—Test medium-sized, lenticular, partly trochospiral; periphery narrowly rounded; one side involute with semi-opaque shell material filling umbilicus; opposite side partly evolute with portions of early whorls visible beneath subtranslucent umbonal material; 7–9 chambers per whorl; sutures distinct, strongly curved, flush; aperture an elongate slit on periphery extending up into apertural face from base of final chamber.

DISCUSSION.—This species differs from all described species in its larger size, and more trochospiral coiling.

DISTRIBUTION.—Common in thanatotope E. DSDP.

*Stilostomella antillea* (Cushman)

PLATE 28: FIGURE 339

*Nodosaria antillea* Cushman, 1923:91, pl. 14: fig. 9.  
*Stilostomella antillea* (Cushman).—Kennett, 1966a, table 6.  
*Stilostomella basicarinata* Hornibrook, 1961:50, pl. 6: figs. 104, 105.

DISTRIBUTION.—Frequent in thanatotope E, rare in thanatotoxes C and D, extremely rare in thanatotope B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

*Stilostomella awamoana* Hornibrook

*Stilostomella awamoana* Hornibrook, 1961:51, pl. 6: fig. 107.

DISTRIBUTION.—Extremely rare in thanatotoxes B, C, D, and E. Pakaurangi Formation, DSDP.

*Stilostomella fijiensis* (Cushman)

PLATE 28: FIGURE 340

*Siphonodosaria fijiensis* Cushman, 1931:30, pl. 4: fig. 10.  
*Stilostomella fijiensis* (Cushman).—Hornibrook, 1961:49, pl. 6: fig. 106.

DISTRIBUTION.—Rare in thanatotoxes C, D, and E, extremely rare in thanatotope B. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, DSDP.

*Stilostomella lepidula* (Schwager)

*Nodosaria lepidula* Schwager, 1866:210, pl. 5: figs. 27–28.  
*Stilostomella finlayi* Hornibrook, 1961:50, pl. 6: fig. 108.

DISTRIBUTION.—Extremely rare in thanatotoxes C and D. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation.

*Stilostomella pomuligera* (Stache)

PLATE 28: FIGURES 341, 342

*Dentalina pomuligera* Stache, 1864:204, pl. 22: fig. 31.  
*Stilostomella pomuligera* (Stache).—Hornibrook, 1961:49, pl. 6: fig. 110; 1971:38, pl. 7: figs. 103–108.

DISTRIBUTION.—Common in thanatotope E, frequent in thanatotope D, rare in thanatotope C, extremely rare in thanatotoxes A, B, and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Stilostomella subspinosa* (Cushman)

PLATE 28: FIGURE 343

*Ellipsonodosaria subspinosa* Cushman, 1943:92, pl. 16: figs. 6, 7.  
*Stilostomella subspinosa* (Cushman).—Douglas, 1973, pl. 5: fig. 10.

DISTRIBUTION.—Extremely rare in thanatotoxes C and E. Pakaurangi Formation, DSDP.

*Stilostomella verneuilii* (d'Orbigny)

*Dentalina verneuilii* d'Orbigny, 1846:48, pl. 2: figs. 7–8.  
*Dentalina aequalis* Karrer, 1864:74, pl. 16: fig. 1.  
*Stilostomella verneuilii* (d'Orbigny).—Hornibrook, 1961:50, pl. 6: fig. 109.  
*Stilostomella aequalis* (Karrer).—Hornibrook, 1971:16, pl. 2: figs. 34–42.

DISTRIBUTION.—Frequent in thanatopos D and E, rare in thanatopos B and C, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere Subgroup, Waitemata Group, DSDP.

*Stomatorbina concentrica* (Parker and Jones)

*Pulvinulina concentrica* Parker and Jones, in Brady, 1864:470, pl. 48: fig. 14.—Brady, 1884:686, pl. 105: fig. 1.  
*Mississippina concentrica* (Parker and Jones).—Hornibrook, 1961:114, pl. 17: figs. 369, 374; 1968:56, fig. 8.

DISTRIBUTION.—Extremely rare in thanatotope F. Undifferentiated Hukatere Subgroup.

*Trifarina bradyi* Cushman

PLATE 28: FIGURE 344

*Trifarina bradyi* Cushman, 1923:99, pl. 22: figs. 3–9.—Hornibrook, 1961:70, pl. 9: figs. 163, 164.—Kennett, 1966a:44, pl. 3: figs. 49, 50.

DISTRIBUTION.—Common in thanatopos B and D, frequent in thanatotope C, rare in thanatopos A and F. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Puketi Formation, undifferentiated Hukatere Subgroup, Waitemata Group.

*Trifarina costornata* (Hornibrook)

PLATE 28: FIGURE 345

*Angulogerina costornata*, Hornibrook, 1961:68, pl. 9: figs. 149, 150.

DISTRIBUTION.—Extremely rare in thanatopos B and D. Nihotupu Formation, Pakaurangi Formation.

*Trifarina esuriens* (Hornibrook)

PLATE 28: FIGURE 346

*Angulogerina esuriens* Hornibrook, 1961:69, pl. 9: figs. 154, 155.

DISTRIBUTION.—Rare in thanatopos C and D, extremely rare in thanatopos B and E. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

*Trifarina tortuosa* (Hornibrook)

PLATE 28: FIGURE 347

*Angulogerina tortuosa* Hornibrook, 1961:68, pl. 9, figs. 151, 152.

DISTRIBUTION.—Rare in thanatopos B, C, D, and F, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, undifferentiated Hukatere subgroup, Waitemata Group.

*Vaginulina awamoana* Hornibrook

*Vaginulina awamoana* Hornibrook, 1961:44, pl. 5: figs. 77, 81, 82.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

*Vaginulina cristellata* (Stache)

*Marginulina cristellata* Stache, 1864:212, pl. 22: fig. 44.  
*Vaginulina cristellata* (Stache).—Hornibrook, 1968:60, fig. 9; 1971:39, pl. 8: figs. 128, 129.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

*Vaginulina elegans* d'Orbigny

*Vaginulina elegans* d'Orbigny, 1826:257, "Modèles" 54.—Hornibrook, 1961:44, pl. 5: figs. 86, 87.

DISTRIBUTION.—Extremely rare in thanatopos A, B, and C. Nihotupu Formation, Pakaurangi Formation.

*Vaginulina neglecta* (Karrer)

*Marginulina neglecta* Karrer, 1864:75, pl. 16: fig. 4.  
*Vaginulina neglecta* (Karrer).—Hornibrook, 1971:17, pl. 2: figs. 24–27, 32, 33.

DISTRIBUTION.—Extremely rare in thanatopos A, B, C, D, and E. Cornwallis Formation, Pakaurangi Formation, Puketi Formation, DSDP.

*Vaginulina vagina* (Stache)

*Dentalina vagina* Stache, 1864:206, pl. 22: fig. 34.  
*Vaginulina vagina* (Stache).—Hornibrook, 1961:44, pl. 5: fig. 85; 1971:39, pl. 7: figs. 119–124.

DISTRIBUTION.—Frequent in thanatotope C, rare in thanatotypes B, D, and E, extremely rare in thanatotope A. Cornwallis Formation, Nihotupu Formation, Pakaurangi Formation, Waitemata Group, DSDP.

*Vaginulinopsis recta* (Karrer)

PLATE 28: FIGURE 348

*Vaginulina recta* Karrer, 1864:74, pl. 16: fig. 2.

*Vaginulinopsis clifdenensis* Hornibrook, 1961:42, pl. 5: figs. 71, 72.

*Vaginulinopsis recta* (Karrer).—Hornibrook, 1971:17, pl. 2: figs. 28–31.

DISTRIBUTION.—Extremely rare in thanatotypes A and B. Pakaurangi Formation, Puketi Formation.

*Victoriella conoidea* (Rutten)

PLATE 28: FIGURE 349

*Carpenteria conoidea* Rutten, 1914:47, pl. 7: figs. 6–9.

*Victoriella conoidea* (Rutten).—Hornibrook, 1961:168, pl. 26: fig. 520; 1968:64, fig. 11.

DISTRIBUTION.—Frequent in thanatotope A. Nihotupu Formation, undifferentiated Hukatere Subgroup.

*Virgulopsis reticulata* Hornibrook

*Virgulopsis reticulata* Hornibrook, 1961:79, pl. 28: figs. 542, 543.

DISTRIBUTION.—Extremely rare in thanatotope B. Pakaurangi Formation.

# Appendix I

## Location, Lithostratigraphic Unit, and Age of Samples Used in Thanatotope Analysis

Grid references are from NZMS 1, Sheets N28, Maungaturoto (2nd ed., 1965); N33 Kaipara (3rd ed., 1971); N37 Helensville (2nd ed., 1964); N41 Waitakere (3rd ed., 1964); and N42 Auckland (3rd ed., 1966).

- N28/f452 (Grid. Ref. N28/807350), west Pakaurangi Point. Pakaurangi Formation, Hollands Member. Lower Pl.
- N28/f453 (Grid. Ref. N28/807350), west Pakaurangi Point. Pakaurangi Formation, Hollands Member. Lower Pl.
- N28/f454 (Grid. Ref. N28/810349), west Pakaurangi Point. Pakaurangi Formation, Waipukua Member. Lower Pl.
- N28/f455 (Grid. Ref. N28/814345), Pakaurangi Point. Pakaurangi Formation, Funnel Member. Lower Pl.
- N28/f456 (Grid. Ref. N28/814344), Pakaurangi Point. Pakaurangi Formation, Funnel Member. Lower Pl.
- N28/f457 (Grid. Ref. N28/811348), west Pakaurangi Point. Pakaurangi Formation, Pakaurangi Member. Lower Pl.
- N28/f458 (Grid. Ref. N28/797349), west Pakaurangi Point. Pakaurangi Formation, Tapu Member. Lower Pl.
- N28/f781 (Grid. Ref. N28/815345), Pakaurangi Point. Puketi Formation, Miogypsina Sandstone. Lower Pl.
- N28/f785 (Grid. Ref. N28/815346), north Pakaurangi Point. Pakaurangi Formation, Pakaurangi Member. Lower Pl.
- N28/f788 (Grid. Ref. N28/815347), north Pakaurangi Point. Pakaurangi Formation, Hollands Member. Lower Pl.
- N28/f792 (Grid. Ref. N28/800350), west Pakaurangi Point. Pakaurangi Formation, Tapu Member. Lower Pl.
- N28/f793 (Grid. Ref. N28/800350), west Pakaurangi Point. Pakaurangi Formation, Waiteroa Member. Lower Pl.
- N28/f795 (Grid. Ref. N28/798350), west Pakaurangi Point. Pakaurangi Formation, Waiteroa Member. Lower Pl.
- N28/f912 (Grid. Ref. N28/737321), north of Bushy Point, Hukatere Peninsula, Undifferentiated Hukatere Subgroup. Pl.
- N28/f913 (Grid. Ref. N28/695362), Nihotetea Creek mouth, Hukatere Peninsula. Undifferentiated Hukatere Subgroup. Pl.
- N28/f914 (Grid. Ref. N28/695362), Nihotetea Creek mouth, Hukatere Peninsula. Undifferentiated Hukatere Subgroup. Pl.
- N33/f505 (Grid. Ref. N33/825211), Okahukura Peninsula, borehole, 1951 (12 m level). Pakaurangi Formation. Lower Pl.
- N33/f531 (Grid. Ref. N33/796297), Puketotara Peninsula. Pakaurangi Formation. Lower Pl.
- N33/f532 (Grid. Ref. N33/798292), Puketotara Peninsula. Pakaurangi Formation. Lower Pl.
- N33/f534 (Grid. Ref. N33/798289), Puketotara Peninsula. Pakaurangi Formation. Lower Pl.
- N33/f536 (Grid. Ref. N33/795286), Puketotara Peninsula. Pakaurangi Formation. Lower Pl.
- N33/f578 (Grid. Ref. N33/814207), Okahukura Peninsula, Tapora Flats borehole (30 m level). Pakaurangi Formation. Lower Pl.
- N33/f579 (Grid. Ref. N33/814207), Okahukura Peninsula, Tapora Flats borehole (31 m level). Pakaurangi Formation. Lower Pl.
- N33/f580 (Grid. Ref. N33/814207), Okahukura Peninsula, Tapora Flats borehole (42 m level). Pakaurangi Formation. Lower Pl.
- N33/f581 (Grid. Ref. N33/814207), Okahukura Peninsula, Tapora Flats borehole (46 m level). Pakaurangi Formation. Lower Pl.
- N37/f585 (Grid. Ref. N37/971939), Jordans Road, south Kaipara. Cornwallis Formation. Upper Po.
- N41/f2d (Grid. Ref. N41/955612), south Muriwai. Nihotupu Formation, Maori Bay Member. Mid Pl.
- N41/f533 (Grid. Ref. N41/069408), Marama Stream. Nihotupu Formation. Upper Po.
- N41/f537 (Grid. Ref. N41/098461), Huia Stream, Smiths Creek. Nihotupu Formation. Lower Pl.
- N41/f539 (Grid. Ref. N41/074464), Huia Stream. Nihotupu Formation. Lower Pl.
- N41/f555 (Grid. Ref. N41/056547), Waitakere River, Kellys Creek. Nihotupu Formation. Mid Pl.
- N41/f590n (Grid. Ref. N41/954616), south Muriwai. Nihotupu Formation, Maori Bay Member. Mid Pl.
- N41/f590u (Grid. Ref. N41/954616), south Muriwai. Nihotupu Formation, Maori Bay Member. Mid Pl.
- N41/f592 (Grid. Ref. N41/957606), south Muriwai. Nihotupu Formation, Wairere Member. Mid Pl.
- N41/f604 (Grid. Ref. N41/955615), south Muriwai. Nihotupu Formation, Maori Bay Member. Mid Pl.
- N41/f622 (Grid. Ref. N41/091479), Nihotupu Stream. Nihotupu Formation. Lower Pl.
- N41/f632 (Grid. Ref. N41/043559), Waitakere River. Nihotupu Formation. Swanson Member. Upper Po.
- N41/f644 (Grid. Ref. N41/071451), Huia Stream, Georges Creek. Nihotupu Formation. Lower Pl.
- N41/f653 (Grid. Ref. N41/069408), Marama Stream. Nihotupu Formation. Upper Po.
- N41/f657 (Grid. Ref. N41/084405), Huia coast Road. Cornwallis Formation. Upper Po.
- N41/f660 (Grid. Ref. N41/992477), Lion Rock, Piha. Piha Formation. Pl.
- N42/f683 (Grid. Ref. N42/285514), Taylors Bay. Waitemata Group. Po.
- N42/f694 (Grid. Ref. N42/117454), Kakamatua Stream. Cornwallis Formation. Upper Po.
- N42/f696 (Grid. Ref. N42/102455), Huia Stream, Smiths Creek. Nihotupu Formation. Lower Pl.
- N42/f701 (Grid. Ref. N42/101474), Nihotupu Stream. Nihotupu Formation. Lower Pl.



N42/f715 (Grid. Ref. N42/120490), Scenic Drive. Nihotupu Formation, Swanson Member. Upper Po.  
 N42/f719 (Grid. Ref. N42/120490), Scenic Drive. Nihotupu Formation, Swanson Member. Upper Po.  
 N42/f723 (Grid. Ref. N42/137485), Parau Dam tributary. Nihotupu Formation, Swanson Member. Upper Po.  
 N42/f728 (Grid. Ref. N42/122512), Waikumete West Coast Road. Waitemata Group. Upper Po.  
 N42/f729 (Grid. Ref. N42/104417), Huia Road. Cornwallis

Formation. Upper Po.  
 N42/f730 (Grid. Ref. N42/104417), Huia Road. Cornwallis Formation. Upper Po.  
 DSDP 34 (Leg 21, site 206), Core 34 CC. New Caledonia Basin.  
 DSDP 35 (Leg 21, site 206), Core 35-2 (50-56 cm). New Caledonia Basin.  
 DSDP 37 (Leg 21, site 206), Core 37 CC. New Caledonia Basin.  
 DSDP 38 (Leg 21, site 206), Core 38-2 (48-51 cm). New Caledonia Basin.

## Appendix II

### Location, Lithostratigraphic Unit, and Age of Additional Samples Referred to in Systematic Section

Grid References are from NZMS 1 Sheets N41 Waitakere (3rd Ed., 1964); and N42 Auckland (3rd Ed., 1966).

N41/f568 (Grid. Ref. N41/954615), south Muriwai. Nihotupu Formation, Maori Bay Member. Mid Pl.  
 N41/f609 (Grid. Ref. N41/099535), Henderson Stream. Waitemata Group. Upper Po.  
 N41/f612 (Grid. Ref. N41/088545), Henderson Stream. Cornwallis Formation. Upper Po.  
 N41/f645 (Grid. Ref. N41/084476), Christies Creek. Nihotupu Formation. Lower Pl.  
 N42/f705 (Grid. Ref. N42/130488), Scenic Drive. Nihotupu

Formation, Parekura Member. Upper Po.  
 N42/f706 (Grid. Ref. N42/103498), Scenic Drive. Nihotupu Formation. Lower Pl.  
 N42/f722 (Grid. Ref. N42/132481), Parau Dam tributary. Waitemata Group. Upper Po.  
 N42/f725 (Grid. Ref. N42/124507), Oratia Stream. Waitemata Group. Upper Po.  
 N42/f727 (N42/122512), Waikumete West Coast Road. Waitemata Group. Upper Po.  
 N42/f731 (N42/104417), Huia Road. Cornwallis Formation. Upper Po.  
 N42/f733 (N42/104417), Huia Road. Cornwallis Formation. Upper Po.

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## PLATES

## PLATE 1

*Globorotalia zealandica incognita* Walters

1. Involute side, N42/f696, hypotype, USNM 243240,  $\times 200$ .
2. Peripheral view, N42/f696, hypotype, USNM 243240,  $\times 200$ .

*Globorotalia zealandica zealandica* Hornibrook

3. Involute side, N41/f590, hypotype, USNM 243241,  $\times 175$ .
4. Peripheral view, N41/f590, hypotype, USNM 243241  $\times 175$ .

*Globorotalia kugleri* Bolli

5. Involute side, N37/f585, hypotype, USNM 243242,  $\times 300$ .

*Globoquadrina dehiscens* (Chapman, Parr and Collins)

6. Involute side, DSDP 206-38-2, hypotype, USNM 243243,  $\times 130$ .

*Ammodiscus finlayi* Parr

7. Side view, N41/f612, hypotype, USNM 243244,  $\times 120$ .

*Bathysiphon* sp.

