NEOGENE HISTORY OF THE CARAPITA FORMATION,
EASTERN VENEZUELA BASIN

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ABSTRACT OF THESIS

The planktonic and benthic foraminifera from the lower to middle Miocene shales of the Carapita Formation of Eastern Venezuela in three exploration wells and one outcrop section are analyzed with the objectives of establishing a precise biostratigraphy of the formation and its bathymetric history. Comparison with the well-preserved microfaunas of the correlative Cipero Formation of Trinidad made possible the achievement of these objectives. The formation, up to 4500 to 6000 m thick in outcrops, extends from northeastern Anzoátegui and North of Monagas States to the Gulf of Paria and is both an important oil reservoir towards the east and the main seal rock for the Oligocene reservoir in the north of Monagas State. In the area studied the Carapita Formation spans lower to lower middle Miocene Zones N6/M3 to N9/M6; its upper part is unconstrained as only rare long ranging early Miocene to early Pliocene planktonic foraminifera occur above the Orbulina datum. Unexpectedly, we found that the four lower to middle Miocene sections are highly discontinuous, with hiastuses as long as 4
Myr. Based on the abundance patterns of sixty-nine species of benthic foraminifera and analysis of morphotype abundance following the methodology of Corliss and Chen (1988) and Corliss and Fois (1993), we show that the Carapita Formation was deposited at outer neritic to middle bathyal depths (≥ 200-1000 m), whereas the Cipero Formation was deposited at middle to lower bathyal depths (≥600-2000 m). Importantly, the bathymetric changes are associated with unconformities in all sections, strongly suggesting that both (shallowing and associated unconformities) were tectonically induced.
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I- INTRODUCTION

In the EVB the Carapita Formation is ~ 4500 to 6000 m thick in outcrops, extending from northeastern Anzoátegui and North of Monagas States to the Gulf of Paria. This formation is both an important oil reservoir towards the east and the main seal rock for the Oligocene reservoir in the north of Monagas State. Because the EVB is a complex tectonic area the National Oil Company of Venezuela (PDVSA) has employed micropaleontology since the mid 1970s in order to minimize risk and time during exploration drilling. The first purpose of this work is to reconstruct the depositional history of the Carapita Formation based on qualitative analysis of both planktonic and benthic foraminifera. The second purpose is to compare the generally poorly preserved faunas from the Carapita Formation (Venezuela) with the well preserved faunas of the Cipero Formation (Trinidad) whose composition and distribution are well understood in order to determine the distribution of the most stratigraphically and/or bathymetrically useful faunal components of the Carapita Formation. The third purpose is to illustrate by Scanning Electron Microscopy (SEM) the most important taxa. Finally, data presented in this work will be integrated and calibrated in the future with sedimentological and structural models generated by PDVSA.

II- LOCATION OF THE STUDY AREA

The four sections from Venezuela which I have studied are from two areas in the EVB. These include three exploration wells located in the north of Monagas State, and a section of the Carapita Formation located north of the town of Santa Ines, Anzoátegui State, near the stratotype section which is now inaccessible (Figures 1 and 2). In addition samples from near the type section of the Cipero Formation exposed south of San
Fernando, Trinidad have been analyzed. The Oligocene to Miocene benthic and planktonic foraminiferal assemblages upon which this study is based were recovered from this material.

III- GEOLOGIC SETTING

III-1. Tectonostratigraphic Evolution of the Eastern Venezuela Basin and Trinidad.

The stratigraphy of the Eastern Venezuela Basin and Trinidad reflects four main episodes of tectonic history (Figures 3 and 4): Pre-Rift, Rifting, Passive Margin and Active Margin (Parnaud., 1995).

Pre-Rift (Cambrian)

Pre-rift Paleozoic sedimentary sequences are very well documented from the western part of the Espino graben (Di Croce et al., 1999). These sedimentary sequences correspond to the Hato Viejo and Carrizal formations (Figure 3), which are the oldest sedimentary rocks known in the EVB (Código Estratigráfico de Venezuela (CEV), 2005). Faulting was the main structural factor that controlled their deposition. These units consist of calcareous sandstones interbedded with conglomerates and greenish shales. Their thickness is about 8500 feet (Parnaud et al., 1995). Yoris and Ostos (1997) suggested that their sedimentary deposition was associated with the Gondwana and Laurentia rifting.

