Neogene Foraminifera of the Limon Basin of Costa Rica.

David Terrance Cassell
Louisiana State University and Agricultural & Mechanical College

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NEOGENE FORAMINIFERA OF THE LIMON BASIN OF COSTA RICA

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NEOGENE FORAMINIFERA OF THE LIMONBasin of COSTA RICA

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in
The Department of Geology

by
David Terrance Cassell
B.A., University of the Pacific, 1976
M.S., Northern Arizona University, 1980
December, 1986
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ABSTRACT

The distribution of foraminifera in the Uscari, Rio Banano, Moin Formations of the Limon Basin, Costa Rica, is the subject of this study. *Heterostegina antillea* and *Lepidocyclina* (L.) *waylandvaughani* place the basal Uscari Formation of Quebrada Terciopelo in Zone N3 of the latest Oligocene. The overlap of *Orbulina universa* and *Globorotalia fchsi peripheroronda* places the type section Uscari Formation in the early Middle Miocene (zones N9 to N10). The overlapping ranges of planktonic foraminifera and the ostracods *Radimella ovata* in the sandstones places that unit in Zone N18 of Early Pliocene. *Globorotalia truncatulinoides excelsa* indicates a Pleistocene age for the Moin Formation.

The algal-foraminiferal limestones of the basal Uscari Formation were deposited on a shallow shelf receiving volcaniclastic sediment from the emerging islands of the Central American arc. During the Late Oligocene and Early Miocene the Limon Basin quickly subsided. In the Quebrada Terciopelo reference section of the Uscari Formation, Early Miocene foraminiferal indicators of a middle to upper bathyal environment include *Siphogenerina transversa* and *Melonis pompilioides*; late Early and early Middle Miocene faunas (*Uvigerina peregrina*, *Bolivina pseudoplicata*, and *Buliminella bassendorfensis*) indicate progressive shoaling. For the Early Miocene Rio Reventazon section of the Uscari
Formation, species such as *Cibicoides wuellerstorfi* and *Melonis pompilioides* indicate depths near 2000 meters.

The type section of the Uscari Formation in Quebrada Uscari is dominated by an outer shelf assemblage containing *Hanzawaia concentrica* and *Fursenkoina pontoni*.

The Early Pliocene sandstones of the Rio Banano Formation were deposited on a shallow, current-swept continental shelf. These rocks contain a mixture of open marine, nearshore, and a few reefal species, including *Cibicidoides floridanus*, *Amphistegina gibbosa*, *Articulina mayorii*, and *Elphidium discoidale*. The claystones of the Pleistocene Moin Formation contain outer shelf to upper slope species, such as *Gyroidina soldanii*, *Cibicidoides floridanus*, and *Cassidulina curvata*.

The foraminiferal record of the Rio Banano sandstones suggests land was emergent in the southern Limon Basin, separating the Caribbean and Pacific basins, by 5 mybp, before such an event occurred in Panama.
CHAPTER 1

INTRODUCTION

SCOPE OF STUDY

The Tertiary rocks of the Limon Basin of Costa Rica were deposited in a back-arc basin behind the uplifted arc of the Cordillera de Talamancas of Costa Rica. The foraminifera of these rocks should reflect changing depositional facies through the Neogene resulting from the uplift of the isthmus linking North and South America. The spatial and temporal distribution of benthic foraminiferal faunas in the Limon Basin rocks provides valuable clues to the geological development of the isthmus.

Due to its intimate association with the large continental blocks of the Americas to the north and south, and its proximity to the complex plate interactions of the Caribbean region to the east and the Middle America Trench to the west, Central America is an exciting geological province in which to work. A thorough understanding of the plate tectonic historical development of the Caribbean/Central American region is currently lacking. It is hoped that this study will add to the body of geological knowledge available regarding Central America, and thus contribute to the unravelling of the tectonic history.
The delineation of the biostratigraphic position of Neogene outcrops of the southern Limon Basin of Caribbean Costa Rica, based upon planktonic foraminiferal faunas, and analysis of the paleoenvironments of benthic foraminiferal faunas will be the main work attempted in this paper. This information will be used in an attempt to interpret the geologic history of the Limon Basin for the time periods represented in the stratigraphic record studied.

This study is one of a number of geological investigations by Louisiana State University faculty and graduate students in Costa Rica.

METHODS OF STUDY

Field work for the present study in the Limon Basin was carried out during December-January, 1982-83; July, 1983; and December-January 1983-84.

Stratigraphic sections of the Uscari, Rio Banano, and Moin Formations were systematically sampled at the best exposures found. These exposures were usually in stream beds. The thickness of the Rio Banano Formation type section and the Rio Reventazon section of the Uscari Formation was measured directly from the outcrop using a Jacob Staff. The thickness of all other sections was estimated by determining the attitude of the beds with a
brunton compass, estimating vertical outcrop distance along the course of the stream with the Jacob Staff, and constructing a cross section taking into account the map course of the stream.

Outcrops are limited and difficult to locate on the Caribbean coastal plain and eastern side of the Cordillera de Talamanca because of the dense vegetation. Where found, the outcrops are usually deeply weathered, often to a lateritic soil. Suitable outcrops, however, were located by walking the small creeks (quebradas) which flow eastward toward the Caribbean from the mountains. Good outcrops can be found in the larger rivers, but are usually inaccessible due to fast moving water. The upper part of the type section of the Uscari Formation could not be fully sampled due to dense vegetative cover.

The samples were prepared for faunal analysis in the laboratory at L.S.U. A known weight of sample, after having first soaked in a Calgon solution for a few hours, was washed through a 63 micron sieve (230 mesh) to remove the clay size fraction, and dried. From the residue, a split containing approximately 300 benthic foraminiferal specimens was picked and identified. Of the approximately 175 samples washed, 66 were analyzed in this fashion. The paleontological analyses presented in this paper are based on the frequency distribution of selected benthic foraminiferal species in these 66 samples (Appendix C). Samples
for analysis were chosen by taking every other sample in
the collection from each of the sections, with allowance
made for unfossiliferous or unusable samples. Biostrati­
graphic determinations were based on planktonic foramin­
ifera picked from scans of the samples. Additional benthic
species were also picked in the scans and included in the
species list and in the plates. Ostracod specimens were
also picked from the scans.

Identification of planktonic foraminifera follows the
work of Bolli and Saunders (1985). Stainforth et. al.
(1975) and Postuma (1971) were used as supplementary refer­
ences. The biozonation scheme of Bolli and Saunders was
used to determine biostratigraphic position and absolute
age. The assignment of absolute ages to the epochs of the
Tertiary in the Neogene by Bolli and Saunders differs only
slightly from ages assigned by Berggren, et. al. (1985).
The largest difference is 2.2 million years at the Middle/
Early Miocene break. Differences at other boundaries are 1
million years or less.

Numerical analyses of the benthic foraminiferal
species data were done with multiple group component
factor analyses of species distributions in the three
stratigraphic formations, and a UPGMA cluster analysis of
all samples. These analytical techniques are contained
within the SAS software package as the VARCLUS Procedure
and the CLUSTER Procedure. Numerical analyses were done on
an IBM 3081 computer. Photomicrographs were taken using a JEOI T-300 scanning electron microscope.

GEOLOGIC AND PLATE TECTONIC SETTING

The Central American isthmus in the area of study is divisible into two parts (Figure 1). The northern part is underlain by crystalline igneous and metamorphic rocks of at least Paleozoic, and possibly Precambrian age (de Boer, 1979). These continental basement rocks are well exposed in Nicaragua and Honduras. The southern part is built upon oceanic basement rocks no older than Late Jurassic (Weyl, 1980). These oceanic rocks have been called the Nicoya Complex after their exposure on the Nicoya Peninsula of Pacific Costa Rica and consist of the igneous and sedimentary rocks typical of an ophiolite. Outcrops of the Nicoya Complex in southern Central America and the continental basement rock of northern Central America are shown in Figure 1.

According to Weyl (1981), the boundary between these two geological provinces lies in a large, linear, northwest to southeast striking fault zone extending from the Pacific coastal area of Nicaragua to the Caribbean coastal area of Costa Rica. In Nicaragua this feature is called the Nicaragua Trough and in Costa Rica it is called the Limon Basin. Figure 2 is a geologic map of Costa Rica showing the
Figure 1. Location of the study area, the Limon Basin, on the Caribbean side of Costa Rica. Costa Rica is in southern Central America, which is characterized by oceanic basement rock of the Mesozoic Nicoya Complex. Northern Central America is characterized by continental metamorphic basement rock of Paleozoic, or older, age. Map modified from Weyl (1980).
Figure 2. Generalized geologic map of Costa Rica. In the southern Limon Basin, the area of study, outcrops consist of Paleocene to Miocene sedimentary and volcanic rocks. To the north, on the coastal plain, the older rocks are covered by Recent alluvium. To the northwest, in the direction of the Nicaragua Graben, the Tertiary sediments are covered by volcanic rocks. The southern Limon Basin offers the best outcrops of the Tertiary section. Map modified from Weyl (1980).
position of the Limon basin.

Reconstructing the plate tectonic development of Central America and the Caribbean region is difficult due to the extreme complexity of the geology. Several reconstructions (Van Andel, et. al., 1971; Malfait and Dinkleman, 1972; Case, 1974; Lonsdale and Klitgord, 1978; Pindel and Dewey, 1982) place the origin of basement rocks of northern Central America in continental blocks which occupied the present area of the Gulf of Mexico, or an area west of Mexico (Dickinson and Coney, 1980) during the initial breakup of Pangaea. In contrast, oceanic basement rocks of southern Central America resulted from plate-plate interaction of the Pacific Plate and the Caribbean Plate at the Middle America Trench from the Late Cretaceous through the Tertiary (Weyl, 1980).

Burke (1984) has suggested from post-Eocene time the Caribbean Plate moved eastward relative to North and South America. This eastward motion became important in the post-Eocene structural development of the region. Figure 3 shows his interpretation of modern plate motion in the Caribbean.

SEDIMENTATION IN THE PACIFIC REALM

The development of the Central American isthmus began in the Late Mesozoic with the appearance of volcanic
Figure 3. Present day relative plate motion of crustal plates in the Caribbean region. The Caribbean area is being squeezed to the east as the North and South American Plates move together. Abbreviations are: NOAM, North American Plate; SOAM, South American Plate; CARIB, Caribbean Plate; Coco, Cocos Plate; NAZ, Nazca Plate. Map modified from Burke, et. al. (1984).
islands of an island arc related to subduction along the Middle America Trench (Weyl, 1981). The development of this arc, and the continuing uplift of the area, eventually resulted in the formation of the Central American isthmus in the Neogene, linking the continental blocks of North and South America. Sedimentation on the Pacific side has occurred in a fore-arc basin (Galli-Olivier, 1979) related to subduction in the Middle America Trench. Figure 4 is a cross section through Costa Rica illustrating the position of these fore-arc basin sediments in relation to the underlying ophiolitic rocks.

Sediments deposited in this fore-arc basin illustrate the tectonic instability of this region. Yuan (1984) described the Middle Eocene to Holocene sedimentary section in the eastern Terraba Trough of southwest Costa Rica and showed the succession of sedimentary facies is not a simple shallowing upwards sequence. Rather, Middle Eocene shallow water limestones are overlain by deeper water sandstones which in turn grade upwards into shallow water and, eventually, terrestrial deposits.

SEDIMENTATION IN THE CARIBBEAN REALM - THE LIMON BASIN

The Limon Basin is located on the Caribbean side of Costa Rica to the east of the central mountains (Figure 4). Sedimentation began in the Early Tertiary with total
Figure 4. Generalized cross section through Costa Rica showing the position of the Limon Basin in the overall tectonic scheme. From Weyl (1980).
sediment accumulation since the Paleocene indicated by Weyl (1980) to be approximately 10,000 meters. This estimate is probably too large. Weyl’s stratigraphic column for the Limon Basin is shown in Figure 5 contrasted with the stratigraphy of Sprechmann (1984), and the stratigraphy presented in this paper. The Weyl and Sprechmann stratigraphic sections are composite sections and the thicknesses reported are based upon thickness estimates taken from previous papers and unpublished sources. They do not show actual measured sections. It is not possible to measure the 1700 meters of Uscari Formation or 1700 meters of Gatun Formation shown in Weyl’s section. The figure for the Uscari Formation is based upon drillers reports in a folded and faulted section. Weyl also shows both the Rio Banano and Gatun Formations above the Uscari Formation. Taylor (1975) reassigned all post-Uscari clastic rocks around the town of Limon to the Rio Banano Formation, documenting an age difference between Limon Basin post Uscari clastics and the type section of the Gatun Formation in the Panama Canal Zone. The oldest rocks above the Uscari Formation reported by Taylor, and here, are Late Miocene beds of the Rio Banano Formation. No rocks of the Gatun Formation were seen in the course of this study and this name is rejected, as per the work of Taylor (1975) for the southern Limon Basin.

Confusion exists regarding the sedimentary section in the Limon Basin due to a proliferation of stratigraphic
Figure 5. Comparison of the stratigraphy of this study with composite stratigraphic sections reported in the literature. Weyl (1980) and Sprechmann (1984) both used a wide variety of sources, including published and unpublished papers, reports, etc., and drilling records of wells in the basin, in compilation of their sections. The stratigraphy reported in this study represents actual measured sections.

Figure 6. Generalized area map showing the approximate locations of the studied stratigraphic sections to the east of the crest of the Cordillera de Talamancas, in southeast Costa Rica.
names for lithostratigraphic units. An overall geologic interpretation has yet to emerge.

PREVIOUS WORK IN THE LIMON BASIN

The first reports on the geology of the area were those of Gabb (1881) and (1895), who conducted horseback reconnaissance through the Cordillera de Talamanca and down onto the Caribbean coastal plain. Gabb described the clay beds near the city of Limon, referring to them as the Moin Beds (Gabb, 1895). Hill, while aware of Gabb’s work, referred to the same outcrops as the Limon (Moen) Beds (Hill; 1898).

The Uscari Formation was named by Olsson (1922) for outcrops of shale exposed in southeastern Costa Rica. Olsson also described mollusk faunas from sandstones overlying the Uscari Formation which he assigned to the Gatun Formation, extending this name into Costa Rica from its type locality in the Panama Canal Zone.

Bold (1967a, b) described ostracods from both the Uscari and Gatun Formations in the Limon Basin. He also reported planktonic foraminiferal biostratigraphic determinations for outcrops of the Gatun Formation in the valley of the Rio Reventazon (1967b) and made correlations of both the Gatun and Uscari Formations (1967a, b) to various other outcrops in Panama and elsewhere in the Caribbean.
Various other authors have published accounts dealing with different aspects of Limon Basin geology. The more notable are studies of molluscan faunas by Woodring (1957), a discussion of the petroleum potential by Redfield (1923), and description of foraminifera by Goudkoff and Porter (1947).

In recent years Rivier (1971, 1973) published an account of various measured sections in the Cordillera de Talamanca area of the Limon Basin, ranging in age from Late Eocene to Early Miocene. Stratigraphic correlations of these sections were proposed and a general paleogeographic framework was developed. Rivier also presented a planktonic foraminiferal biostratigraphic analysis of the sections. Taylor (1975) investigated the geology around the city of Limon. He rejected the use of the name Gatun Formation for sandstones around Limon, renaming these outcrops the Rio Banano Formation based upon differing ages with the Gatun Formation type section. He also showed the Uscari Formation outcrops in his area to be younger than the Uscari Formation type section. Weyl (1980) compiled an overview of all Central American geology based upon previously published studies. Most recently, Sen Gupta (1986) reported foraminifera from the northwest part of the basin and made paleogeographic interpretations.
Studied outcrops of Tertiary rocks in the Limon Basin represent approximately 900 meters of total section. Rocks include the Latest Oligocene to Middle Miocene Uscari Formation, the Late Miocene to Middle Pliocene Rio Banano Formation, and the Pleistocene Moin Formation. Sample numbers from these units for all samples included in this report are listed in Table 1. These rocks represent a variety of depositional environments from shallow shelf to deep slope.

Sedimentation in the Limon Basin took place in a back arc position through the Tertiary. Sediments generally coarsen up section from the Miocene through the Pleistocene. The fine grained clastic rocks of the Uscari Formation are overlain by the sandy Rio Banano Formation, which is in turn overlain by the conglomeratic Suretka Formation. In the Paleocene through Oligocene part of the section, the Rio Lari Formation largely consists of intrusive and extrusive igneous rocks, the partly time equivalent and partly younger Tuis and Las Animas Formations contain shallow water limestones and sandstones, and
TABLE 1

SAMPLE NUMBERS FOR THE SECTIONS USED IN THIS REPORT.

The samples are listed in stratigraphic order.

<table>
<thead>
<tr>
<th>MOIN FM.</th>
<th>RIÓ BANANO FM.</th>
<th>USCARI FM.</th>
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<tr>
<td># 79</td>
<td># 83</td>
<td># 3-66</td>
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<tr>
<td># 77</td>
<td># 81</td>
<td># 3-67</td>
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<tr>
<td># 75 70 meters</td>
<td># 99 50 meters</td>
<td># 3-69 160 meters</td>
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<td># 3-107 565 meters</td>
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the Senosri Formation contains limestones, sandstones, and volcanic breccias (Sprechmann, 1984). The stratigraphy of the basin represents a complicated geologic history controlled primarily by the tectonic forces involved in the development of the isthmus. This study focuses on parts of the latest Oligocene through Pleistocene stratigraphy of the Limon Basin in the area of southeastern Costa Rica from Puerto Limon in the north, south to the Panamanian border. Five stratigraphic sections in this area of the basin were sampled and measured. The generalized locations of these sections are shown in Figure 6.

LITHOSTRATIGRAPHY

Uscuri Formation

The Uscuri Formation, by far the thickest unit in the study area, was sampled at the type section of Olsson (1922) and at outcrops along Quebrada Terciopelo and Rio Reventazon in the Cordillera Central (Figure 8a and Figure 7b).

Hoffstetter (1962), in the Stratigraphic Lexicon for Latin America, assigned authorship of the Uscuri Formation to Olsson. In Olsson's paper, it is apparent that he was not making a formal presentation of a new stratigraphic unit, but rather was using a name which was commonly used at that time. Olsson menfögedet the Quebrada
Figure 7a. Location of the type section of the Uscari Formation in Quebrada Uscari, a tributary of Rio Telire. This sketch map is from the Telire (#3544 I) 1:50,000 topographic sheet of Costa Rica, E761, Edicion 1-IGNCR, 1968. Grid numbers refer to kilometer grid on map. Sample numbers show approximate positions of upper and lower samples collected.

Figure 7b. Location of the principal reference section (here designated) of the Uscari Formation in Quebrada Terciopelo. This sketch map is from the Bonilla (#3446 II) 1:50,000 topographic sheet of Costa Rica, E762, Edicion 2-IGNCR, 1981. Grid numbers refer to kilometer grid on map. Sample numbers show approximate positions of lower, middle, and upper samples collected.

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Figure 8a. Location of the Rio Reventazon section of the Uscari Formation in the valley of the Rio Reventazon, across the river from Peralta. The section is located 1/4 kilometer north of the footbridge on the east river bank. This sketch map is from the Tucurrique (#3445 I) 1:50,000 topographic sheet of Costa Rica, E 762, Edicion 2-IGNCR, 1981. Grid numbers refer to kilometer grid on map. Sample numbers show approximate positions of upper and lower samples collected.

Figure 8b. Location of the Uscari Formation outcrop in Rio Quito. Sample was taken where the road crosses the stream for the second time, from south to north, after passing the village of Rio Blanco. This sketch map is from the Rio Banano (#3545 I) 1:50,000 topographic sheet of Costa Rica, E 762, Edicion 2-IGNCR, 1978. Grid numbers refer to kilometer grid in map.
Uscari in southeast Costa Rica, near the Panama border, as the source for the name of the unit, but failed to give a precise location for the type section. A cursory description of the lithology was given but no estimate of thickness was made. He placed the Uscari Formation in the Lower Miocene. Since Olsson’s paper, the name Uscari has become firmly entrenched in the Central American geological literature although the Uscari Formation has not been adequately defined as a stratigraphic unit. Today, Quebrada Uscari is difficult to locate precisely and the area is completely overgrown. At the time of Olsson’s work the quebrada was on a banana plantation where all vegetation other than the banana trees had been removed. Since then, Quebrada Uscari has been reclaimed by jungle and the name has fallen into disuse by the local people.

Due to the difficulty in finding and sampling the type section of the Uscari Formation a new reference section should be chosen. It is here proposed the section of the Uscari Formation exposed in Quebrada Terciopelo, first investigated by Rivier (1971) and included herein, be formally accepted as the principal reference section for the Uscari Formation as per Article 13 (a), p. 653 of the Code of Stratigraphic Nomenclature (1961), or a holotype, as per the International Stratigraphic Guide, (Hedberg, 1976), chapter 5, part D, number 2, p. 38. The stratigraphic relationships of the Uscari Formation type
section, the Quebrada Terciopelo principal reference section, and the section in the valley of the Rio Reventazon will be discussed later in this paper.

Quebrada Uscari Type Section. At the type section approximately 160 meters of strata were sampled; another 150-175 (estimated) were inaccessible. Figure 7a shows the location of the type section. The sampled section is the lower part of the outcrop, extending from the valley floor to approximately halfway up the side of the bluff along the course of Quebrada Uscari. Here, the Uscari Formation consists of well bedded, dark colored shale. The rock is soft and easily broken with a hammer. Other than bedding, no sedimentary structures were seen. The unit dips 10-12 degrees to the north. The lower contact is not exposed in the type section.

Rio Reventazon Section. Approximately 25 meters of Uscari shale was sampled in the valley of the Rio Reventazon. Here, the Uscari Formation is also well bedded and dark in color, but not as platy as in the type section. Locally the rocks exhibit a prolific planktonic foraminiferal fauna which is visible with a hand lens. The section location is indicated in Figure 8a.
Quebrada Terciopelo Reference Section. By far the thickest section of the Uscari Formation reported from the Limon Basin is that exposed along the course of Quebrada Terciopelo in the Cordillera de Talamanca. Figure 7b shows the location of the section. First described by Rivier (1971), this section (Figure 9) exposes approximately 565 meters of Uscari shale and approximately 20 meters of siltstone at the top of the section, which may be part of the Rio Banano Formation. Near the top of this section a basalt sill, of approximately 140 meters thickness, interrupts the section. The sill is dated at 4.5 mybp + or - 0.5 by K-Ar methods (Geochron Laboratories, Cambridge, MA.). Near the bottom a part of the sequence is repeated by faulting.

Rivier (1971, 1973) first described the Quebrada Terciopelo section as consisting of mainly marl and shale, with 10 meters of limestone at the base containing larger foraminifera, algal structures, and barnacles. Rivier placed the lower 180 meters in the Oligocene and the rocks above in the Miocene, interpreting all the calcareous shales as representing a neritic environment of deposition. Rivier reported the thickness of the basalt intrusive near the top of the section as 80 meters.

In the Quebrada Terciopelo section the greater part of the Uscari Formation consists of well bedded, dark colored shale with consistent dips of 10 to 35 degrees to the west. Rivier (1973) described these rocks as “marly”,

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Figure 9. Stratigraphic section of the Quebrada Terciopelo reference section of the Uscari Formation. Smaller section on the right is an expansion of lowermost few meters of the main section. This lower part of the section is not drawn to scale in the larger section. These basal limestones and sandstone are much thinner than they appear to be.

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indicating their fine grained and calcareous nature. The outcrops are platy and soft. Rivier (1973) also described a zone of contact metamorphism containing garnet immediately above the basalt intrusive. During the present study a metamorphosed zone, probably silicified, was observed above and below the intrusive, but no garnet was seen.

The lowermost 12 meters of section is not typical of Uscari lithology. The lower contact of the section is an erosional surface on a basalt lava flow. Immediately above the basalt there is a 2 meter thick unit of limestone containing clasts of the underlying basalt, indicating the erosional nature of the contact. The contact relations and the texture of the basalt indicate that it is a lava flow. The limestone is composed of the tests of larger foraminifera and red algal rhodolites, both shallow marine indicators. Directly above the limestone is a two meter thick greywacke. This sandstone is soft and easily eroded, giving the outcrop a rounded appearance. Microscopic examination revealed the majority of the constituent grains are pyroxene with a few scattered larger foraminiferal tests in a mud matrix. This sandstone has a massive character and neither sedimentary structures nor lateral or vertical changes in lithology were observed. The contact with the underlying limestone is undulating and abrupt. Immediately above the sandstone is a 7 to 8 meter thick limestone containing larger foraminiferal tests, red
algal rhodolites, clasts of basalt, and, unlike the lower limestone, individual igneous mineral grains. The contact between the limestone and the overlying shale is abrupt and undulating.

The uppermost 20 meters of this section is a muddy siltstone separated by a time gap from the underlying shale (see Biostratigraphy section). An erosional unconformity probably exists between the siltstone and the underlying shale of the Uscari Formation, but no physical evidence of an unconformity was found. As there is no noticeable change in dip over this interval this may be a disconformity. However, the outcrop is heavily vegetated and weathered, so a subtle dip change might not be discernable. The large gap in time indicated by the planktonic foraminifera suggests an erosional contact rather than non-deposition. These upper siltstones may be part of the Rio Banano Formation.

Rio Banano Formation

The Rio Banano Formation was described and named by Taylor (1975) after a series of sandstones, conglomerates, coralline limestones, and claystones. Taylor's conception of the Rio Banano Formation was of a unit with highly variable lithology divided into a sandstone, conglomerate, and reef facies and a Moin Clay Member, elevated here to formation status. Taylor placed the unit in the Late Miocene to Pliocene. The Rio Banano Formation included here
consists only of the sandstone facies of Taylor (1975).

In early 1983 a freshly exposed section of Rio Banano sandstones was found in a landslide at the type section (Figure 10). By early 1984 vegetation had partly obscured the exposure. The Rio Banano sandstones were sampled at this landslide and also directly across the river where good outcrops were found near the water’s edge (Figure 10). Approximately 60 meters of section was sampled at these two localities. In the description of the location of the Rio Banano Formation type section in Taylor’s text there is a typographical error. Taylor’s text says the type section is located east of the railroad bridge at Bomba while, in fact, it is located to the west of the bridge. The correct location of the type section can be determined from Taylor’s sample location map.

At the sampled localities the Rio Banano sandstones are light to medium grey color, tannish orange weathering, medium to fine grained and muddy. Sorting appears to be poor and the outcrops are not well indurated. Locally there are horizons and lenses of mollusks and mollusk fragments which may be profuse enough to be called a fossil hash. Other than bedding, no sedimentary structures were observed.

Moin Formation

The 70 meter thick unit of dark blue claystone north
Figure 10. Location of the Moin Formation and Rio Banano Formation type sections. The Moin Formation type section is located in an unnamed stream draining northward through the residential community of Cangrejos. Sample numbers indicate the approximate positions of the upper and lower samples taken. The Rio Banano Formation type section is located 1/2 kilometer southwest of the railroad bridge on the south side of Rio Banano, above the town of Bomba. This sketch map consists of parts of both the Rio Banano (#3545 I) 1:50,000 topographic sheet of Costa Rica, E 762, Edicion 2-IGNCR, 1978, and the Moin (#3546 II) 1:50,000 topographic sheet of Costa Rica, E 762, Edicion 2-IGNCR, 1976. Grid lines refer to kilometer grid on map.
of the town of Limon is here assigned to the Moin Formation. The name Moin was first used by Gabb (1895) for the exposures of claystone near Limon. Gabb, however, failed to designate a type section so use of the name since then has been informal. Taylor (1975) formally placed this rock unit as a member of his Rio Banano Formation. In doing so he designated a type section which is both well exposed, by Limon Basin standards, and covers the maximum stratigraphic extent of the unit. Taylor included the Moin claystones in the Rio Banano Formation based upon his opinion that they showed lithologic and mineralogic similarities to the sandstones of the Rio Banano Formation. However, the Moin claystone is entirely distinct from the predominantly sandy and limey Rio Banano Formation, and should be separated from it.

The type section of the Moin Formation is exposed in an unnamed stream which drains the north face of the bluff north of Limon, through the residential area known locally as Cangrejos (Figure 10). This section offers the best exposure of the Moin Formation yet identified. Approximately 70 meters of Moin Formation is exposed. Bedding is indistinct and the unit appears massive. No sedimentary structures were observed. Where bedding can be seen the unit is nearly flat lying, having a dip of only 1 to 2 degrees to the north. The rock is soft and easily broken with a rock hammer. Locally, there are horizons of mollusks
and mollusk debris.

The full lateral extent of this unit is unknown because of the vegetative cover. The lower contact of the Moin Formation with the Rio Banano Formation was not observed in this study. Taylor (1975) said the beds have an angular relationship with the reefs of the upper Rio Banano Formation. The upper limit of the unit is the modern erosion surface. Outcrops of the Moin Formation are present only in the area to the north and west of Limon, an area circumscribed by the road connecting Limon with Cangrejos and Fortete on the north, and Moin and Empalme Moin on the west. Moin Formation outcrops are limited to this restricted area on the Moin Peninsula.

BIOSTRATIGRAPHY

Biostratigraphic determinations in this study are based upon the zonation of Bolli and Saunders (1985). Identities were made using adult planktonic foraminiferal tests found in scans of the samples.

Uscari Formation

Quebrada Uscari Type Section. The upper and lower samples (#3-67, #3-74) from the exposed part of the type section yielded the same fauna and are placed in the same zonal range. The fauna included *Orbulina suturalis, O. universa,*
Globigerinoides obliquus obliquus, G. trilobus trilobus, G. trilobus sacculifer, and the important Early Miocene indicator species Globorotalia foehsi peripheroronda. Based on the overlap of these species, the lower part of the type section of the Uscari Formation is placed in the early Middle Miocene Globorotalia foehsi peripheroronda Zone to Globorotalia foehsi foehsi Zone, N9 to N10. Absolute ages for this range are 14.4 mybp to 13.5 mybp. This is in agreement with Taylor (1975) who placed the type section of the Uscari Formation in N8 to N10.

Rio Reventazon Section. The upper and lower samples from this section (#1, #18) yielded the same planktonic fauna and are placed in the same zone. Based on the overlap of Catapsydrax stainforthi, Globorotalia foehsi peripheroronda, Globigerinoides trilobus trilobus, and Globquadrina altispira, the Rio Reventazon section is placed in the Early Miocene, Catapsydrax stainforthi Zone to Globigerinatella insueta Zone, N6 to N7. Absolute ages for this range are 20.3 mybp to 16.4 mypb.

Quebrada Terciopelo Reference Section. The lower limestones in this section are dated as Latest Oligocene based upon reworked specimens of the larger foraminifera Lepidocyclina (Lepidocyclina) waylandvaughni and Heterostegina antillea found in the first shale sample (#304), immediately above
the upper limestone at the base of the section. This corresponds to the Globorotalia kugleri Zone, N3. Absolute ages for this zone are 25.5 mybp to 24.6 mybp. Sample #304 also contained Globorotalia kugleri, indicating this lower shale is latest Oligocene to earliest Miocene in age. Sample #305, the second sample in this section, yielded Catapsydrax stainforthi and Globorotalia kugleri, placing this sample in the Early Miocene Globigerinoides primordius Zone, N4. Absolute ages for this zone are 24.6 mybp to 22.2 mybp. Samples #306 through #311 yielded faunas containing C. stainforthi, C. dissimilis, and Globorotalia fohsi peripheroronda, placing them in the Early Miocene Catapsydrax dissimilis Zone to Globigerinatella insueta Zone, N5 to N7. Absolute ages for this range are 22.2 mybp to 16.4 mybp.

Samples #311 through #314 yielded the Late Oligocene index taxa Globorotalia opima nana and Globigerina c.f. ciperoensis ciperoensis. Some of the specimens of G. opima nana from sample #311 were of the size (0.25 mm to 0.32 mm) that Bolli and Saunders restrict to the Late Oligocene Globorotalia opima opima Zone, P21/N2. Absolute ages for this zone are 33 mybp to 29 mybp. The specimens of G. opima nana from the other samples can range up to P22/N3, or 24.6 mybp.

Samples #316 through #3121 contain taxa which place them in the Early Miocene Catapsydrax dissimilis Zone to
Praeorbulina glomerosa Zone, N5 to N8. Absolute ages for this range are 22.2 mybp to 14.4 mybp.

This biostratigraphy of the Quebrada Terciopelo section is a refinement of Rivier (1971, 1973) where these rocks were dated as Oligocene-Miocene. In addition to the refinement of the biostratigraphy, a short repeated section near the base of the section has been discovered (Figure 9).

Rio Quito Area. In addition to the sampled sections of the Uscari Formation, one sample from Rio Quito, west of the town of Limon (Figure 8b) was analyzed. The fauna included Orbulina universa, Globigerinoides trilobus sacculifer, Globorotalia menardii, G. scitula scitula, Sphaeroidinella dehiscens and Globigerinoides obliquus obliquus. The overlap of these taxa places the sample in the Early Pliocene Globorotalia margaritae evoluta Zone, late N19. Absolute ages for this zone are 4.2 mybp to 3.2 mybp. This is a refinement of Taylor (1975) who placed rocks from this locality in the range of N14 to N18.

Rio Banano Formation

Rio Banano Section. The Rio Banano sandstones yielded a very poor planktonic foraminiferal fauna. Only a few samples in the middle of the section yielded datable planktonic specimens. The fauna was dominated by Globo-
rotalina menardii. Also found were Globigerinoides ruber and G. obliquus extremus, the overlap of which narrows the position of the samples to the Globorotalia margaritae margaritae Zone to Globorotalia exilis Zone, N18 to early N21. Absolute ages for this range are 5.1 mybp to 2.4 mybp. This places these sandstones in the Early to Middle Pliocene. One sample, #97, also yielded a valuable ostracod indicator species, Redimella ovata (W.A. van den Bold, pers. comm., 1985) This species places sample #97 in the earliest Pliocene, early N18 about 5.1 mybp, as the species has a very restricted stratigraphic range from upper N17 to lower N18. As the dated samples are in the middle of the section, the lower and upper parts of the section may extend down to the Late Miocene and up to the later Pliocene respectively. This biostratigraphic determination is a refinement of Taylor (1975) who placed these Rio Banano sandstones in N17 to N21.

Quebrada Terciopelo Rio Banano Formation. The upper 20 meters (approximate) of the Quebrada Terciopelo section is not part of the underlying Usacri Formation. These siltstones are separated from the underlying unit by a time gap of from 19.4 to 10.2 million years (Figure 9). One sample from this upper section yielded a poor planktonic fauna which placed it in the Early to Middle Pliocene, Globorotalia margaritae evoluta Zone to Globigerinoides trilobus...
fistulosus Zone, N19 to N21. The lithology and age of these upper Quebrada Terciopelo rocks suggest they may be Rio Banano Formation. Absolute ages for this range are 4.2 mybp to 2.8 mybp. Species included Orbulina universa, Candeina nitida, Hastigerina siphonifera, Sphaeroctinella dehiscens, and Globoquadridina altispire.

Recopre Refinery Outcrop Near the City of Limon. One sample (#55) from an isolated Rio Banano sandstone outcrop west of Limon, on the Limon-Siquerres highway across from the Recopre refinery (Figure 10), yielded a planktonic fauna dated as Early to Middle Pliocene, Globorotalia margaritae evoluta Zone through Globorotalia exilis Zone, N19 to early N21. Absolute ages for this range are 4.2 mybp to 2.4 mybp. The fauna included Orbulina suturalis, O. universa, Globigerinoides trilobus sacculifer, G. obliquus extremus, Globorotalia menardii, Sphaeroctinella dehiscens, and Hastigerina siphonifera.

Moin Formation

The Moin Formation yielded a good planktonic fauna which contained the Pleistocene indicator species Globorotalia truncatulinoides excelsa. This places the Moin Formation within the Pleistocene to Holocene Globorotalia truncatulinoides truncatulinoides Zone, N22 to N23, absolute age of 1.9 mybp to present. Taylor (1975) reported
the presence of *Sphaeroidinella dehiscens excavata* which is restricted to the Late Pleistocene N23 Zone of Blow (1969). This taxon was not observed by this author who, regardless, has reservations about the subspecific taxonomic identifications upon which many of the refinements of Blow's zonation are based. While Bolli and Saunders use subspecific taxon identifications in their zonation, they do not rely upon subtle morphologic distinctions as the basis for zonal boundaries. The Moin Formation is, therefore, Pleistocene in age, and may be Late Pleistocene.

**Overlap of Biostratigraphic Indicators**

The biostratigraphic work in this section has yielded noteworthy information regarding the stratigraphic ranges of three important indicator taxa. Bolli and Saunders (1985) indicate that *Globorotalia kuoleri* and *Catapsydrax stainforthi* have non-overlapping stratigraphic ranges. *G. kuoleri* is reported from upper P22/N3 to N4 while *C. stainforthi* is reported from N5 to N7. Sample # 305, from the Uscari Formation near the base of the Terciopelo section, yielded good specimens of both of these taxa. No evidence of reworking was noted, indicating their ranges do overlap. These two taxa are illustrated on Plate 24, fig. 8 and Plate 27, fig. 6. It is not possible to say whether the range of *G. kuoleri* should be extended up, or the range of *C. stainforthi* should be extended down.
Bolli and Saunders also show the ranges of *Globorotalia kuoleri* and *Globorotalia opima nana* as non-overlapping. *G. opima nana* is reported from below P20/N1 to lower P22/N3. Sample #312 from the Uscari Formation, near the bottom of the Terciopelo section, yielded good specimens of these two taxa, indicating their ranges do overlap. Once again, no evidence of reworking was seen. These taxa are illustrated on Plate 24, fig. 8 and Plate 25, fig. 3.

The range of *G. opima nana* should probably be extended up in this case. This taxon is not widely used in biostratigraphy because it is differentiated from *G. opima opima* strictly on size. As *G. opima nana* is the smaller of the two, it is difficult to distinguish adults of this taxon from juveniles of *G. opima opima*, which has a more limited stratigraphic range. The occurrence of *G. opima nana* above lower P22/N3 has probably not been reported due to a lack of use by biostratigraphers.

These biostratigraphic results support the opinion of Kennett and Srinivasan (1983) who show these species ranges as overlapping.