8. Side view, N42/f715, hypotype, USNM 243245,  $\times 50$ .

*Martinotiella communis* (d'Orbigny)

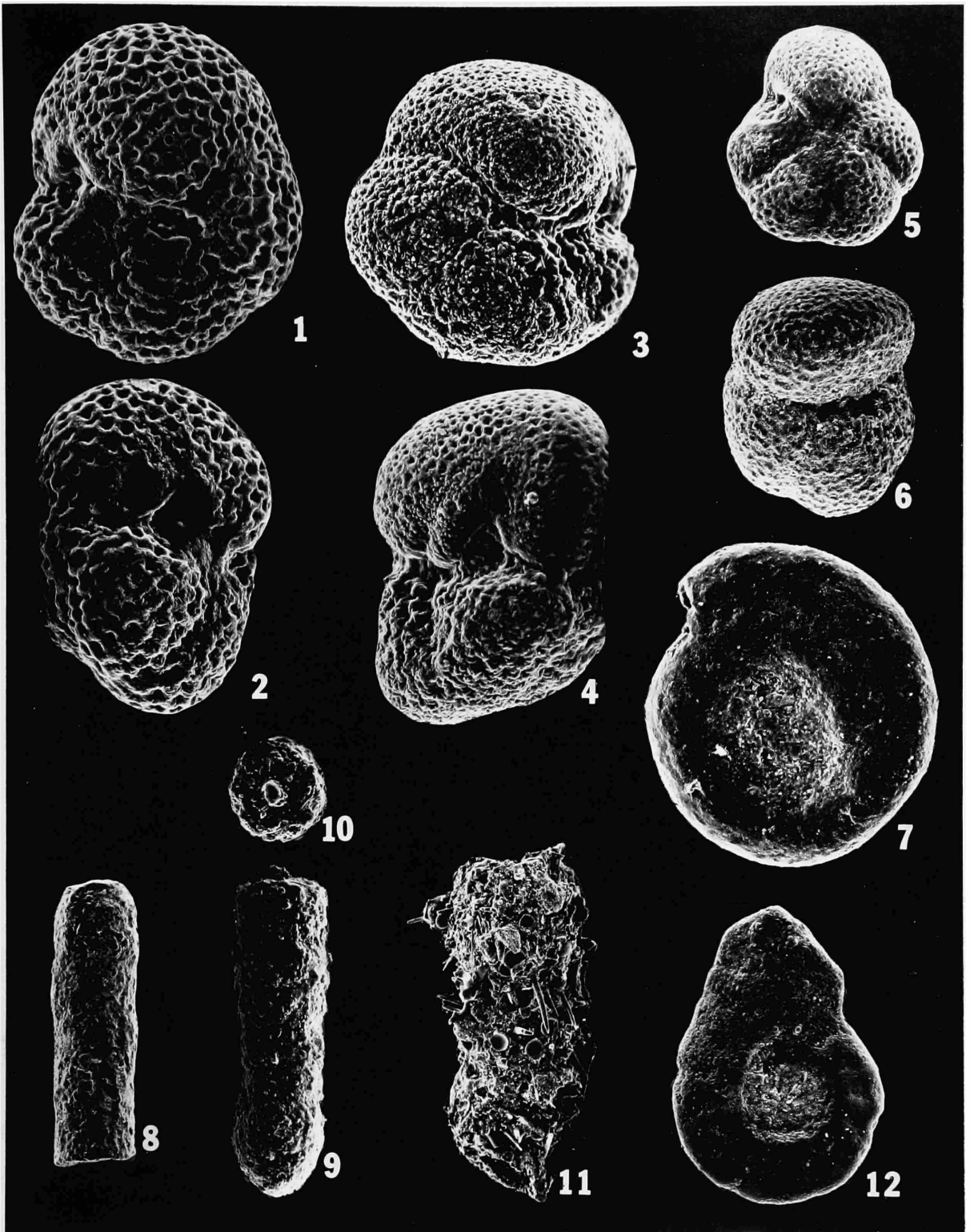
9. Side view, N33/f581, hypotype, USNM 243246,  $\times 90$ .
10. Apertural view, N33/f581, hypotype, USNM 243246,  $\times 90$ .

*Martinotiella* sp.

11. Side view, DSDP 206-45 CC, hypotype, USNM 243247,  $\times 66$ .

*Bolivinoopsis* sp.

12. Side view, DSDP 206-34 CC, hypotype, USNM 243248,  $\times 220$ .



## PLATE 2

*Pelosina complanata* Franke

13. Side view, N41/f533, hypotype, USNM 243249,  $\times 75$ .

*Recurvoides* sp.

14. Side view, N41/f632, hypotype, USNM 243250,  $\times 100$ .

*Semivulvulina capitata* (Stache)

15. Apertural view, N33/f581, hypotype, USNM 243251,  $\times 100$ .

16. Side view, N33/f581, hypotype, USNM 243251,  $\times 100$ .

*Triplasia marwicki* Loeblich and Tappan

17. Side view, N41/f644, hypotype, USNM 243252,  $\times 100$ .

*Articulina parri* Cushman

18. Apertural view, paratype, Victoria, Australia, USNM 243253,  $\times 75$ .

19. Side view, paratype, Victoria, Australia, USNM 243253,  $\times 75$ .

20. Apertural view N33/f505, hypotype, USNM 243254,  $\times 200$ .

21. Side view, N33/f505, hypotype, USNM 243254,  $\times 200$ .

*Lachlanella* cf. *L. schroekingeri* (Karrer)

22. Side view, N28/f914, hypotype, USNM 243255,  $\times 50$ .

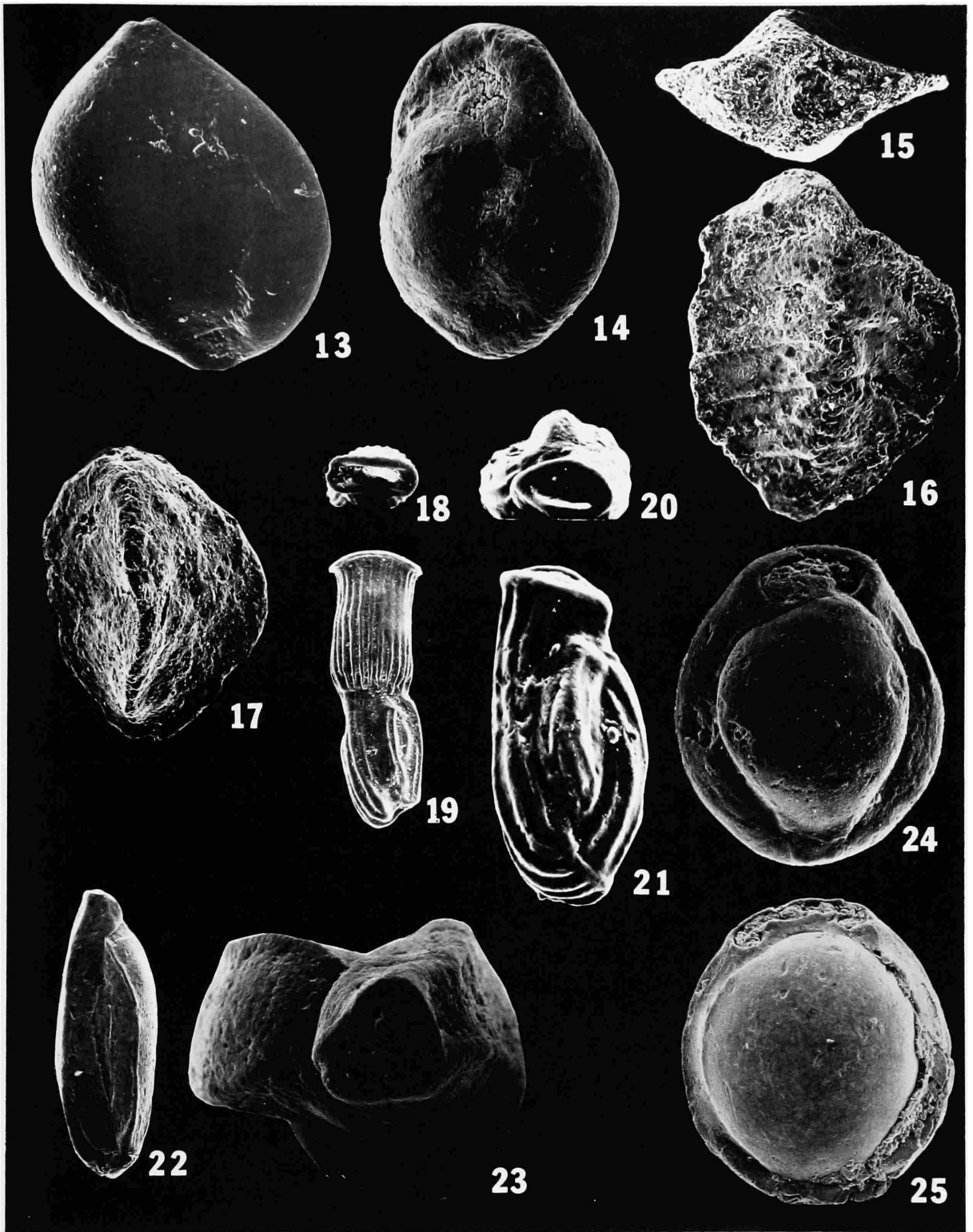
23. Apertural view, N28/f914, hypotype, USNM 243255,  $\times 165$ .

*Pyrgo anomala* (Schlumberger)

24. Front view, N28/f914, hypotype, USNM 243256,  $\times 200$ .

*Pyrgo depressa* (d'Orbigny)

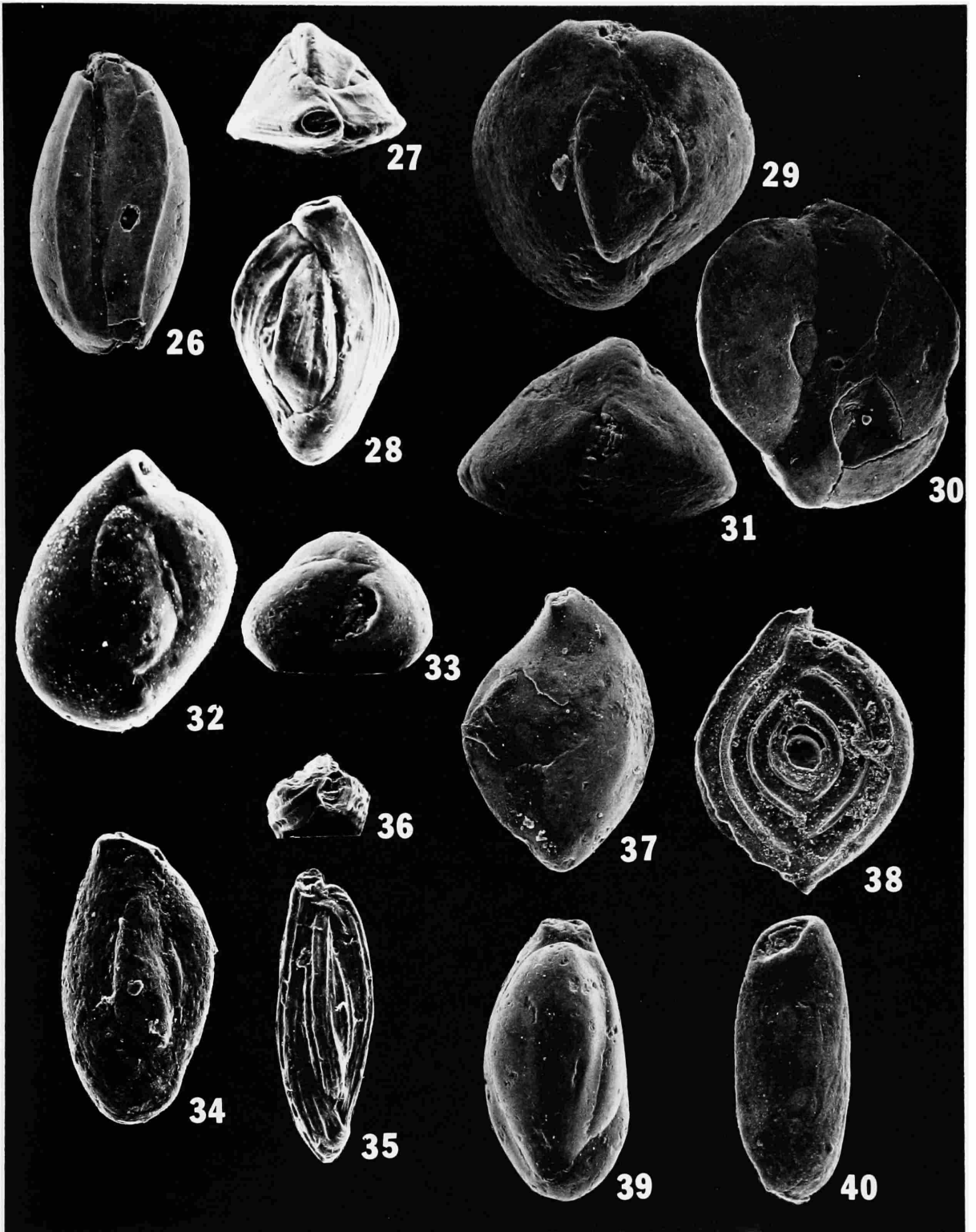
25. Front view, N28/f914, hypotype, USNM 243257,  $\times 60$ .



## PLATE 3

- Pyrgo* cf. *P. lucernula* (Schwager)  
26. Side view, N28/f914, hypotype, USNM 243258,  $\times 65$ .
- Quinqueloculina angulostriata* Cushman and Valentine  
27. Apertural view, N28/f914, hypotype, USNM 243259,  $\times 130$   
28. Front view, N28/f914, hypotype, USNM 243259,  $\times 130$ .
- Quinqueloculina* cf. *Q. buchiana* d'Orbigny  
29. Front view, N28/f914, hypotype, USNM 243260,  $\times 160$ .  
30. Back view, N28/f914, hypotype, USNM 243261,  $\times 160$ .  
31. Apertural view, N28/f914, hypotype, USNM 243260,  $\times 160$ .
- Quinqueloculina plana* d'Orbigny  
32. Front view, N33/f534, hypotype, USNM 243262,  $\times 210$ .  
33. Apertural view, N33/f534, hypotype, USNM 243262,  $\times 210$ .
- Quinqueloculina seminula* (Linnaeus)  
34. Front view, N28/f912, hypotype, USNM 243263,  $\times 175$ .
- Quinqueloculina singletoni* Crespin  
35. Front view, N28/f912, hypotype, USNM 243264,  $\times 80$ .  
36. Apertural view, N28/f912, hypotype, USNM 243264,  $\times 80$ .
- Sigmoilina victoriensis* Cushman  
37. Side view, N28/f452, hypotype, USNM 243265,  $\times 100$ .
- Spiroloculina excavata* d'Orbigny  
38. Side view, DSDP 206-39-2, hypotype, USNM 243266,  $\times 100$ .
- Triloculina trigonula* (Lamarck)  
39. Front view, N28/f914, hypotype, USNM 243267,  $\times 75$ .
- Wiesnerella* sp.  
40. Front view, N28/f458, hypotype, USNM 243268,  $\times 140$ .





## PLATE 4

*Alabamina tenuimarginata* (Chapman, Parr and Collins)

41. Involute side, N28/f456, hypotype, USNM 243269,  $\times 120$ .

*Allomorphina cubensis* Palmer and Bermudez

42. Apertural side, N37/f585, hypotype, USNM 243270,  $\times 160$ .

*Allomorphina pacifica* Cushman and Todd

43. Apertural side, N42/f719, hypotype, USNM 243271,  $\times 90$ .

44. Apertural side, DSDP 206-32-2, hypotype, USNM 243272,  $\times 130$ .

45. Spiral side, DSDP 206-32-2, hypotype, USNM 243273,  $\times 100$ .

*Amphicoryna nebulosa* (Ishizaki)

46. Side view, N41/f539, hypotype, USNM 243274,  $\times 160$ .

*Amphicoryna scalaris seminuda* (Chapman)

47. Side view, N41/f653, hypotype, USNM 243275,  $\times 130$ .

*Amphistegina madagascariensis* d'Orbigny

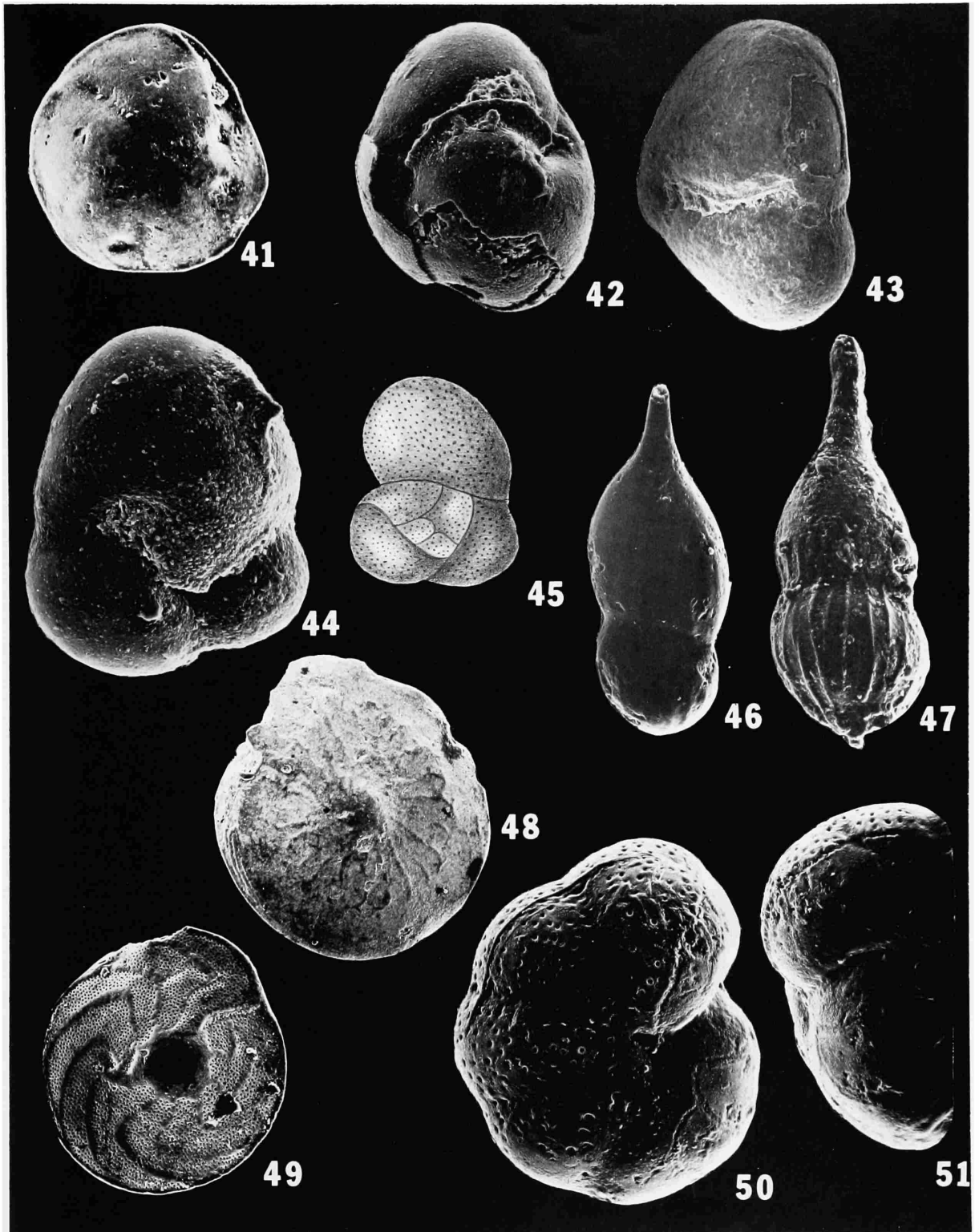
48. Ventral side, robust individual, N28/f913, hypotype, USNM 243276,  $\times 25$ .

