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Thirty nine Early Miocene to Pleistocene sediment samples from the Deep Sea Drilling Project, Leg 90, Sites 587 to 589, located on the Lord Howe Rise, south west Pacific Ocean were investigated for foraminifera. Planktonic foraminifera were used to erect a biostratigraphic framework into which 5 benthic foraminiferal assemblages were integrated. One hundred and eighty species of deep - water benthic foraminifera were identified. Eighteen isobathyal species indicate mid - to lower bathyal depths throughout the interval. The faunal diversity is high.

Assemblage No.1, Early Miocene, indicates the bottom water mass characteristics of 7 to 8°C, normal salinity and 0.5 to 3ml/L oxygen, in a relatively thermally unstratified ocean.

Assemblage No.2, Middle Miocene, indicates the bottom water mass to have been 2 to 3°C with high oxygen content in a thermally stratified ocean.

Assemblage No.3, Late Miocene, indicates similar water mass characteristics to those of the Middle Miocene assemblage.

Assemblage No.4, Pliocene, indicates a relatively less cold bottom water mass than the Miocene assemblages.

Assemblage No.5, Pleistocene, is divided into two sub - assemblages which indicate interglacial and glacial episodes. The interglacial sub - assemblage indicates bottom water of 4 to 8°C and the glacial sub - assemblage indicates 2 to 3°C bottom water temperature.

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MIOCENE TO PLEISTOCENE DEEP - WATER BENTHIC FORAMINIFERA FROM D.S.D.P.
SITES 587 TO 589 (LORD HOWE RISE), SOUTH WEST PACIFIC OCEAN; TAXONOMY AND
PALEOECOLOGY.

by

UDUMALA BALAPRATAP REDDY, M.Sc., M.PHIL.

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of
Master of Science

Department of Earth Sciences

Carleton University
Ottawa, Ontario

April, 1989.

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The undersigned hereby recommend to the Faculty of Graduate Studies and Research, Carleton University, acceptance of this thesis, submitted by Udumala Balapratap Reddy, M.Sc. M.phil., in partial fulfilment of the requirements for the degree of Master of Science.

A handwritten signature in cursive script, appearing to read "G. Ravall", written over a horizontal dotted line.

Chairman, Department of Earth Sciences

A handwritten signature in cursive script, appearing to read "Udumala Balapratap Reddy", written over a horizontal dotted line.

Supervisor

Dedicated to my Parents and to my loving Eldest Brother's family

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The primary emphasis of this thesis is the taxonomic evaluation of deep - water benthic foraminifera. The taxonomic position of some important species is updated according to the revised classification of Loeblich and Tappan, 1987.

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CHAPTER 1

INTRODUCTION

A. GENERAL INTRODUCTION

Deep – sea benthic Foraminiferida is one of the most important groups of microorganisms which inhabit the deep ocean floor. These organisms have contributed significantly to paleoclimatic and paleo - oceanographic reconstructions. Our knowledge of deep – sea benthic foraminifera has been enhanced greatly since 1968, when the Deep Sea Drilling Project began to retrieve samples from the deep ocean floor. At the initial stages of this project, specialists in micropaleontology mainly emphasized Planktonic foraminifera because of their supreme utility in biostratigraphy. Later, deep – sea foraminifers from the world's oceans have been studied by numerous experts (Boltovskoy,1978; Corliss, 1979a, 1983; Douglas,1973; Ingle,1981; Thomas,1985,1986 and Woodruff,1985). Unfortunately, many of these workers have not followed a standardized taxonomy. Nevertheless, studies have progressed rapidly on this group of organisms.

SCOPE AND PURPOSE

There is a confusion in the taxonomy and nomenclature of some of the important species of deep – water benthic foraminifera. Many taxonomic experts feel that there is a need for taxonomic revision of deep sea foraminifera (Boltovskoy,1978, Mead,1985; van Morkhoven *et al.*,1986). Furthermore,there is much work remaining to be done in documenting space - time distributions,evolution, diversification, test morphology, environmental relationships, and extinction of deep – sea benthic foraminifera.

The purpose of the present research is to identify, describe and illustrate important deep - sea taxa. The main emphasis is on taxonomic evaluation of

important species, and based on their distribution, to offer a possible interpretation of paleoecological conditions.

PRESENT STUDY

In the present investigation, the author has taken up a general survey on taxonomy of deep – sea benthic foraminifera of Early Miocene to Pleistocene age of samples from the Deep Sea Drilling Project (D.S.D.P. Leg 90, Sites 587-589) on the Lord Howe Rise in the Southwest Pacific Ocean. Geographic location of the sites and their present day water depths are shown in Figure (1.1). The Southwest Pacific region is ideal for these sorts of study as thick, relatively uncomplicated, continuous pelagic sequences of Neogene and Quaternary sediments are present (Burns and Andrews, 1973; Kennett and Houtz, 1975). Leg 90 was selected because all the sites were located well above the Carbonate Compensation Depth (C.C.D.) and the dissolution of calcareous tests was minimal. Samples were obtained by Hydraulic Piston Corer (H.P.C.) and Extended Core Barrel (E.C.B.); consequently they were continuous and uncontaminated except for a few samples at site 587.

PREVIOUS WORK

The report on the Challenger expedition of 1872-1876 published by H.M. Brady (1884) was in fact a first report on benthic foraminifera from all oceans, except the Arctic. He described more than 280 deep – sea species and his work remains as an important source of information on the taxonomy, morphology and the occurrence of deep – sea foraminifera. Barker (1960) updated Brady's taxonomy and published a condensed version of revised taxonomy with 115 plates. Phleger, Parker and Peirson (1953) reported on deep – sea foraminifera from the Swedish deep sea expedition and Phleger and Parker's (1951) study of ecology of Foraminifera from the northwest Gulf of Mexico are also valuable contributions. Todd (1965) studied Rotaliform families

Fig. 1.1 Location map

Site	Latitude	Longitude	Water depth
587	21°11.87	161°19.99	1101m
588	26°06.70	161°13.60	1533m
589	30°42.72	163°38.39	1391m

from the voyage of the "Albatross" (1899-1900) in the tropical Pacific Ocean. Belford's (1966) report on smaller foraminifera from Papua and New Guinea, and Hornibrook's (1968, 1971) papers on Microfossils from New Zealand were also important findings. Cushman's 1910-1949, and Loeblich and Tappan's (1964, 1987) dedicated work on Foraminifera remain unprecedented. The monograph published by van Morkhoven, Berggren and Edwards (1986) on Cenozoic Cosmopolitan Deep - Sea Benthonic Foraminifera and Murray's (1971) Atlas of British Recent Foraminifera and Poag's (1981) Ecologic Atlas of Benthic Foraminifera are also significant sources of information.

Deep - sea foraminifera of (1) the Eastern Pacific are described by Boltovskoy (1981a, 1983, 1984), Ingle (1973), and Resig (1976, 1981); (2) the Western Pacific by Boltovskoy (1981b), Boersma (1986), Bonnar (1982), Culp - Burke (1981), Heiman (1977), Kurihara and Kennett (1986), Leckie and Webb (1986), Murphy (1985), Phillips (1983), Woodruff (1985); and (3) the Central Pacific by Douglas (1973).

Important papers on the taxonomy of deep - sea foraminifera are contributed by Boltovskoy (1978), Belanger and Berggren (1986), Corliss (1979a), Heiman (1977), Hermelin and Scott (1985), Mead (1985), Miller and Katz (1987), Patterson (1986b) and Nienstedt and Arnold (1988).

BIOSTRATIGRAPHY

The biogeographic distribution of planktonic foraminifera in the oceans is controlled by prevailing circulation patterns, physico-chemical characteristics of surface water masses and ocean basin configuration. The changes in paleoenvironmental and paleogeographic parameters in the geological past have been well documented through spatial distribution of planktonic foraminiferal provinces. Berggren and Hollister (1977) postulated that long term climatic cooling during the Neogene, connected to a series of distinct events, was primarily responsible for the

development of latitudinal provincialization of planktonic foraminifera. Based on the geographic provincialism of planktonic foraminifera, biostratigraphers proposed several zonal schemes to establish the age of sediments in different regions. The first tropical zonal scheme was proposed by Bolli (1957, 1966) and Bolli and Bermudez (1965) based on Caribbean sediments. Later, Blow (1969) established another zonal scheme (also Caribbean-based) in which he gave a detailed discussion on the geographic scope of the zonal schemes. Many workers realized that these two zonal schemes had serious shortcomings and were not applicable beyond tropical regions. Srinivasan and Kennett (1981a,b) suggested that sedimentary sequences of Neogene age in the southwest Pacific are optimal for examining latitudinal differentiation of planktonic foraminifera, because the Neogene was a time of major changes in paleo - oceanographic conditions.

The largely carbonate Neogene sedimentary sequence at Lord Howe Rise is complete and continuous and contains most of the important groups of planktonic microfauna. The age of these sediments was established based on the biostratigraphic zonations of planktonic foraminifera (Jenkins and Srinivasan, 1986) and calcareous nannofossils (Lohman, 1986). D.S.D.P. leg 90 sites 537--589, subjects of the present study, are located in an area characterized at the present time by a warm - subtropical water mass in the Southwest Pacific Ocean. The first Neogene planktonic foraminiferal zonal scheme for the warm-subtropical region was developed by Kennett (1973). His scheme representing a combination of tropical and temperate elements has proven important for correlation between tropical and temperate sequences. The zonal scheme of Jenkins (1971,1985) based on New Zealand sequences was also an important contribution. Srinivasan and Kennett (1981 a,b) established three distinct zonal schemes representing tropical to subantarctic watermasses from six D.S.D.P. sites. Furthermore, they suggested that the major evolution of planktonic foraminifera has taken place in both tropical and temperate regions. The intermediate regions (warm--subtropical) contain a mixture of tropical

or cool--subtropical planktonic foraminiferal assemblages, thus assisting in the correlation of low and higher latitude zonations in the southwest Pacific. The faunal characteristics and the zonal scheme for the subtropical region have been previously discussed by Srinivasan and Kennett (1981 a,b), Kennett and Srinivasan (1983), Jenkins (1985), Jenkins and Srinivasan (1986), Elmstrom and Kennett (1986) and Hodell and Kennett (1986).

Although the main emphasis of this research is benthic foraminifera, examination of the biostratigraphic ranges of planktonic foraminifera has been undertaken to establish the age of the samples under investigation, and to confirm earlier existing zonal schemes. These zonal schemes were proposed by several investigators, especially Kennett (1973), Srinivasan and Kennett (1981, 1983), and Jenkins and Srinivasan (1986). To establish the zonal boundaries, prime importance was given to the initial appearances of zonal index planktonic foraminifers. The zonal boundary based on initial appearance can be drawn with a high degree of confidence, because some species seem to spread rapidly and become very abundant shortly after initial appearance. Hence the probability of finding them is high. Unfortunately, all zonal boundaries were not established based on the first appearance of index fossils. Some species seem to decline slowly becoming less abundant and spotty in distribution before extinction. Therefore, the probability of finding them is less certain. Hence the boundary of any zone based on the last occurrence of a relatively long range index fossil leads to less confidence in defining the boundary.

Keeping these views in mind, the author has confirmed the top boundary of an underlying zone based on the initial appearance of the datum index fossil of the succeeding zone. This means, that the base of the overlying zone was treated as the top of the underlying zone. By following this method, it is easy to confirm the position of a sample as far as the zone is concerned, but it becomes difficult where the zonal boundary is based on the last occurrence of a relatively long range index species. In such cases, the author has scanned the sieved fraction to confirm the absence of

such a species. However, there is always some uncertainty in establishing the boundary. In documenting the biostratigraphy, I discuss each foraminiferal zone, give the most important co-occurring foraminiferal species within the zone and initial appearances of a few species. For each sample, the age, sample details, sub - bottom depth, Blow's numeral zonal scheme number and foraminiferal zonal index fossils are given. The chronological age (in millions of years) was established by extrapolating the sub - bottom depth with sedimentation rates and is given in biostratigraphic tables (Kennett, 1986). The lithology was obtained from Nelson's (1986) paper in the D.S.D.P. reports of leg 90.

GEOGRAPHIC SETTING

During Deep Sea Drilling Project Leg 90 seven sites were drilled of which six were on the Lord Howe Rise, Southwest Pacific Ocean. The Rise is one of the major smooth rolling submarine topographic features of the southwest Pacific, extending northward from central western New Zealand to its northern limits at Lansdowne Bank. The Rise is about 2000 km long and 300 km wide. The present - day water depth ranges from 1101m to 1533m.

Site 587 is located at the margin of the warm subtropics; Site 588 is located in the warm subtropical watermass which lies between the true tropical watermass to the north and transitional watermass to the south. Finally, site 589 is situated on the subtropical divergence.

TECTONIC HISTORY

Various studies have been attempted to unravel the formation of different basins in the Southwest Pacific Ocean. Coleman (1980) suggested that the late Cretaceous was the period of intensification of the rift system between present day Southeastern Australia and Antarctica. At 80 m.y. ago, the Tasman Sea was formed

due to the separation of New Zealand from Antarctica. At the same time a large continental block, called "Tasmanitis", consisting of the Lord Howe Rise and the New Caledonia--Norfolk Ridge, was detached from the Australo - Antarctic Plate. Furthermore, Coleman posits that at 70 m.y. ago the Southern Ocean was formed as an extension of the Tasman seaway. Concurrently, most of the rift systems of Southeastern Australia went off with the Lord Howe Rise (Mutter and Jongsma, 1978; Shaw, 1978). The Rise began to sink soon after separation. Burns and Andrews (1973) hypothesized that during the late Maastrichtian (65-70 m.y. ago) water depths over the Lord Howe Rise were as shallow as shelf depths; subsidence probably started by this period and continued until present day depths were attained in the Early Eocene.

Christoffel (1978) proposed a split in Tasmanitis across New Zealand which might have been the cause for formation of the New Caledonia basin in the earliest Paleocene, approximately 65 m.y. ago. Burns and Andrews (1973) divided the complex region of Tasmanitis into the Western Marginal Basinal Province, the Eastern Marginal Basinal Province, and the Pacific plate. They have placed the Coral Sea basin, the New Queensland plateau, the New Caledonia basin, and the Lord Howe Rise in the Western Marginal Basinal Province. The Eastern Marginal Basinal Province contains Fiji and Lau basins. Coleman (1980) elucidates that the Coral Sea began to form at 65 m.y. ago and its opening is directly linked with a northern extension of the Tasman sea system along Lagnaik-Bismark fracture zone (Tylor and Falvey, 1977). During the Early Eocene (55 m.y. ago) significant sea floor spreading occurred and this was directly related to separation of Australia from Antarctica resulting in establishment of a major circum - Antarctic seaway system (Weissel and Hayes, 1972).

In the Middle Eocene Lord Howe Rise and Coral Sea received high amounts of biogenic sediment. Foraminiferal and Nannofossil ooze was accumulated over Lord Howe Rise during the Neogene and Quaternary Periods. During the Neogene, the sites on the Lord Howe Rise witnessed about 5 to 10° of northerly movement in association with movement of the Indian plate (Sclater, 1985).

PHYSICAL OCEANOGRAPHY

The preservation potential of deep - sea sediments mainly is governed by circulatory patterns of the world's oceans. Different watermasses are mainly characterized by physico - chemical properties, such as dissolved O_2 , total CO_2 , salinity, temperature, nutrients and corrosivity to carbonate; all significantly affect deep sea sediments.

Present - Day bottom Watermass

Kennett and Borch (1986) pointed out that physical oceanography, especially of deep water circulation of the southwest Pacific, is not well understood. Kennett (1977) treated the Southern Ocean as an amphitheater for the formation of the world's abyssal and deep waters originating from seas surrounding Antarctica. He states that the Southern Ocean represents the primary mixing arena for the present - day Pacific, Atlantic and Indian oceans, consequently affecting the chemical budgets of each of them.

Edwards (1978) proposed three main features of present - day bottom - water circulatory movements: (1) eastward and westward flowing Antarctic bottom water originating near the base of the Ross Sea; (2) strong eastward flowing current south of Tasman basin is the Antarctic-circumpolar current; (3) the western boundary undercurrent is a narrow intense northward moving flow along the western margin of the deep Southwest Pacific Ocean. Kennett (1977), with reference to the western boundary undercurrent, suggested that after the development of a strong Antarctic circumpolar current during the Oligocene, northward flow through the Tasman Sea greatly diminished, and consequently continuous sedimentary sequences were deposited throughout the Neogene, from approximately 22 m.y. to the present. Warren

(1973) strengthened the above interpretation and believes that some Antarctic bottom water does enter the southern part of the Tasman Sea, but northward flow is greatly restricted due to sluggish bottom water flow in the deep Tasman Sea. Rodman and Gordon (1982) revealed that a variety of cold (-5°), highly oxygenated, Antarctic deep and intermediate water produced beneath the Ross Ice Shelf flows into the Indian and southwest Pacific Oceans.

Present - Day Surface Watermass

Kennett, Keller and Srinivasan (1985) proposed an important model for present - day surface water circulation in the Pacific Ocean. The above authors suggested clockwise movement of surface waters in the North Pacific and counter-clockwise in the Southwest Pacific Ocean. North and South Pacific currents are separated by a well-defined series of eastward and westward flowing surface currents, including an eastward flowing undercurrent just south of the Equator (Wyrtki, 1967). Furthermore, they explain that the western boundary currents, i.e Kuroshio Current (Northern Hemisphere) and East Australian Current (Southern Hemisphere) flow towards the Poles. Conversely, eastern boundary currents, i.e California Current (Northern Hemisphere) and Peru-Chile Currents (Southern Hemisphere) flow toward the Equator as cold watermasses. Warren (1970) has discovered another minor current, South Equatorial Current, which flows within the southern tropical Pacific region.

B. MATERIALS AND METHODS

In the present research, 39 samples from three Deep Sea Drilling Project (D.S.D.P.) sites (587-589) in the Southwest Pacific Ocean were examined. These samples were collected during D.S.D.P. Leg 90 (November 29th, 1982 - January 9th, 1983). A site usually refers to a location where one or more holes were drilled while keeping the drilling ship within a radius of 900 metres from the beacon.

The first hole drilled at a site is designated a number, eg. Site 588, subsequent holes are followed by a letter, eg. Site 588A, Site 588B, and so on. Each core is generally 9.5 metres in length, which is the normal length of a core barrel and is cut into 1.5 metre sections numbered from 1 through 7, starting from the top of the sediment core. The Core Catcher, which prevents core mixing, is normally placed below section 7. Complete identification of a sample consists of leg number, site number, hole letter, core number, section number, and sample interval in centimetres from the top of the section. For further information, consult initial core descriptions of leg 90 reports.

Site 587 at Lansdowne Bank was continuously cored, obtaining seventeen cores down to the depth of 147 metres. Out of these cores, ten samples were examined in the present study which range in age from Late Miocene through the Pleistocene.

At hole 588A, drilling was uninterrupted, 344.4 metres of sediment were penetrated and twenty-six cores obtained. Twelve samples ranging from Early Miocene through Middle Miocene were examined in the present investigation and one Early Miocene sample from hole 588C was also included.

At hole 588B, thirty-one cores were obtained, penetrating 277.4 metres. Eleven samples ranging in age from Middle Miocene to Pliocene were examined from this hole.

At Site 589, four cores of Quaternary age were retrieved. From this site, five samples were examined in the present investigation.

The samples were weighed and washed through 120 mesh and 230 mesh nested sieves (openings 0.124mm and 0.063mm respectively). Subsequent to sieving, approximately 200 benthic foraminifers were picked using a brush and stereoscopic microscope. If more than 200 benthic specimens occurred within a sample, then the sample was split by use of a microsplitter. Individual species were identified and specimens were counted for each species. The fractional abundance of a species is expressed as a fraction of the abundances of all the species in a sample.

The location map and all figures and tables used in this report were drawn on a Macintosh II computer using various CAD programs and the data base of benthic species was prepared using Excel.1.04 program. The species fractional abundance curves were plotted using the Cricket Graph version 1.2 program.

Cluster analysis is a statistical technique used to simplify a complex set of data so that the relationship can be expressed graphically. Numerous workers use different clustering techniques and there is no standard technique available. Out of total of 39 samples cluster analysis was performed on 32. Out of 180 species R-mode cluster analysis was performed on 68. Data, cluster and factor modules of the "SYSTAT" (System statistics) program (Wilkinson, 1987) were used on a Macintosh SE computer. These 68 species contained statistically significant populations. Patterson and Fishbein (1989) calculated the standard error for specimen countings for considering rare taxa in interpreting the paleo-ecological conditions. According to their algorithmic plot, the occurrence of any species with a fractional abundance of 3% or more in 200 specimen countings of any given sample is considered as a significant proportion.

In the present investigation, clustering was performed using the complete linkage method. For more details consult Davies (1973) and System Statistics program manual. Using this method Q-mode (comparing samples) and R-mode (comparing species) analyses were performed and the results were given in the form of dendrograms. Scanning electron micrographs were taken on the Carleton University Joel JSM-U3 Scanning Electron Microscope using Polaroid PN 665 film.

CHAPTER 2

RESULTS

A. PLANKTONIC SPECIES

The biostratigraphic framework of the study is provided by use of planktonic species of foraminifera.

BIOSTRATIGRAPHY OF SITE 588, HOLE A

From this hole, 12 samples were examined which span the Early through Middle Miocene. The biostratigraphy is shown in Table (2.1). In addition to these samples, one Early Miocene sample from Site 588, hole C, was also included. The details of each zone are as follows:

Globoquadrina dehiscens Zone

The zonal definition of Srinivasan and Kennett (1981, a) is followed herein.

Identifying descriptors: Site 588A-18,cc, 588A-18-2-101-103cm, 588C-8-6-139-141cm.

Results: In addition to the nominate species, I found the following occurring within the samples: *Globigerina woodi*, *G. praebulloides*, *Globigerinoides primordius*, *Catapsydrax dissimilis*, *C. unicavus*, *Cassigerinella chipolensis*, *Globorotalia kugleri* and *Gl. siakensis*.

Discussion: Kennett and Srinivasan (1981 a,b) divided the *Globigerinoides primordius* Zone into N4A and N4B. N4B indicates the boundary between Oligocene/Miocene at approximately 22.5 my (Saito, 1977). The initial appearance of *Globoquadrina dehiscens* distinguishes the base of the N4B Zone and is isochronous all over the South Pacific. Kennett (1980) define the last appearance of *Globorotalia kugleri* as marking the top of the *Globoquadrina dehiscens* Zone. The last occurrence of *Gl. kugleri* is also isochronous in southwest Pacific sites of Srinivasan and Kennett (1984). The presence of *Gl. kugleri* and *Gq. dehiscens* in all my samples indicate that samples represent *Gq. dehiscens* Zone. Keller (1981) assigned the base of this zone to

Table.2.1 Biostratigraphy of Site 588A

Epoch	Lithology	Sample	Depth	Zone	Foraminiferal zone	Age in My
MIDDLE MIOCENE		588A-1-1-0-3cm	236.03m	N12	<i>Globorotalia</i> <i>fohsi s.l</i>	12.3
		588A-1-7-4-6cm	245.05m	↑		12.9
		588A-2-2-3-5cm	247.15m			13.5
		588A-4-6-4-6cm	260.15m			14.8
		588A-6-4-4-6cm	270.15m	N10		
		588A-10-3-144-146cm	290.60m	N9	<i>Globorotalia</i>	16.2
		588A-11-3-49-51cm	294.10m		<i>peripheroacuta</i>	16.4
Early MIOCENE		588A-13-2-144-146cm	303.53m	N8	<i>Praeorbulina</i> <i>glomerosa</i> <i>curva</i>	17.2
		588A-14-3-40-42cm	308.64m	N7		
		588A-17-1-99-101cm	326.20m	N5	<i>Catapsdrax dissimilis</i>	19.4
		588A-18-2-101-103cm	336.40m	N4B	<i>Globoquadrina</i> <i>dehiscens</i>	21.0
		588A-18-CC	344.00m			
588C-8-6-139-141cm		381.80m	22.5			

Latitude 26°06'7"South

Longitude 161°13.6East

present day water depth 1548m

Legend

Foraminifer bearing
Nannofossil ooze

approximately 22.3 my based on the evidence of a radiolarian study.

Catapsydrax dissimilis Zone

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptor: 588A-17-1-99-101cm.

Results: In the present study important taxa in addition to the nominate species occurring within the zone are *Globigerina woodi*, *Globigerinoides subquadratus*, *Cassigerinella chipolensis*, *Globoquadrina altispira*, *Globorotalia mayeri* and *Gl. stakenis*.

Discussion: According to Jenkins and Srinivasan (1986) the base of this zone is established by the last appearance of *Globorotalia kugleri* and the top is defined by the extinction of the nominate species. In the present sample *Gl. kugleri* is absent. Absence of this species establishes the base of this zone. In addition, the nominate species also occurs within the sample. Based on the above findings the present sample represents the *C. dissimilis* Zone.

Praeorbulina glomerosa curva Zone

The zonal definition of Jenkins and Srinivasan (1986) is followed here.

Identifying descriptors: 588A-14-3-40-42cm, 588A-13-2-144-146cm.

Results: I have noticed the following species in addition to *Praeorbulina glomerosa curva* occurring within the samples. *Globigerinoides trilobus*, *Gs. subquadratus*, *Globoquadrina altispira*, *Globorotalia peripheroronda*, *Gl. mayeri*, *Neogloboquadrina continuosa*.

Discussion: According to Jenkins and Srinivasan (1986) the initial appearance of *Praeorbulina glomerosa curva* marks the top of the *Globorotalia miozea* Zone. The base of the zone is distinguished by the extinction of *Catapsydrax dissimilis*. Hence, the absence of *Catapsydrax dissimilis* and the presence of the nominate species indicates that the *Globorotalia miozea* Zone is absent in the present research although the zone is documented in the D.S.D.P. reports of Leg 90 by Jenkins and Srinivasan (1986). I do

not have samples from 588A, sections 15 through 16 which probably represent *Gl. miozea* Zone. The initial appearance of *P. curva* also marks the base of the nominate species zone. Therefore, the presence of nominate species and the absence of *catapsydrax dissimilis* in the present study indicates the samples represent *P. curva* Zone.

Globorotalia peripheroacuta Zone

The zonal definition of Srinivasan and Kennett (1981, a) is followed herein.

Identifying descriptors: 588A-11-3-49-51cm, 588A-10-3-144-146cm.

Results: I found the following taxa in addition to the nominate species occurring within the sample. *Globigerinoides trilobus*, *Gs. subquadratus*, *Globorotalia conoidea*, *Gl. mayeri*, *Gl. peripheroronda*, *Globoquadrina altispira* and *Orbulina suturalis*.

Discussion: Srinivasan and Kennett (1981, a) defined the base of this zone on the initial appearance of the nominate species. The top is defined by the initial appearance of *Globorotalia fohsi*. The presence of nominate species in the above two samples indicate that the samples were taken from the *Gl. peripheroacuta* zone. Furthermore, *Globorotalia fohsi* initially appeared in overlying sample 588A-6-4-4-6cm. That means, the top of the *Gl. peripheroacuta* Zone lies somewhere between samples 588A-10-3-144-146cm and 588A-6-4-4-6cm. *Orbulina suturalis* was absent from the samples which represent the nominate species zone, but initially appears in *Gl. fohsi* Zone sample 588A-6-4-4-6cm.

Srinivasan and Kennett (*op.cit.*) suggest that the appearance of *O. suturalis* in the subtropical region is late compared with the tropical region. Therefore, the presence of *Gl. peripheroacuta* and the absence of *O. suturalis* may strengthen the above author's opinion.

Globorotalia fohsi Zone

The zonal definition of Srinivasan and Kennett (1981, a) is followed herein.

Identifying descriptors: 588A-6-4-4-6cm, 588A-4-4-4-6cm, 588A-2-2-3-5cm, 588A-1-7-4-6cm, 588A-1-1-0-3cm.

Results: In the present study important taxa in addition to the nominate species occurring within the zone are *Globigerina bulloides*, *G. falconensis*, *G. decoraperta*, *Globigerinoides trilobus*, *G. subquadratus*, *Globorotalia conoidea*, *Gl. menardii*, *Gl. panda*, *Orbulina suturalis*, and *Sphaeroclinella seminulina*.

Discussion: According to the definition of Srinivasan and Kennett (1981a) the initial appearance of *Globorotalia fohsi* confirms the base of this zone. Jenkins and Srinivasan (1986) defined the base of the zone on the initial appearance of *Globorotalia peripheroacuta* and the top by the extinction of same species. But in the present study, *Gl. peripheroacuta* has already appeared and it is an ancestral form of *Gl. fohsi* (Kennett and Srinivasan, 1984). Therefore, the presence of *Gl. fohsi* indicates that the samples represent *Gl. fohsi* Zone. *Globorotalia panda* and *Gl. menardii* first appeared in sample 588A-6-4-4-6cm, later they became abundant higher in the section (i.e. 588A-2-2-3-5cm to 588A-1-1-0-3cm). In the top sample (588A-1-1-0-3cm) *Globorotalia nepenthes* initially appeared. Srinivasan and Kennett (1984) mentioned that *Globorotalia fohsi lobata* and *Gl. fohsi robusta* are distinct species occurring within the *Gl. fohsi* Zone at tropical site 289. In the present samples these two species are absent. Hence, this might indicate the environment was not tropical.

BIOSTRATIGRAPHY OF SITE 588, HOLE B

From this hole, eleven samples were examined ranging in age from Middle Miocene through the Pliocene. Biostratigraphy is shown in Table (2.2).

Globorotalia fohsi Zone

Samples 588B-31,cc and 588B-30-3-40-43cm represent the present zone. The zonal

Table.2.2 Biostratigraphy of Site 588B

Epoch	Lithology	Sample	Depth	Zone	Foraminiferal zone	Age in M.Y
PLIOCENE		588B-9-6-4-6cm	85.05m	N19	<i>Globorotalia puncticulata</i>	4.0
		588B-10-3-59-61cm	89.20m	N18	<i>Globorotalia margaritae</i>	5.6
		588B-12-6-79-81cm	113.10m			
LATE MIOCENE		588B-16-6-99-101cm	150.70m	N17B	<i>Globorotalia conomiozea</i>	7.8
		588B-18-6-4-6cm	169.95m	N17A	<i>Globorotalia plesiotumida</i>	8.6
		588B-20-6-147-149cm	191.08m			
		588B-22-6-49-51cm	207.80m	N16	<i>Neogloboquadrina continuosa</i>	9.7
MIDDLE MIOCENE		588B-25-4-29-31cm	233.40m	N15	<i>Globorotalia mayeri</i>	11.3
		588B-26-4-40-42cm	238.53	N14
	588B-30-3-40-43cm	261.61m	N13	<i>Globorotalia fohsi s.l</i>	12.6
		588B-31-CC	277.00m			

Latitude 26°06.7'South

Longitude 161°13.6East

present day water depth 1548m

Legend

Foraminifer bearing

Nannofossil ooze

Foraminifer bearing

Nannofossil chalk

definition and all the elements of this zone are as described above for site 588, hole A.

Globorotalia mayeri zone

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptors: 588B-26-4-40-42cm, 588B-25-4-29-31cm.

Results: In addition to the nominate species the following occur within the samples. *Globigerina nepenthes*, *G. woodi*, *G. decoraperta*, *Globigerinoides trilobus*, *Gs. subquadratus*, *Globorotalia panda*, *Gl. mayeri* and *Orbulina suturalis*.

Discussion: The extinction of *Globorotalia fohsi* marks the base of this zone (Srinivasan and Kennett 1981,a). Jenkins and Srinivasan (1986) defined the base of this zone on extinction of *Globorotalia peripheroacuta*. The top is defined by the extinction of the nominate species. In the present study, *Gl. peripheroacuta* had its last occurrence at the base of the *Globorotalia fohsi* Zone (588A-6-4-4-6cm). Therefore, presence of the nominate species and the absence of *Gl. fohsi* in the present samples possibly indicate the samples represent the *Gl. mayeri* Zone.

Neogloboquadrina continuosa Zone

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptor: 588B-22-6-49-51cm.

Results: In addition to the nominate species the following occur within the sample. *Globigerina bulloides*, *G. decoraperta*, *Gl. nepenthes*, *Globigerinoides trilobus*, *Globorotalia exilis*, *Gl. panda*, *Gl. menardii*, *Gl. conoidea*, *Gl. merotumida* and *Sphaeroidinellopsis seminulina*.

Discussion: In the present study the last appearance of *Neogloboquadrina continuosa* defines the top of this zone and the base of *Globorotalia plesiotumida* Zone. The presence of *Gl. plesiotumida* in sample 588B-20-6-147-149cm indicates the base of the *Gl.*

plesiotumida Zone as already established. This means the boundary must be present somewhere between samples 588B-22-6-49-51cm and 588B-20-6-147-149cm. The absence of *Globorotalia mayeri* and presence of nominate species in the present sample leads the present author to suggest that the sample belongs to *N. continuosa* Zone.

Globorotalia plesiotumida Zone

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptor: 588B-20-6-147-149cm; 588B-18-6-4-6cm

Results: In the present study, in addition to the nominate species the following taxa occur in the sample. *Globigerina bulloides*, *G. falconensis*, *G. nepenthes*, *Globigerinoides trilobus*, *Globorotalia menardii*, *Gl. multicamerata*, *Gl. conoidea*, and *Orbulina universa*.

Discussion: According to Jenkins and Srinivasan (1986) the base of this zone is established by initial appearance of the nominate species. Srinivasan and Kennett (1981a) and Kennett (1973) defined *Globigerina nepenthes* zone as an equivalent to *Globorotalia plesiotumida* Zone, but according to Kennett and Srinivasan (1983) *G. nepenthes* first appears in Blow's N14 zone (Late Middle Miocene) and extends into N19 zone (Early Pliocene). *Gl. plesiotumida* initially appears in zone N17A (Late Miocene) and extends into N19 (Early Pliocene) zone. In the present study, the top of the *Gl. plesiotumida* zone is defined by the presence of *Globorotalia conomiozea* in the overlying sample 588B-16-6-99-101cm. The initial appearance of *Gl. conomiozea* not only marks the base of the zone but it also demarcates the top of *Gl. plesiotumida* zone. The absence of *Gl. merotumida*, (the ancestral form of *Gl. plesiotumida*) also confirms the top of the boundary, because the nominate species (*Gl. plesiotumida*) has a limited time range and is a true subtropical species. Therefore, the *Gl. plesiotumida* Zone very appropriately denotes the N17A zone of Blow (Jenkins and Srinivasan, 1986).

Globorotalia conomiozea Zone

The zonal definition of Kennett (1980) is followed herein.

Identifying descriptors: 588B-16-6-99-101cm.

Results: In addition to the nominate species I found the following occur within the sample: *Globigerina falconensis*, *G. woodi*, *G. bulloides*, *G. nepenthes*, *Globigerinoides trilobus*, *Globorotalia multicamerata*, *Gl. plesiotumida*, *Gl. menardii*, *Candeina nitida* and *Orbulina universa*.

Discussion: The initial appearance of the nominate species marks the base of this zone (Srinivasan and Kennett 1981b). In the present study, the top of this zone is established by the presence of *Globorotalia margaritae* which also marks the base of *Gl. margaritae* zone. Furthermore, *Gl. conoidea* is absent in the sample which also denotes the top boundary of the present zone. *Gl. conomiozea* Zone broadly corresponds to N17B Zone of Srinivasan and Kennett (1981b).

***Globorotalia margaritae* Zone**

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptors: 588B-10-3-59-61cm, 588B-12-6-79-81cm.

Results: In addition to the nominate species I found the following taxa occurring within the samples: *Globigerina falconensis*, *G. decoraperta*, *G. woodi*, *G. nepenthes*, *Globigerinoides conglobatus*, *Globorotalia menardii*, *Gl. limbata*, *Gl. multicamerata* and *Orbulina suturalis*.

Discussion: The base of this zone is established by the initial appearance of the nominate species. *Globorotalia plesiotumida* was absent from 588B-12-6-79-81cm sample onwards. The initial appearance of the nominate species demarcates the Miocene/Pliocene boundary. In the present study, the top of this zone is established by the initial appearance of *Globorotalia puncticulata*, which is zonal index for the overlying zone sample 588B-9-6-4-6cm.

***Globorotalia puncticulata* Zone**

The zonal definition of Srinivasan and Kennett (1981a) is followed here.

Identifying descriptors: 588B-9-6-4-6cm.

Results: In addition to the nominate species I found the following species occurring within the sample. *Globigerina bulloides*, *G. falconensis*, *G. extremus*, *Globigerinoides trilobus*, *Gs. obliquus*, *Pulleniatina primalis*, and *Globigerinotella equilateralis*.

Discussion: The base of this zone is established by the initial appearance of the nominate species. Presence of the nominate species in the sample indicates that the sample is later than the base of the zone. Since I do not have samples from the remaining sections, it is not possible to demarcate the top boundary of this zone.

BIOSTRATIGRAPHY OF SITES 587 AND 589

Core sections starting from 587-13, cc to 587-1-1 represent Late Miocene through the Pleistocene. A total of fifteen samples was examined from these two sites. The samples of Site 589 represent the Pleistocene. At Site 587, in core sections from 13, CC to 7-5-146-149cm planktonic foraminifera are poorly preserved, especially section four of core 11, where foraminifers were virtually absent. Also, the test surface of deep - sea benthic foraminifera are strongly etched. I am not certain of the biostratigraphic position of these samples, but following Jenkins and Srinivasan (1986) these samples were assigned to the *Globorotalia primalis* Zone. Biostratigraphy of these two sites is shown in Table (2.3).

Globorotalia puncticulata Zone

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptor: 587-6-5-1-4cm.

Results: In the present study, in addition to the nominate species, important taxa occurring within the sample are broadly similar to those of site 588B.

Globorotalia tosaensis Zone

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Gonzalez-Donso and Linares (1970) referred *Anomalina wuellerstorfi* Schwager as the type species for a new genus *Fontbotia*. They described the genus as being distinguished by flat trochospiral coiling, numerous, broad and low chambers, strongly recurved sutures, spiral side more coarsely punctate than umbilical side, and with a restricted aperture (Loeblich and Tappan, 1987). In the present study, this species is referred to *Fontbotia wuellerstorfi* (Schwager).

A morphotypic shift has been observed between *F. wuellerstorfi* specimens from Early Miocene to Late Miocene in sample material from my D.S.D.P. sites. As I mentioned earlier, many workers described this species under different genera, because these authors might have looked at different morphotypes from different parts of the section. In the present study, Early Miocene specimens are characterized by slightly sinusoid, limbate, curved raised sutures, partly evolute, smooth, umbilical side. The test is typically plano-convex with an equatorial interiomarginal aperture (pl. 3, fig. 4 & 5). In the Middle Miocene specimens from the present material are characterized by an involute umbilical side with protruding umbonal plug, and strongly backward – curved depressed sutures in the last three chambers. The umbilical side of the morphotype has minute irregularly distributed pores and the spiral side is coarsely punctate. Specimens from the Late Miocene samples show a protruding umbonal plug becoming smoothly convex, and the umbilical area slightly depressed (Pl. 3, fig. 6). Sutures maintain the same pattern as displayed by Middle Miocene specimens. The major morphotypic shift in Late Miocene specimens was towards an even distribution of pores (pl. 3, fig. 6). In addition, the aperture became crescentic with a distinct lip (Pl. 3, fig. 7) that extended on the spiral side for at least 3–4 final chambers. Patterson (personal communication) also noticed a similar morphological trend in specimens from the Neogene of the South Atlantic Ocean. However, a rigorous comparative study utilizing fourier analysis is required to establish the full range of and significance of morphological variation.

Identifying descriptor: 587-5-5-5-8cm.

Results: In addition to the nominate species, I found the following occur within the sample. *Globigerina falconensis*, *Globigerinoides extremus*, *Gs. conglobatus*, *Gs. ruber*, *Globorotalia inflata*, *Gl. menardii*, and *Gl. crassaformis*.

Discussion: According to Jenkins and Srinivasan (1986) the base of this zone is established by the initial appearance of the nominate species. In the present material presence of the nominate species indicates that the sample is from above the base of the zone. The top of this zone is marked by the initial appearance of *Gl. truncatulinoides* in the overlying zone. The top of this zone also demarcates the Pliocene/Pleistocene boundary.

***Globorotalia truncatulinoides*/Gl. tosaensis Overlap Zone**

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptors: 587-3 cc, 587-3-5-96-98cm, 587-3-2-147-149cm, 589-4-6-16-18cm, 589-3-7-9-11cm, 589-2-6-147-149cm.

Results: In addition to the two zonal marker species, I found that among the many taxa occurring within the samples were *Globigerina bulloides*, *Globigerinoides conglobatus*, *Globorotalia menardii* and *Pulleniatina obliquiloculata*.

Discussion: According to Jenkins and Srinivasan (1986) the base of this zone is established based on the initial appearance of *Globorotalia truncatulinoides*. The co-occurrence of the two zonal marker species in my samples indicates that the samples are from above the base of the zone. The top of this zone is demarcated by extinction of *Gl. tosaensis* at the base of overlying zone. The base of this zone also demarcates the Pliocene/Pleistocene boundary.

***Globorotalia truncatulinoides* Zone**

The zonal definition of Jenkins and Srinivasan (1986) is followed herein.

Identifying descriptors: 587-1-1-14-17cm, 589-1-1-3-6cm, 589-1-3-1-4cm.

Results: In the present study, in addition to the nominate species, the following occur within the samples. *Globigerina falconensis*, *Candeina nitida*, *Globorotalia inflata*, *Gl. crassaformis*, *Gl. tumida*, *Gl. menardii*, *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens*.

Discussion: The base of this zone is established on the extinction of *Globorotalia tosaensis* in the presence of *Gl. truncatulinoides*. The former species is absent from my samples. In the tropical zonal scheme, Bolli and Premoli-Silva (1973) divided this zone into four subdivisions based on the occurrence of (1) *Globorotalia viola*, (2) *Gl. hessi*, (3) *Globigerinella calida*, (4) *Globorotalia bermudezi* in time sequence. In the present study, the author found *Globigerinella calida* and *Globorotalia bermudezi* both representing latest Pleistocene.