A chart of the stratigraphic extent of indicator planktonic foraminifera versus the biozonation of Bolli and Saunders (1985) is shown in Figure 11. The biostratigraphic position of the five sections is shown in relation to the biozones.
<table>
<thead>
<tr>
<th>Miocene</th>
<th>Pliocene</th>
<th>Pleistocene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q. USCARI</td>
<td>Q. TERCIOPELO</td>
<td>R. REVENTAZON</td>
</tr>
<tr>
<td>RIO BANANO FM.</td>
<td>MOIN FM.</td>
<td></td>
</tr>
<tr>
<td>C. dissimilis</td>
<td>C. chipolensis</td>
<td>C. nitida</td>
</tr>
<tr>
<td>G. ciperoensis</td>
<td>G. staintorthi</td>
<td></td>
</tr>
<tr>
<td>G. tripartita</td>
<td>G. venezuelana</td>
<td></td>
</tr>
<tr>
<td>G. naparimaensis</td>
<td>G. conglobatus</td>
<td></td>
</tr>
<tr>
<td>G. obliquus obliquus</td>
<td>G. ruber</td>
<td></td>
</tr>
<tr>
<td>G. trilobus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. sicana</td>
<td>G. dehiscens</td>
<td></td>
</tr>
<tr>
<td>G. altispira</td>
<td>G. acostaensis</td>
<td></td>
</tr>
<tr>
<td>G. archaeomenardii</td>
<td>G. crassaformis</td>
<td></td>
</tr>
<tr>
<td>G. kugleri</td>
<td>G. leuconoensis</td>
<td></td>
</tr>
<tr>
<td>G. margaritae</td>
<td>G. menardii</td>
<td></td>
</tr>
<tr>
<td>G. opima nana</td>
<td>G. fohsi peripheroronda</td>
<td></td>
</tr>
<tr>
<td>G. pleistolumida</td>
<td>G. scitula</td>
<td></td>
</tr>
<tr>
<td>G. truncatulinoides</td>
<td>G. lundida</td>
<td></td>
</tr>
<tr>
<td>H. siphonifera</td>
<td>N. dutertrei</td>
<td></td>
</tr>
<tr>
<td>Q. universa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. glomerosa curva</td>
<td>P. transitoria</td>
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</tr>
<tr>
<td>G. obliquiloculata</td>
<td>P. primas</td>
<td></td>
</tr>
<tr>
<td>S. seminulina</td>
<td>S. dehiscens</td>
<td></td>
</tr>
</tbody>
</table>

Figure 11. Stratigraphic ranges, from Bolli and Saunders (1985), of the planktonic foraminifera recovered from the studied sections. The biostratigraphic positions of the sections are plotted against the biozones.
CHAPTER 3

SPECIES OF FORAMINIFERA

The identified benthonic and planktonic foraminiferal faunas of the studied units are placed in systematic order based on the classification of Loeblich and Tappan (1984). The benthic species occurring at the ten percent level in at least one sample are listed in Table 2. Reference abbreviations are listed in the References section.

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIES OF BENTHIC FORAMINIFERA OCCURRING AT 10% LEVEL</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>USCARI FORMATION</th>
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<tbody>
<tr>
<td><strong>Lower</strong> Quebrada Terciopelo</td>
</tr>
<tr>
<td>BOLIVINA ALATA</td>
</tr>
<tr>
<td>BOLIVINA INFLATA</td>
</tr>
<tr>
<td>BOLIVINA SUBEXCAVATA</td>
</tr>
<tr>
<td>CIBICIDOIDES FLORIDANUS</td>
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<tr>
<td>UVIGERINA PEREGRINA</td>
</tr>
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<table>
<thead>
<tr>
<th>Quebrada Uscari</th>
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<tbody>
<tr>
<td>BOLIVINA SUBAENARIENSIS</td>
</tr>
<tr>
<td>EPISTOMINELLA EXIGUA</td>
</tr>
<tr>
<td>FURSEKOINA FONTONI</td>
</tr>
<tr>
<td>HANZAWAIA CONCENTRICA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RIO REVENTAZON</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOLIVINA INFLATA</td>
</tr>
<tr>
<td>BOLIVINA ISIDROENSIS</td>
</tr>
<tr>
<td>BOLIVINA SUBEXCAVATA</td>
</tr>
<tr>
<td>CIBICIDES WUELLERSTORFI</td>
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<td>UVIGERINA HISPIDO-COSTATA</td>
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<table>
<thead>
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<th>MOIN FORMATION</th>
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</thead>
<tbody>
<tr>
<td>BOLIVINA LOWMANI</td>
</tr>
<tr>
<td>BOLIVINA SUBAENARIENSIS</td>
</tr>
<tr>
<td>CASSIDULINA CURVATA</td>
</tr>
<tr>
<td>CASSIDULINA LAEVIGATA</td>
</tr>
<tr>
<td>CASSIDULINA SUBGLOBOSA</td>
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<tr>
<td>CIBICIDOIDES FLORIDANUS</td>
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<td>UVIGERINA PEREGRINA</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>RIO BANANO FORMATION</th>
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<tbody>
<tr>
<td>CASSIDULINA LAEVIGATA</td>
</tr>
<tr>
<td>CASSIDULINA SUBGLOBOSA</td>
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<tr>
<td>CIBICIDOIDES FLORIDANUS</td>
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<tr>
<td>ELPHIDIUM DISCODALE</td>
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<tr>
<td>HANZAWAIA CONCENTRICA</td>
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<tr>
<td>PSEUDONONION BASISPINATA</td>
</tr>
<tr>
<td>ROSALINA GLOBULARIS</td>
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<tr>
<td>TRIFARINA ANGULOSA</td>
</tr>
</tbody>
</table>

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Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1893

Superfamily HORMOSINACEA Haeckel, 1894

Family HORMOSINIDAE Haeckel, 1894

Subfamily REOPHACINAE Cushman, 1910

Genus REOPHAX de Montfort, 1808

REOPHAX AGGLUTINATUS Cushman, 1913

Plate 1, fig. 1

Reophax agglutinatus Cushman
Cushman, 1913, U.S.N.M. Proc., vol. 44, p. 637, pl. 79, fig. 6.

Reophax agglutinatus Cushman

Superfamily LITUOLACEA de Blainville, 1827

Family LITUOLIDAE de Blainville, 1827

Subfamily AMMOMARGINULININAE, Podobina, 1978

Genus AMMOCALCULITES, Cushman, 1910

AMMOCALCULITES SP.

Plate 1, fig. 2

Specimens cannot be identified to specific level due to poor preservation.

Superfamily LOFTUSIACEA Brady, 1884

Family CYCLAMMINIDAE Marie, 1941

Subfamily CYCLAMMININAE Marie, 1941

Genus CYCLAMMINA Brady, 1879

CYCLAMMINA CANCELLATA Brady, 1884

Plate 1, fig. 3

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Cyclammina cancellata Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 351, pl. 37, figs. 8-16.

Cyclammina cancellata Brady
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 3, pl. 1, fig. 15.

Superfamily SPIROPLECTAMMINACEA Cushman, 1927

Family SPIROPLECTAMMININAE Cushman, 1927

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA FLORIDANA (Cushman), 1922

Plate 1, fig. 4

Textularia floridana Cushman
Cushman, 1922, Publ. 311, Carnegie Inst. Wash. vol. 7, p. 24, pl. 1, fig. 7.

Spiroplectammina floridana (Cushman)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 4, pl. 1, figs. 25,26.

Superfamily VERNEUILINACEA Cushman, 1911

Family VERNEUILINIDAE Cushman, 1911

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA BULBROOKI Cushman, 1936

Plate 1, fig. 5

Gaudryina (Pseudogaudryina) bulbrooki Cushman
Cushman, 1936, C.L.F.R. Spec. Publ. No. 6, p. 16, pl. 2, fig. 16.

Gaudryina bulbrooki Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 135, pl. II, fig. 6.

Genus KARRERIELLA Cushman, 1933

KARRERIELLA BRADYI (Cushman), 1911

Plate 1, fig. 6

Gaudryina bradyi Cushman
Karreriella bradyi (Cushman)

Superfamily ATAXOPHRAGMIACEA Schwager, 1877

Family DOROTHIIDAE Balakhmatova, 1972

Subfamily DOROTHIINAE Balakhmatova, 1972

Genus DOROTHIA Plummer, 1931
DOROTHIA BRADYANA Cushman, 1936
Plate 1, fig. 7

Dorothia bradyana Cushman

Dorothia bradyana Cushman

Family EGGERELLIDAE Cushman, 1937

Subfamily LIEBUSELLINAE Saidova, 1981

Genus LIEBUSELLA Cushman, 1933
LIEBUSELLA SOLDANII (Jones and Parker), 1860
Plate 1, fig. 8

Lituola soldanii Jones and Parker

Liebusella soldanii (Jones and Parker)

Family TEXTULARIELLIDAE Gronhagen and Luterbacher, 1966

Genus TEXTULARIELLA Cushman, 1927
TEXTULARIELLA BARRETTI (Jones and Parker), 1863
Plate 1, fig. 10

Textularia barretti Jones and Parker

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*Textulariella barretti* (Jones and Parker)
Cushman, 1927, C.L.F.R. Contr. vol. 3, p. 24, pl. 5, fig. 3.

Superfamily *TEXTULARIACEA* Ehrenberg, 1839
Family *TEXTULARIIDAE* Ehrenberg, 1839
Subfamily *TEXTULARIINAE*, EHRENBERG, 1839
Genus *TEXTULARIA* Defrance, 1824
*TEXTULARIA c.f. AZUANA*, Bermudez, 1949
Plate 1, fig. 9

*Textularia azuana* Bermudez

*TEXTULARIA LALICKERI* Cushman and Renz, 1941
Plate 1, fig. 11

*Textularia lalickeri* Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol. 17, pt. 1, p. 3, figs. 4,5.

*Textularia lalickeri* Cushman and Renz

*TEXTULARIA MEXICANA* Cushman, 1922
Plate 1, fig. 12

*Textularia mexicana* Cushman

*Textularia c.f. mexicana* Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 170, pl. XII, fig. 2.

*TEXTULARIA c.f. SICA* Lalicker and Bermudez, 1941
Plate 2, fig. 1

*Textularia sica* Lalicker and Bermudez
Lalicker and Bermudez, 1941, Torreia, no. 8, p. 16, pl. 4, figs. 5,6.
Textularia si ca Lalicker and Bermudez

BIGENERINA IRREGULARIS Phleger and Parker, 1951

Plate 2, fig. 2

Bigenerina irregularis Phleger and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 4, pl. 1, figs. 16-21.

Bigenerina irregularis Phleger and Parker
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 130, pl. 2, fig. 8.

Family VALVULINIDAE Berthelin, 1880

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA MEXICANA (Cushman), 1922

Plate 2, fig. 3

Clavulina humilis Brady var. mexicana Cushman

Pseudoclavulina mexicana (Cushman)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 27, pl. 2, fig. 12.

Genus MARTINOTTIELLA Cushman, 1933

MARTINOTTIELLA c.f. CYCLOSTOMATA (Galloway and Morrey, 1929)

Plate 2, fig. 4

Verneuilina cyclostomata Galloway and Morrey
Galloway and Morrey, 1929, Bull. Am. Paleo., vol. 15, no. 55, p. 33, pl. 5, fig. 2.

Schenckiella c.f. cyclostomata (Galloway and Morrey)
Renz, 1948, G.S.A. Memoir No. 32, p. 163, pl. II, fig. 16.

Schenckiella was placed in synonymy with Martinottiella by Loeblich and Tappan, 1964.

MARTINOTTIELLA PALLIDA (Cushman), 1927

Plate 2, fig. 5
Clavulina communis d'Orbigny var. pallida Cushman
Tech. Ser., vol. 1, p. 138, pl. 2, fig. 1.

Schenckiella pallida (Cushman)

See note for above species.

Suborder MILIOLINA Delage and Herouard, 1896

Superfamily CORNUSPIRACEA Schultz, 1854

Family CORNUSPIRIDAE Schultz, 1854

Subfamily CORNUSPIRINAE Schultz, 1854

Genus CORNUSPIRA Schultz, 1854

CORNUSPIRA INVOLVENS (Reuss), 1850

Plate 2, fig. 6

Operculina involvens Reuss
Reuss, 1850, Denkschr. Akad. Wiss. Wien., vol. 1, p. 370,
pl. 46, fig. 30.

CORNUSPIRA INVOLVENS (Reuss)
Bock, 1971, Mem. Miami Geol. Soc., vol. 1, p. 12, pl. 3,
fig. 2.

The genus name CORNUSPIRA Schultz was conserved under

Family FISCHERINIDAE Millett, 1898

Subfamily NODOBACULARIELLINAE Millett, 1898

Genus ARTICULINA d'Orbigny, 1826.

ARTICULINA MAYORI Cushman, 1922

Plate 2, fig. 7

Articulina mayori Cushman
Cushman, 1922, Publ. No. 311, Carnegie Inst., p. 71, pl. 13,
fig. 5.
Articulina mavori Cushman

ARTICULINA PACIFICA Cushman, 1944

Plate 2, fig. 8

Articulina pacifica Cushman

Articulina pacifica Cushman
Foag, 1981, Ecologic Atlas of Benthic Foraminifera of the Gulf of Mexico, p. 42, pl. 61, fig. 3, pl. 62, fig. 3.

Genus NODOBACULARIELLA Cushman and Hanzawa, 1937

NODOBACULARIELLA CASSIS (d’Orbigny), 1839

Plate 2, fig. 9

Vertebralina cassis d’Orbigny

Nodobaculariella cassis (d’Orbigny)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 8, pl. 4, fig. 12-14.

Superfamily MILIOLACEA Ehrenberg, 1839

Family MILIOLIDAE Ehrenberg, 1839

Subfamily SPIROLOCULININAE Wiesner, 1920

Genus SPIROLOCULINA d’Orbigny, 1826

SPIROLOCULINA COMMUNIS Cushman and Todd, 1944

Plate 2, fig. 12

Spiroloculina communis Cushman and Todd
C.L.F.R. Spec. Publ. No. 11, p. 65, pl. 9, fig. 4,5,7,8.

Spiroloculina communis Cushman and Todd
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 18, pl. 9, fig. 4,5.

SPIROLOCULINA ROTUNDA d’Orbigny, 1826

Plate 2, fig. 11
Spiroloculina rotunda d'Orbigny

Subfamily MILIOLINAE Ehrenberg, 1839

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA BICARINATA 1826

Plate 3 fig. 5

Quinqueloculina bicarinata d'Orbigny

Quinqueloculina bicarinata d'Orbigny

QUINQUELOCULINA BICOSTATA d'Orbigny, 1826

Plate 3, fig. 1

Quinqueloculina bicostata d'Orbigny

Quinqueloculina bicostata d'Orbigny
 Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 7, pl. 3, fig. 15.

QUINQUELOCULINA BICOSTATA d'Orbigny var. GARRETTI
 Andersen, 1961

Plate 3, fig. 4

Quinqueloculina bicostata d'Orbigny var. garretti Andersen
 Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 30, pl. 4, fig. 5.

QUINQUELOCULINA BOSCIANA d'Orbigny, 1839

Plate 2, fig. 10

Quinqueloculina bosciiana d'Orbigny
Quinqueloculina bosciana d'Orbigny
Bock, 1971, Miami Geol. Soc., Memoir 1, p. 17, pl. 5, fig. 3-5.

QUINQUELOCULINA COMPTA Cushman, 1947
Plate 2, fig. 13

Quinqueloculina compta Cushman
Cushman, 1947, C.L.F.R. Contr. vol. 23, pt. 4, p. 87, pl. 19, fig. 2.

Quinqueloculina compta Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 7, pl. 3, fig. 17.

QUINQUELOCULINA LAMARCKIANA d'Orbigny, 1839
Plate 3, fig. 2

Quinqueloculina lamarckiana d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 189, pl. 11, fig. 14.

Quinqueloculina lamarckiana d'Orbigny
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 7, pl. 4, fig. 1.

QUINQUELOCULINA c.f. POEYANA d'Orbigny, 1839
Plate 2, fig. 14

Quinqueloculina poeyana d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 191, pl. 11, fig. 25-27.

Quinqueloculina poeyana d'Orbigny
McCulloch, 1977, Qualitative Observations on Recent Foraminiferal Tests. p. 502, pl. 206, fig. 11,12.

QUINQUELOCULINA SEMINULA (Linnaeus), 1758
Plate 3, fig. 3

Serpula seminula Linnaeus

Quinqueloculina seminula (Linnaeus)
Renz, 1948, G.S.A. Memoir No. 32, p. 156, pl. III, fig. 1.

Genus EDENTOSTOMINA Collins, 1958
EDENTOSTOMINA FITERREI (Acosta), 1940

Plate 3, fig. 7

*Triloculina fiterei* Acosta
Acosta, 1940, Torreia, Havana, vol. 3, p. 25, 26, pl. 4, fig. 6-8.

Absence of an apertural tooth and variable chamber arrangement suggest placement in *Edentostomina*.

**Genus MASSILINA** Schlumberger, 1893

**MASSILINA TENUISSIMA** Bermudez, 1949

Plate 3, fig. 6

*M assilina tenuissima* Bermudez

**Genus TRILOCULINA** d'Orbigny, 1826

**TRILOCULINA CARINATA** d'Orbigny, 1839

Plate 3, fig. 8

*Triloculina carinata* d'Orbigny

*Triloculina carinata* d'Orbigny

**TRILOCULINA SAIDI** McCulloch, 1977

Plate 3, fig. 9

*Triloculina saidi* McCulloch

**TRILOCULINA TRICARINATA** d'Orbigny, 1826

Plate 4, fig. 1

*Triloculina tricarinata* d'Orbigny
Triloculina tricarinata d’Orbigny
Renz, 1948, G.S.A. Memoir No. 32, p. 172, pl. III, fig. 2.

TRILOCULINA TRIGONULA (Lamarck), 1804
Plate 4, fig. 2

Miliola trigonula Lamarck
Lamarck, 1804, Ann. Mus., vol. 5, p. 351, no. 3; vol. 9, 1807, pl. 17, fig. 4.

Triloculina trigonula (Lamarck)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 6, pl. 3, fig. 15,16.

Genus CRUCILOCULINA d’Orbigny, 1839
CRUCILOCULINA STRIATA, Loeblich and Tappan, 1957
Plate 4, fig. 3

Cruciloculina striata Loeblich and Tappan

CRUCILOCULINA SUBLINEATA (Brady), 1884
Plate 4, fig. 4

Miliolina circularis (Bornemann) var. sublineata Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 169, pl. 4, fig. 7.

Miliolinella sublineata (Brady)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 8, pl. 4, fig. 7.

Cruciform aperture suggests placement in Cruciloculina.

Genus PYRGO Defrance, 1824
PYRGO c.f. OBLONGA (d’Orbigny), 1839
Plate 4, fig. 5

Biloculina oblonga d’Orbigny

Pyrgo c.f. oblonga (d’Orbigny)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 39, pl. 9, fig. 3.
PYRGO SUBSPAERICA (d'Orbigny), 1839

Plate 4, fig. 6

_Biloculina subspaerica_ d'Orbigny


PYRGO subspaerica (d'Orbigny)


PYRGO VESPERTILIO (Schlumberger), 1891

Plate 4, fig. 7

_Biloculina vespertilio_ Schlumberger

Schlumberger, 1891, Soc. Zool. France Mem., tome 4, p. 561, pl. 10, fig. 74-76.

PYRGO vespertilio (Schlumberger)


Subfamily MILIOLINELLINAE Vella, 1957

Genus MILIOLINELLA Wiesner, 1931

MILIOLINELLA FICHTELIANA

PLATE 4, fig. 10

_Triloculina fichteliana_ d'Orbigny


Miliolinella fichteliana (d’Orbigny)

Bock, 1971, Miami Geol. Soc. Memoir. 1, p. 29, pl. 12, fig. 6.

MILIOLINELLA SUBROTUNDA (Montagu), 1803

Plate 4, fig. 9

_Vermiculum subrotundum_ Montagu

Montagu, 1803, Testacea Britannica, or natural history of British shalss, marine, land, and fresh water, including the most minute, p. 521.

Miliolinella subrotunda (Montagu)

Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 8, pl. 4, fig. 3, p. 10, pl. 5, fig. 13,14.
Genus PYRGOELLA Cushman and White, 1936
PYRGOELLA SFHAERA (d’Orbigny), 1839
Plate 4, fig. 9

Biloculina sphaera d’Orbigny
d’Orbigny, 1839, Voyage dans l’Amerique Meridionale;
“Foraminiferes”, tome 5, pt. 5, p. 66, pl. 8, fig. 13-16.

Pyrgoella sphaera (d’Orbigny)
Loeblich and Tappan, 1964, Treat. on Invert. Paleo. p. 465,
textfig. 352, no. 6,7.

Subfamily SIGMOILOPSINAE Vella, 1957
Genus SIGMOILINA Schlumberger, 1887
SIGMOILINA SUBPOEYANA (Cushman), 1922
Plate 4, fig. 11

Quinqueloculina subpoevana Cushman
Cushman, 1922, Publ. Carnegie Inst. Wash., vol 17, no. 311,
p. 66; U.S. Nat. Mus. Bull. No. 104, pt. 6, p. 31, pl. 5,
fig. 3.

Sigmoilina subpoevana (Cushman)
Bandy, 1956, U.S. Geol. Survey Prof Paper 247-6, p. 197,
pl. 29, fig. 1.

SIGMOILINA TENUIS (Czjzek), 1847
Plate 4, fig. 12

Quinqueloculina tenuis Czjzek
Czjzek, 1847, Haidingers Naturwiss. Abh., vol. 2, p. 149,
pl. 13, fig. 31-34.

Sigmoilina tenuis (Czjzek)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 8, pl. 4, fig. 7.

Genus SIGMOILOPSIS Finlay, 1947
SIGMOILOPSIS FLINTII (Cushman), 1946
Plate 5, fig. 1

Sigmoilina flintii Cushman
Cushman, 1946, C.L.F.R. Contr. vol. 22, pt. 2, p. 44,
pl. 6, fig. 35-39.
**Sigmoilopsis flintii** (Cushman)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 34, pl. 7, fig. 9.

**SIGMOILOPSIS SCHLUMBERGERI** (Silvestri), 1904
Plate 5, fig. 2

**Sigmoilina schlumbergeri** Silvestri

**Sigmoilina schlumbergeri** Silvestri
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 8, pl. 4, fig. 6.

Superfamily **SORITACEA** Ehrenberg, 1839

Family **PENEROPLIDAE** Schultz, 1854

Genus **PENEROPLIS** de Montfort, 1808

**PENEROPLIS BRADYI** Cushman, 1930
Plate 5, fig. 3

**Peneroplis bradyi** Cushman

**Puteolina bradyi** (Cushman)

Suborder **SPIRILLININA** Hohenegger and Piller, 1975

Family **SPIRILLINIDAE** Reuss and Fritsch, 1861

Genus **SPIRILLINA** Ehrenberg, 1843

**SPIRILLINA VIVIPARA** Ehrenberg, 1841
Plate 5, fig. 4

**Spirillina vivipara** Ehrenberg

**Spirillina vivipara** Ehrenberg
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 25, pl. 13, fig. 3,4.

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Genus MYCHOSTOMINA Berthelin, 1881

MYCHOSTOMINA REVERTENS (Rhumbler), 1906

Plate 5, fig. 11

Spirillina vivipara Ehrenberg var. revertens Rhumbler

Mychostomina revertens (Rhumbler)
Galloway, 1933, Manual of Foram., p. 88, pl. 7, fig. 6,7.

Family PARELLINIDAE Rhumbler, 1906

Genus PATELLINA Williamson, 1858

PATELLINA CORRUGATA Williamson, 1858

Plate 5, fig. 5

PateLLina corrugata Williamson
Williamson, 1858, Rec. Foram. of Gt. Britain, p. 46, pl. 3, fig. 86-89.

PateLLina corrugata Williamson
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 23, pl. 12, fig. 4.

Suborder LAGENINA Delage and Hercourard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus DENTALINA Risso, 1826

DENTALINA ADVENA (Cushman), 1923

Plate 5, fig. 7

Nodosaria advena Cushman

Dentalina advena (Cushman)
Renz, 1948, G.S.A. Memoir No. 32, p. 130, pl. IV, fig. 27.
DENTALINA PAUPERATA d’Orbigny, 1846

Plate 5, fig. 15

Dentalina pauperata d’Orbigny
d’Orbigny, 1846, Foram. foss. Bass. tertiaire de Vienne,
p. 46, pl. 1, fig. 57,58.

Dentalina pauperata d’Orbigny
Renz, 1948, G.S.A. Memoir No. 32, p. 131, pl IV, fig. 26.

Genus FRONDICULARIA Defrance, 1826
FRONDICULARIA ADVENA Cushman, 1923

Plate 5, fig. 9

Frondicularia advena Cushman
pl. 20, fig. 1,2.

Frondicularia advena Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. , 134, pl. XII,
fig. 5.

FRONDICULARIA SAGITTULA van den Broeck, 1876

Plate 5, fig. 8

Frondicularia alata d’Orbigny var. sagittula van den Broeck
van den Broeck, 1876, Ann. Soc. Belge Micro., vol. 2,
p. 113, pl. 2, fig. 12,14.

Frondicularia sagittula van den Broeck
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 73,
pl. 16, fig. 18-21.

FRONDICULARIA VAUGHANI (Cushman), 1927

Plate 5, fig. 10

Plectofrondicularia vaughani Cushman
Cushman, 1927, C.L.F.R. Contr. vol. 3, p. 112, pl. 23,
fig. 3.

Plectofrondicularia vaughani Cushman
Bermudez, 1949, C.L.F.R. Spec. Publ. No. 25, p. 177,
pl. 11, fig. 46,47.

Lack of initial biserial stage indicates placement in
Frondicularia rather than Plectofrondicularia.
Genus PSEUDONODOSARIA Boomgaart, 1949

PSEUDONODOSARIA COMATULA (Cushman), 1923

Plate 5, fig. 14

_Nodosaria comatula_ Cushman

Pseudoalandulina comatula (Cushman)

_Pseudonodosaria comatula_ (Cushman)

PSEUDONODOSARIA INCISIA (Neugeboren), 1850

Plate 5, fig. 12

_Glandulina incisia_ Neugeboren

_Pseudoalandulina incisia_ (Neugeboren)
Renz, 1948, G.S.A. Memoir No. 32, p. 154, pl. V, fig. 16.

Embracing chambers suggest placement in _Pseudonodosaria._

Genus NODOSARIA Lamarck, 1812

NODOSARIA LONGISCATA d'Orbigny, 1846

Plate 5, fig. 13

_Nodosaria longiscata_ d'Orbigny

_Nodosaria longiscata_ d'Orbigny

NODOSARIA PYRULA d'Orbigny, 1826

Plate 5, fig. 6

_Nodosaria pyrula_ d'Orbigny
Nodosaria ovula d'Orbigny
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 10, pl. 5, fig. 5.

**NODOSARIA RAPHANISTRUM (Linnaeus) var. CARIBBEANA**
Hedberg, 1937

Plate 6, fig. 1

Nodosaria raphanistrum (Linnaeus) var. caribbeana Hedberg
Hedberg, 1937, Jour. Paleo., vol. 11, no. 8, p. 671, pl. 91, fig. 1.

Nodosaria raphanistrum (Linnaeus) var. caribbeana Hedberg
Renz, 1948, G.S.A. Memoir No. 32, p. 147, pl. V, fig. 6, 7.

**NODOSARIA STAINFORTHI** Cushman and Renz, 1941

Plate 6, fig. 2

Nodosaria stainforthi Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol. 17, pt. 1, p. 15, pl. 3, fig. 5.

Nodosaria stainforthi Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 147, pl. IV, fig. 31.

**NODOSARIA VERTEBRALIS** (Batsch), 1791

Plate 6, fig. 3

Nautilus (Orthoceras) vertebralis Batsch
Batsch, 1791, Conchyliien des Seesands, pt. 3, no. 6, pl. 2, fig. 6.

Nodosaria vertebralis (Batsch)
Renz, 1948, G.S.A. Memoir No. 32, p. 147, pl. V, fig. 8-11.

**Genus ORTHOMORPHINA** Stainforth, 1952

ORTHOMORPHINA CHALLENGERINA (Thalmann), 1937

Plate 6, fig. 4

Nodosenerina challengerina Thalmann

Orthomorphina challengerina (Thalmann)

**Genus AMPHICORYNA** Schlumberger, 1881
AMPHICORYNA CAMACHOI Andersen, 1961

Plate 6, fig. 8

Amphicoryna camachoi Andersen
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 67, pl. 16, fig. 4, 5.

AMPHICORYNA HIRSUTA (d'Orbigny), 1826

Plate 6, fig. 5

Nodosaria hirsuta d'Orbigny

Amphicoryna hirsuta (d'Orbigny)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 132, pl. 63, fig. 16.

AMPHICORYNA SOLARIS (Batsch), 1791

Plate 6, fig. 7

Nautilus (Orthoceras) solaris Batsch
Batsch, 1791, Conch. des Seesands, no. 4, pl. 2, fig. 4.

Amphicoryna solaris (Batsch)

AMPHICORYNA SUBLINEATA (Brady), 1884

Plate 6, fig. 6

Nodosaria hispada var. sublineata Brady

Amphicoryna sublineata (Brady)

Genus LAGENA Walker and Jacob, 1798

LAGENA GIBBERA Buchner, 1940

Plate 6, fig. 9

Lagena gibbera Buchner
Lagena gibbosa Buchner

LAGENA GRACILLIMA (SEQUENZA), 1862
Plate 6, fig. 10

Amphorina gracillima Sequenza
Sequenza, 1862, Die terreni Terzlarii del distretto di Messina; Pt. II, p. 51, pl. 1, fig. 37.

Lagena gracillima (Sequenza)

LAGENA GRACILLIS Williamson, 1848
Plate 6, fig. 18

Lagena gracillis Williamson

Lagena gracillis Williamson

LAGENA LAEVIS (Montagu), 1803
Plate 6, fig. 11

Vermiculum laeve Montagu

Lagena laevis (Montagu)

LAGENA STRIATA (d'Orbigny), 1839
Plate 6, fig. 17

Oolina striata d'Orbigny
d'Orbigny, 1839, Foram. Amer. Merid., p. 21, pl. 5, fig. 12.

Lagena striata (d'Orbigny)

Subfamily PLECTOFRONDICULARIINAE Cushman, 1927
Genus PLECTOFRONDICULARIA Liebus, 1902

PLECTOFRONDICULARIA CALIFORNICA Cushman and Stewart, 1926

Plate 6, fig. 12

Plectofrondicularia californica Cushman and Stewart
Cushman and Stewart, 1926, C.L.F.R. Contr. vol. 2, p. 39, pl. 6, fig. 9-11.

Plectofrondicularia c.f. californica Cushman and Stewart
Renz, 1948, G.S.A. Memoir No. 32, p. 151, pl. XII, fig. 10.

PLECTOFRONDICULARIA FLORIDANA Cushman, 1930

Plate 6, fig. 13

Plectofrondicularia floridana Cushman
Cushman, 1930, Florida Geol. Survey, Bull. no. 4, p. 41, pl. 8, fig. 1.

Plectofrondicularia floridana Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 152, pl. VI, fig. 19.

PLECTOFRONDICULARIA c.f. LONGISTRIATA LeRoy, 1939

Plate 6, fig. 14

Plectofrondicularia longistiata LeRoy
LeRoy, 1939, Natuurk. tijdschr. Ned.-Indee, afl. 6, deel 9, p. 241, pl. 5, fig. 4-6.

Plectofrondicularia c.f. longistiata LeRoy
Renz, 1948, G.S.A. Memoir No. 32, p. 152, pl. VI, fig. 21.

Family VAGINULINIDAE Reuss, 1860

Subfamily LENTICULININAE Chapman, Parr and Collins, 1934

Genus LENTICULINA Lamarck, 1804

LENTICULINA CALCAR (Linnaeus), 1767

Plate 6, fig. 15

Nautilus calcar Linnaeus

Robulus calcar (Linnaeus)
Renz, 1948, G.S.A. Memoir No. 32, p. 158, pl. III, fig. 6.
Robulus was placed in synonymy with Lenticulina by Loeblich and Tappan, 1964

LENTICULINA CLERICCI (Fornasini), 1929

Plate 6, fig. 16

Cristellaria clericci Fornasini
Cushman, 1929, C.L.F.R. Contr. vol. 5, p. 84, pl. 12, fig. 16,17.

Robulus clericci (Fornasini)
Renz, 1948, G.S.A. Memoir No. 32, p. 158, pl. III, fig. 8.

LENTICULINA CULTRATA (de Montfort), 1808

Plate 7, fig. 1

Robulus cultratus de Montfort
Montfort, 1808, Conchyliologie systematique et classification methodique des coquilles, tome 1, p. 215.

Lenticulina cultrata (de Montfort)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 146, pl. 70, fig. 4-6.

LENTICULINA OCCIDENTALIS (Cushman) var. TORRIDUS
Cushman, 1923

Plate 7, fig. 2

Cristellaria occidentalis Cushman var. torrida Cushman

Robulus occidentalis (Cushman) var. torrida Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 160, pl. III, fig. 17.

See above note.

LENTICULINA ex. grp. PEREGRINA (Schwager), 1866

Plate 7, fig. 3

Cristellaria peregrina Schwager
Schwager, 1866, Novara Exped., Geol. Theil., vol. 2, p. 245, pl. 7, fig. 89.

Lenticulina peregrina (Schwager)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 9, pl. 4, fig. 19.
LENTICULINA c.f. SERPENS (Sequenza), 1880

Plate 7, fig. 4

Robulina serpens Sequenza

"Robulus" c.f. R serpens (Sequenza)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 52, pl. 10, fig. 10.

See above note.

Genus SARACENARIA Defrance, 1824

SARACENARIA c.f. ITALICA Defrance var. CARAPITANA Franklin, 1944

Plate 7, fig. 8

Saracenaria italica Defrance var. carapitana Franklin
Franklin, 1944, Jour. Paleo., v. 18, p. 312, pl. 45, fig. 14.

Saracenaria c.f. italica Defrance var. carapitana Franklin
Renz, 1948, G.S.A. Memoir No. 32, p. 162, pl. V, fig. 17.

SARACENARIA LATIFORMIS JAMAICENSIS
Cushman and Todd, 1945

Plate 7, fig. 5

Saracenaria latiformis (Brady) jamaicensis Cushman and Todd
Cushman and Todd, 1945, C.L.F.R. Spec. Publ. No. 15, p. 32, pl. 5, fig. 7.

Saracenaria latiformis (Brady) jamaicensis Cushman and Todd

SARACENARIA LATIFRONS (Brady), 1884

Plate 7, fig. 6

Cristellaria latifrons Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 544, pl. 113, fig. 11.

Saracenaria latifrons (Brady)
Renz, 1948, G.S.A. Memoir No. 32, p. 162, pl. V, fig. 22.
Subfamily MARGINULININAE Wedekind, 1937

Genus ASTACOLUS de Montfort, 1808

ASTACOLUS NUDICOSTATA (Cushman and Hanna), 1927

Plate 7, fig. 9

*Cristellaria mexicana* Cushman var. *nudicostata* Cushman


*Lenticulina nudicostata* (Cushman and Hanna)


Oblique sutures and curved axis of test suggest placement in *Astacolus*.

ASTACOLUS OVATUS Galloway and Heminway, 1941

Plate 7, fig. 10

*Astacolus ovatus* Galloway and Heminway

Galloway and Heminway, 1941, The Tertiary foraminifera of Porto Rico, p. 334, pl. 8, fig. 10.

*Astacolus ovatus* Galloway and Heminway

Renz, 1948, G.S.A. Memoir No. 32, p. 115, pl. IV, fig. 12.

ASTACOLUS c.f. PLATENSIS (Bermudez), 1949

Plate 7, fig. 7

*Robulus platensis* Bermudez


Curvilinear nature of test suggests placement in *Astacolus*.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA OBESA Cushman, 1923

Plate 8, fig. 1

*Marginulina glabra* d'Orbigny var. *obesa* Cushman

Marginulina obesa Cushman
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 136, pl. 65, fig. 5, 6.

MARGINULINA c.f. STRIATULA Cushman, 1913
Plate 8, fig. 2

Marginulina striatula Cushman

Marginulina c.f. striatula Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 145, pl. IV, fig. 15, 16.

MARGINULINA SUBBULLATA Hantken, 1875
Plate 8, fig. 3

Marginulina subbullata Hantken
Hantken, 1875 (1876), Magyar Kir. foldt. int. evkon., vol 4, p. 39, pl. 4, fig. 9-10, pl. 5, fig. 9.

Marginulina subbullata Hantken
Renz, 1948, G.S.A. Memoir No. 32, p. 145, pl. IV, fig. 13-14.

Genus MARGINULINOPSIS Silvestri, 1904

MARGINULINOPSIS MARGINULINOIDES (Goes), 1896
Plate 8, fig. 4

Cristellaria acuelata d'Orbigny var. marginulinoides Goes

Marginulina marginulinoides (Goes)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 9, pl. 4, fig. 17.

MARGINULINOPSIS SUBACUELATA GLABRATA (Cushman), 1923
Plate 8, fig. 5

Cristellaria subacuelata Cushman var. glabrata Cushman
Cushman, 1923, U.S. Nat. Mus. Bull. No. 104, pt. 4, p. 124, pl. 32, fig. 4, pl. 33, fig. 3, pl. 34, fig. 3.
Marginulina subacuelata (Cushman) var. glabrata (Cushman)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 9, pl. 5, fig. 4.

Marginulinopsis subacuelata glabrata (Cushman)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 61, pl. 15, fig. 10.

Subfamily VAGINULININAE Reuss, 1860

Genus PLANULARIA Defrance, 1826

PLANULARIA VENEZUELANA Hedberg, 1937
Plate 8, fig. 6

Planularia venezuelana Hedberg

Planularia venezuelana Hedberg
Renz, 1948, G.S.A. Memoir No. 32, p. 100, pl. IV, fig. 5.

Genus VAGINULINA d’Orbigny, 1826

VAGINULINA ADVENA Cushman, 1923
Plate 8, fig. 8

Vaginulina advena Cushman

Vaginulina advena Cushman

VAGINULINA MEXICANA Nuttall, 1932
Plate 8, fig. 7

Vaginulina elegans d’Orbigny var. mexicana Nuttall
Nuttall, 1932, Jour. Paleo., vol. 6, p. 16, pl. 5, fig. 12,16.

Vaginulina mexicana Nuttall

Vaginulina sp. A
Renz, 1948, G.S.A. Memoir No. 32, p. 176, pl. IV, fig. 23.
Family POLYMORPHINIDAE d’Orbigny, 1839

Subfamily POLYMORPHININAE d’Orbigny, 1839

Genus PYRULINA d’Orbigny, 1839

PYRULINA ANGUSTA (Egger), 1857

Plate 8, fig. 10

Polymorphina angusta Egger
Egger, 1857, Neves Jahrb. Min. Geogn. Geol. Petref. -
Kunde, pl. 13, fig. 13-15.