49. Dorsal side, fragile individual, N28/f456, hypotype, USNM 243277,  $\times 120$ .

*Anomalinoides globulosa* (Chapman and Parr)

50. Involute ventral side, N42/f696, hypotype, USNM 243278,  $\times 130$ .

51. Peripheral view, N42/f696, hypotype, USNM 243278,  $\times 130$ .



## PLATE 5

*Anomalinooides macraglabra* (Finlay)

52. Peripheral view, N28/f455, hypotype, USNM 243279,  $\times 160$ .  
53. Spiral side, N28/f455, hypotype, USNM 243279,  $\times 160$ .

*Anomalinooides semicibrata* (Beckman)

54. Involute ventral side, DSDP 206-39-2, hypotype, USNM 243280,  $\times 130$ .  
55. Evolute dorsal side, N41/f590n, hypotype, USNM 243281,  $\times 110$ .

*Anomalinooides* sp.

56. Dorsal side, DSDP 206C-2-2, hypotype, USNM 243283,  $\times 175$ .

*Astrononion stelligerum* (d'Orbigny)

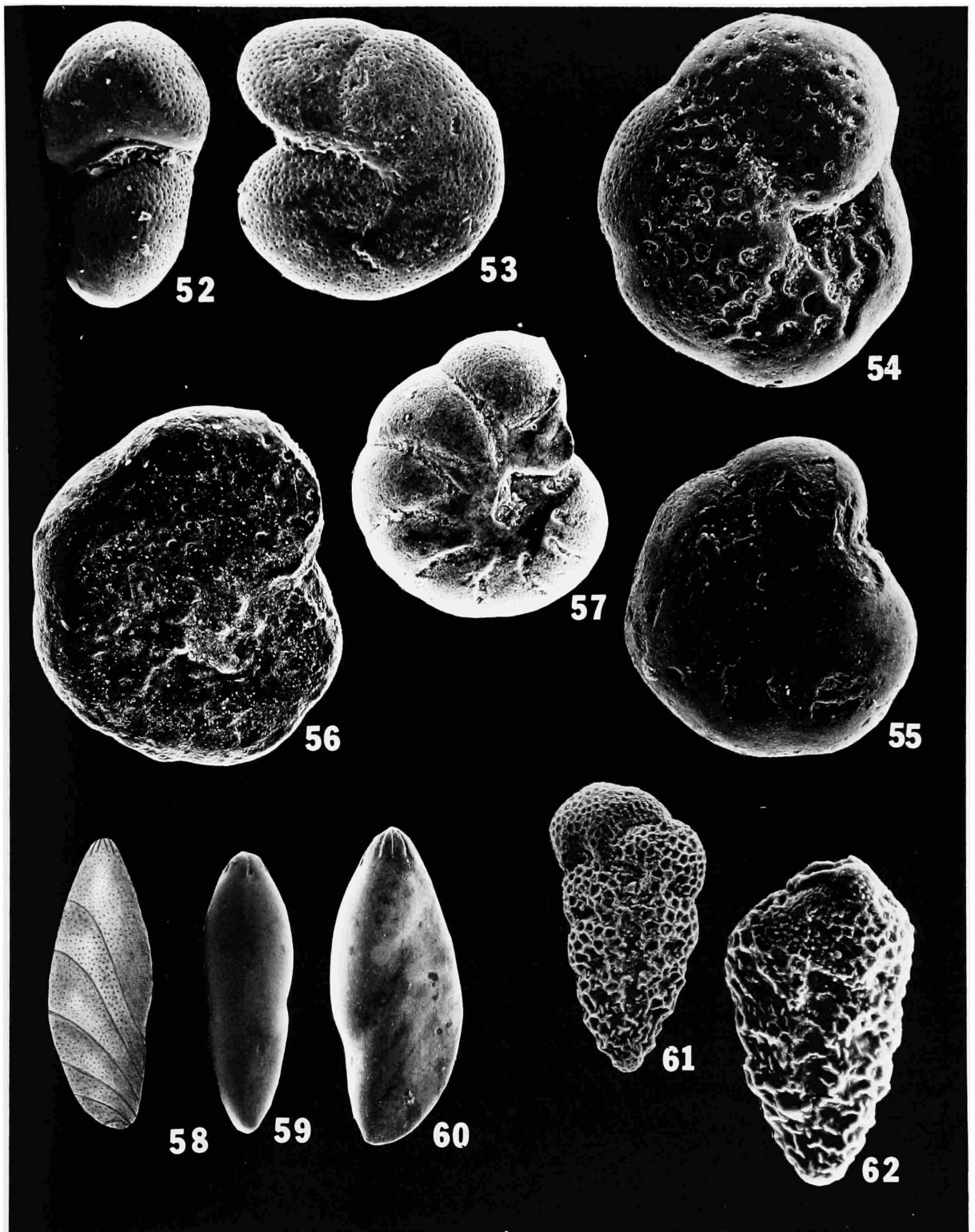
57. Side view, N28/f456, hypotype, USNM 243283,  $\times 125$ .

*Astacolus insolitus* (Schwager)

58. Side view, N41/f644, hypotype, USNM 243284,  $\times 50$ .  
59. Peripheral view, N41/f644, hypotype, USNM 243284,  $\times 50$ .  
60. Side view, N41/f644, hypotype, USNM 243284,  $\times 50$ .

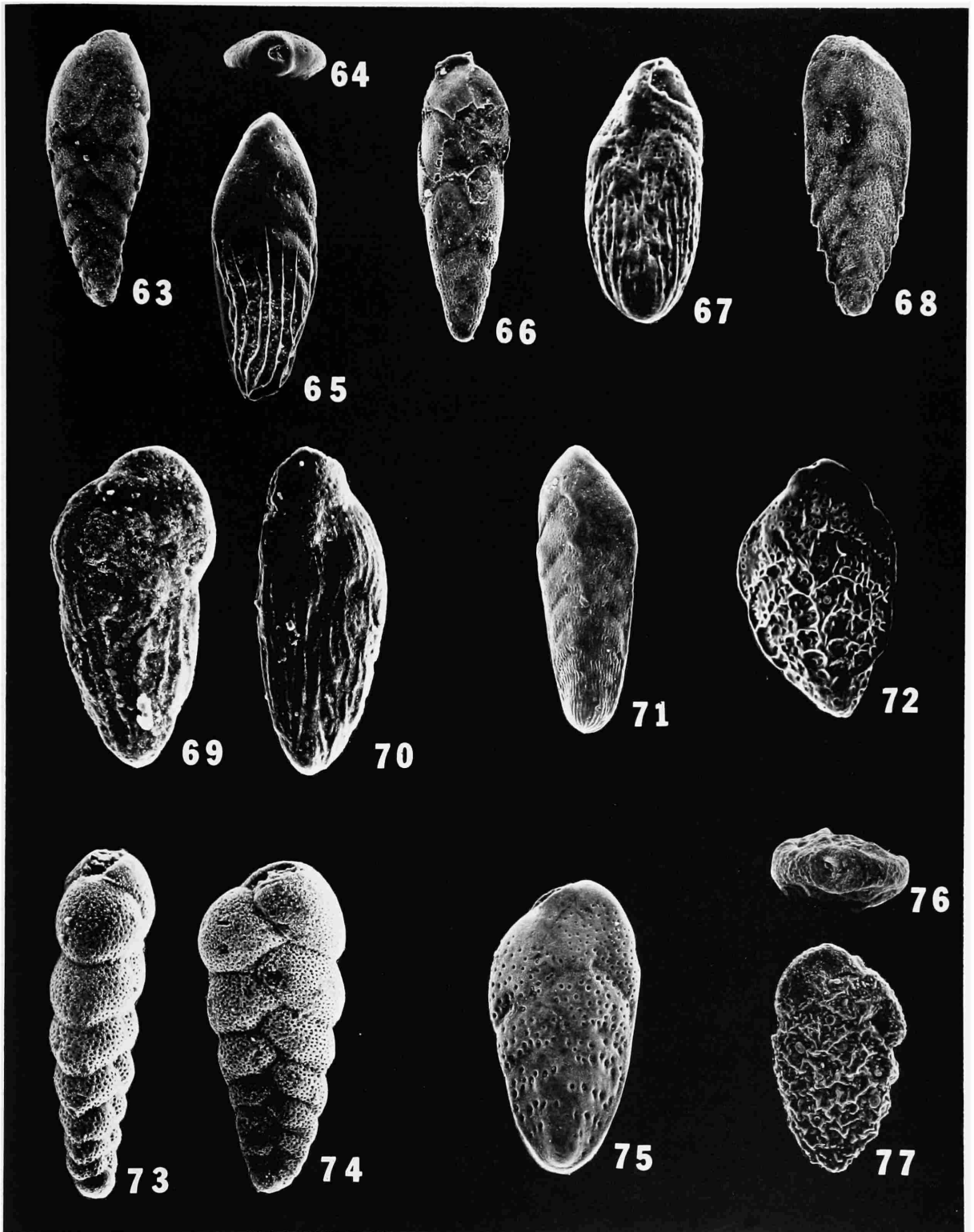
*Bolivina plicatella mera* Cushman and Ponton

61. Side view, N37/f585, hypotype, USNM 243285,  $\times 210$ .  
62. Side view, N41/f590u, hypotype, USNM 243286,  $\times 350$ .



## PLATE 6

- Bolivina acerosa* Cushman  
63. Side view, N33/f532, hypotype, USNM 243287,  $\times 175$ .
- Bolivina aenariensis* (Costa)  
64. Apertural view, DSDP 206–37 CC, hypotype, USNM 243288,  $\times 130$ .  
65. Side view, DSDP 206–37 CC, hypotype, USNM 243288,  $\times 130$ .
- Bolivina beyrichi* Reuss  
66. Side view, N41/f539, hypotype, USNM 243289,  $\times 80$ .
- Bolivina finlayi* Hornibrook  
67. Side view, N42/f729, hypotype, USNM 243290,  $\times 140$ .
- Bolivina mitcheli* Gibson  
68. Side view, N41/f609, hypotype, USNM 243291,  $\times 120$ .
- Bolivina mantaensis* Cushman  
69. Side view, N41/f2d, hypotype, USNM 243292,  $\times 280$ .  
70. Side view, N41/f2d, hypotype, USNM 243293,  $\times 200$ .
- Bolivina punctatostrata* Kreuzberg  
71. Side view, N41/f644, hypotype, USNM 243294,  $\times 80$ .
- Bolivina reticulata* Hantken  
72. Side view, N33/f581, hypotype, USNM 243295,  $\times 130$ .
- Bolivina silvestrina* Cushman  
73. Oblique peripheral view, N41/f609, hypotype, USNM 243296,  $\times 200$ .  
74. Side view, N41/f609, hypotype, USNM 243296,  $\times 200$ .
- Bolivina subcompacta* Finlay  
75. Side view, N37/f585, hypotype, USNM 243297,  $\times 160$ .
- Bolivina thalmani* Renz  
76. Apertural view, DSDP 206–37 CC, hypotype, USNM 243298,  $\times 200$ .  
77. Side view, DSDP 206–37 CC, hypotype, USNM 243298,  $\times 200$ .



## PLATE 7

*Bolivinella australis* Cushman

78. Apertural view, N28/f458, hypotype, USNM 243299,  $\times 100$ .  
79. Side view, N28/f458, hypotype, USNM 243299,  $\times 100$ .  
82. Enlarged apertural view, N28/f458, hypotype, USNM 243299,  $\times 420$ .

*Bolivinella subpectinata* Cushman

80. Side view, N28/f458, hypotype, USNM 243300,  $\times 100$ .  
81. Apertural view, N28/f458, hypotype, USNM 243300,  $\times 100$ .

*Bulimina pupula* Stache s.l

83. Side view, N28/912, hypotype, USNM 243301,  $\times 80$ .

*Bulimina semicostata* Nuttall

84. Apertural view, DSDP 206-38-2, hypotype, USNM 243302,  $\times 200$ .  
85. Side view, DSDP 206-38-2, hypotype, USNM 243302,  $\times 200$ .

*Bulimina striata* d'Orbigny

86. Side view, N42/f696, hypotype, USNM 243303,  $\times 100$ .

*Bulimina truncana* Gumbel

87. Side view, DSDP 206-38-2, hypotype, USNM 243304,  $\times 140$ .  
88. Side view, N33/f581, hypotype, USNM 243305,  $\times 160$ .

*Buliminella missilis* Vella

89. Side view, N42/f694, hypotype, USNM 243306,  $\times 80$ .

*Cassidulina laevigata* d'Orbigny

90. Side view, N28/f785, hypotype, USNM 243307,  $\times 260$ .

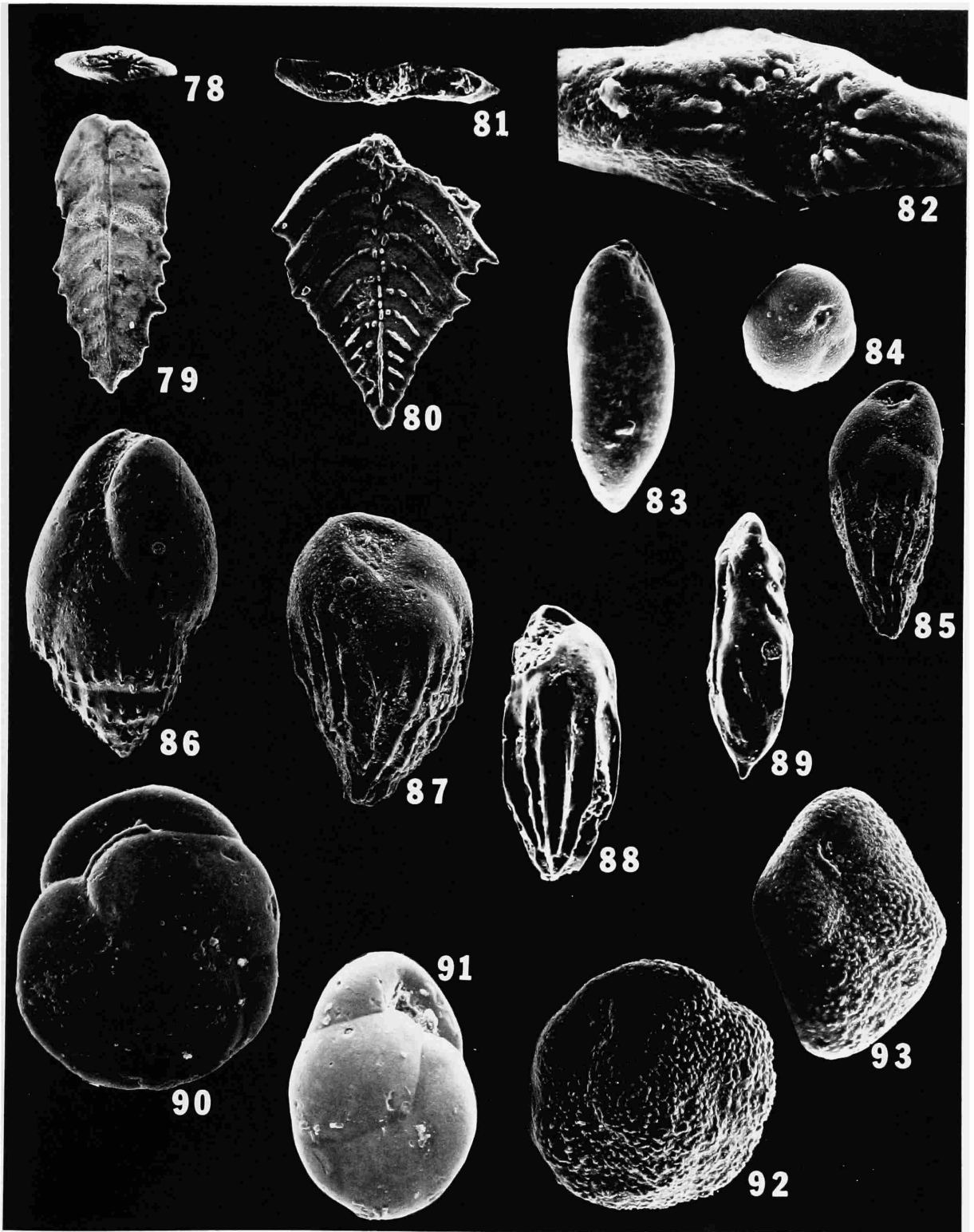
*Cassidulina margareta* Karrer

91. Side view, N33/f581, hypotype, USNM 243308,  $\times 140$ .

*Cassidulina monstruosa* Voloshinova

92. Side view, DSDP 206-34 CC, hypotype, USNM 243309,  $\times 240$ .  
93. Peripheral view, DSDP 206-34 CC, hypotype, USNM 243309,  
 $\times 240$  (see Plate 8: figure 96).