B. BENTHIC SPECIES

One hundred and eighty species of deep - sea benthic foraminifera were identified in thirty-nine samples which range in age from Early Miocene through Pleistocene. All of these have been described previously from various parts of the world oceans. Out of these 180 species, 166 are calcareous, nine are agglutinated and five are porcelaneous forms, belonging to forty-one families and six sub-orders.

The diversity is very high and the number of species per sample ranged from a minimum of twenty-eight to a maximum of sixty-two. In documenting species occurrence a pseudoquantitative scale was used. If fewer than five specimens of a species occur, they are designated as rare and sporadic. Five to ten specimens are designated common, ten to fifteen frequent, and more than fifteen abundant.

Although deep sea benthic foraminifera do not show much spatial morphological variation, I have noticed a distinct variation through the section in fractional

abundances of certain important cosmopolitan species. The following species show such variation and occur commonly to abundantly. *Astrononion echolsi* Kennett, 1967, *Brizalina pusilla* (Schwager, 1866), *Cibicides kullenbergi* Parker, 1953, *Cibicidoides mundulus* (Brady, Parker and Jones, 1888), *Eiloeu'ra weddellensis* (Earland, 1936), *Epistominella exigua* (Brady, 1884), *E. umbonifera* (Cushman, 1933), *Globocassidulina subglobosa* (Brady, 1881), *Gyroidinoides soldanii* (d'Orbigny, 1826), *Oridorsalis umbonatus* (Reuss, 1851), *O. tener* (Brady, 1884), *Pullenia bulloides* d'Orbigny, 1846, and *Pleurostomella dominicana* (Bermudez, 1949). Apart from common to abundant species, a few other species are found commonly and these are: *Anomalinoides semicribrata* (Beckman, 1954), *Bulimina alazanensis* Cushman, 1927b, *Cibicidoides robertsonianus* (Brady, 1884), *Fontbotia wuellerstorfi* (Schwager, 1866), *Gavelinopsis praegeri* (Heron-Allen and Earland, 1913), *Melonis barleanum* (Williamson, 1858), *Pullenia quadriloba* (Reuss, 1851), *Pyramidulina challengeriana* (Thalman, 1937), *Siphonodosaria lepidula* (Schwager, 1866) and *Uvigerina proboscidea* Schwager, 1866. I concur with Boltovskoy (1978) that only three to five species of deep-sea benthic foraminifera make the major proportion of a population in a given sample. Many species are rare and occur intermittently in almost all samples.

I have selected 18 commonly occurring species and plotted fractional abundances against age (Refer to pages 42 - 49 for the plots). These species show vertical variation in fractional abundances with respect to time (i.e Early Miocene through the Pleistocene). *Globocassidulina subglobosa* varies in fractional abundance from 7.6% to 21.5% in Early Miocene, and in Middle Miocene and Late Miocene percentage varies from 0 to 7.33%. It is less common in Pliocene samples and in Quaternary samples its abundance varies between 1% and 9.33%.

Oridorsalis umbonatus occurs in Early Miocene samples makes up 4 to 11%, in Middle Miocene, 2 to 6% and in Late Miocene less than 2 percent. In Pleistocene samples percentage fluctuates between 1 and 6.54%. *Oridorsalis tener* makes up less than 2% in

Early Miocene except in one sample, 2% to 8% in Middle Miocene, and 3.5% to 6% in Late Miocene samples. In Pleistocene samples its percentage ranges between 1% and 4%.

Gyroidinoides lamarckiana fractional abundance varies between 1 and 3.5% in Early Miocene, is less than 3% in Middle Miocene, and less than 4% in Late Miocene samples. Its maximum abundance in Pleistocene is 2.15%. *Gyroidinoides soldani* shows maximum fractional abundance of 7.6% in Early Miocene samples. *Pullenia bulloides* maximum fractional abundance in Early Miocene is 1 to 5%.

The fractional abundance of *Epistominella exigua* in Early Miocene samples varies from 2 to 23.22%, in Middle Miocene 1 to 10.8% except in one sample, and in Late Miocene the maximum percentage is 5.38%. In Pleistocene samples percentage fluctuates between 2 and 16.83%. The fractional abundance of *Epistominella umbonifera* in Early Miocene varies between 3 and 8.46%, in Middle Miocene the maximum percentage is 11.5% and in Late Miocene 2.16 to 12%. The percentage varies in Pleistocene from 0 to 10%.

Astrononion echolsi and *Melonis barleanum* show maximum fractional abundance in Late Miocene samples. *Fontbotia wuellerstorfi* constitutes 6% in Middle Miocene, 2% to 4% in Late Miocene, 5.26% in Pliocene, and 3.93% in Pleistocene samples.

Based on fractional abundances, five assemblages were established. The composition of these five assemblages with respect to important species is given in Appendix A, 1-5, pages 188 - 190. These include, 1. the *Globocassidulina subglobosa* Assemblage which occurs in Early and partly Middle Miocene sections of the present investigation; 2. the *Epistominella exigua* Assemblage which occurs in Middle Miocene and Late Miocene samples; 3. the *Epistominella exigua* and *E. umbonifera* Assemblage occurring in Late Miocene samples; 4. the *Astrononion echolsi* and *Angulogerina angulosa* Assemblage occurring in Pliocene samples; and 5. the *Epistominella exigua* / *Globocassidulina subglobosa* / *Fontbotia wuellerstorfi* Assemblage occurs in the Quaternary section.

The important species in the *Globocassidulina subglobosa* Assemblage are *Globocassidulina subglobosa*, *Oridorsalis umbonatus*, *Cassidulina cuneata* Finlay, 1940, *Gyroidinoides soldanii*, *G. lamarckiana* and *Pullenia bulloides*. In addition to these species *Epistominella exigua*, *E. umbonifera* and *Eilohedra weddellensis* are also important species in the assemblage.

The *Epistominella exigua* Assemblage is dominated by *Epistominella exigua*, *E. umbonifera*, *Eilohedra weddellensis*, *Astrononion echolsi*, *Globocassidulina crassa* (d'Orbigny, 1839a) *G. subglobosa*, *G. molluccensis* (Germeraad, 1946), *Cassidulina biora* Crespin, 1960 and *Oridorsalis tener*.

The *Epistominella exigua* and *E. umbonifera* Assemblage consists of *Epistominella exigua*, *E. umbonifera*, *Eilohedra weddellensis*, *Fontbotia wuellerstorfi*, *Melonis barleanum*, *Oridorsalis tener*, *Globocassidulina crassa*, *Cassidulina laevigata* d'Orbigny, 1826, *Astrononion echolsi*, and *Sphaeroidina bulloides* d'Orbigny, 1826.

The *Astrononion echolsi* and *Angulogerina angulosa* Assemblage represented by *A. echolsi*, *A. angulosa* (Williamson, 1858), *Epistominella umbonifera*, *Globocassidulina crassa*, *Gl. minuta* (Cushman, 1933), *Cassidulina laevigata*, *Brizalina beyrichi* (Reuss, 1851), *Sagrinella lobata* (Brady, 1881), *Patellinella inconspicua* (Brady, 1884), *Trifarina bradyi* Cushman, 1923 and *Uvigerina peregrina* Cushman, 1923.

Finally, the *Epistominella exigua* / *Globocassidulina subglobosa* / *Fontbotia wuellerstorfi* Assemblage is composed of *E. exigua*, *G. subglobosa*, *F. wuellerstorfi*, *Oridorsalis tener*, *Eilohedra weddellensis*, *Melonis barleanum*, *Astrononion echolsi*, *Cassidulina carinata* Silvestri, 1894, *Globocassidulina decorata* (Sidebottom, 1910), *Uvigerina peregrina*, and *Stainforthia complanata* (Egger, 1895).

Q-mode cluster dendrogram (p.49) for samples tends to support the assumption that species distribution is affected by watermass qualities and it also gives the

relationship between samples. R-mode cluster analysis (P.55) for 68 species also tentatively provided these assemblages. In the Q-mode dendrogram samples 10, 15, 7, 13, 2, 5, and 8 belong to Early and Middle Miocene. The Early Miocene samples 2 and 5 (N4B and N8 Zones respectively) are grouped with Middle Miocene samples. Samples 29, 30, 32 and 27, 28 are Pleistocene, and samples 9, 14, 16, 17 and 12 are Middle Miocene. Late Miocene samples include 21, 23, 24, 22, 18, 19 and 20. Samples 25 and 26 are from the Pliocene and are related to Late Miocene and Pleistocene samples, respectively. Early Miocene samples 1, 4, and 3 and Middle Miocene samples 6 and 11 are grouped together.

According to Patterson and Fishbein (1989) 3 percent fractional abundances of species were selected to delineate the assemblages. In the present study 3 percent fractional abundance is not very significant in distinguishing different assemblages. Therefore, the assemblages established in the present study are mainly based on fractional abundances (more than 3 percent) of most important species.

CHAPTER 3

DISCUSSION OF BENTHIC FORAMINIFERAL RESULTS

For the sake of convenience this chapter is divided into two parts. In the first part, discussions on taxonomy and the utility of deep - sea benthic foraminifera are included. In the second part a possible paleoecological interpretation from the Early Miocene to the Pleistocene is given, based on faunal distribution.

A. TAXONOMY OF DEEP – SEA BENTHIC FORAMINIFERA

Benthic foraminifera are primarily used as tools for paleoecological analysis, rather than establishing biostratigraphy. Unfortunately, there is a confusion in the taxonomy and nomenclature of some species of the deep – sea benthic foraminifera. Revision of the taxonomy could enhance the usefulness of such species as paleoecological indicators. Prior to 1968 knowledge of deep – sea foraminifera was limited and studies were confined to a few deep sea expeditions. However, initiation of the Deep Sea Drilling Project (D.S.D.P.) in 1968 greatly enhanced the knowledge of this group, particularly with regard to paleo - oceanographic studies. Unfortunately, while numerous researchers have extensively studied these fauna and fulfilled their paleoecological objectives, they have shown little concern for the taxonomy. As a result much speculation has been raised in the taxonomy. The purpose of taxonomy is concerned with a need for the correct separation or the inclusion of an individual specimen under valid available nomenclature. Boltovskoy (1978) warns that it will be impossible in future to handle the taxonomy of deep – sea foraminifera if we do not take suitable precautions.

While dealing with systematic paleontology, I had difficulty in the identification and comparison of certain species. Many published accounts simply presented the species' names without proper descriptions, or more often than not, also lacked illustrations. In addition, original authors have occasionally, not given complete

descriptions of holotypes either. In several papers illustration of a limited number of views made comparison very difficult. For the proper identification of a species one should always refer to the holotypes in addition to published papers, because, no matter how good the description or illustration, there is always the possibility of misidentification.

Taxonomic problems

Anomalina wuellerstorfi Schwager (1866) has been referred to at least four different genera. This species is important in deep – sea oceanography as it is used by many workers to indicate the presence of North Atlantic deep water. Unfortunately, the taxonomic position of this species is uncertain and has to be re - evaluated. The species has been referred to *Cibicides wuellerstorfi* (Schwager) by Pflum and Frerichs (1976), Boltovskoy (1978), Corliss (1979a), Belanger and Streeter (1980), Belanger *et al.*, (1982) and Streeter *et al.*, (1982). In contrast Mead (1985), and Kurihara and Kennett (1986) referred the species to *Cibicidoides*. Others such as Lohman (1978), Corliss (1979a), Hermelin and Scott (1985) and Belanger and Berggren (1986) referred it to *Planulina*.

These various authors seem to interpret the morphology of this species in slightly different manner. For example, in several papers *Planulina wuellerstorfi* (Schwager) is described as being characterized by a compressed, plano--convex test partly involute on umbilical side, a low equatorial interiomarginal apertural arch with a narrow lip, and by an evolute coarsely punctate spiral side. *Cibicides wuellerstorfi* (Schwager) has been identified based on a plano--convex test completely involute on umbilical side, broad chambers with incurved sutures, an interiomarginal aperture and coarsely punctate spiral side. Finally, *Cibicidoides wuellerstorfi* has been characterized by a compressed large biconvex test, curved sutures with coarse perforations on the spiral side and an only partly perforate umbilical side.

Gonzalez-Donso and Linares (1970) referred *Anomalina wuellerstorfi* Schwager as the type species for a new genus *Fontbotia*. They described the genus as being distinguished by flat trochospiral coiling, numerous, broad and low chambers, strongly recurved sutures, spiral side more coarsely punctate than umbilical side, and with a restricted aperture (Loeblich and Tappan, 1987). In the present study, this species is referred to *Fontbotia wuellerstorfi* (Schwager).

A morphotypic shift has been observed between *F. wuellerstorfi* specimens from Early Miocene to Late Miocene in sample material from my D.S.D.P. sites. As I mentioned earlier, many workers described this species under different genera, because these authors might have looked at different morphotypes from different parts of the section. In the present study, Early Miocene specimens are characterized by slightly sinusoid, limbate, curved raised sutures, partly evolute, smooth, umbilical side. The test is typically plano-convex with an equatorial interiomarginal aperture (pl. 3, fig. 4 & 5). In the Middle Miocene specimens from the present material are characterized by an involute umbilical side with protruding umbonal plug, and strongly backward – curved depressed sutures in the last three chambers. The umbilical side of the morphotype has minute irregularly distributed pores and the spiral side is coarsely punctate. Specimens from the Late Miocene samples show a protruding umbonal plug becoming smoothly convex, and the umbilical area slightly depressed (Pl. 3, fig. 6). Sutures maintain the same pattern as displayed by Middle Miocene specimens. The major morphotypic shift in Late Miocene specimens was towards an even distribution of pores (pl. 3, fig. 6). In addition, the aperture became crescentic with a distinct lip (Pl. 3, fig. 7) that extended on the spiral side for at least 3–4 final chambers. Patterson (personal communication) also noticed a similar morphological trend in specimens from the Neogene of the South Atlantic Ocean. However, a rigorous comparative study utilizing fourier analysis is required to establish the full range of and significance of morphological variation.

Oridorsalis umbonatus (Reuss) and *O. tener* (Brady) are also confusing cosmopolitan deep – sea species. In the present material, I have observed a morphological gradation between these two species. *O. umbonatus* (Reuss) is distinguished by thick, rounded biconvex test and a broadly rounded periphery. The restricted semicircular primary aperture is a distinct diagnostic feature, as is the secondary aperture confined to the umbonal area (pl. 6, figs. 1–3). The type specimen of *Oridorsalis tener* (Brady) is thin, having a highly compressed test with a distinct lobulate acute periphery. The primary aperture is long, extended and slit-like. Tertiary apertures are confined to the spiral suture. Many specimens of both species show intermediate morphological characters often making absolute identification difficult. A more detailed examination is required to assess the morphological variation in these species.

There has been some disagreement as to the taxonomic positioning of *Cibicides kullenbergi* Parker and *Cibicidoides mundulus* (Brady, Parker and Jones). *Cibicides kullenbergi* is distinguished by plano-convex test (Pl.3, figs.1-3) with strongly curved umbilical sutures, normally the pores on the spiral side are uniformly distributed. *Cibicidoides mundulus* is unequally biconvex with moderately curved sutures on the umbilical side. The spiral side is coarsely punctate and the pores are relatively larger than found in the former species. In addition, in early chambers pores are confined along the spiral suture (Pl.6, figs.7-9).

Ehrenbergina bradyi Cushman was referred to *E. trigona* Goes by numerous workers (Phleger, Parker and Peirson, 1953; Hermelin and Scott, 1985; Mead, 1985). The former species has a distinct median furrow with carinal ridges on the ventral borders (pl. 2, figs. 10-12). Type illustration of *E. trigona* does not have a ventral furrow.

Considerable confusion also exists between *Nuttallides umbonifera* (Cushman) and *Epistominella umbonifera* (Cushman). *N. umbonifera* is characterized by a large biconvex test with an umbonal stud. *E. umbonifera* is characterized by a subparallel aperture and is relatively smaller than *N. umbonifera*. In the present study specimens of *N.*

umbonifera are referred to *N. bradyi* (Earland) which is equally biconvex with a slightly divided aperture placed at an angle to the periphery. Some of the other cosmopolitan species, often confused by authors, are included under remarks for each species in the taxonomic chapter of this thesis.

Douglas (1973), and Douglas and Woodruff (1981) postulated that most of the deep sea modern benthic foraminifera evolved in the Middle and Late Miocene. Berggren (1972,P.974) states that "living bathyal – abyssal benthonic fauna developed in the Middle Miocene, about 15 Ma". These views were seriously objected to by Boltovskoy (1978). Based on elaborate studies of Late Cenozoic samples from the Atlantic, Indian, and South Pacific Oceans Boltovskoy (1983,P.83.) concluded that "the Oligocene and Quaternary assemblages appear to consist of almost the same species, which do not show any important changes. This implies that the evolution of benthic foraminifera is slow and that the Recent benthic fauna developed not later than Oligocene, probably in Late Oligocene". In the present study, I found most of the cosmopolitan deep – water benthic species occurring in the Early Miocene samples. However, several common to rare taxa also initially appeared in Middle Miocene samples. Therefore, based on the results of this research and the work of other subsequent workers (Thomas,1986; Woodruff, 1985) the claim of Middle Miocene origin for most of the modern deep – sea benthic foraminifera is not substantiated.

B. PALEOECOLOGY

Modern concepts on the ecology of benthic foraminifera are very important in understanding their paleoenvironmental conditions. The use of modern faunal concepts in interpreting the paleoenvironment depends on the assumption that modern distributional patterns are very similar to those of the past. It also assumes that a species' physiological adaptations do not change with time (Douglas, 1979). The above assumption may have certain drawbacks but can be used with some caution. For example, many workers assume that the distribution of deep sea – benthic foraminifera

was not primarily controlled by depth *per se*, but by watermass characters which are generally correlated with depth.

Paleobathymetry

Douglas (1979) explained his interpretation of benthic foraminiferal paleobathymetry by considering the following factors: (1). species diversity; (2). planktic/benthic ratio; (3). test composition; and (4). isobathyal species.

In the present research samples showed a very high diversity. The number of species per sample ranged from 28 to maximum of 62. The diversity index plot proposed by Fisher *et al.* (1964) is well applicable to shallow water or at the most shelf edge foraminiferal studies. In this plot, the α value 16 possibly delineates the boundary between shelf edge and deep – sea environment. In the present study for most of the samples the mean α value exceeded 20. Therefore it is assumed that values of more than 16 indicate a deep – sea environment (Murray, 1971).

In most of the present samples, the planktic/benthic ratio is approximately 500:1. A high planktic / benthic ratio indicates deep – sea environment (Bandy *et al.*, 1964; Douglas, 1979).

Test composition renders very superficial evidence that the presence of many deep water calcareous benthic forms and a few deep – water agglutinated and porcelaneous forms indicates deep – sea environment.

Much of the ecological literature on modern benthic foraminifera deals with depth zones. According to the depth zone concepts of Frerichs (1970) and Berggren (1976) the bathyal zone ranges in depth from 400 m to 2000 m. They divide the zone into three subzones: upper (400-700m), middle (700-1500 m), and lower (1500-2000 m). Boltovskoy (1980) encountered the following species at mid – bathyal depths from the Atlantic, Indian and South Pacific Oceans: *Astrononion echolsi* Kennett, *Brizalina pusilla*

(Schwager), *Cibicides kullenbergi* Parker, *Cibicidoides mundulus* (Brady, Parker and Jones), *C. robertsonianus* (Brady), *Eggerella bradyi* (Cushman), *Fonbotia wuellerstorfi* (Schwager), *Globocassidulina subglobosa* (Brady), *Gyroidinoides soldanii* (d'Orbigny), *G. lamarckiana* (d'Orbigny), *Melonis barleanum* (Williamson), *Oridorsalis umbonatus* (Reuss), *Pleurostomella dominicana* Bermudez, *Pullenia bulloides* d'Orbigny, *P. quinqueloba* (Reuss), *Pyramidulina challengeriana* (Thalman), *Siphonodosaria lepidula* (Schwager), and *Uvigerina proboscidea* Schwager. The assemblages encountered in the present investigation indicate mid - to lower bathyal depths. This conclusion is based on the presence of the above mentioned 18 mid - to lower bathyal species occurring consistently throughout the Miocene to Pleistocene samples.

Berggren (1983) conducted a paleobathymetric study on deep - sea benthic foraminifera and concluded that the presence of *Fonbotia wuellerstorfi*, *Sphaeroidina bulloides*, *Cibicidoides robertsonianus*, *Pullenia bulloides* indicates a water depth of more than 1000 metres. Furthermore, he determined that the depth range of *Epistominella exigua* varies from 500 m to 1800 m. His study also proves that most of the deep - sea fauna occurs commonly between a depth of 1000 m - 1500 m.

It is quite reasonable to assume the upper depth limit of the present assemblages occurring at Lord Howe Rise, South-west Pacific is probably mid-bathyal. According to Burns and Andrews (1973) the Lord Howe Rise started subsiding in late Maastrichtian time and continued until present - day depths were attained in the early Eocene (Refer to Fig.1.1, P.3 for Present - day depths). Therefore, the depth at Lord Howe Rise during the Neogene and Quaternary periods could be mid - to lower bathyal. The above assumption is strengthened by the occurrence of mid - to lower bathyal assemblages in the present investigation. Boltovskoy (1980,P.164) also believed that the depth at Lord Howe Rise was mid - bathyal since Oligocene based on the occurrence of isobathyal assemblages. The high species diversity of deep sea fauna at Lord Howe Rise during the Neogene also suggest that water depths ranged between 1400 m and 1700 m.

Paleoclimate

As previously mentioned the deep – sea benthic foraminifera are the primary paleoenvironmental indicators because they are sensitive to subtle differences in watermass qualities. Numerous studies have shown that a distinct relationship exists between the distribution of deep – sea benthic fauna and deep ocean hydrographic conditions. An intricate relationship between biotic and abiotic parameters of the environment controls the distribution of the organisms. Abiotic parameters include temperature, salinity, oxygen content, calcium carbonate availability, nutrients, pH, and nature of the substrate. Biotic parameters include organic carbon, competition and predation which is usually adverse on the continental shelf (Belanger and Streeter, 1980). However, it is not exactly known which of these parameters are the primary controlling factors. This is despite the great emphasis which has been placed on faunal changes that vary with water depth, as opposed to lateral and other variations. In the photic zone the distribution is governed by depth, which controls temperature and light intensity. However in the deep – sea environment depth and temperature are two interdependent variables. The temperature shows subtle variations over wide areas below 2000 m (Douglas and Woodruff, 1981). Considering Douglas and Woodruff's (1981) opinion, as the depth at Lord Howe Rise was mid - to lower bathyal during the Neogene (Boltovskoy, 1980 see P.208) the temperature may also have played a minor role in distribution of the fauna. In fact many other factors are associated with temperature and temperature alone does not fully explain the distribution of deep – sea benthic foraminifera (Corliss, 1983).

Recent deep – sea benthic foraminiferal assemblages have been correlated with various watermasses by numerous workers (Streeter, 1973; Schnitker, 1979, 1980; Bremer and Lohman, 1982; Corliss, 1983; Petersen, 1984; Burke, 1981; and Kurihara and Kennett, 1986). Unfortunately, most of these studies are not directly comparable due

to the non-uniformity of sieve-size used by these workers. Selection of sieves with large openings (>150 and 230 microns) allows a significant loss of important species (Schroder *et al.*, 1987). Use of data obtained by using large mesh size also adversely affects the species dominance causing large errors in interpretation of species distribution. Hermelin (1986) discussed the sieve bias of different workers and suggested that 63 microns opening (Tyler mesh 250, U.S.mesh 230) sieves be utilized in order to ensure the coverage of smaller foraminifera. Sen Gupta and Scott (1987) and Schroder *et al.*, (1987) also explained the problem of sieve selection and supported Hermelin's suggestion.

For example, in the present study an important species, *Eilohedra weddellensis* (Earland) is very small, in fact smaller than *Epistominella exigua* (Brady). In most of my samples the former species always occurs in association with *E. exigua* or *E. umbonifera*. *Eilohedra weddellensis* occurs in a significant proportion in the present investigation. It is probable that *E. weddellensis* would not have been counted by many authors using sieves with large – sized mesh openings. Furthermore, among deep – sea benthic foraminiferal populations certain species, due to sexual dimorphism, show bimodal distributions (Gooday,1988). This is especially true with *Globocassidulina subglobosa* (Brady) and *Epistominella exigua* (Brady). Because microspheric forms are always smaller in size, there is always the possibility of missing a significant part of such a species population when using sieves with large – sized mesh openings, as a result distribution pattern will be affected. As a further example many published accounts do not mention bolivinids and brizalinids. Consequently species such as *Bolivina robusta*, *B. minuta* and *Brizalina pusilla* are not recorded. Most species of these genera are very small and are collected on sieves with mesh openings between 63 and 120 microns (Schroder *et al.*, 1987). These species are usually inadvertently washed down the sink and lost by researchers utilizing sieves with mesh openings in excess of 63 microns.

Deep – sea benthic foraminifera have either epifaunal or infaunal modes of life. Epifaunal species are usually high trochospiral, uniserial to triserial and the aperture

is always at the end of last – formed chamber (Takazata, 1983). Corliss (1985) gave important information on the depth stratification of deep – sea taxa within the top few centimetres of the substrate. He observed that *Fontbotia wuellerstorfi*, *Hoeglundina elegans*, *Cibicides kullenbergi*, *Oridorsalis tener* live in the top 0 to 2 cm of the substrate. He also determined that all these forms possess a planoconvex to slightly biconvex test, with pores densely concentrated on the spiral side. Corliss (1985) also reports that *Melonis barleanum*, *Chilostomella oolina* and *Globobulimina affinis* live at depths greater than 2 cm of the substrate. In these species pores are evenly distributed over the entire surface. Corliss (1985) in correlating test morphology and pore distribution with the substrate depth concluded that infaunal benthic foraminifera are not directly controlled by overlying bottom water but are controlled by physico-chemical characters acting at the sediment-water interface. Thus, one must be very careful in selection of species for isotopic studies.

Corliss (1985) study suggested that most epifaunal species possess an unequal distribution of pores on either side of the test as exemplified by *Cibicides*, *Cibicidoides* and *Fontbotia*. Infaunal species are typically smooth with pores uniformly distributed over the entire test surface; for example *Melonis*, *Anomalinoidea*, and *Astrononion*. The primary reason for uniform pore distribution is that the infaunal species needed to maximize oxygen intake from within the sediment (Luttenegger, 1984). In contrast epifaunal species have one side attached to the substrate and the other side exposed to the water column. For instance, in *Cibicidoides* the spiral side in contact with the substrate is coarsely punctate while the umbonal side is smooth. A possible explanation for this pore distribution is that the organism might depend on the substrate to get sufficient oxygen by pushing mitochondria very close to the pores. This type of pore distribution is possible when the epifaunal organism is attached to a photosynthetic plant.

Epifaunal and infaunal species can be differentiated on the degree of ornamentation. Epifaunal species are usually ornamented by various means while

infaunal species are normally smooth. Ornamentation may also be helpful for locomotion in epifaunal species while in infaunal species ornamentation (costae and striae) could impede movement through the sediment. Hence preferential selection for the smooth test would be expected. The assemblages of the present study show a wide range of variation in ornamentation and are composed of both infaunal and epifaunal species. However, the purpose of ornamentation in deep – sea benthic foraminifera is not clearly understood.

C. DISTRIBUTION OF DEEP – SEA BENTHIC FORAMINIFERA

Changes in deep – sea foraminiferal distribution are expected to occur at times of major reorganization in composition and circulation of deep water masses of the world oceans. For example, such changes occurred during times of major glaciation in the northern and southern hemispheres. Such broad changes have been detected in the present research.

Based on the fractional abundances of species five major assemblages were established which are named after the highest abundance of a species, as reported on Page (27) under results. These assemblages are (1). *Globocassidulina subglobosa*. (2). *Epistominella exigua*. (3). *Epistominella exigua* / *E. umbonifera*. (4). *Astrononion echolsi* / *Angulogerina angulosa*. (5). *Epistominella exigua* / *Globocassidulina subglobosa* / *Fonhotia wuellerstorfi*. Details of each assemblage are discussed individually.

1. *Globocassidulina subglobosa* Assemblage

The *Globocassidulina subglobosa* Assemblage occurs in the Early Miocene and Middle Miocene sections. The important species in the assemblage, with decreasing abundance are (Appendix A.1, P.198) *Globocassidulina subglobosa* (Brady), *Oridorsalis umbonatus* (Reuss), *Cassidulina cuneata* Finlay, *G. soldanii* d'Orbigny, *Pullenia bulloides*

d'Orbigny, *Eilohedra weddellensis* (Earland), *Gyroidinoides lamarckiana* (d'Orbigny), *Epistominella exigua* (Brady), *Cibicidoides mundulus* (Brady, Parker and Jones), *E. umbonifera* (Cushman), *Uvigerina proboscidea* Schwager and *Brizalina* spp..

Kennett (1986) conducted oxygen isotopic studies on *Cibicides kullenbergi* Parker from site 588 during D.S.D.P. Leg 90 investigations. Based on high Oxygen 18 isotope values he suggested that before 19.5 Ma the bottom waters were cold. On the evidence of low oxygen isotopic values, he proposed relatively warm temperatures for the bottom watermass from 19.5 Ma to 17.5 Ma. In the present study, these two events can be correlated to some extent. The fractional abundance of *Globocassidulina subglobosa* (Fig 3.1a) in Early Miocene samples (*Globoquadrina dehiscens* to *Praeorbulina glomerosa curva* Zones) ranges from 7.6% to 21.5% showing maximum abundance in the later part of the *Gq. dehiscens* Zone. *Oridorsalis umbonatus* (Fig 3.1b) gradually increased in its fractional abundance from *Gq.dehiscens* to *P. curva* zones reaching a maximum of 10.89% in the latter zone. *Pullenia bulloides* d'Orbigny (Fig 3.2a) occurs in *P.curva* zone with 5.52%. *Gyroidinoides lamarckiana* (Fig 3.2b) and *G. soldanii* d'Orbigny (Fig 3.3a) shows maximum abundance of 3.5% and 7.6% respectively. The abundance of *Globocassidulina subglobosa*, *Oridorsalis umbonatus*, *Pullenia bulloides* and *Gyroidinoides soldanii* indicates bottom waters were relatively warm. Woodruff (1985) also encountered the same species as predominant components in an early Miocene assemblage. In addition to the above species, *Eilohedra weddellensis*, *Epistominella exigua*, and *Epistominella umbonifera* form a major part of the *Globocassidulina subglobosa* assemblage. Within this assemblage, fractional abundance of *Eilohedra weddellensis* (Fig 3.3b) varies between 1.5% to 8.2%. *Epistominella umbonifera* (Fig. 3.4a) and *E. exigua* (Fig. 3.4b) occurring with 3% – 8.46% and 2.11% – 23.22% respectively. According to Burke (1981) and Ingle *et al.*, (1980) the presence of Pacific bottom waters was indicated by the occurrence of *E. exigua*. Most authors concluded that *E. umbonifera* was always connected with the cold, corrosive, undersaturated, highly oxygenated Antarctic bottom water approximately at 4000 m depth (Corliss, 1983;

Fig.3.1a. Fractional abundance of *G.subglobosa*. Fig.3.1b. Fractional abundance of *O.umbonatus*.

Fig.3.2a.Fractional abundance of P.bulloides.

Fig.3.2b.Fractional abundance of *G.lamarckiana*.

Fig.3.3a..Fractional abundance of G.soldanii.

Fig.3.3b. Fractional abundance of E.weddellensis.

Fig.3.4a.Fractional abundanceE.umbonifera.

Fig.3.4t. Fractional abundance of *E. exigua*

Schnitker, 1980; Woodruff, 1985). The presence of *E. umbonifera* in the Early Miocene of the southwest Pacific indicates the influx of Antarctic bottom waters must have occurred. In response to availability of Antarctic bottom water, *E. umbonifera* migrated up – depth to mid-bathyal levels. It means that this species is always associated with cold temperatures. Boersma (1986) also confirmed the updepth migration of this species. The co-occurrence of warm and cold water species in the Early Miocene may indicate that mixed type intermediate waters may have prevailed at the time. The main evidence for this assumption is based on the presence of *Epistominella exigua* and *E. umbonifera* in considerable proportions.

In most of the Early Miocene samples warm water species such as *Globocassidulina subglobosa*, *Oridorsalis umbonatus*, *Gyroidinoides lamarckiana*, and *Pullenia bulloides* were predominant. However, warm and cold water indicator species occur in different Early Miocene samples with varying abundances. Therefore, based on the presence of *Globocassidulina subglobosa* assemblage, it is likely that the Early Miocene ocean in the Southwest Pacific was not thermally well stratified (Woodruff, 1985).

High abundances of *Globocassidulina subglobosa*, *Oridorsalis umbonatus*, *Pullenia bulloides* indicate low oxygen levels in the watermass (Lohman, 1979 and Woodruff, 1985). Burke (1981) concluded that the presence of buliminids, *Globocassidulina subglobosa*, and *Uvigerina proboscidea* also indicate lower levels of oxygen in the water mass. Although fractional abundance of *U. proboscidea* (Fig.3.5a) is relatively less than other species its occurrence may indicate that Southwest Pacific intermediate water masses during the Early Miocene were relatively warm and thermally unstratified and also deficient in oxygen (Woodruff, 1985; Burke, 1981; Phillips, 1983; Murphy, 1985; Pagani, 1985).

In the present research, benthic faunal diversity is very high in the *Catapsydrax dissimilis* and *Pracorbulina glomerosa curva* zones, approximately 19.4 Ma and 17.10 Ma respectively. The sudden increase in species diversity resulted from either: (1)

a change in a species mutational ability or (2) a favourable environment. Vincent and Berger (1987) proposed a marine transgression, coastal onlap throughout the circum-Pacific region from 19 Ma to 14 Ma. Based on the above interpretation, a possible explanation exists for high species diversity during that particular period. The coastal onlap indicates expansion of the photic and neritic zones which supports the maximum growth of phytoplankton. As a result, during 19 Ma to 17 Ma the maximum quantity of dead phytoplankton (nutrients supply) might have reached the bottom and in turn bottom water conditions must also have been favourable. Therefore, numerous species may have evolved in response to this stimulus. The above interpretation is supported by Gooday's (1988) study examining the relationship between availability of nutrients and benthic foraminiferal populations. He concluded that, under favourable conditions, if enough nutrients were available, benthic foraminifera would show high diversity. Considering Gooday's conclusion, a maximum quantity of nutrients may have accumulated at mid-bathyal depths in the southwest Pacific during 19 Ma and 17 Ma. Taking the faunal assemblage into account, the bathyal water temperature in the southwest Pacific could be $7^{\circ}\text{C} - 8^{\circ}\text{C}$ with normal salinity of $34.68^{\circ}/\text{oo}$ and 0.5-3.0 ml./L oxygen content (Corliss, 1979b).

In the Q-mode dendrogram (Fig.3.6) Early Miocene samples 2,5, and 1,4,3, clustered with Middle Miocene samples 10,15,7,13 and 11, 6. The species occurring in these samples are indicative of two distinct assemblages. The clustering of Early Miocene samples 2 & 5 (N4B and N8 respectively) with Middle Miocene sample 8 may indicate that during the Early Miocene the intermediate water mass in the South West Pacific Ocean was less stratified.

2. Epistominella exigua Assemblage

This assemblage occurs in the Middle Miocene section. The dominant species (Appendix A.2, P.189) in the assemblage are *Epistominella umbonifera*, *E. exigua*.

DISTANCE METRIC IS EUCLIDEAN DISTANCE
COMPLETE LINKAGE METHOD (FARTHEST NEIGHBOR)

Fig.3.6 Q-Mode dendrogram of samples from sites 587-589.

Eilohedra weddellensis, *Astrononion echolsi*, *Globocassidulina crassa*, *Gl. subglobosa*, *Gl. molluccensis*, *Oridorsalis tener*, *Cassidulina laevigata*, *C. bitor* and *Bolivina* spp.. During the early Middle Miocene the fractional abundances of *Globocassidulina subglobosa*, *Oridorsalis umbonatus*, *Pullenia bulloides*, *Gyroidinoides soldanii* and *G. amareckiana* gradually decreased. The fractional abundance of *E. umbonifera* and *E. exigua* is less in the *Globorotalia peripheroacuta* zone. These two species became abundant in later part of Middle Miocene, where samples show maximum abundances of 9.84% and 18.7% (fig.3.4a&b), respectively. *Eilohedra weddellensis* (Fig 3.3b) also followed a similar trend. In addition to these species, *Astrononion echolsi* (Fig.3.7a), increased in its percentage gradually from less than 1.0% to 5.70% and *Oridorsalis tener* (Fig.3.7b), also increased in abundance from 2.2% to 7.5% during the Middle Miocene. The fractional abundance of *Epistominella umbonifera* (Fig.3.4a) gradually increased during the interval from 16.5 Ma to 13.5 Ma and *Epistominella exigua* (Fig 3.4b) was also a dominant species in the Middle Miocene. *Globocassidulina subglobosa*, *Oridorsalis umbonatus* and *Pullenia bulloides* gradually decreased in abundance during the interval from 16.4 Ma to 13.9 Ma. This gradual shift in the species relative abundances might have been influenced by the first phase of Antarctic glaciation. The progressive increase in fractional abundance of *Epistominella umbonifera* indicates that an influx of Antarctic bottom water at mid-bathyal depth in the southwest Pacific may have strengthened. The intermediate watermass of the southwest Pacific was thermally stratified as denoted by reduction in fractional abundances of warm water indicator species.

Middle Miocene was a most crucial period in world-wide paleo-oceanography. The South Pacific Ocean climate was reorganized during early Middle Miocene. Temperature gradients from pole to equator and shallow to deep water occurred (Thomas, 1986). Changes in the paleo-oceanographic system were connected to the formation of the Antarctic continent (Eastern and Western). Middle Miocene paleo-oceanographic interpretation in the southwest Pacific was contributed by Shackleton and Kennett (1975), Matthews and Poore (1980), Savin (1981), Kennett

Fig.3.7a. Fractional abundance of *A. echolsi*

Fig.3.7b. Fractional abundance of *O. tener*

(1986). Kennett (1986) concluded that oxygen isotopic increase occurred during the interval approximately 16.5 Ma to 13.5 Ma and he correlated positive isotopic shift to cold bottom water conditions.

Readjustment of intermediate watermasses in the southwest Pacific affected the vertical distribution of many commonly occurring deep – sea taxa. In addition to common species, many rare and sporadically occurring species initially appeared during the Middle Miocene. Comparison of the present findings with modern assemblages reveals that the Middle Miocene assemblage is somewhat similar in composition to those of modern assemblages.

Murray (1973) observed that in bolivinids at cold temperatures the test growth is usually slow; consequently chambers are large and the test attains a prolate shape. According to Murray prolate forms indicate a high oxygen level between 3-6 ml/L with the potential temperatures being 0.5-4°C. Therefore, the presence of prolate bolivinids perhaps indicates cold, well-oxygenated bottom waters at intermediate depth during the Middle Miocene in the southwest Pacific. The abundant occurrence of *Epistominella exigua*, *Epistominella umbonifera*, *Eilohedra weddellensis*, *Oridorsalis tener*, and *Astrononion echolsi* indicates bottom water temperatures could have been 2-3°C with high oxygen content of 5-7 ml/L. Based on the presence of *Epistominella umbonifera*, Schnitker (1979) proposed high oxygen levels in Atlantic Ocean bottom water. Considering the presence of *Epistominella umbonifera* and *Oridorsalis tener*, Corliss (1979b) proposed 0.2°C to 4°C bottom water temperature in the Southeast Indian Ocean. However, Indian Ocean sites were deeper than the present Southwest Pacific sites. Q-mode analysis (Fig.3.6) of Middle Miocene samples 9,14,16 and 12 grouped with Late Miocene samples 17 and 24. In these samples the fractional abundances of *Globocassidulina subglobosa*, *Oridorsalis umbonatus* and *Gyroidinoides lamarckiana* further decreased. Therefore, it is reasonable to infer that Middle and Late Miocene periods were influenced by a cold bottom water mass.

3. *Epistominella exigua* / *Epistominella umbonifera* Assemblage.

This assemblage is essentially similar to the *Epistominella exigua* assemblage, except for a few variations in species fractional abundances. This assemblage characterizes the Late Miocene which was a period of further intensification of Cenozoic climate. The important species in the assemblage are (Appendix A.3, P.189) *Epistominella umbonifera*, *Epistominella exigua*, *Eilohedra weddellensis*, *Fontbotia wuellerstorfi*, *Melonis barleanum*, *Oridorsalis tener*, *Globocassidulina crassa*, *Astronomion echolsi*, *Cassidulina laevigata*, *Sphaeroidina bulloides* and a number of prolate brizalinids. Kennett (1986) postulated that after the middle Miocene event, the isotopic values showed minor fluctuations but average values remained unchanged. According to Kennett's (1986) interpretation, bottom water conditions were fluctuating between cold and relatively warm temperatures. As previously discussed *Globocassidulina subglobosa*, *Oridorsalis umbonatus*, *Pullenia bulloides*, *Gyroidinoides soldanii* are indicative of warm bottom water temperatures. In the present assemblage, these species show fluctuating percentages in the *Globorotalia mayeri* Zone. *Epistominella umbonifera* (Fig 3.4a) maintained the same percentage level as in the *Epistominella exigua* assemblage, but in one sample its percentage suddenly increased to 12% and this sudden shift indicates intensified influx of Antarctic bottom water. In the *Globorotalia plesiotumida* and *G. conomiozea* Zones the fractional abundance of *E. exigua* (Fig 3.5b) ranges from 8.11% to 23%. Therefore, this may indicate that the conditions have fluctuated. The species composition of this assemblage is very similar to the Quaternary assemblages reported from the Pacific Ocean by Burke (1981) and from the Indian Ocean by Corliss (1983).

This assemblage also is characterized by the abundance of *Bolivina minuta*, *B. pseudoplicata*, *Brizalina pusilla*, and *Globocassidulina porrecta*. *Sphaeroidina bulloides* (Fig 3.5b) is rare and sporadic in the Early Miocene but the species is common in Late Miocene and in a few Pleistocene samples. Therefore, this species has an ability to associate with cold water indicator species. The presence of prolate bolivinids indicates cold temperature with high Oxygen content (Murray, 1973). The Q-mode

dendrogram (Fig.3.6) clustered Late Miocene samples 17 and 24 (Assemblage, 3) with Middle Miocene samples 9 and 16 (Assemblage, 2). Therefore, this indicates that these two assemblages have similar distribution. Many workers proposed a second phase of Antarctic glaciation in the Late Miocene but I have not observed any significant changes in the species distribution except in fractional abundances of *Globocassidulina subglobosa* and *Oridorsalis umbonatus* which may indicate slightly warm bottom water conditions.