Pyrulina angusta (Egger)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 150, pl. 72,
fig. 1-3.

Genus GUTTULINA d’Orbigny, 1839

GUTTULINA IRREGULARIS (d’Orbigny), 1846

Plate 8, fig. 11

Globulina irregularis d’Orbigny
d’Orbigny, 1846, Foram. foss. bass. tertiare de Vienne,
p. 226, pl. 13, fig 9,10.

Guttulina irregularis (d’Orbigny)
Renz, 1948, G.S.A. Memoir No. 32, p. 138, pl. VI, fig. 1,2.

GUTTULINA PROBLEMA d’Orbigny, 1826

Plate 8, fig. 12

Guttulina problema d’Orbigny

Guttulina problema d’Orbigny
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 150, pl. 72,
fig. 19,20.

Genus GLOBULINA d’Orbigny, 1839

GLOBULINA GIBBA (d’Orbigny), 1826

Plate 8, fig. 13

Polymorphina gibba d’Orbigny
pl. 2, fig. 52.
Globulina gibba (d'Orbigny)

Subfamily OOLININAE Loeblich and Tappan, 1961

Genus OOLINA d'Orbigny, 1839

OOLINA HEXAGONA (Williamson), 1848
Plate 8, fig. 9

Entosolina squamosa (Montagu) var. hexagona Williamson

Oolina hexagona (Williamson)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 120, pl. 58, fig. 32,33.

Genus FISSURINA Reuss, 1850

FISSURINA ANNECTENS (Burrows and Holland), 1895
Plate 9, fig. 1

Lagena annectens Burrows and Holland

Fissurina annectens (Burrows and Holland)

FISSURINA AURICULATA (Brady), 1881

Not Figured

Lagena auriculata Brady

Fissurina auriculata (Brady)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 126, pl. 60, fig. 29.

FISSURINA MARGINATA (Walker and Boys), 1784
Plate 9, fig. 2
Serpula (Lagena) marginata Walker and Boys
Walker and Boys, 1784, Test. Minuta., p. 2, pl. 1, fig. 7.

Lagena marginata (Walker and Boys)
Renz, 1948, G.S.A. Memoir No. 32, p. 142, pl. V, fig. 30.

Suborder ROBERTININA Loeblich and Tappan, 1984
Superfamily ROBERTINACEA Reuss, 1850
Family EPISTOMINIDAE Wedekind, 1937
Subfamily EPISTOMININAE Wedekind, 1937
Genus HOEGLUNDINA Brotzen, 1948
HOEGLUNDINA ELEGANS (d'Orbigny), 1826
Plate 9, fig. 3

Rotalina (Turbinulina) elegans d'Orbigny

Hoeol Linde na ela on (d'Orbigny)

Suborder ROTALIINA Delage and Herouard, 1896
Superfamily TURRILINACEA Cushman, 1927
Family TURRILINIDAE Cushman, 1927
Genus TURRILINA Andreae, 1884
TURRILINA ALSATICA (Nyiro), 1954
Not Figured

Corrosina alsatica Nyiro

Turritina alsatica (Nyiro)

Family PAVONINIDAE Eimer and Fickert, 1899
Genus POVONINA d'Orbigny, 1826
PAVONINA ATLANTICA Cushman, 1922

Plate 9, fig. 4

Pavonina atlantica Cushman

Pavonina atlantica Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 17, pl. 8, fig. 6, 7.

Family SPHAEROIDINIDAE Cushman, 1927
Genus SPHAEROIDINA d'Orbigny, 1826

SPHAEROIDINA BULLOIDES d'Orbigny, 1826

Plate 9, fig. 5

Spaeroidina bulloides d'Orbigny

Spaeroidina bulloides d'Orbigny

Superfamily EUVIGERINACEA Cushman, 1927
Family BOLIVINIDAE Glaessener, 1937
Genus BOLIVINA d'Orbigny, 1839

BOLIVINA ALATA (Sequenza), 1862

Plate 9, fig. 6

Vulvulina alata Sequenza

Bolivina alata (Sequenza)

BOLIVINA INCONSPICUA Cushman and Renz, 1941

Plate 9, fig. 7

Bolivina inconspicua Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol. 17, pt. 1, p. 18, pl. 3, fig. 10-11.
**Bolivina inconspicua** Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 118, pl. VII, fig. 9,10.

**BOLIVINA INFLATA** Heron-Allen and Earland, 1916
Plate 9, fig. 8

**Bolivina inflata** Heron-Allen and Earland
vol. 31, pt. 64, p. 68, pl. 4, fig. 16-19.

**BOLIVINA ISIDROENSIS** Cushman and Renz, 1941
Plate 9, fig. 11

**Bolivina isidroensis** Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol 17, pt. 1,
p. 17, pl. 3, fig. 8.

**Bolivina isidroensis** Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 118, pl. VII, fig. 5.

**BOLIVINA LOWMANI** Phleger and Parker, 1951
Plate 9, fig. 10

**Bolivina lowmani** Phleger and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 13, pl. 6, fig. 20,21.

**Bolivina lowmani** Phleger and Parker
Akers and Dorman, 1964, Tulane Studies in Geology, pt. 1,
vol. 3, no. 1, p. 25, pl. VIII, fig. 5.

- **BOLIVINA c.f. PLICATA** d'Orbigny, 1839
Plate 9, fig. 9

**Bolivina plicata** d'Orbigny
d'Orbigny, 1839, Voy. Amer. Merid., vol. 5, p. 62, pl. 8,
fig. 4-7.

**Bolivina plicata** d'Orbigny
Cushman and McCulloch, 1942, Some Virgulininae In The
Collections of the Allan Hancock Foundation, p. 203,
pl. 24, fig. 14,15.

**BOLIVINA PSEUDOPLICATA** Heron-Allen and Earland, 1930
Plate 9, fig. 14
**Bolivina pseudolicata** Heron-Allen and Earland
London, vol. 50, p. 81, pl. 3, fig. 36-40.

**Bolivina pseudolicata** Heron-Allen and Earland
Cushman and McCulloch, 1942, Dome Virgulininae In The
Collections of the Allan Hancock Foundation, p. 204,
pl. 25, fig. 4-7.

**BOLIVINA SPINATA** Cushman, 1936
Plate 9, fig. 13

**Bolivina spinata** Cushman
Cushman, 1936, C.L.F.R. Spec. Publ. No. 6, p. 59, pl. 8,
fig. 9.

**Bolivina striatula** Cushman var. *spinata* Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 14, pl. 7, fig. 7.

**BOLIVINA SUBAENARIENSIS** Cushman var. *MEXICANA*
Cushman, 1922
Plate 9, fig. 15

**Bolivina subaenariensis** Cushman var. *mexicana* Cushman
pl. 8, fig. 1.

**Bolivina subaenariensis** Cushman var. *mexicana* Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 15, pl. 7, fig. 8-10.

**BOLIVINA SUBEXCAVATA** (Cushman and Wickenden), 1929
Plate 9, fig. 16

**Bolivina subexcavata** (Cushman and Wickenden)
Cushman and Wickenden, 1929, Proc. U.S. Nat. Mus., vol. 75,
no. 27, p. 9, pl. 4, fig. 4.

**Bolivina subexcavata** Cushman and Wickenden
no. 31, p. 76, pl. 2, fig. 11-22.

**BOLIVINA THALMANNI** Renz, 1948
Plate 9, fig. 17

**Bolivina thalmanni** Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 120, pl. XII, fig. 13.
Bolivina thalmanni Renz
Akers and Dorman, 1964, Tulane Studies in Geology, pt. 1, vol. 3, no. 1, p. 27, pl. VIII, fig. 27.

BOLIVINA TONGI Cushman, 1929
Plate 9, fig. 12

Bolivina tongi Cushman
Cushman, 1929, C.L.F.R. Contr. vol. 5, pt. 4, p. 93, pl. 13, fig. 29.

Bolivina tongi Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 120, pl. VI, fig. 24,25.

BOLIVINA SP.
Not Figured

Family STILOSTOMELLIDAE Finlay, 1947
Genus STILOSTOMELLA Guppy, 1894

STILOSTOMELLA ANTILEA (Cushman), 1923
Plate 10, fig. 2

Nodosaria antilea Cushman

Stilostomella antilea (Cushman)

STILOSTOMELLA BRADYI (Cushman), 1927
Plate 10, fig. 4

Nodosenerina bradyi Cushman
Cushman, 1927, C.L.F.R. Contr. vol. 2, p. 97, fig. pt. 4, p. 79, pl. 76, fig. 8.

Stilostomella bradvi (Cushman)

STILOSTOMELLA CONSOBRINA (d’Orbigny), 1846
Plate 10, fig. 3
**Dentalina consobrina** d'Orbigny
 d'Orbigny, 1846, Foram. foss. bass. tert. de Vienne, p. 46, pl. 2, fig. 1-3.

**Stilostomella consobrina** (d'Orbigny)
 Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 130, pl. 62, fig. 23,24.

**Dentalina consobrina** d'Orbigny
 Renz, 1948, G.S.A. Memoir No. 32, p. 130, pl. IV, fig. 30.

**STILOSTOMELLA VERNEUILI** (d'Orbigny), 1846

Plate 10, fig. 1

**Dentalina verneului** d'Orbigny
 d'Orbigny, 1846, Foram. foss. bass. tertiare de Vienna, p. 48, pl. 2, fig. 7,8.

**Ellipsonodosaria verneului** (d'Orbigny)
 Renz, 1948, G.S.A. Memoir No. 32, p. 131, pl. VIII, fig. 3-7.

Rectilinear test and non-radial aperture suggest **Stilostomella**.

Superfamily **BULIMINACEA** Jones, 1875

Family **STAINFORTHIIDAE** Reiss, 1963

Genus **STAINFORTHIA** Hofker, 1956

**STAINFORTHIA COMPLANATA** (Egger), 1893

Plate 10, fig. 5

**Virgulina schreibersiana** Czjzek var. complanata Egger

**Stainforthia c.f. complanata** (Egger)
 McCulloch, 1981, Qualitative Observations on Recent Foraminiferal Tests, pt. IV, p. 130, pl. 44, fig. 3.

Family **BULIMINIDAE** Jones, 1875

Genus **BULIMINA** d'Orbigny, 1826

**BULIMINA ACULEATA** d'Orbigny, 1826

Plate 10, fig. 8
**Bulimina aculeata** d'Orbigny


**Bulimina affinis** d'Orbigny

Cuba, "Foraminiferes", vol. 8, p. 105, pl. 2, fig. 25,26.

**Bulimina alazanensis** Cushman, 1927

**Bulimina inflata** Sequenza, 1862

**Bulimina marginata** d'Orbigny

no. 4, pl. 12, fig. 10-12.
Bulimina maroinata d'Orbigny
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 16, pl. 7, fig. 27,28.

Genus PRAEGLOBOBULIMINA Hofker, 1951
PRAEGLOBOBULIMINA PUPOIDES (d'Orbigny), 1846
Plate 10, fig. 11

Bulimina pupoides d'Orbigny
d'Orbigny, 1846, Foram. foss. bass. tertiare de Vienne, p. 185, pl. 11, fig. 11,12.

Bulimina pupoides d'Orbigny
Renz, 1948, G.S.A. Memoir No. 32, p. 122, pl. VI, fig. 11,12.

Praeglobobulimina pupoides (d'Orbigny)

Genus GLOBOBULIMINA Cushman, 1927
GLOBOBULIMINA PERVERSA (Cushman), 1921
Plate 10, fig. 14

Bulimina pyrula d'Orbigny var. perversa Cushman

Bulimina (Globobulimina) perversa Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 122, pl. VI, fig. 16. Globular test and embracing chambers suggest Globobulimina.

Family BULIMINELLIDAE Hofker, 1951

Genus BULIMINELLA Cushman, 1911

BULIMINELLA BASSENDORFENSIS Cushman and Parker, 1937
PLATE 10, fig. 12

Buliminella bassendorfensis Cushman and Parker

Buliminella c.f. B. bassendorfensis Cushman and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 17, pl. 8, fig. 1,2.
BULIMINELLA ELEGANTISSIMA d’Orbigny, 1839

Plate 10, fig. 17

Buliminella elegantissima d’Orbigny, 1839
d’Orbigny, 1839, Voy. Amer. Merid., vol. 5, pt. 5,
“Foramianiferes”, p. 51, pl. 7, fig. 13,14.

Buliminella elegantissima d’Orbigny
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 17, pl. 8, fig. 3,4.

Genus BULIMINOIDES Cushman, 1911

BULIMINOIDES BASICOSTATA (Farr), 1950

Plate 10, fig. 15

Buliminella basicostata Parr
Parr, 1950, B.A.N.Z. Antarctic Res. Expd., 1929-1931,
vol. 5 pt. 6, p. 336.

Buliminella basicostata Parr
fig 23,24.

Radial striations on apertural face suggest Buliminoides.

Family REUSSELLIDAE Cushman, 1933

Genus REUSSELLA Galloway, 1933

REUSSELLA MINUTIA Drooger and Kaasschieter, 1958

Plate 10, fig. 13

Reussella minutia Drooger and Kaasschieter
Drooger and Kaasschieter, 1958, Reports of the Orinoco
Shelf Expedition, vol. 4, K. Neder. Akad. Wetensch.,
Afd. Natuurk. Verh., ser. 1, vol. 22, no. 1, p. 64, 65,
pl. 3, fig. 10.

REUSSELLA SPINULOSA (Reuss), 1850

Plate 10, fig. 16

Verneulinia spinulosa Reuss
Reuss, 1850, K. Akad. Wiss. Wien, Math.-Nat. Cl. Denkschr. ,
Wien, Oesterreich, Bd. 1, p. 347.

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Reussella spinulosa (Reuss)

Family Siphogenerinoididae Saidova, 1981

Subfamily Siphogenerininae Saidova, 1981

Genus Rectobolivina Cushman, 1927

RECTOBOLIVINA ADVENA (Cushman), 1922

Plate 11, fig. 1

Siphogenerina advena Cushman
Cushman, 1922, Carnegie Inst. Publ. 311, p. 35, pl. 5, fig. 2.

Rectobolivina advena (Cushman)

RECTOBOLIVINA RAPHANA (Parker and Jones), 1865

Plate 11, fig. 2

Uvigerina (Sagrina) raphanus Parker and Jones

Rectobolivina raphanus (Parker and Jones)

RECTOBOLIVINA(?) SPINESCENS (Cushman), 1911

Plate 11, fig. 3

Bolivina spinescens Cushman
Cushman, 1911, U.S. Nat. Mus. Bu.., no. 71, p. 46, textfig. 76.

Later stages of test appear to be tending toward uniserial chamber arrangement.

Subfamily Siphogenerininae Loeblich and Tappan, 1984

Genus Siphogenerina Schlumberger, 1882

Siphogenerina Fredsmithi Garrett, 1939

Plate 11, fig. 4
**Siphogenerina fredsmithi** Garrett
Garrett, 1939, Jour. Paleo., vol. 13, no. 6, p. 577, pl. 66, fig. 1.

**SIPHOGENERINA MULTICOSTATA** Cushman and Jarvis, 1929
Plate 11, fig. 5

**Siphogenerina multicostata** Cushman and Jarvis
Cushman and Jarvis, 1929, C.L.F.R. Contr. vol. 5, p. 14, pl. 3, fig. 6.

**Siphogenerina multicostata** Cushman and Jarvis

**SIPHOGENERINA SENNI** Cushman and Renz, 1941
Plate 11, fig. 6

**Siphogenerina senni** Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. 17, pt. 1, p. 22, pl. 3, fig. 21,22.

**Siphogenerina senni** Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 165, pl. VII, fig. 29,30.

**SIPHOGENERINA SMITHI** Kleinpell, 1938
Plate 11, fig. 7

**Siphogenerina smithi** Kleinpell
Kleinpell, 1938, Miocene Stratigraphy of California, p. 304, pl.6, fig. 1,2.

**Siphogenerina smithi** Kleinpell
Renz, 1948, G.S.A. Memoir No. 32, p. 165, pl. XII, fig. 18, 19.

**SIPHOGENERINA TRANSVERSA** Cushman, 1918
Plate 11, fig. 8

**Siphogenerina raphanus** (Parker and Jones) var. transversus
Cushman

**Siphogenerina transversa** Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 166, pl. VII, fig. 27,28, pl. XII, fig. 9.
Family UVIGERINIDAE Haeckel, 1894

Subfamily UVIGERININAE Haeckel, 1894

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA AUBERIANA d'Orbigny, 1839

Plate 11, fig. 9

UVIGERINA auberiana d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 106, pl. 2, fig.23,24.

UVIGERINA auberiana d'Orbigny var. attenuata Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 124, pl. VII, fig. 20.

UVIGERINA COCOAENSIS Cushman, 1925

Plate 11, fig. 10

UVIGERINA COCOAENSIS Cushman
Cushman, 1925, C.L.F.R. Contr. vol. 1, pt. 3, no. 16,
p. 68; pl. 10, fig. 12.

UVIGERINA FLINTI Cushman, 1923

Plate 11, fig. 11

UVIGERINA FLINTI Cushman
pl. 42, fig. 13.

UVIGERINA FLINTI Cushman
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 89,
pl. 20, fig. 17.

UVIGERINA c.f. HANNAI Kleinpell, 1938

Plate 11, fig. 13

UVIGERINA hannaia Kleinpell
Kleinpell, 1938, Miocene Stratigraphy of California,
p. 294.

UVIGERINA c.f. hannaia Kleinpell
Renz, 1948, G.S.A. Memoir No. 32, p. 174, pl. XII, fig.
16,17.
UVIGERINA HISPIDO-COSTATA Cushman and Todd, 1945

Plate 11, fig. 14

Uvigerina hispido-costata Cushman and Todd

Uvigerina hispido-costata Cushman and Todd
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 18, pl. 8, fig. 17-21,23.

UVIGERINA ex. grp. PEREGRINA Cushman, 1923

Plate 11, fig. 16

Uvigerina peregrina Cushman

Uvigerina peregrina Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 18, pl. 8, fig. 27-30.

There are many species names for costate Uvigerina and it is the authors opinion that, based upon published figures, most of these "species" are indistinguishable.

UVIGERINA RUSTICA Cushman and Edwards, 1938

Plate 11, fig. 17

Uvigerina rustica Cushman and Edwards

Uvigerina rustica Cushman and Edwards
Renz, 1948, G.S.A. Memoir No. 32, p. 175, pl. VII, fig. 23,24.

Genus UVIGERINELLA Cushman, 1926

UVIGERINELLA SPARSICOSTATA Cushman and Laiming, 1931

Plate 11, fig. 12

Uvigerinella sparsicostata Cushman and Laiming
Cushman and Laiming, 1931, Jour. Paleo., vol. 5, p. 112, pl. 12, fig. 12.

"Uvigerinella" sparsicostata Cushman and Laiming
Renz, 1948, G.S.A. Memoir No. 32, p. 175, pl. XII, fig. 20.
Genus SAGRINA d’Orbigny, 1839

SAGRINA PULCHELLA d’Orbigny, 1839

Plate 11, fig. 18

Sagrina pulchella d’Orbigny
Cuba, "Foraminiferes", vol. 8, p. 150, pl. 1, fig. 23,24.

Akers and Dorman, 1964, Tulane Studies in Geology, pt. 1,
vol. 3, no. 1, p. 52, pl. IX, fig. 8-10.

Genus RECTUVIGERINA Mathews, 1945

RECTUVIGERINA MULTICOSTATA (Cushman and Jarvis), 1929

Plate 11, fig. 15

Siphogenerina multicostata Cushman and Jarvis
Cushman and Jarvis, 1929, C.L.F.R. Contr. vol. 5, p. 14,
pl. 3, fig. 6.

Rectuvigerina multicostata (Cushman and Jarvis)

Loeblich and Tappan, 1964, Treat. on Invert. Paleo. p. 569,
textfig. 448, no. 5.

Subfamily ANGULOGERININAE Galloway, 1933

Genus TRIFARINA Cushman, 1923

TRIFARINA ANGULOSA (Williamson), 1858

Plate 12, fig. 1

Uvigerina angulosa Williamson
Williamson, 1858, On The Recent Foraminifera of Great
Britain. Royal Society, p. 67, pl. 5, fig. 140.

Trifarina angulosa (Williamson)
Loeblich and Tappan, 1964, Treat. on Invert. Paleo. p. 571,
textfig. 450, no. 1-3.

TRIFARINA BRADYI Cushman, 1923

Plate 12, fig. 2

Trifarina bradyi Cushman
pl. 22, fig. 3-9.
Trifarina bradyi Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 172, pl. VII, fig. 33.

TRIFARINA HOLCKI Akers and Dorman, 1964
Plate 12, fig. 3

Trifarina holcki Akers and Dorman

TRIFARINA SP.
Plate 12, fig. 4

Superfamily FURSENKOINACEA Loeblich and Tappan, 1961
Family FURSENKOINIDAE Loeblich and Tappan, 1961
Subfamily FURSENKOININAE Loeblich and Tappan, 1961
Genus FURSENKOINA Loeblich and Tappan, 1961
FURSENKOINA MEXICANA (Cushman), 1922
Plate 12, fig. 6

Viroulina mexicana Cushman

Fursenkoina mexicana (Cushman)

Viroulina mexicana (Cushman)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 19, pl. 9, fig. 6, 7, 8.

FURSENKOINA PONTONI (Cushman), 1932
Plate 12, fig. 7

Viroulina pontoni Cushman
Cushman, 1932, C.L.F.R. Contr. vol. 8, pt. 1, p. 17, pl. 3, fig. 7.

Viroulina pontoni Cushman
Renz, 1948, G.S.A. Memoir No. 32, p. 178, pl. VI, fig. 18.
Fursenkoina pontoni (Cushman)

FURSENKOINA SPINICOSTATA (Phleger and Parker), 1951
Plate 12, fig. 9

Viroulina spinicostata Phleger and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 19, pl. 9, fig. 11-14.

Viroulina placed in synonymy with Fursenkoina by Loeblich and Tappan, 1964.

Subfamily SIGMAVIRGULININAE Saidova, 1981

Genus SIGMAVIRGULINA Loeblich and Tappan, 1957

SIGMAVIRGULINA TORTUOSA (Brady), 1884
Plate 12, fig. 8

BoliVina tortuosa Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 420, pl. 52, fig. 31-34.

Siomaviroulina tortuosa (Brady)

Superfamily CASSIDULINACEA d’Orbigny, 1839

Family CASSIDULINIDAE d’Orbigny, 1839

Subfamily EHRENBERGININAE Cushman, 1927

Genus EHRENBERGINA Reuss, 1850

EHRENBERGINA CARIBBEA Galloway and Heminway, 1941
Plate 12, fig. 5

Ehrenbergina caribbea Galloway and Heminway

Ehrenbergina caribbea Galloway and Heminway
Renz, 1948, G.S.A. Memoir No. 32, p. 131, pl. 9, fig. 17.

Subfamily CASSIDULININAE d’Orbigny, 1839
Genus CASSIDULINA d’Orbigny, 1826

CASSIDULINA CARAPITANA Hedberg, 1937

Plate 12, fig. 10

Cassidulina carapitana Hedberg
Hedberg, 1937, Jour. Paleo., vol. 11, no. 8, p. 680, pl. 96, fig. 6.

Cassidulina carapitana Hedberg
Renz, 1948, G.S.A. Memoir No. 32, p. 124, pl. IX, fig. 8.

CASSIDULINA CARINATA Silvestri, 1896

Plate 12, fig. 11

Cassidulina laevigata d’Orbigny var. carinata Silvestri

Cassidulina carinata Silvestri
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 110, pl. 54, fig. 2,3.

CASSIDULINA CURVATA Phleger and Parker, 1951

Plate 12, fig. 13

Cassidulina curvata Phleger and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 26, pl. 14, fig. 5.

CASSIDULINA LAEVIGATA d’Orbigny, 1826

Plate 12, fig. 12

Cassidulina laevigata d’Orbigny

Cassidulina laevigata d’Orbigny
Renz, 1948, G.S.A. Memoir No. 32, p. 125, pl. IX, fig. 9.

CASSIDULINA SUBGLOBOSA Brady, 1881

Plate 12, fig. 14

Cassidulina subglobosa Brady

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Cassidulina subglobosa Brady
Renz, 1948, G.S.A. Memoir No. 32, p. 125, pl. IX, fig. 11, 12.

Genus CASSIDULINOIDES Cushman, 1927

CASSIDULINOIDES BRADYI (Norman), 1880

Plate 13, fig. 1

Cassidulina bradvi Norman

Cassidulinoidea bradvi (Norman)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 112, pl. 54, fig. 6, 7.

CASSIDULINOIDES ERECTA Cushman and Renz, 1941

Plate 13, fig. 2

Cassidulinoidea erecta Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol. 17, pt. 1, p. 25, pl. 4, fig. 6, 7.

Cassidulinoidea erecta Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 126, pl. IX, fig. 15.

Superfamily PLEUROSTOMELLACEA Reuss, 1860

Family PLEUROSTOMELLIDAE Reuss, 1860

Subfamily PLEUROSTOMELLINAE Reuss, 1860

Genus PLEUROSTOMELLA Reuss, 1860

PLEUROSTOMELLA ALTERNANS Schwager, 1866

Plate 13, fig. 3

Pleurostomella alternans Schwager
Schwager, 1866, Novara-Exped. Geol., vol. 2, p. 238, pl. 6, fig. 79-80.

Pleurostomella alternans Schwager
Renz, 1948, G.S.A. Memoir No. 32, p. 153, pl. VIII, fig. 2.

PLEUROSTOMELLA BIERIGI Palmer and Bermudez, 1936

Plate 13, fig. 5
Superfamily DISCORBACEA Ehrenberg, 1838
Family BAGGINIDAE Cushman, 1927
Subfamily BAGGININAE Cushman, 1927
Genus CANCRIS de Montfort, 1808
CANCRI SAGRA (d'Orbigny), 1839
Plate 13, fig. 6

Rotalia sagra d'Orbigny

Cancris sagra (d'Orbigny)
Renz, 1948, G.S.A. Memoir No. 32, p. 123, pl. IX, fig. 3.
Genus VALVULINERIA Cushman, 1926
VALVULINERIA c.f. HUMILIS (Brady), 1884
Plate 13, fig. 4

Truncatulina humilis Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 665, pl. 94, fig. 7.

Valvulineria c.f. humilis (Brady)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 28, pl. 13, fig. 9,10.

VALVULINERIA PALMERAEE Cushman and Todd, 1945
Plate 13, fig. 8

Valvulineria palmerae Cushman and Todd
Cushman and Todd, 1945, C.L.F.R. Spec. Publ. No. 15, p. 56, pl. 8, fig. 18.

VALVULINERIA VENEZUELANEA Hedberg, 1937
Plate 13, fig. 7
Valvulineria venezuelana Hedberg
Hedberg, 1937, Jour. Paleo., vol. 11, no. 8, p. 678, pl. 91, fig. 7-9.

Valvulineria venezuelana Hedberg
Renz, 1948, G.S.A. Memoir No. 32, p. 178, pl. VIII, fig. 9.

Family EPONIDIDAE Hofker, 1951
Subfamily EPONIDINAE Hofker, 1951
Genus NEOEPONIDES Reiss, 1960
NEOEPONIDES ANTILLARUM (d'Orbigny), 1839
Plate 13, fig. 9

Rotalina antillarum d'Orbigny

Neoeponides antillarum (d'Orbigny)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 102, pl. 23, fig. 4,5.

NEOEPO NIDES BRYAMENSIS (Cushman)
(= Palmer and Bermudez), 1948
Plate 14, fig. 1

Gyrodioides bryamensis (Cushman) var. campester (Palmer and Bermudez)
Palmer and Bermudez, 1948, Geol. Soc. Am., Mem. no. 32, p. 139, pl. VIII, fig. 15, pl. IX, fig. 1.

Strongly recurved dorsal sutures and open umbilicus suggest placement in Neoeponides.

Genus BUCCELLA Andersen, 1952
BUCCELLA HANNAI (Phleger and Parker), 1951
Plate 14, fig. 2

Eponides hannai Phleger and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 21, pl. 10. fig. 11-14.

Buccella hannai (Phleger and Parker)
Family DISCORBIDAE Ehrenberg, 1838

Subfamily DISCORBINAE Ehrenberg, 1838

Genus DISCORBIS Lamarck, 1804

DISCORBIS MIRA Cushman. 1922

Not Figured

Discorbis mira Cushman
Cushman, 1922, Carnegie Inst., Washington, Publ. 311, p. 39, pl. 6, fig. 10,11.

Discorbina(?) mira (Cushman)

Genus GAVELINOPSIS Hofker, 1951

GAVELINOPSIS PRAEGERI (Heron-Allen and Earland), 1913

Plate 14, fig. 4

Gavelinopsis praegeri (Heron-Allen and Earland)
Heron-Allen and Earland, 1913, Roy. Irish Acad. Proc., vol. 31, pt. 64, p. 122, pl. 10, fig. 8-10.

Gavelinopsis praegeri (Heron-Allen and Earland)

Subfamily ROSALININAE Reiss, 1963

Genus ROSALINA d'Orbigny, 1826

ROSALINA BULBOSA (Parker), 1954

Plate 14, fig. 3

Discorbis bulbosa Parker

Rosalina bulbosa (Parker)

ROSALINA GLOBULARIS d'Orbigny, 1826

Plate 14, fig. 5

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Rosalina globularis d'Orbigny

Rosalina globularis d'Orbigny
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 178, pl. 86, fig. 13.

Rosalina globularis d'Orbigny

ROSALINA c.f. VALVULATA d'Orbigny, 1839
Plate 14, fig. 6

Rosalina valvulata d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 103, pl. 3, fig. 21-23.

NEOCONORBINA c.f. FLORIDENSIS (Cushman), 1931
Plate 14, fig. 7

Discorbis bertheloti (d'Orbigny) var. floridensis Cushman

Neoconorbina floridensis (Cushman)

NEOCONORBINA TERQUEMI (Rzechak), 1888
Plate 15, fig. 1

Discorbina terquemi Rzechak
Rzechak, 1888, Austria Geol. Reichsabst, Vehr., no. 11.

Neoconorbina terquemi (Rzechak)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 182, pl. 88, fig. 4-8.

Neoconorbina terquemi (Rzechak)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 102, pl. 21, fig. 5.

Superfamily GLABRATELLACEA Loeblich and Tappan, 1964

Family GLABRATELLIDAE Loeblich and Tappan, 1964

Genus GLABRATELLA Dorreen, 1948

GLABRATELLA c.f. PATELLIFORMIS (Brady), 1884

Plate 15, fig. 9
Discorbina patelliformis Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 647, pl. 88, fig. 3,9, pl. 89, fig. 1.

Pileolina(?) patelliformis (Brady)
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 182, pl. 88, fig. 3, p. 184, pl. 89, fig. 1.

Loeblich and Tappan, 1964 put Discorbina in synonymy with Discorbis, and Pileolina in synonymy with Glabratella. These specimens are clearly not Discorbis.

GLABRATELLA PULVINATA (Brady), 1884
Plate 15, fig. 2

Discorbina pulvinata Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 650, pl. 88, fig. 10.

Glabratella pulvinata (Brady)
Dorren, 1948, Jour. Paleo., vol. 22, no. 3, p. 294, pl. 8

. Superfamily SIPHONINACEA Cushman, 1927
Family SIPHONINIDAE Cushman, 1927
Subfamily SIPHONININAE Cushman, 1927
Genus SIPHONINA Cushman, 1919
SIPHONINA PULCHRA Cushman, 1919
Plate 15, fig. 3

Siphonina pulchra Cushman

Siphonina pulchra Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 24, pl. 12, fig. 15.

Family PSEUDOPARRELLIDAE Voloshinova, 1952
Subfamily PSEUDOPARRELLINAE Voloshinova, 1952
Genus EPISTOMINELLA Husezima and Marohaswi, 1944
EPISTOMINELLA (?) c.f. RUGOSA (Phleger and Parker), 1951
Plate 15, fig. 4
Pseudoparrella rugosa Phleger and Parker
Phleger and Parker. 1951, G.S.A. Memoir No. 46, pt.2, p. 28, pl. 15, fig. 8,9.

Features of the aperture are suggestive, but not conclusive
evidence of Epistominella.

EPISTOMINELLA EXIGUA Brady, 1884
Plate 15, fig. 5

Pulvinulina exigua Brady
Brady, 1884, Challenger Rept. Zoology, vol. 9, p. 696, pl. 103, fig. 13,14.

Epistominella exigua (Brady)

Subfamily STETSONINAE Saidova, 1981

Genus STETSONIA Parker, 1954

STETSONIA MINUTA Parker, 1954
Plate 15, fig. 6

Stetsonia minuta Parker

Stetsonia minuta Parker

Family DISCORBINELLIDAE Sigal, 1952

Subfamily DISCORBINELLINAE Sigal, 1952

Genus DISCORBINELLA Cushman and Martin, 1935

DISCORBINELLA BERTHELOTI (d'Orbigny), 1839
Plate 15, fig. 7

Rosalina bertheloti d'Orbigny

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Disco pulvinulina bertheloti (d’Orbigny)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 126, pl. 21, fig. 3.

Loeblich and Tappan, 1964, put Disco pulvinulina in synonymy with Discorbinella.

Genus LATICARININA Galloway and Wissler, 1927

LATICARININA c.f. PAUPERATA (Parker and Jones), 1865

Plate 15, fig. 8

Pulvinulina rephanda menardii pauperata Parker and Jones
Parker and Jones, 1865, Philos. Trans., vol. 155, p. 395, pl. 16, fig. 50,51.

Laticarinina c.f. pauperata (Parker and Jones)
Renz, 1948, G.S.A. Memoir No. 32, p. 143, pl. X, fig. 4.

Superfamily PLANORBULINACEA Schwager, 1877

Family PLANULINIDAE Barmudez, 1952

Subfamily PLANULININAE Barmudez, 1952

Genus PLANULINA d’Orbigny, 1826

PLANULINA ARIMINENSIS d’Orbigny, 1826

Plate 16, fig. 1

Planulina ariminensis d’Orbigny

Planulina ariminensis d’Orbigny

PLANULINA c.f. SUBTENUISSIMA (Nuttall), 1928

Plate 16, fig. 3

Anomalina subtenuissima Nuttall
Nuttall, 1928, Geol. Soc. London Quart. Jour., vol. 84, p. 100, pl. 7, fig. 13,15, textfig. 6, p. 100.

Planulina subtenuissima (Nuttall)
Renz, 1948, G.S.A. Memoir No. 32, p. 151, pl. XI, fig. 4.
Subfamily CARIBEANELLINAE Saidova, 1981

Genus CARIBEANELLA Bermudez, 1952

CARIBEANELLA POLYSTOMA Bermudez, 1952

Plate 16, fig. 4

Caribeanella polystoma Bermudez

Caribeanella polystoma Bermudez

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus CIBICIDES de Montfort, 1808

CIBICIDES LOBATULUS (Walker and Jacob), 1798

Plate 16, fig. 5

Nautilus lobatulus Walker and Jacob

Cibicides lobatulus (Walker and Jacob)

CIBICIDES WUELLERSTORFI (Schwager), 1866

Plate 16, fig. 2

Anomalina wuellerstorfi Schwager
Schwager, 1866, Novara Exped. Geol. Theil., p. 258, pl. 7, fig. 105, 107.

Planulina wuellerstorfi (Schwager)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 33, pl. 18, fig. 11, pl. 19, fig. 1-3.

Cibicides wuellerstorfi (Schwager)
Subfamily STICHOCIBICIDINAE Saidova, 1981

Genus DYOCIBICIDES Cushman and Valentine, 1930

DYOCIBICIDES BISERIALIS Cushman and Valentine, 1930

Plate 16, fig. 6

Dyocibicides biserialis Cushman and Valentine
Cushman and Valentine, 1930, Contr. Dept. Geol., Stanford
Univ., vol. 1, no. 1, p. 31, fig. 1,2.

Family PLANOBULIMINIDAE Schwager, 1877

Genus PLANORBULINA d’Orbigny, 1826

PLANORBULINA MEDITERRANENSIS d’Orbigny, 1826

Plate 17, fig. 1

Planorbulina mediterranensis d’Orbigny
pl. 23, fig. 4-6.

Planorbulina mediterranensis d’Orbigny
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 33, pl. 19, fig. 5

Family CYMBALOPORIDAE Cushman, 1927

Subfamily CYMBALOPORINAE Cushman, 1927

Genus CYMBALOPORETTA Cushman, 1928

CYMBALOPORETTA ATLANTICA (Cushman), 1934

Plate 17, fig. 3

Tretomphalus atlanticus Cushman
Cushman, 1934, C.L.F.R. Contr. vol. 10, pt. 4, p. 86,
pl. 11, fig. 3, pl. 12, fig. 7.

Tretomphalus atlanticus Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 26, pl. 14, fig. 3.

Cymbaloporetta atlantica (Cushman)
Douglas and Stiter, 1965, Tulane Studies in Geology,
vol. 3, no. 3, p. 156.
CYMBALOPORETTA SQUAMMOSA (d’Orbigny), 1826

Plate 17, fig. 2

Rotalina squammosa d’Orbigny

Cymbaloporetta squammosa (d’Orbigny)

Family VICTORIELLIDAE Chapman and Crespin, 1930

Subfamily CARPENTERIINAE Saidova, 1981

Genus CARPENTERIA Gray, 1858

CARPENTERIA CANDEI (d’Orbigny), 1839

Plate 17, fig. 4

Truncatulina candei d’Orbigny

Sharp peripheral keel, flat and non-overlapping dorsal chambers, and low peripheral outline suggest Carpenteria.

Superfamily ACERVULINACEA Schultz, 1854

Family HOMOTREMATIDAE Cushman, 1927

Genus MINIACINA Galloway, 1933

MINIACINA MINIACEA (Pallas), 1766

Plate 17, fig. 5

Millepora miniacea Pallas

Miniacia miniacea (Pallas)
 Barker, 1960, S.E.P.M. Spec. Publ. No. 9. p. 206, pl. 100, fig. 5-9, p. 208, pl. 101. fig. 1.

Superfamily ASTERIGERINACEA d’Orbigny, 1839

Family ASTERIGERINIDAE d’Orbigny 1839

Genus ASTERIGERINA d’Orbigny 1839
ASTERIGERINA CARINATA d'Orbigny, 1839
Not Figured

Asterigerina carinata d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 118, pl. 5, fig. 25,
pl. 8, fig. 1-2.

Asterigerina carinata d'Orbigny
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 26, pl. 14, fig. 2.

Family AMPHISTEGINADAE Cushman, 1927
Genus AMPHISTEGINA d'Orbigny, 1826
AMPHISTEGINA GIBBOSA d'Orbigny, 1839
Plate 17, fig. 6

Amphistegina gibbosa d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 120, pl. 8, fig. 1-3.