## PLATE 8

*Cassidulina carapitana* Hedberg

94. Peripheral view, N41/f555, hypotype, USNM 243310,  $\times 130$ .

95. Side view, N41/f555, hypotype, USNM 243310,  $\times 130$ .

*Cassidulina monstruosa* Voloshinova

96. Side view, N42/f729, hypotype, USNM 243311,  $\times 130$  (see Plate 7: figures 92, 93).

*Discorbinella stachi* (Asano)

97. Dorsal side, N41/f539, hypotype, USNM 243312,  $\times 200$ .

98. Peripheral view, N41/f539, hypotype, USNM 243312,  $\times 200$ .

99. Ventral side, N41/f539, hypotype, USNM 243312,  $\times 200$  (see Plate 12: figures 153, 154).

*Discorbinella bertheloti* (d'Orbigny)

100. Spiral side, N41/f590n, hypotype, USNM 243313,  $\times 175$ .

101. Peripheral view, N41/f590n, hypotype, USNM 243313,  $\times 175$ .

102. Involute side, N41/f590n, hypotype, USNM 243313,  $\times 175$ .

*Discorbinella complanata* (Sidebottom)

103. Partly involute side, N41/f590n, hypotype, USNM 243314,  $\times 175$ .

104. Peripheral view, N41/f590n, hypotype, USNM 243314,  $\times 175$ .

105. Spiral side, N41/f590n, hypotype, USNM 243314,  $\times 175$  (see Plate 12: figures 151, 152).

*Discorbinella galera* (Finlay)

106. Spiral side, paratype, Pakaurangi Point, USNM 243315,  $\times 66$ .

107. Peripheral view, paratype, Pakaurangi Point, USNM 243315,  $\times 66$ .

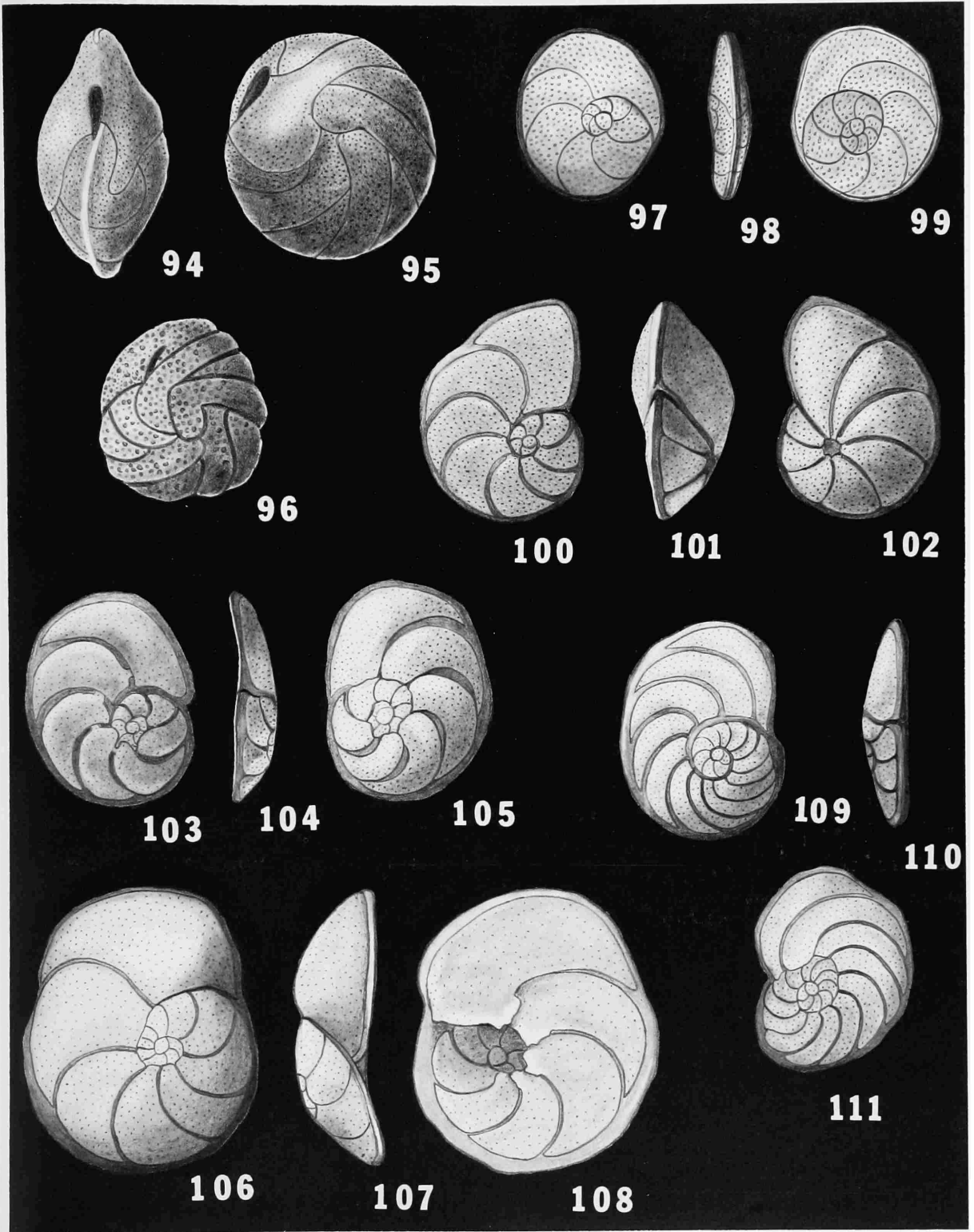
108. Partly involute side, paratype, Pakaurangi Point, USNM 243315,  $\times 66$ .

*Discorbinella* sp.

109. Convex spiral side, N42/f729, hypotype, USNM 243316,  $\times 175$ .

110. Peripheral view, N42/f729, hypotype, USNM 243316,  $\times 175$ .

111. Flat side, N42/f729, hypotype, USNM 243316,  $\times 175$ .



## PLATE 9

*Ceratobulimina kellumi* Finlay

112. Side view, N37/f585, hypotype, USNM 243317,  $\times 100$ .

*Chilostomella czizecki* Reuss

113. Front view, N28/f452, hypotype, USNM 243318,  $\times 90$ .

114. Side view, N28/f452, hypotype, USNM 243318,  $\times 90$ .

*Chilostomella globata* Galloway and Heminway

115. Side view, N37/f585, hypotype, USNM 243319,  $\times 85$ .

116. Front view, N37/f585, hypotype, USNM 243319,  $\times 85$ .

*Chilostomella ovoidea* Reuss

117. Front view, N33/f581, hypotype, USNM 243320,  $\times 120$ .

118. Side view, N33/f581, hypotype, USNM 243320,  $\times 120$ .

*Chilostomelloides oviformis* (Sherborn and Chapman)

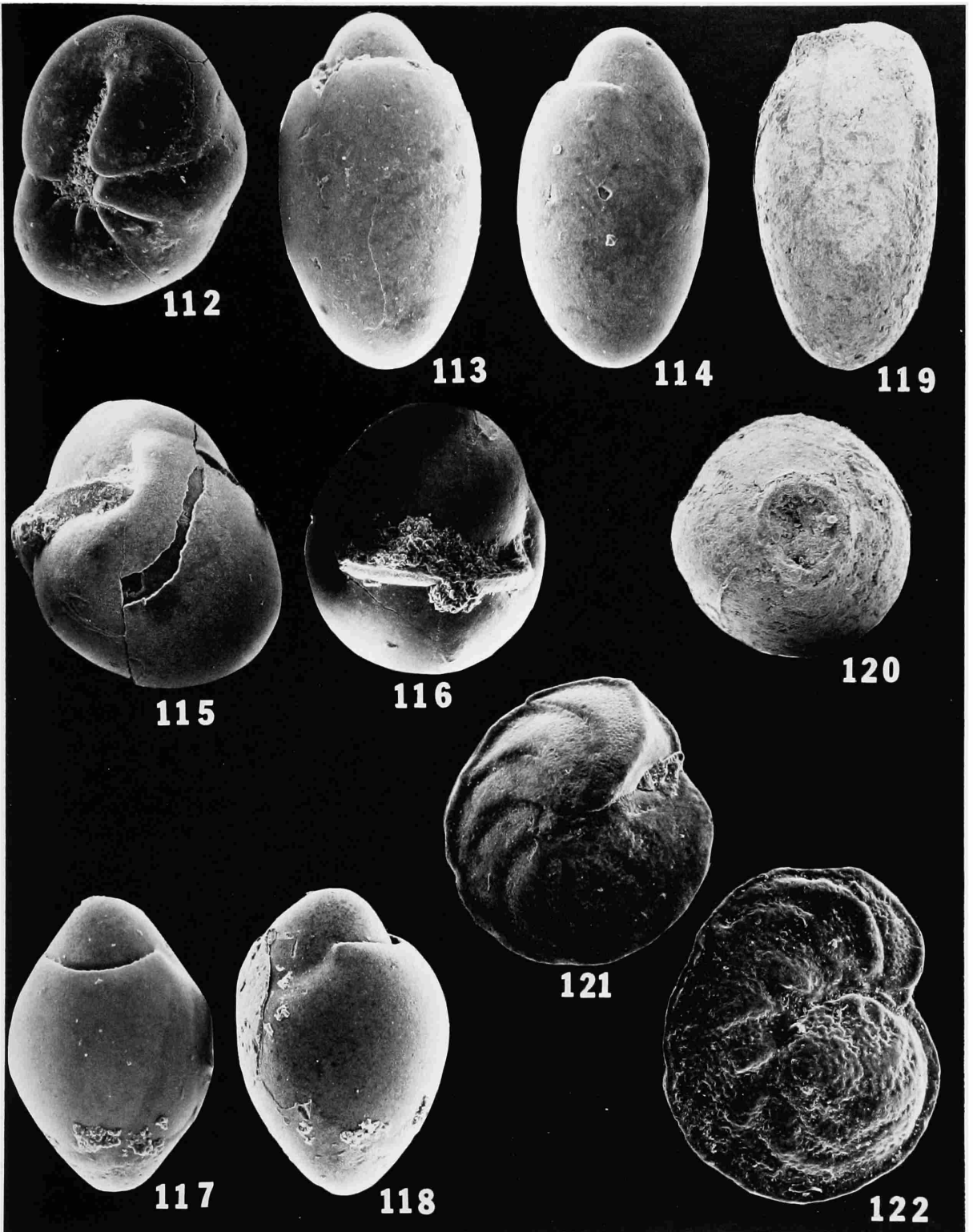
119. Side view, N46/f501, hypotype, USNM 243321,  $\times 33$ .

120. Apertural end view, N46/f501, hypotype, USNM 243321,  $\times 55$ .

*Cibicidoides karreriformis* (Hornibrook)

121. Involute side, N28/f452, hypotype, USNM 243322,  $\times 66$ .

122. Spiral side, N42/f696, hypotype, USNM 243323,  $\times 60$ .



## PLATE 10

*Cibicidoides kullenbergi* (Parker)

123. Involute side, DSDP 206-34 CC, hypotype, USNM 243324,  $\times 200$ .

*Cibicides lobatulus* (Walker and Jacob)

124. Involute side, N28/f456, hypotype, USNM 243325,  $\times 130$ .

125. Peripheral view, N28/f456, hypotype, USNM 243325,  $\times 130$ .

126. Spiral side, N28/f455, hypotype, USNM 243326,  $\times 100$ .

*Cibicides mediocris* Finlay

127. Involute side, N28/f456, hypotype, USNM 243327,  $\times 150$ .

128. Peripheral view, N28/f456, hypotype, USNM 243327,  $\times 150$ .

129. Spiral side, N28/f456, hypotype, USNM 243328,  $\times 120$ .

*Cibicides refulgens* de Montfort

130. Peripheral view, N28/f456, hypotype, USNM 243329,  $\times 170$ .

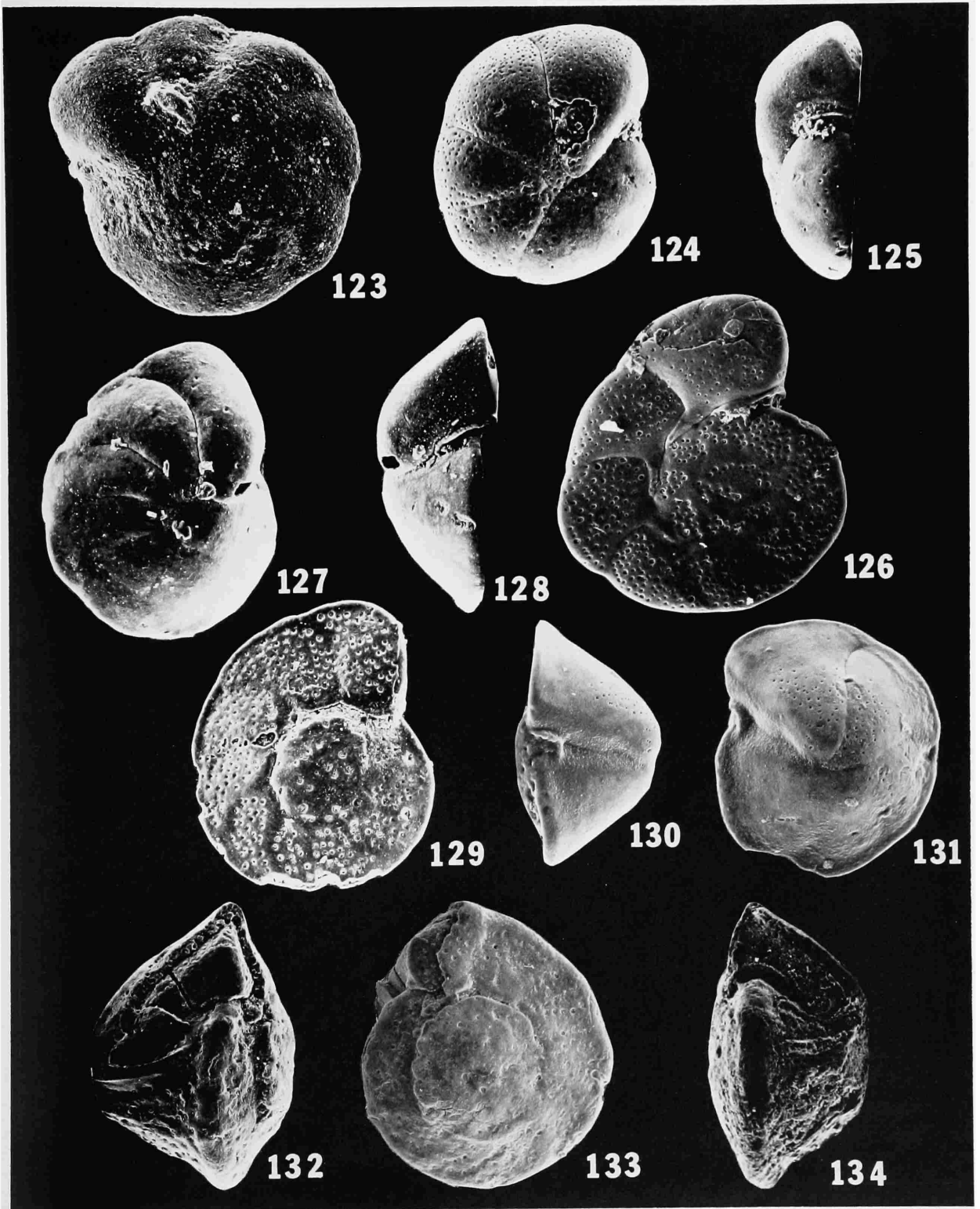
131. Involute side, N28/f456, hypotype, USNM 243329,  $\times 170$ .

*Cibicides notocenicus* Dorreen

132. Peripheral view, N41/f555, hypotype, USNM 243330,  $\times 100$ .

133. Spiral side, N41/f555, hypotype, USNM 243330,  $\times 100$ .

134. Peripheral view, N41/f537, hypotype, USNM 243331,  $\times 85$ .



## PLATE 11

*Cibicidoides temperatus* (Vella)

- 135. Spiral side, N28/f456, hypotype, USNM 243332,  $\times 125$ .
- 136. Peripheral view, N28/f456, hypotype, USNM 243333,  $\times 120$ .
- 137. Involute side, N28/f456, hypotype, USNM 243333,  $\times 120$ .

*Cibicides vortex* Dorreen

- 138. Peripheral view, N28/f456, hypotype, USNM 243334,  $\times 175$ .
- 139. Involute side, N28/f456, hypotype, USNM 243334,  $\times 175$ .

*Cibicides wuellerstorfi* (Schwager)

- 140. Spiral side, DSDP 206-32-2, hypotype, USNM 243335,  $\times 80$ .
- 141. Peripheral view, DSDP 206-32-2, hypotype, USNM 243336,  $\times 80$ .
- 142. Involute side, DSDP 206-32-2, hypotype, USNM 243336,  $\times 80$ .

*Dentalina* cf. *D. albatrossi* (Cushman)

- 143. Side view, N33/f581, hypotype, USNM 243337,  $\times 30$ .

*Dentalina intorta* (Dervieux)

- 144. Side view, DSDP 206-41-1, hypotype, USNM 243338,  $\times 70$ .

*Dentalina spirostriolata* (Cushman)

- 145. Side view, N41/f632, hypotype, USNM 243339,  $\times 30$ .

*Dentalina subemaciata* Parr

- 146. Side view, N33/f581, hypotype, USNM 243340,  $\times 30$ .

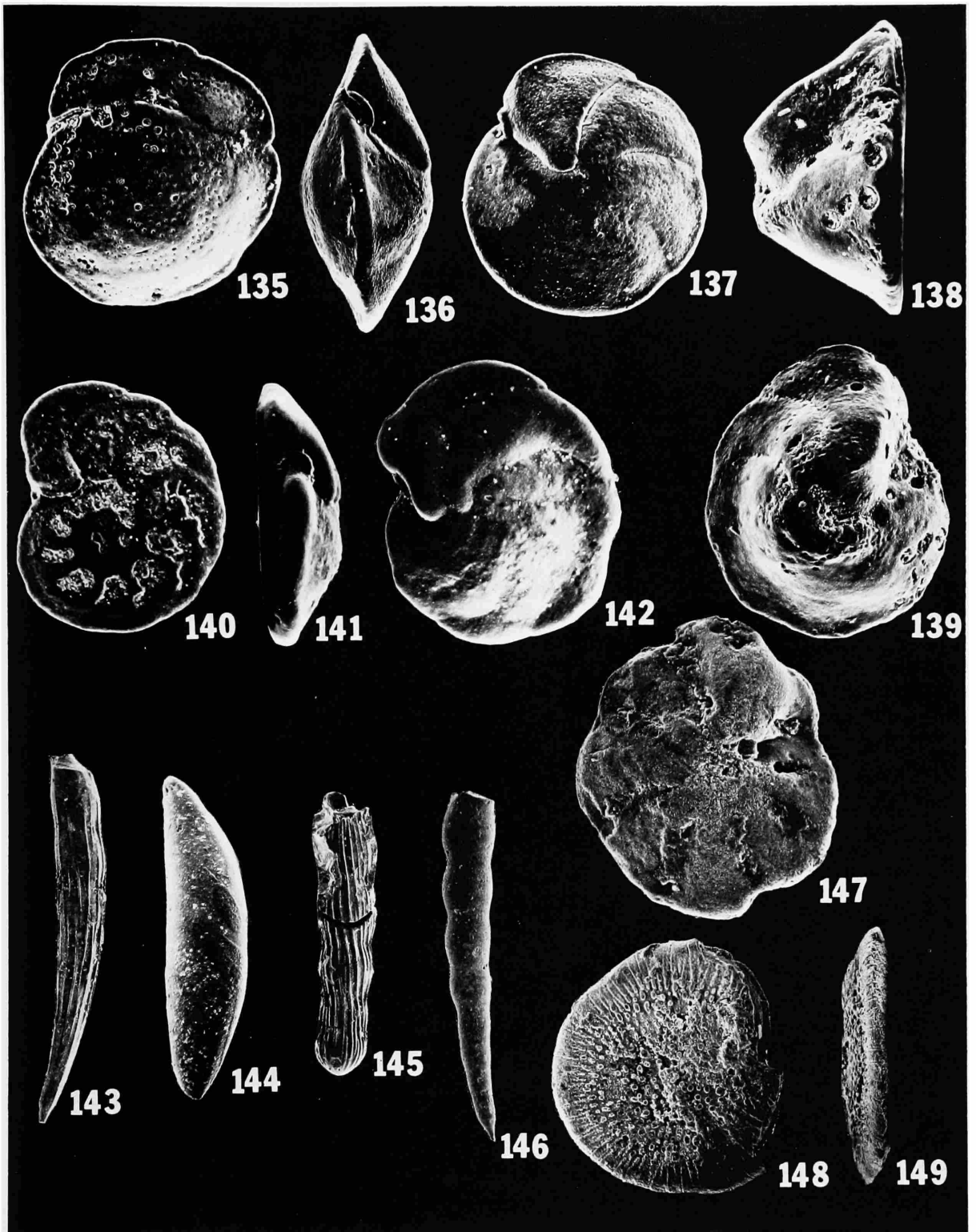
*Discorbis balcombensis* Chapman, Parr and Collins

- 147. Involute side, N28/f914, hypotype, USNM 243341,  $\times 130$ .

*Discorbis semiopercularis* Hornibrook

- 148. Involute side, N28/f455, hypotype, USNM 243342,  $\times 80$ .
- 149. Peripheral view, N28/f455, hypotype, USNM 243342,  $\times 80$ .