Rifting (Jurassic to Early Cretaceous)

During the Jurassic to Early Cretaceous period, Pangaea break up resulted in the development of several grabens in the EVB, with a predominantly southwest to northeast orientation. These grabens influenced the tectonic evolution in the youngest sub-basins in
the Eastern Venezuela Basin (Yoris and Ostos, 1997). In the western part of the Maturin sub-basin, Jurassic sediments were deposited in the Espino Graben (Di Croce et al., 1999). These sediments consist of red bed deposits interbedded with basaltic flows (CEV, 2005).

**Passive Margin (Early Cretaceous to Eocene)**

A passive margin was established during the Early Cretaceous in the north of Venezuela; It was characterized by thermal subsidence that ended in the Eocene (Erikson and Pindell, 1993). The tectonic-sequence is thicker in the north and thins towards the northeast. The main source sediments were derived from the Guyana Shield (Di Croce et al., 1999). According to Ostos et al. (2005), a transgression diachronous from the east to the west occurred in the Eastern Venezuela Basin at the end of the Albian. As a result, organic-rich siltstones and shales are the dominant lithology of the Chimana, Querecual and San Antonio Formations (Figures 3 and 4). Equivalent sedimentary units are present to the east in Trinidad. From base to top they are: the shallow water Gautier Formation, correlative with the Chimana Formation, followed by the deep water Naparima Hill and Guayaguare Formations. These units are homologous to the Querecual and San Antonio Formations, respectively. The Santa Anita Group is the youngest deposit on the passive margin. From base to top the Santa Anita Group is formed by the San Juan, Vidoño and the Caratas formations the latter with its Tinajitas Member (Figures 3 and 4). The San Juan Formation consists mainly of light-grey, fine-grained quartzitic sandstone. Dark-grey, silty, poorly fissile to concretionary foraminiferal shales make up almost the entire interval assigned to the Vidoño Formation, and very minor amounts of thin bedded, glauconitic siltstone to fine-grained sandstone form a more or less persistent horizon in the lower middle part of the formation. The Caratas Formation is typified by dark-grey to
blue-grey, very hard, massive, calcareous siltstones. Finally, the Tinajitas Member consists of interbedded lavender-grey quartzitic sandstone, grey and greenish grey slightly glauconitic sandstone and siltstone, and grey silt, and, in places, foraminiferal shale. In Trinidad, the Paleogene sediments of the Lizard Springs, Navet and San Fernando Formations represent deeper water conditions.

**Active Margin (Oligocene to Recent)**

Above the Santa Anita Group lies a transgressive sequence corresponding to the Merecure Group, which consists of the Los Jabillos, Areo and Naricual Formations (Figures 3 and 4). The Los Jabillos Formation consists principally of massive to thick-bedded quartzitic, medium-grained to pebbly, grey to pink sandstones, with minor shale and siltstones breaks. The Areo Formation consists of gray shales with seams of yellowish or reddish glauconitic ironstone concretions, and occasional hard whitish gray quartzitic sandstones. The Naricual Formation consists of fine to coarse compact grey sandstones, frequently quartzitic and occasionally friable. The oblique collision between South America and the Caribbean began during the Paleogene and reached its maximum intensity during the early to middle Miocene (Jacome et al., 2003). The Oligocene-Miocene boundary interval is associated with transgressive deposits and a progressive increase in the flexural subsidence of the basin. During this time, sediments were transported from three different sources. One was east-west, parallel to the basin axis, the second one was in the south, with sediments from the Guayana Shield and the third one in the north, with sediments derived from the belt of emerged thrusts (PDVSA Internal Report, 2009). The deepest Oligocene to lower Miocene deposits in the north of Monagas belong the Carapita Formation (Figures 3 and 4). The Carapita Formation is ~ 4500 to 6000 m thick in outcrops in eastern Venezuela, extending from both northeastern
Anzoátegui and north of Monagas to the Gulf of Paria. The type section of the Carapita Formation is located in the Carapita Gulch, north of the town of Santa Ines, Anzoátegui State. Another small outcrop is located on the Rio Oregano to the east. In the type section, the Carapita formation is an essentially homogeneous, foraminiferal shale (Hedberg, 1937). The shales are dark gray and ferruginous, sometimes finely micaceous and with subconchoidal fracture. The upper contact of the Carapita Formation is unconformable with the overlying La Pica Formation, and the basal contact is lithologically gradational with the underlying Naricual Formation (Figures 3 and 4).