Amphistegina lessonii d'Orbigny
Renz, 1948, G.S.A. Memoir No. 32, p. 113, pl. IX, fig. 4.

Superfamily NONIONACEA Schultz, 1854
Family NONIODINIDAE Schultz, 1854
Subfamily NONIONINAE Schultz, 1854
Genus NONION de Montfort, 1808
NONION INCISIUM (Cushman) var. KERNENSIS
Kleinpell, 1938
Plate 17, fig. 7

Nonion incisium (Cushman) var. kernensis Kleinpell
Kleinpell, 1938, Miocene Stratigraphy of California,
p. 232.

Nonion incisium (Cushman) var. kernensis Kleinpell
Renz, 1948, G.S.A. Memoir No. 32, p. 148, pl. VI, fig. 4.

Genus PSEUDONONION Asano, 1836

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PSEUDONONION BASISPINATA Cushman and Moyer, 1930

Plate 17, fig. 9

Nonion pizarrense Berry var. basispinata Cushman and Moyer
Cushman and Moyer, 1930, C.L.F.R. Contr., vol. 27, p. 54,
pl. 17, fig. 18.

Nonionella atlantica Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2,
p. 11, pl. 5, fig. 21-23.

Pseudononion atlanticus (Cushman)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 84,
pl. 18, fig. 1,2.

Based upon published figures, P. atlanticus and P. basi-
spinata are the same. Pseudononion is indicated as the
final chamber fails to cover the umbilical area, as per
Saunders and Miller—Merz, 1982, Jour. Foram. Res., vol. 12,
no. 3, p. 264-266, pl. 3, fig.19-25, textfig. 1.

PSEUDONONION COSTIFERUM (Cushman), 1926

Plate 17, fig. 10

Nonionina costifera Cushman
Cushman, 1926, C.L.F.R. Contr. vol. 1, p. 90, pl. 13,
fig. 2.

Nonion costiferum (Cushman)
Renz, 1948, G.S.A. Memoir No. 32, p. 48, pl. VI, fig. 6.

Following Saunders and Muller-Merz, 1982, Jour. Foram.
Res., vol. 12, no. 3, p. 261-272, this taxon is placed in
Pseudononion.

PSEUDONONION GRATELOUPI (d'Orbigny), 1826

Plate 17, fig. 11

Nonionina grate loupi d'Orbigny
no. 19.

Pseudononion grate loupi (d'Orbigny)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 84,
pl. 18, fig. 3.

Genus NONIONELLA Voloshinova, 1958
NONIONELLA BASILOBA Cushman and McCulloch, 1940

Plate 17, fig. 8

Nonionella basi1oba Cushman and McCulloch
Cushman and McCulloch, 1940, Allan Hancock Pacific Expd., vol 6, no. 3, p. 162, pl. 18, fig. 30.

Nonionella basi1oba Cushman and McCulloch
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 85, pl. 18, fig. 5.

NONIONELLA MIOCENICA Cushman, 1926

Plate 18, fig. 1

Nonionella miocenica Cushman
Cushman, 1926, C.L.F.R. Contr. vol. 2, pt. 3, p. 64;
C.L.F.R. Contr. 1926, vol. 1, pt. 4, p. 91, pl. 13, fig. 4.

Nonionella miocenica Cushman
Cushman and McCulloch, 1940, Some Nonionidae in the Collections of the Allan Hancock Foundation, vol. 6, no. 3, p. 161, pl. 18, fig. 1.

NONIONELLA MIOCENICA Cushman var. STELLA
Cushman and Mayer, 1930

Plate 18, fig. 2

Nonionella miocenica Cushman var. stella Cushman and Mayer
Cushman and Mayer, 1930, C.L.F.R. Contr. vol. 6, p. 56, pl. 7, fig. 17.

Nonionella miocenica Cushman var. stella Cushman and Mayer
Cushman and McCulloch, 1940, Some Nonionidae in the Collections of the Allan Hancock Foundation, p. 162, pl. 18, fig. 2.

Subfamily PULLENIINAE Schwager, 1877

Genus PULLENIA Parker and Jones, 1862

PULLENIA BULLOIDES (d’Orbigny), 1826

Plate 18, fig. 3

Nonionina bulloides d’Orbigny

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Pullenia bulboides (d'Orbigny)
Renz, 1948, G.S.A. Memoir No. 32, p. 154, pl. X, fig. 2.

PULLENIA SUBCARINATA (d'Orbigny), 1839
Plate 18, fig. 4

Nonionina subcarinata d'Orbigny
d'Orbigny, 1839, "Foraminiferes", Voyage dans l'Amerique Meridionale, tome 5, pt. 5, p. 28, pl. 5, fig. 23, 24.

Pullenia subcarinata (d'Orbigny)

Family MELONIDAE Chapman, Farr and Collins, 1934
Genus MELONIS de Montfort, 1808

MELONIS BARLEEANUS (Williamson), 1858
Plate 18, fig. 6

Nonionina barleeana Williamson
Williamson, 1858, Recent Foraminifera of Great Britain, p. 32, pl. 3, fig. 68, 69.

Gavelinion barleeanum (Williamson)

Planispiral and symmetrical, deeply biumbilicate, rounded periphery suggest Melonis.

MELONIS POMPILIOIDES (Fichtel and Moll), 1798
Plate 18, fig. 5

Nautilus pompilioides Fichtel and Moll
Fichtel and Moll, 1798, Test. Micr., p. 31, pl. 2, fig. a-c.

Nonion pompilioides (Fichtel and Moll)
Renz, 1948, G.S.A. Memoir No. 32, p. 149, pl. V, fig. 31, 32.

Melonis pompilioides (Fichtel and Moll)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 11 pl. 5, fig. 19, 20.

Superfamily CHILOSTOMELLACEA Brady, 1881
Family QUADRIMORPHINIDAE Saidova, 1981

Genus QUADRIMORPHINA Finlay, 1939
QUADRIMORPHINA VILARDEBOANA GLABRA (Cushman), 1927

Plate 18, fig. 7

Valvulineria vilardeboana (d'Orbigny) var. glabra Cushman

Quadrimorphina vilardeboana glabra (Cushman)

Family CHILOSTOMELLIDAE Brady, 1881

Genus CHILOSTOMELLA Reuss, 1849
CHILOSTOMELLA OVOIDEA Reuss, 1850

Plate 18, fig. 10

Chilostomella ovoidea Reuss

Chilostomella ovoidea Reuss
Barker, 1960, S.E.P.M. Spec. Publ. No. 9, p. 112, pl. 55, fig. 15,16,19-23.

Family PARRELLOIDIDAE Hofker, 1956

Genus CIBICIDOIDES Thalmann, 1939
CIBICIDOIDES COMPRESSUS (Cushman and Renz), 1941

Plate 18, fig. 8

Cibicides floridanus (Cushman) var. compressus Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol. 17, pt. 1, p. 26, pl. 4, fig. 9.

Cibicides compressus Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 127, pl. X, fig. 9.

Lenticular test, peripheral aperture, and overlapping ventral chambers suggest Cibicidoides.
CIBICIDOIDES FALCONENSIS Renz, 1948

Plate 18, fig. 9

Cibicides falconensis Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 128, pl. XI, fig. 6,7.

Placement in Cibicides as per above comment. This taxon is only found in the Early Miocene lower bathyal to abyssal deposits of the Uscari Fm. Rio Reventazon section. It seems to be a good paleodepth indicator.

CIBICIDOIDES FLORIDANUS Cushman, 1918

Plate 18, fig. 11

Truncatulina floridana Cushman
Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 62, pl. 19, fig. 12.

Cibicides aff. floridanus (Cushman)
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 30, pl. 16, fig. 1-4.

Cibicidoides floridanus (Cushman) forma sublittoralis Poag
Poag, 1981, Ecologic Atlas of Benthic Foraminifera of the Gulf of Mexico, p. 53, pl. 29, fig. 2, pl. 30, fig. 2.

CIBICIDOIDES GRANULOSUS (Bermudez), 1949

Plate 19, fig. 1

Cibicides granulosus Bermudez

See comment for C. compressus.

CIBICIDOIDES SP. A

Not Figured

Family ALABAMINIDAE Hofker, 1951

Subfamily GYROIDININAE Saidova, 1981

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA FARVA Cushman and Renz, 1941

Plate 19, fig. 2

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Gyroidina parva Cushman and Renz
Cushman and Renz, 1941, C.L.F.R. Contr. vol. 17, pt. 1, p. 23, pl. 4, fig. 2.

Gyroidina parva Cushman and Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 139, pl. VIII, fig. 12.

GYROIDINA REGULARIS (Phleger and Parker), 1951
Plate 19, fig. 3

Eponides regularis Phleger and Parker
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 21, pl. 11, fig. 3-4.

Gyroidina regularis (Phleger and Parker)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 103, pl. 23, fig. 3.

GYROIDINA SOLDANII d'Orbigny
Plate 19, fig. 4

Gyroidina soldanii d’Orbigny

Gyroidinoideas soldanii (d’Orbigny) var. altiformis (R.E. and K.C. Stewart)
Renz, 1948, G.S.A. Memoir No. 32, p. 140, pl. VIII, fig. 13.

Genus GYROIDINOIDES Brotzen, 1942

GYROIDINOIDES VENEZUELANA Renz
Plate 19, fig. 5

Gyroidinoideas venezuelana Renz
Renz, 1948, G.S.A. Memoir No. 32, p. 141, pl. XII, fig. 21.

Subfamily ALABAMININAE Hofker, 1951

Genus SVRATKINA Pokorny, 1956

SVRATKINA AUSTRALIENSIS (Chapman, Parr, and Collins), 1934
Plate 19, fig. 6

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**Discorbis tuberculata** (Balkwill and Wright) var. *australiensis* Chapman, Parr, and Collins

**Syratkina australiensis** (Chapman, Parr, and Collins)

Family **ORIDORSALIDAE** Loeblich and Tappan, 1984

**Genus ORIDORSALIS** Andersen, 1961

**ORIDORSALIS UMBONATUS** (Reuss), 1851

Plate 19, fig. 7

**Rotalina umbonata** Reuss

**Eponides umbonatus** (Reuss) var. *ecuadorensis* (Galloway and Morrey)
Renz, 1948, G.S.A. Memoir No. 32, p. 133, pl. XII, fig. 25.

**Oridorsalis westi** Andersen

Published figures suggest that the specific names *umbonatus* and *westi* are synonyms, with *umbonatus* having priority.

Family **OSANGULARIIDAE** Loeblich and Tappan, 1964

**Genus OSANGULARIA** Brotzen, 1940

**OSANGULARIA CULTER** (Parker and Jones), 1865

Plate 20, fig. 1

**Planorbulina culter** Parker and Jones
Parker and Jones, 1865, Phil. Trans., p. 421, pl. 19, fig. 1.

**Osangularia culter** (Parker and Jones)

Family **GAVELINELLIDAE** Hofker, 1956

**Genus ANOMALINDIDES** Brotzen, 1942

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ANOMALINOIDES IO (Cushman), 1931

Plate 20, fig. 3

*Cibicides pseudounaeriana* (Cushman) var. io Cushman

*Cibicides io* Cushman
Phleger and Parker, 1951, G.S.A. Memoir No. 46, pt. 2, p. 30, pl. 16, fig. 5, 6.

Extension of the aperture onto the spiral side, instead of maintaining a peripheral position, suggests *Anomalinooides*.

Genus HANZAWAIA Asano, 1944

HANZAWAIA CONCENTRICA (Cushman), 1918

Plate 20, fig. 2

*Truncatulina concentrica* Cushman
Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 64, pl. 21, fig. 3.

*Cibicides concentricus* (Cushman)
Renz, 1948, G.S.A. Memoir No. 32, p. 127, pl. X, fig. 8.

Hanzawaia concentrica (Cushman)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 124, pl. 28, fig. 5.

HANZAWAIA MANTAENSIS (Galloway and Morrey), 1929

Plate 20, fig. 4

*Anomalina mantaensis* Galloway and Morrey
Galloway and Morrey, 1929, Bull. Amer. Paleo., vol 15, no. 55, p. 28, pl. 4, fig. 5.

*Cibicides mantaensis* (Galloway and Morrey)
Renz, 1948, G.S.A. Memoir No. 32, p. 128, pl. XI, fig. 8.

Closed ventral umbilicus, strongly recurved sutures, and dorsal flaps suggest *Hanzawaia*.

Superfamily ORBITOIDACEA Schwager, 1876

Family LEPIDOCYCLINIDAE Scheffen, 1932

Subfamily LEPIDOCYCLININAE Scheffen, 1932
Genus LEPIDOCYCLINA Gumbel, 1870

LEPIDOCYCLINA (LEPIDOCYCLINA) WAYLANDVAUGHNI Cole, 1928

Plate 20, fig. 5

*Lepidocyclina (Lepidocyclina) waylandvaughni* Cole
Cole, 1928, Bull. Amer. Paleo., vol. 14, no. 53, p. 221, pl. 35, fig. 1-8,10

Superfamily ROTALIACEA Ehrenberg, 1839
Family ROTALIIDAE Ehrenberg, 1839
Subfamily PARAROTALIINAE Reiss, 1963
Genus PARAROTALIA LeCalvez, 1949
PARAROTALIA SARMIENTOI (Redmond), 1953

Plate 20, fig. 6

*Rotalia sarmientoi* Redmond
Redmond, 1953, Jour. Paleo., vol. 27, no. 5, p. 726, pl. 76, fig. 11.

Non-spinose keel, flat dorsal side, umbilical plug, and pointed central part of ventral chambers suggest *Pararotalia*.

Subfamily ROTALIINAE
Genus AMMONIA Brunnich, 1772

AMMONIA PARKINSONIANA (d'Orbigny) forma TYPICA Poag, 1981

Plate 21, fig. 1

*Rosalina parkinsoniana* d'Orbigny

*Ammonia parkinsoniana* (d'Orbigny) forma *typica* Poag

AMMONIA PARKINSONIANA (d'Orbigny) forma TEPIDA
Cushman, 1926

Plate 21, fig. 2
Rotalia beccarii (Linnaeus) var. tepida Cushman

Ammonia parkinsoniana (d'Orbigny) forma tepida Poag

Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIINAE Galloway, 1933
Genus HAYNESINA Banner and Culver, 1978
HAYNESINA (?) GERMANICA (Ehrenberg), 1840
Plate 21, fig. 5

Nonionina germanica Ehrenberg

Haynesina germanica (Ehrenberg)

It is not clear whether the lack of retral processes qualifies as an acceptable criterion for the establishment of a new genus separate from Elphidium. If a gradational sequence from specimens having retral processes through specimens lacking processes can be established, then this taxon should be considered Elphidium.

Genus ELPHIDIUM de Montfort, 1808
ELPHIDIUM DISCOIDALE (d'Orbigny), 1839
Plate 21, fig. 3

Polystomella discoidale d'Orbigny

Elphidium discoidale (d'Orbigny)
Andersen, 1961, La. Geol. Surv., Geol Bull. No. 35, p. 109, pl. 18, fig. 7.

ELPHIDIUM GUNTERI Cole, 1931
Plate 21, fig. 4

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Elphidium gunteri Cole
Cole, 1931, Florida State Geol. Surv., Bull. no. 6, p. 34, pl. 4, fig. 9,10.

Elphidium gunteri Cole
Poag, 1981, Ecologic Atlas of Benthic Foraminifera of the Gulf of Mexico, p. 61, pl. 37, fig. 2.

ELPHIDIUM LANIERI (d'Orbigny), 1839
Plate 21, fig. 7

Polystomella lanieri d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 56, pl. 7, fig. 12,13.

Elphidium lanieri (d'Orbigny)
Poag, 1981, Ecologic Atlas of Benthic Foraminifera of the Gulf of Mexico, p. 62, pl. 37, fig. 4, pl. 38, fig. 4.

ELPHIDIUM POEYANUM (d'Orbigny), 1839
Plate 21, fig. 8

Polystomella poeyana d'Orbigny
Cuba, "Foraminiferes", vol. 8, p. 55, pl. 6, fig. 25,26.

Elphidium poeyanum (d'Orbigny)
Renz, 1948, G.S.A. Memoir No. 32, p. 132, pl. VI, fig. 6.

ELPHIDIUM SP.
Plate 21, fig. 6

Superfamily NUMMULITACEA de Blainville, 1827
Family NUMMULITIDAE de Blainville, 1827
Genus HETEROSTEGINA d'Orbigny, 1826
HETEROSTEGINA ANTILLEA Cushman, 1919
Plate 21, fig. 9

Heterostegina antillea Cushman
Cushman, 1919, Carnegie Inst. Washington, Publ. 291, p. 49, pl. 2, fig. 1, pl. 5, fig. 1,2.

Heterostegina antillea Cushman
Suborder GLOBIGERININA Delage and Herouard, 1896

Superfamily HANTKENINACEA Cushman, 1927

Family CASSIGERINELLIDAE Bolli, Loeblich and Tappan, 1957

Genus CASSIGERINELLA Pokorny, 1955

CASSIGERINELLA CHIPOLENSIS Cushman and Ponton, 1932

Plate 22, fig. 3

Cassigerinella chipolensis Cushman and Ponton
Cushman and Ponton, 1932, Florida Geol. surv. Bull., vol. 9, p. 98, pl. 15, fig. 2.

Cassigerinella chipolensis Cushman and Ponton

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Subfamily GLOBIGERININAE Carpenter, Parker and Jones, 1862

Genus GLOBIGERINA Bolli, 1954

GLOBIGERINA CIPEROENSIS CIPEROENSIS Bolli, 1954

Plate 22, fig. 1

Globigerina ciperoensis Bolli

Globigerina ciperoensis ciperoensis Bolli

GLOBIGERINA TRIPARTITA Koch, 1926

Plate 22, fig. 4

Globigerina bulloides d'Orbigny var. tripartita Koch

Globigerina tripartita Koch
GLOBIGERINA VENEZUELANA Hedberg, 1937

Plate 22, fig. 2

Globigerina venezuelana Hedberg
Hedberg, 1937, Jour. Paleo., vol. 11, no. 8, p. 681, pl. 92, fig. 7.

Globigerina venezuelana Hedberg

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES CONGLOBATUS (Brady), 1879

Plate 22, fig. 5

Globigerina conglobata Brady

Globigerinoides conglobatus (Brady)

GLOBIGERINOIDES OBLIQUUS EXTREMUS
Bolli and Bermudez, 1965

Plate 22, fig. 7

Globigerinoides obliquus extremus Bolli and Bermudez

Globigerinoides obliquus extremus Bolli and Bermudez

GLOBIGERINOIDES OBLIQUUS OBLIQUUS Bolli, 1957

Plate 22, fig. 6

Globigerinoides obliquus Bolli

Globigerinoides obliquus obliquus Bolli
GLOBIGERINOIDES PRIMORDIUS Blow and Banner, 1962

Plate 23, fig. 3

Globigerinoides quadrilobatus (d'Orbigny) primordius Blow and Banner
Blow and Banner, 1962, Fundamentals of Mid-Tertiary Stratigraphical Correlation, p 115, pl. IX, fig. Dd-Ff.

Globigerinoides primordius Blow and Banner

GLOBIGERINOIDES RUBER (d'Orbigny), 1839

Plate 23, fig. 1

Globigerina rubra d'Orbigny

Globigerinoides ruber (d'Orbigny)

GLOBIGERINOIDES TRILOBUS TRILOBUS (Reuss), 1850

Plate 23, fig. 2

Globigerina triloba Reuss

Globigerinoides trilobus trilobus (Reuss)

Genus SPHAEROIDINELLA Cushman, 1927

SPHAEROIDINELLA DEHISCENS (Parker and Jones), 1865

Plate 23, fig. 4

Sphaeroidina bulloides d'Orbigny var. dehiscens Parker and Jones

Sphaeroidinella dehiscens (Parker and Jones)

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SPHAEROIDINELLA DEHISCENS (Parr and Jones)  
EXCAVATA Banner and Blow, 1965  
Plate 23, fig. 5  

Sphaeroidinella dehiscens (Parr and Jones) excavata Banner and Blow  

Sphaeroidinella dehiscens (Parr and Jones) excavata Banner and Blow  

Genus SPHAEROIDINELLOPSIS Banner and Blow, 1959  
SPHAEROIDINELLOPSIS SEMINULINA (Schwager), 1866  
Plate 23, fig. 6  

Sphaeroidinellopsis subdehiscens paendehiscens Blow  

Sphaeroidinellopsis seminulina (Schwager)  

Subfamily ORBULININAE Schultz, 1854  
Genus PRAEORBULINA Olsson, 1964  
PRAEORBULINA c.f. GLOMEROSA CURVA (Blow), 1956  
Plate 23, fig. 7  

Globigerinoides glomerosa Blow  

Praeorbulina glomerosa curva (Blow)  

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PRAEORBULINA SICANA (de Stefani), 1952

Plate 23, fig. 10

Globigerinoides sicanus De Stefani

Praeorbulina sicana (de Stefani)

PRAEORBULINA TRANSITORIA (Blow), 1956

Plate 23, fig. 9

Globigerinoides transitoria Blow

Praeorbulina transitoria Blow

Genus ORBULINA d'Orbigny, 1839

ORBULINA SUTURALIS Bronnimann, 1951

Plate 24, fig. 1

Orbulina suturalis Bronnimann

Orbulina suturalis Bronnimann

ORBULINA UNIVERSA d'Orbigny, 1839

Plate 24, fig. 2

Orbulina universa d'Orbigny
Orbulina universa d'Orbigny

ORBULINA UNIVERSA var. BILOBATA (d’Orgigny), 1846
Plate 24, fig. 3

Globigerina bilobata d’Orbigny
d’Orbigny, 1846, Foram. foss. du bass. tertiare de Vienne, p. 164, pl. 9, fig. 11-14.

Orbulina universa d’Orbigny var. bilobata

Family CANDEINIDAE Cushman, 1927
Genus CANDEINA d’Orbigny, 1839
CANDEINA NITIDA d’Orbigny, 1839
Plate 24, fig. 4

Candeina nitida d’Orbigny

Candeina nitida d’Orbigny

Family HASTIGERINIDAE Bolli, Loeblich and Tappan, 1957
Genus HASTIGERINA Thomson, 1876
HASTIGERINA SIPHONIFERA (d’Orbigny), 1839
Plate 24, fig. 5

Globigerina aequilateralis Brady

Hastigerina siphonifera (d’Orbigny)

Superfamily GLOBOROTALIACEA Cushman, 1927

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Family GLOBOROTALIIDAE Cushman, 1927
Subfamily GLOBOROTALIINAE Cushman, 1927
Genus GLOBOROTALIA Cushman, 1927
GLOBOROTALIA ACOSTAENSIS ACOSTAENSIS Blow, 1959

Plate 24, fig. 6

Globorotalia acostaensis Blow

Globorotalia acostaensis acostaensis Blow

GLOBOROTALIA ARCHEOMENARDII Bolli, 1957

Plate 24, fig. 9

Globorotalia archeomenardii Bolli

Globorotalia archeomenardii Bolli

GLOBOROTALIA CRASSAFORMIS CRASSAFORMIS (Galloway and Wissler), 1927

Plate 24, fig. 7

Globigerina crassaformis Galloway and Wissler
Galloway and Wissler, 1927, Jour. Paleo., volo. 1, p. 41, pl. 7, fig. 12.

Globorotalia crassaformis crassaformis (Galloway and Wissler)

GLOBOROTALIA KUGLERI Bolli, 1957

Plate 24, fig. 8

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**Globorotalia kuoleri Bolli**

**Globorotalia kuoleri Bolli**

**GLOBOROTALIA LENGUANENSIS Bolli, 1957**
Plate 25, fig. 1

**Globorotalia lenquaensis Bolli**
Bolli, 1957, U.S. Nat. Mus. Bull. No. 215, p. 120, pl. 29, fig. 5.

**Globorotalia lenquaensis Bolli**

**GLOBOROTALIA c.f. MARGARITAE MARGARITAE**
Bolli and Bermudez, 1965
Plate 25, fig. 2

**Globorotalia margaritae Bolli and Bermudez**

**Globorotalia margaritae maroaritae Bolli and Bermudez**

**GLOBOROTALIA MENARDII MENARDII (Parker, Jones and Brady), 1865**
Plate 25, fig. 4

**Rotalia menardii d'Orbigny**

**Globorotalia menardii menardii (Parker, Jones and Brady)**

**GLOBOROTALIA OPIMA NANA Bolli, 1957**
Plate 25, fig. 3
Globorotalia opima nana Bolli

Globorotalia opima nana Bolli

GLOBOROTALIA FOHSI PERIPHERORONDA Blow and Banner, 1966
Plate 25, fig. 5

Globorotalia peripheroronda Blow and Banner
Blow and Banner, 1966, Micropaleo., vol. 12, no. 3, p. 294, pl. 1, fig. 1.

Globorotalia fohsi peripheroronda Blow and Banner

GLOBOROTALIA PLEISOTUMIDA Blow and Banner, 1965
Plate 26, fig. 1

Globorotalia (Globorotalia) pleisotumida Blow and Banner

Globorotalia pleisotumida Blow and Banner

GLOBOROTALIA SCITULA SCITULA (Brady), 1882
Plate 26, fig. 3

Pulvinulina scitula Brady

Globorotalia scitula scitula (Brady)

GLOBOROTALIA SIAKENSIS (Leroy), 1939
Plate 26, fig. 2

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Globigerina siakensis Leroy

Globorotalia siakensis (LeRoy)
Bolli, Saunders, Perch-Nielsen, 1985, Plankton Stratigraphy, Cambridge Univ. Press, p. 309, textfig. 6, no. 11.

GLOBOROTALIA TRUNCATULINOIDES EXCELSA Sprovieri, Ruggieri and Unti, 1980
Plate 26, fig. 4

Rotalia truncatulinoides d'Orbigny

Globorotalia truncatulinoides excelsa Sprovieri, Ruggieri and Unti

GLOBOROTALIA TUMIDA TUMIDA (Brady), 1877
Plate 26, fig. 5

Pulvinulata menardii (d'Orbigny) var. tumida Brady

Globorotalia tumida tumida (Brady)

Family PULLENIATINIDAE Cushman, 1927
Genus PULLENIATINA Cushman, 1927

PULLENIATINA OBLIQUILOCULATA (Parker and Jones), 1865
Plate 26, fig. 6

Pullenia sphaeroides (d'Orbigny) var. obliquiloculata Parker and Jones
Pulleniatina obliquiloculata (Parker and Jones)

PULLENIATINA PRIMALIS Banner and Blow, 1967
Plate 26, fig. 7

Pulleniatina primalis Banner and Blow
Banner and Blow, 1967, Micropaleo., vol. 13, no. 2, p. 142, pl. 3, fig. 2.

Family GLOBIGERINITIDAE Bermudez, 1961
Subfamily GLOBIGERINITINAE Bermudez, 1961
Genus GLOBIGERINITA Bronnimann, 1951
GLOBIGERINITA NAPARIMAENSIS Bronnimann, 1951
Plate 27, fig. 4

Globigerinita naparimaensis Bronnimann

Globigerinita naparimaensis Bronnimann

Family CATAPSYDRACIDAE Bolli Loeblich and Tappan, 1957
Genus GLOBOQUADRINA Finlay, 1947
GLOBOQUADRINA ALTISPIRA (Cushman and Jarvis), 1936
Plate 27, fig. 2

Globigerina altispira Cushman and Jarvis
Cushman and Jarvis, 1936, C.L.F.R. Contr. vol. 12, no. 1, p. 5, pl. 1, fig. 13.

Globoguadrina altispira (Cushman and Jarvis)
GLOBOQUADRINA DEHISCENS (Chapman, Parr and Collins), 1934

Plate 27, fig. 1

Globogerina dehiscens Chapman, Parr and Collins

Globoquadrina dehiscens (Chapman, Parr and Collins
Bolli, Saunders, Perch-Nielsen, 1985, Plankton Stratigraphy. p. 183, textfig. 15, no. 4-7, 8, 9, 12.

Genus NEOGLOBOQUADRINA Rogl and Bolli, 1973

NEOGLOBOQUADRINA DUTERTREI DUTERTREI
(d’Orbigny), 1839

Plate 27, fig. 3

Globogerina dutertrei d’Orbigny
Cuba, “Foraminiferes”, vol. 8, p. 84, pl. 4, fig. 19-21.

Neogloboquadrina dutertrei dutertrei (d’Orbigny)
Bolli, Saunders, Perch-Nielsen, 1985, Plankton Stratigraphy. Cambridge Univ. Press, p. 211, textfig. 27, no. 1-4,
textfig. 28, no. 1-8.

Genus CATAPSYDRAX Bolli, Loeblich and Tappan, 1957

CATAPSYDRAX DISSIMILIS (Cushman and Bermudez), 1937

Plate 27, fig. 5

Globigerina dissimilis Cushman and Bermudez
Cushman and Bermudez, 1937, C.L.F.R. Contr. vol. 13, no. 1, p. 25, pl. 3. fig. 4-6.

Catapsydrax dissimilis (Cushman and Bermudez)

CATAPSYDRAX DISSIMILIS Cushman and Bermudez var. UNICAVUS
Bolli, Loeblich and Tappan, 1975

Not Figured

Catapsydrax unicavus Bolli, Loeblich and Tappan
**Catapsydrax dissimilis** (Cushman and Bermudez) var. **unicavus**
Bolli, Loeblich and Tappan

**CATAPSYDRAX STAINFORTHI** Bolli, Loeblich and Tappan, 1957

Plate 27, fig. 6

**Catapsydrax stainforthi** Bolli, Loeblich and Tappan

**Catapsydrax stainforthi** Bolli, Loeblich and Tappan
CHAPTER 4

MULTIVARIATE DATA ANALYSIS

Two computer aided analytical techniques were used to analyze benthic foraminiferal species distributions in the three stratigraphic units in the study area. The techniques used were a multiple group component factor analysis and a UPGMA cluster analysis. The data analyzed were the percentage abundance data of selected benthic foraminiferal species. Methods of species selection are described below. The species counts from which percentages were calculated are in Appendix C.

FACTOR ANALYSIS

Preliminary Comments

The use of factor analysis in paleoecological studies of foraminifera is valuable in the identification of independent assemblages of species. The number of species assemblages produced by the analysis is far fewer than the number of species analyzed. Thus, the foraminiferal variables which need to be considered in the paleoecological analysis is greatly reduced, and interpretation is easier (Corliss, 1979b, 1979c). The factor analysis also has the advantage of reducing counting error and reduction
of problems associated with the analysis of relative abundance data (Davis, 1973) expressed as percentages (Lohmann, 1978). The use of factor analysis in determination of number and composition of foraminiferal assemblages has been documented by Imbrie and Kipp (1971), who applied the method to analysis of foraminiferal faunas in deep sea cores and interpreted paleoenvironmental variables based upon correlation with the Recent.

Factor analysis is valuable in the investigation of a large matrix of faunal distribution data. The analysis does not do anything that cannot be done without a computer, however, it allows analysis of much more data in a given amount of time. This is accomplished by the calculation of mutually independent "factors", which are groups of variables having a relatively high degree of covariance. In the case of foraminiferal studies the variables are species which have similar distributions in the samples. These groups of species are considered to be assemblages and the assemblage distributions are interpreted, rather than the distributions of the original species. In a study relating deep sea benthic foraminifera to bottom water masses Schnitker (1980) showed the similarity of results between factor analytical and non-factor analytical interpretations. Based upon 54 Recent taxa in 75 core-top samples Streeter and Lavery (1982) identified 5 assemblages (factors) that accounted for over 80% of the data varia-
bility. The factors were related to depth zonation.

In this study factor analysis is used to investigate the faunal variability in the Uscari, Rio Banano, and Moin Formations. The major assemblages of species in each formation are identified and interpreted as representing paleoenvironments of deposition based upon the ecological implications of the species in each assemblage. Calculation of factor scores for each factor on every sample allows the determination of the relative importance of each faunal assemblage (factor) for every sample. Thus, the paleoecological interpretation of the factors can be related to the samples, and changes in paleoenvironment with time can be seen in the formations. Changes in paleoenvironment can then be related to geological history of the area.

The distribution of benthic foraminifera on the modern seabed is influenced by a number of physical-chemical variables in the marine environment. Some of these variables are water temperature, nature of the substrate, amount of light, dissolved oxygen content, nutrient supply, salinity, predation, pressure, turbidity, degree of agitation, etc. Many studies of modern distributions of living foraminifera have tried to relate these distributions to physical parameters of the environment, but it is difficult to know which parameter, or combination of parameters, is actually controlling distribution. There has emerged an overall relationship of foraminiferal assem-
blages with water depth. This is probably due to the correlation of depth with other parameters, such as increased pressure, reduction in grain size of substrate, and probably most importantly, water temperature.

Based upon the known distributions of extant species, and the assemblage relationships among different species, it is possible to make paleodepth interpretations of fossil assemblages. Implied in this approach is the assumption that species have not changed their habitat to any significant degree over the course of geological time. Obviously, the older rocks in question, the less valid is this assumption. The use of assemblages lessens the possibility of an incorrect interpretation based upon a species that has changed habitat.

A multiple group method of factor analysis (M.G.A. for multiple group analysis) was employed to identify species assemblages in the three formations. This analytical procedure is contained in the SAS software package as the VARCLUS Procedure (see SAS User's Guide, Statistics, 1985 edition). For a more in-depth explanation of this procedure see Anderberg (1973), Harman (1954), or Harman (1976). The M.G.A. is similar to the more widely used principal components analysis, or P.C.A., but differs in two aspects. First, the factors extracted in M.G.A. are not necessarily orthogonal to each other as they are in P.C.A. This is due to the manner in which the factors are extracted from the
correlation matrix. In P.C.A. the factors are mathematically constrained to be orthogonal, while they are not in M.G.A. In M.G.A. a factor correlation matrix is calculated so the interdependence of factors can be determined. The second difference between the two methods is the manner in which the factors are defined. In P.C.A., all of the original variables go into the makeup of each factor extracted. That is, for each factor all of the original variables will have a factor loading value on that factor and the variance accounted for by that factor will be the result of some variance input by all of the original variables. This is not the case in M.G.A. where a variable can only have a non-zero loading on one factor. (In the VARCLUS Procedure of SAS used here, factor loadings are called Standardized Scoring Coefficients). Variables are constrained to load only on one factor, so for all other factors the loading will be zero. The result is the variance of a variable can only be applied to one factor in M.G.A. and cannot be parcelled out among many factors as in a P.C.A. The practical result is that factors in a M.G.A. will be easier to interpret, but will account for a smaller amount of the total variance than will an equal number of principal components in a P.C.A.

Before the factor analysis can be applied to the data there must be some idea of how many major factors are actually controlling the species distribution. An initial
multivariate analysis of the eigenvectors and their associated eigenvalues gives an idea of the number of major factors and their relative sizes. In each multiple group factor analysis presented here, an examination of the relative sizes of the eigenvalues of the correlation matrix for the species included in the analysis was used to help choose the appropriate number of factors to extract.

Application of a factor analysis requires that the number of observations (samples in this study) be greater than the number of variables (species in this study) (Anderson, 1984, p. 460). In the three analyses presented here, the number of species in the stratigraphic sections was greater than the number of samples in each section. A reduction in the number of species was necessary for each analysis. This is a common problem in applying factor analytical methods to foraminiferal paleoecology where the number of species in a sample can be high.

Species number reduction was accomplished using a variance cutoff with the species having the largest variances used in the analysis. In this reduction, the number of species retained for the factor analysis was one less than the number of samples in the section being analyzed. This satisfied the mathematical constraint that the number of variables be less than the number of observations.
The use of a variance cutoff in these analyses is a departure from the method of species reduction commonly used in foraminiferal studies. Usually a percentage cutoff, commonly 1% or 2%, is applied to the species distributions where any species that does not attain the cutoff level in at least one sample is eliminated from the analysis. The use of the variance cutoff is based on the fact that these factor analyses use the correlation matrix, where the correlation coefficient \( P \) is calculated as:

\[
P = \frac{\text{covariance}(x \times y)}{\text{variance}(x) \times \text{variance}(y)}
\]

where \( x \) and \( y \) are two variables in the matrix.

In this calculation it can be seen that the value of \( P \) is a function of the variance of the variables and not of the value of their percentage dominance in the samples. Therefore, it is appropriate to use a variance cutoff in species number reduction. Realistically, since the variance is proportional to the mean, the variables with the largest variances will be those with the largest mean values.

Interpretation of each factor is based upon the values of the standardized scoring coefficients for the variables which are used to construct the factors from the original variables. Each factor is a bipolar linear combination of the original variables with positive and negative coefficient values. Species having positive values are acting as an assemblage and have similar distributions. These species
are used to define the factor. Negative values indicate species that have distributions opposite to the definition species. Both positive and negative values can be valuable in factor interpretation.

Plots of the factor scores versus the samples show the relative strengths of the factors throughout the stratigraphic extent of the sections. As the factors are considered new variables, these plots are analogous to plots of frequency distributions of individual species in the sections. These plots are used to interpret the changes in paleoenvironmental parameters represented by the factors.

Table 3 lists the first ten eigenvalues of the correlation matrix for all species in the Uscari, Rio Banano, and Moin Formations. These values were used to decide how many factors to extract in each analysis. The standardized scoring coefficients for the species in each factor analysis are in Table 4. The factors outlined below are interpreted in Chapter 5.

Uscari Formation

The first large increment in the eigenvalues is between the fifth and sixth eigenvalues, so five factors were extracted. The five factor solution accounts for 40 percent of the variance of the variables in the reduced data set. The five factors with their included species are as follows:
Factor #1. Species with positive coefficients are Bolivina subaenariensis, Epistominella exigua, E. (?) rugosa, Fur-senkoina pontoni, Hanzawaiia concentrica, and Pseudononion basispinata. The single species with a negative coefficient is Stilostomella antillea.

Factor #2. Species with positive coefficients are Bolivina isidroensis, Cibicidoides falconensis, Lenticulina calcar, Cibicides wuellerstorfi, Trifarina bradyi and Uvigerina hispido-costata. Species with negative coefficients are Bolivina spinata, Cassidulina subolobosa, and Trifarina angulosa.

Factor #3. Species with positive coefficients are Siphogenerina transversa, Bolivina alata, Gyroidina parva, Uvigerina hannai, and Gyroidina regularis. Species with negative coefficients are Buliminella elegantissima, Nonionella miccenica, and Bolivina subexcavata.

Factor #4. Species with positive coefficients are Amphitegina gibbosa, Cassidulina laevigata, Hanzawaiia manta-iensis, and Sigmocilina tenuis. No species have negative coefficients.