**PLATE 12***Discorbis zealandica* (Vella)

150. Involute side, N28/f458, hypotype, USNM 243343,  $\times 175$ .

*Discorbinella complanata* (Sidebottom)

151. Partly involute side, N28/f456, hypotype, USNM 243344,  $\times 120$ .

152. Peripheral view, N28/f456, hypotype, USNM 243344,  $\times 120$ .

*Discorbinella stachi* (Asano)

153. Partly involute side, N28/f795, hypotype, USNM 243345,  $\times 140$ .

154. Peripheral view, N28/f795, hypotype, USNM 243345,  $\times 140$ .

*Dyocibicides biserialis* Cushman and Valentine

155. Spiral side, N28/f455, hypotype, USNM 243346,  $\times 120$ .

*Ehrenbergina marwicki* Finlay

156. Face view, N33/f581, hypotype, USNM 243347,  $\times 160$ .

*Elphidium advenum* (Cushman)

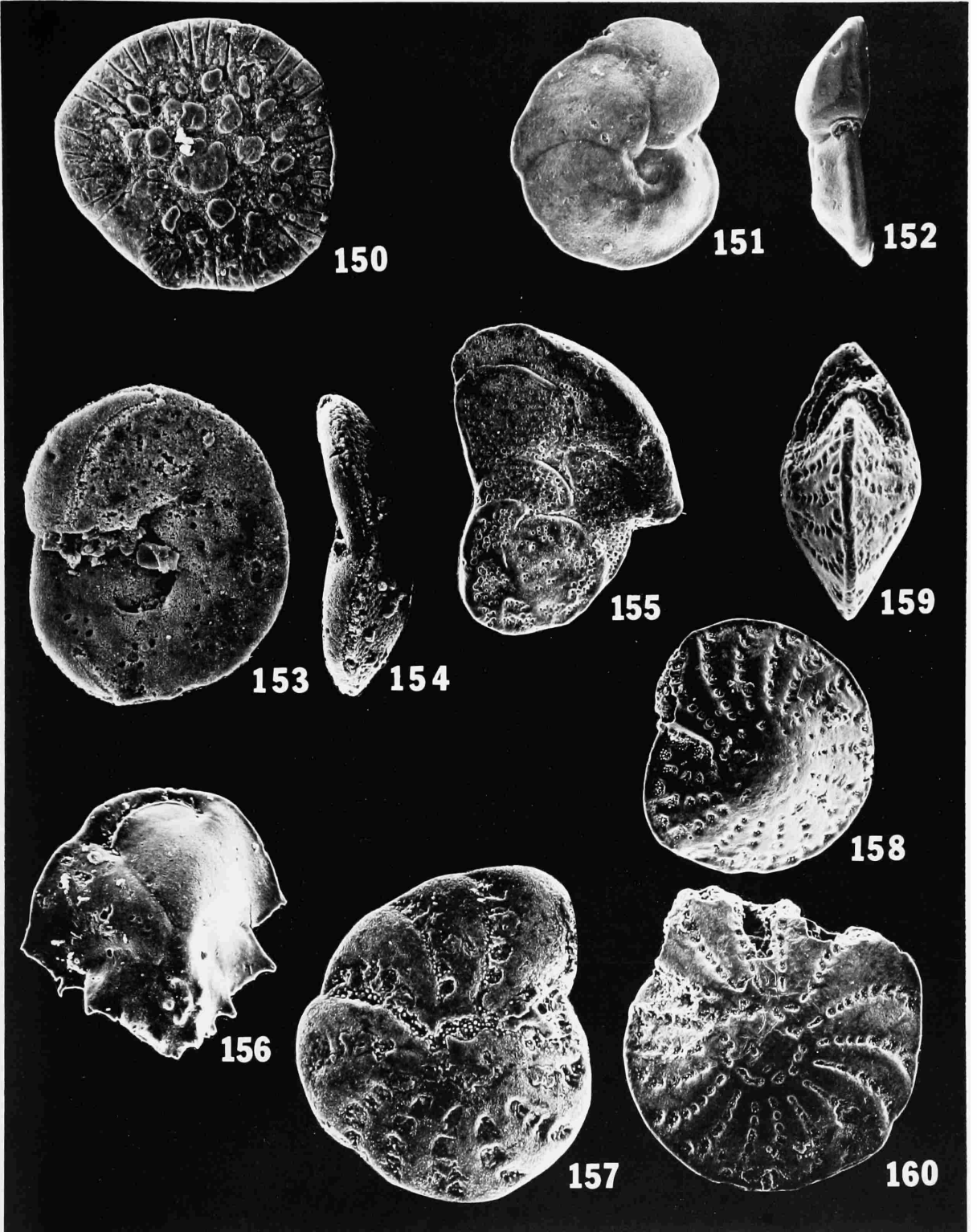
157. Side view, N41/f537, hypotype, USNM 243348,  $\times 200$ .

*Elphidium gibsoni* Hayward, new species

158. Side view, N28/f455, paratype, USNM 243349,  $\times 100$ .

159. Peripheral view, N42/f709, paratype, USNM 243350,  $\times 95$ .

160. Side view, N28/f792, paratype, USNM 243351,  $\times 110$  (see Plate 15: figure 182).



**PLATE 13***Elphidium nigarense* Cushman

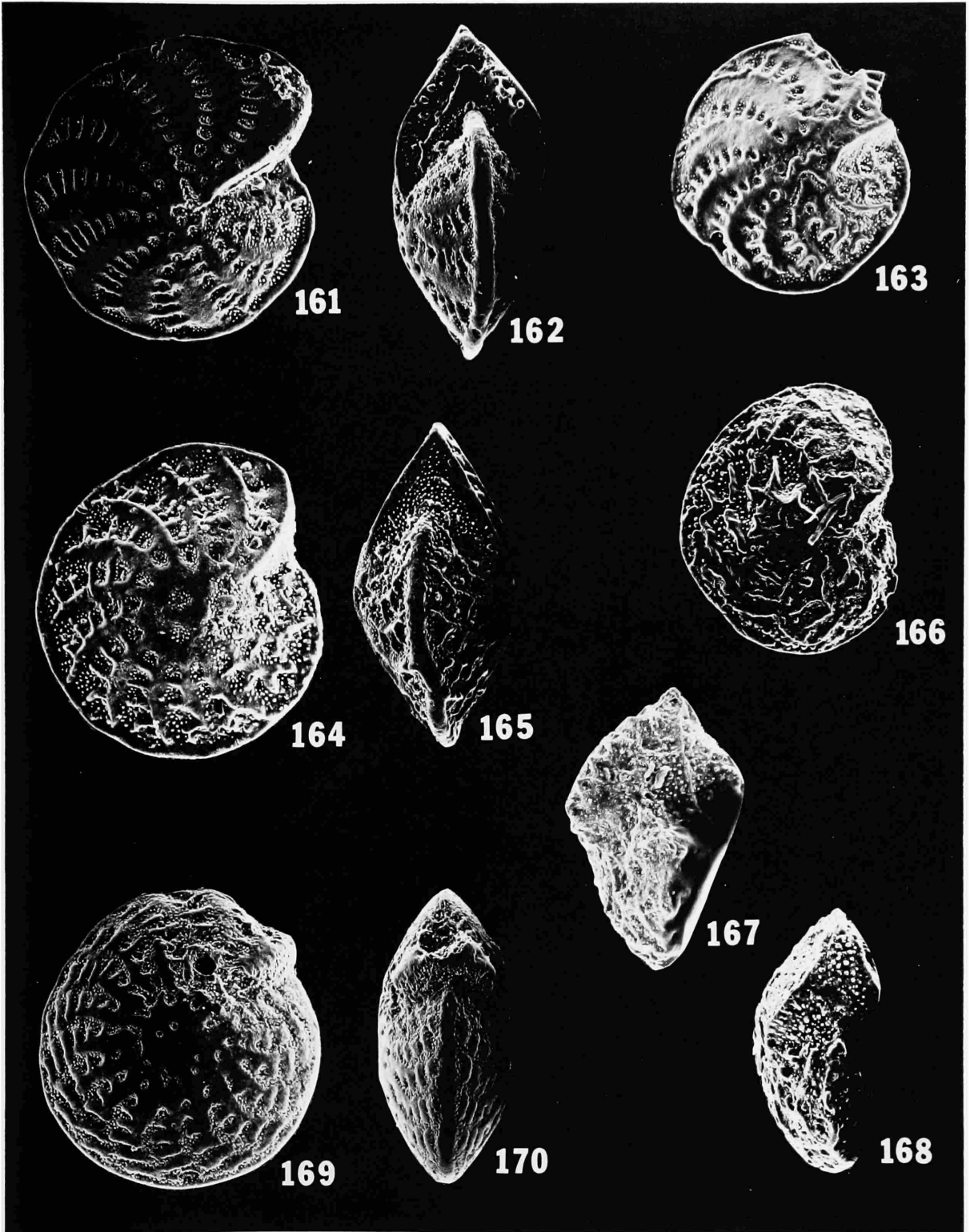
161. Side view, N33/f581, hypotype, USNM 243355,  $\times 180$ .
162. Peripheral view, N33/f505, hypotype, USNM 243356,  $\times 120$ .
163. Side view, N33/f532, hypotype, USNM 243357,  $\times 110$ .
164. Side view, N33/f505, hypotype, USNM 243356,  $\times 120$ .
165. Peripheral view, N33/f581, hypotype, USNM 243355,  $\times 180$ .

*Elphidium pseudoinflatum* Cushman

166. Side view, N28/f455, hypotype, USNM 243358,  $\times 125$ .
167. Peripheral view, N28/f457, hypotype, USNM 243359,  $\times 120$ .
168. Peripheral view, N28/f455, hypotype, USNM 243358,  $\times 125$ .

*Elphidium kanoum* Hayward, new species

169. Side view, N28/f792, paratype, USNM 243360,  $\times 90$ .
170. Peripheral view, N28/f792, paratype, USNM 243360,  $\times 90$   
(see Plate 15: figures 183, 184).



## PLATE 14

*Eoepomidella scotti* Hayward, new species

- 171. Involute side, last chamber broken off, N28/f912, paratype, USNM 243362,  $\times 270$ .
- 172. Peripheral view, N28/f458, paratype, USNM 243363,  $\times 220$ .
- 173. Spiral side, N28/f458, paratype, USNM 243363,  $\times 220$ .
- 174. Involute side, N28/f795, paratype, USNM 243364,  $\times 230$ .
- 175. Peripheral view, N28/f795, paratype, USNM 243364,  $\times 230$  (see Plate 15: figures 187–189).

*Epistominella exiqua* (Brady)

- 176. Involute side, DSDP 206–34 CC, hypotype, USNM 243368,  $\times 200$ .
- 177. Peripheral view, DSDP 206–34 CC, hypotype, USNM 243368,  $\times 200$ .

*Euvvigerina miozea* (Finlay)

- 178. Side view, N33/f581, hypotype, USNM 243369,  $\times 90$ .

*Evolvocassidulina bradyi* (Norman)

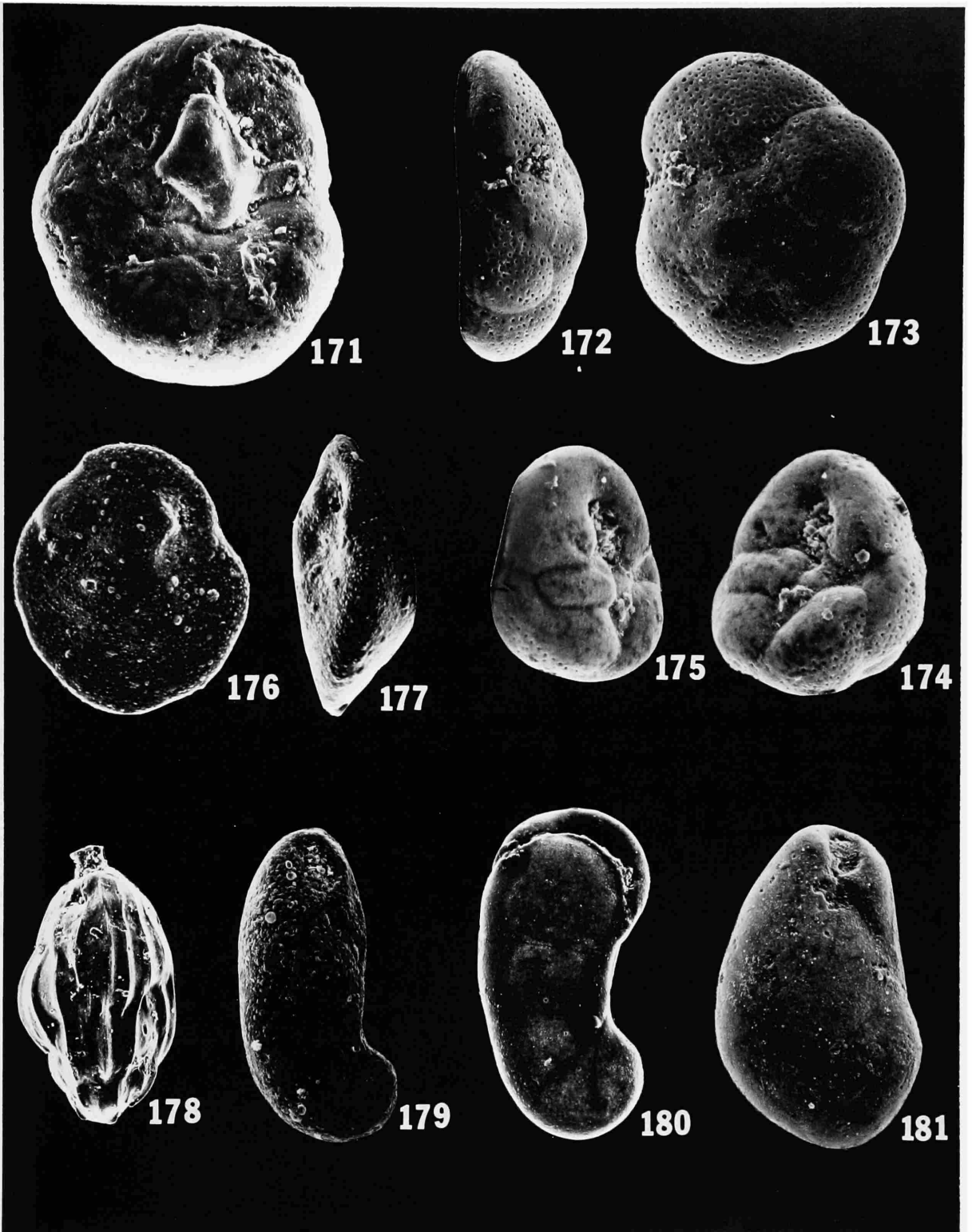
- 179. Side view, DSDP 206–32–2, hypotype, USNM 243370,  $\times 360$ .

*Evolvocassidulina* cf. *E. chapmani* Parr

- 180. Side view, N33/f532, hypotype, USNM 243371,  $\times 200$ .

*Evolvocassidulina orientalis* (Cushman)

- 181. Side view, N33/f505, hypotype, USNM 243372,  $\times 220$ .



## PLATE 15

*Elphidium gibsoni* Hayward, new species

182. Side view, N41/f539, holotype, TF 1579/1,  $\times 50$  (see Plate 12: figures 158–160).

*Elphidium vitrum* Hayward, new species

183. Side view, N28/f457, holotype, TF 1580/1,  $\times 50$ .

184. Peripheral view, N28/f457, holotype, TF 1580/,  $\times 50$  (see Plate 13: figure 169, 170).

*Frondicularia tenuissima* Hantken

185. Broken basal portion, N37/f585, hypotype, USNM 243373,  $\times 50$ .

186. Broken apertural portion, N33/f581, hypotype, USNM 243374,  $\times 60$ .

*Eoepionidella scotti* Hayward, new species

187. Involute side, N28/f457, holotype, TF 1581/1,  $\times 160$ .

188. Peripheral view, N28/f457, holotype, TF 1581/1,  $\times 160$ .

189. Spiral side, N28/f457, holotype, TF 1581/1,  $\times 160$  (see Plate 14: figures 171–175).

*Glabratellina sigali* Seiglie and Bermudez

190. Spiral side, N28/f458, hypotype, USNM 243375,  $\times 175$  (see Plate 17: figures 213–215).

*Lenticulina planula* (Galloway and Heminway)

191. Side view, N37/f585, hypotype, USNM 243376,  $\times 50$ .

192. Peripheral view, N33/f580, hypotype, USNM 243377,  $\times 130$  (see Plate 20: figures 250–252).

*Osangularia culter* (Parker and Jones)

193. Involute side, N37/f585, hypotype, USNM 243378,  $\times 50$ .

194. Spiral side, N37/f585, hypotype, USNM 243378,  $\times 50$  (see Plate 22: figures 279–281).

*Planulina* cf. *P. crassa* Galloway and Heminway

195. Spiral side, N42/f715, hypotype, USNM 243379,  $\times 130$ .

196. Peripheral view, N42/f715, hypotype, USNM 243379,  $\times 130$ .

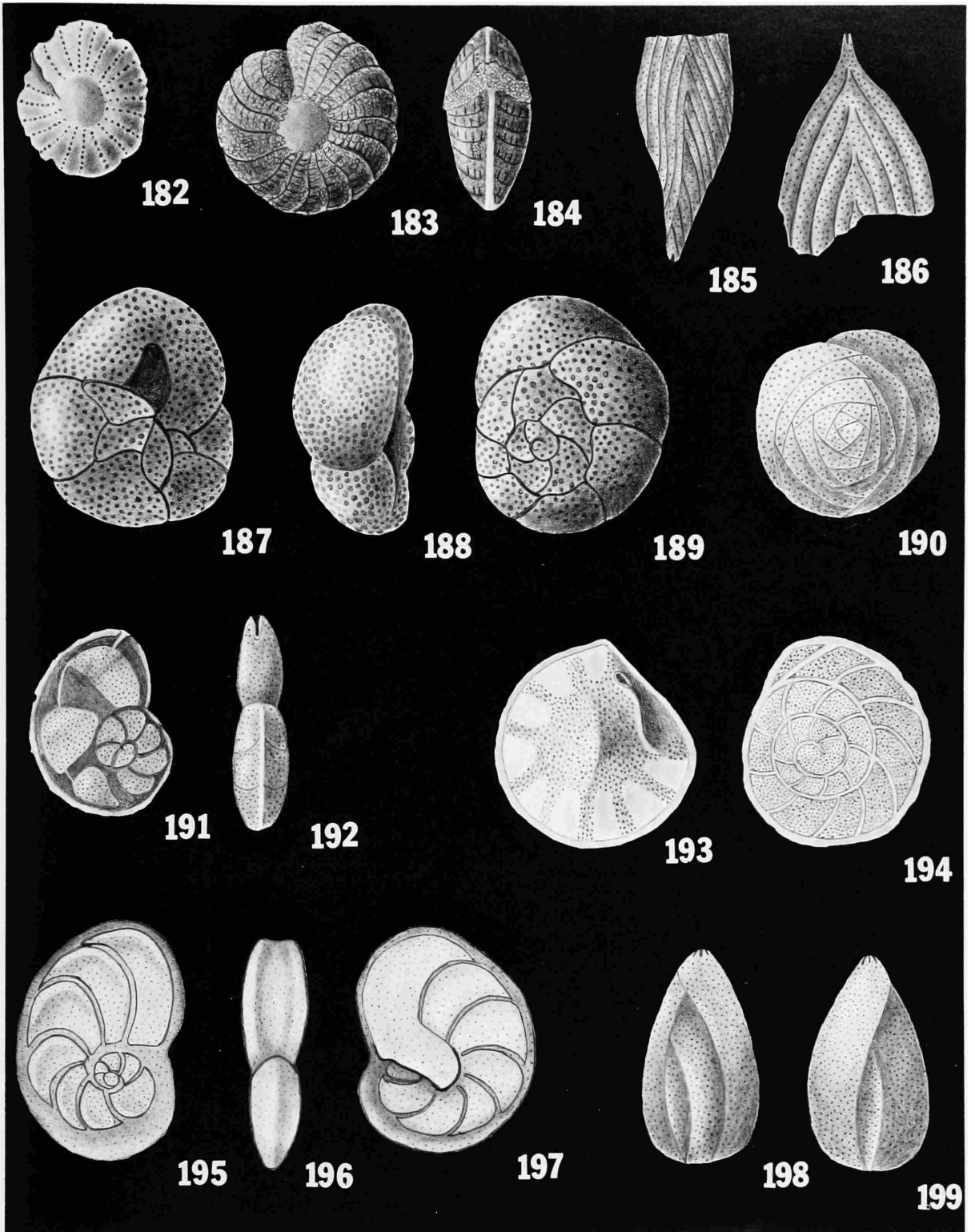
197. Involute side, N42/f715, hypotype, USNM 243379,  $\times 130$ .