Keigwin (1979) and Elstrom and Kennett (1986) have proposed global cooling of bottom watermass and a world-wide regression due to the second phase of (Western) Antarctic glaciation. In the present study, superficial evidence probably supports the idea of regression. At Site 587, which is located at the northern limits of the Lord Howe Rise, reworked shallow water species were found in a few samples. At this site the lithology was foraminiferal nannofossil ooze until the Late Miocene. In the Late Miocene skeletal sandy gravel mixed with foraminiferal nanno-fossil ooze was deposited (Nelson, 1986). The reworked species mostly consist of a wide variety of articulonids, miliolinids, *Elphidium poeyanum*, *E. crispum*, *Neoconorbina crustata*, *N. patelliformis* and many other genera. On comparison of bathymetric charts, the present author came to the conclusion that these fauna were mostly derived from shallow water pedestals at Lansdowne Bank where the depth is approximately 100 m – 200 m. The shallow water fauna was reworked into deep water when the shallow – water sediments bearing them were transported to deep water, possibly through the action of turbidity currents at that time of regression.

4. Astrononion echolsi / Angulogerina angulosa Assemblage

This assemblage occurred in Late Miocene and Pliocene samples. Important species of this assemblage (Appendix A.4, P.189) are *Fontbotia wuellerstorfi*, *Astrononion echolsi*, *Globocassidulina crassa*, *Gl. minuta*, *Cassidulina laevigata*, *Melonis barleanum*, and *Uvigerina proboscidea*. In addition, less important species (Fig.3.8) such as *Brizalina*

DISTANCE METHOD IS FULLY BORN DISTANCE
COMPLETE LINKAGE METHOD (PARTIAL RE-ORDER)

TRUE 0.10000

DISTANCE

3.000

LEGEND

1. *Amphistegina gibbosa*
2. *A. madagascariensis*
3. *Anomalinoides semicribatus*
4. *Astronomen australe*
5. *A. echel.*
6. *A. novaezealandicum*
7. *Bollivina compacta*
8. *B. minuta*
9. *B. pseudoplicata*
10. *B. robusta*
11. *Bollivopsis cubensis*
12. *Brizalina boyrichi*
13. *B. pusilla*
14. *Bullmina alaxanensis*
15. *B. aculeata*
16. *B. rostrata*
17. *Cassidulina blora*
18. *C. cuneata*
19. *C. carinata*
20. *Paracassidulina quasitricata*
21. *Cassidulina laevigata*
22. *Cassidulinoides bradyi*
23. *Globocassidulina porrecta*
24. *Chilastomella eolina*
25. *Cibicides kullenbergi*
26. *Cibicidoides mundulus*
27. *C. robertsonianus*
28. *Cymbaloporella bradyi*
29. *Eggerella bradyi*
30. *Ellisella weddellensis*
31. *Epistominella exigua*
32. *E. umbonifera*
33. *Eponides polius*
34. *Gavellinopsis praegeri*
35. *Globocassidulina crassa*
36. *G. minuta*
37. *G. molluccensis*
38. *Pontobella wuellerstorfi*
39. *Globocassidulina subglobosa*
40. *Gyroldinoides soldanii*
41. *G. lamarckiana*
42. *G. orbicularis*
43. *G. brochiana*
44. *Melonis bartanum*
45. *M. pompilioides*
46. *Nonion depressulus*
47. *Nuttallides bradyi*
48. *Oridorsalis umbonatus*
49. *O. tenuis*
50. *Oscularia cultor*
51. *Pyramidulina challengeriana*
52. *Pullenia bulloides*
53. *P. quadriloba*
54. *P. quinqueloba*
55. *Pleurostomella dominicana*
56. *Sigamirgulinella tortuosa*
57. *Sagrinella lobata*

58. *Siphonodasaria lapidula*
59. *S. subspinosus*
60. *Stainforthia complanata*
61. *Sphaeroidina bulloides*
62. *Uvigerina auberiana*
63. *U. peregrina*
64. *U. proboscidea*
65. *Virgulinoopsis pustulata*
66. *Parallinella inconspicua*
67. *Angulogorina angulosa*
68. *Trifarina bradyi*

Fig.3.8.R-mode dendrogram of benthic species.

heyrichi, *Sagrinella lobata*, *Patellinella inconspicua*, *Fijiella simplex*, *Trifarina bradyi* and *Uvigerina peregrina* are also characteristic of this assemblage. Proportions of *Epistominella exigua* and *E. umbonifera* were reduced to negligible abundances. The reduction in fractional abundances of *Epistominella exigua* and *E. umbonifera* and the presence of a few cold water indicator species as occurred in Late Miocene samples, indicates that the intermediate water mass in the southwest Pacific was less cold during the Pliocene. In a few samples at site 587 benthic foraminifers were poorly preserved. The sample spread is very limited in the Pliocene. Because of poor preservation of fauna the author is unable to evaluate watermass characteristics with confidence.

5. *Epistominella exigua* / *Globocassidulina subglobosa* / *Fontbotia wuellerstorfi* Assemblage.

This Quaternary assemblage compositionally is of mixed type. The following species are important in the assemblage (Appendix A.5, P.190 and Fig.3.8): *Epistominella exigua*, *Fontbotia wuellerstorfi*, *Eilohedra weddellensis*, *Globocassidulina subglobosa*, *Oridorsalis tener*, *Melonis barleanum*, *Astrononion echolsi*, *Cassidulina carinata*, *Globocassidulina decorata*, *Paracassidulina quasisulcata* and *Stainforthia complanata*.

The Quaternary period is known for fluctuations in surface and bottom water conditions. Glacial and interglacial periods are broadly represented by benthic fauna. This assemblage consists two sub - assemblages which consists of warm and cold water indicator species. The alternate occurrence of warm and cold water species in the Quaternary samples may indicates glacial and interglacial periods. *Globocassidulina subglobosa* (Fig.3.1a), *Gyroidinoides lamarckiana* (Fig.3.2b), *Pullenia bulloides* (Fig.3.2a) and *Oridorsalis umbonatus* (Fig.3.1b) occur in Pleistocene samples 27 and 28. These species show fluctuation in fractional abundances throughout the Quaternary period. The fractional abundance of *Fontbotia wuellerstorfi* (Fig.3.9a) ranges from 1% to 5.26%. The presence of these species perhaps indicates interglacial periods in the earlier part of *Globorotalia truncatulinoides* and *Gt.tosaensis* overlap Zone of the present

investigation. The glacial episodes are represented by *Epistominella exigua*, *E. umbonifera*, *Cassidulina laevigata* (Fig.3.9b), *Melonis barleanum* (Fig.3.10a), and *Globocassidulina crassa* (Fig.3.10b) in the *Globorotalia truncatulinoides* Zone.

In the Q-mode dendrogram (fig.3.6) the Quaternary samples were clustered individually into three groups. In the first group, samples 27 and 28 contain warm water species predominantly which perhaps indicates an interglacial interval with a probably intermediate water temperature of 4 - 8°C (Ingle, 1981; Woodruff, 1985). The group of samples 29,30, and 32 is dominated by cold temperature indicator species which probably indicate a glacial episode. The cold water assemblage may indicate a 2-3°C temperature (Schnitker, 1980; Burke, 1981; Corliss, 1983). The third group is represented by sample no.31 which perhaps indicates warm temperature. Kennett and Mead (1987) have given temperature tolerance of *Bulimina aculeata* and *Uvigerina peregrina* as 0.5 to 1.71°C and 0.4 to 2.60°C, respectively. Hermelin and Scott (1985) suggested 3-4°C bottom water temperature in the Atlantic Ocean based on occurrence of *Epistominella exigua* and *Planulina ariminensis*. The Quaternary assemblage encountered by Corliss (1979b) in the Indian Ocean is similar in composition to the present assemblage.

Many of the cosmopolitan species showed an increase in size from the Miocene through the Pleistocene. In contrast some species showed a reverse trend. In general individual specimens of Quaternary species are slightly larger in size than those of Neogene species. This may be due to well-oxygenated conditions in the Quaternary (Kennett, 1981). However, the main reason for this increase in size may be the greater abundance of phytoplankton in the Quaternary Period contributing a rich nutrient supply. As a result, species may have attained a larger size. Nienstadt and Arnold (1988) have noticed size enlargement of certain deep-sea benthic foraminifera near hydrothermal active zones at the east Pacific sea mounts where temperature is in excess of +2°C. They have recorded highest increase in the mean size in *Uvigerina auberiana*, *Sphaeroidina bulloides*, *Oridorsalis tener* and *Chilostomella oolina*. Thus, a general size

increase may also have been governed by slightly higher bottom temperatures and availability of nutrient supply in the Quaternary Period.

In summary, the distribution of these assemblages from Miocene to the Pleistocene is shown in table 3.1. Based on these distributions, a possible paleoclimatic interpretation also shown in table 3.2.

Site 588A
&
588B

Site 587

Site 589

Table 3.1 Distribution of Benthic Assemblages from Miocene to Pleistocene

Site 588A

&

588B

Table 3.2 Paleo-temperatures of bottom water masses of 3 study sites (continued on next page).

Site 587

Table 3.2. contd.

Site 589

CHAPTER 4

CONCLUSIONS

Deep — water benthic foraminifera are primarily used as tools for paleoecological analysis. To use benthic foraminifera as ecological, paleoecological, or paleo-oceanographic tools a stable taxonomy is required, especially when comparing deep-sea foraminiferal studies from different Oceans. Some of the confusion in the taxonomy and nomenclature of some of the important species of deep-sea benthic foraminifera has been resolved, and their taxonomic position is updated according to the revised classification (Loeblich and Tappan, 1987).

Most of the cosmopolitan Neogene and Quaternary deep-sea benthic foraminifera originated before Early Miocene and some rare to commonly occurring taxa initially appeared in the Middle Miocene. The species showed high diversity. Benthic foraminifera are less useful in biostratigraphy than the planktics because of long stratigraphic ranges resulting in less refined stratigraphy.

The occurrence of 18 isobathyal species indicates mid- to lower bathyal depth at Lord Howe Rise during the Neogene and Quaternary periods.

The distributions of deep-sea benthic foraminiferal populations are not primarily controlled by depth *per se* but by various other parameters, because they are very sensitive to subtle variations in watermass qualities such as temperature, salinity, oxygen content, availability of calcium carbonate and nutrients. Competition and predation may also play a major role in controlling the distribution. However, we do not know which of these parameters are the primary controlling factors.

Under favorable environment, if enough nutrients were available benthic fauna would show high diversity.

The changes occurring during times of major glaciations in the northern and the southern hemispheres affected the distribution of deep — sea benthic foraminifera. Such broad changes have been detected in the present research. Based on the fractional abundances of species, five assemblages were established. These assemblages are (1). *Globocassidulina subglobosa*. (2). *Epistominella exigua*. (3). *Epistominella exigua* / *E. umbonifera*. (4). *Astrononion echolsi* / *Angulogerina angulosa* (5). *Epistominella exigua* / *Globocassidulina subglobosa* / *Fontbotia wuellerstorfi*. All these assemblages have overlapping percentage occurrences.

Globocassidulina subglobosa Assemblage occurs in the Early Miocene section of the present study. The important species are *Globocassidulina subglobosa* (Brady), *Oridorsalis umbonatus* (Reuss), *Cassidulina cuneata* Finlay, *Gyroidinoides soldanu* d'Orbigny and *Pullenia bulloides* d'Orbigny. These species indicates warm bottom water temperature. According to many workers *Epistominella exigua* and *E. umbonifera* indicate cold temperature. The occurrence of *Epistominella exigua* (Brady), *E. umbonifera* (Cushman), and *Eilohedra weddellensis* (Earland) within the *Globocassidulina subglobosa* Assemblage indicates that intermediate watermass in the southwest Pacific during the Early Miocene was thermally unstratified. *Epistominella umbonifera* (Cushman) is usually associated with Antarctic bottom water. The presence of this species indicates periodic influx of Antarctic bottom water must have occurred. Taking the faunal assemblage into account, the temperature of the bottom watermass at Lord Howe Rise could have been 7°C - 8°C with normal salinity 34.68‰, and 0.5-3ml/L oxygen content.

The important species in the *Epistominella exigua* Assemblage are *Epistominella exigua* (Brady), *E. umbonifera* (Cushman), *Eilohedra weddellensis* (Earland), *Globocassidulina crassa* (d'Orbigny), *Astrononion echolsi* Kennett, *Cassidulina bitor* Crespin and *C. laevigata* d'Orbigny. This assemblage occurs in the Middle Miocene section. The South Pacific Ocean climate was reorganized and the temperature gradients were established due to the formation of the eastern Antarctic continent. Broad changes were detected in the faunal distribution. The fractional abundance of

warm water species is greatly diminished. *Epistominella exigua* (Brady), *E. umbonifera* (Cushman) became consistent and abundant. Based on faunal occurrence, the temperature could be 2°C – 3°C and O₂ content high.

Epistominella exigua / *E. umbonifera* Assemblage is similar in composition to that of *E. exigua* Assemblage except with a few fluctuations in the species distribution. In a few samples the fractional abundances of *Epistominella exigua* and *E. umbonifera* fluctuated. This may indicate that influx of glacially derived Antarctic bottom water must have also fluctuated. A few samples at Site 587 were reworked with shallow – water fauna.

Astrononion echolsi and *Angulogerina angulosa* Assemblage occurred in Pliocene samples. This assemblage consists of *Astrononion echolsi*, *Angulogerina angulosa*, *Fondbotia wuellerstorfi*, *Globocassidulina crassa*, *Gl. minuta*, *Cassidulina laevigata*, *Melonis barleanum*, and *Uvigerina proboscidea*. In addition, less important species such as *Brizalina heyrichi*, *Sagrinella lobata*, *Patellinella inconspicua*, *Fijiella simplex*, *Trifarina bradyi* and *Uvigerina peregrina*. The fractional abundances of *Epistominella exigua* and *E. umbonifera* are greatly reduced. Based on the occurrence of cold water species the bottom water mass in the south west Pacific during the Pliocene was cold but may not have been as cold as in late Miocene as indicated by *E. exigua* / *E. umbonifera* Assemblage.

Epistominella exigua / *Globocassidulina subglobosa* / *Fondbotia wuellerstorfi* Assemblage compositionally is of mixed type and occurs in Quaternary samples. The predominant species in the assemblage are *Epistominella exigua*, *Fondbotia wuellerstorfi*, *Eulohedra weddellensis*, *Globocassidulina subglobosa*, *Oridorsalis tener*, *Melonis barleanum*, *Astrononion echolsi*, *Cassidulina carinata*, *Globocassidulina decorata*, *Paracassidulina quasiusulcata* and *Stainforthia complanata*. The presence of *Globocassidulina subglobosa* (Brady), *Gyroidinoides lamarckiana* d'Orbigny, *Pullenia bulloides* d'Orbigny, *Oridorsalis umbonatus* (Reuss), and *Fondbotia wuellerstorfi* (Schwager) indicate interglacial episode.

The glacial episode is indicated by the presence of *Epistominella exigua* (Brady), *E. umbonifera* (Cushman), *Eilohedra weddellensis* (Earland), *Cassidulina laevigata* d'Orbigny and *Melonis barleanum* (Williamson). The interglacial sub - assemblage may indicate 4°C – 8°C temperatures and glacial sub - assemblage may indicate 2°C – 3°C. Some of the Quaternary fauna are relatively larger in size than Neogene fauna, probably due to slightly warmer temperatures in Quaternary and abundant phytoplankton. The dead phytoplankton form an organic detritus which after reaching the bottom becomes a nutrient supply for benthonic organisms.

CHAPTER 5

SYSTEMATIC PALEONTOLOGY

The suprageneric classification of Loeblich and Tappan (1987) is followed herein. The taxa are presented in the order given by this classification. Specimens were identified and placed in specific categories based on original descriptions and type figures as recorded in the Catalogue of Foraminifera (Ellis and Messina, 1940), and several other publications. For the sake of taxonomic revision, most important recent references were included in the synonymies. Due to high diversity encountered in the samples of present study, some species are represented by a few specimens, making the identification difficult. In such cases sp.cf. was used which indicate probably belong to a previously described species, but for which positive identification is not possible. The complete list of species with page numbers is included in appendix B (P.188).

Order	FORAMINIFERIDA	Eichwald, 1830
Suborder	TEXTULARIINA	Delage and Herouard, 1896
Superfamily	SPIROPECTAMMINACEA	Cushman, 1927
Family	SPIROPECTAMMINIDAE	Cushman, 1927
Subfamily	SPIROPECTAMMINAE	Cushman, 1927
Genus	BOLIVINOPSIS	Yakovlev, 1891

Bolivinopsis cubensis (Cushman and Bermudez)

Spiroplectoides cubensis CUSHMAN and BERMUDEZ, 1937, p. 13, pl. 1, Figs. 44-45.

Bolivinopsis cubensis (Cushman and Bermudez). HORNIBROOK, 1961, pl. 1, fig 1.

Spiroplectammuna spectabilis (Grzybowski). HEIMAN, 1977, p. 38, pl. 1, fig.10.

Description: Test elongate, slender, fairly large, initial portion planispirally coiled later becoming biserial, chambers uniform in size, sides of biserial portion almost

parallel; sutures slightly depressed, strongly oblique in biserial portion; aperture indistinct; wall coarsely perforated.

Remarks: The species differs from *Spiroplectoides spectabilis* (Gyzybowski) by having large initial coiled portion and relatively less arcuate periphery.

Occurrence: Rare and sporadic in Early Miocene of site 588A and 588B, Late Miocene through Pliocene sites of 588B and 587 and the Pleistocene samples of site 589.

Superfamily	TEXTULARIACEA	Ehrenberg, 1838
Family	EGGERELLIDAE	Cushman, 1927
Subfamily	DOROTHIINAE	Balakhmatova, 1972
Genus	DOROTHIA	Plummer, 1931

Dorothia braevis Cushman and Stainforth

Dorothia braevis CUSHMAN and STAINFORTH, 1945, p. 18, pl. 2, fig. 5. — HEIMAN, 1977, p. 43 (No illustration) — BOLTOVSKOY, 1978, p. 158, pl. 3, fig. 31. *Karriarella bradyi* (Cushman). CORLISS, 1979a, p. 5, pl. 1, fig. 6.

Description: Test stout and flaring as broad as long, rapidly increasing in breadth, initial end acute; chambers a few, highly inflated, strongly overlapping, last pair of chambers as large as rest of the test; sutures slightly depressed; apertural end rounded, aperture interiomarginal with a lip; wall finely agglutinated.

Remarks: The species somewhat resembles *Dorothia retusa* (Cushman) but differs by possessing strong overlapping chambers. *Karriarella bradyi* (Cushman) is much more elongate with a distinct triserial initial stage. Corliss (1979) fig. 6 is not *K. bradyi* as it has a pair of broad terminal chambers and his specimen very well fits into the description of the present species.

Occurrence: Rare and sporadic in Early Miocene through the Middle Miocene of sites 588A and 588B. Very rare in Late Miocene of site 588B and 587. Sporadic in Pliocene and Pleistocene of sites 587 and 589.

Subfamily	EGGERELLINAE	Cushman, 1927
Genus	EGGERELLINA	Cushman, 1935

Eggerella bradyi (Cushman)

Verneulina bradyi CUSHMAN, 1911, p. 54-55, T.f. 87. *Eggerella bradyi* (Cushman). PHLEGER and PARKER, 1953, p. 6, pl. 3, figs. 1-2. —. BARKER, 1960, p. 96, pl. 47, figs. 4-5. —. HEIMAN, 1977, p. 43, pl. 1, fig. 1a. —. BOLTOVSKOY, 1978, p. 158, pl. 3, fig. 33 —. CORLISS, 1979a, p. 5, pl. 1, figs. 3-4. —. THOMAS, 1985, p. 676, pl. 1, fig. 4. —. MEAD, 1985, p. 225, pl. 1, fig. 1. —. BELANGER and BERGGREN, 1986, p. 331, pl. 1, fig. 1.

Description: Test triserial, tapering towards base, chambers 5 in each vertical series, highly inflated, chambers in the final two whorls increasing rapidly in size, sutures distinct, depressed; aperture a short slit at the base of the last formed chamber, often bears a distinct lip.

Remarks: The present species shows close resemblance to *Karreriella bradyi* (Cushman) but the latter ends in a final biserial stage and also differs from *Dorothia braevis* Cushman and Stainforth in having a distinct terminal triserial stage.

Occurrence: Rare in Early Miocene samples of site 588A. Common in the Middle Miocene through Late Miocene of site 588A and 588B. Rare and sporadic in Pliocene through recent sites of 587 and 589.

Genus KARRERIELLA Cushman, 1933

Karreriella bradyi (Cushman)

Gaudryina bradyi CUSHMAN, 1911, p. 67, T.F. 107. *Karreriella bradyi* (Cushman). BARKER, 1960, p. 94, pl. 46, figs. 1-4. —. MURRAY, 1971, p. 47, pl. 16 —. HEIMAN, 1977, p. 45, pl. 1, fig. 18. —. BOLTOVSKOY, 1978, p. 162, pl. 4, figs. 28-29. —. CORLISS, 1979a, p. 5, pl. 1, fig. 5 —. HERMELIN and SCOTT, 1985, p. 212, pl. 1, fig. 8. —. BELANGER and BERGGREN, 1986, p. 331, pl. 1, fig. 2. *Karreriella subglabra* (Gumbel). MILLER and KATZ, 1987, p. 134, pl. 1, fig. 3.

Remarks: This species was widely reported from many parts of the world. The description of Cushman (1911) is followed herein. *Karreriella bradyi* resembles *Eggerella bradyi* (Cushman) except in the terminal biserial stage. It differs from *Karreriella barbati* Cushman by possessing a stouter and more elongate test. *Karreriella subglabra* (Gumbel) described by Miller and Katz (1987) has very similar chamber arrangement to the present species hence the latter may be referable to the present species.

Occurrence: Rare and sporadic in Early Miocene of site 588A; rare and sporadic in Late Miocene through Pleistocene samples of sites 587 and 589.

Family	TEXTULARIIDAE	Ehrenberg, 1833
Subfamily	TEXTULARIINAE	Ehrenberg, 1838
Genus	TEXTULARIA	DeFrance, 1824

Textularia agglutinans d'Orbigny

Textularia agglutinans D'ORBIGNY, 1839a, p. 136, pl. 1, figs. 17-18. — . BRADY, 1884, p. 363, pl. 43, figs. 1-2. — . CUSHMAN, 1911, p. 9, Tf. 10 — . BARKER, 1960, p. 88, pl. 43, figs. 1-3. — . THOMAS, 1985, p. 678, pl. 1, fig. 5. — . BOERSMA, 1986, p. 1025, pl. 10, figs. 3-4.

Description: Test stout, somewhat elongated, tapering towards base, chambers biserial, wide and high, gradually increasing in size; sutures distinct, depressed; aperture slit-like, interiomarginal, wall coarsely agglutinated.

Remarks: The species differs from the rest by having a coarsely agglutinated test.

Occurrence: Very rare and sporadic in Early Miocene and Late Miocene samples of site 588A and only two specimens from single sample of site 589 of Pleistocene.

Textularia conica d'Orbigny

Textularia conica D'ORBIGNY, 1939, p. 143, pl. 1, figs. 19-20. — . CUSHMAN, 1932, p. 11, pl. 2, figs. 8-10 — . BARKER, 1960, p. 88, pl. 43, figs. 13-14. — . PHILLIPS, 1985, p. 12.

Description: Test biserial, wider than high, triangular in front view, tapering sharply towards base, slightly compressed; sutures distinct chambers regularly increasing in size as added; aperture a narrow interiomarginal slit; wall agglutinated and smoothly finished.

Remarks: The species is similar to *Textularia monicana* Zalesny but the latter has fewer chambers with broadly rounded test.

Occurrence: Very rare and sporadic in Miocene of site 588A.

Textularia milletti Cushman

Textularia milletti CUSHMAN, 1911, p. 13, figs. 18-19.

Description: Test slightly elongated, compressed, chambers biserially arranged throughout, increasing in width rapidly as added; lateral margins acutely pointed; wall coarsely agglutinated; sutures limbate; aperture a narrow looped slit at the inner margin of the last formed chamber.

Remarks: The species is similar to *Textularia agglutinans* D'Orbigny but the latter shows a broadly rounded periphery.

Occurrence: Only three specimens from one Late Miocene sample of site 588B.

Genus SIPHOTEXTULARIA Finlay, 1939

Siphotextularia catenata (Cushman)

Textularia catenata CUSHMAN, 1911, p. 23, Tf. 39. *Siphotextularia rohlsauseni* PHLEGER, PARKER and PEIRSON, 1953, p. 4, pl. 1, figs. 23-24. *Siphotextularia* sp. nov. BARKER, 1960, p. 88, pl. 43, fig. 11. *Siphotextul ia catenata* (Cushman). CORLISS, 1979a, p. 5, pl. 1, figs. 1-2. —. HERMELIN and SCOTT, 1985, p. 217, pl. 1, figs. 6-7. *Karreriella cubensis* (Cushman and Bermudez). MILLER and KATZ, 1987, p. 134, pl. 1, fig. 6.

Remarks: The species description of Cushman (1911) is followed herein. Corliss (1979a) has not observed any essential difference between the present species and *Siphotextularia rohlsauseni* Phleger and Parker except the former is slightly bigger than the latter. Thomas (1985) also supports the idea of Corliss that *S. rohlsuaseni* is a

synonym of the present species. *Siphotextularia catenata* also differs from *Siphotextularia obesa* Parr by not acquiring a twisted test and not having slightly oblique sutures. *Karreriella cubensis* (Cushman and Bermudez) described by Miller and Katz (1987) shows complete traits of the present species. Therefore it may be conspecific with the present species.

Occurrence: Rare in Early Miocene of site 588A, common in Middle Miocene of site 588A and 588B. Rare and sporadic in Pliocene and Pleistocene samples of sites 587 and 589.

Family	VALVULINIDAE	Berthelin, 1880
Subfamily	VALVULININAE	Berthelin, 1880
Genus	VALVULINA	d'Orbigny, 1826

Valvulina Pennatula (Batsch)

Nautilus (*Orthoceras*) *pennatula* BATSCH, 1791, p. 3-5, pl. 4, fig. 13. *Bigenerina pennatula* (Batsch). CUSHMAN, 1921, pl. 25, fig. 3. *Valvulina pennatula* (Batsch). BARKER, 1960, p. 92, pl. 45, figs. 1-4 (not figs. 5-8).

Description: Test biserial, wide and low, strongly arched chambers overlapping on earlier ones; sutures distinct and slightly raised; periphery strongly acute; aperture a low interiomarginal arch with a lip; wall coarsely agglutinated.

Remarks: The species differs from others by possessing a wide and low terminal stage with an acute periphery.

Occurrence: Very rare in Early Miocene of site 588A and Late Miocene of site 588B.

Suborder	MILIOLINA	Delage and Herouard, 1896
Superfamily	MILIOLACEA	Ehrenberg, 1839
Family	HAUERINIDAE	Ehrenberg, 1839
Subfamily	HAUERININAE	Schwager, 1876
Genus	QUINQUELOCULINA	d'Orbigny, 1876

Quinqueloculina venusta Karrer

Quinqueloculina venusta KARRER, 1868, p. 147, pl. 2, fig. 6. —. CUSHMAN, 1917, p. 45, pl. 1, fig. 1. —. BARKER, 1960, p. 10, pl. 5, fig. 5. —. BOLTOVSKOY, 1978, p. 167, pl. 6, figs. 32-33. —. LOHMAN, 1978, p. 25, pl. 4, figs. 8-9. —. COLLINS, 1979a, p. 6, pl. 1, figs. 9-11. —. KURIHARA and KENNETT, 1986, p. 1069, pl. 1, figs. 14-15.

Description: Test free, elongate, 2-2½ times as long as wide, periphery acute, surface smooth, aperture circular on a short neck bears distinct tooth; wall smooth, porcelaneous, imperforate.

Remarks: In the present study, this species exhibits wide variation in periphery from angular to subangular margins, with a thin keel which readily distinguishes the species.

Occurrence: Very rare and sporadic in Early Miocene and Middle Miocene of sites 588A and 588B. Only two specimens from Pliocene of site 588B. Rare in Pleistocene samples of site 589.

Quinqueloculina seminulum (Linné)

Serpula seminulum Linné, 1758, p. 786. *Miliolina seminulum* (Linné). BRADY, 1884, p. 157-158. *Quinqueloculina seminulum* (Linné). BARKER, 1960, p. 10, pl. 5, fig. 6.

Description: Test free, elongate to oval, slightly compressed with chambers one-half coil in length, regularly alternating; aperture circular with a distinct tooth; wall smooth, porcelaneous, somewhat transparent.

Remarks: The species is distinguished by chambers one half coil in length regularly alternating in five planes with an approximate angle of 72°.

Occurrence: Very rare - occur only in Quaternary samples of site 587.

Subfamily MILIOLINELLINAE Vella, 1957

Genus PYRGO Defrance, 1824

Pyrgo murrhina (Schwager)

Biloculina murrhina SCHWAGER, 1866, p. 203, pl. 4, figs. 15 a-c. — BARKER, 1960, p. 4, pl. 2, figs. 10-11 and 15. — BOLTOVSKOY, 1978, p. 164, pl. 6, fig. 26. — HEIMAN, 1977, p. 50, pl. 2, fig. 3. — THOMAS, 1985, p. 678, pl. 1, fig. 10. — KURIHARA and KENNETT, 1986, p. 1069, pl. 1, fig. 13. — NIENSTEDT and ARNOLD, 1988, p. 244, pl. 1, fig. 15.

Description: Test compressed, nearly circular in outline, periphery sharply angled, basal portion has two sharp spines; surface smooth, wall porcelaneous, aperture circular, on a somewhat protruding neck.

Remarks: The species differs from *Pyrgo depressa* (d'Orbigny) by having a circular aperture with a bifid tooth on a neck and a sulcus with two spines at the end. It is also distinguished from *Pyrgo phlegeri* Andersen by possessing a strongly developed keel and more circular test.

Occurrence: Very rare and sporadic in Middle through Late Miocene of site 588B. Single specimens sporadically occur in Pliocene and Pleistocene samples of site 587 and 589.

Pyrgo depressa (d'Orbigny)

Biloculina depressa d'ORBIGNY, 1926, p. 298. — CUSHMAN, 1917, p. 74, pl. 28, figs. 1-2. *Pyrgo depressa* (d'Orbigny). BARKER, 1960, p. 4, pl. 2, figs. 12, 16-17. — MURRAY, 1971, p. 71, pl. 27. — BOLTOVSKOY, 1978, p. 167, pl. 6, fig. 25. — PATTERSON, 1986b, p. 45, pl. 4, figs. 3-4.

Description: Test free, circular in side view, chambers biloculine, periphery angular to carinate; aperture terminal, elongate narrow slit; wall smooth, porcelaneous, imperforate.

Remarks: D'Orbigny (1826) has not given the type description. *Pyrgo longirostra* (Fornasini) is similar to the present species but it differs in having an oblong test. [See *Pyrgo murrhina* for additional remarks.]

Occurrence: Very rare and occurs as a single specimen from Miocene samples of sites 588A and 588B.

Subfamily	SIGMOILINOPSINAE	Vella, 1957
Genus	SIGMOILINOPSIS	Finlay, 1947

Sigmoilinopsis schlumbergeri Silvestri

Sigmoilina s. schlumbergeri SILVESTRI, 1904, p. 267, pl. 7, figs. 12-14. — BARKER, 1960, p. 16, pl. 8, figs. 4. — HEIMAN, 1977, p. 52, pl. 2, fig. 1. — BOLTOVSKOY, 1978, p. 167, pl. 7, fig. 14. — HERMELIN and SCOTT, 1985, p. 217, pl. 2, fig. 6. — KURIHARA and KENNETT, 1986, p. 1069, pl. 1, figs. 11-12.

Remarks: The description of Silvestri (1904) is followed herein. The species is distinguished by elongate, ovate test, with acute periphery and an agglutinated test. *Sigmoilinopsis celata* (Costa) has more rounded periphery. Otherwise it is identical with the present species.

Occurrence: Rare and sporadic in Middle Miocene through Pliocene of sites 588A and 587, and common in one Pleistocene sample of site 589.

Suborder	LAGENINA	Delage and Herouard, 1896
Superfamily	NODOSARIACEA	Ehrenberg, 1838
Family	NODOSARIIDAE	Ehrenberg, 1838
Subfamily	NODOSARIINAE	Ehrenberg, 1838
Genus	DENTALINA	RISSO, 1826

Dentalina communis d'Orbigny

Nodosaria (Dentalina) communis D'ORBIGNY, 1826, p. 254. — CUSHMAN, 1913, p. 54, pl. 28, figs. 1-2. — PARKER, 1964, pl. 97, fig. 23.

Description: Test elongate, slender, arcuate, composed of numerous chambers, chambers inflated; sutures oblique, slightly depressed; aperture radiate somewhat eccentric.

Remarks: The species differs from *Dentalina roemeri* Neugeboren by having very slender, more arcuate test. *Nodosaria mucronata* (Neugeboren) possess broadest chambers near apertural end.

Occurrence: Rare and sporadic in Early Miocene through Middle Miocene of site 588A. Two specimens in Pleistocene samples from site 589.

Dentalina intorta (Dervieux)

Nodosaria intorta DERVIEUX, 1894, p. 610, pl. 5, figs. 32-34. *Nodosaria mucronata* (Neugeboren). BRADY, 1884, pl. 62, figs. 27-31. —. CUSHMAN, 1913, p. 56, pl. 25, fig. 20.

Description: Test elongate, slightly curved, chambers a few, inflated, final four chambers rapidly increasing in size as added; sutures oblique, depressed; aperture distinctly radiate, slightly eccentric; wall smooth and finely finished.

Remarks: Dervieux's (1894) type illustration is not clear. However, it differs from *Nodosaria nana* Reuss by having fewer chambers and a rapidly enlarging test.

Occurrence: Rare and sporadic in the Middle Miocene of Site 588A. Rare in Pliocene of site 587 and also Pleistocene of site 589.

Dentalina costai (Schwager)

Nodosaria costai SCHWAGER, 1866, p. 229, pl. 6, fig. 62. *Nodosaria filiformis* d'Orbigny. CUSHMAN, 1912, p. 55, pl. 27, figs. 1-4.

Description: Test very elongate, slender, tapering, arcuate, chambers numerous, strongly inflated initial chambers, later becoming normal; sutures distinct, initial end oblique, later becoming straight, slightly limbate; aperture radiate, terminal; wall smooth and finely finished.

Remarks: The species differs from *Dentalina neugeboreni* (Schwager) by having tubular chambers in the adult stages and in the latter species sutures are much depressed.

Occurrence: Only three specimens from the Middle Miocene site 588B.

Dentalina sp.cf. *D. equisetiformis* (Schwager)

Nodosaria equisetiformis SCHWAGER, 1866, p. 231, pl. 6, fig. 66.

Description: Test elongate, uniserial, rectilinear, chambers cylindrical, enlarging gradually in size as added; sutures horizontal, slightly constricted; wall ornamented with numerous longitudinal costae which tend to become twisted at later stages; aperture terminal.

Remarks: Loeblich and Tappan (1987) have placed all specimens which possess longitudinal costae under genus *Dentalina* Risso. The present species superficially

resembles *Nodosaria equisetiformis* Schwager, the only difference being the twisted longitudinal costae.

Occurrence: Rare and sporadic in Pliocene of site 587. Only one specimen from the Pliocene of site 588B.

Genus NODOSARIA Lamarck, 1812

Nodosaria vertebralis (Batsch)

Nautilus vertebralis BATSCH, 1791, pl. 2, fig. 6. *Nodosaria vertebralis* (Batsch) CUSHMAN, 1912, p. 60, pl. 32, fig. 1. — . BARKER, 1960, p. 134, pl. 63, fig. 35.

Description: Test greatly elongated, slender, straight, chambers numerous, slightly inflated; sutures depressed, wall constricted; several thin continuous longitudinal costae extend from the base to half of the final chamber; apical end with a small spine; aperture terminal, radial, slightly protruded.

Remarks: The species differs from *Nodosaria decepta* (Bagg) by more chambers with continuous costae. *Nodosaria subradicula* (Schwager) possesses fewer chambers and the aperture is on a tubular neck. *Nodosaria vertebralis* (Batsch) var. *albatrossi* Cushman is similar to the present species but the former is an arcuate form with a greater number of chambers.

Occurrence: Only single specimens occur throughout Miocene samples of site 588A and 588B. Only three specimens from Pliocene samples of site 589.

Nodosaria sp.

Test universal, rectilinear, chambers vary in number, cylindrical in shape; sutures straight, depressed and occasionally flush with the surface, wall smooth and polished.

Remarks: Specimens were broken at both ends and it is extremely difficult to identify to species level with certainty.

Occurrence: Sporadic occurrences throughout the section.

Genus PYRAMIDULINA Fornasini, 1894

Pyramidulina challengeriana (Thalman)

(Pl.5, fig.12)

Nodogenerina challengeriana THALMAN, 1937, p., 341. *Nodosaria perversa* Schwager. BRADY, 1884, p. 512, pl. 64, figs. 25-27. —. CUSHMAN, 1921, pl. 37, fig. 2. *Orthomorphina challengeriana* (Thalman). PARKER, 1964, pl. 97, fig. 27. —. BARKER, 1960, p. 136, pl. 64, figs. 25-26. —. HEIMAN, 1977, p. 65, pl. 3, fig. 16. —. BOLTOVSKOY, 1978, p. 163, pl. 5, figs. 16-17. *Pyramidulina challengeriana* (Thalman). PATTERSON, 1986b, p. 152, pl. 32, fig. 12.

Description: Test free, uniserial, elongate, 6-8 subglobular chambers which vary in width, gradually enlarging in size as added; numerous longitudinal costae extend from the base to three fourth's of the last formed chamber; aperture circular with a phialine lip on short, narrow neck; test translucent.

Remarks: Loeblich and Tappan (1987) placed forms which have globular to subcylindrical chambers, longitudinal costae and a terminal aperture with a phialine lip under *Pyramidulina*. *Nodogenerina* differs from *Pyramidulina* by having companulate chambers with a row of spines at the edge of the chamber shoulder. *Orthomorphina* has a globular proloculus, later chambers increasing rapidly in height rather than breadth, becoming ovoid in outline; sutures slightly depressed; aperture terminal with an averted rim.

In the present study, *Nodogenerina challengeriana* Thalman is placed under *Pyramidulina* based on the Loeblich and Tappan's description. *Nodosaria perversa* Schwager shows a very elongated last formed chamber and a circular aperture on a pointed neck.

Occurrence: Rare and sporadic to common from Early Miocene through Middle Miocene samples of sites 588A and 588B. Rare in Late Miocene samples of sites 587 and 588B. Frequent in two Pliocene samples of site 589 and common in Pleistocene of site 589.

Subfamily	LENTICULININAE Chapman, Parr and Collins, 1930
Genus	ROBULUS Reuss

Robulus limbosus (Reuss)

Robulina limbosa REUSS, 1855, p. 55, pl. 6, fig. 69. — CUSHMAN, 1933, p. 3, pl. 1, figs. 4-6, pl. 2, fig. 5. — TODD, 1965, p. 3, pl. 1, figs. 4-6.

Description: Test biconvex lenticular, closely coiled, biumbonate with umbonal boss, chambers 6-8, wedge - shaped, uniform size as added, periphery acute with a strong keel, sutures distinctly limbate, curved, tangential to the central portion, wall smooth and transparent. Aperture radiate at the peripheral angle, ventral slit distinct.

Remarks: *Robulina* differs from *Lenticulina* in having a ventral slit in the radiate aperture, otherwise it is identical to *Lenticulina*. *Robulina simplex* d'Orbigny possess thin radial sutures.

Occurrence: Rare and sporadic in Early Miocene through the Quaternary samples of all sites.

FAMILY	VAGINULINIDAE	Reuss, 1860
Subfamily	VAGINULININAE	Reuss, 1860
Genus	VAGINULINA	d'Orbigny, 1826

Vaginulina elegans d'Orbigny

Vaginulina elegans D'ORBIGNY, 1826, p. 257, fig. 33. NOT KUBLER and ZWINGLI, 1866, p. 8. *Vaginulina legumen* (Linnaeus) var. *elegans* Fornasini. CUSHMAN, 1921, p. 258, pl. 41, fig. 4.

Description: Test elongate, uniserial, rectilinear, tapering basal end with a spine; ventral margin acute, 7-8 inflated chambers; sutures more oblique on ventral side, dorsal side somewhat straight, limbate but not raised; surface smooth, transparent; aperture terminal, radiate, located on dorsal margin.

Remarks: The species described by Kubler and Zwingli (1866) has fewer chambers, the dorsal margin shows lobulate periphery and chambers are highly inflated. The present species differs from *Vaginulina legumen* (Linné) by not having a beaded appearance and by possessing inflated chambers and a basal spine; aperture is on an extended neck.

Occurrence: Common in Early Miocene through Middle Miocene samples of site 588. Rare and sporadic in Pliocene and the Pleistocene samples of site 587 and 589.

Vaginulina legumen (Linné)

Nautilus legumen LINNE, 1758, p. 711. NOT CUSHMAN, 1913, p. 80, pl. 39, fig. 4.

Vaginulopsis sublegumen Parr. BARKER, 1960, p. 138, pl. 66, figs. 13-14.

Description: Test elongate, uniserial, rectilinear, laterally compressed, chambers numerous; dorsal margin subrounded, ventral margin acute, chambers inflated; sutures horizontal, very thick and elevated, giving beaded appearance; surface smooth, aperture radiate, located at dorsal margin.

Remarks: Cushman's (1913) illustration does not show any of the traits of the present species. See also under remarks of *Vaginulina elegans* d'Orbigny.

Occurrence: Two specimens from the Early Miocene of site 588A.

Family LAGENIDAE

Genus HYALINONETRION Patterson and Richardson, 1988

Hyalinonetrion sahalense PATTERSON and RICHARDSON, 1988, p. 243, figs. 5-6.