Factor #5. Species with positive coefficients are Bolivina pseudoplicata, Buliminella bassendorfensis, Elphidium spp., Uvigerina peregrina, and U. rustica. Species with negative coefficients are Bolivina inflata, Cassidulina carapitana, B. subexcavata, and Gyroidina soldanii.

The taxon Elphidium spp. includes all specimens of
this genus which could not be identified to specific level. Throughout the identification process the same criteria were applied for assignment to this group.

**Río Banano Sandstones**

The first large increment in the eigenvalues of the correlation matrix is between the third and fourth eigenvalues so three factors were extracted in the analysis. The three factor solution accounts for 64.3 percent of the variation of the species used in the analysis. The three factors with their species are as follows:

**Factor #1.** Species with positive coefficients are *Amphisterina gibbosa*, *Cibicidoides floridanus*, *Hanzawaia concentrica*, and *Trifarina angulosa*. *Cassidulina subglobosa* has a negative coefficient.

**Factor #2.** Species with positive coefficients are *Fararotalia sarmientoi*, *Pseudonion basispinata*, and *Elphidium discoidale*. *Cassidulina laevigata* has a negative coefficient.

**Factor #3.** Species with positive coefficients are *Articulina mayorii*, and *Quinqueloculina lamarckiana*. *Rosalina globularis* has a negative coefficient.

**Moin Formation**

The eigenvalues of the correlation matrix suggest extraction of four factors, however, only three factors
have been extracted. The small number of species upon which
the analysis is based makes interpretation of four factors
difficult. There are not enough species to allow interpreta-
tion of four factors.

The three factor solution accounts for 75 percent of
the variance of the species used in the analysis. The
factors and their species are as follows:
Factor #1. Species with positive coefficients are Bolivina
lowmani, Cassidulina subglobosa, and Gyroidina soldanii. No
species have negative coefficients.
Factor #2. Species with positive coefficients are Cibicidoi-
des floridanus, Melonis barleeanus, and Siphonina
pulchra. Cassidulina laevigata and Gyroidina regularis have
negative coefficients.
Factor #3. Species with positive coefficients are Cassidu-
lina curvata, Sigmoilina tenuis, and Uvigerina auberiana.
Bolivina subaenariensis has a negative coefficient.

CLUSTER ANALYSIS

Preliminary Comments

A cluster analysis was performed on all of the samples
using the species analyzed in the factor analyses. The
cluster analysis performed here is that of the SAS Insti-
tute, Statistical Analysis System (see SAS User’s Guide,
Statistics, 1985 ed.). Good explanations of cluster
analysis can be found in Anderberg (1973), Everitt (1980), and Romesburg (1984). A Q-Mode analysis was done with the unweighted pair group method using arithmetic averaging (UPGMA). Data were in the form of percent abundance of selected species in the samples.

**Application**

The purpose in performing a cluster analysis is to group the samples into clusters based upon the species distributions. If the interpretation of the factor analyses are valid, a cluster analysis using the same species should support the interpretations. Both methods form groups of samples. The cluster analysis does this directly in the clusters and the factor analysis forms sample groups by the calculation of factor scores. Figure 12b is a dendrogram of the cluster structure. The species used in the analysis are listed in Table 5. The vertical scale of the dendrogram is euclidian distance between clusters.

Figure 12a is a plot of the R squared value calculated by the cluster algorithm versus the number of clusters. R squared is a measure of the proportion of variance in the data accounted for by the cluster solution. Where the rise in the value of R squared begins to drop off with the addition of more clusters, additional clusters are not significant. The dropoff point in the plot was chosen at number of clusters equal to 25. Of these 25 clusters,
indicated by a horizontal line on the dendrogram, 16 are single sample clusters and are considered as outliers in the data set, not indicative of cluster structure. According to Milligan (1980) outliers should be present in data sets which do possess cluster structure and the UPGMA cluster method is largely unaffected by the presence of a few outliers in its ability to recover cluster structure from the data set. As such, the outliers will not be interpreted as clusters. Interpretation of the clusters is presented in Chapter 6, Paleoenvironments.
Figure 12a. Plot of number of clusters versus squared. 25 clusters have been chosen for interpretation. Of these, 16 are single sample clusters and are considered outliers.

Figure 12b. Dendrogram illustrating cluster structure. Scale is euclidian distance. The numbers refer to clusters that are interpreted in the text.
### TABLE 3

**EIGENVALUES OF THE CORRELATION MATRIX FOR ALL SPECIES APPEARING IN THE USCARI FM. SECTIONS**

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<td>0.0967</td>
<td>0.2088</td>
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<td>0.0814</td>
<td>0.2902</td>
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<tr>
<td>4</td>
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**EIGENVALUES OF THE CORRELATION MATRIX FOR ALL SPECIES APPEARING IN THE RIO BANANO SANDSTONES**

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**EIGENVALUES OF THE CORRELATION MATRIX FOR ALL SPECIES APPEARING IN THE MOIN FORMATION**

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**STANDARDIZED SCORING COEFFICIENTS FOR ALL SPECIES IN EACH FACTOR ANALYSIS**

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### Rio Banano Formation

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TABLE 5
SPECIES USED IN CLUSTER ANALYSIS

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CHAPTER 5

RELATIVE ABUNDANCE OF PLANKTONIC FORAMINIFERA

The relative amounts of planktonic and benthic foraminifers in sediments can be used to determine the relative water depths of samples in environments shallower than lower slope depth. This analysis was introduced by Grimsdale and Morkhoven (1955), who tried to use the method to determine the absolute depth of samples from traverses across the northern Gulf of Mexico.

The percent planktonic content of a sample is the percent of the total number of foraminifera, planktonic plus benthic, that the planktonic foraminifera constitute. This value was determined in this study by counting the first 200 specimens in a sample and noting subtotals of planktonic and benthic specimens.

Grimsdale and Morkhoven (1955) pointed out that it is desirable to use an average of percent planktonics in a few samples, rather than values from individual samples, due to the variability in the percent of planktonics that can exist in samples of the same water depth. In this way the percent planktonic value will give a more reliable estimate of the change in planktonic percentage that can be attributed to change in water depth. Any sampling error or uneven distribution of planktonic specimens unrelated to
water depth will be reduced. In this study, a moving average was calculated for each stratigraphic section by using three adjacent samples and changing one sample for each calculation. The end values are the average of two samples and all in between values are the average of three samples. The percent planktonic abundance value and the moving average value for each sample are shown in Table 6. These values are plotted in Figure 13.

**USCARI FORMATION**

**Quebrada Uscari Type Section**

All five values are close to 40 percent in this section, indicating little change in water depth over the course of deposition. The values do not show a trend within the section.

**Rio Reventazon Section**

The lower and middle parts of the section have values around 80 percent, while the few samples at the top of the section show a steady drop in value to a low of near 70 percent. This may indicate a shallowing trend, but the range of values is not considered sufficient to make an unequivocal interpretation.

**Quebrada Terciopelo Reference Section**

The lower part of the section, samples #305 through
#3-32, has values around 80 percent. Up section from sample #3-32 a decrease in values shows a steady shallowing trend throughout the middle and upper parts of the section.

**RIO BANANO FORMATION**

High and low values are 27.0 percent and 16.4 percent. Most of the values are around 20 percent. The samples which yielded datable planktonic faunas, #96, #97, and #98 have the highest percentages in the section. The increase in values from 16.4 percent in sample #217 to 27 percent in sample #96 may indicate a deepening trend within the section between these two values. The range of values between these two extremes is not considered sufficient to make an unequivocal interpretation of within section changes in water depth.

**MOIN FORMATION**

The planktonic abundance within the Moin Formation does not change much over the stratigraphic extent of the section. Most of the values are near 30 percent with high and low values of 40.3 percent and 23.6 percent. These values indicate water depth did not change significantly during the course of deposition. There does not appear to be a within section trend.
### TABLE 6

PLANKTONIC/BENTHIC VALUES

<table>
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<tr>
<th>Sample Number</th>
<th>USCARI FM.</th>
<th>MOIN FM.</th>
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<th>Quebrada Terciopelo</th>
<th>Río Quiroga</th>
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Figure 13. Plot of percent planktonics in the foraminiferal fauna for the five studied sections. Only the Quebrada Terciopelo section of the Uscari Formation shows a systematic change. Above sample 3-32 the percentage shows a steady decline, suggesting a progressive shoaling.
PALEOENVIRONMENTS

FACTOR ANALYSIS

Paleoenvironmental interpretations are based upon interpretations of the factor analyses and paleoecologic implications of species identified from scans of the samples. These scan species were not included in the factor analyses. Table 7 is a compilation of paleoenvironmental information for benthic foraminifera identified from the rocks of the Uscari, Rio Banano, and Moin Formations. The information in this table was used in the interpretation of the factors. For each factor analysis the corresponding factor scores were calculated. These scores are presented in Table 8.

Uscari Formation

Based upon the species listed in Chapter 4 the interpretation of the factors is as follows:

Factor #1 - A continental shelf, open marine assemblage. Hanzawaia concentrica, Bolivina subaenariensis, and Fursenkoina pontoni indicate an open marine, probably middle continental shelf environment. Both species of Epistominella are wide ranging although Epistominella
exigua is more commonly found in deeper water. Pseudonion basispinata is more common in shallow shelf environments. Factor #1 is a middle shelf assemblage.

Factor #2 - The interpretation of this factor is indicated by the dominance of Cibicides wuellerstorfi, a well known deep water species associated with modern distribution of North Atlantic Deep Water at depths in the 2000 meter range. Little is known of the distribution of the other species with positive coefficients in this group, but association with C. wuellerstorfi in this factor indicates they all have deep water affinities. Uvigerina hispido-costata is largely hispid, suggesting a deep water environment. Bolivina spinata is found in shelf environments and, consequently, has a negative coefficient, as do the common shelf to bathyal species Cassidulina subglobosa, and the shallow shelf species Trifarina annulosa. This factor is interpreted as deposition in a lower bathyal to abyssal environment.

Associated with C. wuellerstorfi in factor #2 is Cibicidoides falconensis which, like Cibicides wuellerstorfi, is found only in the Rio Reventazon section. The other species included in factor #2 are more widespread in occurrence although Bolivina isidroensis and Trifarina bradyi are found in greater abundance in samples of the Rio Reventazon section than elsewhere.

Factor #3 - Siphogenerina transversa is a well known deep
water species usually inhabiting an upper to middle bathyal environment. *Gyroidina regularis* and *Bolivina alata* are found on the shelf to upper slope. *Gyroidina parva* indications are unknown. An upper to middle slope environment is indicated. *Buliminella elegantissima* and *Nonionella miocenica* are shallow water species, both with negative coefficients.

**Factor #4 - Amphistegina gibbosa** is a shallow water species found in association with the well agitated environments of reefs and sandy substrates of the inner to middle shelf. *Cassidulina laevigata* and *Sigmoilina tenuis* are wide ranging species from the outer shelf to middle slope, usually characteristic of a muddly substrate. Nothing is known of *Hanzawaia mantaensis* but the genus suggests shelf. This factor is interpreted as a mixed assemblage of inner to middle shelf taxa with upper to middle slope taxa.

**Factor #5 - Elphidium** is an inner to middle shelf taxon. *Bolivina pseudoplicata* and *Buliminella bassendorfensis* are characteristic of shelf deposits. The indications of *Uvigerina rustica* are unknown. *Uvigerina peregrina* is a costate uvigerinid, suggesting a shelf to upper slope habitat. *Gyroidina soldanii* is commonly found in deeper bathyal environments, consequently, it has a negative coefficient. This factor is interpreted as an outer shelf to upper slope factor. The elphidids present in this assemblage are all small. It is possible they represent an
environmentally depauperate fauna. Some species of Elphidium have been reported living at depths much greater than interpreted for this assemblage (Streeter and Lavery, 1982).

Plots of these scores versus the samples in the section are shown in Figure 14. In the plots samples #311, #312, and #314 have been omitted from the Quebrada Terciopelo plot. These samples are in a repeated section. Factor #1 shows high scores on samples from the Quebrada Uscari type section, indicating the environment of deposition in the type section was on the continental shelf. Factor #2 shows high scores on samples from the Rio Reventazon section, indicating these sediments were deposited in a lower bathyal to abyssal environment. Factor #3 shows high scores on samples from the lower Quebrada Terciopelo section, indicating an upper to middle bathyal environment. The similarity between planktonic percentage values of the lower bathyal Rio Reventazon samples and the lower Quebrada Terciopelo samples suggests the depth was middle, rather than upper bathyal. Factor #4 shows high scores on scattered samples in the Rio Reventazon section, the Quebrada Terciopelo section, and the isolated Rio Quito sample. As factor #4 is interpreted as a mixture of species from different environments, this factor is identifying downslope movement of sediment. The deep water samples of the Rio Reventazon and lower Terciopelo sections have been
**USCARI F.M.**

**FACTOR #1**
- middle continental shelf, open marine

**FACTOR #2**
- lower bathyal to abyssal

**FACTOR #3**
- middle slope, mixed fauna

**FACTOR #4**
- upper to middle slope, mixed fauna

**FACTOR #5**
- outer shelf to upper slope

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**Sample Numbers**

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**Figure 14.** Plots of factor scores for the five Uscuri Formation factors on the three sections of the Uscuri Formation.

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contaminated with shallow water species, probably by turbidity currents. Factor #5 shows high scores on the upper part of the Terciopelo section, indicating this section was deposited on the upper slope to outer shelf. High factor #5 scores on the Quebrada Uscari section suggest a facies correlation between the Quebrada Uscari and upper Quebrada Terciopelo sections, although the scores of factor #1 indicate a shallow environment for Quebrada Uscari sediments.

The factor analysis separates the three sections of the Uscari Formation into distinct units. The Early Miocene samples in the Rio Reventazon section have high scores for the deep water factor, #2, suggesting the Rio Reventazon sediments were deposited in a lower bathyal to abyssal environment, at a depth of approximately 2000 meters. The Early to early Middle Miocene shales of the Quebrada Terciopelo section show a difference in paleodepth between the lower and upper parts of the section. The lower part of the section has high scores for the middle to upper slope factor, #3, indicating, in conjunction with the planktonic percentage values, deposition on the middle slope. In the upper part of the section the dominant factor is #5, suggesting an outer shelf to upper slope environment. This up section change is also reflected in the planktonic percentage values. The Quebrada Uscari section is a shelf deposit, representing the shallowest facies of
the Uscari Formation, indicated by high scores for factor #1.

The basal limestones of the Terciopelo section contain larger benthic foraminifera and red algal rhodoliths, both indicative of shallow, agitated, conditions. These fossil larger foraminifera were probably associated with endosymbiotic algae in reef and carbonate shoal environments (Brasier, 1980). The relationship of larger foraminifera with symbiotic algae suggests they lived in the upper part of the photic zone in clear, non-turbid water. The rhodoliths suggest a wave or current agitated environment, probably between 1 to 10 meters depth. The two identified larger foraminiferal taxa from the Terciopelo section limestones, Heterostegina antillea, and Lepidocyclina (L.) waylandvaughni, have also been reported in algal limestone lenses from the Pacific coastal area of the Oligocene Bohio Formation in Panama (Cole, 1952). These algal limestone lenses, the thickest of which is 60 cm, are interbedded with basaltic conglomerates and, as in Quebrada Terciopelo, the sedimentary section rests directly on igneous rock (Woodring, 1957). Yuan (1984) reported the co-occurrence of rhodoliths and larger foraminifera in Oligocene limestones of the Terraba Formation of southwestern Costa Rica. He interpreted the depositional environment of these limestones as a carbonate shelf less than 10 meters depth which was periodically swept by storm cur-
rents. A similar environment is suggested for the lime-
crystals of the lower Terciopelo section. The interbedded 
graywacke sandstone between the two limestone beds may 
indicate a local deepening of water followed by a shal-
lowing back to previous depth, or a lateral change in 
facies.

The lower of the two limestones contains clasts of the 
underlying basalt, but lacks individual igneous mineral 
grains. The upper limestone contains basalt clasts and also 
contains individual igneous mineral grains. The lower 
limestone is interpreted as a deposit of a shallower 
environment in which individual mineral grains either did 
not survive weathering processes, or were swept out. The 
upper limestone may have been deposited in deeper water, or 
at a higher rate of sedimentation, allowing for the 
preservation of the mineral grains by rapid burial.

The Early Miocene shales in the lower part of the 
Quebrada Terciopelo section have high scores of factor 
#3. This factor is interpreted as a middle bathyal factor 
due to the presence of an assemblage containing Siphogener-
erina transversa, and the planktonic percentage. This part 
of the Terciopelo section has a faunal similarity to the 
Rio Reventazon section. The deep water foraminifers 
Chilostomella ovoidea, Martinottiella pallida, Melonis 
compiloides, and Pullenia bulloides are all found in both 
sections, indicating the environments were similar. This
interpretation is in disagreement with Rivier (1973) who, based upon a fauna of benthic foraminifera, suggested a neritic environment for the shales of the Quebrada Terciopelo section.

Both the Rio Reventazon and lower Quebrada Terciopelo deep water sections show evidence of significant downslope movement of sediment from shallow water, probably as fine grained turbidites. Factor #4, interpreted as representing downslope movement of shallow water fauna, has high scores on scattered samples in the Rio Reventazon and Quebrada Terciopelo sections. The following shallow water taxa are found in one or both of the sections: Amphistegina gibbosa, Asterigerina carinata, Cibicides lobatulus, Cymbaloporetta squamosa, Elphidium discoidale, Elphidium poevanum, and Hanzawajia concentrica. The possibility of turbiditic deposition in the Rio Reventazon section is especially evident in sample #13. This is the only Rio Reventazon sample having a negative score for the deep water factor (#2), and it contains unusually high numbers of the shallow water taxa mentioned, in addition to Buccella hannai, Reussella spinulosa, and Trifarina angulosa. This sample is an outlier in the cluster analysis. If turbidite deposits are present, they must be very fine grained as no field evidence of turbidite deposition was seen. The deposits are probably the distal ends of turbidites from a fine grained source region, although this is speculative.
The late Early to early Middle Miocene shales in the middle and upper parts of the Quebrada Terciopelo section have high scores on factor #5, suggesting deposition on the upper slope to shelf. The planktonic percentage of these samples shows a steadily decreasing amount of planktonic foraminifera, indicating water depth was steadily shallowing through the depositional history.

The Quebrada Terciopelo section represents shallow water carbonate bank deposition in the basal part of the section during the Late Oligocene. A very rapid increase in water depth during the Late Oligocene to Early Miocene resulted in deposition of the lower shales in the section on the middle continental slope. A gradual reduction in water depth during the later Early Miocene is suggested by the change in benthic assemblages and the steady decrease in percent of planktonic species in the middle and upper parts of the section. From the earliest Miocene to early Middle Miocene deposition of the Terciopelo section occurred in shallowing water, from middle to upper slope, to outer shelf deposition at the top of the section.

The early Middle Miocene type section of the Uscari Formation in Quebrada Uscari is characterized by the continental shelf assemblage of factor #1. *Bolivina subaenariensis* and *Fursenkoina pontoni* suggest middle to outer shelf while *Epistominella exigua* and *Epistominella* (?) *rugosa* are more suggestive of outer shelf to upper
slope. *Hanzawaia concentria* and *Pseudononion basispinata* are nearshore species which were probably transported out into deeper shelf waters.

The Quebrada Uscari section shows a faunal similarity to the upper part of the Terciopelo section. The following species are found in abundance in both sections: *Buliminella bassendorfensis*, *Bolivina pseudoplicata*, *Cassidulina laevigata*, *Fursenkoina pontoni*, and *Pseudononion basispinata*. This faunal similarity indicates the upper part of the Quebrada Terciopelo section and the Quebrada Uscari type section are roughly correlative shelf to upper slope deposits of the late Early to early Middle Miocene.

In summary, the sections of the Uscari Formation studied in this report represent different environments. The deepest water deposition occurred in the Rio Reventazon section where water depths may have been as great as 2000 meters in a lower bathyal to abyssal environment. The approximately 560 meters of Uscari Formation exposed in the Quebrada Terciopelo reference section is the thickest section of the Uscari Formation. The lowest rocks in the section are Late Oligocene rhodolitic limestones deposited on a shallow carbonate platform which was receiving volcanic detritus from nearby volcanic highlands. Immediately above the basal limestones are Late Oligocene to Early Miocene marine shales which were deposited on the middle continental slope. The lower part of the Terciopelo
section is roughly correlative with the Early Miocene Rio Reventazon section, although water depths were not as great in the Terciopelo section. A steady shoaling trend through the later Early Miocene and early Middle Miocene, middle and upper parts of the Terciopelo section, resulted in transition to upper slope and shelf environments. The early Middle Miocene type section of the Uscari Formation was deposited on the continental shelf and is roughly correlative with the upper part of the Quebrada Terciopelo section, although a shallower water deposit. Both the bathyal to abyssal deposits of the Rio Reventazon section, and the middle bathyal deposits of the lower Quebrada Terciopelo section were subject to turbidites and the introduction of shallow water taxa into the deep water environment.

Rio Banano Formation

Based on the species listed in Chapter 4 the interpretation of the factors is as follows:

Factor #1 - *Trifarina angulosa*, *Cibicidoides floridanus*, *Hanzawaia concentrica*, and *Amphistegina gibbosa* are all found on the sandy, open marine shelf. *Cassidulina subglobosa*, while found on the shelf, has a widespread distribution and is commonly found on muddy substrates. This accounts for its negative coefficient. This assemblage is characteristic of an inner to middle continental shelf,
open marine, sandy substrate depositional environment, perhaps 10 to 25 meters depth.

Factor #2 - *Elphidium discoidale*, *Pararotalia sarmientoi*, and *Pseudononi basispinata* all indicate nearshore, well agitated conditions, 0 to 20 meters depth with a sandy substrate.

Factor #3 - *Articulina mayorii* is commonly found in well agitated reef environments while *Quinqueloculina lamarckiana* is suggestive of the intertidal or shallow nearshore zones. *Rosalina globularis*, which has a negative coefficient, is found on rocky substrates. This factor is interpreted as representing a nearshore environment near a reef, lacking a rocky substrate.

Plots of the factor scores are shown in Figure 15. Factors #2 and #3, both representing some aspect of a shallow water fauna, have a similar distribution with generally positive scores on the lower part of the section and negative scores on the upper part of the section.

Factor #1, representing a deeper water fauna, has a distribution opposite to factors 2 and 3, with positive scores on the upper section and negative scores on the lower section.

The mixture of environments suggested by these factors leads to the interpretation that the Rio Banano sandstones were deposited on the inner continental shelf at a depth of about 10 to 20 meters. Nearshore sediment was carried out
Figure 15. Plots of factor scores for the three factors of the Rio Banano sandstones on the type section of the Rio Banano Formation.
to the shelf area and redeposited, introducing the tests of nearshore and reef related taxa into the deeper water environment of deposition. The greatest amount of transport of nearshore sediment occurred during deposition of the lower part of the section, suggesting that deepening occurred up section. Also present in the Rio Banano sandstone samples is *Neoconorbina terquemi*, a species found in the high energy, nearshore environment represented by factor #2. This species is common in the lower and middle parts of the section, and absent in the upper part.

**Moin Formation**

Based on the species noted in Chapter 4 the interpretation of the factors is as follows:

**Factor #1** - *Bolivina lowmani*, *Cassidulina subglobosa*, and *Gyroidina soldanii* all indicate a muddy substrate environment of outer shelf to upper slope depths.

**Factor #2** - *Cibicidoides floridanus* and *Siphonina pulchra* suggest a middle to outer shelf environment with a sandy substrate. *Melonis barleeanus* is a deeper water indicator suggestive of a muddy substrate, however, *Cassidulina laevigata* and *Gyroidina regularis*, both with negative coefficients, also are suggestive of deep water, muddy environments. Although difficult to interpret, this factor may represent a deep shelf environment with input of sand from nearshore.
Factor #3 - *Cassidulina curvata, Sigmoilina tenuis*, and *Uvigerina auberiana* are indicative of deposition in a middle to outer shelf environment with a more muddy substrate. The negative coefficient of *Bolivina subaenariensis*, which seems to fit in with this assemblage, is not accounted for.

The interpretation of the Moin Formation factors is difficult, but factor #1 probably represents the deepest water deposition in the Moin Formation. Factors #2 and #3, while both representing a shallower water environment than factor #1, are difficult to distinguish from each other. The difference between them appears to be the sand content of the substrate.

Plots of the factor scores are shown in Figure 16. Factor #1 has positive scores on only the two stratigraphically lowest samples in the section. The lowest part of the Moin Formation was deposited in the deepest water, perhaps as deep as upper slope, approximately 200 meters. Factors #2 and #3, representing different aspects of shelf deposition, dominate the middle and upper parts of the section. Where one factor has a positive score, the other generally has a negative score suggesting that the amount of sand introduced into the environment was variable during the deposition of the middle and upper parts of the Moin Formation, perhaps as a result of changing water depths. The first shelf factor to show positive scores up section
MOIN FM.

Figure 16. Plots of factor scores for the three factors of the Moin Formation on the Moin Formation type section.
above the two lowest samples is factor #3, the muddy substrate, shelf factor.

The interpretation of nearshore sediment input defining factor #2 is supported by the presence of the attached species *Miniacina miniacea* in the scan of sample #69, which has the highest score on factor #2. This species may have been transported from the nearshore. The agglutinated foraminifers *Textularia sicca* and *Textulariella barretti* (from split) are also found only in sample #69, and *Liebusella soldanii* and *Sigmoilopsis flinti* are found in the sample scan. These species require silt and sand sized grains for test construction. They are probably not transported in this sample, but rather were using clastic material transported from the nearshore.

The lower Moin Formation was deposited on the slope at depths of approximately 200 meters. In the middle part of the section shallowing occurred to outer shelf depths, probably around 150 meters. The middle and upper parts of the section show changes from a muddy, to a sandy mud substrate through the depositonal history of the unit. The introduction of sand into the environment may be related to changing water depths either resulting from local tectonic adjustments or eustatic sea level changes related to Pleistocene glaciation.
CLUSTER ANALYSIS

The grouping of the samples into 9 multi-sample clusters identified in the dendrogram (Figure 12b) is similar to the results of the factor analyses.

CLUSTER #1 - Contains only samples from the Rio Reventazon section of the Uscari Formation. These samples are in the deepest water part of the Uscari Formation, deposited near the slope/abyss break. This grouping is similar to factor #2 of the Uscari Formation analysis which had high scores on the Rio Reventazon samples, the deepest part of the Uscari Formation.

CLUSTER #2 - Contains only samples from the lower Quebrada Terciopelo section of the Uscari Formation. These samples are in the deepest water part of the Terciopelo section, from the middle slope. Factor #3 of the Uscari Formation analysis had highest scores on the lower Quebrada Terciopelo section. This grouping shows the lower part of this section is faunally different from the upper part.

CLUSTER #3 - Contains only samples from the middle and upper parts of the Terciopelo section. These samples are in the shallowing sequence of the Terciopelo section, from middle slope through outer shelf. The samples from the middle and upper parts of this section have high scores on factor #5 of the Uscari Formation analysis.

CLUSTER #4 - Contains only samples from the Quebrada Uscari
section of the Uscari Formation. Factor #1 of the Uscari Formation analysis has high scores on these same samples. This section, while correlative with the upper part of the Quebrada Terciopelo section, retains a faunal distinction.

CLUSTER #5 - Contains only samples from the Rio Banano Formation.

CLUSTER #6 - Contains two samples, #212 and #219, from the Rio Banano sandstones. These two samples both have high scores on factor #2, the nearshore indicator, and low scores on factor #3, the reef indicator, suggesting they are samples with a well developed nearshore fauna that were not contaminated with reef taxa during transport. The only other sample with a high nearshore score, #213, also has a high reef score, suggesting mixing with a reef derived fauna during transport.

CLUSTER #7 - Contains only samples from the Moin Formation.

CLUSTER #8 - Contains two samples, #63 and #79, from the Moin Formation. These two samples both have high scores on factor #2, the sandy substrate indicator. The reason these two samples fail to cluster with sample #69, which also has a high score on factor #2, may be due to the high negative score for sample #69 on factor #3. Both samples #63 and #79 have lesser negative scores on factor #3, suggesting sample #69 has the best developed sandy substrate fauna. Sample #69 acts as an outlier in the analysis.

CLUSTER #9 - Contains two samples, #16 and #18, from the
Rio Reventazon section of the Uscari Formation. The factor analysis offers no clue as to why these samples cluster together, separate from the other samples in the section. Examination of the species distribution shows these samples to be contaminated with shallow water species. It is possible the contaminating fauna is different enough from the fauna of factor #4 to cause this clustering. If this is the case, this fauna represents a source of variation not examined in the factor analysis.
### TABLE 7

**SUMMARY OF ECOLOGICAL IMPLICATIONS OF SPECIES USED IN PALEOEKOLOGICAL INTERPRETATION**

**GENUS Amphi steaina**

**A. gibbosa**
1) dominant in reef facies of Puerto Rico; (Murray, 1973)
2) dominant in reef facies of Belize; (Murray, 1973)
3) found at less than 55m on Yucatan shelf; (Murray, 1973)
4) characteristic of Gulf Coast middle shelf, 20-100m; (Albers et al., 1966)
5) found on submerged sand banks in the Gulf of Mexico; (Poag, 1981)

**GENUS Bolivina**

**B. alata**
1) found on shelf and slope in Gulf of Mexico; (Poag, 1981)

**Bolivina lowmani**
1) abundant on outer shelf to upper slope of Gulf of Mexico; (Poag, 1981)
2) found in turbid deltaic marine environment of normal salinity; (Murray, 1973)
3) found in low salinity area of Mississippi delta; (Boltovskoy and Wright, 1976)
4) common on shelf and upper slope of Gulf of Mexico; (Phleger and Parker, 1951)

**B. pseudoplicata**
1) present in low salinity estuary waters of Argentina; (Murray, 1973)
2) common in shelf assemblages worldwide; (Murray, 1973)

**B. spinata**
1) ranges from 30-225 m, abundant at about 120 m off Gulf Coast; (Phleger and Parker, 1951)
2) abundant on outer shelf of Gulf of Mexico; (Poag, 1981)
3) found from 20-244m off Central America; (Smith, 1964)
4) found from 26-225m from California to Ecuador; (Cushman and McCulloch, 1948)
5) found in normal marine salinity on shelf off eastern South America; (Boltovskoy and Wright, 1976)
6) found on Texas shelf, common between 20-100m; (Albers et al., 1966)
**B. subaenariensis**

1) characteristic of Gulf Coast at depths of 110-260m; (Phleger and Parker, 1951)

2) subsp. *mexicana* abundant at 75-125m on Gulf Coast; (Phleger, 1960)

3) found in warm coastal waters off eastern South America; (Boltovskoy and Wright, 1976)

4) characteristic of outer shelf open marine of Gulf Coast, 100-200m; (Albers et. al., 1966)

**GENUS Bulimina**

**B. aculeata**

1) characteristic of upper slope, 200-500m, Gulf Coast; (Albers et. al., 1966)

2) found in epibathyal and meso bathyal deposits, 200-2500m, in modern oceans; (Caralp, 1984)

3) isobathyal species found from upper bathyal to abyssal zones in Gulf of Mexico; (Pflum and Frerichs, 1976)

**B. alazanensis**

1) characteristic of lower slope, 500-2000m, Gulf of Mexico; (Albers et. al., 1966)

**B. marginata**

1) abundant in muddy sediment at depth of 129-139m, Celtic Sea; (Murray, 1973)

2) prefers a muddy substrate with greatest abundance at 10-275m off Central America and California; (Natland, 1950)

3) most abundant on outer shelf to upper slope of Gulf of Mexico; (Poag, 1981)

4) characteristic of depths above 200m on Gulf Coast; (Phleger and Parker, 1951)

5) characteristic of Gulf Coast open marine shelf between 100-200m; (Albers et. al., 1966)

**GENUS Buliminella**

**B. bassendorfensis**

1) middle shelf open marine of Gulf Coast, 20-100m; (Albers et. al., 1966)

2) fine grained substrate with some turbidity, shallower than 10m, Mississippi delta; (Murray, 1973)

3) abundant above than 100m, Gulf Coast; (Phleger, 1960)

4) common on inner to middle shelf, Gulf of Mexico; (Poag, 1981)

5) characteristic shallower than 100m, Gulf Coast; (Phleger and Parker, 1951)
**B. elegansima**
1) most common on the inner to middle shelf of the western Gulf of Mexico; (Murray, 1973)
2) prefers a clay substrate, Hudson Bay; (Boltovskoy and Wright, 1976)
3) common in lagoons near open ocean, worldwide; (Boltovskoy and Wright, 1976)
4) found in littoral, high energy zones; (Boltovskoy and Wright, 1976)
5) maximum depth of 150m off San Diego; (Boltovskoy and Wright, 1976)
6) depth range of 0-820m off southern California and Baja; (Murray, 1973)
7) range of 100-230m in Hudson Bay; (Murray, 1973)
8) depth limit of 27-32m in Todos Santos Bay; (Murray, 1973)

**GENUS Cassidulina**

*C. curvata*
1) generally restricted to depths of greater than 90-100m on Gulf Coast; (Phleger and Parker, 1951)
2) common on the shelf to upper slope of the Gulf of Mexico; (Poag, 1981)
3) common from 100-500m on the Gulf Coast; (Phleger, 1960)

*C. laevigata*
1) found between 50-1700m off Central America; (Smith, 1964)
2) chiefly occurs on shelf in Gulf of Mexico; (Poag, 1981)

*C. subglobosa*
1) occurrence over a wide depth range in shelf seas; (Murray, 1973)
2) found living at 1932m in Peru-Chile Tranch; (Murray, 1973)
3) found to depth of 6750m; (Boltovskoy and Wright, 1976)
4) characteristic of deep outer shelf, Gulf Coast; (Albers et. al., 1966)

**GENUS Chilostimella**

*C. ovicola*
1) found below 1932m in Peru/Chile Trench; (Murray, 1973)
2) found between 650-1100m. Todos Santos Bay, Baja California; (Walton, 1955)
GENUS Cibicides

C. lobatulus
1) preference for coarse sand substrate in Newfoundland; (Boltovskoy and Wright, 1976)
2) found between 10-40m in Antarctica; (Murray, 1973)
3) found in shelly sands, 84-95m in English Channel; (Murray, 1973)
4) dominant on pebbles, shells, sands, and seagrass of Irish coast; (Murray, 1973)
5) found in nearshore sands of New Hampshire; (Murray, 1973)

C. wuellerstorfi
1) deeper than 2000m in western Gulf of Mexico and 1500m in eastern Gulf; (Pflum and Frerichs, 1976)
2) found at 1932m in Peru-Chile Trench; (Boltovskoy and Wright, 1976)
3) found in abundance deeper than 2000m in Sigsbee deep, Gulf of Mexico; (Phleger, 1960)
4) associated with bathyal zone; (Boltovskoy and Wright, 1976)
5) characteristic of lower slope, 500-2000m in Gulf Coast; (Albers et. al., 1966)
6) characteristic of deep sea, lower slope to abyssal plain, Gulf of Mexico; (Poag, 1981)
7) minimum depth of 700m and abundant between 2700-2800m in Gulf Coast; (Phleger and Parker, 1951)
8) found between 2500-4600m in Indian Ocean; (Corliss, 1979a)
9) common at depths of 2500m in well oxygenated North Atlantic Deep Water of temperate and subantarctic zones; (Caralp, 1984)

GENUS Cibicidoides

C. florianus
1) occurs in sandy sediments, 31-34 per mille salinity, off California coast; (Murray, 1973)
2) common on shelf and upper slope of Gulf of Mexico; (Poag, 1981)
3) common on coarse sand substrate of Bay of Biscay; (Boltovskoy and Wright, 1976)
4) characteristic of Gulf Coast shelf and slope between 20-200m; (Albers et. al., 1966)
5) becomes abundant deeper than 80m on Gulf Coast; (Phleger, 1980)
6) highest abundance between 71-122m on Gulf Coast; (Phleger and Parker, 1951)
GENUS Clavulina

*C. mexicana*
1) characteristic of outer shelf, 100-200m, Gulf Coast; (Albers et. al. 1966)

GENUS Cymbaloporella

*C. squammosa*
1) occurs on reefs in Gilbert Islands; (Murray, 1973)
2) occurs on barrier reefs in Belize; (Murray, 1973)

GENUS Dentalina

*D. pauperata*
1) found between 800-1600m of Central America; (Smith, 1964)

Genus Dyocibicidies

*D. biserialis*
1) found between 20-60m, Todos Santos Bay, Baja California; (Walton, 1955)

Genus Elphidium

*E. disoidale*
1) characteristic of upper faunal facies, Gulf of Mexico; (Phleger and Parker, 1951)
2) abundant in dead fauna of drowned reefs off Texas Gulf Coast; (Murray, 1973)
3) abundant in littoral zone, 0-15m off southern South America; (Murray, 1973)
4) present in brackish lagoonal waters off Brazil; (Boltovskoy and Wright, 1976)

GENUS Epistominella

*E. exigua*
1) extends from 20 to more than 1800m, abundant between 450-1800m, Gulf Coast; (Phleger and Parker, 1951)
2) upper depth limit of 600m, eastern Gulf of Mexico; (Pflum and Frerichs, 1976)
3) found between 200-3000m, Gulf Coast; (Phleger, 1960)
4) common in the shelf assemblage of eastern U.S.; (Murray, 1973)
5) found below 1932m in Chile-Peru Trench; (Murray, 1973)
6) scattered from outer shelf to abyssal plain, Gulf of Mexico; (Poag, 1981)
7) found between 37-140m off Central America; (Smith, 1964)
8) abundant between 2500-3500m, northern Pacific; (Saidova, 1961)
9) present in the shallow water off eastern South America; (Boltovskoy and Wright, 1976)
10) found between 2500-4600m in Indian Ocean; (Corliss, 1979a)

E(?) c.f. rugosa
1) ranges from 265-3400m, Gulf Coast; (Phleger and Parker, 1951)

GENUS Frondicularia

F. vaughani
1) outer neritic to middle bathyal species; (van Morkhoven, 1981)

GENUS Fursenkoina

F. pontoni
1) abundant on Texas shelf; (Poag, 1981)
2) characteristic of shelf fauna above 125m, Gulf Coast; (Phleger and Parker, 1951)
3) depth limit of 73m in Todos Santos Bay; (Murray, 1973)
4) depth range, 15-80m in Gulf of Mexico; (Murray, 1973)

GENUS Gavelinopsis

G. praegeri
1) 84-95m on a shelly substrate in the English Channel; (Murray, 1973)
2) 60-245m on a muddy to gravelly sand substrate in the Bay of Biscay; (Murray, 1973)