*Sigmoidina pacifica* Cushman and Ozawa

198. Face view, N28/f781, hypotype, USNM 243380,  $\times 85$ .

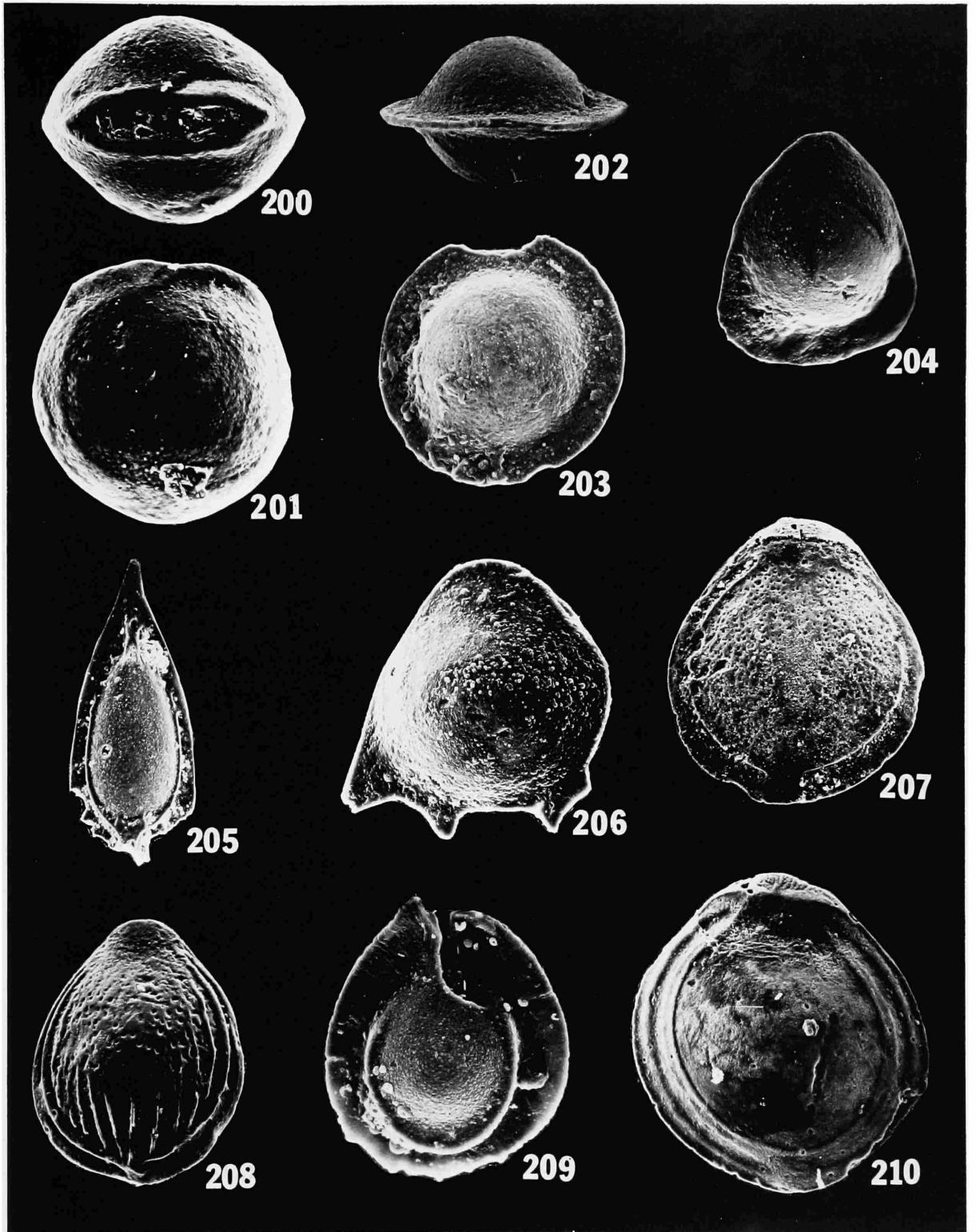
199. Back view, N28/f781, hypotype, USNM 243380,  $\times 85$  (see Plate 27: figure 332).





## PLATE 16

- Fissurina aperta* Seguenza  
200. Apertural view, N28/f456, hypotype, USNM 243381,  $\times 200$ .  
201. Side view, N28/f456, hypotype, USNM 243381,  $\times 200$ .
- Fissurina aureoligera* (Buchner)  
202. Apertural view, N28/f788, hypotype, USNM 243382,  $\times 230$ .  
203. Side view, N28/f788, hypotype, USNM 243382,  $\times 230$ .
- Fissurina basifimbriata* Parr  
204. Side view, DSDP 206-38-2, hypotype, USNM 243383,  $\times 200$ .
- Fissurina lagenoides* (Williamson)  
205. Side view, DSDP 206-32-2, hypotype, USNM 243384,  $\times 130$ .
- Fissurina kerguelenensis* Parr  
206. Side view, DSDP 206-37 CC, hypotype, USNM 243385,  $\times 400$ .
- Fissurina marginata* (Walker and Boys)  
207. Side view, N33/f581, hypotype, USNM 243386,  $\times 200$ .
- Fissurina* aff. *F. obscurocostata* Galloway and Wissler  
208. Side view, N28/f914, hypotype, USNM 243387,  $\times 160$ .
- Fissurina radiata* Seguenza  
209. Side view, DSDP 206-37 CC, hypotype, USNM 243388,  $\times 400$ .
- Fissurina orbignyana* Seguenza  
210. Side view, N41/f660, hypotype, USNM 243389,  $\times 200$ .



## PLATE 17

*Florilus stachei* (Cushman)

211. Side view, last chamber broken, N28/f455, hypotype, USNM, 243390,  $\times 90$ .

*Fursenkoina schreibersiana* (Czjzek)

212. Side view, N33/f581, hypotype, USNM 243391,  $\times 120$ .

*Glabratellina sigali* Seiglie and Bermudez

213. Side view, N28/f458, hypotype, USNM 243392,  $\times 175$ .

214. Involute side, N28/f458, hypotype, USNM 243392,  $\times 175$ .

215. Side view of plastagamic pair, hypotype, N28/f458, USNM 243393,  $\times 175$  (see Plate 15: figure 190).

*Globbulimina pacifica* Cushman

216. Side view, N42/f705, specimen lost,  $\times 130$ .

217. Side view, N42/f696, specimen lost,  $\times 100$ .

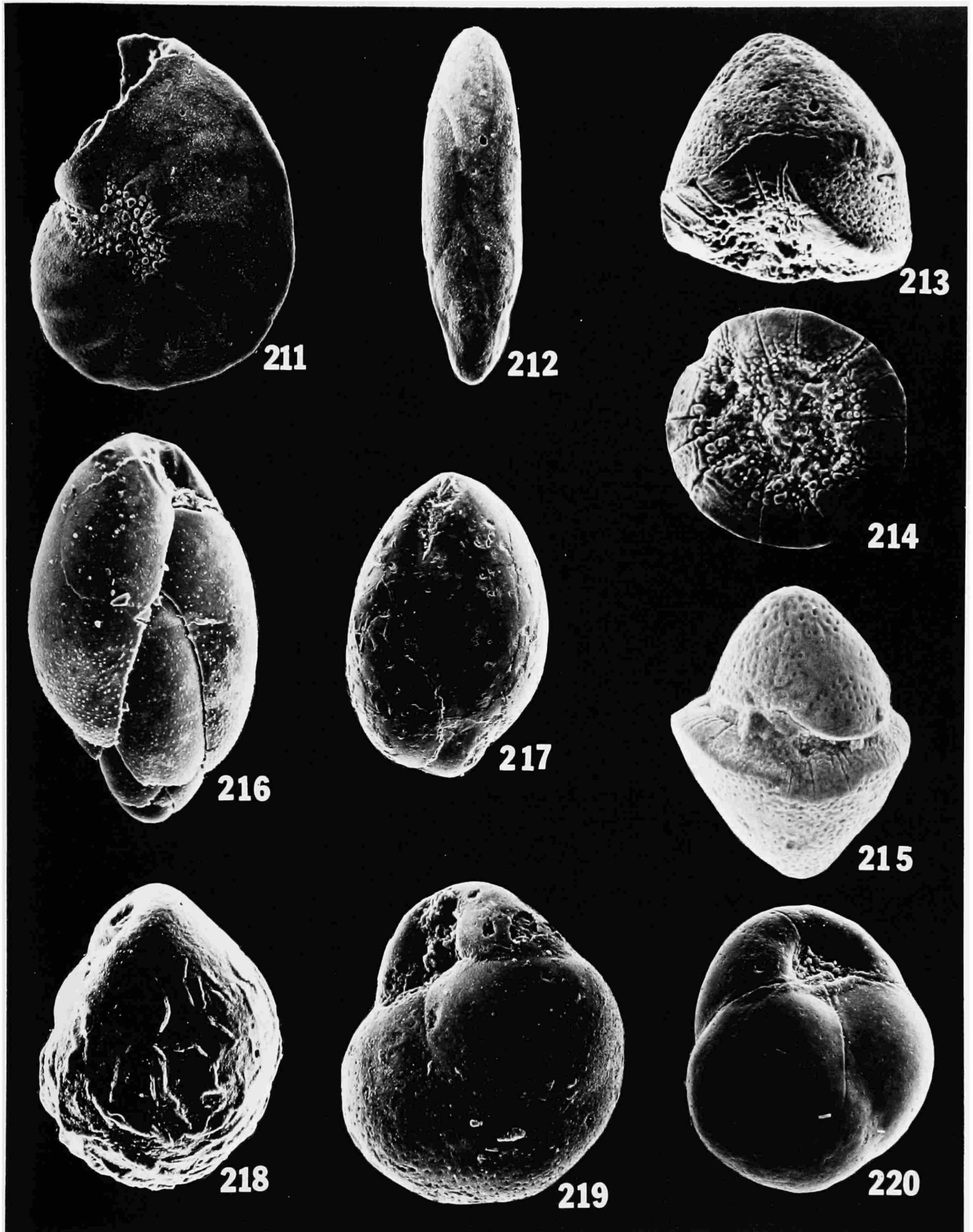
*Globocassidulina arata* (Finlay)

218. Side view, N28/f456, hypotype, USNM 243394,  $\times 200$ .

*Globocassidulina subglobosa* (Brady)

219. Side view, N33/f581, hypotype, USNM 243395,  $\times 240$ .

220. Side view, DSDP 206-38-2, hypotype, USNM 243396,  $\times 230$ .



## PLATE 18

*Gyroidina zelandica* Finlay

- 221. Involute side, N33/f581, hypotype, USNM 243397,  $\times 130$ .
- 222. Peripheral view, N33/f581, hypotype, USNM 243397,  $\times 130$ .
- 223. Spiral side, N33/f581, hypotype, USNM 243398,  $\times 200$ .

*Gyroidina danvillensis* Howe and Wallace

- 224. Involute side, N33/f581, hypotype, USNM 243399,  $\times 200$ .
- 225. Spiral side, N33/f581, hypotype, USNM 243400,  $\times 200$ .

*Gyroidina* sp.

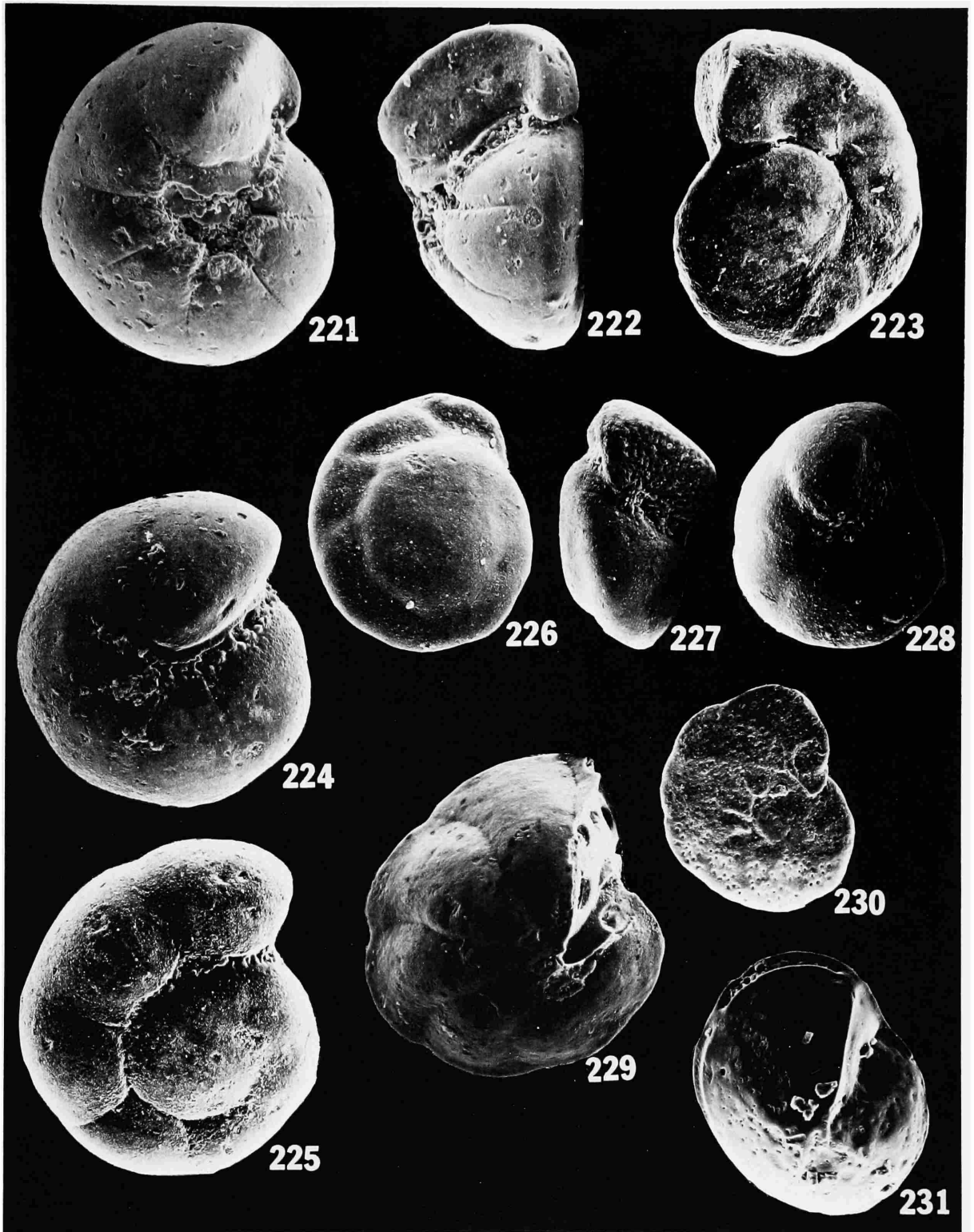
- 226. Spiral side, DSDP 206-38-2, hypotype, USNM 243401,  $\times 160$ .
- 227. Peripheral view, DSDP 206-38-2, hypotype, USNM 243401,  $\times 160$ .
- 228. Involute side, DSDP, 206-38-2, hypotype, USNM 243402,  $\times 200$ .

*Hanzawaia laurissae* (Mallory)

- 229. Involute side, N42/f723, hypotype, USNM 243403,  $\times 180$ .
- 230. Dorsal side, N28/f788, hypotype, USNM 243404,  $\times 130$ .

*Hoeglundina elegans* (d'Orbigny)

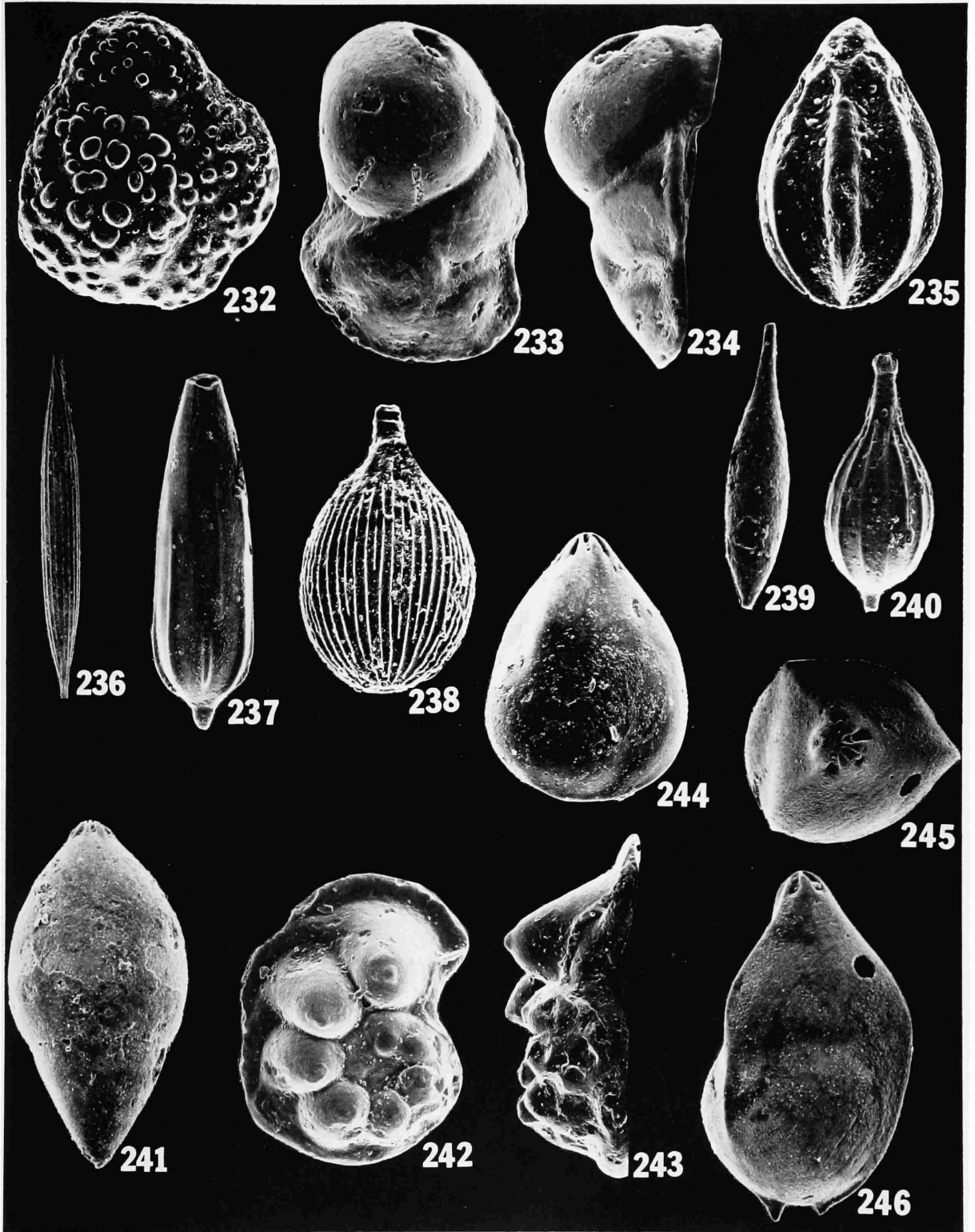
- 231. Oblique view of involute side, N28/f456, hypotype, USNM 243405,  $\times 160$ .