Description: Test unilocular, fusiform, long, maintaining a constant maximum diameter for the main portion of the test; sides are parallel and tapering gradually, two walls originate just above the apical and apertural ends; aperture small, round with a small phialine lip, wall smooth.

Remarks: In the present study, my specimens are more elongate spindle shaped and match all the characteristics of the holotype. The genus *Hyalinonetrion* differs from *Lagena* by having a fusiform test and an elongate neck. The present species also somewhat resembles *Lagena distomapolita* Walker and Jacob but the present species has a gradually tapering test.

Occurrence: Rare and sporadic in Pliocene and Pleistocene samples at sites 587 and 589.

Genus PYGMAEOSEISTRON Patterson and Richardson, 1988

Pygmaeoseistrion hispidula (Cushman)

Lagena hispidula CUSHMAN, 1913, p. 14, pl. 5, figs. 2-3. *Pygmaeoseistron hispidula* (Cushman). PATTERSON and RICHARDSON, 1988, p. 243, figs. 7-10.

Description: Test unilocular, subglobular, wall calcareous, somewhat translucent, surface coarse; aperture small circular with a phialine lip on an elongated neck.

Remarks: Patterson and Richardson (1988) proposed a distinction between *Lagena* and *Pygmaeoseistron*; the latter lacks costae and it also differs from *Pygmaeoseistron* by possessing a globular test, rather than fusiform. The above authors transferred all lagenid species which had subglobular, rough surface to the present genus. *P. hispidula* also resembles *Lagena hispida* Reuss but the former can be differentiated on the basis of even, finer spines.

Occurrence: Rare and sporadic in Miocene samples of site 588.

Genus PROCEROLAGENA Puri, 1954

Procerolagena purii ANDERSEN, 1961, p. 79, pl. 16, fig. 6.

Description: Test unilocular, elongate, constant diameter for most of the test; tapering at both ends; 5-6 longitudinal costae extend from the base to the apertural end; aperture terminal and rounded.

Remarks: The species can be easily confused with *Lagena gracillima* Williamson but the latter has more, closely spaced longitudinal costae.

Occurrence: Sporadic in Middle Miocene samples of site 588B.

Genus LAGENA Walker and Jacob

Lagena meridionalis Wiesner

Lagena gracilis (Williamson). BRADY, 1884, p. 464, pl. 58, fig. 19. *Lagena gracilis* var. CUSHMAN, 1913, p. 25, pl. 8, fig. 7. *Lagena gracilis* Williamson, var. *meridionalis* WIESNER, 1931, p. 117, pl. 18, fig. 211. *Lagena meridionalis* Wiesner, LOEBLICH and TAPPAN, 1954, p. 62, pl. 12, fig. 1.

Description: Test unilocular, subglobular, broadest near the base, tapering towards apertural end; numerous longitudinal costae extend from the base to slightly below apertural neck; neck narrow and slightly elongate aperture small and rounded.

Occurrence: Rare and sporadic in Early to Middle Miocene samples of site 588.

Family ELLIPSOLAGENIDAE Silvestri, 1923

Subfamily OOLININAE Loeblich and Tappan, 1961

Genus FAVULINA Patterson and Richardson

Favulina hexagona Williamson

Entosolenia squamosa Montagu var. *hexagona* Williamson, 1848, p. 20, pl. 2, fig. 23.

Lagena hexagona (Williamson) BRADY, 1884, p. 472, pl. 58, figs. 32. *Favulina hexagona* (Williamson) PATTERSON and RICHARDSON, 1988, p. 249, figs. 32-33, 47.

Description: Test unilocular, globular to slightly ovate, circular in side view; surface is ornamented with a network of raised polygonal ridges; aperture small and terminal on a weakly developed neck.

Remarks: The present species has been reported in the literature as either *Lagena hexagona* (Williamson) or *Oolina melo* d'Orbigny. Patterson and Richardson transferred all the species which possess reticulate outer surface ornamentation to the genus *Favulina*.

Occurrence: Single specimens occur in Early Miocene through Pliocene samples of sites 587 and 588A.

Favulina quasiperthensis PATTERSON, 1986c, p. 75, pl. 10, figs. 7 — 9 .

Description: Test unilocular, subglobular, circular in side view; numerous longitudinal costae extend from the base and a few costae extend up to the neck; numerous fine transverse costae extend across the longitudinal costae; aperture small and circular at end of short neck.

Remarks: The present species differs from *Lagena substriata* (Williamson) by possessing transverse costae.

Occurrence: Single specimen occurs in Late Miocene sample of site 588B.

Genus EXSCULPTINA Patterson and Richardson

Exsculptina sidebottomi (Earland)

Lagena sidebottomi EARLAND, 1936, p. 161, pl. 7, fig. 23. *Exsculptina sidebottomi* (Earland). PATTERSON and RICHARDSON, 1988, p. 247, pl. 14-21.

Description: Test unilocular, pyriform to conical, circular in side view; slightly translucent, surface with minute pores; basal margin excavated, truncate; aperture round and terminal.

Remarks: *Exsculptina* differs from other genera of the Oolininae in possessing incised rather than raised surface sculpture (Patterson and Richardson, 1988).

Occurrence: Rare and sporadic in Early Miocene of site 588.

Genus HOMALOHEDRA Patterson and Richardson, 1988

Homalohedra subamphora (Asano)

Lagena subamphora ASANO, 1956, p. 38, pl. 5, figs. 23-25. *Homalohedra subamphora* (Asano). PATTERSON, 1986b, p. 106, pl. 19, figs. 10-11.

Description: Test unilocular, subglobular, circular in side view, broad near middle of the test; 10-14 longitudinal costae extend from the base to smooth area just beneath aperture; aperture small and circular, on an elongated neck.

Remarks: The present species has more costae than in the figured holotype.

Occurrence: Single specimen in Late Miocene sample of site 588B.

Subfamily ELLIPSOLAGENINAE Silvestri, 1923

Genus LAGENOSOLENIA McCulloch, 1977

Lagenosolenia elliptica (Cushman)

Lagena orbignyana (Seguenza) var. *elliptica* CUSHMAN, 1923, p. 42, pl. 6, figs. 10-12.
Lagena elliptica CUSHMAN. BOLTOVSKOY and WATANABE, 1977, p. 53, pl. 3, fig. 4.
Lagena solenia elliptica (Cushman). PATTERSON, 1986b, p. 109, pl. 20, figs. 1-4.

Description: Test unilocular, partly elongate, pyriform, compressed; thin lateral keel covers entire test; two sharp peripheral keels follow the outer edges of the test and terminate at the base of the neck; aperture small and oval.

Remarks: The species in the present study does not show any hispid projections as described in holotype.

Occurrence: Rare and sporadic in the Middle Miocene samples of site 588B.

Genus FISSURINA Reuss, 1850

Fissurina auriculata (Brady)

Lagena auriculata BRADY, 1884, p. 487, pl. 60, fig. 29. *Fissurina auriculata* (Brady). BARKER, 1960, p. 126, pl. 60, fig. 29.

Description: Test unilocular, pyriform, laterally compressed; two compressed, open end depressions project at the base of the test, test slightly tapered towards apertural end; aperture small and oval.

Remarks: The present species is distinguished from others by possessing open end depressions at the base of the test.

Occurrence: Single specimens occurring in Early and Middle Miocene samples of site 588.

Fissurina marginata (Montagu)

Vermiculum marginatum MONTAGU, 1803, p. 524. *Fissurina marginata* (Montagu). ASANO, 1956, p. 53, pl. 5, figs. 59-60. *Entosolenia marginata* (Montagu). CUSHMAN and GRAY, 1946, p. 30, pl. 5, figs. 19-20. *Entosolenia submarginata* BOOMGAART, 1949, p. 107, pl. 9, fig. 7. — BARKER, 1960, p. 124, pl. 59, fig. 21.

Description: Test free, unilocular, compressed, periphery with a thin narrow keel, ovate in side view with slightly produced apertural end; wall smooth, finely perforate, aperture terminal at the end of thickened neck, somewhat elliptical.

Remarks: Boomgaart (1949) described *Fissurina submarginata* but it is essentially the same as that of Montagu's species hence it is a junior synonym of *Fissurina marginata* (Montagu).

Occurrence: Rare and sporadic in Early Miocene to Pleistocene samples of three sites.

Subfamily PARAFISSURININAE Jones, 1984

Genus PARAFISSURINA Parr, 1947

Parafissurina carinata (Buchner)

Lagena lateralis Cushman *forma carinata* BUCHNER, 1940, p. 521, pl. 23, figs. 497-500.

Parafissurina lateralis (Cushman) *forma carinata* (Buchner).

Description: Test unilocular, circular in side view; wall translucent, smooth; a thin marginal carina of moderate width completely surrounds the test and terminates near the aperture; aperture elongate, at one side shows a small dent.

Occurrence: Single specimens occur in Early Miocene samples of site 588A.

Parafissurina sp.

Test unilocular, partly elongate, subglobular, test slightly compressed; aperture protruding, elongate, opening parallel to the periphery.

Occurrence: Single specimens occur in Middle Miocene samples at sites 588A and 588B.

Genus LAGNEA R.W. Jones, 1984

Lagnea sp

Description: Test unilocular, elongate, compressed, widest near the middle of the test; carina extends from the aperture and covers entire periphery except a small area at the base; carina bifurcates and separated by a series of cross struts; aperture circular and projecting at the top of the test.

Occurrence: Single specimens occur in the Late Miocene and one Pliocene sample of 588A and 567, respectively.

Suborder ROBERTININA Loeblich and Tappan, 1984

Superfamily CERATOBULIMINACEA Cushman, 1927

Family EPISTOMINIDAE Wedekind, 1937

Subfamily EPISTOMININAE Wedekind, 1937

Genus HOEGLUNDINA Brotzen, 1948

Hoeglundina elegans (d'Orbigny)

Rotalia (Turbinulina) *elegans* D'ORBIGNY, 1826, p. 276. *Pulvinulina elegans* (d'Orbigny). BRADY, 1884, p. 699, pl. 105, figs. 5-6. *Hoeglundina elegans* (d'Orbigny). PHLEGER and PARKER, 1951, p. 22 pl. 12, fig. 10. —. PHLEGER, PARKER, and PEIRSON, 1953, p. 43, p. 1.9, figs. 24-25.

Description: Test trochospiral, biconvex, 8-9 chambers in the final whorl, enlarging gradually in size as added; sutures curved back wards at the periphery on spiral side, oblique on umbilical side; periphery with a distinct keel; surface smooth; primary aperture lateromarginal and slit-like parallel to the peripheral keel, secondary apertures interiomarginal on the umbilical side.

Remarks: This species is distinguished by its primary lateromarginal aperture and secondary interiomarginal aperture, and also with a thick opaque wall.

Occurrence: Common in one Pleistocene sample of site 587.

Suborder ROTALINA Delage and Herouard, 1896

Superfamily BOLIVINACEA Glassner, 1937

Family BOLIVIDAE Glassner, 1937

Genus BOLIVINA d'Orbigny, 1839

Bolivina advena Cushman

Bolivina advena CUSHMAN, 1925, P.29, Figs 1a&b.

2

MICROD

Description: Test elongate, somewhat fusiform, early portion compressed, greatest breadth toward the apertural end, chambers distinct; sutures of early chambers somewhat limbate, later becoming thin and depressed; aperture narrow, elongate opening at the base of the last formed chamber; wall smooth but distinctly perforate.

Remarks: *Bolivina advena* Cushman differs from *Bolivina dilatata* Reuss by having subrounded periphery, fewer chambers and depressed limbate sutures. *Bolivina compacta* Sidebottom has less compressed test and the wall is ornamented by a series of irregularly arranged pores.

Occurrence: Rare in Early Miocene through the Late Miocene samples of sites 588A and 588B.

Bolivina cincta Heron-Allen and Earland

Bolivina cincta HERON-ALLEN and EARLAND, 1932, p. 356, pl. 9, figs. 16-18. —. CUSHMAN, 1937, p. 150, pl. 19, figs. 21-23.

Description: Test about twice as long as broad, compressed, tapering, greatest breadth at the last pair of chambers, periphery truncate; chambers slightly inflated, much broader than high; sutures distinct, limbate, somewhat raised in early portion later depressed, oblique, making 45° with the horizontal; Surface rough, wall perforated, opaque at sutures; aperture elongate, narrow with a slight lip.

Remarks: The present species differs from *Bolivina minuta* Natland by having more compressed test, with less numerous chambers and limbate sutures. It also superficially resembles *Bolivina subreticula* Parr but the latter has limbate sutures, wall ornamented with irregular costae.

Occurrence: Rare and sporadic in Middle Miocene samples of site 588B. Two specimens from Pliocene of site 587.

Bolivina compacta Sidebottom

Bolivina robusta (Brady) var. *compacta* SIDEBOTTOM, 1905, p. 15, pl. 3, fig. 7. *Bolivina compacta* Sidebottom. CUSHMAN, 1921, p. 137, pl. 26, fig. 7. —. TODD, 1965, p. 20, pl. 7, figs. 2-3.

Description: Test elongate, tapering, $2\frac{1}{2}$ to 3 times as long as broad; initial end bluntly rounded, 8-9 pairs of inflated chambers; sutures depressed, periphery lobulate, aperture elongate, extending from the base of the last formed chamber; wall ornamented with a series of coarse irregularly arranged pores.

Remarks: The present species differs from *Bolivina robusta* (Brady) by not possessing a broad robust test. See also under remarks of *Bolivina advena* Cushman.

Occurrence: Common in Early Miocene samples of site 588A; common in two samples of Middle Miocene of site 588B, and Late Miocene of site 587. Rare in Pleistocene samples of site 589.

Bolivina dilatata Reuss

Bolivina dilatata REUSS, 1850, p. 381, pl.48, fig.15. —, CUSHMAN, 1911, p. 33, T.f. 54.

Description: Test twice as long as broad, regularly tapering, highly compressed; periphery acute, chambers 6-7 pairs, long and broad throughout maintaining uniform shape; sutures oblique, depressed, making 45° angle with the horizontal; aperture narrow, an elongate slit, surface distinctly perforate.

Remarks: The present species differs from *Bolivina spathulata* Williamson by possessing a very compressed test with fewer chambers.

Occurrence: Rare in Early Miocene of site 588A; Common in Middle Miocene of 588A; rare to common in Late Miocene through Pleistocene samples of sites 588B, 587 and 589.

Bolivina minuta Natland

(Pl.1, fig.2)

Bolivina minuta NATLAND, 1938, p. 146, pl. 5, fig. 10. —. PHLEGER, PARKER and PEIRSON, 1953, p. 35, pl. 7, fig. 12. —. KURIHARA and KENNETT, 1986, p. 1070, pl. 2, fig. 3. *Bolivinita minuta* (Natland). HEIMAN, 1977, p. 87, pl. 4, fig. 2.

Description: Test elongate, compressed, sides nearly parallel, periphery flattened and truncated, lobulate; 9-10 pairs of low and broad chambers rapidly expanding from the initial end, sutures thin and raised, oblique, making 40° angle with the horizontal; wall coarsely perforated, giving a very rough appearance; aperture loop-shaped at the inner-margin of the last formed chamber.

Remarks: This species superficially resembles *Bolivina cincta* Heron-Allen and Earland but it differs by having very broad and long test, with numerous chambers and a very rough surface appearance because of coarse perforations. It is also similar to *Bolivina subexcavata* Cushman and Wickenden but the latter has more globular chambers and a rounded periphery, with sinuous sutures.

Occurrence: Rare and sporadic in Early Miocene of site 588A; frequent in Late Miocene and Pliocene samples of site 588B and Pleistocene of site 587.

Bolivina pseudoplicata Heron-Allen and Earland

(Pl.1, fig.4)

Bolivina pseudoplicata HERON-ALLEN and EARLAND, 1930, p. 81, pl. 3, figs. 36-40. —. HEIMAN, 1977, p. 87, pl. 4, fig. 3.

Description: Test twice as long as broad, 6-8 pairs of chambers, surface with pronounced ornamentation consisting of numerous pits surrounded by ridge-like projections; aperture narrow, an elongate slit at the inner margin of the last formed chamber.

Remarks: The present species is distinguished from other species on the basis of ornamentation. It shows similar features to *Abditodentrix pseudothalmanni* (Boltovskoy) but differs in not having irregular broken raised limbate sutures.

Occurrence: Common in one sample of Early Miocene of site 588A; rare to common in Middle Miocene of site 588A; common to frequent in Late Miocene samples of sites 588B and 587. Rare and sporadic in Pleistocene samples of site 589.

Bolivina robusta (Brady)

(Pl.1, fig.5)

Bolivina robusta BRADY, 1881, p. 421, pl. 53, figs. 7-9. —. CUSHMAN, 1911, p. 36, T.F. 59-60. —. BARKER, 1960, p. 108, pl. 53, figs. 7-9. —. TODD, 1965, p. 17, pl. 6, fig. 2.

Description: Test about twice as long as broad, greatest breadth at the last pair of chambers; periphery subacute, 7-8 pairs of chambers, slightly inflated, increasing gradually in size; sutures oblique, curved, making a 45° angle with the horizontal;

basal margins of the chambers possess alternating lobe and ridge-like projections. Wall ornamented with coarse perforations; aperture is small and oval.

Remarks: The species is distinguished from *Bolivina compacta* Sidebottom by its robust appearance. In the present study, a few specimens showed a distinct basal spine.

Occurrence: Rare and sporadic from Early Miocene through Pliocene samples of site 587, 588A and 588B. Common in Pleistocene samples of site 589.

Genus BRIZALINA Costa, 1856

Brizalina beyrichi (Reuss)

(Pl. I, fig. 1)

Bolivina beyrichi REUSS, 1851, p. 83, pl. 6, fig. 51. — CUSHMAN, 1911, p. 35, T.f. 56B.

Bolivina alata (Sequenza). PHLEGER and PARKER, 1951, p. 12, pl. 6, fig. 11. *Bolivina pseudobeyrichi* (Cushman). BELFORD, 1966, p. 28, pl. 1, figs. 13-16, TG.f. 2 (4-6).

Bolivina pygmaea Brady. HERMELIN and SCOTT, 1985, p. 204, pl. 2, fig. 15.

Description: Test elongate, strongly compressed, three times as long as broad, 6-8 pairs of chambers; periphery lobulate, each chamber shows at the end a distinct backwardly projecting point; chambers increasing rapidly in size; sutures distinct, depressed, making a 35° angle with the periphery; aperture elongate oval with a lip.

Remarks: This species somewhat resembles *Bolivina difformis* (Williamson) but the latter is more compressed, and has very sharp, long, backwardly projecting spines at the end of each chamber. It also differs from *Bolivina alata* (Sequenza) by not having broad, more inflated chambers, and a distinct peripheral keel.

Occurrence: Common in Pliocene samples of site 587 and in Pleistocene samples of sites 587 and 589.

Brizalina oceanica (Cushman)

Bolivina oceanica CUSHMAN, 1937, p. 147, pl. 19, fig. 31. — TODD, 1965, p. 24, pl. 7, fig. 4.

Description: Test small, slender, tapering, compressed, 8-10 pairs of chambers which are of uniform size and shape; sutures distinct, depressed; aperture small; surface smooth and translucent.

Remarks: *Bolivina oceanica* Cushman differs from *Bolivina vadeszens* Cushman by possessing uniformly shaped and size chambers. The present species is more slender than the latter form. The former species also characterized by thick, oblique, curved sutures.

Occurrence: Rare and sporadic in Miocene through the Pleistocene samples at all sites.

Brizalina Pusilla (Schwager)

(Pl.1, fig.3)

Bolivina pusilla SCHWAGER, 1866, p. 254, pl. 7, fig. 101. —. CUSHMAN, 1911, p. 41, T.f. 67. —. PFLUM and FRERICHs, 1976, pl. 1, fig. 7. —. HEIMAN, 1977, p. 88, pl. 4, fig. 60. —. BOLTOVSKOY, 1978, p. 152, pl. 1, figs. 16-18.

Remarks: The description of Schwager (1866) is followed herein. The present species is distinguished by 6-8 pairs of chambers. sutures straight, limbate, and test surface ornamented with numerous sinuous fine costae which are continuous across the sutures and all of them extend from the pointed basal end of the test to about the middle of the last formed chamber.

Occurrence: Rare and sporadic in Miocene of site 588A; common in Middle through Late Miocene of holes 588A and 588B; common in two Pliocene samples of site 587. Rare and sporadic in Pleistocene of sites 587 and 589.

Brizalina spathulata (Williamson)

Textularia variabilis Williamson var. *spathulata* WILLIAMSON, 1858, p. 76, pl. 6, figs. 164-165. *Bolivina spathulata* (Williamson). CUSHMAN, 1937, p. 162, pl. 15, figs. 20-24. —. BARKER, 1960, p. 106, pl. 52, figs. 20-21.

Description: Test elongate, compressed, about $2\frac{1}{2}$ times as long as broad, 9-10 pairs of inflated chambers, much broader than height, increasing regularly in size as added; periphery acute, sutures oblique and depressed; aperture narrow elongate slit; surface smooth and perforate.

Remarks: The present species differs from *Bolivina dilatata* Reuss by having a much more compressed test with more inflated chambers. *Bolivina catenensis* Sequenza appears similar but it has very elongated, tapering, test, with oblique sutures.

Occurrence: Rare and sporadic in Early Miocene through the Pliocene of site 588A and 588B; common in two Pleistocene samples of site 589.

Brizalina subaenariensis Cushman

Bolivina subaenariensis CUSHMAN, 1922, p. 46, pl. 7, fig. 6. —. BARKER, 1960, p. 110, pl. 53, fig. 10. —. MURRAY, 1971, p. 111, pl. 45.

Description: Test elongate, much compressed tapering, 8-10 pairs of chambers; periphery acute, thinly carinate; sutures oblique, depressed; surface ornamented with long thin raised costae running from the base to the middle of the test, later chambers smooth and transparent; aperture semicircular.

Remarks: The present species superficially resembles *Brizalina pusilla* (Schwager) but differs by having less compressed, broader test, with costae extending only up to the middle of the test.

Occurrence: Rare and sporadic from Middle Miocene through Pleistocene samples of all sites.

Brizalina vadescens Cushman

Bolivina vadescens CUSHMAN, 1933, p. 81, pl. 8, fig. 11. —. TODD, 1965, p. 15, pl. 5, fig. 4.

Description: Test elongate, twice as long as broad, periphery subrounded, tapering, 12-13 pairs of chambers, early chambers rapidly increasing in width as added, later becoming uniform in shape and size; sides parallel, sutures distinct, sigmoid, slightly limbate; aperture loop-shaped at the inner margin of the last formed chamber; surface smooth, translucent and distinctly perforate.

Remarks: This species is distinguished by its sigmoid sutures. See also under remarks of *Brizalina oceanica* (Cushman).

Occurrence: Rare and sporadic throughout the Miocene to Pleistocene of all sites.

Superfamily LOXOSTOMATACEA Loeblich and Tappan, 1962

Family BOLIVINELLIDAE Hayward, 1980

Genus BOLIVINELLA Cushman, 1927

Bolivinella folia (Parker and Jones)

Textularia folium PARKER and JONES, 1865, p. 370, pl. 18, fig. 19. — CUSHMAN, 1911, p. 19, T.f. 31-33. *Bolivinella folia* (Parker and Jones). BARKER, 1960, p. 876, pl. 42, figs. 1-2. — LOEBLICH and TAPPAN, 1964, pc. 526, fig. 411 (4a-b).

Description: Test free, strongly compressed, broad and triangular in front view, 8-9 pairs of very broad, narrow chambers, widest near the middle, tapering towards both ends; chambers in alternating series; sutures thick and sigmoid, thick median suture slightly raised; periphery shows minute spines at the outer angle of each chamber.

Remarks: The species differs from *Bolivinella margaritacea* Cushman by having very broad and low chambers. The latter species also has minute tubercles on the sutures.

Occurrence: The species occur only in one Pliocene sample (three specimens) and in Pleistocene samples (one specimen in each) from site 589.

Superfamily BOLIVINITACEA Cushman, 1927

Family BOLIVINITIDAE Cushman, 1927

Genus ABDITODENTRIX Patterson, 1985

Abditodentrix sp. cf. *A. pseudothalmanni* (Boltovskoy)

Bolivinita pseudothalmanni BOLTOVSKOY, 1981b, p. 44-46, pl. 1, figs. 1-5. *Abditodentrix asketocompiella* PATTERSON, 1986b, p. 140, pl. 1, figs. 1-9.

Description: Test elongate, biserial throughout, sides flattened, edges truncate, 6-8 pairs of chambers; sutures elevated on the flat sides of the test giving serrate margins; wall ornamented with numerous reticulations; aperture elongate, narrow at the inner margin of the last-formed chamber.

Remarks: Specimens in the present study show prominent reticulations all over the test, but in the type species reticulations confined only to the initial portion of the test.

Otherwise the specimens are identical with the type species. The coarse reticulations, truncate periphery with serrate margins are diagnostic features of the present species.

Occurrence: The species is rare and sporadic in Early Miocene samples at site 588A. Three specimens were found in samples from the Pleistocene site at 589.

Genus **BOLIVINITA** Cushman, 1927

Bolivinita quadrilatera (Schwager)

Textularia quadrilatera SCHWAGER, 1866, p. 253, pl. 7, fig. 10. CUSHMAN, 1911, pl. 24, figs. 42-44. *Bolivinita quadrilatera* (Schwager). BARKER, 1960, p. 86, pl. 42, figs. 8-12.

Description: Test elongate, tapering, compressed, 7 pairs of high and narrow chambers, gradually increasing in size; periphery flat with a truncate keel on either side; sutures straight and slightly depressed; aperture slightly at one side of the base of the last formed chamber, slightly elongated; wall distinctly perforate.

Remarks: Specimens in the present study do not show a broad spine. The species is distinguished by the quadrilateral appearance in end view, with the flattened somewhat truncate periphery and well developed keel on either side of the test.

Occurrence: Only four specimens from the Pliocene sample at site 587.

Superfamily **CASSIDULINACEA** d'Orbigny, 1839

Family **CASSIDULINIDAE** d'Orbigny, 1839

Subfamily **CASSIDULININAE** d'Orbigny, 1839

Genus **CASSIDULINA** d'Orbigny, 1839

Cassidulina biora Crespin

(Pl.2, figs.1 - 2)

Cassidulina biora CRESPIN, 1960, p.146, pl.3, figs.3 -5.

Description: Test biconvex, almost circular in side view, ovate on edge view, periphery subrounded, 5 pairs of chambers in the last formed whorl, last formed chamber slightly larger, partly overlapping previous chamber on the ventral side; sutures slightly

depressed; aperture oval and large, on ventral side, partly covered by tooth-plate; surface smooth and polished.

Remarks: This species shows wide range of variation in degree of compression of the test. *Cassidulina bora* differs from *Globocassidulina minuta* Cushman in having a subrounded periphery and less depressed sutures. The present species also superficially resembles *Globocassidulina crassa* (d'Orbigny) but the latter has a typical tripartite, extended aperture.

Occurrence: Rare to common in Early Miocene samples at site 588A, common in Middle Miocene at site 588A and 588B. Rare and sporadic in Late Miocene and Pliocene samples at site 587 and 589.

Cassidulina carinata Silvestri

Cassidulina laevigata (d'Orbigny) var. *carinata* SILVESTRI, 1896, p. 104. [not *Cassidulina carinata* (Silvestri). CUSHMAN, 1922, p. 124]. *Cassidulina carinata* Silvestri. BARKER, 1960, p. 110, pl. 54, figs. 2-3. —. TODD, 1965, p. 40, pl. 17, fig. 4. —. BELFORD, 1966, p. 138, pl. 24, figs. 1-4; T.f. 16(1-2). —. MURRAY, 1971, p. 187, pl. 78, figs. 1-5. —. MEAD, 1985, p. 232, pl. 3, figs. 1-3. *Cassidulina laevigata carinata* Silvestri. INGLE *et al.*, 1980, p. 131, pl. 6, figs. 5-6. *Cassidulina carinata* Silvestri NOMURA, 1983b. p. 51, pl. 4, figs. 9-11.

Description: Test biconvex, nearly circular in side view, periphery with thin keel, lobulate; chambers elongated, curved, last pair of chambers inflated, 4 pairs of chambers in the last whorl; sutures distinct, depressed, slightly limbate; aperture elongate, narrow slit at the base of the apertural face parallel to periphery; wall smooth and polished.

Occurrence: Rare and sporadic in Early Miocene through Late Miocene samples at site 588A and 588B. Rare to common in Early Pliocene through Pleistocene samples at site 587 and 589.

Cassidulina cuneata Finlay

(Pl.2, figs.3 - 4)

Cassidulina cuneata FINLAY, 1940, p. 456, pl. 63, figs. 62-66. —. HORNIBROOK, 1961, p. 61. *Globocassidulina molluccensis* (Germeraad). BELFORD, 1966, pl. 26, figs. 10-11. —. PFLUM and FRERICHS, 1976, pl. 4, fig. 5. *Cassidulina cuneata* Finlay. HEIMAN, 1977, p. 154, pl. 11, figs. 15-16. —. MURRAY, 1971, p. 187, pl. 78, figs. 1-5. —. MEAD, 1985, p. 232, pl. 3, figs. 1-3.

Description: Test medium, cuneate, wedge shaped; chambers triangular except the central, which is square shaped, and bulbous; sutures distinct, slightly limbate; aperture semicircular, large, set at 45° to the suture with a strong flat tooth; surface smooth and polished.

Remarks: The species is distinguished by a bulbous central chamber and a large semicircular aperture. *Cassidulina cuneata* Finlay also resembles *Globocassidulina murrhyna* Schwager but latter differs by chink-like aperture produced on a beak-like last chamber. *Globocassidulina molluccensis* (Germeraad) described by Belford (1966) has distinct central square shaped chamber surrounded by triangular chambers.

Occurrence: Abundant in Early Miocene samples at sites 588C and 588A. Common in Middle Miocene samples at sites 588A and 588B. Only two specimens were recovered from Pliocene samples site 587.

Cassidulina laevigata d'Orbigny

(Pl.2, fig.5,6)

Cassidulina laevigata d'ORBIGNY, 1826.

Description: Test lenticular to flattened, periphery subangular, 5 pairs of long, broad, low chambers planispirally enrolled; sutures flush, somewhat radial and curved; surface smooth; aperture a narrow arched slit at the base of apertural face, parallel to the peripheral margin, slightly closed by an apertural plate.

Remarks: The species is characterized by possessing long broad low chambers. *C. laevigata* differs from *Globocassidulina minuta* by having larger and much more compressed test.

Occurrence: Rare and sporadic in Early Miocene samples at site 588A. Common in the Middle and Late Miocene samples from site 588A and 588B, and 587.

Cassidulina reflexa Galloway and Wiessler

Cassidulina reflexa GALLOWAY and WIESSLER, 1927, p. 80.

Description: Test equally biconvex, planispirally enrolled, biumbonate, 7-8 pairs of chambers in the last whorl, meeting the periphery at an angle; periphery subacute; sutures distinct, limbate; aperture an elongate slit, parallel to the plane of coiling; wall finely perforated.

Remarks: The species resembles *Cassidulina tortuosa* Cushman and Hughes but the latter has knob-like bluntly rounded chambers around the umbo. *C. reflexa* also superficially resembles *Cassidulina curvata* Phleger and Parker but the latter has a coarsely perforated test, with an acute margin.

Occurrence: Rare and sporadic in Miocene samples at site 588A and 588B. Very rare in three Pleistocene samples from sites 589 and 587.

Genus CASSIDULINOIDES Cushman, 1927

Cassidulinoides bradyi (Norman)

Cassidulina bradyi NORMAN in WRIGHT, 1881, p. 152. ____ BRADY, 1884, p. 431, pl. 54, figs. 6-9. *Cassidulinoides bradyi* (Norman). BOLTOVSKOY, 1978, p. 167, pl. 3, figs. 36-38. ____ PATTERSON, 1986b, p. 204, pl. 46, figs. 9-10.

Remarks: This species is well documented in the literature. *Cassidulinoides bradyi* is characterized by reniform, biserial test with a loop-shaped aperture on the inner end of slightly tapering final chamber. *Cassidulinoides tenuis* (Phleger and Parker) has more an elongated test with numerous chambers.

Occurrence. Rare in Early Miocene samples at site 588A and four Middle Miocene samples from the same site. The species was also rare and sporadic in Pliocene samples from site 587 and from Pleistocene samples at site 589.

Genus FAVOCASSIDULINA Loeblich and Tappen, 1957

Favocassidulina australis Eade

Favocassidulina australis EADE, 1967, T.f.1, no.23-24.

Description: Test elongate, central portion thick, periphery acute, lobulate, 6-8, comma shaped chambers thinning towards the periphery in final whorl, sutures distinct, depressed; aperture a narrow slit at center of the last formed chamber parallel to the periphery.

Remarks: This species has very coarse perforations over the surface, and differs from *Favocassidulina favus* (Brady) by not having honeycomb ornamentation.

Occurrence: Rare to common in Pleistocene samples at site 587.

Genus GLOBOCASSIDULINA Voloshinova, 1960

Globocassidulina crassa (D'Orbigny)

(Pl. I, figs. 8 & 9)

Cassidulina crassa D'ORBIGNY, 1839, p. 56, pl. 7, figs. 18-20. ____ CUSHMAN, 1929, p. 100, pl. 14, figs. 10 a-b. ____ PHLEGER and PARKER, 1951, p. 26, pl. 14, figs. 4 a-b. ____ BARKER, 1960, p. 110, pl. 54, figs. 4-5. *Globocassidulina crassa* (d'Orbigny) BELFORD, 1966, p. 151, pl. 26, figs. 5-9; T.f. 17: 9-10.

Description: Test small, compressed, nearly circular in side view, 5 pairs of chambers in the final whorl; periphery slightly lobulate and rounded with last formed chamber arch shaped; sutures distinct, depressed; aperture tripartite at the base of the last formed chamber and extending down along the suture; wall smooth and transparent.

Remarks: The present species differs from *Globocassidulina oriangulata* Belford by possessing the tripartite aperture.

Occurrence: Rare to common in Early Miocene site at 588A. Frequent in Middle Miocene samples at site 588A and 588B; common to abundant in samples from Late Miocene through the Pleistocene at sites 588B, 587 and 589.

Globocassidulina decorata (Sidebottom)

(Pl. I, fig. 11)

Cassidulina decorata SIDEBOTTOM, 1910, p. 107, pl. 4, fig. 2. *Globocassidulina decorata* (Sidebottom). BELFORD, 1966, p. 146, pl. 24, figs. 19-21, T.f. 16. ____ NOMURA,

1983b, p. 27, pl. 2, figs. 14-17. —, THOMAS, 1985, p. 676, pl. 7, fig. 5. —, PATTERSON, 1986b, p. 207, pl. 47, figs. 3-5.

Description: Test subglobular, slightly inflated, periphery broadly rounded, 4-5 pairs of chambers in the final whorl, sutures distinct, slightly curved; aperture at base of the last formed chamber; wall transparent, surface ornamented with a network of irregular costae except part of the final chamber.

Remarks: This species is characterized by strong ornamentation, subglobular test and narrow elongated aperture. *Globocassidulina decorata* differs from *Globocassidulina subglobosa* (Brady) by having dense ornamentation.

Occurrence: Common in three Pleistocene samples of site 587.

Globocassidulina minuta (Cushman)

(Pl. 2, figs. 7 & 8)

Cassidulina minuta CUSHMAN, 1933, p. 92, pl. 10, fig. 3. *Cassidulina crassa* (d'Orbigny). BARKER, 1960, p. 110, pl. 54, figs. 4-5. *Cassidulina minuta* Cushman. TODD, 1965, p. 43, pl. 17, fig. 3. —, BOLTOVSKOY, 1978, p. 155, pl. 2, fig. 29. —, HEIMAN, 1977, p. 156, pl. 11, figs. 7-8.

Description: Test minute, compressed, periphery broadly rounded with 4 pairs of slightly inflated chambers, as long as broad in last whorl; sutures distinct, slightly depressed; aperture a narrow slit 3-4 times as long as wide; wall smooth, and polished.

Remarks: This species differs from *Cassidulina bitor* Cressin by having more chambers and a narrow aperture parallel to the periphery. *G. minuta* Cushman also superficially resembles *Paracassidulina quasisulcata* (Belford) but the latter has an extended aperture.

Occurrence: Common in the Early Miocene at site 588C and 588A; rare to common in the Middle and Late Miocene at sites 588A and 588B. Common to abundant in Pliocene samples from site 587. Common in Pleistocene samples at sites 587 and 589.

Globocassidulina molluccensis (Germeraad)

Cassidulina molluccensis GERMERAAD, 1946, p. 72, pl. 2, figs. 29-32. —, PFLUM and FRERICHS, 1976, pl. 4, fig. 5. —, BURKE, 1981, pl. 2, figs. 9-10. *Cassidulina*

murrhyna (Schwager). BELFORD, 1966, p. 152, pl. 26, figs. 10-13; pl. 18, fig. 5.

Cassidulina molluccensis (Germeraad). TODD, 1965, p. 43, pl. 15, fig. 2.

Description: Test somewhat oval, periphery rounded, about 4 pairs of inflated chambers, involute, sutures limbate and slightly depressed; aperture large and loop-shaped, with a distinct tooth-plate at one side; wall smooth, and polished.

Remarks: The species differs from *Cassidulina lens* Earland by possessing an oval test with four pairs of chambers, whereas the latter has 5 pairs of chambers and is highly biconvex with a broadly rounded periphery. *C. murrhyna* (Schwager) is a typical tear drop-shaped form, with an apertural face that is very protruding and pointed.

Occurrence: Rare to common in Miocene samples from site 588A and 588B. Rare to sporadic in Pliocene and Pleistocene at sites 587 and 589.

Globocassidulina porrecta (Heron-Allen and Earland)

(Pl.1, fig. 10)

Cassidulina crassa d'Orbigny var. *porrecta* HERON-ALLEN and EARLAND, 1932, p. 358, figs. 34-37. *Cassidulina* sp. cf. *C. porrecta* Heron-Allen and Earland. ____ HEIMAN, 1977, p. 157, pl. 11, figs. 11-12.

Description: Test elongate, slightly compressed, one and one half times as long as broad with 5 pairs of slightly inflated chambers in final whorl; final chamber elongate, drawn out into a neck-like projection; sutures distinct, nearly flush with the surface; aperture an oblique slit, supported by a tooth-plate; wall smooth and polished.

Remarks: In the present study, this species shows a wide range of variation in the projection of the final chamber. In the final stages, this species tends to become uniserial with very outward projected final chamber. This is the most diagnostic character of the species.

Occurrence: Rare in Middle Miocene from site 588A; abundant in one sample from the Late Miocene at site 587; common in Pliocene samples at site 587; rare and sporadic in Pleistocene samples from site 589.

Globocassidulina rarilocula (Cushman)

Cassidulina rarilocula CUSHMAN, 1933, figs. 8-9. *Cassidulina subtumida* Cushman. TODD, 1965, p. 45, pl. 16, fig. 6. ____, HEIMAN, 1977, p. 159, pl. 11, figs. 3-4. *Globocassidulina rarilocula* (Cushman). PATTERSON, 1986b, p. 173, pl. 48, fig. 2.

Description: Test small, somewhat compressed and very broad, periphery broadly rounded with about 3 pairs of chambers in the final whorl; sutures distinct, slightly depressed; wall smooth, and finely perforate; aperture very broad and loop-shaped at the base of the last formed chamber with a weakly developed tooth-plate at one side.

Remarks: The present species differs from others by possessing very broad chambers and a broad loop-shaped aperture with a smooth tooth-plate. *Cassidulina subtumida* Cushman has 4 pairs of chambers about twice as long as broad, and the test is strongly compressed with an acute periphery.

Occurrence: Rare and sporadic in Early Miocene samples from site 588A. Very rare in Pliocene samples from site 589.

Globocassidulina subglobosa (Brady)

(Pl.2, fig.9)

Cassidulina subglobosa BRADY, 1881, p. 60. ____, BRADY, 1884, p. 430, pl. 54, fig. 17.(Fide Ellis and Messina,1940, *et seq.*) *Globocassidulina subglobosa* (Brady). BELFORD,1966, P.149,Pl.25,figs. 11-16.____BELANGER and BERGGREN, 1986, P.61, Pl.4 , fig.6.____Nienstedt and Arnold, 1988, P.247 PL.2, Fig.9

Remarks: This species is well-documented in the literature. In the present study, the species shows a wide range of variation in apertural angle with the suture. The subglobular test and elongate aperture with the tooth-plate in the final protruding chamber are characteristic features. *G. subglobosa* (Brady) differs from *G. oriangulata* Belford by not having the divided aperture.

Occurrence: Very abundant in Early Miocene samples from sites 588C and 588A. Abundant in Middle Miocene samples at site 588A and 588B. Frequent in Late Miocene samples from sites 588A and 588B. Common in Pliocene at sites 587 and 589. Abundant in Pleistocene samples of Sits 587 and 589.

Genus PARACASSIDULINA Nomura, 1983

Paracassidulina sulcata (Belford)

Cassidulina sulcata BELFORD, 1966, p. 142-144, pl. 24, figs. 11-14; T.f. 16 (7-8).

Cassidulina delicata Cushman. TODD and POST, 1954, p. 365-366, pl. 90, fig. 25.

Cassidulina sp. cf. *C. delicata* Cushman. HEIMAN, 1977, p. 155, pl. 11, figs. 5-6.

Description: Test medium, compressed, nearly circular in side view, elongate oval in edge view. Periphery narrowly rounded, 4-5 pairs of rhomboid chambers in the last whorl; sutures moderately curved towards periphery; aperture elongate, narrow, extend from end to end at the base of the last formed chamber; wall smooth to slightly rugged, translucent.

Remarks: The present species differs from *Globocassidulina minuta* Cushman by having very extended aperture.

Occurrence: Common in two Middle Miocene samples from site 588A. Common in one sample of Late Miocene at site 587. Rare and sporadic in Late Miocene through Pleistocene samples at site 587, 588B and 589.