GENUS Gyroidina

G. regularis
1) moderate abundance on the outer shelf to upper slope of the Gulf of Mexico; (Poag, 1981)
2) upper depth limit of 600m in Gulf of Mexico; (Pflum and Frerichs, 1976)
3) low abundance on Gulf Coast between 150-1000m; (Phleger and Parker, 1951)
4) abundant between 100-200m on Gulf coast; (Phleger, 1960)

G. soldanii
1) found in Indian Ocean between 2500-4600m; (Corliss, 1979a)
2) characteristic of upper slope, 200-500m, Gulf Coast; (Albers et. al., 1966)
3) found between 1300-3200m off Pacific Coast of Central America; (G. altiformis of Smith, 1964)
4) found between 280-2600m in Catalina Channel; (Natland, 1933)
5) found between 1850-3800m of Pt. Arguello, California; (Bandy, 1953)

Genus Hanzawaiia

H. concentrica
1) common on inner shelf, estuaries, and bays of the Gulf of Mexico; (Poag, 1981)
2) abundant in less than 100m; (Phleger and Parker, 1951)
3) inner shelf, 0-20m; (Albers et. al., 1966)
4) 22-78m on Texas shelf; (Murray, 1973)

GENUS Hoeclundina

H. elegans
1) found at 2524, 2897, 3071, and 4289m in the Indian Ocean, where it appears to be an bathyal form; (Corliss, 1979a)
2) found in the warmer, upper part of North Atlantic Deep Water; (Caralp, 1984)
3) characteristic of upper slope, 200-500m, Gulf Coast; (Albers et. al., 1966)

GENUS Karreriellia

K. bradyi
1) uncommon occurrence in Indian Ocean at 2500-3100m; (Corliss, 1979a)

GENUS Laticariniina

L. pauperata
1) commonly found in association with Cibicides wueller-storfi in modern North Atlantic Deep Water at depths of 2500m; (Caralp, 1984)
2) characteristic of lower slope, 500-2000m, Gulf Coast, (Albers et. al., 1966)
3) upper depth limit of 400m in Gulf of Mexico; (Pflum and Frerichs, 1976)

GENUS Martinottiiella

M. pallida
1) found in deep basins off southern California; (Murray, 1973)
GENUS Melonis

M. barleeanus
1) deep sea indicator; (Murray, 1973)
2) questionable upper depth limit of 200m; (Pflum and Frerichs, 1976)
3) upper slope environment, 200-500m; (Albers et al., 1966)
4) commonly found in Indian Ocean between 2500-4500m; (Corliss, 1979a)

M. pompilicidens
1) found between 3257-4606m in Peru/Chile Trench; (Murray, 1973)
2) found in Indian Ocean between 2500-4600m; (Corliss, 1979a)
3) upper depth limit of 1500m; (Ingle, 1967)
4) characteristic of abyssal environment, > 2000m, Gulf Coast; (Albers et al., 1966)
5) a reliable indicator of deep water, > 1800m, in the modern world ocean; (van Morkhoven, 1981)
6) found between 1859-3800m off Pt. Arguello, California; (Bandy, 1953)

GENUS Miliolinella

M. subrotunda
1) found on protected boulder beaches in New England; (Murray, 1973)

GENUS Miniacina

M. miniacea
1) found in Posidonia habitats in Provence, southern France; (Murray, 1973)

GENUS Neoconorbina

N. terguemi
1) found on coarse sand substrate off southern California; (Murray, 1973)

GENUS Neoeponides

N. antilarum
1) characteristic of middle shelf, 20-100m, Gulf of Mexico; (Albers et al., 1966)

N. bryamensis
1) an upper bathyal species; (van Morkhoven, 1981)
GENUS *Nodobaculariella*

*N. cassis*
1) found on drowned reefs on Gulf Coast, 70-100m; (Murray, 1973)

GENUS *Nonionella*

*N. miocenica*
1) common in shelf seas off northeast Japan; (Murray, 1973)
2) common in Mississippi delta region and rare in deeper water of Gulf of Mexico; (Poag, 1981)
3) characteristic of middle shelf, 0-50m, California coast; (Bandy, 1953)

GENUS *Osanularia*

*O. culter*
1) characteristic of lower slope, 500-2000m, Gulf Coast; (Albers et al., 1966)

GENUS *Pararotalia*

*P. sarmientoi*
1) sandy shallow deposits less then 13m; (Drooger and Kaasschieter, 1958)
2) abundant in nearshore clastic sediments on Caribbean shelf of Nicaragua; (Manning, 1985)

GENUS *Planulina*

*P. ariminensis*
1) characteristic of upper and middle bathyal zones; (van Morkhoven, 1981)

GENUS *Plectofrondicularia*

*P. floridana*
1) outer neritic to bathyal species; (van Morkhoven, 1981)

GENUS *Pseudononion*

*P. basispinata*
1) common in shallow waters off Caribbean coast of Nicaragua; (P. *atlanticum* of Manning, 1985)
2) characteristic of upper faunal facies, 0-120m, Gulf of Mexico; (P. *atlanticum* of Phleger and Parker, 1951)
3) common in fine sediment, 0-24m off southern California, and found to the base of turbulent zone, 82m; (Nonionella in Murray, 1973)
4) found in living assemblage to 65m off Santa Catalina Island; (Nonionella in Murray, 1973)
5) found in fine sands and silts, 18-73m, Todos Santos Bay, Baja California; (Nonionella in Murray, 1973)
6) found between 0-20m, Pacific coast of Central America; (Nonionella of Smith, 1964)
7) found between 12-30m off San Diego; (Nonionella of Bandy, 1953)
8) found between 0-25m off San Diego; (Nonionella of Uchio, 1960)

P. grateloupia
1) characteristic of inner shelf, 0-20m, Gulf Coast; (Albers et. al., 1966)

GENUS Pullenia

P. bulloiides
1) found between 1932-6011m in Peru/Chile Trench; (Murray, 1973)
2) commonly found in Indian Ocean between 2500-4600m; (Corliss, 1979a)
3) found between 1300-3200m off Pacific coast of Central America; (Smith, 1964)
4) found between 2000-2600m in Catalina Channel; (Natland, 1933)

GENUS Quinqueloculina

Q. lamarckiana
1) living in intertidal zone and tidepools, Santa Monica Bay, California; (Murray, 1973)
2) found between 5-32m, Gulf of California; (Murray, 1973)
3) characteristic of upper faunal facies, Gulf of Mexico; (Phleger and Parker, 1951)

GENUS Rectuvigerina

R. multicoxtata
1) found at bathyal depths; (van Morkhoven, 1981)

GENUS Reussella

R. spinulosa
1) inner shelf, 0-20m; (Albers et. al., 1966)
2) most abundant less than 120m; (Phleger and Parker, 1951)
GENUS Rosalina

R. globularis
1) abundant on rocky coasts of Wales; (Murray, 1973)

GENUS Sicoilina

S. tenuis
1) low abundance on Gulf Coast between 150-2000m; (Phleger, 1960)
2) found from 38-2100m off Central America; (Smith, 1964)

GENUS Siphogenerina

S. transversa
1) upper to mid slope preference; (Lamb and Miller, 1984)
2) most common in upper bathyal deposits; (van Morkhoven, 1981)

S. senni
1) a bathyal species; (van Morkhoven, 1981)

GENUS Siphonina

S. pulchra
1) most common of Gulf Coast between 3-225m; (Phleger and Parker, 1951)
2) common in middle shelf open marine areas, 20-100m; (Albers et. al., 1966)

GENUS Sphaeridina

S. bulloides
1) uncommon occurrence in Indian Ocean at 2500-4300m; (Corliss, 1979a)
2) characteristic of upper slope, 200-500m, Gulf Coast; (Albers et. al., 1966)
3) predominantly a middle and upper bathyal form; (van Morkhoven, 1981)

GENUS Trifarina

T. angulosa
1) characteristic of outer shelf, 50-200m, off San Diego; (Bandy, 1953)

GENUS Textularia

T. mexicana
1) found between 125-430m on Gulf Coast; (Phleger and Parker, 1951)
GENUS Trifarina

T. angulosa
1) 0-15m off Argentina; (Boltovskoy and Wright, 1976)
2) 25-82m off southern California; (Murray, 1973)
3) found in fine sands and silts, 0-27m off Baja California; (Murray, 1973)
4) sandy shelf sediments off Carolinas; (Murray, 1973)
5) characteristic of the shallow shelf off eastern South America; (Boltovskoy and Wright, 1976)
6) prefers sandy substrate in the Bay of Biscay; (Boltovskoy and Wright, 1976)

GENUS Triloculina

T. trigonula
1) common in carbonate rich biotopes of the Gulf of Mexico continental shelf; (Poag, 1981)
2) preference for fine grained (silty) substrate off French coast; (Boltovskoy and Wright, 1976)

GENUS Uvigerina

U. auberiana
1) rare occurrence in deep water muds off southern France between 370-2400m; (Murray, 1973)
2) common between 825-1190m off southern California; (Murray, 1973)
3) 200-5000m on Gulf Coast; (Phleger, 1960)
4) indicative of depths greater than 120-250m; (Boltovskoy and Wright, 1976)
5) abundant on outer shelf and upper slope of Gulf of Mexico; (Poag, 1981)
6) upper limit of 30m, abundant between 100-210m on Gulf Coast; (Phleger and Parker, 1951)
7) deeper than 1000m in Gulf; (Parker, 1955)

U. ex. gr. peregrina
1) abundant on outer shelf to upper slope of Gulf of Mexico; (Poag, 1981)
2) characteristic of depths of 45-135m on Gulf Coast; (Phleger and Parker, 1951)
3) outer shelf open marine, 100-200m; (Albers et. al., 1966)
4) muddy substrate off French coast; (Boltovskoy and Wright, 1976)

U. flinti
1) restricted to 100-200m on Gulf Coast; (Phleger and Parker, 1951)
2) common on outer shelf to upper slope in Gulf of Mexico; (Poag, 1981)
### TABLE 8

**FACTOR SCORES**

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<th>Sample #</th>
<th>Factor #1</th>
<th>Factor #2</th>
<th>Factor #3</th>
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<tr>
<td>3-121</td>
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<td>-0.173</td>
<td>-0.434</td>
<td>-0.488</td>
<td>3.446</td>
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<p>| <strong>Quebrada Uscaari Section</strong> | | | | | |
| 3-74 | 2.412 | -0.353 | -0.294 | -0.020 | 0.337 |
| 3-71 | 2.683 | -0.209 | 0.048 | -0.487 | 0.263 |
| 3-69 | 2.225 | -0.274 | -0.016 | -0.012 | 0.176 |
| 3-67 | 2.492 | -0.251 | -0.222 | -0.325 | 0.726 |
| 3-66 | 2.306 | -0.357 | -0.038 | -0.194 | 1.376 |</p>
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<th>Factor #3</th>
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<td>112</td>
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**Rio Banano Sandstones**

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<th>Factor #3</th>
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<tr>
<td>213</td>
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<td>218</td>
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<td>83</td>
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**Moin Formation**

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<td>61</td>
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<tr>
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<tr>
<td>65</td>
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<tr>
<td>67</td>
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<td>79</td>
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</table>
CHAPTER 7

OSTRACODA

During the course of laboratory work ostracoda were picked from the washed sample residues along with foraminifera from the three formations. The specimens identifiable to specific level are included in the Plates.

The ostracoda were not used in paleoenvironmental analysis. Rather, the ostracods were picked in the hope that they might be useful in the deliniation of biostratigraphy in sections where planktonic foraminifera were found to be either sparse or lacking in precision. In the Rio Banano sandstones, where the foraminiferal faunas were sufficient only to place the unit in the Late Miocene to Early Pliocene, the presence of Radi mel1 ovata served to precisely place the section at the Miocene-Pliocene boundary, based on the very restricted biostratigraphic range of this taxon (W.A. van den Bold, pers. comm., 1986). In the deep water Uscari Formation the ostracods did not enhance the foraminiferal biostratigraphic determinations, although the foraminiferal faunas in some samples did not exhibit narrow ranges. The Moin Formation exhibited a well developed foraminiferal fauna and ostracods were not used in this unit.

The paleoecological difference between the Uscari
Formation type section in Quebrada Uscari, and outcrops in the Rio Reventazon and Quebrada Terciopelo sections is reflected in the relative abundances of ostracods in these sections. Ostracods were not found in the type section, but were present in all other sections, albeit in low abundance. The upper part of the Uscari Formation in Quebrada Terciopelo had a lower abundance of ostracods than the lower part of the section, or the Rio Reventazon section. Table 9 is a list of all identified ostracoda.

---

**TABLE 9**

**OSTRACODA IDENTIFIED FROM THE UNITS OF STUDY**

All identifications by W. A. van den Bold, 1986. NF means "Not Figured".

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARGILLOECIA SP.</td>
<td></td>
</tr>
<tr>
<td>AURILA SP.</td>
<td></td>
</tr>
<tr>
<td>BYTHOCERATINA SP.</td>
<td></td>
</tr>
<tr>
<td>BRADLEYA EX. GRP. DICTYON</td>
<td>28</td>
</tr>
<tr>
<td>CAUDITES SP.</td>
<td></td>
</tr>
<tr>
<td>CYTHERELLA SP.</td>
<td></td>
</tr>
<tr>
<td>CYTHEROPTERON FALTON(?)</td>
<td>28</td>
</tr>
<tr>
<td>CYTHEROPTERON WARDENSIS</td>
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</tr>
<tr>
<td>ECHINOCYTHEREIS MARGARITIFERA</td>
<td>28</td>
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<tr>
<td>KRITHE DOLICHODER A.</td>
<td>28</td>
</tr>
<tr>
<td>LOXOCHONCHA LAPIDISCOLA</td>
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<tr>
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<tr>
<td>PTERYGOCYTHEREIS SP.</td>
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<tr>
<td>RADIMELLA SP.</td>
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**RIO BANANO FORMATION**

**a. SAMPLE #213**

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<tr>
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<tr>
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</tr>
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<td>LOXOCHONCHA FISCHERI</td>
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<tr>
<td>PUMILOCYTHERIDEA SANDBERGI</td>
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**b. SAMPLE #97**

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<tr>
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<td>RADIMELLA OVATA</td>
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**c. SAMPLE #50 (from Recope Refinery outcrop)**

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<td>KANGARINA QUELLITA</td>
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<tr>
<td>LOXOCHONCHA DORSOTUBERCULATA</td>
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<td>MICROCYTHERE INFLEXA</td>
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<tr>
<td>ORIONINA SERRULATA</td>
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<td>PARACYTHERIDEA TSCHOPPI</td>
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<td>PERISOCYTHERIDEA RUGATA</td>
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USCARI FORMATION

a. RIO REVENTAZON SECTION

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<td>KRITHE SP.</td>
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b. QUEBRADA TERCIOPELO SECTION

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The Quebrada Uscari type section samples of the Uscari Formation did not yield any ostracoda.
CHAPTER 8

FAUNAL COMPARISONS

The benthic foraminiferal faunas of the Uscari, Rio Banano, and Moin Formations are here compared with the foraminifera of other time equivalent stratigraphic units in Central America and the Caribbean region. Table 10 is a summary of the units compared.

OLIGOCENE

The basal Uscari Formation in Quebrada Terciopelo is dated as Late Oligocene. These thin limestones containing larger foraminifera and rhodoliths were deposited on a warm, shallow, current swept carbonate shelf in 0 to 10 meters of water. A similar foraminiferal fauna is present in thin limestones of the Oligocene part of the Terraba Formation (Henningsen, 1966; Yuan, 1985). These limestones contain Lepidocyclina (L.) waylandvaughnii and Heterostegina antillea, which are present in the Uscari Formation, and several other species of larger foraminifera. Yuan defined the Rio Claro Member of the Terraba Formation as thin beds of Oligocene limestone containing rhodoliths and larger foraminifera. In the Canal Zone of Panama, Cole
(1952) identified a larger foraminiferal fauna from thin limestones of the Late Oligocene Bohio Formation and the upper Oligocene part of the Caimito Formation. In addition to the two species reported from the Uscari Formation, several other species were identified.

EARLY MIOCENE

In the Limon Basin the stratigraphic sequence of the Uscari Formation shows a drastic change in environment from shallow water Late Oligocene limestones to deep water Late Oligocene to Early Miocene shales. The deep water, fine grained clastic nature of Early Miocene sedimentation is seen in a number of other units in the Central American/Caribbean region.

The Early Miocene mudstones, siltstones, and sandstones of the Terraba Formation on the Nicoya Peninsula (McKee, 1985) and Terraba Trough in southern Costa Rica (Yuan, 1984) show faunal similarities to the lower Uscari Formation. Both units contain species which indicate a deep bathyal to abyssal environment. Lower bathyal to abyssal foraminifers were reported in both units. Melonis pompilioides, Siphogenerina transversa, Ehrenbergina caribbea, Pullenia bulloides, Martinottiella pallida, and Cibicides wuellerstorfi were all found both in the lower Uscari and Terraba Formations.
There is evidence for turbidite deposition in both units. Yuan, on the basis of sedimentological evidence, interpreted the sediments in the Terraba Trough to be turbidites. On the Nicoya Peninsula McKee reported the presence of shallow water foraminifers in deep water sediments, but offered no field evidence for turbidites. This is similar to the Uscari Formation of the southern Limon Basin where turbidites are inferred based upon a displaced shallow water fauna.

In Panama, the foraminifera of the thinly bedded shales and limestones of the Aquaqua and Aruza Formations and the calcareous shales and marls of the Caimito Formation of Early Miocene age (Terry, 1956) also suggest deposition in a deep bathyal to abyssal environment. Deep water Uscari species found in these units include Chilostomella ovoidea, Osangularia culter, Cyclammina cancellata, Melonis pompilioides, Sphaeroidina bulloides, Textularia agglutinans, Martinottiella cyclostromata (Clavulina of Terry), Pullenia bulloides, and Siphogenerina transversa. The limestones of the Aquaqua and Aruza Formations were reported to be a compact ooze composed largely of radiolarian tests, while the clays were reported to be bentonitic. Uscari Formation claystones are also bentonitic (Taylor, 1975) suggesting that the clastic source area for both was volcanic, probably nearby volcanic islands. All units have a significant amount of planktonic foraminifera.
The trend of Early Miocene deep water sedimentation can be followed southward into northern South America. Shales in the Lower Magdalena Basin of Colombia (Dugue-Caro, 1972; Bordine, 1974) and the siltstones and mudstones of the San Lorenzo and lower Pozon Formations in northern Venezuela (Renz, 1948) contain the same deep water species found in the Uscari Formation. Bordine suggested an abyssal environment subject to turbidites for the Magdalena Basin rocks. Blow (1959) reported planktonic percentages of 70% to 78% in the deepest water sediments of the San Lorenzo and lower Pozon Formations, values comparable to the lower Uscari Formation planktonic percentage values.

Further to the east in the area of Trinidad, the environment of deposition was definitely abyssal. The Cipero Formation (Cushman and Stainforth, 1945) is essentially an abyssal ooze having a planktonic percentage of 98%. The sediments also contain the abyssal benthic taxa *Hyperammina* and *Hormosina*.

**LATE EARLY TO EARLY MIDDLE MIocene**

During this time interval sedimentation in the southern part of the Limon Basin was occurring in a shallowing sequence from middle to upper bathyal to continental shelf environments. The middle and upper parts of the Uscari Formation show this shallowing trend. Other units of
correlative age in the Central American/Caribbean region show similar environments.

On the Pacific side of Costa Rica the foraminifera of the Middle Miocene Terraba Formation (McKee, 1985) indicate a bathyal environment subject to downslope transport of shallow water material. *Ehrenbergina caribbea* indicates a slope environment, but the majority of the fauna is shelf derived material. The absence of other deep water species suggests an upper slope environment.

Farther to the southeast, in Venezuela, the foraminifera of the Huso Member of the Middle Miocene Pozon Formation, Agua Salada Group, (Renz, 1948; Blow, 1959) were deposited on a continental shelf at depths of 50 to 100 meters. The fauna is dominated by common shelf taxa also found in the upper Uscari Formation. Both the Middle Miocene Uscari Formation and Agua Salada Group have a less diverse fauna than the Early Miocene sediments. In the Magdalena Basin of northern Colombia the paleodepth was much greater. The area was a deep trough receiving turbiditic sediments (Dugue-Caro, 1972).

At the end of the Early Miocene the area around Trinidad remained an abyssal basin. Deep water benthic foraminifera of Zone III of the upper Cipero Formation (Cushman and Stainforth, 1945) indicate an abyssal environment. The planktonic percentage of Zone III is 96% (Blow, 1959).
LATE MIOCENE TO EARLY PLIOCENE

The inner shelf deposits of the Rio Banano sandstones in the Limon Basin are shallower than deposits of the same age on the Pacific side of Costa Rica. On the Nicoya Peninsula the Early to Middle Pliocene siltstones and sandstones of the Montezuma Formation show foraminiferal evidence of deposition on the outer continental shelf to upper slope (McKee, 1985). These Montezuma sediments contain many shelf species found in the Rio Banano sandstones, but also contain deeper water taxa such as Gyroïdina soldanii and Plectofrondicularia. Farther to the south, on the Osa Peninsula, the foraminifera of the Punta La Chancha Formation were interpreted by Lew (1983) as Middle Pliocene deposits in water depths as great as 600 to 1200 meters. A few shallow water contaminants were also present.

In the Magdalena Basin of Colombia the Late Miocene to Early Pliocene Tubara Formation (Bordine, 1974) was deposited in conditions similar to the Rio Banano sandstones. The benthic foraminifera show affinities to the Rio Banano fauna with shallow shelf and reef derived material mixed with shelf taxa. An open marine, neritic environment of moderate depth has been suggested for the Tubara Formation (Redmond, 1953). Both units were deposited on a current swept, sandy shelf where nearshore sediments were

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carried out onto the shelf.

The shallow shelf conditions of the Limon Basin in Costa Rica and Magdalena Basin in Colombia also existed in southern Mexico in the Early Pliocene. The siltstones and calcareous clays of the Concepcion and Encanto Formations of the Salina Basin were deposited in a shallowing sequence from upper bathyal (700 meters), through outer neritic, to inner neritic (50 meters) (Kohl, 1985). The upper part of the sequence, the upper Concepcion Formation, was deposited in an environment similar to that of the Rio Banano sandstones. The same shelf taxa are found in both units and the planktonic percentage of the upper Concepcion (22%) is similar to the Rio Banano sandstones.

PLEISTOCENE

In Panama the foraminifera of the Playa Grande and Mare Formations of the Cabo Blanca Group (Bermudez and Fuenmayor, 1962) show similarities to the Moin Formation. The Playa Grande Formation was placed in the Pliocene but, in actuality, is Pleistocene (Bermudez and Bolli, 1969).

The characteristic lithology is marl containing abundant foraminifera (also planktonics) and coral fragments, interbedded with conglomerate. Nearshore or attached/biohermal species are found mixed with taxa preferring deeper water and a fine grained substrate.
TABLE 10

STRATIGRAPHIC UNITS IN THE CENTRAL AMERICAN/CARIBBEAN REGION COMPARABLE WITH THE MOIN, RIO BANANO, AND USCARI FORMATIONS.

Taxonomic names listed in this table have been changed to conform with the taxonomy of this study.

+---------------------------------+---------------------------------+
|                                |                                |
|                                |                                |
| **MOIN FORMATION**             |                                |
|                                |                                |
| Panama                         |                                |
|                                |                                |
| Bermudez and Fuenmayor, 1962   |                                |
| Playa Grande and Mare Formations |                                |
|                                |                                |
| **Nearshore Taxa**             |                                |
| CYMBALOFORETTA SQUAMMOSA      | PARAROTALIA SARMIENTOI         |
| ARCHAIS ANGULATUS              | QUINQUELOCULINA LAMARCKIANA     |
| Q. POEYANUM                    | AMMONIA PARKINSONIANA          |
| AMPHISTEGINA GIBBOSA           | ASTERIGERINA CARINATA          |
| ELPHIDIUM LANIERI              | E. DISCOIDALE                  |
|                                |                                |
| **Shelf Taxa**                 |                                |
| BULIMINA MARGINATA             | CIBICIDOIDES FLORIDANUS        |
| HANZAWAIA CONCENTRICA          | LIEBUSELLA SOLDANI             |
| NONIONELLA GRATELOUPI          | FURSENKOINA PONTONI            |
| UVIGERINA AUBERIANA            | U. PEREGRINA                   |
| SARACENARIA ITALICA            | SIPHONINA PULCHRA              |
| FRONDICULARIA SAGGIYULA        | ROSALINA GLOBULARIS            |
|                                |                                |
| **RIO BANANO FORMATION**       |                                |
|                                |                                |
| **Costa Rica**                 |                                |
|                                |                                |
| McKee, 1995                    |                                |
| Montezuma Formation            |                                |
| Nicoya Peninsula, Pacific coast|                                |
|                                |                                |
| **Shelf Taxa**                 |                                |
| CASSIDULINA LAEVIGATA          | FURSENKOINA PONTONI            |
| BOLIVINA SPP.                  | PLANORBULINA MEDITERRANENSIS   |
| PYRGO SUBSPHAERICA             | ROSALINA GLOBULARIS            |
|                                |                                |

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GYROIDINA SOLDANII  
PLECTOFRONDICULARIA SP.
Lew, 1983  
Punta La Chancha Formation  
Osa Peninsula, Pacific coast

Slope Taxa

CIBICIDES LOBATULUS  
PLANULINA ARIMINENSIS  
UVIGERINA PÆREGRINA  
CASSIDULINA SP.

Shelf Taxa

HANZAWAIA CONCENTRICA  
TRIFARINA ANGULOSA  
PLANORBULINA MEDITERRANENSIS

Slope Taxa

EHRENBERGINA BRADYI  
PYRGÔ SARSI  
BOLIVINITA SP.

PULLENIA QUINQUELOBA

Redmond, 1953
Tubara Formation  
Magdalena Basin of northern Colombia

Nearshore Taxa

AMMONIA SP.  
PARAROTALIA SARMIENTOI  
BULIMINELLA ELEGANTISSIMA  
ELPHIDİUM SP.
AMPHISTEGINA SP.  
ASTERIGERINA CARINATA  
CYMBALOFORETTA SQUAMMOSA  
QUINQUELOCULINA SPP.

Shelf Taxa

FAVONINA MIOCENICA  
ANOMALINOIDES IO  
UVIGERINA PÆREGRINA  
CASSIDULINA SP.  
PLANULINA ARIMINENSIS

Mexico

Kohl, 1985
Concepcion Formation and Encanto Fm. Salina Basin of southeastern Mexico

Nearshore Taxa

AMMONIA PARKINSONIANA  
AMPHISTEGINA GIBBOSA  
ELPHIDİUM POEYANUM  
PSEUDONONION BASISPINATA

Shelf Taxa

BULIMINA MARGINATA  
CIBICIDIOIDES FLORIDANUS  
FURSENKOINA PÆNTONI  
LENTICULINA CALCAR  
CASSIDULINA CURVATA  
PSEUDONONION GRATELOUPI  
HANZAWAIA CONCENTRICA  
REUSSELLA SPINULOSA
USCARI FORMATION

********** Late Oligocene **********

Costa Rica

Henningsen, 1966; Yuan, 1984
Rio Claro Member of the Terraba Formation southwestern Costa Rica

Nearshore Taxa
LEPIDOCYCLINA (L.) WAYLANDVAUGHNI L. (L.) VAUGHNI L. (L.) YURNAGUNENSIS L. (N.) VAUGHNI L. (L.) ÜNDOSA L. (L.) YURNAGUNENSIS L. (L.) MANTELLI MYOGYPSINA SP. CF. PANAMAENSIS

Panama

Cole, 1952
Bohio Formation Canal Zone

Nearshore Taxa

********** Early Miocene **********

Costa Rica

McKee, 1985
Terraba Formation Pacific coast of Costa Rica

Shelf Taxa
FURSENKOINA PONTONI HANZAWAIA CONCENTRICA BOLIVINA SP.
<table>
<thead>
<tr>
<th>Deep Slope to Abyssal Taxa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>STILOSTOMELLA FAUPERATA</td>
<td>GYROIDINA ALTIFORMIS</td>
</tr>
<tr>
<td>STILOSTOMELLA VERNEUILI</td>
<td>SIPHOGENERINA TRANSVERSAL</td>
</tr>
<tr>
<td>EHRENBERGINA CARIBBEA</td>
<td>PULLENIA BULLOIDESY</td>
</tr>
<tr>
<td>MELONIS POMPILIOIDES</td>
<td>CIBICIDES WUELLERSTORFI</td>
</tr>
</tbody>
</table>

Yuan, 1984
Terraba Formation Tarraba Trough of southwestern Costa Rica

<table>
<thead>
<tr>
<th>Deep Slope to Abyssal Taxa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PRAEGLOBULIMINA PUPOIDES</td>
<td>MELONIS POMPILIOIDES</td>
</tr>
<tr>
<td>SIPHOGENERINA TRANSVERSAL</td>
<td></td>
</tr>
</tbody>
</table>

Panama

Terry, 1956
Aquaqua and Aruza Formations

<table>
<thead>
<tr>
<th>Deep Slope to Abyssal Taxa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CHILOSTOMELLA OVOIDEA</td>
<td>OSANGULARIA CULTER</td>
</tr>
<tr>
<td>CYCLAMMINA CANCELLATA</td>
<td>STILOSTOMELLA CONSOBRINA</td>
</tr>
<tr>
<td>MELONIS POMPILIOIDES</td>
<td>SPHAERIDINA BULLOIDES</td>
</tr>
<tr>
<td>TEXTULARIA AGGULITINANS</td>
<td>PLECTOFRONDICULARIA CALIFORNICA</td>
</tr>
<tr>
<td>PLECTOFRONDICULARIA FLORIDANA</td>
<td></td>
</tr>
</tbody>
</table>

Terry, 1956
Caimito Formation

<table>
<thead>
<tr>
<th>Nearshore and Shelf Taxa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPHISTEGINA GIBBOSA</td>
<td>PENEROPLIS SP.</td>
</tr>
<tr>
<td>QUINQUELOCULINA LAMARCKIANA</td>
<td></td>
</tr>
</tbody>
</table>

Blacut and Kleinpell, 1969
La Boca Formation

<table>
<thead>
<tr>
<th>Nearshore Taxa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ELPHIDIIUM SP.</td>
<td>AMPHISTEGINA LESSONI</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shelf and Upper Slope Taxa</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MARGINULINA SUBBULLATA</td>
<td>DENTALINA FAUPERATA</td>
</tr>
<tr>
<td>FURSENKOINA PONTONI</td>
<td>CASSIDULINA SUBGLOBOSA</td>
</tr>
<tr>
<td>NONION INCISIUM</td>
<td>CIBICIDIOIDES FLORIDANUS</td>
</tr>
</tbody>
</table>

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### Northern South America

<table>
<thead>
<tr>
<th>Location</th>
<th>Formation / Time Period</th>
<th>Taxa</th>
</tr>
</thead>
</table>
Deep Slope and Abyssal Taxa: Hoeplundina elegans, Pulleinia bulloides, Melonis pompidoides, Cyclammina cancellata, Cibicides Wueellerstorfi |
| Renz, 1948 | San Lorenzo and lower Pozon Formations, northeastern Venezuela | Deep Slope and Abyssal Taxa: Planulina Dohertyi, Planulina Marialana, Textularia Lalickeri, Laticarinina pauperata, Pseudoglobobulimina Pupoides, Siphogenerina Transversa |
| Cushman and Stainforth, 1945 | Cipero Formation Trinidad | Abyssal Taxa: Hyperammina sp., Hormosina sp. |

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### Costa Rica

<table>
<thead>
<tr>
<th>Location</th>
<th>Formation / Time Period</th>
<th>Taxa</th>
</tr>
</thead>
</table>
| McKee, 1985 | Terraba Formation Pacific Coast of C.R. | Nearshore and Shelf Taxa: Pseudononion basispinata, Ammonia Parkinsoniana, Hanzawaia Concentrica, Cibicoides floridanus  
Slope Taxa: Ehrenbergina Caribea, Cassidulina subglobosa |
Northern South America

Renz, 1948
Huso Member, Pozon Formation   Northeast Venezuela

Shelf and Nearshore Taxa
AMPHISTEGINA GIBBOSA   CASSIDULINA LAEVIGATA
CIBICIDES CONCENTRICA   MARGINULINA SUBBULLATA
PSEUDONONION COSTAFERUM   LENTICULINA CALCAR
HISTORY OF SEDIMENTATION

The presence of extrusive basalts below the Uscari Formation in Quebrada Terciopelo, and the inclusion of clasts of the basalt in the Latest Oligocene limestones of this section, suggests exposure and erosion in the earlier Oligocene, 25 to 30 mybp. Vail and Hardenbol (1979) report a global sea level drop of greater than 200 meters in the Late Oligocene which could account for the erosion of the basalt. In the Limon Basin during Late Oligocene time carbonate deposition was occurring on a shallow continental shelf receiving volcanioclastic sediment input from volcanic islands to the west. Upper Eocene and Oligocene rocks near Quebrada Terciopelo contain reef and bioclastic limestone facies rocks (Rivier, 1971). Yuan (1984) interpreted the sequence in the Terraba Trough on the Pacific side of southern Costa Rica to indicate exposure and erosion at approximately 30 mybp, related to a global sea level drop. The northwestern Limon Basin during the Middle to Late Oligocene was either emergent, or the site of shallow water carbonate shoal deposition.

A very rapid basin subsidence is indicated in the
latest Oligocene to earliest Miocene. The beginning of subsidence in the basin may be reflected in the differing textures of the lower and upper limestones in the Quebrada Terciopelo section. A small amount of subsidence may have allowed the preservation of igneous mineral grains in the upper of the two limestones, perhaps as a result of increased sedimentation rate. Deep water shales of the lower Terciopelo section overlie shallow water limestones. The rapid subsidence of the basin in the area of Quebrada Terciopelo has been attributed by Rivier (1973) to a down-dropped graben structure. This idea is based upon the greater thickness of the Uscari Formation in Quebrada Terciopelo compared with other sections in the area. Although no evidence of faulting was offered by Rivier to support his idea, a rapidly subsiding graben would help account for the change in environments. This rapid deepening of the depositional environment of the Uscari Formation, indicated by the shales of the lower Quebrada Terciopelo section, also reflects a global rise in sea level of greater than 100 meters in the Late Oligocene–Early Miocene (Vail and Hardenbol, 1979). This sea level rise alone cannot account for the bathyal depth of these shales but, in conjunction with the downdropping of a graben, can account for the very rapid change in depositional environment from shallow water limestone to bathyal shale seen in the lower Uscari Formation.
If the rapid change in depositional facies of the lower Quebrada Terciopelo sediments can be, at least partially, attributed to a rapidly subsiding graben in the Early Miocene, the structure must have been local. Rivier postulated the existence of a graben based upon the greater thickness of the Uscari Formation in Quebrada Terciopelo than in other quebradas nearby. Any large scale down-dropping of the Nicaragua Depression, rather than a localized event, should be reflected in the sedimentary facies of the rocks farther to the northwest, in Nicaragua. The Oligocene-Miocene sequence on the coastal plain of Nicaragua shows no similar event in the Early Miocene. During the Oligocene and Early Miocene the Masachapa Formation consists of a "... monotonous sequence of tuffitic and carbonate shales, siltstones, and sandstones..." (Weyl, 1980, p. 106).

Geological mapping of the Nicaragua Trough in Nicaragua has shown that structure to be composed of many individual grabens, rather than one large structure (Weyl, 1980). This is probably also the situation in the Limon Basin. The connection between the Limon Basin and the Nicaragua Trough was probably interrupted from the Middle Oligocene onwards by the emergence of a large island area in the northwest of Costa Rica (Weyl, 1980). The subsidence of a localized graben in the area of Quebrada Terciopelo would not necessarily be reflected in rocks elsewhere.
in the Nicaragua Depression.

In the late Early Miocene the Limon Basin began to be uplifted. The middle slope deposits of the lower Terciopelo section grade up section into upper slope and shelf deposits in the upper Terciopelo section. Near the top, an unconformity separates the Uscari Formation from younger rocks which are lateral equivalents of the Rio Banano sandstones. The upper 20 meters of the Terciopelo section is placed in the Early Pliocene zones N19 to N21.

The inner continental shelf deposits of the Rio Banano Formation suggest that by the time these rocks were being deposited, land was emergent in the area of the southern Limon Basin. The middle samples from the Rio Banano section, placed in early zone N18, suggest emergent land in the southern Limon Basin at least by the beginning of N18 time, in the earliest Pliocene at about 5 mybp, and probably in the Late Miocene. A Late Miocene (N 17) brackish water, nearshore foraminiferal fauna from the northern part of the Limon Basin, which Sen Gupta, et. al. (1986) interpret as a Late Miocene shoreline deposit, suggests emergent land in the northern Limon Basin by Late Miocene time.

Keigwin (1982) reported planktonic foraminiferal faunas recovered from deep sea cores in the Caribbean and Pacific indicate gradual faunal divergence in the two areas did not occur until 3 to 4 mybp. Keigwin suggested by 3
mybp surface water exchange was cutoff due to a completely emergent isthmus. The taxa used by Kegwin to date the faunal divergence are *Pulleniatina* and *Globorotalia*. These are non-spinose forms with heavy tests (*Globorotalia* has a heavy keel) adapted to living in the middle to lower reaches of the water column (Haq and Boersma, 1978). Neither taxa has been reported containing the symbiotic algae characteristic of spinose, surface water species which inhabit the photic zone. The depth indications of these two taxa are an upper limit of about 50 to 75 meters extending down to hundreds of meters. Thus, it is possible that surface waters, above 50 to 75 meters, could have been exchanged even later than 3 mybp without involving exchange of these deeper species. The presence of *Amphistegina gibbosa* in Late Neogene sediments both on and offshore Southern California (Crouch and Poag, 1979) is evidence for continued surface water exchange between the Caribbean and Pacific basins subsequent to 3 mybp. Crouch and Poag suggest this shallow water benthic foraminifer migrated from the Caribbean as late as 1.8 mybp through a shallow seaway connection at that time, with severe restriction of interchange of planktonic organisms between the Caribbean and Pacific about 3.5 mybp, culminating in complete emergence of the isthmus by 1.8 mybp.

The evidence presented here for emergent land at least by 5 mybp in the Limon Basin suggests uplift of
the Central American isthmus progressed in a north to south direction. By 5 mybp the area of the Limon Basin, close to the continental basement exposed in Nicaragua, was undergoing shallow water inner shelf deposition receiving sediment from the emerging mountains of the Central American land mass to the west. However, the faunal evidence presented by Kegwin (1982) and by Crouch and Poag (1979) supports an exchange of Caribbean and Pacific waters subsequent to this time, perhaps as late as 1.8 mybp. The area to the south of the Limon Basin, presently occupied by Panama, was probably the site of this longer lasting seaway.