IV EARLIER MICROPALÆONTOLOGICAL STUDIES

IV-1. Carapita Formation

Important studies have been made on the Carapita Formation by Hedberg (1937), Franklin (1944) and a series of internal/unpublished foraminiferal reports have been carried out by Fournier (1957), Jouval and Villain (1986), Saint Marc (1988), De Cabrera and De Macquhae (1990) and Sanchez (2006).

Hedberg and Pyre (1944) divided the type section of the Carapita Formation into two members. The lower sandstones member was called the “Capaya tongue” and the upper member, the Carapita Shale. Hedberg (1937) described from the type section of the Carapita Formation eighteen new species of foraminifera including the taxonomically distinctive and stratigraphically useful form *Uvigerina carapitana* and assessed the age as Middle to Late Oligocene. Franklin (1944) reported an Early Oligocene age from the outcrop section located in the vicinity of Rio Oregano, Anzoátegui State. Fournier (1957) established a biozonation based on benthic foraminifera for the lower part of Carapita Formation. This biozonation is recognized between 800 to 1000 feet above the top of the
Naricual Formation (main reservoir in the EVB). This biozonation is based on the following occurrences (from lowest to highest): *Eggerella* aff. *scabra, Textularia* 18, *Quinqueloculina seminula, Nonion costiferum* and *Nonion incisum.  

Sulek (1961), Lamb (1964) and Lamb and Sulek (1965a) recovered a normal succession of zones, from the Lowest Occurrence (LO) of *Globigerina ciperoensis ciperoensis* to the Highest Occurrence (HO) of *Globorotalia menardii* in the upper part. Peirson (1965) examined the Carapita Formation between the LO of *Globigerinatella insueta* and the HO of *Catapsydrax dissimilis* and assigned it to the lower Miocene. Jouval and Villain (1986) produced an atlas with a total of one hundred and sixty (160) foraminifera from the Carapita Formation: One hundred and thirty six (136) benthic foraminifera and twenty four (24) planktonic foraminifera. Saint Marc (1988) estimated depths of outer neritic to lower bathyal from the Miocene section of the Carapita and the Oficina formations using benthic foraminifera. De Cabrera and De Macquhae (1990) studied the Oligocene – Miocene interval recovered from thirty five (35) wells drilled in the Naricual and Carapita formations in the EVB. They estimated that the lower Miocene was deposited at lower to middle bathyal depths and the middle Miocene at upper bathyal depths. Water depths interpretation was based on definition of biofacies described in all the sections. These biofacies are: *Lenticulina vaughani / Lenticulina americana* var. *grandis, Cyclammina cancellata* and *Siphonina pozonensis / Liebusella soldanii*. They also stated that the Carapita Formation was deposited at high sedimentation rates. Sanchez (2006) described five morphotypes of calcareous benthic foraminifera in the Carapita Formation (west of the EVB) following the Corliss and Fois (1991) methodology. Only three morphotypes were the same as described in the Northwest Gulf of Mexico: Plano-Convex, biconvex and trochospiral the other two were elongate.
(uniserial/biserial) and planispiral. No clear correlation between Northwest of Gulf of Mexico and EVB was found.

**IV-2. Cipero Formation**

The Cipero Formation was named by Thomas (1924) who originally ascribed to it some 2500 to 3000 feet (761 to 914 m) of light-colored marls and orbitoidal silts exposed south of San Fernando. Lehner (1935) used the name of Cipero Silt to describe one of the type sections located on the Cipero Coast sequence. Renz (1942) made a detailed lithological description of the Cipero Formation. Cushman and Stainforth (1945) described a total of three hundred and twelve (312) foraminifera from the type section exposed to the south of San Fernando. Two hundred and ninety six benthic (296) and sixteen (16) planktonic foraminifera were identified. Stainforth (1948) assigned an Early Oligocene to Early Miocene age to the outcrop exposed on the Cipero Coast of San Fernando. Bolli (1957c) made a detailed study of the planktonic foraminifera and their stratigraphic distribution in the Cipero and Lengua formations. In his work Bolli placed the Oligocene/Miocene boundary between the *Globorotalia kugleri* and *Catapsydrax dissimilis* zones. Liska (1983) placed the middle/upper Miocene boundary at the contact of the Cipero and Lengua-Lower Cruse Formations. Pearson and Wade (2009) made a taxonomic study of well-preserved planktonic foraminifera from the uppermost Oligocene and the lowermost Miocene from Trinidad. Using SEM they show details of foraminifera test construction and wall ultrastructures: calcite crust of species such as *Catapsydrax dissimilis* and *Turborotalia quinqueloba* and microperforate wall texture in *Tenuitella* and *Globigerinita*.
Paleogene and Neogene zonations based on the planktonic foraminifera were developed in Trinidad, between 1945 and 1957. This was spurred by the increasing need of the oil industry there to achieve greater resolution in the correlation of the geologically complex marine sedimentary sequences under active exploration and development.