Subfamily EHRENBEGININAE Cushman, 1927

Genus EHRENBEGINA Reuss, 1850

Ehrenbergina bosoensis Takayanagi

Ehrenbergina bosoensis TAKAYANAGI, 1951, p. 87-88, T.f. 8. *Ehrenbergina serrata* Reuss. ASANO, 1936, p. 40. *Ehrenbergina trigona* Goes. BELANGER and BERGGREN, 1986, p. 340, pl. 4, fig. 5. *Ehrenbergina bosoensis* (Takayanagi) NOMURA, 1983b, p. 61, pl. 4, figs. 18 a-c; pl. 5, fig. 7-9; pl. 22, fig. 7.

Description: Test triangular, broad in dorsal view, subtriangular in apertural view. Dorsal side convex, ventral side with a much reduced furrow. Periphery acute, 6-7 pairs of distinct chambers in final whorl; Edges of the chambers bear downward projecting short, sharp spines; dorsal sutures curved, overlapping and raised, ventral sutures slightly depressed; aperture an elongate, narrow, slightly curved slit at the base of the apertural face, parallel to the margin.

Remarks: The species is subtriangular to subquadrate in outline. Belanger and Berggren's illustration fits very well with the above description. Their species shows a very reduced ventral furrow and raised sutures. Therefore, possibly they might have misidentified the species. *Enrenbergina trigona* Goes has a distinct weak ventral furrow.

Occurrence: Rare and sporadic in Early through the Middle Miocene samples of site 588B. Only two specimens present in the Pleistocene samples of site 587.

Ehrenbergina bradyi Cushman

(Pl.2, figs. 10 - 12)

Ehrenbergina bradyi CUSHMAN, 1922, p. 134, pl. 26, fig. 5. *Ehrenbergina trigona* Goes. BRADY, 1884, pl. 55, figs. 2-3, ____ BARKER, 1960, p. 112, pl. 55, fig. 20. ____ HEIMAN, 1977, p. 162, pl. 12, figs. 13-15. ____ CORLISS, 1979a, p. 8, pl. 3, figs. 10-13. ____ HERMELIN and SCOTT, 1985, p. 206, pl. 4, figs. 15-16. ____ MEAD, 1985, p. 232, pl. 3, figs. 4-7.

Description: Test triangular, dorsal side slightly curved, smooth, sutures flush, ventral side with a prominent groove along the median line; wall finely perforate and smooth. each chamber extended into rounded, long, almost horizontal spines at peripheral margin; ventral borders of the chambers characterized by distinct carinal ridges; aperture an elongate curved slit set at right angles to the border of the final chamber parallel to the margin;

Remarks: *Ehrenbergina trigona* Goes can be easily confused with the present species. The former has a weakly developed ventral furrow but does not possess carinal ridges. In numerous papers (Hermelin and Scott, 1985; Mead, 1985; Corliss, 1979) illustration of *E. trigona* Goes shows distinct ventral furrow with partially developed carinal ridges. Therefore, *E. trigona* Goes as documented in the literature is possibly referable to *E. bradyi* Cushman.

Occurrence: Rare and sporadic in Middle Miocene samples from site 588A. Common in one sample of Pliocene of site 587.

Ehrenbergina carinata Eade

Ehrenbergina carinata EADE, 1967, p. 448-450.

Description: Test triangular in dorsal view, flat, chambers numerous, final chambers slightly inflated, periphery very sharp and distinctly carinate, with a large spine at the end of each chamber; sutures distinct, almost flush; apertural face flat and broad, aperture a narrow elongate slit parallel to the margin, ventral side covered with a faint lip.

Remarks: The species is readily distinguished by the triangular shape with a pronounced keel with sharp spines at the end of each chamber. This species differs from *E. bradvi* Cushman by not having a ventral furrow.

Occurrence: Three specimens from Pleistocene samples of site 589.

Ehrenbergina sp. cf. *E. cubensis* Cushman and Bermudez

Ehrenbergina cubensis CUSHMAN and BERMUDEZ, 1936, p. 38.

Description: Test slightly broader than the height in front view, somewhat compressed, periphery acute, chambers inflated, last pair extends more than half of the test, wall of the last chambers smooth; early chambers with slight plications; periphery with weakly developed spines at the chambers margins just previous to the last pair; aperture elongate, slightly curved.

Remarks: The present species differs from *E. trigona* Goes by having a compactly coiled initial end.

Occurrence: Only four specimens (two broken) from Late Miocene at site 588B.

Superfamily TURRILINACEA Cushman, 1927

Family STAINFORTHIDAE Reiss,

Genus STAINFORTHIA Hofker, 1956

Stainforthia complanata (Egger)

(Pl. 8, fig.3)

Virgulina schreibersiana Czjzek var. *complanata* EGGER, 1893, p. 292, pl. 8, figs. 91-92.

Stainforthia complanata (Egger). PHLEGER, PARKER and PEIRSON, 1953, p. 34, pl. 7, fig. 3. *Cassidella Pacifica* Hofker. BARKER, 1960, p. 106, pl. 52, figs. 2-3. *Virgulina*

complanata (Egger). TODD, 1965, p. 13, pl. 4, figs. 2-5. *Fursenkoina schreibersiana* (Czjzek). MURRAY, 1971, p. 185, pl. 77, figs. 7-8, 10. *Virgulina complanata* (Egger). BOLTOVSKOY 1978, p. 173, pl. 8, figs. 34-35. ____, INGLE, et al. 1980, p. 144, pl. 5, fig. 11. *Fursenkoina fusiformis* (Williamson). HERMELIN and SCOTT, 1985 p. 210, pl. 4, fig. 14. *Stainforthia complanata* (Egger). THOMAS, 1985, p. 678, pl. 2, fig. 9. ____, PATTERSON, 1986b, pl. 44, fig. 1. ____, KURIHARA and KENNETT, 1986, p. 1070, pl. 2, fig. 17.

Description: Test small, delicate, elongate, thin, biserial, twisted, chambers high and narrow, inflated, 4-5 pairs of chambers, sutures irregular, distinct, depressed; initial end with short spine; wall smooth; aperture loop-shaped in the face of final chamber, with a narrow distinct incurved lip.

Remarks: The present species differs from *Stainforthia concava* (Höglund) in possessing a biserial stage throughout, and chambers are small. The latter species has a triserial initial stage and very large chambers, aperture is a very broad and loop-shaped with a distinct infold. *Fursenkoina fusiformis* (Williamson) possesses a broad test and chambers are very elongated.

Occurrence: Rare and sporadic in Late Miocene samples from site 588B. Common in Pliocene and Pleistocene samples from sites 587 and 589 respectively.

Genus VIRGULOPSIS Finlay, 1939
 Virgulopsis pustulata Finlay
 (Pl. 8, fig.7)

Virgulopsis pustulata FINLAY, 1939a, p. 321.

Description: Test elongate, slightly tapering, with a triserial initial end becoming twisted and biserial, 4-6 pairs of elongated chambers, biserial stage gradually enlarging in size; sutures slightly oblique, depressed; aperture a curved loop extending up the apertural face in a slight depression; surface rough, with irregular pustules.

Remarks: The present species is characterized by an initial triserial to twisted biserial stage, and a loop-shaped aperture. It superficially resembles *Virgulina primitiva*

Cushman but the latter has a shorter biserial stage and the aperture is circular in a depression.

Occurrence: Abundant in Early Miocene through Late Miocene samples from sites 588A and 588B. Very rare and sporadic in Pliocene samples from site 587.

Superfamily	BULIMINACEA
Family	SIPHOGENERINOIDIDAE Saidova, 1981
Subfamily	SIPHOGENERINOIDINAE Saidova, 1981
Genus	RECTOBOLIVINA Cushman, 1927

Rectobolivina bifrons (Brady)

Sagrina bifrons BRADY, 1881, p. 64.

Description: Test elongate, slightly compressed, chambers broad and low, biserial in initial stage, later becoming uniserial, rectilinear, in later stages chambers slightly arched, sutures straight and depressed; surface rough; aperture a broad circular opening with a projecting lip.

Remarks: In the original illustration, this species shows longitudinal costae, but in the present study longitudinal costae seem to be obscured due to the alteration of the test. *Rectobolivina bifrons* differs from *Siphogenerina raphanus* (Parker and Jones) in possessing a much elongated, compressed, biserial test with a very broad aperture and weakly developed apertural rim.

Occurrence: Only two specimens from the Pliocene samples at site 587.

Genus	SAGRINELLA Saidova, 1975
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Sagrinella lobata (Brady)

(Pl.8, figs, 1 & 2)

Bolivina lobata BRADY, 1881, p. 425, pl. 53, figs. 22-23. *Loxostoma lobatum* (Brady). CUSHMAN, 1937, p. 188, pl. 22, figs. 2-4.

Description: Test elongate, slightly compressed, biserial, chambers broad and low, closely coiled in early stages, later becoming loosely biserial and finally uniserial; chambers sharply angled, chamber edges broken, appear as serrate margin; sutures slightly oblique, depressed; surface rough; aperture oval, terminal with a distinct bordering lip.

Remarks: This species somewhat resembles *Bitubulogenerina vicksbergensis* Howe but the latter has a distinct initial triserial end, the test terminates with a biserial stage, and each chamber has an irregular continuous keel.

Occurrence: Common in two Late Miocene samples from site 588 Abundant in one Early Pliocene sample at site 587.

Subfamily TUBULOGENERININAE Saidova, 1981

Genus AMPLECTOPRODUCTINA Patterson, 1984

Amplectopproductina carnatolintra Patterson, 1986

Amplectopproductina carnatolintra PATTERSON, 1986b, p. 194, pl. 44, figs. 3-5.

Description: Test elongate, uniserial, tapering, chambers rapidly enlarging in size, test broadest near penultimate chamber; approximately 12 primary longitudinal costae extending the length of the test, alternating with eight secondary costae extending only two thirds of the length of the test; upper three quarters of the final chamber smooth; sutures depressed, costae continuous; aperture terminal, small, circular, surrounded by a raised lip.

Remarks: This species is very similar to the holotype described by Patterson (1986) from the Atlantic Ocean.

Occurrence: Very rare in two Middle Miocene samples at site 588B. Only two specimens from a single Late Miocene sample of site 588B.

Genus RECTUVIGERINA Matthews, 1945

Rectuvigerina ongleyi (Finlay)

Siphogenerina ongleyi FINLAY, 1939b, p. 111, pl. 13, figs. 42-43. ____, HORNIBROOK, 1968, p. 102 and 105.

Description: Test elongate, slightly tapering, broadly rounded, long triserial initial end, with a very short uniserial terminal stage; chambers globular, inflated, with slightly curved sides; sutures distinct, deeply depressed, surface ornamented with numerous irregular costae which end up as sharp tapering spines; aperture terminal, on a cylindrical neck with an everted lip.

Remarks: This species is distinct from others by having a long triserial initial stage followed by short uniserial chambers. *R. ongleyi* (Finlay) is similar to *Rectuvigerina pohana* (Finlay) but the latter has very thin closely spaced costae.

Occurrence: Rare and sporadic in Early Miocene through Late Miocene samples at Sites 588A and 588B. Rare in Pliocene samples at Site 587.

Rectuvigerina pohana (Finlay)

Siphogenerina pohana FINLAY, 1939, p. 109, pl. 13, figs. 44-45. *Rectuvigerina pohana* (Finlay). HORNIBROOK, 1968, p. 102-105. ____, HEIMAN, 1977, p. 110, pl. 5, fig. 1. *Rectuvigerina tasmana* BOERSMA, 1986, p. 1032, pl. 17, fig. 4.

Description: Test elongate, slightly tapering, initial portion broadly round and triserial, later becoming uniserial; chambers bulbous, inflated, gradually enlarging in size as added; sutures distinct and depressed; surface ornamented with numerous thin, irregular very closely spaced striae, majority of them are continuous across the sutures; all striae merge into a distinct apical spine; aperture terminal on a cylindrical neck.

Remarks: This species differs from *Rectuvigerina striata* (Schwager) by possessing more bulbous, inflated chambers. It also resembles *Rectuvigerina vesca* and *Rectuvigerina rerensis* (Finlay) but differs in having very fine, numerous, closely spaced striations.

Occurrence: Rare and sporadic in Early Miocene samples at site 588A; only two specimens from single Late Miocene sample at site 588B.

Rectuvigerina striata (Schwager)

Dimorphina striata SCHWAGER, 1866, P. 251, Pl. 7, fig. 2.

Siphogenerina striata (Schwager). CUSHMAN, 1921, p. 280 pl. 56, fig. 5. *Rectuvigerina striata* (Schwager). BELFORD, 1966, p. 84, pl. 9, figs. 1-2. _____. BOERSMA, 1986, p. 1032, pl. 17, fig. 5. _____. van MORKHOVEN et al., 1986, p. 115, pl. 36, figs. 3-4.

Description: Test slender, elongate, slightly tapering, initial end short, triserial, followed by three uniserial inflated chambers, chambers slightly bulbous; sutures distinct, depressed, showing slight crenulations at the junction of final and penultimate chambers; surface ornamented with numerous, raised costae; aperture terminal on a protruded neck, neck encircled by a weakly developed frill.

Remarks: Belford's illustration of *Rectuvigerina striata* (Schwager) has very fine, closely spaced costae suggesting that it may be actually *Rectuvigerina pohana* (Finlay). The species differs from *Siphogenerina postprandia* Finlay by having a stouter test with very short triserial portion. *Rectuvigerina paggoensis* Leroy is much more slender and longer.

Occurrence: Very rare and sporadic in Early through Middle Miocene samples at sites 588A and 588B.

Genus SIPHOGENERINA Schlumberger, 1882

Siphogenerina dimorpha (Parker and Jones)

Uvigerina (*Sagrina*) *dimorpha* PARKER and JONES, 1865, p. 420, pl. 18, fig. 18. *Sagrina dimorpha* (Parker and Jones) BRADY, 1884, p. 582, pl. 76, fig. 1.

Description: Test elongate, nearly cylindrical, slightly tapering, short early triserial stage, later becoming uniserial, with subcylindrical chambers; chambers regularly increasing in size; sutures distinct, excavated; surface ornamented with large pitted perforations; aperture terminal with a short neck and a distinct phialine lip.

Remarks: The species is distinguished from *Siphogenerina raphanus* Parker and Jones by having excavated sutures and a coarsely perforated pitted surface. The latter has several widely separated, well developed costae.

Occurrence: Rare in Pliocene and Pleistocene samples from sites 587 and 589 respectively.

Family BULIMINIDAE Jones, 1875

Genus BULIMINA d'Orbigny, 1826

Bulimina aculeata d'Orbigny

Bulimina aculeata D'ORBIGNY, 1826, p. 269. ____ CUSHMAN, 1921, pl. 31, fig. 5. ____ BELFORD, 1966, pl. 5, fig. 3. ____ HORNIBROOK, 1968, p. 71. ____ PFLUM and FRERICHS, 1976, pl. 1, fig. 8.

Description: Test triserial, tapering, last two pairs of chambers greatly overlapping the previous ones; highly inflated, last three chambers usually large; at the base of each whorl a fringe of thick, well developed sharp spines; aperture broadly loop-shaped, in a depression on the apertural face, with a raised lip; final chambers smooth and polished.

Remarks: This species can be easily confused with *Bulimina gibba* Fornasini but the latter has very globular final chambers, a much broader test and a broad loop-shaped aperture.

Occurrence: Common in Late Miocene samples at site 588B. Rare to common in Pliocene to the Pleistocene samples from sites 587 and 589.

Bulimina alazanensis Cushman

(Pl. 1, figs. 6 & 7)

Bulimina alazanensis CUSHMAN, 1927a, p. 161, pl. 25, fig. 4. ____ PHLEGER, PARKER, PEIRSON, 1953, p. 32, pl. 6, fig. 23. ____ BELFORD, 1966, pl. 5, figs. 9-11. ____ THOMAS, 1986, p. 676, pl. 2, fig. 6.

Description: Test elongated, slightly tapering, triserial, greatest breadth near apertural end, chambers obscured by longitudinal costae, costae ending at the basal end and coalescing into apical spine; costae continuous, extending up to the shoulder of the apertural chamber; surface between costae slightly corrugated; apertural end smooth, aperture comma-shaped with distinct plate along one side

Remarks: This species is commonly confused with *Bulimina rostrata* Brady and *Bulimina semicostata* Nuttall. *B. rostrata* Brady is smaller, both the ends are pointed, costae thick, and do not touch, extending up to the penultimate chamber. *Bulimina*

semicostata Nuttall is similar to the present species but it has weakly developed costae terminating at about three quarters of the test. The present species is very distinct from the above two species in its broad test with inflated sub-globular chambers, rounded apertural end, and rapidly enlarging chambers. In the present study this species shows a slight variation in costae and in some specimens costae are broken. Thomas (1985) referred to reticulate ornamentation because the corrugation between the broken costae and the costae run perpendicular to sutures, hence the specimen has a reticulate appearance.

Occurrence: Rare to common in Early through Late Miocene samples at site 588A and 588B. Common in Pliocene and Pleistocene samples from site 587 and 589 respectively.

Bulimina inflata Seguenza

Bulimina inflata SEGUENZA, 1862, p. 109 [not *Bulimina inflata* PERNER, 1892, p. 55].

Description: Test large triserial, tapering, broadest at the apertural end, chambers rapidly enlarging in size, as added; and chambers inflated, overlapping on previous ones; sutures thin, depressed; chambers undercut, ending with a distinct short spine projecting from just above the basal margin of each chamber; final three chambers smooth and polished; aperture loop-shaped and terminal, with a lip.

Remarks: The present species resembles *Bulimina mexicana* Cushman but the latter differs in having raised costae merging into distinct spines at the base of the chamber.

Occurrence: Very rare and sporadic in the Middle Miocene samples of site 588B.

Bulimina jarvisi Cushman and Parker

Bulimina jarvisi CUSHMAN and PARKER, 1936, p. 39, pl. 7, fig. 1.

Description: Test large, triserial, tapering, twice as long as broad; 6-7 whorls, chambers indistinct, especially in the earlier portion; sutures depressed; surface coarsely pitted; aperture loop-shaped with a faint lip.

Remarks: The species distinguished by the characteristic rough, pitted surface and large tapering test.

Occurrence: Rare in Early Miocene samples at site 588A. Only two specimens were observed in two Middle Miocene samples from site 588B.

Bulimina marginata d'Orbigny

Bulimina marginata D'ORBIGNY, 1826, p. 269. —, BARKER, 1960, p. 104, pl. 51, figs. 3-5. —, MURRAY, 1971, p. 119, pl. 49, figs. 1-7.

Description: Test medium, tapering, widest in the last whorl; chambers numerous, somewhat inflated, undercut at the margin; sutures distinct and depressed; wall smooth except along margins of the chambers; each chamber margin is ornamented with tooth-like crenulations which are usually extended into sharp short spines; aperture loop-shaped with a distinct lip.

Remarks: Specimens from the present study show variation in crenulations at the base of each chamber. The "skirt"-like basal margin of each chamber is a distinctive feature. *Bulimina denticulina* Cushman and Parker is identical with *B. marginata* except for the finely scalloped basal margin of each chamber, and chambers are finely porous. Hence *B. denticulina* may be a synonym of the present species.

Occurrence: Rare and sporadic in Middle through Late Miocene samples of sites 588A and 588B.

Bulimina rostrata Brady

Bulimina rostrata BRADY, 1884, p. 63, pl. 63, figs. 8-9.

Description: Test elongate, fusiform, broadest near middle, tapering unequally towards the two ends; apertural end relatively round, basal end tapering to a sharp spine; chambers and sutures obscured by thick, stout, continuous longitudinal costae covering the test, except for a small area near the aperture; aperture loop-shaped.

Remarks: See under *Bulimina alazanensis* Cushman.

Occurrence: Rare and sporadic in all three sites; common in two Late Miocene samples of site 587.

Bulimina tuxpamensis Cole

Bulimina tuxpamensis COLE, 1928, p. 212. *Bulimina miolaevs* FINLAY, 1940, p. 454, pl. 64, figs. 70-71.

Description: Test stout, tapering, regular in outline, broadest near the apertural end; very finely perforate; many closely arranged in flated chambers; sutures wide, limbate, almost flush; aperture extremely terminal, broad loop-shaped.

Remarks: *Bulimina miolaervis* Finlay is identical to the present species and is a synonym of the present species

Occurrence: Very rare in Early Miocene samples at site 588A.

Family UVIGERINIDAE Haeckel, 1894
Subfamily UVIGERININAE Haeckel, 1894
Genus NEOUVIGERINA Thalman, 1952

Neouvigerina ampullacea (Brady)

(Pl. 8, fig. 5)

Uvigerina asperula Czjzek var. *ampullacea* BRADY, 1884, p. 579, pl. 75, figs. 10-11. *Uvigerina ampullacea* (Brady). CUSHMAN, 1921, pl. 55, fig. 7. *Uvigerina auberiana* (d'Orbigny). PHLEGER, PARKER and PEIRSON 1953, pl. 7 fig. 31. *Neouvigerina ampullacea* (Brady). BARKER, 1960, p. 156, pl. 75, figs. 10-11. *Uvigerina proboscidae* forma *ampullacea* (Brady). BOLTOVSKOY, 1978, p. 171, pl. 8, fig. 24. *Uvigerina ampullacea* (Brady). HEIMAN, 1977, p. 101, pl. 5, fig. 10. *Siphouvigerina ampullacea* (Brady). BURKE, 1981, p. 4., pl. 1, fig. 15. *Neouvigerina ampullacea* (Brady). PATTERSON, 1986b, p. 199, pl. 45, fig. 8.

Remarks: Many authors described this species under different genera mostly under *Uvigerina* and *Neouvigerina*. *Uvigerina* is characterized by triserial stage throughout and early chambers closely coiled later becoming loose and inflated, whereas *Neouvigerina* is distinguished by early triserial stage, later becoming irregularly uniserial, with chambers more inflated from the early stage. Based on these criteria the present species belongs to *Neouvigerina*. However, it can easily be confused with *Siphouvigerina*, but the latter has early triserial inflated chambers and terminates with a biserial stage.

Occurrence: Rare and sporadic in all samples of three sites 587, 588 and 589.

Genus SIPHOUVIGERINA Parr, 1950

Siphouvigerina interrupta Brady

Uvigerina interrupta BRADY, 1884, CUSHMAN, 1913, p. 103, pl. 44, fig. 1. *Neouvigerina interrupta* (Brady). BARKER, 1960, p. 156, pl. 75, figs. 12-14. ____, BELFORD, 1966, p. 86, pl. 8, figs. 9-11. *Uvigerina proboscidea* (Schwager) forma *interrupta* (Brady). BOLTOVSKOY, 1978, p. 171, pl. 8, figs. 31-32. *Siphouvigerina interrupta* (Brady). BURKE, 1981, p. 4, pl. 1, fig. 16.

Description: Test elongate; early portion triserial, with closely arranged chambers, becoming biserial, loosely appressed in later stages; chambers subglobular, gradually increasing in size, the last one or two chambers appear to be independent and tend to be uniserial; aperture terminal on a tubular neck; surface finely hispid.

Remarks: *S. interrupta* differs from *Neouvigerina ampullacea* (Brady) by later interrupted chambers.

Occurrence: Only two specimens from one Early Miocene sample of site 588A. Rare in Pleistocene samples of site 587.

Siphouvigerina porrecta (Brady)

(Pl.8, fig.6)

Uvigerina porrecta BRADY, 1884, P.294, Pl.8, figs. 15-16. ____, CUSHMAN, 1942, p. 48, pl. 13, figs. 7-8. *Neouvigerina porrecta* (Brady). BARKER, 1960, p. 156, pl. 74, figs. 21-23. *Uvigerina porrecta* Brady. BOLTOVSKOY, 1978, p. 171, pl. 8, fig. 20. ____, BURKE, 1981, p. 4, pl. 1, fig. 17.

Description: Test elongate, triserial in early stage, chambers closely arranged, later loosely triserial becoming biserial; chambers carinate, and undercut sharply resulting in a sort of umbrella-like arrangement of loose chambers; sutures constricted; each chamber ornamented with irregular costae; aperture terminal and rounded at the end of short tubular neck.

Remarks: Fimbriate margin, umbrella - like chambers and loosely triserial coiling are the diagnostic features of this species. See also under *Neouvigerina ampullacea*.

Uvigerina caribbeana Keijzer shows fimbriate chamber margin but chambers very closely appressed.

Occurrence: Rare and sporadic in Early Miocene and Late Miocene samples at Sites 588A and 588B.

Genus UVIGERINA d'Orbigny, 1826

Uvigerina auberiana d'Orbigny

Uvigerina auberiana D'ORBIGNY, 1839b, p. 106, pl. 2, figs. 23-24. _____. CUSHMAN, 1913, p. 103, pl. 37, fig. 5. HEIMAN, 1977, p. 102, pl. 5, fig. 13. _____. not *Uvigerina auberiana* (d'Orbigny) LOHMAN, 1978, p. 26, pl. 9, fig. 16. _____. INGLE *et al.*, 1980, p. 146, pl. 6, fig. 1. _____. HERMELIN and SCOTT, 1985, p. 218, pl. 3, fig. 8. _____. KURIHARA and KENNETT, 1986, p. 1035, pl. 20, fig. 1.

Description: Test small, conical, initial end stout, triserial; chambers globular, in the last whorl overlapping on previous chambers for at least half the test length; sutures depressed; surface smooth; aperture on a short neck surrounded by distinct lip.

Remarks: In the present material, this species shows a wide range of variation in chamber overlapment. It differs from *Uvigerina proboscidea* (Schwager) being small and having strong overlapping chambers. *U. rustica* Cushman and Edwards has very coarse ornamentation.

Occurrence: Rare in Early Miocene through Middle Miocene samples at site 588A. Common in one sample of Late Miocene at site 588B. Rare and sporadic in Pleistocene samples at Site 589.

Uvigerina dirupta Cushman and Todd

(Pl. 8, Fig. 12)

Uvigerina peregrina Cushman var. *dirupta* TODD, 1948, p. 267, pl. 34, fig. 3. _____. PFLUM and FRERICHS, 1976, pl. 8, fig. 5. *Euuvigerina peregrina* (Cushman). BELFORD, 1966, pl. 7, fig. 3. *Uvigerina hispidocostata* Cushman and Todd. HEIMAN, 1977, p. 102, pl. 5, fig. 6. *Uvigerina dirupta* Cushman and Todd. INGLE *et al.*, 1980, p. 146, pl. 5, figs. 16-17. _____. BOERSMA, 1986, p. 1034, pl. 19, figs. 3-4.

Description: Test slightly elongate, widest in the middle, chambers fairly uniform, inflated; sutures depressed, with each chamber ornamented with 10-12 noncontinuous longitudinal costae; towards both ends of the test costae are broken into spines or irregular short projections; aperture circular at the end of distinct cylindrical neck with a phialine lip.

Remarks: The author has observed a wide range of variation especially in broken costae. It is slightly different from the holotype by having broken costae towards both ends of the test and shows no sign of individual spines. My specimens are less elongated than the type species. The present species also resembles *Uvigerina pygmaea* d'Orbigny, but the latter has coarser longitudinal costae except on final chamber, which is smooth. *Uvigerina hispido-costata* Cushman and Todd is closely related to the present species and it may be a phenotypic variant.

Occurrence: Rare and sporadic in Late Miocene samples of site 588B. Rare in Pliocene through recent samples of sites 587 and 589.

Uvigerina flinti Cushman

Uvigerina flinti CUSHMAN, 1923, PHLEGER and PARKER, 1951, p. 18, pl. 8, figs. 15-16. *Euuvigerina flinti* (Cushman). BELFORD, 1966, p. 80, pl. 7, figs. 21-23. *Uvigerina flinti* (Cushman). PFLUM and FRERICHS, 1976, pl. 7, fig. 9. ____ , POAG, 1981, p. 86, pl. 27, fig. 5.

Description: Test slightly elongated, oval in appearance; triserial, much inflated chambers; sutures slightly depressed, surface with longitudinal costae confined to each chamber; apertural neck originates from a sunken hollow, aperture with a distinct lip.

Remarks: This species superficially resembles *Uvigerina excellence* Todd but the latter has a more elongate test with numerous inflated chambers and an aperture on a short neck.

Occurrence: Only three specimens from single Pliocene sample at site 587.

Uvigerina peregrina Cushman

(Pl, fig. 11)

Uvigerina peregrina CUSHMAN, 1923, p. 51, pl. 7, fig. 31. *Euuvigerina peregrina* (Cushman). BARKER, 1960, p. 154, pl. 74, figs. 11-12. ____, HERMELIN and SCOTT, 1985, p. 218, pl. 3, fig. 10. ____, MEAD, 1985, p. 229, pl. 1, figs. 7-9 (NOT fig. 10). *Euuvigerina peregrina* (Cushman). PATTERSON, 1986b, p. 197, pl. 45, figs. 4-6. *Uvigerina hispido-costata* Cushman and Todd. KURIHARA and KENNETT, 1986, p. 1034, pl. 20, figs. 3-4.

Remarks: This species was described by many authors. It is distinguished by possessing strong serrate costae. The costae towards apertural end broken into distinct, sharp spines.

Occurrence: Rare in Late Miocene samples of site 588B. Common to rare in Pliocene through the Pleistocene samples of sites 587 and 589.

Uvigerina proboscidea Schwager

(Pl. 8, fig. 13)

Uvigerina proboscidea SCHWAGER, 1866, p. 250, pl. 7, fig. 96. ____, CUSHMAN, 1942, p. 49, pl. 14, figs. 1-4. *Siphouvigerina proboscidea* (Schwager). BELFORD, 1966, p. 87, pl. 1, figs. 12-18. *Uvigerina proboscidea* Schwager. BOLTOVSKOY, 1978, p. 171, pl. 8, figs. 34-38. *Neouvigerina proboscidea* (Schwager). PATTERSON, 1986b, p. 200, pl. 45, figs. 9-10. *Uvigerina proboscidea* Schwager. BELANGER and BERGGREN, 1986, p. 334, pl. 2, fig. 7. ____, KURIHARA and KENNETT, 1986, p. 1035, pl. 20, fig. 2.

Remarks: This species has been well documented in the literature. It is related to *Uvigerina senticosa* Cushman but the latter has a larger test with more inflated chambers, with spines on surface.

Occurrence: Rare and sporadic from Early Miocene through Pleistocene samples from all three sites, 587-589.

Uvigerina nitidula Schwager

Uvigerina nitidula SCHWAGER, 1866, pl. 7, fig. 93. ____, TODD, 1957, p. 273, pl. 73, fig. 6. *Euuvigerina nitidula* (Schwager). BELFORD, 1966, p. 82, pl. 8, figs. 6-8. *Uvigerina nitidula* Schwager. HEIMAN, 1977, p. 104, pl. 5, figs. 18-19.

Description: Test stout, base rounded, twice as long as wide, triserial, chambers inflated; sutures distinct, depressed, curved; surface ornamented with numerous fine, closely spaced discontinuous costae; aperture circular on a long cylindrical neck with a phialine lip.

Remarks: My specimens show very fine closely spaced costae, otherwise identical with the original species. *Uvigerina multicosata* Leroy is a very elongated, loosely coiled form with coarse, raised costae.

Occurrence: Very rare in Late Miocene samples at site 588B. Only one specimen from a single Pliocene sample at site 587.

Uvigerina tenuistriata Reuss

Uvigerina tenuistriata REUSS, 1870, p. 485. _____. CUSHMAN, 1921, p. 269, pl. 55, fig. 2. *Trifarina tenuistriata* (Reuss). HEIMAN, 1977, p. 114, pl. 5, fig. 21.

Description: Test elongate, fusiform, subcylindrical, tapering, initial end closely coiled, later becoming loose, chambers inflated; sutures distinct, depressed; surface with numerous longitudinal raised continuous costae, aperture with a short comparatively thick tubular neck with a distinct lip.

Remarks: The present species differs from *Uvigerina gracillimaris* Papp and Turnovsky by possessing a large test with more inflated chambers. In the latter species chambers are alternating, with thick costae.

Occurrence: Rare in Middle Miocene through Pliocene samples at sites 588B and 587 respectively.

Subfamily ANGULOGERININAE Galloway, 1933

Genus ANGULOGERINA Cushman, 1923

Angulogerina angulosa (Williamson)

(Pl.8, fig. 10)

Uvigerina angulosa WILLIAMSON, 1858, p. 67, pl. 5, fig. 4. _____. CUSHMAN, 1913, p. 98, pl. 44, fig. 4. *Angulogerina angulosa* (Williamson). BARKER, 1960, p. 154, pl. 74, figs. 15-16. *Trifarina angulosa* (Williamson). HEIMAN, 1977, p. 112, pl. 5, fig.3. not

Trifarina angulosa (Williamson). HERMELIN and SCOTT, 1985, p. 217, pl. 3, fig. 111.

Trifarina angulosa (Williamson). MEAD, 1985, p. 229, pl. 1, figs. 11-13. ____.

BELANGER and BERGGREN, 1986, p. 336, pl. 3, fig. 4. *Angulogerina angulosa* (Williamson). PATTERSON, 1986b, p. 195, pl. 44, figs. 8-9.

Remarks: This species is well documented by many workers. *Angulogerina angulosa* is distinguished by its elongate sharply angled test with early chambers nearly as wide as high, later becoming much higher than wide and surface ornamented with weakly developed discontinuous costae. Loeblich and Tappan (1987) placed this species in *Angulogerina* based on the presence of an *Uvigerina*-like internal tooth-plate and triserial coiling throughout. Hermelin and Scott's (1985) illustration shows close similarity to *U. peregrina*.

Occurrence: Very rare in Middle Miocene samples from site 588A. Common in three Late Miocene samples from site 587. Rare in Pliocene through Pleistocene samples from sites 587 and 589.

Angulogerina carinata Cushman

Angulogerina carinata CUSHMAN, 1927c, p. 159. ____, BARKER, 1960, p. 154, pl. 74, fig. 18. *Trifarina angulosa* (Cushman). MURRAY, 1971, p. 123, pl. 51, figs. 1-6. not *Trifarina carinata* Cushman. HERMELIN and SCOTT, 1985, p. 217, pl. 3, figs. 12-13].

Description: Test triangular, initial end bluntly rounded, chambers distinct, and flattened on three sides; edges very sharp, angular with a distinct keel; sutures depressed; surface smooth; aperture on an elongated cylindrical neck.

Remarks: The present species is distinguished by sharp triangular edges with a pronounced keel. The species differs from *Trifarina bradyi* Cushman by being bigger in size, more elongated and possessing acute angles. Hermelin and Scott's (1985) illustration of the present species does not show sharp, angular, keeled margins.

Occurrence: Rare in two Late Miocene and Pliocene samples from site 587.

Angulogerina sp.

Description: Test small, elongate, about twice as long as broad, triangular, edges more or less rounded; chambers rapidly expanding in size as added towards apertural side,

chambers fairly distinct, irregular, often arched, sutures distinct and strongly curved, depressed; wall coarsely perforated; aperture terminal on a short neck with a lip.

Occurrence: Rare in Pliocene through Pleistocene samples from sites 587 and 589.

Genus TRIFARINA CUSHMAN, 1923

Trifarina bradyi Cushman

(Pl.8, fig.9)

Trifarina bradyi CUSHMAN, 1923, p. 99, pl. 22, figs. 3-9. _____. PHLEGER and PARKER 1951, p. 18 figs. 10-11. _____. BARKER, 1960, p. 140, pl. 67, figs. 1-3. _____. BELFORD, 1966, p. 88, pl. 9, figs. 16-17. _____. MURRAY, 1971, p. 125, pl. 52. _____. HEIMAN, 1977, p. 113, pl. 5, fig. 2. _____. BOLTOVSKOY, 1978, p. 171, pl. 8, fig. 1. _____. PATTERSON, 1986b, p. 195, pl. 44, figs. 6-7.

Description: Test elongate, perfectly triangular in apertural view, periphery acute, distinctly keeled; sutures distinct, slightly curved and depressed; surface smooth; aperture terminal on a neck.

Remarks: This species is distinguished from *Angulogerina angulosa* (Williamson) by the perfect triangular shape in apertural view, as well as the acute keeled lobulate, periphery with a keel.

Occurrence: Very rare in Middle Miocene samples at site 588A. Abundant in two samples of Late Miocene and Pliocene from site 587.

Family REUSSELLIDAE Cushman, 1933

Genus FIJIELLA Loeblich and Tappan, 1962

Fijiella simplex (Cushman)

Trimosina simplex CUSHMAN, 1929, p. 158, Tf. 2.

Description: Test of medium size, triangular, angles acute, chambers triserial throughout, uniformly increasing in size as added, edges of the chambers slightly spinose; sutures distinct, slightly limbate, rather evenly curved; surface coarsely

perforated, especially along the borders of the sutures; apertural face slightly convex, smooth, aperture elongate without a lip, a few supplementary openings also found in the centre of the terminal face.

Remarks: The species is distinguished by its characteristic aperture and by the coarse pores along the sutures.

Occurrence: Common in Pliocene through Pleistocene samples from sites 587 and 589.

Genus **REUSSELLA** Galloway, 1933

Reussella spinulosa (Reuss)

Verneuilina spinulosa REUSS, 1860, p. 374, pl. 47, fig. 12. *Reussella spinulosa* (Reuss). CUSHMAN, 1945, p. 33, pl. 6, figs. 8-9.

Description: Test pyramidal, somewhat triserial, distinctly triangular throughout, chambers gradually increasing in size as added; margins carinate, with distinct backward projecting thick spines; sutures oblique; surface rough; aperture slit-like, in a terminal, triangular sunken pit.

Remarks: This species is characterized by triangular carinate margins with stout, sharp backward projecting spines. In the present material, the species shows a wide range of variation in ornamentation.

Occurrence: Common in one Pliocene sample at Site 587; common in two Pleistocene samples at site 589.

Superfamily **FURSENKOINACEA** Loeblich and Tappan, 1961

Family **FURSENKOINIDAE** Loeblich and Tappan, 1961

Genus **FURSENKOINA** Loeblich and Tappan, 1961

Fursenkoina bradyi (Cushman)

Virgulina bradyi CUSHMAN, 1922, p. 115, pl. 24, fig. 1. *Fursenkoina bradyi* (Cushman). THOMAS, 1985, p. 676, pl. 3, fig. 7.

Description: Test elongate, slightly compressed, fusiform, tapering, initial end bluntly rounded, apertural end somewhat broadly rounded; chambers high, narrow and inflated, biserial throughout, plane of biseriality twisted; sutures distinct, slightly oblique, depressed; aperture, narrow, elongate, extending up the face of final chamber; surface smooth.

Remarks: The present species resembles *Cassidella tegulata* but the latter has very unequal chambers, last pair extends more than half of the test, aperture very broad and loop-shaped.

Occurrence: Only two specimens from two Early Miocene samples at site 588A. Rare in Pliocene through the Pleistocene samples of sites 587 and 589.

Genus SIGMAVIRGULINA Loeblich and Tappan, 1957

Sigmavirgulina tortuosa (Brady)

Bolivina tortuosa CUSHMAN, 1942, p. 20, pl. 7 fig. 2-3. —. PHLEGER, PARKER and PEIRSON, 1953, p. 37, pl. 7, fig. 26. —. BARKER, 1960, p. 106, pl. 52, figs. 31-32. —. TODD, 1965, p. 20, pl. 7, fig. 1.

Description: Test short and broad, compressed, biserial throughout, early portion twisted, with later chambers widened; periphery acutely angled and carinate; sutures slightly depressed; aperture an elongate oval surrounded by a lip that grades laterally into the marginal keel; surface smooth.

Remarks: The present species is distinguished by tortuous appearance, kite-shaped with an acute peripheral keel.

Occurrence: Abundant in two Late Miocene samples at site 587 and one Pleistocene sample from same site.

Superfamily	DELOSINACEA Parr, 1950
Family	CAUCASINIDAE Bykova, 1959
Subfamily	CAUCASININAE Bykova, 1959
Genus	FRANCESITA Loeblich and Tappan, 1963

Francesita advena (Cushman)

Virgulina advena CUSHMAN, 1922, p. 120, pl. 25, figs. 1-3. —. PARKER, 1964, pl. 98, fig. 32. —. PFLUM and FRERICHS, 1976, pl. 4, figs. 6-7. *Francesita advena* (Cushman). THOMAS, 1985, p. 6767, pl. 2, fig. 8.

Description: Test elongate, slightly tapering, early stage triserial, later becoming biserial; broadest near apertural end, sides nearly straight; sutures slightly depressed to flush, oblique; aperture an elongate slit extending from the base of the final chamber up the face; surface smooth.

Remarks: *Francesita advena* (Cushman) differs from *Fursenkoina bradyi* (Cushman) by possessing a short, relatively stout, thick test with a triserial initial end.

Occurrence: Two specimens from two Middle Miocene samples from site 588A. Two specimens from two Pliocene samples of site 587.

Superfamily	PLEUROSOMELLACEA Reuss, 1860
Family	PLEUROSOMELLIDAE Reuss, 1860
Subfamily	PLEUROSOMELLINAE Reuss, 1860
Genus	PLEUROSOMELLA Reuss, 1860

Pleurostomella acuminata Cushman

Pleurostomella acuminata CUSHMAN, 1922, p. 50, pl. 19, fig. 6. —. BARKER, 1960, p. 106, pl. 50, fig. 21. —. BOLTOVSKOY, 1978, p. 163, pl. 5, figs. 39-41.

Description: Test elongate, somewhat asymmetric in front view, triserial initially with a distinct spine; chambers few, tightly arranged toward initial end, later becoming more elongate; sutures distinct, depressed; aperture terminal, large, hooded on one side, opposite with two small teeth.

Remarks: The species differs from *P. dominicana* Bermudez by the more compact test the with very elongated final chambers.

Occurrence: Rare in Early Miocene samples from site 588A. Common in one Late Miocene sample from site 587. Rare and sporadic in Pleistocene samples from site 589.

Pleurostomella acuta Hantken

Pleurostomella acuta HANTKEN, 1875, p. 44, pl. 13, fig. 18.

Description: Test stout, slightly elongated about twice as long as wide, tapering sharply toward base from broadest at the final chamber; 3-4 pairs of much inflated chambers, increasing rapidly in height and width as added; sutures depressed and oblique, surface smooth; aperture terminal with projecting hood on one side, two small teeth on opposite side.

Remarks: The present species differs from *Pleurostomella hebata* Cushman and Bermudez by a having test tapered towards both ends. *P. hebata* has a very broad subglobular final chamber which covers three quarters of the test.