Evidence supporting this hypothesis can be found in the Pliocene and Pleistocene stratigraphic sequence of the Panama Canal Zone. The Pliocene Chagres Sandstone is a unit consisting of massive fine grained sand and silt containing mollusks indicative of "moderate depth" of water (Woodring, 1957, p. 50). No absolute depth is given, but an indication of Woodring’s intent can be seen in his comparison of the Chagres sandstones with the Toro Limestone Member at the base of the Chagres Formation. The Toro Limestone is a thin bioclastic limestone containing shallow water marine fossils, such as corals, echnoid spines, and barnacles. Lenses of cross-bedded medium to coarse grained sandstone are also present (Woodring, 1957, p. 50). The typical Chagres sandstones are described as massive, fine sand-
stones with some siltstones. Clearly, when Woodring refers to the "moderate depth" of Chagres sandstone mollusks he is referring to an environment removed from the nearshore area on the continental shelf; not the shallow, reefal, turbulent zone in which the Toro Limestone was deposited. If the Chagres sandstones do represent deposition on the continental shelf, this was possibly a site of surface water communication between the Caribbean and Pacific basins during the Pliocene, while to the north, in the Limon Basin, land was fully emergent.

The Pleistocene deposits of the Canal Zone consist of black, organic swamp sediments interbedded with layers containing marine fossils (Woodring, 1957, p. 50). Woodring suggests the marine deposits are Late Pleistocene in age and notes they can be found as far inland as the town of Gamboa in the Canal Zone, which is nearly in the middle of the isthmus. These marine deposits may have been deposited in a shallow seaway connecting the Caribbean and Pacific basins. During the Pleistocene marine sedimentation in Panama was occurring nearly in the center of what is now the isthmus, while in Costa Rica Pleistocene marine sedimentation was restricted to the isthmus periphery.

Whitmore and Stewart (1965) suggested a broad and stable land mass in Central America, north of the canal zone, was connected to North America throughout the Tertiary. Based upon their study of a fossil mammalian
fauna from the Cucaracha Formation in the canal zone, they concluded open water communication between the Caribbean and Pacific basins was primarily through a permanent seaway in the Bolivar Trench of northern Colombia, and secondarily through intermittent seaways in the area of the canal zone. Whitmore and Stewart assigned the animals represented in the fauna to North American stocks. Contained in the fauna was a large rhinoceros. The presence of this heavy, terrestrial animal indicates a continuous land bridge must have existed from North America as far south as the canal zone in the Early Miocene. While this land bridge did not stay emergent throughout the rest of the Neogene, the presence of a large, stable land mass north of the canal zone connected to North America supports the idea put forward here that eventual uplift of the isthmus occurred from north to south.

The emergence of the Central American isthmus, and its affect on the evolution of planktonic foraminifera in the region, may also be reflected in the many first and last evolutionary occurrences of species from the latest Miocene and throughout the Pliocene. Bolli and Saunders (1985) compare this period of time as second only to the Cretaceous-Tertiary boundary for the evolutionary development of planktonic foraminifera. Foraminiferal biostratigraphic resolution in the Late Miocene can be as poor as 3.1 m.y. while resolution in the Pliocene is about 0.6 m.y.
The hypothesis presented here of shallow water deposition in the Late Oligocene followed by a very rapid deepening through the Early Miocene, then shallowing through the later Early Miocene, is supported by sedimentary sections of the same age from other parts of Central America. As noted above, the rhodolitic limestones of the Rio Claro Member of the Terraba Formation in the eastern Terraba Trough on the Pacific side of southern Costa Rica were deposited on a shallow carbonate platform, perhaps as shallow as 6 meters (Yuan, 1985). The presence of clastic debris in both the Limon Basin and Terraba Trough limestones indicates local emergence near to the site of deposition at this time. Immediately overlying the Rio Claro limestones are bathyal shales. Yuan suggests the period of rapid subsidence took place in the latest Oligocene, probably due to a change in the rate of subsidence along the Middle America Trench. From the Early through the early Middle Miocene the lithology of the Terraba Formation shows shallowing and infilling of the basin.

The Late Oligocene through Early Miocene sedimentary sections in the Limon Basin and Terraba Trough are similar and the environmental changes seen within these sections probably are genetically related to geological processes affecting the entire area of southern Costa Rica during this time. The causes for rapid subsidence in the Limon
Basin proposed here are a Late Oligocene eustatic sea level rise coupled with possible block faulting in the Quebrada Terciopelo area (suggested by Rivier, 1971). Yuan attributes rapid subsidence in the Terraba Trough to an increase in the rate of subduction of the Pacific Plate beneath the emerging magmatic arc of Central America. The downfaulting of the Quebrada Terciopelo area is problematical, as there is no field evidence of contemporaneous faulting. It seems reasonable that plate tectonic processes which caused a rapid deepening of the Terraba Trough on the Pacific side of Costa Rica would also affect the Limon Basin, on the opposite side of the arc. The tectonic affect of subsidence, coupled with a rise in sea level, caused the rapid subsidence of the Terraba and Limon Basins in the Late Oligocene to Early Miocene.

The foraminiferal fauna of the La Boca Fm. in the Panama Canal Zone (Blacut and Klienpell, 1969) supports the general Late Oligocene through late Early Miocene trend seen in the Quebrada Terciopelo section of the Uscari Formation. Blacut and Klienpell place their studied sequence in the N3, N4, N5 zones of the Late Oligocene to Early Miocene, based primarily upon correlation of benthic foraminiferal zones with well studied sequences in California. The environments of deposition in the La Boca Formation, interpreted from benthic foraminifera, change up section. The basal part of the section is characterized by
a horizon containing *Elphidium*, and reef building corals in a thin limestone. Overlying these shallow water deposits are shales indicative of at least an upper bathyal environment. These deep water shales grade upwards in continental shelf deposits.

A striking difference between the Late Oligocene to Early Miocene sedimentary sections in the Limon Basin and Terraba Trough is the lack of coarse volcaniclastic material in the Limon Basin rocks. The sequence exposed in Quebrada Terciopelo contains no sandstones or siltstones. The shales are rich in montmorillonite (Taylor, 1975), indicating a volcanic source area, but no other evidence of volcanic activity was seen. In the Terraba Trough, representing the same time period, Yuan (1985) reports an increase in intensity of local volcanic activity resulting in increasing amounts of coarser volcaniclastic sediments being deposited in the basin through the Early Miocene. Yuan reported petrographic analysis of sandstones in the Terraba Formation, suggesting the volcaniclastic material in the rocks was derived from a "... first cycle, undissected volcanic arc ..." (p. 47). During the Early Miocene both the southern Limon Basin and the Terraba Trough were oceanic deeps experiencing turbiditic sedimentation (although the evidence for turbidites in the Limon Basin is displaced faunas, rather than sedimentological, as in Yuan's study). Both basins were close to the proto Cordil-
lura de Talamancas, presumably receiving input of clastic material from the Cordillera. Why, then, is the character of sedimentation so different? If the volcanic source area for Terraba Trough Early Miocene sediments was the Talamanca, there should be more volcaniclastic sediment in the Limon Basin in the Early Miocene rocks.

Where was the volcanic arc identified by Yuan? The Cordillera de Talamanca is an uplifted, fault bounded block composed primarily of plutons (Weyl, 1980). Evidence from the southern Limon Basin suggests there was little volcanic activity in the area of the present Talamancas from Late Oligocene to Early Miocene. The source area for Middle Eocene to the Middle Oligocene volcaniclastic sediments in the Terraba Trough may thus have been to the southwest, in the present Pacific Ocean (Weyl, 1980). If this volcanic source area existed in the Late Oligocene to Early Miocene, the difference in sedimentary facies between the Terraba Trough and southern Limon Basin can be explained.

PALEOCEANOGRAPHY

Keller and Barron (1983) have identified several hiatuses in the depositional record of deep sea cores of Miocene sediments. The authors suggest that these hiatuses should correlate with onshore unconformities caused by eustatic lowering of sea level resulting from periods of
increased polar glaciation. Two of the hiatuses identified by Keller and Barron correlate with unconformities in the Quebrada Terciopelo section of the Uscari Formation.

A Late Oligocene hiatus, called Hiatus PH, dated as 23.0 - 22.5 mybp (Keller and Barron) correlates with the unconformity between Late Oligocene rhodolitic limestones and underlying igneous rock at the base of the section. A second hiatus, called Hiatus NH 2, is dated at 16.0 - 15.0 mybp by Keller and Barron and correlates with the unconformity between rocks of the upper Uscari Formation (dated as 22.2 - 14.4 mybp) and the Rio Banano equivalent rocks (dated as 4.2 - 2.8 mybp).

PALEOGEOGRAPHY

The paleogeography of Costa Rica during the Miocene was extensively outlined in a paper by Fischer (1981). The results of this study suggest some corrections and clarifications of details concerning the Limon Basin in Fischer’s paper.

Fischer reported in it’s type region the Uscari Formation is approximately 1500 meters thick. No reference was given. The type section of the Uscari Formation reported here is estimated to be about 400 meters thick. No outcrop has been reported in the type area of the Uscari that would lead to a thickness estimate of 1500 meters.
Fischer also reported that of this 1500 meters, 300 meters was Lower Miocene. The correct position of the Uscari Formation type section has been shown here, and by Taylor (1975), to be early Middle Miocene. Fischer also stated that sedimentation in the Uscari Formation changes drastically from the type area to Quebrada Terciopelo in the "Lower" Miocene. This comparison is inappropriate due to the difference in age, documented in this paper, between these two areas.

Fischer stated that in the "Atlantic region of Costa Rica", here interpreted to include the Limon Basin, Early Miocene sedimentation occurred in a neritic marine environment. The analysis of the Quebrada Terciopelo and Rio Reventazon sections shows Early Miocene sediments of the Uscari Formation were deposited at middle slope to abyssal depths.

An analysis of several stratigraphic sections from the western side of the Limon basin was done by Rivier (1973). Rivier was the first to report on the Quebrada Terciopelo section which is designated here as a reference section of the Uscari Formation. The Terciopelo section was not assigned by Rivier to any stratigraphic unit. The results of this study disagree with Rivier on the biostratigraphic position of the Terciopelo section, the paleoenvironment it represents, and the thickness of the section.

Rivier assigned the lower 180 meters of the section to
the Oligocene and the remaining 552 meters (his figures) to
the Lower Miocene. This study has shown that only the lower
few meters containing the algal/foraminiferal limestones,
and possibly a few meters of shale, are Oligocene in
age. The bulk of the shales overlying the limestones are
Early Miocene. The shallow water deposits at the base of
the section containing larger foraminifera and algal
structures were recognized by Rivier, but he interpreted
the overlying bathyal shales as a neritic deposit. Middle
to lower bathyal benthic foraminifera in these shales
preclude a neritic origin.

The information on paleoenvironments of the units
presented in this report is used in conjunction with
the faunal comparisons of other areas in the Central
America/Caribbean region to interpret the paleogeography of
the Limon Basin in relation to other areas.

**Late Oligocene**

The Late Oligocene paleogeography of the Limon Basin,
the Pacific side of Costa Rica, and the Canal Zone in
Panama all indicate a shallow water, carbonate platform
receiving volcaniclastic sediment from emerging islands of
the Central American island arc.

The rhodolitic limestones exposed at the bottom of the
Quebrada Terciopelo section of the Uscari Formation indi-
cate deposition on a shallow wave and current agitated
carbonate platform in the intertidal zone. This geographic setting is in agreement with environments of similar limestones in the Terraba Trough in southwestern Costa Rica (Henningsen, 1966; Yuan, 1985) and foraminiferal limestones of the Bohio and Caimito Formations of the Canal Zone (Cole, 1952).

**Early Miocene**

The Early Miocene rocks of the Limon Basin were deposited in the same lower bathyal to abyssal environment as Early Miocene rocks on the Pacific side of Costa Rica and in northern South America. These areas were experiencing deep bathyal sedimentation at this time, at depths of up to 2000 meters, subject to shallow water sediment input, probably in the form of turbidites.

McKee (1985) and Yuan (1985) have interpreted Early Miocene siltstones and sandstones of the Terraba Formation on the Nicoya Peninsula and in southwest Costa Rica as lower bayhyal to abyssal deposits. Yuan (1985) suggested the Terraba Formation was deposited by turbidity currents. During the Early Miocene both the Caribbean and Pacific realms of Costa Rica were deep oceanic troughs receiving sediment input from the emerging island arc of Central American. The Pacific side was probably closer to the sediment source and/or was characterized by a steeper continental slope, as suggested by the silty and sandy
character of the sediments in contrast to the shales found in the Limon Basin.

In northern Colombia Early Miocene shales are interpreted as abyssal turbiditic deposits (Bordine, 1974). The Early Miocene shales of northeastern Venezuela (Renz, 1948) have lower bathyal indicator species. Both of these areas are comparable in age and environment to the lower Uscari Formation. The Early Miocene depositional record of the Cipero Formation in Trinidad suggests this area was in deeper water than the Uscari Formation. Abyssal benthic foraminifera from a planktonic ooze are found in the Cipero Formation (Cushman and Stainforth, 1945).

Late Early to Early Middle Miocene

The Middle Miocene was a time of basin filling and shallowing of water depths in the Limon Basin, the Pacific realm of Costa Rica, and northern South America. All areas experienced decreasing water depths as the Early Miocene depositional basins were filled in. The Limon Basin and the Terraba Trough were receiving sediment from the continued development of the Central American island arc. To the east, the area of Trinidad remained an abyssal environment far removed from land masses.

The Limon Basin in the late Early to early Middle Miocene was shallower than the same area in the Early Miocene. This is similar to the Pacific side of Costa Rica.
where McKee (1985) interpreted Middle Miocene siltstones and sandstones of the Terraba Formation as a bathyal deposit (probably upper bathyal) rather than the deeper bathyal rocks of the Early Miocene. A similar shallowing sequence is seen in the rocks of the Uscari Formation where Early Miocene rocks represent deep bathyal to abyssal environments, while the later Early Miocene to Middle Miocene rocks represent upper bathyal to outer shelf deposition. The Early to Middle Miocene sequence in the Terraba Trough represents basin infilling and shoaling through the Miocene (Yuan, 1985).

The area of northeastern Venezuela also experienced a reduction of water depth and basin infilling through the Miocene. Parts of the Middle Miocene Pozon Formation (Renz, 1948; Blow, 1959) were deposited in 50 to 100 meters of water. The Cipero Formation in Trinidad (Cushman and Stainforth, 1945) remained an area of abyssal sedimentation in the Middle Miocene. Abyssal benthic foraminiferal taxa and very high planktonic percentages continued into the Middle Miocene.

**Pliocene**

Water depth during the Early Pliocene was greater on the Pacific side of Costa Rica where sandstones were being deposited in an outer shelf to upper slope environment. The Limon Basin was almost filled with sediment by the Early
Pliocene as the Central American land mass in the southern Limon Basin was fully emergent by this time. Rocks in northern South America were also deposited in middle shelf areas near to a land mass.

The Montezuma Formation on the Nicoya Peninsula was deposited at outer shelf to upper slope depths (McKee, 1985). On the Osa Peninsula deposition may have occurred as deep as 1200 meters in the Pliocene (Lew, 1983). In both of these Pacific coastal areas the indicated water depths are greater than in the Limon Basin, where the Rio Banano sandstone fauna suggests inner shelf deposition grading upward into the interbedded reefs of the upper Rio Banano Formation (Taylor, 1975).

The fauna of Late Miocene to Early Pliocene rocks in Colombia (Redmond, 1953) suggests middle shelf deposition and a mixture of open marine, reefal, and nearshore faunas. Like the Rio Banano sandstones, the indicated environment is a current swept, inner shelf.
CHAPTER 10

SUMMARY AND CONCLUSIONS

AGE

Based upon planktonic foraminifera, larger benthic foraminifera, and a diagnostic ostracod species, the biostratigraphic zonation of studied sections of the Uscari, Rio Banano, and Moin Formations along the Caribbean coast of Costa Rica has been determined, using the scheme of Bolli and Saunders (1985).

The Uscari Formation was studied in three sections. The Quebrada Uscari type section is placed in zones N9 to N10, 14.4 to 13.5 mybp. Diagnostic planktonic species include Globigerinoides obliquus obliquus and Globorotalia fohsi peripheroronda. The Rio Reventazon section is placed in zones N6 to N7, 20.3 to 16.4 mybp, based upon the presence of Catapsydrax stainforthi, Globorotalia fohsi peripheroronda, and Globoquadrina altispira. The Quebrada Terciopelo reference section spans a longer amount of time. The basal limestones are placed in the Late Oligocene zone N3, 25.5 to 24.6 mybp, based upon the presence of the larger benthic foraminifera Lepidocyclina (L.) wayland-vaughni and Heterostegina antillea. The lower part of the shale section is placed in the Early Miocene zone N4, 24.6
to 22.2 mybp. Typical taxa include *Catapsydrax stainforthi* and *Globorotalia kugleri*. The presence of samples containing the Late Oligocene indicator species *Globorotalia opima nana* and *Globigerina c.f. ciperoensis ciperoensis*, above an Early Miocene section, suggests faulting and indicates the section is, in part, repeated.

The sandstones of the Rio Banano Formation, exposed at the type section along Rio Banano, are placed in the Early Pliocene, zone N18, based upon the overlapping ranges of the short ranging ostracode *Radimella ovata* and the planktonic foraminiferal fauna. The correlative siltstones outcropping at the top of the Quebrada Terciopelo section are placed in the Pliocene, zone N19 to N21, 4.2 to 2.8 mybp. Diagnostic taxa include *Candeina nitida*, *Hastigerina siphonifera*, and *Sphaeroidinella dehiscens*.

The Moin Formation is placed in the Pleistocene, zone N22 to N23, based upon the presence of *Globorotalia truncatulinoides*.

**LOCAL AND REGIONAL CORRELATIONS**

The Early Miocene sediments of the Rio Reventazon and lower Quebrada Terciopelo sections of the Uscari Formation are similar. Both are Early Miocene deep water deposits containing a similar benthic foraminiferal fauna. These sections represent the deepest water phase of Uscari.
sedimentation, ranging from middle slope to abyssal environments. The late Early Miocene and early Middle Miocene upper Quebrada Terciopelo and Quebrada Uscari sections represent sedimentation in a shallowing environment, from middle slope to outer shelf. The type section represents the shallowest deposition of the Uscari Formation.

The Quebrada Terciopelo section is here designated as a principal reference section of the Uscari Formation. The approximately 565 meters of sediments exposed in this section is by far the thickest exposure reported of the unit. This section also gives a much more representative exposure of the formation than does the type section.

The rhodolitic limestones at the base of the Uscari Formation in Quebrada Terciopelo are similar to other Late Oligocene limestones in western Costa Rica and Panama. The Terraba Formation in the Terraba Trough of southwestern Costa Rica and the Bohio Formation in the Panama Canal Zone both contain shallow water rhodolitic limestones indicating a regional shallow carbonate shelf in the Late Oligocene.

Regional similarities can be found with the Early Miocene deep water shales of the Uscari Formation in Panama and western Costa Rica. The Terraba Formation of the Terraba Trough, and on the Nicoya Peninsula in western Costa Rica, consists of Early Miocene deep water shales with transported shallow water species. In Panama the
Aquaqua and Aruza Formations, in Colombia the Lower Magdalena Basin, and in Venezuela the San Lorenzo and lower Pozon Formation, all contain Early Miocene deep water shales with evidence of downslope transport of sediment. In the late Early to early Middle Miocene, regional similarities continue. The Terraba Formation on the Pacific side of Costa Rica, and the Huso Member of the Pozon Formation in Venezuela both contain shales of a shallower environment than the Early Miocene shales.

**BENTHIC FORAMINIFERAL FAUNAS**

196 different species of benthic foraminifera have been identified from the Uscari, Rio Banano, and Moin Formations. Of these, 17 are agglutinated, 32 are calcareous imperforate, and 147 are calcareous perforate (including two species of larger foraminifera). 43 species of planktonic foraminifera have been identified. 34 species of ostracoda are identified. At the 10% abundance level there are 20 different benthic foraminiferal species in the three formations.

A few benthic foraminifera appear to have biostratigraphic significance. *Cibicidoides falconensis* is present only in the Early Miocene Rio Reventazon section of the Uscari Formation and *Lagenina gibbera* and *Lenticulina clericii* are restricted to the same time interval in both
the Rio Reventazon and Quebrada Terciopelo sections. *Uvigerina hannai* is restricted to the Early Miocene in Quebrada Terciopelo. However, these distributions may be environmentally controlled and may only represent teiil zones.

**RELATIVE PALEOBATHYMETRY AND PALEOENVIRONMENTS**

The planktonic foraminiferal percentages of the samples indicate relative bathymetries of the sections. The Uscari Formation, in the valley of the Rio Reventazon, has the highest values, suggesting deepest depositional environment with slightly lower values in the lower Quebrada Terciopelo section. Up section in Quebrada Terciopelo the values decrease steadily in response to a shallowing trend through time in the Uscari Formation. The values in the Quebrada Uscari type section are similar to those at the top of the Quebrada Terciopelo section. The Rio Banano and Moin Formations do not exhibit systematic changes in planktonic percentages at their type sections.

Interpretation of the factor analyses suggests benthic foraminiferal assemblage relationships in the three units and allows interpretation of paleoenvironments. An open marine, continental shelf assemblage containing *Hanzawaia concentrica*, *Fursenkoina pontoni*, and *Bolivina subaenariensis* dominates the Uscari Formation in the Quebrada Uscari type section. The deepest water part of the
Uscari Formation, in the Rio Reventazon section, is dominated by a *Cibicides wuellerstorfi* assemblage, suggesting depths near 2000 meters. The deepest water part of the Uscari Formation in Quebrada Terciopelo is the lower part of the section, exclusive of the basal limestones. Here, the benthic assemblage is dominated by an upper to middle bathyal assemblage containing *Siphogenerina transversa*, *Gyroidina regularis*, and *Bolivina alata*. Downslope transport of sediment derived from nearshore regions is evident in the distribution of an assemblage containing *Amphistegina gibbosa*, a nearshore taxon. This assemblage is found in scattered samples from the abyssal and bathyal portions of the Uscari Formation, suggesting the possibility of turbidites. A second upper slope to shelf assemblage containing *Elphidium* spp., *Bolivina pseudoplicata*, and *Buliminella bassendorfensis* is present in both the Quebrada Uscari section and the upper part of the Quebrada Terciopelo section of the Uscari Formation, suggesting a facies relationship. Both sections were deposited in a shelf to upper slope environment.

The distinctiveness of the five stratigraphic sections is shown by the results of the cluster analysis. Separate clusters are formed by samples from the Rio Reventazon, the lower Quebrada Terciopelo, the middle and upper Quebrada Terciopelo, and the Quebrada Uscari sections of the Uscari Formation. The Rio Banano samples are grouped into one
large cluster, suggesting overall faunal homogeneity, and one smaller cluster, indicating a locally distinctive aspect of the fauna, interpreted as a significant nearshore contamination of some of the samples. The Moin Formation samples are grouped into two clusters, indicating possible differences in substrate.

PALEOGEOGRAPHY AND GEOLOGIC HISTORY

The Limon Basin in the area of study during the Late Oligocene was a shallow, well agitated carbonate shelf upon which the rhodolitic/foraminiferal limestones of the basal Uscari Formation were deposited. Volcaniclastic sediment was introduced into the area from the emerging volcanic islands of the proto-island arc of Central America. In the Late Oligocene to Early Miocene a rapid subsidence occurred. The floor of the basin may have been downdropped as a graben. More likely, the basin subsided as a result of increased subsidence rate along the Middle America Trench. The tectonic subsidence was compounded by a worldwide rise in sea level at this time, resulting in a rapid change in sedimentary facies in the Uscari Formation from Late Oligocene to Early Miocene.

By late Early Miocene, the Limon basin began to be uplifted. The sediments in the Uscari Formation show a gradual shallowing trend in Quebrada Terciopelo. By early
Middle Miocene time, the Uscari Formation was being deposited on the upper slope to outer shelf.

The unconformity between the basal limestones and overlying shales of the Uscari Formation correlates with a Late Oligocene deep sea depositional hiatus. The unconformity between the upper Uscari Formation and siltstones, possibly of the Rio Banano Formation, at the top of the section correlates with a second deep sea hiatus. These hiatuses may be related to eustatic lowering of sea level during periods of increased polar glaciation.

By Early Pliocene time the Limon Basin in the study area was filled with sediment. The sandstones of the Rio Banano Formation were deposited on a shallow shelf bordering the emergent Central American land mass.

SPECULATIONS ON Isthmus FORMATION

The benthic foraminiferal record in rocks of the Limon Basin suggests that the Central American land mass in the area of Costa Rica was emergent by 5 mybp. This does not agree with published deep-sea planktonic foraminiferal studies, suggesting isthmus formation and isolation of Caribbean and Pacific waters around 3 to 4 mybp. The emergence of the isthmus may have progressed in a north to south direction, allowing surface water communication between the Caribbean and Pacific in the area of Panama.
while Costa Rica was largely emergent. Evidence of the migration of shallow water benthic foraminifera from the Caribbean to the Pacific as late as 1.8 mybp supports this idea. Pliocene and Pleistocene sediments in the Canal Zone in Panama lend support to this hypothesis. These marine sediments are located in inland positions while sediments of the same age in Caribbean Costa Rica are found along the coast. Evidently, the sea persisted for a longer time in covering the emerging isthmus in Panama than in Costa Rica.
REFERENCES

The following abbreviations are used in the references:

A.A.P.G. — American Association of Petroleum Geologists
C.L.F.R. — Cushman Laboratory for Foraminiferal Research
G.C.A.G.S. — Gulf Coast Association of Geological Societies
G.S.A. — Geological Society of America
J.F.R. — Journal of Foraminiferal Research
S.E.P.M. — Society of Economic Paleontologists and Mineralogists
U.S.G.S. — United States Geological Survey
U.S.N.M. — United States National Museum


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PLATES

The following plates illustrate most of the identified foraminifera and ostracoda from the Uscari, Rio Banano, and Moin Formations. The figures are numbered below and to the right, keyed to the identifications on the preceding page. Unless otherwise specified all images are S.E.M. micrographs.
AGGLUTINATED BENTHIC FORAMINIFERA

#1) *Reophax agglutinans*, x50. Rio Reventazon section of the Uscari Fm.

#2) *Ammobaculites* sp., x35. Rio Reventazon section of the Uscari Fm.

#3) *Cyclammina cancellata*, x75. Rio Reventazon section of the Uscari Fm.

#4) *Spiroplectammina floridana*, x100. Moin Fm.

#5) *Gaudryina bulbrooki*, x50. Rio Reventazon section of the Uscari Fm.

#6) *Karrariella bradyi*, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#7) *Dorthia bradyana*, x50. Rio Reventazon section of the Uscari Fm.

#8) *Liuebusella soldanii*, x50. Moin Fm.

#9) *Textularia azuana*, x75. Moin Fm.

#10) *Textulariella barretti*, Moin Fm., a. x35 side view, b. x 35 top view.

#11) *Textularia lelickeri*, x75. Rio Reventazon section of the Uscari Fm.

#12) *T. mexicana*, x75. Rio Reventazon section of the Uscari Fm.
#1) *Textularia sica*, $\times$75. Moin Fm.

#2) *Bigenepina irregularis*, $\times$75. Moin Fm.

#3) *Clavulina mexicana*, $\times$50. Rio Reventazon section of the Uscari Fm.

#4) *Martininctella c.f. cyclolostomata*, $\times$50. Rio Reventazon section of the Uscari Fm.

#5) *M. pallida*, $\times$100. Lower Quebrada Terciopelo section of the Uscari Fm.

**PORCELLANEOUS (IMPERFORATE) BENTHIC FORAMINIFERA**

#6) *Cornuspira involvens*, $\times$50. Rio Reventazon section of the Uscari Fm.

#7) *Articulina majori*, $\times$150. Rio Banano Fm.

#8) *A. pacifica*, $\times$150. Moin Fm.

#9) *Nodobaculariella cassis*, $\times$100. Rio Banano Fm.

#10) *Quinqueloculina bosciana*, Rio Banano Fm. a. $\times$200, side view, b. $\times$200, peripheral view.

#11) *Spiroloclulina rotunda*, Rio Reventazon section of the Uscari Fm. a. $\times$200, peripheral view, b. $\times$200, side view.

#12) *S. communis*, Moin Fm. a. $\times$50, peripheral view, b. $\times$75, side view.

#13) *Quinqueloculina compta*, Rio Banano Fm. a. $\times$200, side view, b. $\times$200, peripheral view.

#14) *Q. c.f. poeyana*, Moin Fm. a. $\times$100, side view, b. $\times$100, peripheral view.
PLATE 3

#1) *Quingueloculina bicostata*, Moin Fm. a. ×35, side view, b. ×35, peripheral view.

#2) *Q. lamarckiana*, Rio Banano Fm. a. ×100, side view, b. ×100, peripheral view.

#3) *Q. seminula*, Moin Fm. a. ×100, side view, b. ×100, peripheral view.

#4) *Q. bicostata garretti*, Moin Fm. a. ×75, side view, b. ×75, side view.

#5) *Q. bicarinata*, Lower Quebrada Terciopelo section of the Uscari Fm. a. ×100, peripheral view, b. ×100 side view.

#6) *Massilina tenuissima*, ×50. Rio Banano Fm.

#7) *Edentostomina fiterrei*, Rio Banano Fm. a. ×200 side view, b. ×200, peripheral view.

#8) *Triloculina carinata*, Moin Fm. a. ×150, peripheral view, b. ×100, side view.

#9) *I. saidi*, ×350. Moin Fm.
PLATE 4

#1) *Triloculina tricarinata*, Moin Fm. a. x100, top view, b. x100, side view.

#2) *T. trigonula*, Moin Fm. a. x150, top view, b. x100, side view.

#3) *Cruciloculina striata*, x100. Moin Fm.

#4) *C. sublineata*, x100. Moin Fm.

#5) *Pyrgo oblonga*, Moin Fm. a. x75, side view, b. 75, peripheral view.

#6) *P. subsphaerica*, Moin Fm. a. x100, side view, b. x100, peripheral view.

#7) *P. vespertilio*, x75. Moin Fm.

#8) *Pyrgoel la sphaera*, Moin Fm. a. x150, top view, b. x150, side view.

#9) *Miliolinella subrotunda*, x200. Río Banano Fm.

#10) *M. fichteliana*, x200. Río Banano Fm.

#11) *Sigmoidina subpoevana*, Río Banano Fm. a. x200, peripheral view, b. x 200, side view.

#12) *S. tenuis*, Río Reventazon section of the Oiscari Fm. a. x200, peripheral view, b. x200, side view.
PLATE 5

#1) *Sigmoilopsis flintii*, x50. Moin Fm.

#2) *S. schlumbergeri*, x150. Rio Banano Fm.

#3) *Peneroplis bradyi*, x25. Rio Banano Fm. Light photograph.

HYALINE (PERFORATE) BENTHIC FORAMINIFERA

#4) *Spirillina vivipara*, x350. Moin Fm.

#5) *Patellina corrugata*, Rio Banano Fm. a. x150, dorsal view, b. x200, dorsal-peripheral view.

#6) *Nodosaria pyrula*, x75. Rio Reventazon section of the Uscari Fm.

#7) *Dentalina advena*, x50. Rio Reventazon section of the Uscari Fm.

#8) *Frondicularia sagittula*, x50. Moin Fm. Light microscopy.

#9) *F. advena*, x100. Rio Reventazon section of the Uscari Fm.

#10) *F. vaughni*, x50. Rio Reventazon section of the Uscari Fm. Light microscopy.

#11) *Mychostomina revertens*, x200. Moin Fm.

#12) *Pseudonodosaria incisia*, x50. Rio Reventazon section of the Uscari Fm.

#13) *Nodosaria longiscata*, x75. Lower Quebrada Terciopelo section of the Uscari Fm. Light microscopy.

#14) *Pseudonodosaria comatula*, x50. Rio Reventazon section of the Uscari Fm.

#15) *Dentalina pauperata*, x50. Rio Reventazon section of the Uscari Fm.
PLATE 6

#1) Nodosaria raphanistrum, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#2) N. stainforthi, x50. Lower Quebrada Terciopelo section of the Uscari Fm.

#3) N. vertebralis, x50. Moin Fm.

#4) Orthomorphina challengerina, x150. Rio Reventazon section of the Uscari Fm.

#5) Amphicoryna hirsuta, x75. Rio Reventazon section of the Uscari Fm.

#6) A. sublineata, x100. Rio Reventazon section of the Uscari Fm.

#7) A. sclaris, x75. Uscari Fm., Rio Reventazon section.

#8) A. comachoi, x75. Moin Fm.

#9) Lagena gibbera, x150. Lower Quebrada Terciopelo section of the Uscari Fm.

#10) L. gracillima, x150. Rio Reventazon section of the Uscari Fm.

#11) L. laevis, x100. Rio Reventazon section of the Uscari Fm.

#12) Plectofrondicularia californica, x75. Rio Reventazon section of the Uscari Fm.

#13) P. floridana, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#14) P. c.f longistriata, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#15) Lenticulina calcar, Moin Fm. a. x100, peripheral view, b. x100, side view.

#16) L. clericii, a. Lower Quebrada Terciopelo section of the Uscari Fm. x100, side view, b. Rio Reventazon section of the Uscari Fm. x100, peripheral view.

#17) Lagena striata, xx200. Moin Fm.

#18) L. gracillis, x200. Rio Reventazon section of the Uscari Fm.
PLATE 7

#1) *Lenticulina cultrata*, Rio Reventazon section of the Uscari Fm. a. x50, side view, b. x75, peripheral view.

#2) *L. occidentalis*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x25, side view, light microscopy, b. x35, peripheral view.

#3) *L. peregrina*, Moin Fm. a. x200, peripheral view, b. x100, side view.

#4) *L. serpens*, Moin Fm. a. x100, side view, b. x75, peripheral view.

#5) *Saracenaria latiformis jamaicensis*, x75. Moin Fm.

#6) *S. latifrons*, x150. Rio Reventazon section of the Uscari Fm.

#7) *Astacolus c.f. platensis*, x150. Lower Quebrada Terciopelo section of the Uscari Fm.

#8) *Saracenaria italica*, x35. Rio Reventazon section of the Uscari Fm.

#9) *Astacolus nudi costata*, x150. Rio Reventazon section of the Uscari Fm.

#10) *A. ovatus*, x100. Rio Reventazon section of the Uscari Fm.
PLATE B

#1) Marginulina obesa, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#2) M. c.f. striatula, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#3) M. subbullata, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#4) Marginulinopsis marginulinoides, x75. Moin Fm.

#5) M. subacuelata glabrata, x50. Rio Reventazon section of the Uscari Fm.

#6) Planularia venezuelana, Moin Fm. a. 150, side view, b. 100, peripheral view.

#7) Vaginulina mexicana, x50. Rio Reventazon section of the Uscari Fm.

#8) V. advena, x100, Lower Quebrada Terciopelo section of the Uscari Fm.

#9) Oolina hexagona, x350. Rio Banano Fm.

#10) Pyrulina angusta, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#11) Guttulina irregularis, x75. Rio Reventazon section of the Uscari Fm.

#12) G. problema, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#13) Globulina gibba, x50. Rio Reventazon section of the Uscari Fm.
PLATE 9

#1) **Fissurina annectens**, x350. Rio Banano Fm.

#2) **F. marginata**, x75. Rio Banano Fm.

#3) **Hoeglundina elegans**, Moin Fm. a. x100, side view, b. x150, peripheral view.

#4) **Pavonina atlantica**, x150. Rio Banano Fm.

#5) **Sphaeroidina bulloides**, Rio Reventazón section of the Uscari Fm. a. x100, b. x100, showing aperture.

#6) **Bolivina alata**, x150. Lower Quebrada Terciopelo section of the Uscari Fm.

#7) **B. inconspicua**, x200. Rio Banano Fm.

#8) **B. inflata**, x200. Moin Fm.

#9) **B. c.f. plicata**, x200. Rio Banano Fm.

#10) **B. lowmani**, x200. Moin Fm.

#11) **B. isidroensis**, x150. Rio Reventazón section of the Uscari Fm.

#12) **B. tongi**, x150. Lower Quebrada Terciopelo section of the Uscari Fm.

#13) **B. spinata**, x150. Rio Banano Fm.

#14) **B. pseudoplicata**, x150. Quebrada Uscari section of the Uscari Fm.

#15) **B. subaenariensis** var. **mexicana**, x150. Moin Fm.

#16) **B. subexcavata**, x150. Rio Banano Fm.

#17) **B. thalmanni**, x150. Lower Quebrada Terciopelo section of the Uscari Fm.
PLATE 10

#1) **Stilostomella verneuili**, x75. Rio Reventazón section of the Uscari Fm.

#2) *S. antillea*, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#3) *S. consobrina*, x75. Rio Reventazón section of the Uscari Fm.

#4) *S. bradyi*, x100. Lower Quebrada Terciopelo section of the Uscari Fm.

#5) **Stainforthia complanata**, x350. Moin Fm.

#6) **Bulimina alazanensis**, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#7) *B. inflata*, x100. Rio Reventazón section of the Uscari Fm.

#8) *B. aculeata*, x200. Moin Fm.

#9) *B. affinis*, x200. Moin Fm.

#10) *B. marginata*, x200. Moin Fm.

#11) **Praeglobobulimina pupoides**, x75. Rio Reventazón section of the Uscari Fm.

#12) **Buliminella bassendorfensis**, x150. Rio Reventazón section of the Uscari Fm.

#13) **Reussella minutia**, Rio Banano Fm. a. x200, b. x200.

#14) **Globobulimina perversa**, x75. Rio Reventazón section of the Uscari Fm.

#15) **Buliminoides basicostata**, x350. Upper Quebrada Terciopelo section of the Uscari Fm.

#16) **Reussella spinulosa**, x200. Rio Banano Fm.

#17) **Buliminella elegantissima**, x350. Rio Reventazón section of the Uscari Fm.
PLATE 11

#1) Rectobolivina advena, xl50. Moin Fm.

#2) R. rephanus, x150. Rio Banano Fm.

#3) R. (?) spinescens, x150. Rio Banano Fm.

#4) Siphogenerina fredsmithi, x100. Lower Quebrada Terciopelo section of the Uscari Fm.

#5) S. multicostata, x100. Lower Quebrada Terciopelo section of the Uscari Fm.