The initial effort in using the planktonic foraminifera for the subdivision and correlation of the younger Cenozoic sediments of Trinidad led to a second, more concerted effort by the local oil industry to investigate and utilize the planktonic foraminifera for correlation of the Cenozoic marine sediments. This resulted in the zonal scheme established by Bolli (1957a, 1957b, 1957c) for the Paleocene to Middle Miocene marine sediments of Trinidad.

V- MATERIALS AND METHODS

V-1. Samples

A total of two hundred nine samples (209) were analyzed in order to carry out the micropaleontological study (Table 1): 1) One hundred twenty one (121) cutting samples from three PDVSA exploration wells, collected at approximately 100 ft (30 m) intervals; 2) sixty seven (69) outcrop samples from the type locality of the Carapita Formation collected (by me in April, 2009) at one (1) meter intervals (except between 45-47 m and 51-53 m, which were covered by vegetation) from north of Monagas, EVB; and 3) Nineteen (19) outcrop samples from the Cipero Formation, from Trinidad.

V-2. Sample Processing

Samples were processed as follows:
For all samples from Venezuela, about 100 g of material were soaked in water for a few hours to disaggregate particles. When samples did not disintegrate using only water, the shales were gently boiled in “Quaternary O” for a short time and washed. The process was repeated as many times as necessary. Disaggregated samples were washed over a 200-mesh sieve and the residues were dried. All samples were weighed before and after processing to monitor the proportion of residue produced. Each dried residue was passed through a nest of sieves (standard sizes 40, 60, 80, 100 µ and collecting pan). All foraminifera (planktonic, calcareous benthic and agglutinated) present in residues were picked and collected in a specialized slide. The foraminifera on each slide were sorted, taxonomically identified, and counted to establish the ratio between planktonic and benthic foraminifera.

For each sample analyzed, the micropaleontological suite of slides represents the size-segregated fauna. Both slides and the residues are stored in the Core House Facilities, PDVSA El Chaure in Puerto La Cruz. All other data are stored on computer files in the Micropaleontology databanks (Stratabugs) in the same laboratory.

Washed residues from the Cipero section were made available. The same analytical procedure was followed as for the Carapita Formation.


A total of two thousand six hundred and thirty three (2633) pictures were taken in the SEM AMRAY – 18301 in the Nelson Biological Laboratories at Rutgers University: 1) One thousand one hundred and sixty nine (1169) pictures from the Carapita Formation; and 2) One thousand four hundred and sixty four (1464) pictures from the Cipero Formation (Plates 1-34).
V-4. Taxonomic framework

Planktonic and benthic foraminifera were identified as far as their preservation permitted. Therefore, prior to attempting any type of sample analysis it was necessary to make a literature review of previous investigations in Venezuela and the Caribbean. Foraminiferal assemblages from the Carapita Formation were compared with type collections of the same age from Trinidad and Jamaica, based on the extensive collections of Profs. W. A. Berggren, R. K. Olsson and Dr. R. D. Liska. The planktonic and benthic foraminifera taxonomy and biostratigraphy of the Cipero Formation (Figure 6) provided a guiding tool in identifying poorly preserved specimens from the Carapita Formation and firmly establish its biozonal content. This helped refine the biostratigraphy of the Carapita Formation. At the same time this permitted a construction of the bathymetric history of eastern Venezuela and provided important data, which contribute to the knowledge of oil accumulation in the EVB. For planktonic foraminiferal identifications I have used the “standard” literature such as: Bolli (1957c), Postuma (1971), Kennett and Srinivasan (1983), Bolli et al. (1985), Spezzaferri (1994) and Pearson and Wade (2009); the age was determined using Berggren et al. (1995). For benthic foraminiferal identifications I have used the “standard” literature such as: Cushman and Stainforth (1945), Cushman and Renz (1947), Renz (1948), Bermúdez (1949), Bandy (1967), Poag (1981), van Morkhoven et al. (1986), Whittaker (1988 Bolli et al. (1994), Robertson (1998), Green et al. (2004) and Kender et al. (2008). Planktonic and benthic foraminifera are documented separately on distribution and abundance charts for each studied section (Figures 7-15).
V-5. Stratigraphic and temporal interpretations