Occurrence: Only two specimens from Middle Miocene of site 588A.

Pleurostomella dominicana Bermudez

(Pl.7, figs.9 & 12)

Pleurostomella schuberti Cushman and Harris var. *dominicana* BERMUDEZ, 1949, p. 230, pl. 14, figs. 67-70. *Pleurostomella alternans* SCHWAGER, 1866, p. 238, pl. 6, fig. 80 (NOT fig. 79). — CUSHMAN, 1911, p. 50, T.f. 81. *Pleurostomella* sp. nov. BARKER, 1960, p. 106, pl. 50, fig. 23. *Pleurostomella dominicana* Bermudez. BOLTOVSKOY, 1978, p. 164, pl. 5, figs. 43-44. *Pleurostomella alternans* (Schwager). THOMAS, 1985, p. 677, pl. 14, fig. 5. *Pleurostomella dominicana* Bermudez. PATTERSON, 1986b, pl. 60, figs. 3-4.

Description: Test elongated, slightly tapering, periphery lobulate, initially biserial later becoming uniserial, last two chambers much longer than wide; chambers wedge-shaped; sutures depressed; wall smooth, aperture terminal with a projecting hood on one side and opposite with two short teeth.

Remarks: The specimens in the present study show some variation in the size of the last two chambers. There was great confusion between the present species and *Pleurostomella alternans* Schwager. Schwager (1866) illustrated two different specimens under *P. alternans* and his figure (80) is not *P. alternans*. Numerous workers referred to this figure with its very elongated chambers, especially the final two chambers. The apertural hood is also very sharp. These are the distinctive features of *Pleurostomella*

dominicana Bermudez. Therefore, most of the forms that authors referred to *P. alternans* Schwager actually belong to *P. dominicana* Bermudez.

Occurrence: Rare to common in all samples from sites 587 588 and 589.

Pleurostomella elliptica Galloway and Heminway

Pleurostomella elliptica GALLOWAY and HEMINWAY, 1941, p. 438, pl. 35, fig. 3.—HEIMAN, 1977, p. 142, pl. 9, figs. 7-8.

Description: Test elongated, tapering towards the base, periphery slightly lobulate; 6-7 pairs of wedge-shaped, alternating chambers, final few chambers are equal in size, sutures distinct, depressed; aperture large, and open hooded with two distinct teeth.

Remarks: This species is recognized by its regularly alternating chambers and by the final chambers about equal size.

Occurrence: Only three specimens from Middle Miocene samples at site 588A.

Pleurostomella subnodosa Reuss

Pleurostomella subnodosa REUSS, 1860, p. 204, pl. 8, fig. 2. — CUSHMAN, 1911, p. 51, fig. 82. *Pleurostomella* aff. *P. subnodosa* Reuss. HEIMAN, 1977, p. 147, pl. 11, figs. 11-12. *Pleurostomella obtusa* Berthelin. BOLTOVSKOY, 1978, p. 164, pl. 6, fig. 4-6. — THOMAS, 1985, p. 677, pl. 14, figs. 3-4. Possibly *Pleurostomella refocillata* PATTERSON, 1986b, p. 225, pl. 60, figs. 5-6.

Description: Test elongate, periphery lobulate; five pairs of wedge-shaped chambers regularly alternating, the last chamber is slightly bigger than the rest; sutures distinct, depressed; surface smooth and translucent; aperture nearly circular covering only about top half of the last chamber.

Remarks: This species superficially resembles *Pleurostomella alternans* Schwager but the latter has a large chamber which overlaps more on preceding chamber. *Pleurostomella refocillata* Patterson has a short biserial portion followed by a series of alternate chambers which are of equal shape and size, and moreover the test is very elongated.

Occurrence: Rare and sporadic in Middle Miocene samples at site 588A and also in Pliocene samples from site 587.

Genus PLEUROSKELIDION Patterson, 1987

Pleuroskelidion sp. cf. *P. unda* Patterson

Pleuroskelidion unda PATTERSON, 1986, p. 251, pl. 59, figs. 5-8.

Description: Test elongate tapering to the base and terminating with a short apical spine; periphery lobulate; initial chambers biserial later becoming alternate in position, with depressed oblique sutures; chambers slightly inflated; smooth, slightly raised longitudinal costae continuous on sutures extending only up to the middle of the apertural chamber; aperture terminal with a long hood.

Remarks: The present species differs from *Pleurostomella dominicana* Bermudez (1949) by having distinctive longitudinal costae. The species superficially resembles *Pleurostomella sappari* Schubert but differs in having more inflated chambers with a distinct lobulate periphery and a circular tube extends into the previous chamber.

Occurrence: Only one specimen from the Middle Miocene at site 588A and two specimens from the Pleistocene samples at site 589.

Superfamily STILOSTOMELLACEA Finlay, 1947

Family STILOSTOMELLIDAE Finlay, 1947

Genus ORTHOMORPHINA Cushman, 1927

Orthomorphina jedlitschkai (Thalman)

Nodogenerina jedlitschkai THALMAN, 1937, p. 341. *Nodosaria radícula* (Linné) var. *annulata* (Terquem and Berthelin). BRADY, 1884, pl. 62, figs. 1-2. *Orthomorphina jedlitschkai* (Thalman). HEIMAN, 1977, p. 66, pl. 2, fig. 17.

Description: Test uniserial, rectilinear, about 7-8 highly inflated chambers which are varying in size, initial chambers small followed by abruptly enlarged 2 or 3 chambers and final chambers more or less equal with the initial chambers, chambers subglobular,

final chamber slightly elongated; sutures deeply constricted; periphery lobulate; surface smooth; aperture terminal, circular, with a thin lip.

Remarks: Specimens in the present study show some variation in chamber enlargement. The species superficially differs from *Orthomorphina koina* and *Orthomorphina hemirensis* by possessing very irregularly enlarging chambers, with the final two chambers being more enlarged and oval in outline.

Occurrence: Only two specimens from Late Miocene samples from sites 588B and 587.

Orthomorphina koina (Schwager)

Nodosaria koina SCHWAGER, 1866, p. 220, pl. 5, fig. 47. *Orthomorphina koina* (Schwager). BOERSMA, 1986, p. 1028, pl. 13, fig. 1.

Description: Test elongate, uniserial, rectilinear, 5-7 globular chambers, increasing rapidly in height rather than width; sutures distinct, constricted; periphery lobulate, surface smooth; aperture circular, terminal, apertural chamber slightly tapered at the top, aperture surrounded by a thin rim.

Remarks: *Orthomorphina himerensis* (De Amicis) is slightly arcuate, with rounded large initial chamber, later chambers enlarged in breadth and height almost equally and chambers are much more inflated.

Occurrence: Rare and sporadic in Middle through Late Miocene samples from site 588A and 588B.

Genus SIPHONODOSARIA Silvestri, 1924

Siphonodosaria abyssorum (Brady)

Nodosaria abyssorum BRADY, 1884, p. 63. *Stilostomella abyssorum* (Brady). BARKER, 1960, p. 132, pl. 63, figs. 8-9. —. HEIMAN, 1977, p. 90, pl. 4, fig. 15. —. BOLTOVSKOY, 1978, p. 169, pl. 7, fig. 16. —. THOMAS, 1985, p. 678, pl. 14, fig. 9.

Description: Test uniserial, elongate, straight; five subglobular chambers increasing gradually in size as added; later chambers produced on an elongated neck one below the other; sutures slightly limbate and depressed; surface smooth; aperture terminal on a short, broad neck with a well developed phialine lip.

Remarks: This species is similar to the original illustration of Brady except for the large initial chamber with a spine. This species differs from *Siphonodosaria consobrina* (d'Orbigny) by having subglobular chambers and aperture on a short neck. It also superficially resembles in shape *Siphonodosaria lepidula* but the latter has a distinct ring of spines at the base of each chamber.

Occurrence: Rare and sporadic throughout all three sites.

Siphonodosaria consobrina (d'Orbigny)

Dentalina consobrina D'ORBIGNY, 1846, p. 46, p. 2, fig. 6. *Stilostomella consobrina* (d'Orbigny). BARKER, 1960, p. 130, pl. 62, figs. 23-24. —. HEIMAN, 1977 p. 92, pl. 44, fig. 14. —. THOMAS, 1985, p. 678, p. 14, figs. 6-7. *Siphonodosaria consobrina* (d'Orbigny). PATTERSON, 1986b, p. 221, pl. 51, figs. 8-10.

Description: Test elongate, uniserial, slightly arcuate, 7-8 inflated chambers, twice as long as wide; final chambers more elongated than the earlier ones; sutures distinct, slightly depressed; aperture on an elongated neck surrounded by a phialine lip, minute teeth projecting into the aperture; surface smooth.

Remarks: In the present study specimens show variation in number of chambers. Thomas (1985) distinguished this species on the basis of the elongated final chamber. This species differs from others by having very long, slender chambers with slightly depressed sutures and a smooth surface.

Occurrence: Rare in Early Miocene through Late Miocene samples from sites 588A and 588B. Common in one Late Miocene sample from site 587. Rare and sporadic in Pliocene through the Pleistocene samples at sites 587 and 589.

Siphonodosaria lepidula (Schwager)

(Pl. 8, fig.4)

Nodosaria lepidula SCHWAGER, 1866, pl. 14, fig. 8. —. CUSHMAN, 1911, p. 203, pl. 36, fig. 6. *Stilostomella lepidula* (Schwager). HEIMAN, 1977, p. 90, pl. 4, fig. 12. —. BOLTOVSKOY, 1978, p. 170, pl. 7, figs. 32-46. —. THOMAS 1985, p. 678, pl. 14, fig. 8. *Stilostomella aculeata* (Cushman and Renz). BELANGER and BERGGREN, 1986, p.

332, pl. 1, figs. 12-14. *Siphonodosaria lepidula* (Schwager). PATTERSON, 1986b, p. 222, pl. 51, figs. 11-12.

Remarks: This species has been reported by many workers as *Stilostomella lepidula* (Schwager). According to Loeblich and Tappan (1987) *Stilostomella* should have a short robust test with rapidly enlarging subglobular chambers and smooth surface. *Siphonodosaria* is very narrow, elongate test, with numerous spines on subglobular to pyriform chambers, aperture rounded on a small neck with a phialine lip (Loeblich and Tappan, 1987). Specimens in the present study comprise all siphonodosarid characters and I am therefore describing these species as *Siphonodosaria*. The present species is distinguished by rectilinear test with subglobular chambers and chamber lower margins possess a well developed ring of short spines and aperture with phialine lip.

Occurrence: Rare to common in all three sites, 587, 588 and 589.

Siphonodosaria subspinosa (Cushman)

(Pl.8, fig.8)

Ellipsonodosaria subspinosa CUSHMAN, 1943, p. 92, pl. 16, figs. 16-17. *Stilostomella spinea* Cushman. HEIMAN, 1977, p. 93, pl. 4, figs. 8-9. *Stilostomella subspinosa* (Cushman). BOLTOVSKOY, 1978, p. 170, pl. 7, figs. 24-28. —. THOMAS, 1985, p. 678, pl. 14, fig. 10. *Siphonodosaria subspinosa* Cushman. PATTERSON, 1986b, p. 224, pl. 52, figs. 4-6. —. MILLER and KATZ, 1987 p. 138, pl. 1, fig. 12.

Description: Test elongate, straight, uniserial, 6-8 subglobular chambers gradually increasing in size as added; sutures strongly depressed, surface of the test comprised of more elongated spines all over the chambers, especially spines concentrated more on the lower margin of chambers; aperture rounded, produced on a neck, with teeth projecting into the aperture.

Remarks: The species is distinguished from *Siphonodosaria lepidula* (Schwager) by having very elongated spines all over the test.

Occurrence: Rare and sporadic in all three sites.

Superfamily DISCORBACEA Ehrenberg, 1838

Family PLACENTULINIDAE Kasimora, Poroshina and
Geodakchan, 1980

Subfamily ASHBROOKIINAE Loeblich and Tappan, 1984

Genus PATELLINELLA Cushman, 1928

Patellinella inconspicua (Brady)

(Pl.7, figs.1 & 2)

Textularia inconspicua BRADY, 1884, p. 357, pl. 43, fig. 6. —. HORNIBROOK, 1968, p. 79, fig. 14. —. CUSHMAN, 1911, p. 18, T.f. 30. —. TODD, 1965 p. 9, pl. 1, fig. 3. —. BARKER, 1960, p. 86, pl. 42, fig. 6.

Description: Test short, subconical, slightly compressed; apertural end broadly rounded, initial end tapering, apertural face flat, initial end triangular, later becoming biserial, truncate margins, periphery lobulate; aperture a broad umbilical arch, partly covered with an opposite margin of next chamber.

Remarks: Specimens in the present study show a wide range of variation in the truncate margin of the chamber and my specimens show slight rugosity along the chamber margins. The elongated arch shaped aperture is very characteristic feature of this species.

Occurrence: Abundant in three Late Miocene samples from site 587. Only three specimens from a single Pleistocene sample at site 587.

Family EPONIDAE Hofker, 1951

Subfamily EPONIDINAE Hofker, 1951

Genus EPONIDES de Montfort, 1808

Eponides polius Phleger and Parker

(Pl.4, figs.1-3.)

Eponides polius PHLEGER and PARKER, 1951, p. 21, pl. 11, figs. 1-2. —. BOLTOVSKOY, 1978, p. 158, pl. 4, figs. 4 and 5. —. LAROUCHE, 1979, p. 91, pl. 6, figs. 1-3. —. MURPHY, 1985, p. 28.

Description: Test plano - convex to slightly biconvex, trochospiral, spiral side flat and umbilical side strongly convex, periphery acute; spiral side evolute, all chambers visible, umbilical side involute, only final whorl visible, with 10-11 inflated chambers; sutures limbate, oblique on spiral side, radial on umbilical side; apertural face very angular and elevated, at umbilicus, very angular; aperture interiomarginal restricted; surface smooth and transparent.

Remarks: In the present material, the species show a wide range of variation in extension of final chamber on umbilicus. *E. pusillus* Parr is relatively larger than the present species.

Occurrence: Common to abundant in Early Miocene through Middle Miocene samples from site 588A. Rare and sporadic in Late Miocene through the Pleistocene samples from sites 587, 588B and 589.

Eponides tumidulus (Brady)

Truncatulina tumidula BRADY, 1884, p. 666, pl. 95, figs. 8 a-d. —. CUSHMAN, 1915, p. 38, pl. 15, fig. 3. *Eponides tumidula* (Brady). TODD, 1965, p. 21, pl. 7, fig. 1. —. PFLUM and FRERICHS, 1976, pl. 2, figs. 4-5. —. POAG, 1981, p. 64, pl. 1, fig. 2.; pl. 2, fig. 2 a-b.

Description: Test minute, trochoid, slightly compressed, spiral side evolute, umbilical side involute, convex, six inflated, tumid-shaped chambers, periphery lobulate, sutures distinct, radial on umbilical side, slightly sinuous, oblique on spiral side; aperture interiomarginal; surface smooth and polished.

Remarks: Typical tumid-type chambers, very rounded, convex chambers on umbilical side are characteristic features.

Occurrence: Common in Early Miocene samples from site 588A; rare and sporadic in Late Miocene through Pliocene and Pleistocene samples from sites 587, 588B and 589.

Family DISCORBIDAE Ehrenberg, 1838

Genus DISCORBIS Lamark, 1804

Discorbis conica Fujita and Ito, 1957

Discorbis conica FUJITA and IOTA, 1957, p. 510, pl. 10, fig. 23 a-c. not *Discorbis conica* VAN BELLEN, 1946, p. 48, po. 5, figs. 4-6.

Description: Test small, plano-convex; spiral side convex, conical; umbilical side flat, with five chambers in the last whorl; dorsal sutures slightly limbate and oblique; ventral sutures depressed; aperture a small slit at the end of the final chamber on umbilical side.

Remarks: Van Bellen's species has eight chambers on umbilical side and sutures straight and oblique, at the centre a large umbonal boss distinct. In the present species none of the above features were observed.

Occurrence: Rare in Late Miocene samples of site 587.

Family ROSALINIDAE Reuss, 1863

Genus GAVELINOPSIS Hofker, 1951

Gavelinopsis praegeri Heron-Allen and Earland

(Pl. 7, figs. 10 & 11)

Discorbis praegeri HERON-ALLEN and EARLAND, 1913, p. 122, pl. 10, figs. 8-10. *Rotalia praegeri* (Heron-Allen and Earland). PHLEGER, PARKER and PEIRSON, 1953, pl. 9, figs. 19-21. *Gavelinopsis praegeri* (Heron-Allen and Earland). TODD, 1965, p. 18, pl. 8, fig. 1, not *Gavelinopsis praegeri* (Heron-Allen and Earland). MURRAY, 1971, p. 131, p. 55. *Gavelinopsis lobatulus* (Parr). BOLTOVSKOY, 1978, p. 160, pl. 4, figs. 12-13.

Description: Test unequally biconvex, trochospiral, spiral side convex, evolute with crescentic chambers, sutures thick and flush; umbilical side involute, subtriangular chambers, with depressed radial sutures around circular umbonal stud; periphery carinate, distinctly lobulate; aperture a low interiomarginal extraumbilical slit on umbilical side; ventral side distinctly punctate, dorsal side translucent, smooth, and no evidence of perforations.

Remarks: There exists a considerable confusion between the present species and *Gavelinopsis lobatulus* (Parr). *G. lobatulus* (Parr) has six very inflated, chambers on the umbilical side with thick depressed sutures. Chambers on the evolute side are not

Pulvicarinina allocamerata (Heron-Allen and Earland). BELFORD, 1966, pl. 14, figs. 14-16.

Description: Test planispiral, planoconvex highly conical; 6-8 highly inflated chambers in final whorl, chambers bordered by a wide transparent keel on the flat side; aperture interiomarginal, small slit.

Remarks: The present species differs from *Laticarinina pauperata* Parker and Jones by a plano-convex high conical test. See also under *Laticarinina pauperata*.

Occurrence: Rare and sporadic in Middle Miocene samples; only two specimens from Pleistocene samples of site 589.

Laticarinina pauperata (Parker and Jones)

Pulvinulina repanda var. *menardii* subvar. *pauperata* PARKER and JONES, 1865, p. 395, pl. 16, figs. 50-51. *Laticarinina pauperata* (Parker and Jones). BARKER, 1960, p. 214, pl. 104, figs. 3-11. —. BELANGER and BERGGREN, 1986, p. 338, pl. 3, fig. 7. —. THOMAS, 1985, p. 677, pl. 11, fig. 10. KURIHARA and KENNETT, 1986, pl. 4, fig. 11. —. van MORKHOVEN *et al.*, 1986, p. 89, pl. 26, —. MILLER and KATZ, 1987, p. 134, pl. 3, figs. 7a-b.

Remarks: The description of Parker and Jones (1865) is followed herein. The present species differs from *Laticarinina allocamerata* (Heron-Allen and Earland) by possessing saddle-type biconvex chambers on either side of the keel.

Occurrence: Rare and sporadic throughout the section.

Superfamily PLANULINACEA Schwager, 1877

Family PLANULINIDAE Bermudez, 1952

Genus HYALINEA Hofker, 1951

Hyalinea balthica (Schroeter)

Nautilus balthica SCHROETER, 1783, pl. 1, fig. 2.

Description: Test discoidal, low trochospiral to nearly planispiral, semicvolute on both sides, about two whorls visible; 10-14 chambers in the final whorl; umbilical region

Rosalina globularis D'ORBIGNY, 1826 p. 271, pl. 13, figs. 1-4. *Discorbis globularis* (d'Orbigny). CUSHMAN, 1911, p. 11, pl. 9, fig. 4. *Rosalina globularis* d'Orbigny. BARKER, 1960, p. 178, pl. 86, fig. 13. —. TODD, 1965, p. 11, pl. 3, fig. 4. —. MURRAY, 1971, p. 135, pl. 56, figs. 1-6. —. HEIMAN, 1977, p. 122, pl. 6, figs. 11-12.

Description: Test trochospiral, umbilical side involute, flat, spiral side evolute, convex; umbilicus depressed with chamber flaps, periphery acute, 5-6 chambers on umbilical side; sutures depressed, slightly curved, wall appears to be coarsely perforated, aperture on umbilical side.

Remarks: See the comments of *Rosalina floridana* (Cushman).

Occurrence: Rare and sporadic in Miocene samples at site 588A and 588B. Abundant in one Pleistocene sample from site 587.

Rosalina floridana Cushman

Discorbis floridana CUSHMAN, 1922, p. 39, pl. 5, fig. 11-12. —. TODD, 1965, p. 10-11, pl. 3, figs. 1 and 3. —. HEIMAN, 1977, p. 121, pl. 3, figs. 9-10.

Description: Test subcircular, slightly longer than wide, laterally compressed, periphery acute with thin keel, slightly lobulate; 5-6 chambers in the final whorl, sutures distinct, depressed, slightly limbate; wall coarsely perforated on both sides; aperture an elongate arch extending on umbilical area.

Remarks: The present species superficially resembles *Rosalina globularis* but the latter is not keeled and does not possess limbate sutures. In the present specimens the periphery is entire and slightly lobulate.

Occurrence: Abundant in one Late Miocene sample from site 587.

Family SPHAEROIDINIDAE Cushman, 1927

Genus SPHAEROIDINA d'Orbigny, 1826

Sphaeroidina bulloides d'Orbigny

(Pl. 7, fig. 3)

Sphaeroidina bulloides D'ORBIGNY, 1826, p. 267. —. BARKER, 1960, p. 174, pl. 84, figs. 1-7. —. BOLTOVSKOY, 1978, p. 169, pl. 7, fig. 11. —. LOHMAN, 1978, p. 26, pl. 4, fig. 4. —. HEIMAN, 1977, p. 86, pl. 4, fig. 1. —. CORLISS, 1979, p. 7, pl. 2, figs. 1-2. —. INGLE *et al.*, 1980, p. 144, pl. 9, fig. 16. —. MEAD, 1985, p. 228, pl. 1, fig. 2. —. THOMAS, 1985, p. 678. —. BELANGER and BERGGREN, 1986, p. 332, pl. 1, fig. 1. —. van MORKHOVEN *et al.*, 1986, p. 80, pl. 24.

Remarks: This species was well documented in the literature.

Occurrence: Rare and sporadic in Early Miocene through Middle Miocene samples ; common in Late Miocene samples from site 588B; common in Pleistocene samples at site 589.

Superfamily GLABRATELLACEA Loeblich and Tappan, 1964

Family HERONALLENIIDAE Loeblich and Tappan, 1984

Genus HERONALLENIA Cushman and Parr, 1931

Heronallenia lingulata (Burrows and Holland)

Discorbina lingulata BURROWS and HOLLAND, 1896, p. 297, pl. 7, fig. 33. *Discorbina biconcava* BRADY, 1834, p. 653, fig. 3. *Heronallenia lingulata* (Burrows and Holland). THOMAS, 1985, p. 677, pl. 3, fig. 7 —. MURPHY, 1985, p. 28.

Description: Test compressed, flat or concavo-convex, outline somewhat square shaped and periphery lobulate and carinate; sutures limbate on convex side; only 5 chambers visible on ventral side, last chamber extends one-fourth of the test; aperture interiomarginal, broad and oval shaped.

Remarks: The present species differs from *Heronallenia inflatabula* Patterson in having numerous chambers and much more compressed test.

Occurrence: Rare and sporadic in Middle to Late Miocene samples from sites 588A and 588B.

Heronallenia wilsoni (Heron-Allen and Earland)

Discorbina wilsoni HERON-ALLEN and EARLAND, 1922, p. 206, pl. 7, figs. 17-19. ____.

LOEBLICH and TAPPAN, 1987, p. 569, pl. 623, figs. 1-18.

Remarks: The description of Loeblich and Tappan (1987) is followed herein. The present species differs from *Heronallenia lingulata* (Burrows and Holland) by having a perfect oval test, sutures on umbilical side flush and thick, raised on dorsal side.

Occurrence: Rare and sporadic in Early Miocene through Pliocene samples from sites 588A, 588B and 587.

Superfamily DISCORBINELLACEA Sigal, 1952

Family PARRELLOIDIDAE Hofker, 1956

Genus CIBICIDOIDES Thalmann, 1939

Cibicidoides bradyi (Trauth)

Truncatulina bradyi TRAUTH, 1884, v. 95, p. 235, pl. 4, figs. 7-9. *Cibicidoides bradyi* (Trauth). BARKER, 1960, p. 196, pl. 95, fig. 5. ____ PFLUM and FRERICHS, 1976, p. 114, pl. 3, figs. 6-7. ____ BOLTOVSKOY, 1978, p. 155, pl. 3, figs. 6-8. ____ CORLISS, 1979, p. 9, pl. 3, figs. 1-3. not *Cibicidoides bradyi* (Trauth) INGLE *et al.*, 1980, p. 312, pl. 6, figs. 11-12. ____ MEAD, 1985, p. 242, pl. 7, figs. 1-2. ____ THOMAS, 1985, p. 675, pl. 10, figs. 7-8. ____ BELANGER and BERGGREN, 1986, p. 344, pl. 6, fig. 4. ____ MILLER and KATZ, 1987, p. 126, pl. 7, fig. 2.

Description: Test moderately convex, rounded three whorls visible on evolute spiral side with 6-8 inflated chambers in the final whorl; Periphery broadly rounded, sutures on spiral side oblique to slightly curved; sutures on umbilical side radial thin and depressed, slightly offset in umbilical area; spiral side coarsely perforate with umbilical side finely perforate; aperture small, interiomarginal with a lip, extending onto the spiral side.

Remarks: The species differs from *Cibicidoides robertsonianus* (Brady) by possessing broad, periphery with fewer chambers. It superficially resembles *Cibicides akneriana* (d'Orbigny), but the latter has a large umbonal depression, and is also evenly perforate.

Ingle and others' (1980) illustration shows a coarse wall on the umbilical side and the periphery appears to be much angled. Hence, I am not certain of their identification. The illustration of MILLER and KATZ (1987, pl. 7, figs. 1 and 2) is not *Cibicidoides robertsonianus* (Brady) as they show distinct characters of *C. bradyi* (Trauth).

Occurrence: Rare to common in Early Miocene samples from site 588A; common in Middle Miocene through Pliocene samples from sites 588A, 588B and 587. Rare in Pleistocene samples at site 589.

Cibicidoides opacus Carter

(Pl.3, figs. 8 - 10)

Cibicides opacus CARTIER, 1969, p. 95-96, pl. 7a, figs. A-C. _____. HEIMAN, 1977, p. 131, pl. 6, figs. 17-19 as *Cibicidoides opacus* (Carter). _____. KURIHARA and KENNETT, 1986, p. 1077, pl. 9, figs. 4-6.

Description: Test trochospiral small to medium size, subcircular, equally biconvex, biumbonate, periphery acute with a thin keel, lobulate in final few chambers, umbilical side involute with an umbonal plug; sutures slightly limbate and depressed on both sides of the test; umbilical sutures slightly curved or radial; spiral side with more pores than umbilical side; aperture a narrow, interiomarginal slit with a distinct lip.

Remarks: The species differs from *Cibicides umbonatus* Phleger and Parker, possessing fewer chambers and a less punctate test.

Occurrence: Rare and sporadic in Early Miocene through Late Miocene samples of sites 588A and 588B. Rare in Pleistocene samples of site 589.

Cibicidoides mundulus (Brady, Parker and Jones)

(Pl.6, figs.7 - 9)

Truncatulina mundula BRADY, PARKER, JONES, 1888, p. 288, pl. 45, fig. 12. _____. CUSHMAN, 1915, p. 41, pl. 13, figs. 4-5. *Cibicidoides mundulus* (Brady, Parker and Jones). BARKER, 1960, p. 196, pl. 95, fig. 6. *Cibicides mundulus* (Brady, Parker and

Jones). HEIMAN, 1977, p. 130, pl. 7, figs. 13-15. *Cibicidoides mundulus* (Brady, Parker and Jones). THOMAS, 1985, p. 676, pl. 8, figs. 5-6. *Cibicides mundulus* (Brady, Parker and Jones). MILLER and KATZ, 1987, p. 130, pl. 7, fig. 3. *Cibicidoides cenop* WOODRUFF, 1985, p. 163, pls. 1-3.

Description: Test trochospiral, almost equally biconvex, periphery acute with an imperforate keel; about 9-10 chambers in the final whorl; sutures on spiral side curved thick and limbate; slightly convex umbo on spiral side; sutures limbate and slightly depressed, radiating from central umbo on umbilical side; spiral side coarsely perforate, pores irregular, early whorls characterized by coarse pores along the spiral suture, umbilical side almost smooth; aperture an interiomarginal arch with a distinct imperforate lip, extending on to at least 5 chambers along the spiral suture.

Remarks: Many workers distinguish this species on the basis of the biumbonate test, with coarse perforations on spiral side. In the present study the species shows a wide range of variation. Thomas (1985) considered less curved sutures on the umbilical side and coarse pores on spiral side as distinctive characters. The present species was often documented as *Cibicides kullenbergi* Parker. However, the latter species is distinguished by a plano-convex or weakly biconvex test with strongly curved umbilical sutures. Pores on the spiral side are normally uniformly distributed. In contrast the present species is inequally biconvex with moderately curved sutures on umbilical side. The spiral side is coarsely punctate and pores are relatively larger than in the former species and are somewhat randomly distributed along the spiral suture. *C. mundulus* also resembles *Cibicidoides mollis* Parker but in the latter species final chambers do not possess a keel. *Cibicidoides pseudoungerianus* (Cushman), another similar species, does not have a keel. Woodruff (1986) described a new species *Cibicidoides cenop* which does not show any essential differences from the present species except that the former is more plano-convex. The sutural pattern is quite similar to that of the present species. Therefore, I assume that *Cibicidoides cenop* Woodruff is a synonym of the present species. *Cibicidoides dutemplei* (d'Orbigny) is flat on the spiral side with slightly

depressed sutures on the umbilical side and shows a more or less uniform pore distribution.

Occurrence: Rare to common in the Early Miocene at site 588A. Rare and sporadic in Middle Miocene samples from site 588B and common in two samples from the Late Miocene at 588B. Rare and sporadic in Pliocene through Pleistocene samples at sites 587 and 589.

Cibicidoides robertsonianus (Brady)

(Pl.6, figs.10 & 11)

Truncatulina robertsoniana BRADY, 1884, p. 65. *Cibicidoides robertsonianus* (Brady). PFLUM and FRERICHS, 1976, p. 1.3, figs. 4-5. *Cibicides robertsonianus* (Brady). HEIMAN, 1977, p. 132, pl. 8, figs. 1-3. *Cibicidoides robertsonianus* (Brady). THOMAS, 1985, p. 676, pl. 10, figs. 5-6. —, BELANGER and BERGGREN, 1986, p. 334, pl. 6, fig.5.

Description: Test biconvex, trochospiral, periphery bluntly rounded with an often acute margin; spiral side characterized by 3 whorls, completely evolute, umbilical side partially evolute with 10-13 slightly inflated chambers; sutures limbate and curved on spiral side, umbilical sutures limbate but depressed; umbilical side with distinct umbonal boss, surface coarsely perforated on spiral side and smooth to finely perforate on umbonal side; aperture an interiomarginal arch extending on to spiral side.

Remarks: In the present material this species shows variation in convexity and in the number of chambers in the final whorl; (see also under the comments of *C. bradyi* (Trauth)).

Occurrence: Rare and sporadic in Early Miocene samples from site 588A; rare to common in Middle and Late Miocene samples at sites to 588A and 588B. Rare and sporadic in Pliocene through Pleistocene samples from sites 587 and 589.

Cibicidoides sp.

Description: Test trochospiral, spiral side slightly biconvex, umbilical side strongly convex, periphery broad rounded, 6 inflated chambers in the final whorl; umbilical

sutures thin, curved and depressed around bulky, strongly raised, umbonal boss; Dorsal sutures limbate and curved; wall on spiral side coarsely perforated and umbilical side virtually smooth. Aperture an interiomarginal slit with a lip extending on to the spiral side.

Occurrence: These specimens are rare and sporadic in Early Miocene through Late Miocene samples of site 588A, 588B and 587.

Family PSEUDOPARRELLIDAE Voloshinova, 1952

Subfamily PSEUDOPARRELLINAE Voloshinova, 1952

Genus EILOHEDRA Lipps, 1966

Eilohedra weddellensis (Earland).

(Pl.7, figs.4 - 6)

Eponides weddellensis EARLAND, 1936, v. 13, p. 57, pl.1, figs. 65-67. —, BOLTOVSKOY, 1980, pl. 2, fig. 6. *Eilohedra levicula* Resig, INGLE et al., 1980, p. 134, pl. 2, figs. 2-3. —, THOMAS, 1985, p. 676, pl. 13, figs. 5-6.

Description: Test minute, trochospiral, biconvex, spiral side subconical, about three tightly coiled whorls visible, chambers broad and low; umbilical side involute, with five chambers in the final whorl; periphery broadly rounded; sutures radial, depressed on umbilical side; spiral sutures curved, and flush with the surface, surface smooth and polished; aperture an interiomarginal slit extending up the depressed apertural face of final chamber on umbilical side.

Remarks: The present species superficially resembles *Eponides pusillus* Parr, but in the latter species the aperture does not extend up into the apertural face parallel to the periphery as in *E. weddellensis*. Lipps (1965) considered *Epistominella levicula* Resig as the type species for the genus *Eilohedra*. However, Thomas (1985) suggested that *Epistominella levicula* Resig is a junior synonym of *Eponides weddellensis*. In the present study, I compared my specimens with both of the original illustrations, and came to support Thomas' conclusion.

Occurrence: Abundant in Miocene and Pleistocene samples from sites 588A, 588B and 589; common in Pliocene samples of site 587.

Genus **EPISTOMINELLA** Husezima and Mairuhasi, 1944

Epistominella exigua (Brady)

(Pl.7, fig. 7)

Pulvinulina exigua BRADY, 1884, v. 9, p. 696, pl. 103, figs. 13-14. *Epistominella exigua* (Brady). BARKER, 1960, p. 212, pl. 103, figs. 13-14. —. BOLTOVSKOY, 1978, p. 158, pl. 3, figs. 37-38. —. CORLISS, 1979a, p. 7, pl. 2, figs 7-8. —. POAG, 1981, p. 63, pl. 5, fig. 4. —. HERMELIN and SCOTT, 1985, p. 208, pl. 4, fig. 1. —. THOMAS, 1985, p. 676, pl. 13, figs. 4-3. —. BELANGER and BERGGREN, 1986, p. 336, pl. 3, fig. 6. —. KURIHARA and KENNETT, 1986, p. 107, pl. 3, figs. 10-12. —. MILLER and KATZ, 1987, p. 132, pl. 5, fig. 6a-b.

Remarks: The description of Brady (1884) is followed herein. This species was well documented in the literature. A compressed test with five chambers and an extended aperture parallel to the periphery, readily distinguishes the species.

Occurrence: Abundant in Miocene and Pleistocene samples from sites 588A, 588B and 589; common in Pliocene samples of site 587.

Epistominella umbonifera (Cushman)

(Pl.7, fig.8)

Pulvinulinella umbonifera CUSHMAN, 1933, p. 90, pl. 9, fig. 9. *Epistominella umbonifera* (Cushman). CORLISS, 1979a, p. 7, pl. 2, fig. 10-12. —. BURKE, 1981, pl. 2, figs. 5-6. *Nuttallides umbonifera* (Cushman). HERMELIN and SCOTT, 1985, p. 214, pl. 5, figs. 11-13. —. THOMAS, 1985, p. 677, pl. 13, figs 1-2. —. KURIHARA and KENNETT, 1986, p. 1072, pl. 4, figs. 1-3. —. KATZ and MILLER, 1987, p. 136, pl. 5, fig. 5.

Remarks: The description of Cushman (1933) is followed herein. This species can be easily confused with *Nuttallides bradyi* Earland but the latter form has a greater

number of low and broad crescentic chambers with raised limbate sutures. In addition, the aperture has a distinct notch. *Epistominella umbonifera* is relatively smaller and has an umbonal boss.

Occurrence: Common to abundant in Early Miocene samples from site 588A; abundant in Middle and Late Miocene samples from site 588B; common in Pleistocene samples from site 589.

Epistominella vitrea Parker

Epistominella vitrea PARKER, 1953, p. 9, pl. 4, figs. 34-36. —. MURRAY, 1971, p. 131, pl. 54, figs. 1-6. —. POAG, 1981, p. 63, pl. 5, fig. 3 and pl. 6, fig. 3a-b. —. WARD and WEBB, 1986, p. 190, pl. 4, figs. 15-16.

Description: Test small, rounded, weakly convex on spiral side, slightly depressed on umbilical side; periphery rounded and slightly lobulate; slightly inflated six chambers in last whorl, umbilical sutures radial, spiral sutures gently curved, sutures are depressed on both sides; aperture long and narrow parallel to the periphery with a distinct lip.

Remarks: The present species differs from *Epistominella exigua* Brady by having a rounded, slightly lobulate periphery and a long narrow oval aperture with a distinct lip.

Occurrence: Rare and sporadic in Middle Miocene samples of site 588B.

Family DISCORBINELLIDAE Sigal, 1952

Subfamily DISCORBINELLINAE Sigal, 1952

Genus LATICARININA Galloway and Wissler, 1927

Laticarinina altocamerata (Heron-Allen and Earland)

(Pl. 4, fig. 6)

Truncatulina tenuimargo BRADY, 1884, pl. 93, fig. 2. *Truncatulina tenuimargo* Brady var. *altocamerata* HERON-ALLEN and EARLAND, 1922, p. 209, pl. 7, figs. 24-27.

Pulvicarinina altocamerata (Heron-Allen and Earland). BELFORD, 1966, pl. 14, figs. 14-16.

Description: Test planispiral, planoconvex highly conical; 6-8 highly inflated chambers in final whorl, chambers bordered by a wide transparent keel on the flat side; aperture interiomarginal, small slit.

Remarks: The present species differs from *Laticarinina pauperata* Parker and Jones by a plano-convex high conical test. See also under *Laticarinina pauperata*.

Occurrence: Rare and sporadic in Middle Miocene samples; only two specimens from Pleistocene samples of site 589.

Laticarinina pauperata (Parker and Jones)

Pulvinulina repanda var. *menardii* subvar. *pauperata* PARKER and JONES, 1865, p. 395, pl. 16, figs. 50-51. *Laticarinina pauperata* (Parker and Jones). BARKER, 1960, p. 214, pl. 104, figs. 3-11. —. BELANGER and BERGGREN, 1986, p. 338, pl. 3, fig. 7. —. THOMAS, 1985, p. 677, pl. 11, fig. 10. KURIHARA and KENNETT, 1986, pl. 4, fig. 11. —. van MORKHOVEN *et al.*, 1986, p. 89, pl. 26, —. MILLER and KATZ, 1987, p. 134, pl. 3, figs. 7a-b.

Remarks: The description of Parker and Jones (1865) is followed herein. The present species differs from *Laticarinina altocamerata* (Heron-Allen and Earland) by possessing saddle-type biconvex chambers on either side of the keel.

Occurrence: Rare and sporadic throughout the section.

Superfamily PLANULINACEA Schwager, 1877

Family PLANULINIDAE Bermudez, 1952

Genus HYALINEA Hofker, 1951

Hyalinea balthica (Schroeter)

Nautilus balthica SCHROETER, 1783, pl. 1, fig. 2.

Description: Test discoidal, low trochospiral to nearly planispiral, semievolute on both sides, about two whorls visible; 10-14 chambers in the final whorl; umbilical region

characterized by a pronounced umbonal boss; sutures radiate, and slightly curved, limbate, elevated, gradually merging with weakly developed keel; surface smooth on umbilical side except elevated sutures, spiral side coarsely perforated; aperture a low interiomarginal arch bordered by a narrow lip continuing laterally beneath umbilical region and around the spiral suture.

Remarks: This species is distinguished by semievolute coiling on both the sides, thick elevated sutures and an equatorial interiomarginal aperture extends on both the sides readily distinguishes the species.

Occurrence: Rare and sporadic in Early Miocene through Pliocene samples. Two specimens from Pleistocene samples at site 587.

Genus PLANULINA d'Orbigny, 1826

Planulina ariminensis d'Orbigny

Anomalina ariminensis D'ORBIGNY, 1826, p. 280, pl. 14, figs. 1-3. _____. CUSHMAN, 1915, p. 44, pl. 19, fig. 1. _____. PHLEGER, PARKER, PEIRSON, 1953, p. 48, pl. 11, figs. 3-4. *Planulina ariminensis* (d'Orbigny). BARKER, 1960, p. 192, pl. 93, figs. 10-11. [not *Planulina ariminensis* (d'Orbigny). POAG, 1981, p. 75, pl. 43, fig. 3 and pl. 44, fig. 3].

Description: Test discoidal, very low trochospiral, umbilical side partially evolute, 9-11 broad, arched chambers, spiral side evolute; sutures thick limbate, nonperforate and elevated, strongly curved back at the peripheral margin, periphery with imperforate marginal keel, spiral surface pierced by numerous pores; aperture an interiomarginal, equatorial arch with an imperforate lip, extending onto the umbilical side and spiral side.

Remarks: According to Loeblich and Tappan (1987) *Planulina* is distinguished by a low trochospiral discoidal test with the partially evolute umbilical side and evolute spiral side, broad and low arched chambers, thick raised nonperforate sutures and an aperture which extends almost half way along the spiral suture with an imperforate lip. *Planulina ariminensis* d'Orbigny differs from *Fontbotia gigas* (Keijzer) by possessing

truncate keel and low arched chambers as well as an asymmetrical aperture. The present species is also similar to *Planulina plana* Belford in its evolute coiling on both the sides and also superficially resembles *Cibicides catillus* Finlay in spiral view, but the latter has very strong reflexed sutures. Poag's (1981) illustration of the present species shows a strongly pitted rugose surface and deeply depressed sutures. These features do not match those of the type description.

Occurrence: This species occurs only in two Pliocene samples (specimens) from site 587.

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus CIBICIDES de Montfort, 1808

Cibicides cicatricosus (Schwager)

Anomalina cicatricosa SCHWAGER, 1866, p. 260, pl. 7, fig. 4. *Truncatulina aknertana* (d'Orbigny). BRADY, 1884, pl. 96 fig. 8. *Cibicides cicatricosus* (Schwager). BARKER, 1960, p. 194, pl. 94, fig. 8. —, HEIMAN, 1977, p. 127, pl. 8, figs. 13-15. *Cibicidoides cicatricosus* (Schwager). BOERSMA, 1986, p. 1021, pl. 6, figs. 4-6.