#6) S. senni, x100. Lower Quebrada Terciopelo section of the Uscari Fm.

#7) S. smithi, x100. Lower Quebrada Terciopelo section of the Uscari Fm.

#8) S. transversa, x50. Rio Reventazon section of the Uscari Fm.

#9) Uviogerina auberiana, x200. Moin Fm.

#10) U. cocoensis, x75. Lower Quebrada Terciopelo section of the Uscari Fm.

#11) U. flinti, x75. Rio Reventazon section of the Uscari Fm.

#12) Uviogerinella sparsicostata, x100. Rio Reventazon section of the Uscari Fm.

#13) Uviogerina c.f. hannai, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#14) U. hispido-costata, x150. Lower Quebrada Terciopelo section of the Uscari Fm.

#15) Rectuviogerina multicostata, x75. Rio Reventazon section of the Uscari Fm.

#16) Uviogerina ex. grp. peregrina, x150. Rio Reventazon section of the Uscari Fm.

#17) U. rustica, x100. Rio Reventazon section of the Uscari Fm.

#18) Sagrina pulchella, x200. Rio Banano Fm.

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PLATE 12

#1) Trifarina angulosa, x200. Rio Banano Fm.

#2) I. bradvi, x200. Rio Reventazon section of the Uscari Fm.

#3) I. holcki, x200. Rio Banano Fm.

#4) Trifarina sp. x200. Upper Quebrada Terciopelo section of the Uscari Fm.

#5) Ehrenbergina caribbea, x150. Apertural view.

#6) Fursenkoina mexicana, x150. Moin Fm.

#7) F. pontoni, x150. Rio Banano Fm.

#8) Sigmavirgulina tortuosa, x200. Rio Banano Fm.

#9) Fursenkoina spinicostata, x200. Moin Fm.

#10) Cassidyulina carapitana, Rio Reventazon section of the Uscari Fm. a. x200, peripheral view. b. x200, side view.

#11) C. carinata, Rio Reventazon section of the Uscari Fm. a. x350, peripheral view. b. x350, side view.

#12) C. laevigata, Moin Fm. a. x150, side view. b. x150, peripheral view.

#13) C. curvata, Moin Fm. a. x200, peripheral view. b. x200, side view.

#14) C. subolobosa, Lower Quebrada Terciopelo section of the Uscari Fm. a. x150. b. x150.
PLATE 13

#1) **Cassidulinoides bradyi**, x200. Upper Quebrada Terciopelo section of the Uscari Fm.

#2) **C. erecta**, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#3) **Pleurostomella alternans**, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#4) **Valvulineria c.f. humilis**, Upper Quebrada Terciopelo section of the Uscari Fm. a. x200, dorsal view, b. x200, ventral view, c. x200, peripheral view.

#5) **Pleurostomella bierigi**, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#6) **Cancris saora**, Moin Fm. a. x200, ventral view, b. x200, dorsal view, c. x200, peripheral view.

#7) **Valvulineria venezuelana**, Rio Reventazon section of the Uscari Fm. a. x150, peripheral view, b. x150, dorsal view, c. x150, ventral view.

#8) **V. palmerae**, Rio Banano Fm. a. x200, peripheral view, b. x200, dorsal view, c. x200, ventral view.

#9) **Neoeponides antillarum**, Rio Banano Fm. a. 100, dorsal view, b. x100, ventral view, c. x150, peripheral view.
#1) **Neoponides bryamensis**, Moin Fm. a. x75, dorsal view, b. x75, peripheral view, c. x50, ventral view.

#2) **Buccella hannai**, Rio Banano Fm. a. x200, ventral view, b. x200, peripheral view, c. x200, dorsal view.

#3) **Rosalina bulbosa**, Rio Banano Fm. a. x200, dorsal view, b. x200, peripheral view, c. x200, ventral view.

#4) **Gavelinopsis praegeri**, Rio Reventazon section of the Uscari Fm. a. x350, peripheral view, b. x150, ventral view, c. x150, dorsal view.

#5) **Rosalina globularis**, Rio Banano Fm. a. x150, dorsal view, b. x200, peripheral view, c. x150, ventral view.

#6) **R. c.f. valvulata**, Rio Banano Fm. a. x200, ventral view, b. x200, dorsal view.

#7) **Neoconorbina c.f. floridensis**, Moin Fm. a. x50, dorsal view, b. x50, ventral view, c. x350, peripheral view.
PLATE 15

#1) *Neoconorbina terquemi*, Rio Banano Fm. a. x200, dorsal view, b. x350, peripheral view, c. x200, ventral view.

#2) *Glabratella pulvinata*, a. Moin Fm, x200, dorsal view, b. Rio Reventazon section of the Uscari Fm., x200, ventral view.

#3) *Siphonina pulchra*, Rio Banano Fm. a. x100, ventral view, b. x100, dorsal view.

#4) *Epistominella (?) c.f. rugosa*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x150, dorsal view, b. x200, peripheral view, c. x150, ventral view.

#5) *E. exigua*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x350, ventral view, b. x350, dorsal view.

#6) *Stetsonia minutia*, Moin Fm. a. x350, ventral view, b. x350, peripheral view.

#7) *Discorbinella bertheloti*, Moin Fm. a. x100, ventral view, b. x100, dorsal view.

#8) *Laticarinina c.f. pauperata*, x75. Lower Quebrada Terciopelo section of the Uscari Fm. Light microscopy.

#9) *Glabratella c.f. patelliformis*, Moin Fm. a. x200, peripheral-ventral view, b. x200, dorsal view.
#1) *Planulina ariminensis*, Rio Reventazon section of the Uscari Fm. a. x150, dorso-peripheral view showing raised sutures on dorsal side, b. x100, dorsal view, c. x100, ventral view.

#2) *Cibicides wuellerstrofi*, Rio Reventazon section of the Uscari Fm. a. x100, ventral view, b. x100, dorsal view, c. x100, peripheral view.

#3) *F. c.f. subtenuissima*, Rio Reventazon section of the Uscari Fm. a. x75, dorsal view, b. x75, ventral view.

#4) *Caribbeanella polystoma*, Rio Reventazon section of the Uscari Fm. a. x200, ventral view, b. x200, dorsal view.

#5) *Cibicides lobatulus*, Rio Banano Fm. a. x150, dorsal view, b. x150, ventral view, c. x150, peripheral view.

#6) *Dyocibicides biserialis*, Moin Fm. a. x75, dorsal view, b. x75, ventral view.
#1) *Planorbulina mediterranensis*, Rio Banano Fm. a. ×75, ventral view, b. ×75, dorsal view.

#2) *Cymbacoloporella squammosa*, Moin Fm. a. ×100, ventral view, b. ×100, dorsal view.

#3) *C. atlantica*, Moin Fm. a. ×150, dorsal view, b. ×150, ventral view.

#4) *Carpenteria candei*, Moin Fm. a. ×200, ventral view, b. ×200, dorsal view.

#5) *Miniacina miniacea*, ×25, Rio Banano Fm. Light microscopy.


#7) *Nonion incisium*, Moin Fm. a. ×350, side view, b. ×350, peripheral view.

#8) *Nonionella basiloba*, Rio Reventazon section of the Uscari Fm. a. ×200, peripheral view, b. ×200, ventral view.

#9) *Pseudononion basispinata*, Rio Reventazon section of the Uscari Fm. a. ×100, dorsal view, b. ×150, peripheral view, c. ×100, ventral view.

#10) *P. costiferum*, Lower Quebrada Terciopelo section of the Uscari Fm. a. ×350, dorsal view, b. ×150, peripheral view, c. ×150, ventral view.

#11) *P. grateloupii*, Rio Banano Fm. a. ×150, dorsal view, b. ×150, ventral view, c. ×150, dorsal view.
PLATE 18

#1) Nonionella miocenica, Rio Reventazon section of the Uscari Fm. a. x150, ventral view, b. x150, peripheral view.

#2) N. miocenica stella, x350. Umbilical view. Moin Fm.

#3) Pullenia bulboides, x200. Lower Quebrada Terciopelo section of the Uscari Fm.

#4) P. subcarinata, x200. Moin Fm.

#5) Melonis pompilioides, Lower Quebrada Terciopelo section of the Uscari Fm. a. x150, peripheral view, b. x200, side view.

#6) M. barleanus, Moin Fm. a. x150, side view, b. x150, peripheral view.

#7) Quadrimorphina vilardeboana glabra, Upper Quebrada Terciopelo section of the Uscari Fm. a. x350, dorsal view, b. x350, ventral view.

#8) Cibicidoides compressus, Rio Reventazón section of the Uscari Fm. a. x75, ventral view, b. x100, dorsal view.

#9) C. falconensis, Rio Banano Fm. a. x100, peripheral view, b. x75, dorsal view, c. x75, ventral view.

#10) Chilostomella ovidea, x75. Rio Reventazón section of the Uscari Fm.

#11) Cibicidoides floridanus, Moin Fm., a. x100, ventral view, b. x100, dorsal view, c. x100, Rio Reventazón section of the Uscari Fm., peripheral view.
PLATE 19

#1) *Cibicidoides granulosus*, Rio Reventazon section of the Uscari Fm. a. x100, ventral view, b. x100, dorsal view, c. x75, peripheral view, Lower Quebrada Tercio-pelo section of the Uscari Fm.

#2) *Gyroidina parva*, Rio Reventazon section of the Uscari Fm. a. x200, ventral view, b. x200, peripheral view, c. x350, dorsal view.

#3) *G. regularis*, Moin Fm. a. x200, dorsal view, b. x200, ventral view, c. x200, periphero-ventral view.

#4) *G. soldanii*, a. x50, Moin Fm., ventral view, b. x75, Rio Reventazon section of the Uscari Fm., dorsal view, c. x75, Moin Fm., peripheral view.

#5) *Gyroidinoides venezuelana*, Rio Reventazon section of the Uscari Fm. a. x200, peripheral view, b. x200, dorsal view, c. x200, ventral view.

#6) *Syratkina australiensis*, Rio Banano Fm. a. x350, ventral view, b. x350, dorsal view.

#7) *Oridorsalis umbonatus*, Rio Reventazon section of the Uscari Fm. a. x200, peripheral view, b. x100, dorsal view, c. x100, ventral view.
PLATE 20

#1) Osangularia culter, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, peripheral view, b. x100, ventral view, c. x100, dorsal view.

#2) Hanzawaia concentrica, Moin Fm. a. x100, dorsal view, b. x150, peripheral view, c. x200, ventral view.

#3) Anomaloides sp., Rio Banano Fm. a. x150, peripheral view, b. x100, dorsal view, c. x100, ventral view.

#4) Hanzawaia mantaensis, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, peripheral view, b. x150, ventral view, c. x150, dorsal view.

#5) Lepidocyclina (L.) waylandvaughni, x75, Lower Quebrada Terciopelo section of the Uscari Fm.

#6) Pararotalia sarmiento, Rio Banano Fm. a. x200, dorso-peripheral view, b. x150, dorsal view, c. x150, ventral view.
PLATE 21

#1) *Ammonia parkinsoniana typica*, Rio Banano Fm. a. ×200, ventral view, b. ×200, dorsal view.

#2) *A. parkinsoniana tepida*, Rio Banano Fm. a. ×200, ventral view, b. ×200 dorsal view.

#3) *Elphidium discodale*, Rio Banano Fm. a. ×150, side view, b. ×100, peripheral view.

#4) *E. gunteri*, Rio Banano Fm. a. ×100, side view, b. ×100, peripheral view.

#5) *Havnesina germanica*, Moin Fm. a. ×200, peripheral view, b. ×200, side view.

#6) *Elphidium sp.* Rio Banano Fm. a. ×150, side view, b. ×200, peripheral view.

#7) *Elphidium lanieri*, Rio Banano Fm. a. ×100, peripheral view, b. ×100, side view.

#8) *E. poeyanum*, Rio Banano Fm. a. ×150, side view, b. ×200, peripheral view.

#9) *Heterostegina antillea*, ×12, Lower Quebrada Terciopelo section of the Uscri Fm. Light microscopy.
PLANKTONIC FORAMINIFERA

#1) *Globigerina ciperoensis ciperoensis*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x150, ventral view, b. x150, dorsal view.

#2) *G. venezuelana*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x100, dorsal view, b. x100, ventral view.

#3) *Cassigerinella chipolensis*, x200, Lower Quebrada Terciopelo section of the Uscari Fm.

#4) *Globigerina tripartita*, a. x100, ventral view, Rio Reventazon section of the Uscari Fm. b. x100, dorsal view, Lower Quebrada Terciopelo section of the Uscari Fm.

#5) *Globogerinoides conglobatus*, Rio Banano Fm. a. x100, dorsal view, b. x100, ventral view.

#6) *G. obliquus obliquus*, Rio Banano Fm. a. x150, ventral view, b. x150, dorsal view.

#7) *G. obliquus extremus*, Rio Banano Fm. a. x150, dorsal view, b. x150, ventral view.
#1) *Globigerinoides ruber*, Rio Banano Fm. a. x150, ventral view, b. x150, dorsal view.

#2) *G. trilobus trilobus*, x100. Rio Banano Fm.

#3) *G. primordius*, Rio Reventazon section of the Uscari Fm. a. x150, dorsal view, b. x150, ventral view.

#4) *Sphaeroidenella dehiscens*, x75. Moin Fm.

#5) *S. dehiscens excavata*, x75. Moin Fm.

#6) *Sphaeroidenellopsis seminulina*, x150. Rio Banano Fm.

#7) *Praeorbulina c.f. glomerosa*, x100. Upper Quebrada Terciopelo section of the Uscari Fm.

#8) *P. transitoria*, x100. Upper Quebrada Terciopelo section of the Uscari Fm.

#9) *P. transitoria*, x100. Upper Quebrada Terciopelo section of the Uscari Fm.

#10) *P. sicana*, Upper Quebrada Terciopleo section of the Uscari Fm. a. x100, b. x100.
PLATE 24

#1) **Orbulina suturalis**, x100. Quebrada Uscari section of the Uscari Fm.

#2) **G. universa**, x100. Rio Banano Fm.

#3) **G. universa var. bilobata**, x75. Rio Banano Fm.

#4) **Candeina nitida**, x150. Rio Banano Fm. equivalent rocks of the Quebrada Terciopelo section.

#5) **Hastigerina siphonifera**, a. x150, side view, Rio Banano Fm. b. x100, peripheral view, Rio Banano Fm. equivalent rocks of the Quebrada Terciopelo section.

#6) **Globorotalia acostaensis acostaensis**, a. x200, dorsal view, Quebrada Uscari section of the Usvari Fm. b. x200, ventral view, Moin Fm.

#7) **G. crassaformis crassaformis**, Moin Fm. a. x150, ventral view, b. x150, peripheral view, c. x150, dorsal view.

#8) **G. kugleri**, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, peripheral view, b. x200, dorsal view, c. x200, ventral view.

#9) **G. archaeomenardii**, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, ventral view, b. x200, dorsal view, c. x200, peripheral view.
#1) *Globorotalia lenquanensis*, Quebrada Uscari section of the Uscari Fm. a. x350, dorsal view, b. x200, ventral view.

#2) *G. c.f. margaritae margaritae*, a. x350, dorsal view, b. x350, peripheral view.

#3) *G. opima nana*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, peripheral view, b. x200, ventral view, c. x200, dorso-peripheral view.

#4) *G. menardii menardii*, Moin Fm. a. x100, peripheral view, b. x100, ventral view, c. x100, dorsal view.

#5) *G. fohsi peripheroronda*, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, ventral view, b. x200, peripheral view, c. x200, dorsal view.
PLATE 26

#1) Globorotalia pleisotumida, Moin Fm. a. x100, peripheral view, b. x100, dorsal view, c. x100, ventral view.

#2) G. siakensis, Rio Banano Fm. equivalent rocks of the upper Quebrada Terciopelo section, a. x200, peripheral view, b. x200, ventral view, c. x200, dorsal view.

#3) G. scitula scitula, Rio Reventazon section of the Uscari Fm. a. x200, dorsal view, b. x200, peripheral view, c. x200, ventral view.

#4) G. truncatulinoides excelsa, Moin Fm. a. x100, peripheral view, b. x150, ventral view, c. x150, dorsal view.

#5) G. tumida tumida, Moin Fm. a. x75, ventral view, b. x100, dorsal view.

#6) Pulleniatina obliqueculata, Moin Fm. a. x100, ventral view, b. x100, side view.

#7) P. primals, Moin Fm. a. x100, ventral view, b. x100, side view.
PLATE 27

#1) Globoquadrina dehiscens, Upper Quebrada Terciopelo section of the Uscari Fm. a. x100, ventral view, b. x100, dorsal view.

#2) G. altispira, Upper Quebrada Terciopelo section of the Uscari Fm. a. x100, ventral view, b. x100, dorsal view.

#3) Neogloboquadrina dutertrei dutertrei, Moin Fm. a. X100, dorsal view, b. x100, ventral view, c. x100, ventro-peripheral view.

#4) Globogerinita naparimaensis, x100. Lower Quebrada Terciopelo section of the Uscari Fm.

#5) Catapsydrax dissimilis, Lower Quebrada Terciopelo section of the Uscari Fm. a. x100, ventral view showing bulla, b. 100, dorsal view.

#6) C. stainforthi, Lower Quebrada Terciopelo section of the Uscari Fm. a. x200, ventral view showing bulla, b. x200, ventral view showing bulla, c. x200, dorsal view, d. x200, ventral view showing bulla.
PLATE 28

OSTRACODA

MDIN FM.

#1) *Bradleya* ex. grp. *dictyon*, x75.

#2) *Cytheropteron palton* (?), x100.

#3) *Krithe dolichooera*, x150.

#4) *Echinocythereis margaritifera*, x50.

#5) *Munsevellla bermudezi*, x100.

#6) *Loxochoncha tricornata*, x100.

#7) *Cytheropteron wardensis*, x100.

#8) *Pelusistoma howei*, x100.

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#9) *Gangamocythereidea dictyon*, x100.

#10) *Cativella navis*, x100.

#11) *Caudites nipeensis*, x150.

#12) *Loxochoncha fischeri*, x150.

#13) *Pumilcythereidea sandbergi*, x150.

#14) *Basslerites minutus*, x150.

#15) *Puriana gatunensis*, x100.

#16) *Reussicythere howei*, x100.

#17) *Actinocythereis qamillionensis*, x75.
PLATE 29

#1) **Occultocythereis angusta**, x150.
#2) **Kangarina quellita**, x100.
#3) **Loxochoncha lapidoscola**, x150.
#4) **Cytherura ex. grp. johnsoni**, x100.
#5) **Radimella ovata**, x100.
#6) **Orionina serrulata**, x75.
#7) **Hemicytherura bradyi**, x100.
#8) **Quadracythere howei**, x100.
#9) **Loxochoncha dorsotuberculata**, x150.
#10) **Microcythere inflexa**, x100.
#11) **Cushmanidea cristifera**, x100.
#12) **Paracytheridea tschoppi**, x150.
#13) **Perissocytheridea rugata**, x100.
#14) **Krithe trinidadensis**, x75.
#15) **Procythereis deformis**, x100.
#16) **Cytherella aff. vulgata**, x50.
#17) **Loxochoncha wagneri**, x100.
APPENDIX A

ALPHABETICAL LIST OF BENTHIC FORAMINIFERAL SPECIES

AMMOCYTE SP.
AMMONIA PARKINSONIANA PARKINSONIANA
A. PARKINSONIANA TEPIDA
AMPHIGORNA CAMACOH
A. HIRSUTA
A. SCALARIS
A. SUBLINEATA
AMPHISTEGINA GIBBOSA
ANOMALINOIDES ID
ARTICULINA MAYORI
A. PACIFICA
ASTACOLUS NUDICOSTATA
A. OVATUS
A. c.f. PLATENSIS
ASTERIGERINA CARINATA
BIGENERINA IRREGULARIS
BOLIVINA ALATA
B. INCONSPICUA
B. INFLATA
B. ISIDROENSIS
B. LOWMANI
B. PLICATA
B. PSEUDOPPLICATA

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B. SPINATA
B. SUBAENARIENSIS
B. SUBEXCAVATA
B. THALMANNI
B. TONGI
BUCCELLA HANNAI
BULIMINA ACULEATA
B. AFFINIS
B. ALAZANENSIS
B. INFLATA
B. MARGINATA
BULIMINELLA BASSENDORFENSIS
B. ELEGANTISSIMA
BULIMINOIDES BASICOSTATA
CANCRI SAGRA
CARIBBEANELLA POLYSTOMA
CARPENTERIA CANDEI
CASSIDULINA CARAPITANA
C. CARINATA
C. CURVATA
C. LAEVIGATA
C. SUBGLOBOSA
CASSIDULINOIDES BRADYI
C. ERECTA
CHILOSTOMELLA OVOIDEA
CIBICIDES LOBATULUS
C. WUELLERSTORFI
CIBICIDOIDES COMPRESSUS
C. FALCONENSI S
C. FLORIDANUS
C. GRANULOSUS
CLAVULINA MEXICANA
CORNUSPIRA INVOLVENS
CRUCILOCULINA STRIATA
C. SUBLINEATA
CYCLAMMINA CANCELLATA
CYMBALOPORETTA ATLANTICA
C. SQUAMMOSA
DENTALINA ADVENA
D. PAUPERATA
DISCORBINELLA BERTHELOTI
DISCORBIS MIRA
DOROTHIA BRADYANA
DYOCICIBIDIES BISERIALIS
EDENTOSTOMINA FITERREI
EHRENBERGINA CARIBBEA
ELPHIDIUM DISCOIDALE
E. GUNTERI
E. LANIERI
E. POEYANUM
EPISTOMINELLA EXIGUA
E.(?) c.f. RUGOSA
FISSURINA ANNEXENTS
F. AURICULATA
F. MARGINATA
FRONDICULARIA ADVENA
F. SAGGITULA
F. VAUGHANI
FURSENKOINA MEXICANA
F. PONTONI
F. SPINICOSTATA
GAUDRYINA BULBROOKI
GAVELINOPIST PRAEGERI
GLABRATELLA c.f. PATTELIFORMIS
G. PULVINATA
GLOBOBULIMINA PERVERSA
GLOBULINA GIBBA
GUTTULINA IRREGULARIS
G. PROBLEMA
GYROIDINA PARVA
G. REGULARIS
G. SOLDANII
GYROIDINOCIDES VENEZUELANA
HANZAWAIA CONCENTRICA
H. MANTAENSIS
HAYNESINA GERMANICA
HETEROSTEGINA ANTILLEA
HOEGLUNDINA ELEGANS
KARRERIELLA BRADYI
LAGENA GIBBREA
L. GRACILLIMA
L. GRACILLIS
L. LAEVIS
L. STRIATA
LATICARININA PAUPERATA
LENTICULINA CALCAR
L. CLERICII
L. CULTRATA
L. OCCIDENTALIS
L. PERIGRINA
L. c.f. SERPENS
LEPIDOCYCLINA (L) WAYLANDVAUGHNI
LIEBUSELLA SOLDANII
MARGINULINA OBESA
M. c.f. STRIATULA
M. SUBBULLATA
MARGINULINOPSIS MARGINULINOIDES
M. SUBACUELATA GLABRATA
MARTINOTTIELLA c.f. CYCLOSTOMATA
M. FALIDA
MASSILINA TENUISSIMA
MELONIS BARLEEANUS
M. POMPILIOIDES
MILIOLINELLA FICHTELIANA
M. SUBROUTUNDA
MINIACINA MINIACEA
MYCHOSTOMINA REVERTENS
NEOCONORBINA c.f. FLORIDENSIS
N. TERQUEMI
NEODEPONIDES ANTILLARUM
N. BRYAMENSIS
NODOBACULARIELLA CASSIS
NODOSARIA LONGISCATA
N. PYRULA
N. RAPHANISTRUM
N. STAINFORTHI
N. VERTEBRALIS
NONION INCISUM
NONIONELLA BASILoba
N. MIOCENICA
N. MIOCENICA var. STELLA
OOLINA HEXAGONA
ORIDORSALIS UMBONATUS
ORTHOMORPHINA CHALLENGERINA
OSANGULARIA CULTER
PARAROTALIA SARMIENTOI
PATELLINA CORRUGATA
PAVONINA ATLANTICA
PENEROPLIS BRADYI
PLANORBULINA MEDITERRANENSIS
PLANULARIA VENEZUELANA
PLANULINA ARIMINENSIS
P. c.f. SUBTENUISSIMA
PLECTOFRONDICULARIA CALIFORNICA
P. FLORIDANA
P. c.f. LONGISTRIATA
PLEUROSTOMELLA ALTERNANS
P. BIERIGI
PRAEGLOBOBULIMINA PUPOIDES
PSEUDONODOSARIA COMATULA
P. INCISIA
PSEUDONONION BASISPINATA
P. COSTIFERUM
P. GRATELOUPI
PULLENIA BULLOIDES
P. SUBCARINATA
PYRGO c.f. OBLONGA
P. SUBSPHAERICA
P. VESPERTILIO
PYRGOELLA SPHAERA
PYRULINA ANGUSTA
QUADRIMORPHINA VILARDEBOANA GLABRA
QUINQUELOCULINA BICARINATA
Q. BICOSTATA
Q. BICOSTATA GARRETTI
Q. BOSCIANA
Q. COMPTA
Q. LAMARCKIANA
Q. c.f. POEYANA
Q. SEMINULA
RECTOBOLIVINA ADVENA
R. RAPHANUS
R. SPINESCENS
RECTUVIGERINA MULTICOSTATA
REOPHAX AGGLUTINATUS
REUSSELLA MINUTIA
R. SPINULOSA
ROSALINA BULBOSA
R. GLOBULARIS
R. c.f. VALVULATA
SAGRINA PULCHELLA
SARACENARIA c.f. ITALICA
S. LATIFORMIS JAMAICENSIS
S. LATIFRONS
SIGMAVIRGULINA TORTUOSA
SIGMOILINA SUBPOEYANA
S. TENUIS
SIGMOILOPSIS FLINTII
S. SCHLUMBERGERI
SIPHOGENERINA FREDSMITHI
S. MULTICOSTATA
S. SENNI
S. SMITHI
S. TRANSVERSA
SIPHONINA PULCHRA
SPHAEROIDINA BULLOIDES
SPIRILLINA VIVIPARA
SPIROLOCULINA COMMUNIS
S. ROTUNDA
SPIROPLECTAMMINA FLORIDANA
STAINFORTHIA COMPLANATA
STETSONIA MINUTA
STILOSTOMELLA ANTILLEA
S. BRADYI
S. CONSOBRINA
S. VERNUEILI
SVRATKINA AUSTRALIENSIS
TEXTULARIA c.f. AZUANA
T. LALICKERI
T. MEXICANA
T. c.f. SICA
TEXTULARIELLA BARRETTI
TRIFARINA ANGULOSA
T. BRADYI
T. HOLCKI
TRILOCULINA CARINATA
T. SAIDI
T. TRICARINATA
T. TRIGONULA
TURRILINA ALSATICA
UVIGERINA AUBERIANA
U. COCOAENSIS
U. FLINTI
U. c.f. HANNAI
U. HISPIDO-COSTATA
U. ex. grp. FEREGRINA
U. RUSTICA
UVIGERINELLA SPARSICOSTATA
VAGINULINA ADVENA
V. MEXICANA
VALVULINERIA c.f. HUMILIS
V. PALMERAE
V. VENEZUELANA

The following species lists show presence of benthic foraminifera identified in scans in the five sections used in this report. These species are in addition to the species identified in splits, listed in Appendix C.

MOIN FORMATION

AMMONIA PARKINSONIANA PARKINSONIANA
AMPHICORYNA CAMACHOI
BIGENERINA IRREGULARIS
BULIMINA AFFINIS
CIBICIDOIDES GRANULOSUS
CRUCILOCULINA STRIATA
CYMBALOPORETTA ATLANTICA
DISCORBINELLA BERTHELOTI
DYOCICICIDES BISERIALIS
EHRENBERGINA CARIBBEA
FRONDICULARIA SAGGITULA
LENTICULINA SERPENS
LIEBUSELLA SOLDANII
MARGINULINOPSIS MARGINULINOIDES
MINIACINA MINIACEA
NEOCONORBINA c.f. FLORIDENSIS
NEOEDEPONIDES BRYAMENSIS
PYRGO c.f. OBLONGA
QUINQUELOCULINA BICOSTATA GARRETTI
SARACENARIA LATIFORMIS
SIGMOILOPSIS FLINTI
SPIROLOCULINA COMMUNIS
STETSONIA MINUTA
TEXTULARIA c.f. AZUANA
TRILOCULINA TRICARINATA

RIÓ BANANO FORMATION

DISCORBINA MIRA
EDENTOSTOMINA FITTERREI
ELPHIDIMUM GUNTERI
PATELLINA CORRUGATA
PAVONINA MIOCENICA
PLANORBULINA MEDITERRANENSIS
QUINQUELOCULINA c.f. POEYANA
SPIROLOCULINA ROTUNDA

LOWER QUEBRADA TERCIOPELO REFERENCE SECTION OF THE
USCARI FORMATION

AMPHICORYNA HIRSUTA
BULIMINELLA BASICOSTATA
GLOBULINA GIBBA
KARRERIELLA BRADYI
LATICARININA FAUPERATA
LENTICULINA OCCIDENTALIS
MARGINULINA OBESA
NODOSARIA RAPHANISTRUM
N. STAINFORTHI
PLEUROSTOMELLA BIERIGI
PSEUDONODOSARIA COMATULA
QUINQUELOCULINA BICOSTATA
SIPHOGENERINA SENNI
VAGINULINA SP.
UPPER QUEBRADA TERCIOPELO REFERENCE SECTION OF THE USCARI FORMATION

MARGINULINA c.f. STRIATULA
QUINQUELOCULINA BICARINATA
TRIFARINA SP.
VALVULINERIA HUMILIS

QUEBRADA USCARI TYPE SECTION OF THE USCARI FORMATION

SPIROLOCULINA ROTUNDA
TRIFARINA ANGULOSA

RIO REVENTAZON SECTION OF THE USCARI FORMATION

AMMOBACULITES SP.
AMMONIA PARKINSONIANA PARKINSONIANA
AMPHICORYNA HIRSUTA
A. SUBLINEATA
CARIBBEANELLA POLYSTOMA
CIBICIDOIDES COMPRESSUS
C. GRANULOSUS
CLAVULINA MEXICANA
DOROTHIA BRADYANA
FRONDICULARIA ADVENA
GLOBULINA GIBBA
GUTTALINA IRREGULARIS

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G. PROBLEMA

HAYNESINA GERMANICA
LAGENA GRACILLIS
MARGINULINA OBESA
MARTINOTTIELLA CYCLOSTOMATA
M. PALLIDA
NODOSARIA STAINFORTHI
PLANULINA SUBTENUISSIMA
PLECTOFRONDICULARIA FLORIDANA
PSEUDONONION GRATELOUIPI
QUINQUELOCULINA BICOSTATA
RECTOBOLIVINA ADVENA
RECTUVIGERINA MULTICOSTATA
REOPHAX AGGLUTINATUS
Sphaeroidina Bulloides
SPIROLOCULINA ROTUNDA
TEXTULARIA LALICKERI
UVIGERINELLA SPARSICOSTATA
VAGINULINA MEXICANA
APPENDIX B

ALPHABETICAL LIST OF PLANKTONIC FORAMINIFERAL SPECIES

CANDEINA NITIDA
CASSIGERINELLA CHIPOLENSIS
CATAPSYDRAX DISSIMILIS
C. STAINFORTHI
C. DISSIMILIS var. UNICAVUS
GLOBIGERINA CIPEROENSIS CIPEROENSIS
G. TRIPARTITA
G. VENEZUELANA
GLOBIGERINITA NAPARIMAENSIS
GLOBIGERINOIDES CONGLOBATUS
G. OBLIQUS EXTREMUS
G. OBLIQUS OBLIQUS
G. PRIMORDIUS
G. RUBER
G. TRILOBUS TRILOBUS
GLOBOQUADRINA ALTISPIRA
G. DEHISCENS
GLOBOROTALIA ACOSTAENSIS ACOSTAENSIS
G. ARCHEOGENARDII
G. CRASSAFORMIS CRASSAFORMIS
G. KUGLERI
G. LENGUANENSIS

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G. c.f. MARGARITAE MARGARITAE
G. MENARDII MENARDII
G. DPIMA NANA
G. FOHSI PERIPHERORONDA
G. PLEISOTUMIDA
G. SCITULA SCITULA
G. SIAKENSIS
G. TRUNCATULINOIDES EXCELSA
G. TUMIDA TUMIDA
HASTIGERINA SIPHONIFERA
NEOGLOBOQUADRINA DUTERTREI
ORBULINA SUTURALIS
O. UNIVERSA
O. UNIVERSA var. BILOBATA
PRAEORBULINA GLOMEROSA CURVA
P. SICANA
P. TRANSITORIA
PULLENIA DEHISCENS
P. PRIMALIS
SPHAERIDINELLA DEHISCENS
S. DEHISCENS EXCAVATA
SPHAERIDINELLOPSIS SEMINULINA
APPENDIX C

FREQUENCY DISTRIBUTIONS OF BENTHIC FORAMINIFERA
IDENTIFIED IN SPLITS OF ALL SAMPLES

Data are in specimen counts for each species. The total number of specimens counted for each sample is given as the last row entry. Species are in alphabetical order.
<table>
<thead>
<tr>
<th>SAMPLE NUMBERS</th>
<th>RIO</th>
<th>REVENTAZON</th>
<th>MOIN FM</th>
<th>RIO BANANO FM</th>
<th>QUEBRADA</th>
<th>TERCIOPELO</th>
<th>QUE. USCARI</th>
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<th>QUEBRADA TERCIOPELO</th>
<th>USCARIM</th>
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<th>F. marginata</th>
<th>F. spinosella</th>
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APPENDIX D

RELATIONSHIP OF SOME SPECIES EXCLUDED FROM FACTOR ANALYSES TO FACTOR INTERPRETATIONS

The following species, which were not included in the factor analyses, show abundance distributions (see Appendix C) which help to separate the stratigraphic sections.

**Astacolus nudicostata.** Occurs only in the Rio Reventazon section of the Uscari Formation. Appears to be an abyssal to lowermost bathyal indicator.

**Bolivina thalmanni.** Occurs in the Rio Reventazon and Quebrada Terciopelo sections of the Uscari Formation. Although widespread in the Terciopelo section, it is excluded in the upper four samples. Evidently, this species can be found from abyssal to upper bathyal environments, but is excluded from the uppermost bathyal and outer shelf environments.

**Buccella hannai.** Found throughout the Rio Banano sandstones and in sample #13 of the Rio Reventazon section, and two samples in the middle Quebrada Terciopelo section of the Uscari Formation. This species is a shallow shelf indicator. Its presence in the deep water deposits of the Uscari Formation reinforces the interpretation of turbidite deposition in this unit.

**Cassidulinoides bradyi.** Found only in the middle and upper parts of the Quebrada Terciopelo section of the Uscari Formation. This is an upper bathyal indicator.

**Cibicides lobatulus.** Found throughout the Rio Banano sandstones. Also found in scattered samples in the Rio Reventazon and middle Quebrada Terciopelo sections of the Uscari Formation, where its presence denotes turbidite deposits.

**Dentalina pauperata.** Common in the Rio Reventazon and lower Quebrada Terciopelo sections of the Uscari Formation. This is evidently a deep bathyal species. Single occurrences in one sample from the upper Quebrada Terciopelo Uscari Formation, and two samples from the Moin Formation, may indicate misidentification of these specimens, or, this species is found in very low abundance in a wide range of depths.
Ehrenbergina caribbea. Found throughout the Quebrada Terciopelo section of the Uscari Formation where its presence suggests a middle to upper bathyal habitat for this species.

Elphidium poeyanum. Common in the Rio Banano sandstones. This genus is characteristic of the shallow shelf.

Frondicularia vaughni. Found in the Rio Reventazon and throughout the Quebrada Terciopelo sections of the Uscari Formation, suggesting a wide bathyal preference. One isolated occurrence in the Rio Banano sandstones may be a misidentification.

Melonis pompilioides. Restricted to the Rio Reventazon and lower to middle Quebrada Uscari sections of the Uscari Formation. This is a deep water indicator species.

Miliolinella subrotunda. Found only in the Rio Banano sandstones, indicating an inner shelf, nearshore habitat.

Neoepinoidea antillarum. Found in abundance in the Rio Banano sandstones and scattered throughout the Quebrada Terciopelo section of the Uscari Formation, indicating downslope transport by turbidites. This species is a shelf indicator.

Nodobaculariella cassis. Restricted to the Rio Banano sandstones. This is a reefal indicator.

Nodosaria longiscata. Found in abundance in the Rio Reventazon and Quebradad Terciopelo sections of the Uscari Formation. This species has a wide ranging bathyal depth tolerance.

Planulina ariminensis. Restricted to the Moin and Rio Banano Formations where it is common. A shelf indicator.

Plectofrondicularia californica. Common in the Rio Reventazon and lower Quebrada Terciopelo sections of the Uscari Formation. This species is a lower to middle bathyal indicator.

Pseudonodosaria comatula. Restricted to the deep water deposits of the Rio Reventazon section of the Uscari Formation. A lower bathyal to abyssal indicator.

Pullenia bulloides. Common in the lower to middle Quebrada Terciopelo section of the Uscari Formation. A deep bathyal to abyssal indicator.


Stilostomella bradyi. Found only in the middle to upper bathyal deposits of the Quebrada Terciopelo section of the Uscari Formation.

Syratkina australiensis. Restricted to the inner shelf deposits of the Rio Banano sandstones, and one isolated occurrence in the upper Moin Formation. A shallow shelf indicator.

Triloculina trigonula. Found only in the Rio Banano sandstones and the Moin Formation. A shelf indicator.

Valvulineria venezuelana. Restricted to the deep water deposits of the Rio Reventazon and lower Quebrada Terciopelo sections of the Uscari Formation. A middle to lower bathyal to abyssal indicator.
VITA

David Terrance Cassell was born on December 3, 1952 in Terre Haute, Indiana. He was raised in the San Francisco Bay Area, receiving a B.A. in Geology from The University of the Pacific in Stockton, California in May, 1976. After receiving a M.S. in Geology from Northern Arizona University in Flagstaff, he worked for three years as a petroleum geologist in the United States, Singapore, and Saudi Arabia. He married Khoo Nam Eng, a native of the Republic of Singapore, in December, 1979. They have one child, a daughter named Faye Xian-Hui, born in August of 1986.
Candidate: David Terrance Cassell

Major Field: Geology

Title of Dissertation: NEogene Foraminifera of the Limon Basin of Costa Rica

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