(i) Zonal assignment

Stratigraphic ranges for marker microfossils were used to subdivide the sections into biozones, using the classical zonal schemes of Kennett and Srinivasan (1983), Bolli et al. (1985) and Berggren et al. (1995) for planktonic foraminifera and Martini (1971) and Bukry (1973, 1975) for calcareous nannofossils (O. Rodriguez. personal communication Spring, 2010). Planktonic foraminiferal LOs/FADs and HOs/LADs (Table 2) have been plotted on a X-Y diagram (depth in meters or feet vs time in Ma). I have used these datum levels with the geochronology of Berggren et al. (1995). Sedimentation rate curves were constructed using LOs and HOs of species regarded as stratigraphically most useful. In some cases, there were several possible choices to establish the age-depth curve and it was difficult to determine which points were the best options to constrain them. This was either because samples are cuttings, resulting in imprecise locations of the LOs or HOs of taxa in the section (interval of uncertainty of 100 ft) or because the preservation of the marker taxa was poor. Ultimately, the sedimentation rate curves were drawn using the datums that have proven to be most useful in Venezuelan stratigraphy. Positioning an unconformity precisely may be difficult even where a high-resolution biostratigraphic study is available (Aubry, 1995).

(ii) Sedimentation rate curve (s) and stratigraphic interpretation of sections

The methodology (Aubry, 1995) is based on the principle that the thickness of biozones (and magnetozones or any other stratigraphic unit) are proportional to the duration of the corresponding biochrons (or magnetochrons) where stratigraphic sections are continuous (Aubry, 1995). When sections are continuous, the sedimentation rate
curves are straight lines or possibly broken with inflexion points indicative of changes in sedimentation rates. When sections are discontinuous the sedimentation rate curves are represented by discontinuous lines, with offsets of different parts of the lines where unconformities occur and possibly different slopes reflecting different sedimentation rates. In general there is greater confidence in the stratigraphic interpretation of the middle Miocene intervals in the wells, than the lower Miocene ones.

(iii) Temporal Interpretation

The last step consists in dating the upper and lower surfaces of each unconformity (Aubry, 1991). Using cutting samples it is difficult but possible to date these surfaces.

V-6 Paleobathymetry

Different multivariate statistical techniques such as Factor Analysis (Imbrie and Purdy, 1962), Principal Components Analysis (Mc Cammon, 1968), Cluster Analysis (Bonham-Carter, 1965 and Parks, 1966), have proven useful to manipulate large amount of data and to extract an interpretation of the data from hundreds of analyses. It was however inappropriate to use these techniques for this study because of the low abundance of foraminifera at most levels in the Carapita and Cipero formations (Figure 14); larger samples would have been necessary (about ~300 g). It would have been inordinately time consuming to collect 300 specimens of benthic foraminifera per sample.

For all sections (wells and outcrops) a general bathymetric survey was conducted. For outcrop samples (Venezuela and Trinidad) I have used morphotypes analysis, in order to infer water depths of selected benthic foraminifera based on microhabitat preferences and complement this information with classical paleobathymetric publications.
V-6-a. General survey

To determine general depth distribution I have used classical publications such as Hedberg (1937), Cushman and Renz (1945), Renz (1948), Phleger and Parker (1951), Bandy (1967), van Morkhoven, Berggren and Edwards (1986), Whittaker (1988), Robertson (1988) and Kaminski and Gradstein (2005); (figures 16-18; terminology and numerical bathymetric estimates from van Morkhoven et al. 1986).

V-6-b. Morphotype analysis

(i) Morphotype (M) assignment

The shape of the test of benthic foraminifera was used to distinguish several morphotypes, following the classification developed by Corliss and Chen (1988) and Corliss and Fois (1991). Samples analyzed from the Louisiana and Texas Coasts at 15-40 km intervals and in water depths greater than 100 m; samples above 100 m were omitted. They observed that the morphology of species is related to microhabitat preferences. Epifaunal morphotypes have surface pores present only on one side of the test and the foraminifera live on or above the sediment. Infaunal morphotypes usually have pores on both sides of the test and the foraminifera live in the sediment with low oxygen conditions. Two categories and ten (10) morphotypes were considered in Corliss and Chen (1991) (original description of morphotypes): 1) Epifaunal (rounded trochosiral, plano-convex trochosiral, milioline and biconvex trochosiral) and 2) infaunal (rounded planispiral, tapered / cylindrical, flattened tapered, spherical, tapered/cylindrical and flattened ovoid). The relationship between morphotypes and (paleo) bathymetry is shown in Table 5.