Description: Test trochospiral, planoconvex, spiral side flat, umbilical side convex, 10-12 chambers in the last whorl; chambers inflated, periphery acutely rounded, sutures curved, limbate and slightly depressed on umbilical side, but raised on spiral side; wall coarsely perforate on dorsal side and somewhat smooth to weakly perforate on the umbilical side; aperture an interiomarginal arch shaped with a lip, extends at least half the distance of final whorl, along the spiral suture.

Remarks: According to Loeblich and Tappan (1964, 1987) *Cibicides* and *Cibicidoides* are two distinct genera. *Cibicidoides* is characterized by a trochospiral, lenticular, biconvex and biumbonate test, with curved and limbate sutures on the spiral side and straight and radial sutures on umbilical side; on the spiral side, in early chambers coarse perforations are confined only near the spiral suture, whereas *Cibicides* is a trochospiral strictly planoconvex form with thick, elevated sutures on flat evolute

spiral side and radial depressed sutures on involute umbilical side; spiral side with coarse perforations and umbonal side smooth to finely perforated. Aperture extends more on dorsal suture.

In the present report, the above characteristics were strictly followed in assigning the species to these two genera. The species shows wide range of ornamentation on umbilical side. *Cibicidoides akneriana* (d'Orbigny) has more chambers and less punctate test.

Occurrence: Rare and sporadic in Middle Miocene through Pleistocene samples at all sites.

Cibicides kullenbergi Parker

(Pl.3, figs.1 - 3)

Cibicides kullenbergi PARKER, 1953, p. 49, pl. 11, figs. 7-8. _____. PFLUM and FRERICHS, 1976, p. 112, pl. 2, figs. 6-8. _____. HEIMAN, 1977, p. 128, pl. 7, figs. 8, 12, 16. _____. BOLTOVSKOY, 1978, p. 155, pl. 3, figs. 9-12. _____. CORLISS, 1979b, p. 10, pl. 3, figs. 4-6. _____. THOMAS, 1985, p. 675, pl. 8, figs. 1-2. *Cibicidoides* sp. cf. *kullenbergi* Parker. MEAD, 1985, p. 242, pl. 6, figs. 6-7. *Cibicidoides floridana-kullenbergi* group. BELANGER and BERGGREN, 1986, p. 334, pl. 6, fig. 7. *Cibicidoides kullenbergi* (Phleger, Parker, Peirson). KURIHARA and KENNETT, 1986, p. 1076, pl. 8, figs. 1-3.

Description: Test large, plano-convex to biconvex, evolute side less convex, periphery with an acute imperforate keel, chambers distinct, 11-13 in final whorl, meeting the centre on the umbilical side in an area of clear shell material; sutures flush with the surface meeting the peripheral keel at an angle; wall finely perforate on umbilical side with a few fine pores developed on each chamber on spiral side; aperture peripheral, interiomarginal with a thin lip, extending on spiral suture.

Remarks: In the present report this species shows a wide range of variation in test size, shape and number of chambers in the final whorl. I have placed the specimens in the present species strictly on the basis of original description. There exists considerable confusion in the nomenclature of the present species.

In Thomas' (1985) opinion, *C. kullenbergi* has strong curved sutures which meet the periphery with a tangential angle on the umbilical side. She did not give much importance to biconvexity of the test. Morkhoven *et al.* (1986) compared the holotype of the present species (United States National Museum) and the lectotype of *Cibicidoides mundulus* (British Museum of Natural History) and found no essential difference between them except the size, accordingly they have placed *C. kullenbergi* as a junior synonym of *C. mundulus*. In the type descriptions of both the species they do show a variation in the test size, sutures, biconvexity. At this point, validity of Morkhoven's *et al.* (*op. cit.*) assumption is uncertain.

Occurrence: Common in Early Miocene through Late Miocene of sites 588A and 588B; rare and sporadic in Pliocene and Pleistocene samples of sites 587 and 589.

Cibicides lucidus (Reuss)

Truncatulina lucida REUSS, 1866, p. 160, pl. 4, fig. 15.

Description: Test medium, slightly biconvex, slightly compressed, periphery weakly lobulate with a distinct keel; umbilical side involute, spiral side evolute with two and one-half whorls, 8-10 chambers in the last whorl, sutures curved and strongly depressed on umbilical side, wall finely perforated; sutures radiating, curved, slightly depressed on spiral side with coarsely perforated wall; aperture interiomarginal arch with a lip extending back on two chambers of the spiral side.

Remarks: This species shows a close relationship to *Fonbotia* but it differs in having very depressed sutures, and low arched chambers. It also superficially resembles *Cibicides spirata* (Sequenza) but latter has very sharp angled periphery, broad low, strongly arched chambers.

Occurrence: Rare and sporadic in Middle Miocene through Late Miocene samples at sites 588A and 588B. Only four specimens from Pleistocene samples at site 589.

Cibicides refulgens Montfort

Cibicides refulgens MONTFORT, 1808, p. 122.

Description: Test trochospiral, planoconvex, spiral side flat, evolute, sutures thickened, strongly convex umbilical side, involute with depressed sutures, periphery acute with a keel; apertural face angular; aperture low interiomarginal, extends a short distance on to the umbilical side, also continue along the spiral suture.

Remarks: This species differs from *Lobatula lobatus* (Walker and Jacob) in having flat spiral side, high trochospiral, strongly convex umbilical side.

Occurrence: Abundant in one Late Miocene sample of site 587. Rare in several Pleistocene samples of site 587.

Genus FONTBOTIA Gonzalez-Donso and Linares, 1970

Fontbotia gigas Keijzer

Planulina marialana Hadley var. *gigas* KEIJZER, 1945, p. 604. *Planulina marialana gigas* (Keijzer) BOLTOVSKOY, 1978, p. 163, pl. 5, figs. 35-38.

Description: Test compressed, equally convex, periphery acute with distinct sharp keel, except along the last formed chamber, 11-13 chambers in the last whorl, partly evolute on umbilical side, evolute on dorsal side; sutures distinct, spiral sutures curved meeting the periphery at an angle, limbate, raised except in the last few chambers where sutures are depressed; aperture peripheral, interiomarginal and symmetrical with a distinct lip, extending on spiral sutures onto four chambers. Surface densely perforated.

Remarks: The present species differs from the holotype by having much larger test and more numerous chambers. The species also differs from *Planulina palmerae* van Hellen by possessing roughly finished test and much obscured earlier chambers. van Morkhoven *et al.*, (1986) referred to smaller Oligocene forms to *Planulina renzi* Cushman and Stainforth and larger Miocene forms to *Planulina gigas* Keijzer. Furthermore, they have placed the former species under the synonym of latter based on their co-occurrence in the same type level. *P. renzi* is very similar to the present species except for its more numerous chambers. Boltovskoy (1978) proposed a phylogenetic

trend between *Planulina gigas* and *Fontbotia wuellerstorfi* (Schwager), the former being the ancestor to the latter. Validation of this concept needs to be established.

Occurrence: Only three specimens were recovered from Early Miocene samples at site 588A. One specimen from the Middle Miocene of same site.

Fontbotia wuellerstorfi (Schwager)

(Pl.3, figs, 4 - 7.)

Anomalina wuellerstorfi SCHWAGER, 1866, pl. 7, figs. 105-107. *Truncatulina wuellerstorfi* (Schwager) CUSHMAN, 1921, p. 314, pl. 64, T.f. 1 a-c. *Planulina wuellerstorfi* (Schwager) BARKER, 1960, p. 192, pl. 93, fig. 9. ____ PFLUM and FRERICHS, 1976, p. 116, pl. 4, figs. 2-4. *Cibicides wuellerstorfi* (Schwager) HEIMAN, 1977, p. 136, pl. 7, figs. 1-3. *Planulina wuellerstorfi* (Schwager) LOHMAN, 1978, p. 26, pl. 2, figs. 1-4. ____ CORLISS, 1979a, p. 7, pl. 2, figs. 13-15. ____ POAG, 1981, p. 92-93, pl. 3 and 4, figs. 1-2. ____ HERMELIN and SCOTT, 1985, p. 216, pl. 4, figs. 12-13. ____ MEAD, 1985, p. 240, pl. 6, figs. 1-2. ____ THOMAS, 1985, p. 676, pl. 11, figs. 1-4. ____ BELANGER and BERGGREN, 1986, p. 338, pl. 3, figs. 9-11. *Fontbotia wuellerstorfi* (Schwager) PATTERSON, 1986b, p. 248, pl. 58, figs. 5-8. *Planulina wuellerstorfi* (Schwager) MILLER and KATZ, 1987, p. 136, pl. 6, fig. 2.

Description: Test compressed, characterized by low trochospiral coiling, spiral side slightly concave to flat, umbilical side strongly convex, umbonate, 10-13 broadly inflated strongly arched chambers in the final whorl; sutures strongly curved, limbate, elevated; periphery carinate with an imperforate keel; wall smooth and finely perforate on umbilical side and coarse, evenly perforated on evolute spiral side; aperture small, interiomarginal, with an imperforated lip, extending only four chambers along the spiral suture.

Remarks: The taxonomic position of this species is uncertain. In the literature this species was documented under either *Planulina wuellerstorfi* (Schwager) or *Cibicides wuellerstorfi* (Schwager). Gonzalez-Donso and Linares (1970) raised a new genus *Fontbotia* which is characterized by flat trochospiral coiling, more numerous, broad, low

Family AMPHISTEGINIDAE Cushman, 1927

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina gibbosa d'Orbigny

Amphistegina gibbosa D'ORBIGNY, 1903, p. 304, pl. 2, fig. 4. —. BARKER, 1960, p. 228, pl. 110, figs. 2-4. *Amphistegina radiata* (Fichtel and Moll). TODD, 1965, p. 34, pl. 3, figs. 1-3.

Description: Test circular, equally biconvex, distinctly biumbonate, sutures radiating from ventral umbo, sharply angled; periphery acute and carinate.

Remarks: Barker's *Amphistegina quoyi* d'Orbigny closely resembles the present species but the former differs in having more chambers and is much larger in size.

Occurrence: Abundant in two Pliocene samples from site 587; rare in Pleistocene samples at site 587.

Amphistegina madagascarensis d'Orbigny

Amphistegina madagascarensis D'ORBIGNY, 1903, p. 30-4, pl. 2, fig. 5. *Amphistegina lessonii* d'Orbigny. BARKER, 1960, p. 228, pl. 111, figs. 5-6. *Amphistegina madagascarensis* d'Orbigny. TODD, 1965, p. 34, pl. 12, figs. 1-2.

Description: Test biconvex, lenticular, 10-14 chambers in final whorl, periphery acute, sutures radial, supplementary chambers curved backwards at their outer ends on the umbilical side; aperture interiomarginal.

Remarks: *Amphistegina lessonii* d'Orbigny illustrated by Barker (1960, fig. 5) appears similar to the present species. The author compared the original illustration of the present species and *Amphistegina lessonii* d'Orbigny and found no essential difference between them, in fact they appear as mirror images. Hence, *A. lessonii* d'Orbigny is probably a synonym of *Amphistegina madagascarensis* d'Orbigny.

Occurrence: Common in Pliocene samples from site 587. Abundant in one Pleistocene sample from site 587.

Lobatula lobatulus (Walker and Jacob)

Nautilus lobatulus WALKER and JACOB, 1798, p. 642, pl. 14, fig. 367. *Truncatulina lobatula* (Walker and Jacob). CUSHMAN, 1921, p. 313, pl. 63, fig. 2. *Cibicides lobatulus* (Walker and Jacob). BARKER, 1960, p. 190, pl. 92, fig. 10 and pl. 93, figs. 1, 4, 5. —, MURRAY, 1971, p. 175, pl. 73. —, HEIMAN, 1977, p. 129, pl. 6, figs. 16, 20. *Cibicidoides lobatulus* (Walker and Jacob). CORLISS, 1979a, p. 10, pl. 3, figs. 7-9. *Cibicides lobatulus* (Walker and Jacob). SEJRUP and others, 1981, p. 290, pl. 1, fig. 4.

Description: Test trochospiral, spiral side flat to irregular, sutures thickened, depressed to slightly elevated, curved backward at the periphery on spiral side; umbilical side gently convex, 7 - 8 slightly inflated chambers in final whorl; sutures depressed, radial around the shallow umbilicus; periphery rounded to angular, carinate and lobulate; wall coarsely perforated; aperture an interiomarginal, equatorial arch bordered by a lip, extending on to the spiral side.

Remarks: According to Loeblich and Tappan (1987), *Lobatula* is differentiated from *Cibicides* by having irregular spiral side and a gently convex umbilical side, with radial depressed sutures around a shallow umbilicus. They have quoted *Nautilus lobatulus* Walker and Jacob as type species but the original illustration is poor and there is no proper description. The present species was documented in the literature as *Cibicides lobatulus* (Walker and Jacob). Todd (1965) described this species as *C. lobatulus* (Walker and Jacob) but her illustration does not match the characters of the present species.

Occurrence: Rare and sporadic in Early Miocene through Late Miocene samples from sites 588A and 588B. Very rare in Pleistocene samples at sites 587 and 589.

Family CYMBALOPORIDAE Cushman, 1927

Subfamily CYMBALOPORINAE Cushman, 1927

Genus CYMBALOPORETTA Cushman, 1928

Cymbaloporetta bradyi Cushman

Cymbalopora poeyi (d'Orbigny) var. *bradyi* CUSHMAN, 1915, p. 25, pl. 10, fig. 2; pl. 14, fig. 2. —, TODD, 1965, p. 37, pl. 19, figs. 1-4; pl. 20, fig. 4.

Description: Test flat to gently convex, with very irregular convex side; The umbilical side flat with an open umbilicus; sutures depressed and irregular; wall coarsely perforated.

Remarks: The distinction between this species and *Cymbaloporella squamosa* is mainly on the basis of open or closed umbilicus. However, *C. squamosa* has an almost subconical shape in side view. *Cymbalopora milletti* Heron-Allen and Earland has more bulbous chambers in the later stages of coiling.

Occurrence: Abundant in the Pleistocene samples at Sites 587 and 589.

Superfamily ASTERIGERINACEA Loeblich and Tappan, 1962

Family EPISTOMARIIDAE Hofker, 1954

Subfamily NUTTALLIDAE Saidova, 1981

Genus NUTTALLIDES Finlay, 1939

Nuttallides bradyi (Earland)

(Pl.3, figs.11 - 13)

Truncatulina pygmaea BRADY, 1884, pl. 95, figs. 9-10 [NOT *Truncatulina pygmaea* HANTKEN, 1875]. *Eponides bradyi* EARLAND, 1934, p. 187, pl. 8, figs. 36-38.

Description: Test biconvex, lenticular, trochospiral, with a sharply angled periphery, Seven to nine broad, low, sharply curved chambers on umbilical side; sutures radiating and gently curved; three whorls on spiral side visible, with limbate, oblique sutures; prominent umbonal boss characterizes umbonal side; surface coarsely perforate on both sides; aperture an interiomarginal slit extending from umbilical boss to near the outer margin with a small notch parallel to plane of coiling.

Remarks: See under *Epistominella umbonifera*.

Occurrence: Rare and sporadic in Middle Miocene through Pliocene samples from sites 588B and 587; common in the Pleistocene samples from site 589.

Family AMPHISTEGINIDAE Cushman, 1927

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina gibbosa d'Orbigny

Amphistegina gibbosa D'ORBIGNY, 1903, p. 304, pl. 2, fig. 4. —. BARKER, 1960, p. 228, pl. 110, figs. 2-4. *Amphistegina radiata* (Fichtel and Moll). TODD, 1965, p. 34, pl. 3, figs. 1-3.

Description: Test circular, equally biconvex, distinctly biumbonate, sutures radiating from ventral umbo, sharply angled; periphery acute and carinate.

Remarks: Barker's *Amphistegina quoyi* d'Orbigny closely resembles the present species but the former differs in having more chambers and is much larger in size.

Occurrence: Abundant in two Pliocene samples from site 587; rare in Pleistocene samples at site 587.

Amphistegina madagascarensis d'Orbigny

Amphistegina madagascarensis D'ORBIGNY, 1903, p. 30-4, pl. 2, fig. 5. *Amphistegina lessonii* d'Orbigny. BARKER, 1960, p. 228, pl. 111, figs. 5-6. *Amphistegina madagascarensis* d'Orbigny. TODD, 1965, p. 34, pl. 12, figs. 1-2.

Description: Test biconvex, lenticular, 10-14 chambers in final whorl, periphery acute, sutures radial, supplementary chambers curved backwards at their outer ends on the umbilical side; aperture interiomarginal.

Remarks: *Amphistegina lessonii* d'Orbigny illustrated by Barker (1960, fig. 5) appears similar to the present species. The author compared the original illustration of the present species and *Amphistegina lessonii* d'Orbigny and found no essential difference between them, in fact they appear as mirror images. Hence, *A. lessonii* d'Orbigny is probably a synonym of *Amphistegina madagascarensis* d'Orbigny.

Occurrence: Common in Pliocene samples from site 587. Abundant in one Pleistocene sample from site 587.

Superfamily	NONIONACEA Schultze, 1854
Family	NONIONIDAE Schultze, 1854
Subfamily	NONIONINAE Schultze, 1854
Genus	NONION de Montfort, 1808

Nonion depressulum (Walker and Jacob)

Nautilus depressulum WALKER and JACOB in Kanmacher, 1788, p. 641, pl. 14, fig. 33.

Nonionina depressulum (Walker and Jacob) BRADY, 1884, p. 725, pl. 109, figs. 6-7.

Nonion depressulum (Walker and Jacob). BARKER, 1960, p. 224, pl. 109, figs. 6-7.

Description: Test planispiral, involute, slightly compressed with a weak lobulate periphery; 6-9 partly inflated chambers in the last whorl increasing rapidly in size as added; surface smooth; aperture an arched, equatorial interiomarginal slit.

Occurrence: Rare and sporadic in Early Miocene through middle Miocene samples. Common in one Late Miocene sample from site 588, hole B.

Nonion havanense Cushman and Bermudez

Nonion havanense CUSHMAN and BERMUDEZ, 1937, p. 19, pl. 2, figs. 13-40. —. THOMAS, 1985, 677, pl. 4, fig. 10.

Description: Test compressed, slightly depressed in the umbilical regions, completely involute, periphery somewhat lobulated, 10-11 uniformly shaped chambers in final whorl; sutures distinct, slightly limbate and depressed, gently curved; aperture low and interiomarginal.

Remarks: This species differs from *Nonion advenum* (Cushman) by possessing a depressed rather than an umbilical raised boss. The present species also superficially resembles *Nonion ibericum* Cushman, but the latter species is slightly evolute with shallow umbilicus.

Occurrence: Rare and sporadic in Early Miocene through Late Miocene samples from site 588, holes A and B. A single specimen was also found in one sample from site 587.

Genus NONIONELLINA Voloshinova, 1958

Nonionellina labradorica (Dawson)

Nonionina labradorica DAWSON, 1860, p. 191. *Nonionellina labradorica* (Dawson). VOLOSHINOVA, 1958, p. 142. —. LOEBLICH and TAPPAN, 1987, p. 617, pl. 689, figs. 8-17.

Description: Test trochospiral in early stage, later becoming planispiral and involute; 9-11 chambers visible in final whorl enlarging rapidly as added; biumbilicate with umbilici unequal in size; periphery subangular to rounded; surface smooth, aperture a low interiomarginal equatorial arch.

Remarks: The present species differs from *Nonionella miocenica* Cushman by the open biumbilici and by having less inflated chambers. *Nonion scaphum* (Fichtel and Moll) resembles *Nonionellina labradorica* but the former species has fewer chambers.

Occurrence: Rare and sporadic in Late Miocene through Pleistocene samples of site 588 and 589 respectively.

Nonionella miocenica Cushman

Nonionella miocenica CUSHMAN, 1926, p.53 - 69. —. LOEBLICH and TAPPAN, 1987, p.617, pl. 689, figs. 5-7, 18-21.

Description: Test low and trochospiral, with rounded periphery; spiral side partially evolute, especially around umbonal boss, umbilical side involute, 10-12 low broad, gradually enlarging chambers; chambers with a flap-like extension around the umbonal boss; sutures curved and depressed, periphery slightly lobulate, surface smooth; aperture small and interiomarginal, with an equatorial arch extending slightly onto the umbilical side.

Remarks: *Nonionella miocenica* Cushman differs from *Nonionella stella* Cushman and Moyer by having more chambers and a flaring test. *Nonionella pulchella* Hada has fewer broad chambers. See also under *Nonionellina labradorica* (Voloshinova).

Occurrence: Single specimens occur in Middle and Late Miocene samples of site 588, holes A and B.

Genus PSEUDONONION Asano, 1936

Pseudononion japonicum (Asano)

Nonionina japonicum ASANO, 1936, p. 347, figs. a-c. *Pseudononion japonicum* (Asano).
LOEBLICH and TAPPAN, 1988, p. 618, pl. 692, figs. 1-6.

Description: Test asymmetrical, slightly depressed; ventral side involute, dorsal side evolute; 10-11 broad and low chambers in final whorl; sutures distinct, slightly depressed, gently curved; surface smooth; aperture a narrow slit at the base of the apertural face.

Remarks: *Pseudononion japonicum* Asano differs from *Nonionellina labradorica* (Voloshinova) by possessing compressed, very slender test. It also differs from *Nonionella miocenica* Cushman in having a compressed, less asymmetrical test, and by the gently curved sutures.

Occurrence: Common in two Early Miocene samples from site 588A. Rare and sporadic in rest of the samples.

Subfamily ASTRONONIONINAE Saidova, 1980

Genus ASTRONONION Cushman and Edwards, 1937

Astrononion australe Cushman and Edwards

Astrononion australe CUSHMAN and EDWARDS, 1937, p. 33, pl. 3, figs. 13-14.

Description: Test slightly compressed, periphery broadly rounded, slightly lobulate; both sides involute, umbilical region slightly depressed, chambers regularly increasing in size as added, supplementary chambers somewhat tubular extending only short distance towards the periphery; aperture low, narrow, interiomarginal, supplementary apertures oblique to the periphery; surface smooth and polished.

Remarks: See under *Astrononion stelligerum* (d'Orbigny).

Occurrence: Common in Early Miocene through Late Miocene at sites 588A and 588B.

Astrononion echolsi Kennett

(Pl. 5, figs. 1 & 2)

Astrononion echolsi KENNETT, 1967, p. 134-135, pl. 11, figs. 7-8. —. CORLISS, 1979a, p. 8, pl. 3, figs. 16-17. —. MEAD, 1985, p. 235, pl. 4, figs. 3-4. —. BELANGER and BERGGREN, 1985, p. 341, pl. 4, figs. 7-8. *Astrononion pusillum* Hornibrook, MILLER and KATZ, 1987, p. 121, pl. 4, fig. 6.

Remarks: The description of Kennett (1967) is followed herein. It is distinguished by less extended supplemental chambers and supplementary apertures in sunken pits as shown in the illustration (Pl.5, figs. 1, 2). *Astrononion pusillum* Hornibrook is distinguished by its very tubular, short restricted supplementary apertures. It is also similar to *Astrononion umblicatulum* Uchio but the latter has very lengthy, tubular supplementary chambers.

Occurrence: Rare to common in Early Miocene samples from site 588A. Abundant in Middle Miocene samples from site 588A; common in Late Miocene samples from site 588B. Abundant in one Late Miocene sample from site 587. Rare in Pleistocene samples from site 587 and 589.

Astrononion stelligerum (d'Orbigny)

Nonionina stelligera, 1839, p. 128, pl. 3, fig. 8. —. CUSHMAN, 1914, p. 27, pl. 14, fig. 4; pl. 15, fig. 4. *Astrononion stelligerum* (d'Orbigny). BARKER, 1960, p. 224, pl. 109, figs. 3-4.

Description: Test compressed, periphery acute, slightly lobulate, both sides involute, 9-10 inflated chambers rapidly increasing in size as added; chambers somewhat arch-shaped; thin supplementary chambers appearing star like extending half of the chamber; apertural face higher than broad; primary aperture low-arched, interiomarginal; supplementary apertures terminate in sharp pointed ends; surface smooth and glassy.

Remarks: The present species differs from *Astrononion galloway* Loeblich and Tappan by having a very compressed test, and thin stellate supplementary chambers. *Astrononion australe* Cushman and Edwards shows fewer chambers and the chambers are

less inflated. *Astrononion gallowayi* Loeblich and Tappan has a more inflated test and is characterized by broader umbilical flaps along the sutures.

Occurrence: Rare and sporadic in Middle Miocene and Late Miocene samples from sites 588A, 588B and 587.

Genus **PACINONION** Vella, 1962

Pacinonion novozealandicum (Cushman and Edwards)

(Pl.5, figs, 3 & 4)

Astrononion novozealandicum CUSHMAN and EDWARDS, 1937, p. 35, pl. 3, fig. 8. —. THOMAS, 1985, p. 675, pl. 4, fig. 9. *Pacinonion novozealandicum* (Cushman and Edwards). LOEBLICH and TAPPAN, 1988, p. 620, pl. 694, figs. 11-15.

Description: Test moderately compressed, biumbilicate, 9-10 slightly inflated chambers, enlarging gradually in size in final whorl; supplementary chambers elongate, tubular and of uniform shape, extending three fourths towards the periphery; primary aperture interiomarginal, semicircular supplementary apertures at the end of each chamber; surface smooth and perforated.

Remarks: The present species is distinguished by uniform, tubular, supplementary chambers with semicircular apertures at the end. Present species differs from *Astrononion stelligerum* (d'Orbigny) by having a much more compressed test and more elongated supplementary chambers. *A. echolsi* Kennett has a broadly rounded periphery.

Occurrence: Frequent in two Early Miocene samples from site 588A. Common in Middle Miocene through Late Miocene samples from sites 588B and 587. Rare in Pliocene samples from site 589.

Subfamily **PULLENIINAE** Schwager, 1877

Genus **MELONIS** de Montfort, 1808

Melonis barleanum (Williamson)

(Pl.5, figs, 5 & 6)

Nonionina barleana WILLIAMSON, 1858, p. 24, pl. 3, figs. 68-69. *Gavelinomon barleanum* (Williamson) BARKER, 1960, p. 224, pl. 109, figs. 8-9. *Melonis pompilioides* (Fichtel and Moll). MURRAY, 1971, p. 199, pl. 89. *Melonis barleanum* (Williamson). PFLUM and FRERICHS, 1976, pl. 7, figs. 5-6. *Nonion affinis* (Reuss). BOLTOVSKOY, 1978, p. 162, pl. 5, figs. 1-2. *Melonis barleanum* (Williamson). CORLISS, 1979a, p. 10, pl. 5, figs. 7-8. *Melonis affinis* (Reuss). INGLE *et al.*, 1980, p. 140, pl. 5, fig. 1-2. *Melonis barleanum* (Williamson). THOMAS, 1985, p. 677, pl. 12, fig. 3. —. KURIHARA and KENNETH, 1986, pl. 9, figs. 10-11. —. BELANGER and BERGGREN, 1986, p. 346, pl. 7, figs. 7-8. —. MILLER and KATZ, 1988, p. 136, pl. 4, fig. 5a-b.

Remarks: The description of Williamson (1858) is followed herein. *Nonionina umbilicatula* (Montagu) has thin, slightly curved limbate sutures. *Nonion affinis* (Reuss) described by Boltovskoy (1978) is very small, more compressed, characterized by a small umbilicus and a very narrow semicircular aperture. Murray's (1971) illustration does not fit into the type description.

Occurrence: Rare in Early Miocene samples from site 588A. Rare to common throughout the section.

Melonis pompilioides (Fichtel and Moll)

Nautilus pompilioides FICHTEL and MOLL, 1798, p. 59, pl. a-c. *Nonion pompilioides* (Fichtel and Moll). BARKER, 1960, p. 224, pl. 109, figs. 10-11. not *Melonis pompilioides* (Fichtel and Moll). MURRAY, 1971, p. 199, pl. 84. *Melonis pompilioides* (Fichtel and Moll). INGLE *et al.*, 1980, p. 142, pl. 9, figs. 14-15. —. THOMAS, 1985, p. 677, pl. 12, figs. 1-2. —. HERMELIN and SCOTT, 1985, p. 212, pl. 6, fig. 5. *Melonis sphaeroides* Voloshinova. MEAD, 1985, p. 242, pl. 7, figs. 3 a and b. —. BELANGER and BERGGREN, 1986, p. 346, pl. 7, figs. 9-10. *Melonis pompilioides* (Fichtel and Moll). KURIHARA and KENNETT, 1986, pl. 9, figs. 7-8. —. NIENSTEDT and ARNOID, 1988, pl. 2, fig. 17. *Melonis sphaeroides* Voloshinova. MILLER and KATZ, 1988, p. 136, pl. 4, fig. 3.

Remarks: The description of Fichtel and Moll (1798) is followed herein. *Melonis pompilioides* differs from *Melonis barleanum* (Williamson) by possessing a very deep umbilicus and a very broad, narrow, apertural face. The present species is larger than *Melonis sphaeroides* Voloshinova and the latter is very similar to the present species. Many authors expressed the opinion that *M. pompilioides* shows a wide range of morphological variation. Deep and shallow water forms of the present species and its morphological variants are bathymetrically controlled ecotypes rather than distinct taxa (van Morkhoven *et al.*, 1986). When discussing *Melonis sphaeroides* Voloshinova, Mead (1985), stated that Voloshinova had noticed some deficiencies in the type drawings of *Nonionina pompilioides* and she raised *Melonis sphaeroides* from Brady's (1884) hypotypes. Murray's (1971) form is very compressed and it does not definitely belong to the present species as it shows all the characteristics of *Melonis barleanum* (Williamson).

Occurrence: Rare and sporadic in samples of all sites.

Genus PULLENIA Parker and Jones, 1862

Pullenia bulloides d'Orbigny

(Pl.5, fig.7)

Nonionina bulloides D'ORBIGNY, 1846, p. 107, pl. 5, figs. 9-10. *Pullenia bulloides* d'Orbigny. BARKER, 1960, p. 174, pl. 84, figs. 12-13. —. TODD, 1965, p. 48, pl. 18, fig. 6. —. BOLTOVSKOY, 1978, p. 166, pl. 6, fig. 16. —. LOHMAN, 1978, p. 26, pl. 1, figs. 10-11. —. CORLISS, 1979a, p. 8, pl. 4, figs. 1-2. —. BURKE, 1981, p. 8, pl. 3, figs. 5-6. —. HERMELIN and SCOTT, 1985, p. 236, pl. 4, fig. 6. —. KURIHARA and KENNETT, 1986, p. 1074, pl. 6, figs. 7-8. —. MILLER and KATZ, 1987, p. 136, pl. 4, fig. 4. —. NIENSTEDT and ARNOLD, 1988, p. 247, pl. 2, fig. 14.

Remarks: The description of d'Orbigny is followed herein.

The present species is easily distinguished by the sphaeroidal test, circular in side view, with the highly inflated chambers and narrow crescentic aperture. *Pullenia*

subsphaerica Parr is a slightly compressed form and can be considered as a synonym of the present species.

Pullenia osloensis Feyling-Hanssen

Pullenia quinqueloba (Reuss) subsp. *minuta* Feyling-Hanssen, 1954 [Emend.] *Pullenia osloensis* FEYLING-HANSEN, 1954, p. 194. —. BOLTOVSKOY, 1978, p. 166, pl. 6, figs. 15-18. —. CORLISS, 1979a, p. 9, pl. 4, figs. 3-4. —. BELANGER and BERGGREN, 1986, p. 342, pl. 5, figs. 2-3. —. KURIHARA and KENNETT, 1986, p. 1074, pl. 6, figs. 7-8.

Description: Test almost circular in side view, compressed, six chambers visible in final whorl, slightly inflated; sutures radial, depressed, slightly curved at the peripheral margin; periphery lobulate; last formed chamber asymmetric to the axis of coiling; aperture interiomarginal extending end to end with a distinct lip.

Remarks: *Pullenia pedrona* Kleinpell is similar to the present species but differs by having very high apertural face and a restricted aperture.

Occurrence: Rare and sporadic throughout the section except at site 587.

Pullenia octaloba Barat and von Estorff

Pullenia octaloba BARAAT and VON ESTORFF, 1933, p. 168, pl. 23, fig. 11a-b. *Pullenia multilobata* Chapman. BOLTOVSKOY, 1978, p. 166, pl. 4, figs. 13-14.

Description: Test planispiral, involute, biconvex, slightly compressed, periphery slightly lobulate in side view; eight chambers in the last whorl gradually increasing in size as added; sutures radial, and almost flush with the surface; a triangular, high-arched, interiomarginal aperture extends to the umbilicus; surface smooth and polished.

Remarks: The present species is distinguished from *Pullenia multilobata* Chapman by possessing a less lobulate and more rounded periphery. *P. multilobata* has a very acute periphery.

Occurrence: Single specimens occur only in three samples from Late Miocene samples at site 588B.

Pullenia quadriloba Reuss

(Pl.5, figs.8 - 9)

Pullenia compressiuscula Reuss var. *quadriloba* REUSS —. THOMAS, 1985, p. 678, pl. 4, fig. 1.

Description: Test slightly compressed, periphery rounded, four chambers visible, rapidly enlarging in size as added; sutures depressed, radial; aperture a low interiomarginal arch, extending to the umbilicus on either side; surface smooth and polished.

Remarks: The present species is distinguished by a quadrangular test. *Pullenia quadriloba* differs from *Pullenia bulloides* d'Orbigny in having four slightly compressed chambers, a more lobulate periphery, and an almost quadrangular test. *Pullenia quinqueloba* (Reuss) also resembles the present species, but the former is more compressed and possesses more chambers.

Occurrence: Rare to common in Early Miocene samples from site 588A. Rare and sporadic in Middle through Late Miocene samples from site 588A and 588B. Rare and sporadic in Pleistocene samples from site 589.

Pullenia quinqueloba (Reuss)

(Pl.5, figs.10 - 11)

Nonionna quinqueloba REUSS, 1851, p. 71, pl. 5, fig. 31a-b. *Pullenia simplex* Rhumbler. CORLISS, 1979a, p. 9, pl. 4, figs. 5-6. *Pullenia quinqueloba* (Reuss) INGLE *et al.*, 1980, p. 142, pl. 5, fig. 8. —. THOMAS, 1985, p. 678, pl. 4, fig. 2. *Pullenia simplex* Rhumbler. BELANGER and BERGGREN, 1986, p. 342, pl. 5, figs. 4-6. *Pullenia quinqueloba* (Reuss). MILLER and KATZ, 1987, p. 138, pl. 4, fig. 2.

Remarks: The description of Reuss (1851) is followed herein. *Pullenia subcarinata* (d'Orbigny) differs from the present species by possessing six gradually enlarging chambers and the test is more inflated. *Pullenia quinqueloba* is more compressed than *Pullenia quadriloba* (Reuss).

Occurrence: Rare to common in Early Miocene samples from site 588A. Common in Middle through Late Miocene samples from Sites 588A and 588B. Rare and sporadic in Pleistocene samples from site 589.

Pullenia salisburyi Stewart and Stewart

Pullenia salisburyi STEWART and STEWART, 1930, p. 72, pl. 8, fig. 2a-b. —. BOLTOVSKOY, 1978, p. 166, pl. 6, fig. 19. —. THOMAS, 1985, p. 678, pl. 4, fig. 4. —. MEAD, 1985, p. 236, pl. 4, figs. 7-8.

Description: Test planispiral, involute, compressed, periphery subacute in edge view, slightly lobulate in side view, six distinct chambers, gradually enlarging in size as added; sutures radial, slightly depressed, and slightly curved; apertural face slightly pointed; aperture a narrow, crescentic, interiomarginal slit with a narrow lip extending from umbilicus of one side to the opposite side; surface smooth and polished.

Remarks: The present species differs from *Pullenia quinqueloba* (Reuss) in possessing six chambers, slightly lobulate periphery and a more compressed test.

Occurrence: Rare and sporadic in Middle Miocene through Pleistocene samples from sites 588A, 588B and 589.

Superfamily	CHILOSTOMELLACEA	Brady, 1881
Family	CHILOSTOMELLIDAE	Brady, 1881
Subfamily	CHILOSTOMELLINAE	Brady, 1881
Genus	CHILOSTOMELLA	Reuss, 1849

Chilostomella oolina Schwager

Chilostomella oolina SCHWAGER, 1878, p. 527, pl. 1, fig. 16. —. BARKER, 1960, p. 112, pl. 55, figs. 12-14, 17-18. *Chilostomella ovoidea* Reuss. BOLTOVSKOY, 1978, p. 155, pl. 3, fig. 3. *Chilostomella oolina* Schwager. HEIMAN, 1977, p. 166, pl. 13, fig. 1. —. PATTERSON, 1986b, p. 233, pl. 54, figs. 4-5.

Description: Test elongate, ovate, broadly rounded, planispiral involute; about two embracing chambers per whorl.

Remarks: The present species differs from *Chilostomella czizeki* Reuss by its more cylindrical shape and greater exposure of the penultimate chamber.

Occurrence: Rare and sporadic in Middle Miocene through Pleistocene samples from sites 587, 588B and 589.

Family OSANGULARIIDAE Loeblich and Tappan, 1964

Genus OSANGULARIA Brotzen, 1940

Osangularia culter (Parker and Jones)

(Pl.6, fig.12)

Planorbulina farcta (Fichtel and Moll) var. *ungeriana* (d'Orbigny) subvar. *culter* PARKER and JONES, 1865, p. 382, pl. 19, figs. 1a-b. *Osangularia culter* (Parker and Jones). BARKER, 1960, p. 175, pl. 35, figs. 1-5. —. BOLTOVSKOY, 1978, p. 163, pl. 5, figs. 29-34. —. NIENSTEDT and ARNOLD, 1988, pl. 2, fig. 4.

Remarks: The type description of Parker and Jones (1865) is followed herein. *Osangularia culter* is distinguished from *Osangularia bengalensis* (Schwager) by having an unequally biconvex, smaller test, with a carinate periphery and reflex sutures on the spiral side. In the present study, I have also observed supplementary apertures on spiral side.

Occurrence: Common in Middle Miocene and Late Miocene samples from site 588A and 588B. Rare and sporadic in Pliocene through Pleistocene samples from sites 587, 588B and 589.

Family ORIDORSALIDAE Loeblich and Tappan, 1984

Genus ORIDORSALIS Andersen, 1961

Oridorsalis umbonatus (Reuss)

(Pl.6, figs.1 - 3)

Rotalina umbonata REUSS, 1851, p. 75, pl. 5, fig. 35. *Pulvinulina umbonata* (Reuss). CUSHMAN, 1915, p. 60, pl. 27, fig. 2. *Eponides umbonatus* (Reuss). BARKER, 1960, p.

216, pl. 105, fig. 2. *Oridorsalis umbonatus* (Reuss). TODD, 1965, p. 23, pl. 6, fig. 2. —, BELFORD, 1966, p. 172, pl. 30, figs. 1-6; T.f. 22 (4-5). *Oridorsalis tener umbonatus* (Reuss). PFLUM and FRERICHS, 1976, pl. 6, figs. 5-7. *Oridorsalis umbonatus* (Reuss). BOLTOVSKOY, 1978, p. 162, pl. 5, figs. 5-6. —. LOHMAN, 1978, pl. 4, figs. 1-3. —. BURKE, 1981, pl. 3, figs. 9-10. —. THOMAS, 1985, pl. 4, figs. 7-8. —. HERMELIN and SCOTT, 1985, p. 214, pl. 5, fig. 10. —. KURIHARA and KENNETT, 1986, p. 1074, pl. 6, figs. 11-13.

Description: Test trochospiral, biconvex, periphery broadly rounded, circular in side view; 5-6 distinct chambers in the last whorl, slightly inflated chambers, all visible on spiral side, the last chamber projecting into the centre of the test on the umbilical side; sutures slightly limbate, radial on the umbilical side, partly curved on the spiral side; primary aperture an interiomarginal slit with a thin lip restricted to the middle of the last - formed chamber; supplementary aperture on the umbilical side located at the end of the projection of the last - formed chamber; wall smooth and polished.

Remarks: In the present study, *Oridorsalis umbonatus* (Reuss) shows a wide range of variation in morphological characters. This species can easily be confused with *Oridorsalis tener* (Brady) but the latter is more compressed, petaloid, with acute periphery, and it has an extended aperture. In the present material these two species are very distinct. In the type illustration given by Reuss (1851) the test is more convex than *O. tener* (Brady). *Oridorsalis stellatus* (Silvestri) has hooked sutures on the umbilical side.

Occurrence: Common to frequent in the Early Miocene of site 588A, abundant in Middle Miocene of 588A, common in Late Miocene through Pleistocene at site 587, 588B and 589.

Oridorsalis tener (Brady)

(Pl.6, figs.4 - 6)

Truncatulina tenera BRADY, 1884, p. 665, pl. 95, figs. 11a-c. —. CUSHMAN, 1921, p. 37, pl. 16, fig. 2; pl. 23, fig. 2. *Eponides tener* (Brady). BARKER, 1960, p. 196, pl. 95,

fig. 11. *Oridorsalis tener tener* (Brady). PFLUM and FRERICHS, 1976, pl. 6, figs. 2-4. *O. tener* (Brady). LOHMAN, 1978, pl. 4, figs. 5-7. —. CORLISS, 1979, p. 9, pl. 4, figs. 10-15. INGLE *et al.*, 1980, p. 142, pl. 5, figs. 5-6. —. THOMAS 1985, p. 677, pl. 4, figs. 5-6. —. KURIHARA and KENNETT, 1986, p. 1075, pl. 7, figs. 1-3. —. MILLER and KATZ, 1987, p. 133, pl. 6, fig. 6.

Description: Test trochospiral, lenticular with a carinate periphery, five chambers on ventral side in the last formed whorl, all chambers visible on spiral side; sutures on umbilical side depressed, radiating and curved, spiral sutures radial and flush with the surface; small secondary sutural openings are distinct on the spiral side near the junctions of the spiral and septal sutures; aperture interiomarginal and extending from the periphery nearly to the closed umbilicus on the ventral side with a distinct lip.