## PLATE 19

- Hofkerina semiornata* (Howchin)  
232. Spiral side, N28/f913, hypotype, USNM 243406,  $\times 50$ .
- Karrerria maoria* (Finlay)  
233. Involute side, N28/f456, hypotype, USNM 243407,  $\times 120$ .  
234. Peripheral view, N28/f456, hypotype, USNM 243407,  $\times 120$ .
- Lagena acuticostata* Reuss  
235. Side view, N41/f2d, hypotype, USNM 243408,  $\times 250$ .
- Lagena distoma* Parker and Jones  
236. Side view, N33/f581, hypotype, USNM 243409,  $\times 60$ .
- Lagena gracilis* Williamson  
237. Side view, N28/f458, hypotype, USNM 243410,  $\times 120$ .
- Lagena substriata* Williamson  
238. Side view, N33/f581, hypotype, USNM 243411,  $\times 200$ .
- Lagena elongata* (Ehrenberg)  
239. Side view, N42/f696, hypotype, USNM 243412,  $\times 160$ .
- Lagena striata* (d'Orbigny)  
240. Side view, N33/f581, hypotype, USNM 243413,  $\times 100$ .
- Lagenoglandulina annulata* (Stache)  
241. Side view, N33/f581, hypotype, USNM 243414,  $\times 200$ .
- Laticarinina altocamerata* (Heron-Allen and Earland)  
242. Convex side, N41/f632, hypotype, USNM 243415,  $\times 100$ .  
243. Peripheral view, N41/f632, hypotype, USNM 243415,  $\times 100$ .
- Lenticulina callifera* (Stache)  
244. Side view, N28/f785, hypotype, USNM 243416,  $\times 175$ .  
245. Apertural view, N33/f579, hypotype, USNM 243417,  $\times 160$ .  
246. Side view, N33/f579, hypotype, USNM 243417,  $\times 160$ .





## PLATE 20

*Lenticulina mamilligera* (Karrer)

247. Side view, N33/f579, hypotype, USNM 243418,  $\times 40$ .

*Lenticuline* cf. *L. nitida* (Reuss)

248. Peripheral view, N33/f581, hypotype, USNM 243419,  $\times 90$ .

249. Side view, N33/f581, hypotype, USNM 243419,  $\times 90$ .

*Lenticulina planula* (Galloway and Heminway)

250. Side view, N42/f723, hypotype, USNM 243420,  $\times 130$ .

251. Peripheral view, N42/f723, hypotype, USNM 243420,  $\times 130$ .

252. Peripheral apertural view, N42/f723, hypotype, USNM 243420,  $\times 130$  (see Plate 15: figures 191, 192).

*Loxostomum pakaurangiensis* Hornibrook

253. Side view, last chamber broken off, N28/f456, hypotype, USNM 243421,  $\times 100$ .

*Melonis simplex* (Karrer)

254. Peripheral view, DSDP 206-44-2, hypotype, USNM 243422,  $\times 230$ .

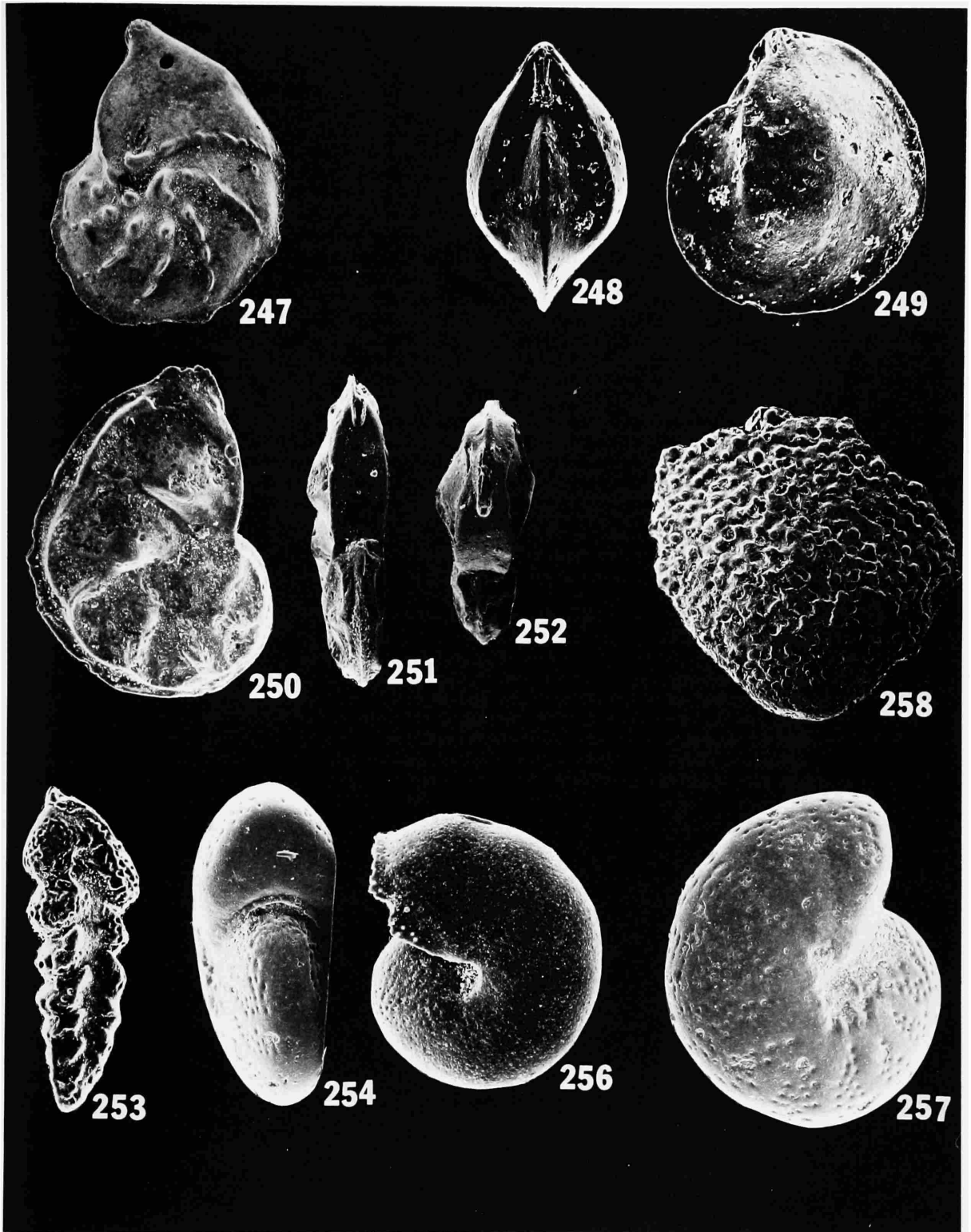
257. Side view, DSDP 206-44-2, hypotype, USNM 243422,  $\times 230$ .

*Melonis affinis* (Reuss)

256. Side view, DSDP 206-33-2, hypotype, USNM 243423,  $\times 150$ .

*Miogypsina intermedia* Drooger

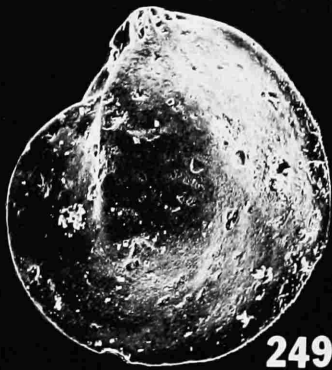
258. Side view, N28/f913, hypotype, USNM 243424,  $\times 30$ .



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## PLATE 21

*Nodosarella tuberosa* (Gümbel)

259. Side view, DSDP 206C-2-2, hypotype, USNM 243425,  $\times 40$ .

260. Enlarged apertural view, DSDP 206C-2-2, hypotype, USNM 243425,  $\times 90$ .

*Nodosaria holoserica* Schwager

261. Side view, N33/f581, hypotype, USNM 243426,  $\times 100$ .

*Nodosaria longiscata* d'Orbigny

262. Side view, broken section, N33/f581, hypotype, USNM 243427,  $\times 50$ .

*Nodosaria substrigata* Stache

263. Side view, broken basal section, N33/f578, hypotype, USNM 243428,  $\times 40$ .

*Nonion* cf. *N. mexicanum* Cole

264. Peripheral view, N41/f539, hypotype, USNM 243429,  $\times 125$ .

265. Side view, N41/f539, hypotype, USNM 243429,  $\times 125$ .

*Nonionella novozealandica* Cushman

266. Involute side, N41/f660, hypotype, USNM 243430,  $\times 100$ .

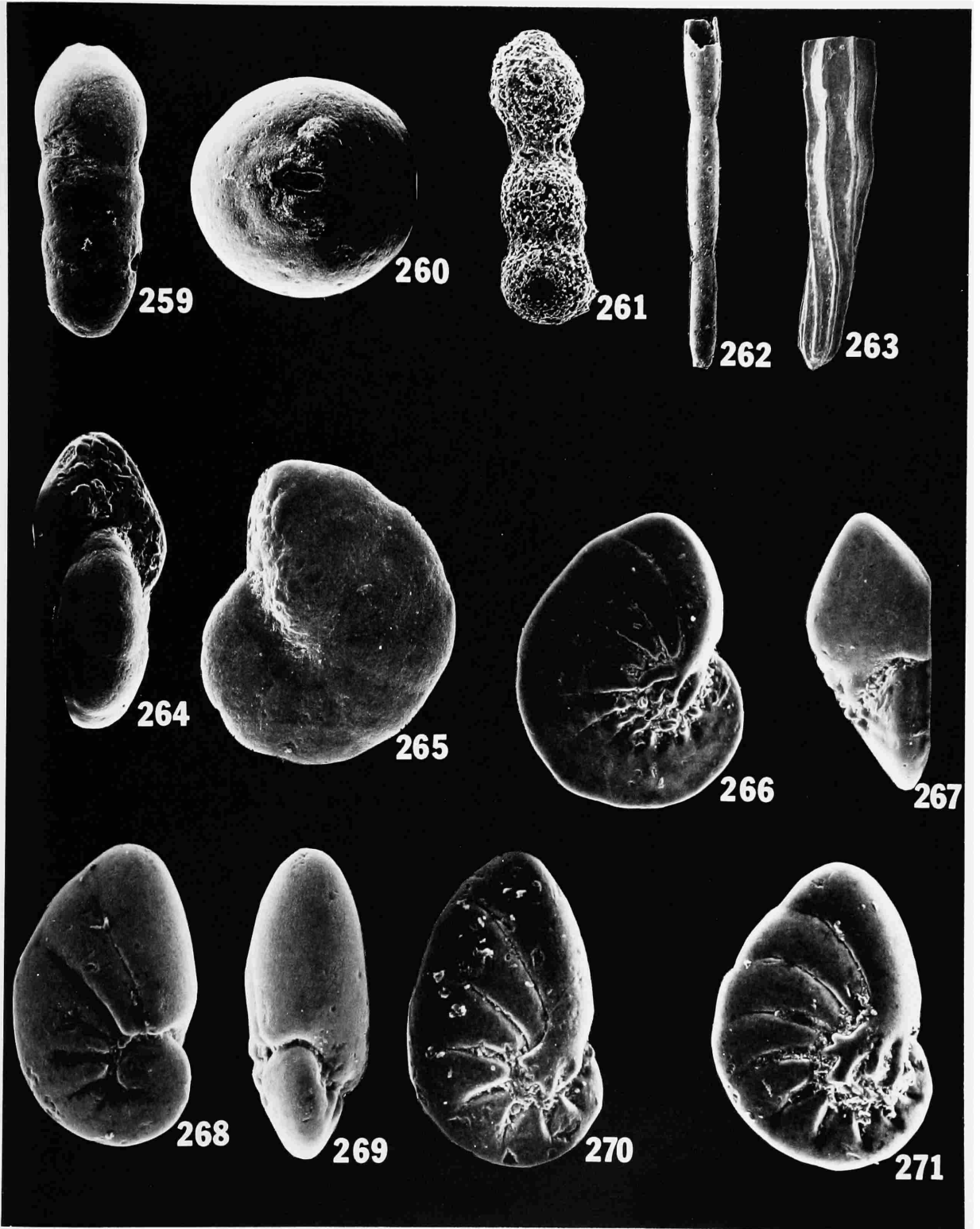
267. Peripheral view, N41/f660, hypotype, USNM 243430,  $\times 100$ .

268. Spiral side, N33/f580, hypotype, USNM 243431,  $\times 160$ .

269. Peripheral view, N33/f580, hypotype, USNM 243431,  $\times 160$ .

270. Involute side, N33/f580, hypotype, USNM 243432,  $\times 150$ .

271. Involute side, N33/f581, hypotype, USNM 243433,  $\times 110$ .



## PLATE 22

*Nonion tuberculatum* (d'Orbigny)

272. Side view, N28/f455, hypotype, USNM 243434,  $\times 175$ .

273. Peripheral view, N28/f455, hypotype, USNM 243434,  $\times 175$ .

*Notorotalia miocenica* (Cushman)

274. Peripheral view, N42/f732, hypotype, USNM 243435,  $\times 80$ .

275. Spiral side, N42/f732, hypotype, USNM 243435,  $\times 80$ .

276. Involute side, N28/f793, hypotype, USNM 243436,  $\times 90$ .

277. Spiral side, N28/f793, hypotype, USNM 243437,  $\times 80$ .

278. Involute side, N41/f555, hypotype, USNM 243438,  $\times 105$ .

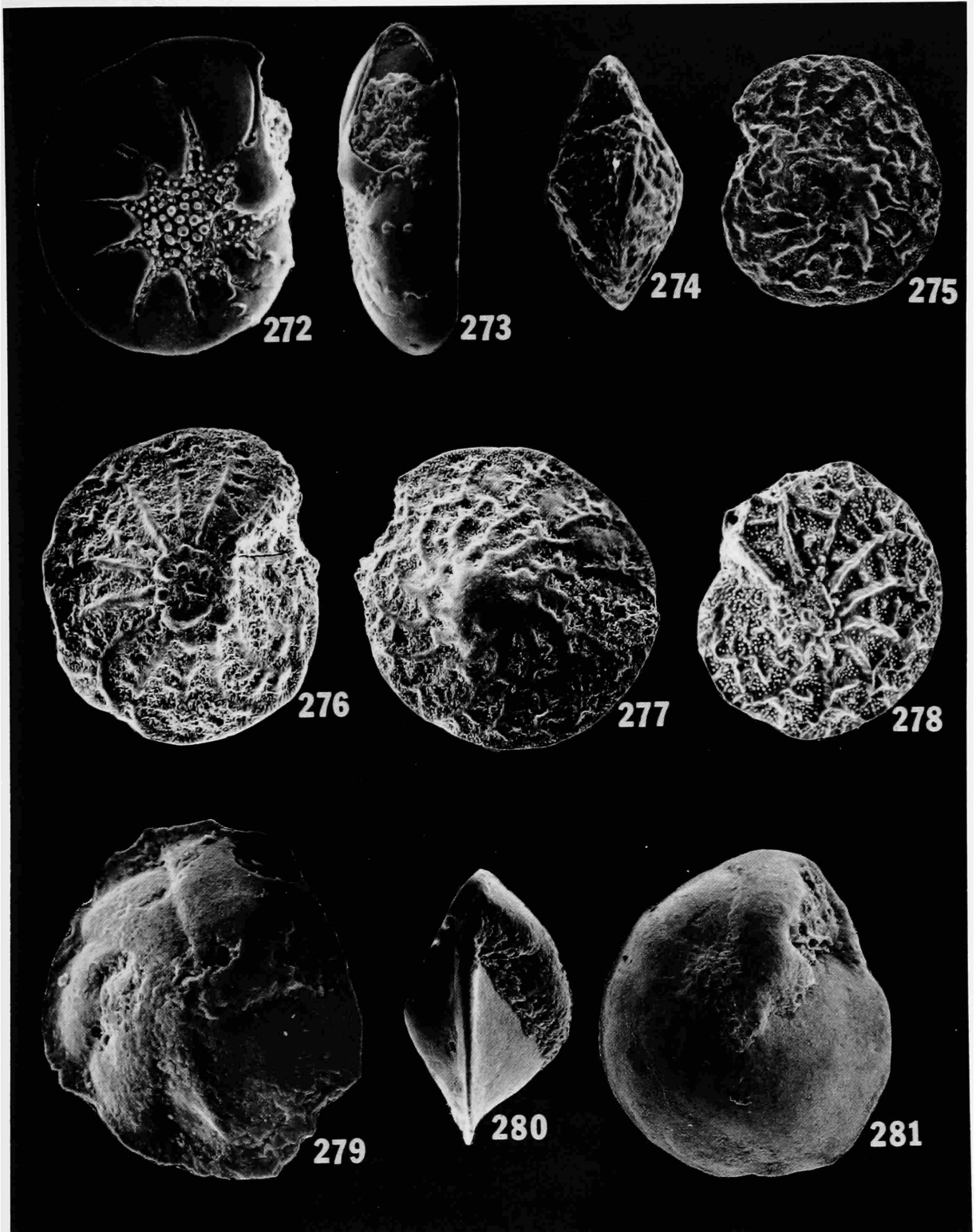
*Osangularia culter* (Parker and Jones)