Remarks: The present species is distinguished from *Oridorsalis umbonatus* (Reuss) by possessing a petaloid test with an acute periphery and an extended aperture. Supplementary apertures on the spiral side are the most diagnostic features [see also under *Oridorsalis umbonatus* (Reuss)].

Occurrence: Frequent in Early Miocene, common in Middle Miocene through Pleistocene samples at sites 588A, 588B and 589.

Family HETEROLEPIDAE Gonzalez-Donoso, 1969

Genus ANOMALINOIDES Brotzen, 1942

Anomalinoides globulosus (Chapman and Parr)

Anomalina globulosa CHAPMAN and PARR, 1937, p. 117, pl. 9, fig. 27. NOT BARKER, 1960, p. 194, pl. 94, figs. 4-5]. —. THOMAS, 1985, p. 675, pl. 12, figs. 6-7. NOT HERMELIN and SCOTT, 1985 p. 203, pl. 16, figs. 1-2.] —. BOERSMA, 1986, p. 988, pl. 2, figs. 1-3. —. van MORKHOVEN *et al* 1986, p. 36, pl. 9.

Description: Test compact, equally biconvex, lobulate periphery, broadly rounded, 5-7 inflated chambers in the last formed whorl; gently curved depressed sutures on both sides; umbilicus small, open; surface coarsely punctate on spiral side and weakly on

umbilical side; aperture a low, elongated interiomarginal arch at the centre of the last formed chamber.

Remarks: The present species differs from *Anomalinoides semicribratus* (Beckman) in possessing elongated triangular chambers and aperture starting at the midpoint of the periphery and extending onto the umbilicus on either side.

Occurrence: Rare and sporadic throughout the sections.

Anomalinoides semicribratus (Beckman)

Anomalina pompilioides Galloway and Heminway var. *semicribrata* BECKMAN, 1954, p. 400, pl. 27, fig. 3. *Anomalina globulosa* Chapman and Parr. BARKER, 1960, p. 194, pl. 94, fig. 5. *Anomalinoides* sp. LOHMAN, 1978, pl. 2, figs. 13-15. *Anomalinoides globulosa* (Chapman and Parr). HERMELIN and SCOTT, 1985, p. 203, pl. 6, figs. 1-2. —, BOERSMA, 1986, p. 988, pl. 1, figs. 1-6. —, van MORKHOVEN *et al.*, 1986, p. 147, pl. 48.

Description: Test planispiral, spiral side less involute than the umbilical side, periphery broadly rounded; 5-6 chambers in the final whorl; sutures radial on ventral side, curved on spiral side; spiral surface coarsely punctate; umbilical surface smooth; crescentic narrow aperture, slightly eccentric.

Remarks: The present species differs from *Anomalinoides globulosa* (Chapman and Parr) by possessing chambers, a broadly rounded periphery and an eccentric aperture extending from the peripheral edge to the umbilicus.

Occurrence: Rare and sporadic throughout the section.

Family GAVELINELLIDAE Hofke, 1956

Subfamily GYROIDINOIDINAE Saidova, 1981

Genus GYROIDINOIDES Brotzen, 1942

Gyroidinoides acuta Boomgaart

Gyroidina neosoldani Brotzen var. *acuta* BOOMGAART, 1949, p. 125, pl. 14, fig. 1

Gyroidina acuta Boomgaart. BELFORD, 1966, p. 165, pl. 28, figs. 1-9, T.f. 21(6-7).

Gyroidina altiformis acuta Boomgaart. PFLUM and FRERICHS, 1976, pl. 4, figs. 8-9; pl. 5, fig. 1. *Gyroidina acuta* Boomgaart. HEIMAN, 1977, p. 174, pl. 14, figs. 5-6.

Description: Test trochospiral, plano - to slightly biconvex, periphery acute, 7-8 chambers in the final whorl, three whorls visible from the spiral side, umbilical shoulder large; sutures depressed, oblique on spiral side, radial on umbilical side; aperture interiomarginal umbilical extraumbilical, wide open; surface smooth and polished.

Remarks: This species differs from *Gyroidina soldanii* d'Orbigny by its smaller size, acute periphery, fewer chambers and wide open extra-umbilical aperture.

Occurrence: Rare and sporadic in Early Miocene through Late Miocene samples at site 588A, 588B and 587. Single specimens from Pliocene through Pleistocene samples of sites 587, 588B and 589.

Gyroidinoides broeckhiana (Karrer)

(Pl.4, figs.10 - 12)

Rotalia broeckhiana KARRER, 1878, p. 98, pl. 5, fig. 26. —. CUSHMAN, 1921, p. 346, pl. 72 fig. 1a-c. *Gyroidina broeckhiana* (Karrer). BARKER, 1960, p. 220, pl. 107, fig. 4. —. BELFORD, 1966, p. 167, pl. 29, figs. 107; T.f. 21 (10-11). —. HEIMAN, 1977, p. 175, pl. 24, figs. 1-3.

Description: Test high trochospiral, spiral side highly convex, 7-8 chambers in the final whorl; three and three half to four whorls visible on spiral side; sutures depressed on both the sides, radial on umbilical side, strongly curved on spiral side; apertural face angular, and aperture extends from the periphery to the umbilicus.

Remarks The present species is distinguished by the strongly convex spiral side, and the aperture arch - shaped with a lip; *Gyroidinoides broeckhiana* (Karrer) also superficially resembles *Eponides politus* Phleger and Parker but the latter species has a distinct plano-convex test.

Occurrence: Common in Early Miocene through Late Miocene samples at sites 588A and 588B. Rare and sporadic in Pliocene through Pleistocene samples from sites 587, 588B and 589.

Gyroidinoides lamarckiana (d'Orbigny)

(Pl.4, figs. 7 - 9)

Rotalina lamarckiana D'ORBIGNY, 1839b, p. 131, pl. 2, figs. 13-15. *Gyroidina lamarckiana* D'orbigny. BOLTOVSKOY, 1978, p. 160, pl. 4, fig. 14-15. — *Gyroidinoides lamarckiana* d'Orbigny. THOMAS, 1985, p. 677, pl. 5, figs. 1-2.

Description: Low trochospiral, plano-convex test, involute on umbilical side, evolute spiral side, periphery broadly rounded, test slightly compressed with less prominent umbilical shoulder; sutures flush with surface, umbilical side radial, spiral side slightly curved; aperture extends from periphery to umbilicus on umbilical side; surface smooth.

Remarks: The present species differs from *Gyroidina orbicularis* d'Orbigny by possessing a rounded periphery with fewer chambers. *Gyroidinoides lamarckiana* (d'Orbigny) also superficially resembles to *Gyroidina obesa* Brady but the latter has fewer chambers and the aperture is relatively large.

Occurrence: Common in Early and Middle Miocene samples at site 588A; frequent in Late Miocene of Site 588B; rare and sporadic in Pliocene through Pleistocene samples from sites 587 and 589.

Gyroidinoides soldanii (d'Orbigny)

(Pl.4, figs. 4 - 5)

Gyroidina soldanii D'ORBIGNY, 1826, p. 278. — BOLTOVSKOY, 1978, p. 160, pl. 4, figs. 18-19. not *Gyroidinoides soldanii* (d'Orbigny). CORLISS, 1979a, p. 9, pl. 5, figs. 4-6]. *Gyroidina soldanii* d'Orbigny. INGLE *et al.*, 1980, p. 138, pl. 7, figs. 12-13. — not HERMELIN and SCOTT, 1985, p. 677, pl. 6, figs. 7-8. — not BILANGIER and BERGGREN, 1986, p. 344, pl. 6, fig. 3a-c. *Gyroidina* sp. A. KURIHARA and KENNETT, 1986, pl. 7, figs. 10-12.

Description: Test large, trochospiral, biconvex to nearly plano-convex, periphery acute; open umbilicus, 10-11 chambers in the last whorl, three and one-half to four whorls distinct on spiral side; last formed chambers more inflated forming a broad umbilical shoulder; sutures slightly curved on umbonal side, oblique to nearly radial on spiral side; aperture a large opening extending from the periphery to umbilicus; surface smooth.

Remarks: *Gyroidina neosoldanii* Brotzen is similar to the present species but differs in having more protruded whorls on spiral side and a much wider open aperture. Mead (1985) suggested that *Gyroidina neosoldanii* Brotzen is a synonym of *Gyroidina soldanii* d'Orbigny.

Occurrence: Common in Early Miocene of Site 588A; frequent in two Middle Miocene samples of Site 588B; common in Late Miocene through Pleistocene of Sites 587, 588B and 589.

Gyroidinoides torulus Belford

Gyroidinoides torulus BELFORD, 1966, p.168, pl.28, figs.10-20; T.f. 21 (8-9).

Description: Test trochospiral, unequally biconvex, spiral side more convex, periphery slightly lobulate; 7-9 chambers visible on umbonal side; sutures narrow, those on the umbilical side radial, and the spiral side straight; aperture interiomarginal, umbilical – extraumbilical with a narrow lip and triangular umbilical flaps on umbilical side.

Remarks: The present species superficially resembles *Gyroidinoides soldanii* (d'Orbigny) but differs in having triangular apertural flaps. *Gyroidina girardana* (Reuss) also resembles the present species but differs by possessing elongate and narrow spiral chambers.

Occurrence: Rare in Early Miocene samples from site 588A, common to frequent in Middle Miocene through Late Miocene samples from site 588A and 588B. Rare to common in Pliocene through Pleistocene samples at sites 588A, 588B and 589.

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1. *Globocassidulina subglobosa* Assemblage

Globocassidulina subglobosa (Brady)
Cassidulina cuneata Finlay
Oridorsalis umbonatus(Reuss)
O tener(Brady)
Epistominella exigua (Brady)
E.umbonifera (Cushman)
Bolivina compacta Sidebottom
Pacinonion novozealandicum
 Cushman & Edwards)
Bulimina rostrata Brady
B spathulata(Williamson)
Brizalina pusilla(Schwager)
Cibicides kullenbergi Parker
Globocassidulina minuta (Cushman)
Gyroidinoides lamarckiana (d'Orbigny)
G toruius Belford
Melonis barleanum(Williamson)
Sanguularia culter (Parker and Jones)
Pullenia bulloides d'Orbigny
Virgulinopsis pustulata Finlay
Pyramidulina challengeriana (Thalman)
Siphonodosaria lepidula (Schwager)

2. *Epistominella exigua* Assemblage

Epistominella umbonifera (Cushman)
E. exigua (Brady)
Eilohedra weddellensis (Earland)
Oridorsalis tener (Brady)
Astrononion echolsi Kennett
Oridorsalis umbonatus (Reuss)
Globocassidulina subglobosa (Brady)
Globocassidulina crassa (d'Orbigny)
Cassidulina laevigata d'Orbigny
Pullenia quinqueloba (Reuss)
Fontbotia wuellerstorfi (Schwager)
Melonis barleanum (Williamson)
Gyroidinoides soldanii (d'Orbigny)
Cibicides kullenbergi Parker
Pullenia bulloides d'Orbigny
Pleurostomella dominicana Bermudez
Cibicidoides mundulus (Brady, Parker
and Jones)
Siphonodosaria lepidula (Schwager)
Uvigerina proboscidea (Schwager)

3. *Epistominella exigua* / *E. umbonifera* Assemblage

Epistominella umbonifera
(Cushman)
E exigua (Brady)
Fontbotia wuellerstorfi
(Schwager)
Melonis baeleanum (Williamson)
Oridorsalis tener (Brady)
Globocassidulina crassa (d'Orbigny)
G subglobosa (Brady)
Cassidulina laevigata d'Orbigny
Eilohedra weddellensis (Earland)
Sphaeroidina bulloides d'Orbigny
Pullenia quinqueloba (Reuss)
Pullenia bulloides d'Orbigny
Astrononion echolsi Kennett
Gyroidinoides soldanii d'Orbigny
Oridorsalis umbonatus (Reuss)
Siphonodosaria lepidula (Schwager)
Cibicidoides mundulus Brady, Parker
Jones)
Cibicides kullenbergi (Parker)
Pleurostomella dominicana Bermudez

4. *Astrononion echolsi* / *Angulogerina angulosa* Assemblage

Astrononion echolsi Kennett
Angulogerina angulosa
(Williamson)
Fontbotia wuellerstorfi (Schwager)
Bolivina pseudoplicata (Heron-Allen &
Earland)
Brizalin beyrichi (Reuss)
B. minuta Cushman
Globocassidulina minuta (Cushman)
Sigmavirgulina tortuosa (Brady)
Gyroidinoides lamarckiana d'Orbigny
Oridorsalis tener (Brady)
Sagrinella lobata (Brady)
Trifarina bradyi Cushman
Patelinella inconspicua (Brady)
Cassidulina laevigata d'Orbigny
Globocassidulina porrecta
(Heron-Allen and Earland)
Uvigerina proboscidea Schwager
Melonis barleanum (Williamson)
Gyroidinoides soldanii d'Orbigny
Globocassidulina crassa (d'Orbigny)
Siphonodosaria subspinoso (d'Orbigny)
Ehrenbergina bradyi Cushman

**5. *Epistominella exigua* / *Globocassidulina*
subglobosa / *Fontbotia wuellerstorfi*
 Assemblage**

Epistominella exigua (Brady)

Fontbotia wuellerstorfi (Schwager)

Eilohedra weddellensis (Earland)

Paracassidulina quasisulcata (Belford)

Uvigerina peregrina Cushman

Cassidulina carinata Silvestri

Globocassidulina subglobosa (Brady)

Melonis barleanum (Williamson)

Astrononion echolsi Kennett

Oridorsalis tener (Brady)

Globocassidulina crassa (d'Orbigny)

Uvigerina proboscidea Schwager

Stainforthia complanata Egger

Cassidulina laevigata d'Orbigny

Oridorsalis umbonatus (Reuss)

Pullenia quinqueloba (Reuss)

Gyroidinoides lamarckiana (d'Orbigny)

Gyroidinoides soldanii (d'Orbigny)

Pleurostomella dominicana (Bermudez)

Cibicidoides mundulus (Brady, Parker,
and Jones)

Sphaeroidina bulloides d'Orbigny

APPENDIX A (continued)

APPENDIX. B. ALPHABETICAL LIST OF BENTHIC FORAMINIFERAL SPECIES.

Abditodentrix pseudothalmanii (P.94)
Amphistegina gibbosa (P.154)
A. madagascarensis (P.154)
Amplectoproductina carnatolintra (P.108)
Angulogerina angulosa (P.119)
A. carinata (P.120)
Angulogerina Sp. (P.120)
Anomalinoides globulosa (P.167)
A. semicribratus (P.168)
Astronoinion australe (P.157)
A. echolsi (P.157)
A. stelligerum (P.157)
Bolivina advena (P.87)
B. compacta (P.88)
B. cincta (P.88)
B. dilatata (P.89)
B. minuta (P.89)
B. pseudoplicata (P.90)
B. robusta (P.90)
Bolivinita quadrilatera (P.95)
Brizalina spathulata (P.92)
B. oceanica (P.91)
B. vadeszens (P.94)
Bolivinopsis cubensis (P.68)
Bolivinella folia (P.84)
Brizalina beyrichi (P.91)
B. pusilla (P.92)
B. subaenarensis (P.93)
Bulimina alazanensis (P.111)
B. aculeata (P.111)
B. inflata (P.112)
B. jarvesi (P.112)
B. marginata (P.113)
B. luxapamensis (P.113)
B. rostrata (P.113)
Cassidulina bora (P.95)
C. carinata (P.96)
C. cuneata (P.96)
C. laevigata (P.97)
C. reflexa (P.97)
Cassidulinoides bradyi (P.98)
Chilostomella oolina (P.164)
Cibicides cicatricosus (P.146)
C. kullenbergi (P.147)
C. lucidus (P.148)
C. refulgens (P.148)
Cibicidoides bradyi (P.137)
C. mundulus (P.138)
C. opacus (P.138)
C. robertsonianus (P.140)
Cymbaloporella bradyi (P.152)
Dentalina communis (P.762)
D. costai (P.77)
D. intorta (P.77)

Dentalina sp.cf.*D.equisetiformis* (P.77)
Discorbis conica (P.132)
Dorothia braevis (P.69)
Eggerella bradyi (P.70)
Ehrenbergina bosoensis(P.103)
E. bradyi (P.104)
E. carinata (P.104)
E. sp.cf.E.cubensis (P.105)
Eilohedra weddellensis (P.141)
Epistominella exigua (P.142)
E. umbonifera (P.142)
E. vitrea (P.143)
Eponides polius (P.131)
E. tumidulus (P.132)
Exsculptina sidebottomi (P.84)
Favocassidulina australis ((P.98)
Favulina hexagona (P.83)
F. quasiperthis (P.83)
Fijiella simplex (P.121)
Fissurina auriculata (P.85)
Fontbotia wuellerstorfi (P.150)
F. gigas (P.149)
Francesita advena (P.124)
Fursenkoina bradyi (P.122)
Gavelinella praegeri (P.133)
Globocassidulina crassa (P.99)
G. decorata (P.99)
G. minuta (P.100)
G. molluccensis (P.100)
G. porrecta (P.101)
G. rarilocula (P.101)
G. subglobosa (P.102)
Gyroidinoides acuta (P.168)
G. broeckhiana (P.169)
G. lamarckiana (P.170)
G. soldanii (P.170)
G. torulus (P.171)
Hamolohedra subamphora (P.84)
Heronallenia lingulata (P.136)
H. wilsoni (P.136)
Hoeglundina elegans (P.87)
Hyalinea balthica (P.144)
Hyalinonetrion sahalense (P.81)
Karrerella bradyi (P.70)
Lagena meridionalis (P.82)
Lagena sp.(P.86)
Lagenosolenia elliptica (P.84)
Laticarinina pauperata (P.144)
L. alto-camareta (P.144)
Lobatula lobatulus(P.152)
Melonis barleanum (P.159)
M. pompilioides (P.160)
Nodosaria vertebralis (P.78)
Nodosaria sp.(P.78)
Nonion depressulus (P.155)
N. havanense (P.155)
Neouvigerina ampullaea (P.114)
Nonionelia labradorica (P.156)

N. miocenica (P.156)
Nuttallides bradyi (P.153)
Oridorsalis umbonatus (P.165)
O. tener (P.166)
Osangularia culter (P.165)
Orthomorphina koina (P.128)
O. jedlitschkai (P.127)
Pacinonion novozealandicum (P.159)
Paracassidulina sulcata (P.103)
Parafissurina carinata (P.86)
Planulina ariminensis (P.145)
Patellinella inconspicua (P.131)
Procerolagena purii (P.82)
Pseudononion japonicum (P.157)
Pullenia bulloides (161)
P. quinqueloba (P.164)
P. quadriloba (162)
P. salisburyi (P.164)
P. osloensis (P.162)
P. octaloba (P.162)
Pygmaeoseistron hispidula (P.82)
Pyramidulina challengeriana (79)
Pyrgo depressa (P.75)
P. murrhina (P.74)
Pleurostomella acuta (P.124)
P. acuminata (P.124)
P. dominicana (P.125)
P. elliptica (P.125)
P. subnodosa (P.126)
Pleuroskelidion unda (P.127)
Quinqueloculina venusta (P.73)
Q. semilunum (P.74)
Rectobolivina bifrons (P.107)
Reussella spinulosa (P.122)
Robulus limbosus (P.80)
Rosalina berthloti (P.134)
R. floridana (P.135)
R. globularis (P.134)
Rectuvigerina ongleyi (P.108)
R. pohana (P.109)
R. striata (P.109)
Sigmavirgulina tortuosa (P.123)
Sagrinella lobata (P.107)
Sigmoilinopsis schlumbergeri (P.76)
Siphogenerina dimorpha (P.110)
Siphonodosaria abyssorum (P.128)
S. consobrina (P.129)
Siphonodosaria lepidula (P.129)
S. subspinosa (P.130)
Trifarina bradyi (P.121)
Stainforthia complanata (P.105)
Siphonextularia catenata (P.72)
Sphaeroidinella bulloides (P.135)
Siphouvigerina interrupta (P.115)
S. porrecta (P.115)
Uvigerina auberiana (P.116)
U. flinti (P.117)
U. nitidula (P.118)

U. perigrina disrupta (P.116)
U. peregrina (P.117)
U. proboscidea (P.118)
U. tenuistriata (P.119)
Virgulopsis pustulata (P.106)
Valvulina pennatula (P.73)
Vaginulina elegans (P.80)
Textularia agglutinans (P.71)
T. conica (P.72)
T. milletti (P.73)
Vaginulina legumen (P.81)

PLATE.1

1. Brizalina beyrichi (Reuss) Side view of hypotype (CUBR 007) from 587-6-5-1-4cm; Pliocene, X227
2. Bolivina minuta Cushman. Side view of hypotype (CUBR 004) from 588A-14-3-40-43cm; Middle Miocene, X310
3. Brizalina pusilla (Schwager). Side view of hypotype (CUBR 008) from 588C-8-6-139-141cm; Early Miocene, X143
4. Bolivina psuedoplicata Heron- Allen and Earland
Side view of hypotype (CUBR 005) from 588A-4-4-4-6cm; Middle Miocene, X208
5. Bolivina robusta Brady. Side view of hypotype (CUBR 006) from 588A-6-4-4-6cm; Middle Miocene, X165
- 6,7. Bulimina alazanensis Cushman. Side view of hypotype (CUBR 009). X192 7. apertural view, X500 from 588B-22-6-49-51cm; Late Miocene.
- 8,9. Globocassidulina crassa (d'Orbigny). 8. side view of hypotype, (CUBR 0024), X227. 9. Edge view, X350 from 588A-4-4-4-6cm
10. Globocassidulina porrecta (Heron- Allen and Earland)
Side view of hypotype, (CUBR 0027) from 588A-1-1-0-3cm; Middle Miocene, X350
- 11 Globocassidulina decorata (Sidebottom). Side view of hypotype (CUBR 0025), from 587-3-5-96-98cm, X227

Plate 1

PLATE.2

- 1,2. Cassidulina biora Crespin. 1. Side view of hypotype, (CUBR 0010), X312. 2. Edge view, X357, from 588C-8-6-139-141cm Early Miocene.
- 3,4 Cassidulina cuneata. Finlay. 1. Side view of hypotype (CUBR 0011), X192. 2. dorsal view, X227, from 588A-18-2-101-103cm; Early Miocene.
- 5,6 Cassidulina laevigata d'Orbigny. 5. Side view of hypotype, (CUBR 0012), X 416. 6. dorsal view, X416, from 588B-25-4-29-31cm Middle Miocene.
- 7,8 Globocassidulina minuta (Cushman). 7. Side view of hypotype, (CUBR 0026), X 310. 8. Edge view, X500 from 588B-31, CC; Middle Miocene.
- 9 Globocassidulina subglobosa (Brady). Side view of hypotype (CUBR 0028), X166, from 588A-17-1-99-101cm; Early Miocene.
- 10-12 Ehrenbergina bradyi Cushman. 10. ventral view of hypotype, (CUBR 0017), X 167. 11. Dorsal view, X192. 12. apertural view X156 from 588B-16-6-99-101cm; Late Miocene.

Plate 2

PLATE.3

- 1-3 Cibicides kullenbergi Parker. 1. umbilical view of hypotype (CUBR 0013), X145. 2. Side view, X147. 3. Spiral view, X125, from 588A-17-1-99-101cm; Early Miocene
- 4-7 Fontbotia wuellerstorfi (Schwager). 4. Umbilical view of hypotype (CUBR 0022), X100. 5. apertural view X125, from 588A-14-3-40-43cm; Early Miocene. 6. Umbilical view, X83, 7. Side view X113, from 588B-12-6-79-81cm; Late Miocene.
- 8-10 Cibicidoides opacus Carter. 8. Umbilical view of hypotype (CUBR 0015), X192. 9. Side view X192. 10. Spiral view X192, from 588A-1-1-0-3cm; Middle Miocene.
- 11-13 Nuttallides bradyi (Earland). 11. Umbilical view of hypotype (CUBR 0035), X131. 12. Side view X138. 13. Spiral view X138, from 588A-2-2-3-5cm; Middle Miocene.

PLATE.4

- 1-3 Eponides polius Phleger and Parker. 1.Umbilical view of hypotype (CUBR 0021), X415. 2.Side view, X357. 3.Spiral view,X416,from 588A-18-2-101-103cm;Early Miocene.
- 4,5 Gyroidinoides soldanii (d'Orbigny). 1.Umbilical view of hypotype (CUBR 0031), X104. 5.Spiral view, X60,from 588B-20-6-147-149cm;Late Miocene.
- 6 Laticarinina altocamerata Heron - Allen and Earland Side view of hypotype (CUBR 0032),X125, from 588A-14-3-40-42cm;Early Miocene.
- 7-9 Gyroidinoides lamarckiana (d'Orbigny). 7.Umbilical view of hypotype (CUBR 0030),X192. 8.Side view,X192, 9.Spiral view,X208,from 588A-2-2-3-5cm;Middle Miocene.
- 10-12 Gyroidinoides broeckhiana (Karrer). 10.Umbilical view of hypotype (CUBR 0029), X225, 11.Side view, X250, 12. Spiral view, X250,from 588B-20-6-147-149cm;Middle Miocene

Plate 4

PLATE.5

- 1,2 Astrononion echolsi Kennett. 1. Side view of hypotype (CUBR 003), X225. 2. apertural view, X227, from 588B-18-2-101-103cm; Early Miocene.
- 3,4 Pacinonion novozealandicum (Cushman and Edwards). 3. Side view of hypotype (CUBR 0039), X350. 4. apertural view, X410, from 588A-6-4-4-6cm; Middle Miocene.
- 5,6 Melonis barleanum (Williamson), 5. Side view of hypotype (CUBR 0033), X125. 6. apertural view, X208, from 588A-14-3-40-43cm; Early Miocene.
- 7 Pullenia bulloides d'Orbigny. Apertural view of hypotype (CUBR 0042), X166, from 588A-17-101-103cm; Early Miocene.
- 8,9 Pullenia quadriloba Reuss, 8. Side view of hypotype (CUBR 0043), X227. 9. apertural view, X250, from 588A-18-2-101-103cm; Early Miocene.
- 10-11 Pullenia quinqueloba (Reuss). 10. Side view of hypotype (CUBR 0044), X178. 11. apertural view, X250, from 588A-1-99-101cm; Early Miocene.
- 12 Pyramidulina challengeriana (Thalman). Side view of hypotype (CUBR 0045), X131, from 588A-18, CC; Early Miocene.

Plate 5

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PLATE.6

- 1-3 Oridorsalis umbonatus (Reuss), 1.Umbilical view of hypotype (CUBR 0037),X178. 2.Side view,X156.
3. Spiral view,X139, from 588A-1-7-4-6cm;Early Miocene.
- 4-6 Oridorsalis tener (Brady), 4.Umbilical viciw of hypotype (CUBR 0036),X166. 5.Side view,X98. 6.Spiral view, X139, from 588A-1-7-4-6cm;Middle Miocene.
- 7-9 Cibicidoides mundulus (Brady,Parker and Jones).
7.umbilical view of hypotype (CUBR 0014), X125. 8.Side view, X150. 9.Spiral view,X120, from 588A-13-2-144-146cm;Early Miocene.
- 10,11 Cibicidoides robertsonianus (Brady). 10. umbilical view of hypotype (CUBR 0017),X83. 11.Side view, X119 from 588B-30-3-40-43cm;Middle Miocene.
- 12 Osangularia culter (Parker and Jones). Side view of hypotype (CUBR 0038),X100,from 588A-16-6-99-101cm; Late Miocene.

Plate 6

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PLATE.7

- 1,2 Patellinella inconspicua Brady. 1.Side view of hypotype (CUBR 0040),X250. 2.apertural view, X312 from 587-7- 146-149cm;Late Miocene.
- 3 Sphaeroidina bulloides d'Orbigny. Apertural view of hypotype (CUBR 0050),X227,from 589-4-6-16-18cm; Pleistocene.
- 4-6 Eilohedra weddellensis (Earland), 4.Umbilical view of hypotype (CUBR 0018),X500. 5.Side view, X500. 6.Spiral view, X415, from 588A-17-1-99=101cm; Early Miocene.
- 7 Epistominella exigua (Brady).Side view of hypotype (CUBR 0019),X275,from 588B-12-6-79-81cm;Middle Miocene.
- 8 Epistominella umbonifera (Cushman).Side view of hypotype (CUBR 0020),X275,from 588A-2-2-3-5cm;Middle Miocene.
- 9,12 Pleurostomella dominicana Bermudez, 9.apertural view of hypotype (CUBR 0041),X90. 12.Side view,X108, from 588A-17-1-99-101cm;Early Miocene.
- 10,11 Gavelinopsis praegeri Heron - Allen and Earland. 10.Umbilical view of hypotype (CUBR 0023),X155. 11.Spiral view, X140, from 588A-14-3-40-42cm;Early Miocene.

Plate 7

PLATE.8

- 1,2 Sagrinella lobata (Brady), 1.Side view of hypotype
(CUBR 0046),X410. 2.apertural view, X500, from
587-6-5-1-4cm; Pliocene.
- 3 Stainforthia complanata (Egger).Side view of hypotype
(CUBR 0051),X192,from 587-3,CC; Pleistocene.
- 4 Siphonodosaria lepidula (Schwager).Side view of hypotype
(CUBR 0047),X60,from 588B-16-6-99-101cm;Late Miocene.
- 5 Neouvigerina ampullacea (Brady). Side view of hypotype
(CUBR 0034),X114, from 587-6-5-1-4cm; Pliocene.
- 6 Siphouvigerina porrecta (Brady). Side view of hypotype
(CUBR 0049),X167, from 587-5-5-5-8cm; Pliocene.
- 7 Virgulopsis pustulata Finlay. apertural view of hypoytpe
(CUBR 0055),X208,from 588A-18-2-101-103cm;Early Miocene.
- 8 Siphonodosaria subspinosa (Cushman).Side view of hypotype
(CUBR 0048),X55,from 588A-13-2-144-146cm;Early Miocene.
- 9 Trifarina bradyi (Cushman). Side view of hypotype (CUBR
002),X250,from 587-6-5-1-4cm; Pliocene.
- 10 Angulogerina angulosa (Williamson). Side view of hypotype
(CUBR 00167),X167,from 587-5-5-5-8cm; Pliocene.
- 11 Uvigerina peregrina Cushman. Side view of hypotype
(CUBR 0053),X113,from 589-1-3-1-4cm; Pleistocene.
- 12 Uvigerina dirupta Cushman and Todd. Side view of hypotype
(CUBR 0052), X109,from 598-1-1-3-6cm; Pleistocene.
- 13 Uvigerina proboscidea Schwager. Side view of hypotype
(CUBR 0054),X125,from 587-7-5-146-149cm; Pleistocene.

Species/Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	
<i>Abduodenitis speudothalamus</i>	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amphisigina globosa</i>	0	0	0	0	0	0	0	0	1	1	4	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>A. madagascariensis</i>	4	0	19	0	0	0	0	0	0	0	0	6	3	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Amphicoproductina carmentolus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Angulograna angulosa</i>	4	0	0	0	0	0	0	0	1	0	0	13	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	
<i>Trifarina bradyi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		
<i>A. carinata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		
<i>Angulograna sp.</i>	0	0	0	0	0	0	0	0	0	0	0	2	3	2	4	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Asomalimoides globulosa</i>	1	0	1	0	0	0	0	0	1	0	0	1	0	1	0	5	0	1	0	0	4	1	0	1	0	1	0	1	0	6	3	1	5	1	4	3	4	3	
<i>A. semicubitus</i>	0	0	2	0	0	0	0	0	0	0	1	0	0	0	3	0	6	0	1	0	0	0	0	0	0	1	2	2	0	2	1	2	0	1	0	0	4		
<i>Astronomium australe</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>A. echolu</i>	0	0	0	1	5	3	0	3	2	0	1	4	20	0	5	8	0	5	4	1	0	1	5	13	0	2	0	0	1	11	2	5	4	1	0	9	1	9	
<i>A. selligerum</i>	0	0	0	0	0	0	0	0	1	0	0	0	2	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Bolivina advena</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. compacta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	2	3	0	0	0	0	6	2	1	0	4	0	0	0	7	0	0	0	1	2	4	0	3	
<i>B. cincta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. dilatata</i>	0	5	0	2	0	0	0	0	0	3	4	0	2	3	5	1	0	0	1	3	0	1	0	3	2	1	0	2	1	3	0	0	7	2	3	10	1	0	
<i>B. niwana</i>	0	3	0	3	0	7	2	0	0	0	0	1	1	0	0	3	3	2	11	8	9	4	5	1	0	0	3	0	4	1	0	0	0	7	1	1	0	0	
<i>B. pseudoplicata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. robusta</i>	5	1	1	0	0	0	0	0	0	5	0	0	1	2	8	3	2	0	0	0	0	0	0	0	1	0	0	0	0	0	6	2	0	2	4	2	0	0	
<i>Bolivina quadriculata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Bizantina beyrichi</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. oceanica</i>	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. pusilla</i>	0	1	1	1	1	6	0	0	0	0	0	0	3	0	0	1	0	0	1	0	0	0	0	0	1	2	6	3	0	3	0	3	4	3	0	0	2	0	
<i>B. subaerensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. spatulata</i>	0	0	0	4	0	0	0	0	2	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. vadeses</i>	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	4	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Bolivina cubensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Bolivina folia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Bolivina aculeata</i>	0	1	9	7	4	1	0	0	1	1	0	1	0	1	0	0	0	0	2	5	1	3	4	1	1	1	0	1	0	1	1	0	0	0	0	0	0		
<i>B. alazanensis</i>	0	1	6	6	4	0	0	1	0	1	0	1	0	1	0	4	2	3	9	2	3	1	1	1	2	1	2	7	5	1	1	0	0	0	4	4	1	1	
<i>B. raffina</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. jarvisi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. marginata</i>	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. tasparensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>B. rostrata</i>	0	3	0	2	1	1	0	1	3	0	0	2	1	0	5	4	2	1	3	1	0	4	1	2	0	1	0	2	0	1	0	1	2	1	0	0	1	2	
<i>Cassidulina bicolor</i>	5	4	4	5	0	4	1	1	8	1	1	0	3	1	3	3	4	0	0	2	1	4	7	0	6	4	2	3	8	0	0	1	0	0	2	5	4	2	
<i>C. caranua</i>	0	1	2	1	2	4	1	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>C. cucuma</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	47	14	3	2	2	0	0	7	0	10	2	4	2	3	2	7	23	16	14	3	2	4	9	
<i>C. laevigata</i>	1	4	1	0	1	0	0	1	1	1	2	0	0	0	0	3	4	2	8	6	0	6	0	0	3	2	1	6	5	4	2	3	1	1	2	2	3	0	
<i>C. reflexa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Cassidulinoides bradyi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Cassidulinella oolina</i>	1	0	0	0	0	0	0	1	0	2	2	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>C. bricoides circumcincta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>C. latidorsalis</i>	1	2	1	1	2	0	0	1	1	0	1	0	0	1	2	1	2	1	2	1	2	2	2	0	3	0	7	1	4	7	1	1	1	5	4	9	1	2	
<i>C. lineata</i>	0	5	1	0	0	0	0	1	0	0	1	2	0	0	8	0	0	0	3	1	1	0	0	1	2	3	1	0	4	1	4	1	1	0	0	0	2		
<i>C. reticulata</i>	5	0	1	0	0	0	0	0	2	0	1	2	17	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Cassidulinoides bradyi</i>	1	1	0	2	1	0	0	0	0	0	0	1	2	1	1	0	0	0	1	0	0	1	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0		
<i>C. mandulus</i>	1	1	2	0	1	0	1	1	2	1	0	0	0	2	3	1	2	2	4	1	1	2	0	0	1	1	3	3	0	0	1	0	0	0	0	0	0		
<i>C. sparsa</i>	0	1	0	0	2	0	0	0	0																														

Species/Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	
<i>Medons barileum</i>	1	2	1	6	3	1	0	1	1	0	0	1	2	1	0	1	5	7	10	2	3	2	0	5	1	2	7	1	2	7	1	2	0	1	2	9	0	2	1
<i>N pompoliorides</i>	1	2	0	0	0	0	0	1	0	0	6	2	1	3	1	0	0	0	0	0	0	1	6	0	1	1	0	0	1	0	0	1	0	0	0	1	0	1	0
<i>Nodosaria ventralis</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1	
<i>Nodosaria sp</i>	0	0	0	0	0	1	1	1	0	0	0	2	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	
<i>Nonon depressus</i>	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	
<i>N nonvatus</i>	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	
<i>Nonviferia napulacea</i>	0	0	1	0	0	0	1	1	0	0	0	0	0	4	0	2	0	0	0	1	0	1	0	1	2	1	0	0	0	0	1	3	2	3	1	1	0	0	
<i>Nonimella labradore</i>	0	2	1	0	0	1	0	0	3	0	0	4	0	5	1	0	0	0	1	1	1	0	0	2	0	0	0	0	0	0	1	2	0	0	0	1	0	0	
<i>N notocasta</i>	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Nusallides bradyi</i>	0	15	2	4	0	1	0	2	3	0	0	0	0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Orideralis umbonae</i>	0	3	14	4	4	4	0	2	4	1	3	2	0	1	3	2	1	2	3	5	2	7	5	10	2	18	11	10	4	4	11	12	20	9	15	12	0	0	
<i>O tener</i>	0	2	0	1	3	0	0	1	0	0	0	14	4	2	0	4	2	5	7	3	3	5	6	5	3	2	5	1	10	10	6	9	6	7	15	2	6	6	
<i>Orbulina culter</i>	2	5	0	0	0	1	0	0	2	2	0	6	0	0	0	1	2	6	4	2	1	0	0	0	1	1	1	0	0	0	0	2	0	0	1	1	1	1	
<i>Orbulomorphina kosa</i>	0	0	0	0	0	0	2	8	0	0	0	0	0	0	18	2	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	
<i>O jeditchai</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	3	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	1	0	
<i>Pacionon novorelae</i>	0	0	0	0	1	1	0	0	3	2	1	11	2	0	0	0	0	2	2	4	0	10	6	5	0	0	1	4	4	0	4	11	2	12	0	1	0	1	
<i>Paracymadella solana</i>	2	1	2	4	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Platylasia arminaeasis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Pmetlusa inconspicua</i>	3	0	0	0	0	0	0	0	0	0	0	16	2	29	17	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Procerolopaea purti</i>	1	1	1	2	1	3	2	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		
<i>Pseudononon isoponicum</i>	0	0	1	1	0	0	0	0	0	0	0	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		
<i>Pulemia bulborea</i>	0	0	3	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	4	1	3	1	4	0	0	6	2	5	0	3	12	6	7	8	6
<i>P quaqueitoba</i>	0	0	3	0	2	0	0	1	0	1	0	1	0	0	0	0	1	2	0	3	2	2	2	0	0	0	8	5	4	4	8	3	8	3	8	3	2	1	
<i>P quetriloba</i>	0	0	3	1	2	0	1	1	3	0	2	2	0	0	1	0	1	4	4	3	5	1	0	0	0	1	3	0	1	3	1	3	0	4	9	3	4	5	
<i>P seligheruy</i>	0	0	1	1	2	0	0	1	1	0	4	0	0	0	1	0	0	1	0	0	1	0	0	1	1	3	0	1	0	0	1	1	0	4	1	0	0		
<i>P soloneras</i>	0	0	2	1	1	0	0	1	1	0	1	0	0	0	1	0	0	1	1	1	0	0	0	1	0	1	0	0	2	0	0	5	2	4	3	1	0		
<i>P octaloba</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Pygmaeus bipudela</i>	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Pyramid challegerina</i>	1	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Pyrgo depressa</i>	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	2	2	2	1	0	3	3	3	3	2	1	2	2	
<i>P murina</i>	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0		
<i>Pleurotonella acuta</i>	0	0	1	1	0	0	0	0	0	1	1	0	2	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>P dentatacava</i>	0	0	1	1	0	0	0	0	0	0	0	2	1	0	0	0	1	1	0	0	1	1	0	1	1	0	1	9	2	1	0	0	1	0	0	4	2		
<i>P elliptica</i>	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	1	1	0	1	1	1	0	1	3	1	2	2	2	0	2	0	0	2	4	3	2	1		
<i>P suberosa</i>	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	1	0	0	1		
<i>Pterostadion unda</i>	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	2	0	0	1	3	0	0	0	2	0	0	0	0		
<i>Quaqueitoba repens</i>	6	1	1	0	0	0	2	1	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0		
<i>Q seniliana</i>	0	1	2	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Reinboldiana bifrons</i>	3	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Russelia sprema</i>	0	0	1	1	0	0	4	1	0	0	2	0	1	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

NO	SAMPLES	AGE	NO	SAMPLES	AGE
1	587-1-1-14-17cm	PLEISTOCENE	22	588B-25-4-29-31cm	MIDDLE MIOCENE
2	589-1-1-3-6cm		23	588B-26-4-40-42cm	
3	589-1-3-1-4cm		24	588B-30-3-40-43cm	
4	589-2-6-147-149cm		25	588B-31 cc	
5	589-3-7-9-11cm		26	588A-1-1-0-3cm	MIDDLE MIOCENE
6	589-4-6-16-18cm		27	588A-1-7-4-6cm	
7	587-3-2-147-149cm		28	588A-2-2-3-5cm	
8	587-3-5-96-98cm		29	588A-4-6-4-6cm	
9	587-3 cc		30	588A-6-4-4-6cm	
10	587-5-5-5-8cm	PLIOCENE	31	588A-10-3-144-146cm	
11	587-6-5-1-4cm		32	588A-11-3-49-51cm	EARLY MIOCENE
12	587-7--5-146-149cm	LATE MIOCENE	33	588A-13-2-144-146cm	
13	587-8-6-100-103cm		34	588A-14-3-40-42cm	
14	587-13 cc		35	588A-17-1-99-1010cm	
15	588B-9-6-4-6cm	PLIOCENE	36	588A-18-2-101-103cm	
16	588B-10-3-59-61cm		37	588A-18-cc	
17	588B-12-6 79-81cm		38	588C-8-6-139-141cm	
18	588B-16-6-99-101cm	LATE MIOCENE	■ 587-11-4-147-149cm not shown		
19	588B-18-6-4-6cm				
20	588B-20-6-147-149cm				
21	588B-22-6-49-51cm				

END

18.02.90

FIN