279. Involute side, N41/f622, hypotype, USNM 243452,  $\times 200$ .

280. Peripheral view, N37/f585, hypotype, USNM 243453,  $\times 70$ .

281. Involute side, N37/f585, hypotype, USNM 243454,  $\times 66$

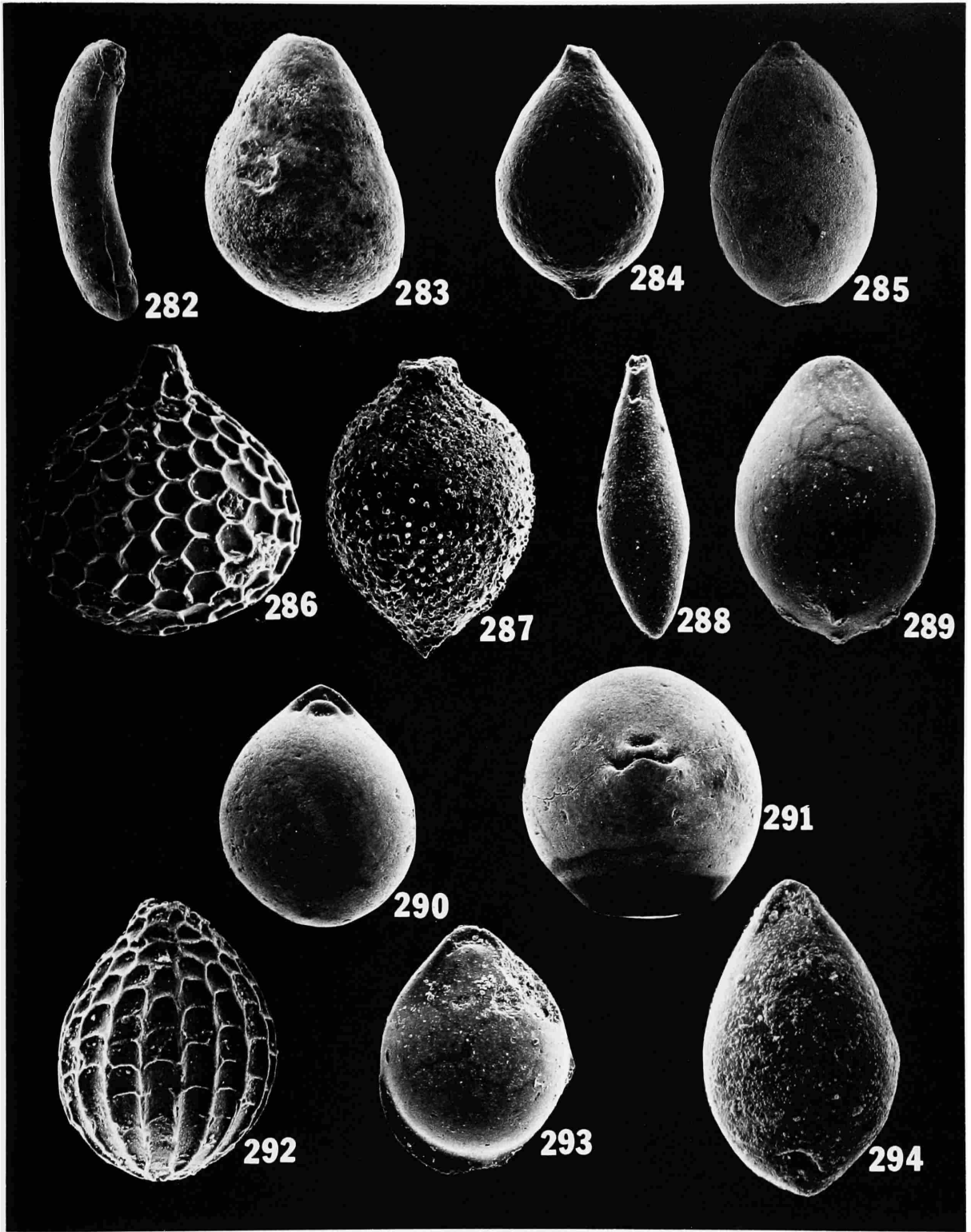
(see Plate 15: figures 163, 164).



## PLATE 23

- Oolina botelliformis* (Brady)  
282. Side view, N33/f536, hypotype, USNM 243455,  $\times 130$ .
- Oolina* aff. *O. collaris* (Cushman)  
283. Side view, N41/f533, hypotype, USNM 243456,  $\times 160$ .
- Oolina globosa* (Montagu)  
284. Side view, N42/f719, hypotype, USNM 243457,  $\times 100$ .  
285. Side view, N42/f696, hypotype, USNM 243458,  $\times 180$ .
- Oolina hexagona* (Williamson)  
286. Side view, N33/f581, hypotype, USNM 243459,  $\times 180$ .
- Oolina hispida* (Reuss)  
287. Side view, N42/f696, hypotype, USNM 243460,  $\times 160$ .
- Oolina punctulata* (Sidebottom)  
288. Side view, DSDP 206-38-2, hypotype, USNM 243461,  $\times 120$ .
- Oolina setosa* (Earland)  
289. Side view, DSDP 206-38-2, hypotype, USNM 243462,  $\times 90$ .
- Parafissurina abnormis* Parr  
290. Front view, N42/f696, hypotype, USNM 243463,  $\times 66$ .  
291. Enlarged apertural view, N42/696, hypotype, USNM 243463,  $\times 85$ .
- Oolina squamosa* (Montagu)  
292. Side view, N33/f581, hypotype, USNM 243464,  $\times 175$ .
- Parafissurina basicarinata* Parr  
293. Front view, DSDP 206-41-1, hypotype, USNM 243465,  $\times 80$ .
- Parafissurina lateralis* (Cushman)  
294. Front view, DSDP 206-37 CC, hypotype, USNM 243466,  $\times 260$ .





## PLATE 24

*Oridorsalis umbonatus* (Reuss)

295. Involute side, DSDP 206-32-2, hypotype, USNM 243467,  $\times 130$ .  
296. Peripheral view, DSDP 206-32-2, hypotype, USNM 243467,  $\times 130$ .

*Pavonina triiformis* Parr

297. Side view, N28/f455, hypotype, USNM 243468,  $\times 66$ .

*Planorbulinella zelandica* Finlay

298. Convex side, N28/f453, hypotype, USNM 243469,  $\times 80$ .  
299. Peripheral view, N28/f453, hypotype, USNM 243469,  $\times 80$ .

*Plectofrondicularia proparri* Finlay

300. Side view, N33/f580, hypotype, USNM 243470,  $\times 80$ .

*Plectofrondicularia awamoana* Finlay

301. Side view, broken section, N33/f581, hypotype, USNM 243471,  $\times 100$ .

*Planulina catilla* (Finlay)

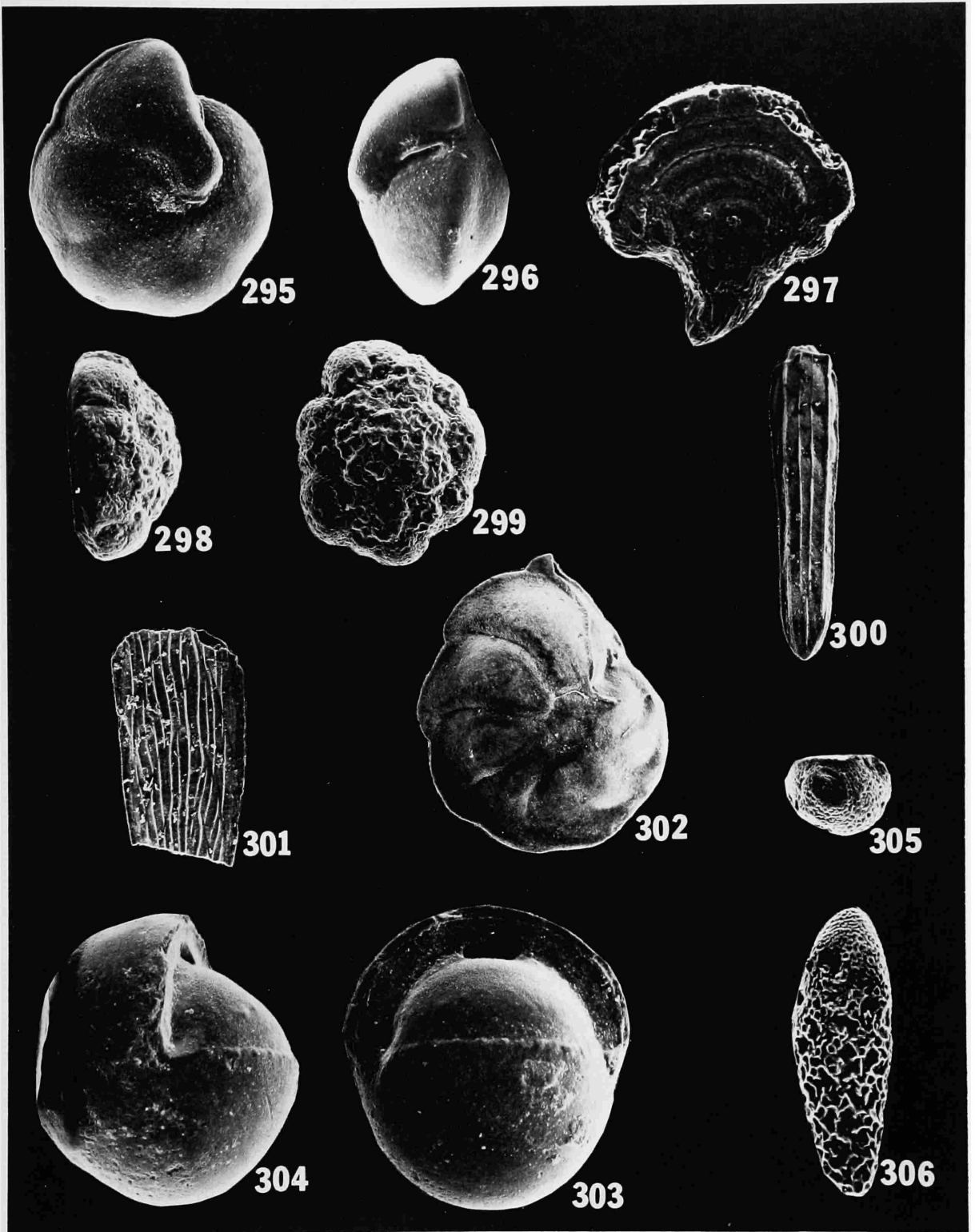
302. Partly involute side, N37/f585, hypotype, USNM 243472,  $\times 60$ .

*Pullenia bulloides* (d'Orbigny)

303. Peripheral view, DSDP 206-44-2, hypotype, USNM 243473,  $\times 140$ .  
304. Side view, DSDP 206-44-2, hypotype, USNM 243473,  $\times 140$ .

*Rectobolivina maoriella* Finlay

305. Apertural view, N33/f505, hypotype, USNM 243474,  $\times 140$ .  
306. Side view, N33/f505, hypotype, USNM 243474,  $\times 140$ .



## PLATE 25

*Pleurostomella aguafrescaenis* Todd and Kniker

307. Side view, DSDP 206-38-2, hypotype, USNM 243475,  $\times 130$ .  
308. Front view, DSDP 206-38-2, hypotype, USNM 243475,  $\times 130$ .

*Pleurostomella bierigi* Palmer and Bermudez

309. Side view, N42/f723, hypotype, USNM 243476,  $\times 80$ .  
310. Front view, N42/f723, hypotype, USNM 243476,  $\times 80$ .

*Pleurostomella obtusa* Berthelin

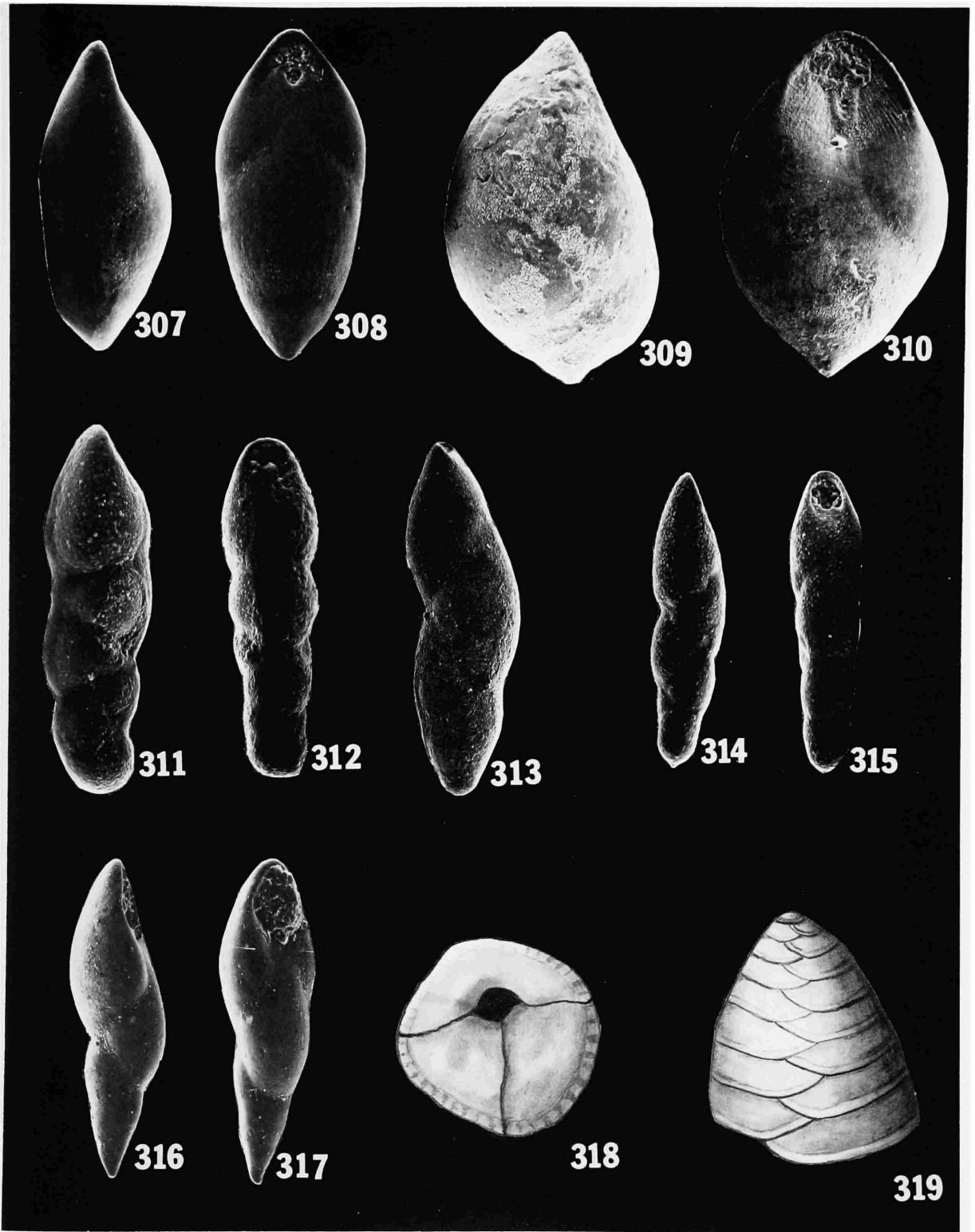
311. Side view, DSDP 206-38-2, hypotype, USNM 243477,  $\times 260$ .  
312. Front view, DSDP 206-38-2, hypotype, USNM 243477,  $\times 260$ .

*Pleurostomella tenuis* Hantken

313. Side view, small aperture, N41/f644, hypotype, USNM 243478,  $\times 120$ .  
314. Side view, DSDP 206-38-2, hypotype, USNM 243479,  $\times 200$ .  
315. Front view, DSDP 206-38-2, hypotype, USNM 243479,  $\times 200$ .  
316. Side view, N41/f644, specimen lost,  $\times 140$ .  
317. Front view, N41/f644, specimen lost,  $\times 140$ .

*Pseudopatellinoides* aff. *P. primus* Krasheninnikov

318. Apertural view, N42/f694, hypotype, USNM 243480,  $\times 130$ .  
319. Side view, N42/f694, hypotype, USNM 243480,  $\times 130$ .



## PLATE 26

*Rectobolivina striatula* (Cushman)

320. Side view, N41/f660, hypotype, USNM 243481,  $\times 100$ .

321. Enlarged apertural view, N41/f660, hypotype, USNM 243481,  $\times 215$ .

*Rectuvigerina ruatoria* (Vella)

322. Side view, N33/f581, hypotype, USNM 243482,  $\times 120$ .

*Rectuvigerina vesca* (Finlay)

323. Side view, N41/f590, hypotype, USNM 243483,  $\times 120$ .

*Ramulina* sp.

324. Side view, N33/f581, hypotype, USNM 243484,  $\times 100$ .

*Rosalina concinna* (Brady)

325. Involute side, N28/f781, hypotype, USNM 243485,  $\times 100$ .

326. Peripheral view, N28/f781, hypotype, USNM 243485,  $\times 100$ .

*Saracenaria obesa* Cushman and Todd

327. Face view, N33/f579, hypotype, USNM 243486,  $\times 90$ .

328. Side view, N33/f579, hypotype, USNM 243486,  $\times 90$ .

329. Side view, N33/f578, hypotype, USNM 243487,  $\times 45$ .



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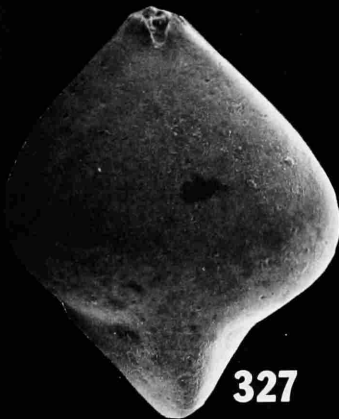
324



325



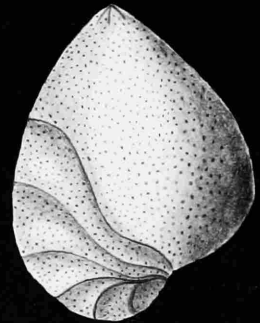
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## PLATE 27

*Reussella spinulosa* (Reuss)

330. Side view, N33/f578, hypotype, USNM 243488,  $\times 130$ .

*Saracenaria latifrons* (Brady)

331. Side view, N33/f581, hypotype, USNM 243489,  $\times 100$ .

*Sigmoidina pacifica* Cushman and Ozawa

332. Front view, N41/f622, hypotype, USNM 243490,  $\times 220$   
(see Plate 15: figures 198, 199).

*Siphonina australis* Cushman

333. Involute side, N41/f622, hypotype, USNM 243491,  $\times 90$ .

*Siphouwigerina proboscidea* (Schwager)

334. Side view, N33/f581, hypotype, USNM 243492,  $\times 160$ .

*Sphaeroidina bulloides* d'Orbigny

335. Front view, N33/f581, hypotype, USNM 243493,  $\times 130$ .

*Spirillina vivipara* Ehrenberg

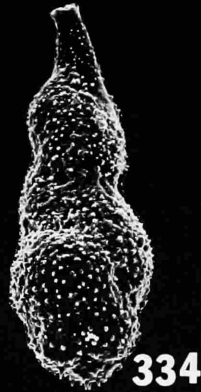
336. Side view, N41/f624, hypotype, USNM 243494,  $\times 270$ .

*Stetsonia* sp.

337. Peripheral view, DSDP 206-38-2, hypotype, USNM 243495,  $\times 210$ .

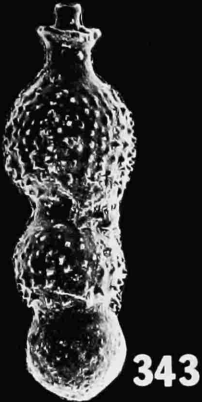
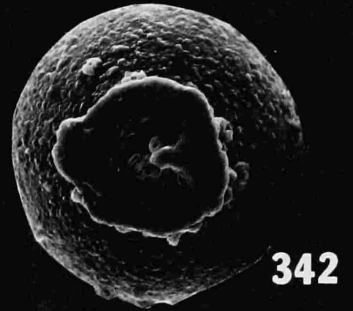
338. Side view, DSDP 206-38-2, hypotype, USNM 243495,  $\times 210$ .





## PLATE 28

- Stilostomella antillea* (Cushman)  
339. Side view, N33/f581, hypotype, USNM 243496,  $\times 90$ .
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