(ii) Taxonomic content of the morphotypes
Figures 19-25 and tables 3 and 4 show the morphotypes (M) recognized in the study area.

(iii) Comparison of morphotypes (M1 to M9) from the Carapita and Cipero formations.

Table 5 shows the morphotypes (M1 to M9) and its respectively water depths. This information was compiled using data previously presented by Corliss and Chen (1991) (page 595, figures 3-9) (Table 5).

VI- BIOSTRATIGRAPHY OF THE CARAPITA FORMATION

VI-1. Stratigraphic interpretation of the lower to middle Miocene

Carapita Formation, EVB

The three wells studied here are located in the northern part of the Monagas State (Figures 1,2), between the Pirital and Tropical Oilfieds. Well A (WA) is located 10 km from Well B (WB) and 25 km from Well C (WC) (Figures 4,5). The stratigraphic succession is the same in the three wells (Figure 3) and as follows: Caratas (Paleocene), Vidoño (Eocene), Los Jabillos (Oligocene), Areo (Oligocene), Naricual (Oligocene), Carapita (Oligo-Miocene) and Mesa/Las Piedras (Plio-Pleistocene) Formations. The sandstones of the lower part of the Carapita Formation and those of the underlying Naricual Formation were the main drilling objectives. This work focuses on the Carapita Formation. The supplementary section of the Carapita Formation analyzed here is located in the Oregano River north of the town of Santa Ines, Anzoátegui State (Figure 1). Both planktonic and benthic foraminifera provided the major stratigraphic control for this Oligocene-Miocene formation. Calcareous nannofossil data were integrated in this research (PDVSA Internal Report; 2006, 2010). However, the distribution of all marker
species of planktonic and benthic foraminifera and calcareous nannofossils identified in each well have been revised and are documented in detail (Figures 7-15 and in the appendix I, II and III).

The use of (admittedly approximate) LOs of *O. universa*, *O. suturalis* and *P. sicana* is based on the fact that no specimens of these taxa were found at lower depths (Figure 7,9,11,13). The same applies to LO of the calcareous nannoplankton *S. belemnos*. The HO of *G. ciperoensis* is questionable in WA ascribed to reworking in view of the fact that it is recorded 420 ft (128 m) apart from the HO of *H. recta*, although the LADs of these two taxa have almost the same age. No massive down-hole contamination was observed in any other well.

**VI-1-a. Well A (WA), Travi Oilfield**

(i) **Zonal subdivision**

WA was drilled in 2004 and its bottom depth was 21,838 ft (6,656 m). The Carapita Formation is 7,735 ft (2,21357 m) thick in this well. Twelve (12) genera and twenty two (22) species of planktonic foraminifera were identified in WA (Figure 7), and two (2) genera and six (6) species of calcareous nannofossils were reported (PDVSA Internal Report, 2006). Long-ranging, early Miocene to early Pliocene planktonic foraminifera occur in WA between 2,300 ft (701 m) to 9,740 ft (2,968 m), such as: *Globigerinella obesa*, *G. praesiphonifera*, *?Neogloboquadrina siakensis*, *Dentoglobigerina venezuelana*, *D. altispira*, *D. altispira globosa*, *Globorotalia scitula*, *Globoquadrina dehiscens*, and *Globigerinoides trilobus* (Figure 6); the species *Sphaeroidinellopsis seminulina* only occurs between 2,300 ft (701 m) to 6,240 ft (1,901 m) and *Globorotalia fohsi peripheroronda* between 6,240 ft (1,901 m) to 7,040 ft (2,145 m).
Lower middle Miocene, Zone N9/M6

Sample interval: 2,300 ft (701 m) – 6,240 ft (1,901 m)

Cutting samples: 20

In general, planktonic foraminifera show poor preservation and in some intervals tend to be internally pyritized between 2,450 ft (746 m) – 2,900 ft (883 m) or glauconitic between 4,390 ft (1,338 m) – 4,650 ft (1,417 m). The HOs of *Orbulina universa* and *Orbulina suturalis* (Figure 7) are located at 2,450 ft (746 m), and their LOs at 6,240 ft (1,901 m). The lower boundary of Zone N9/M6 is thus placed between 6,240 ft (1,901 m) and 6,390 ft (1,947 m). The HO of the calcareous nannofossil *Helicosphaera ampliaperta* is at 6,390 ft (1,947 m), implying that the NN4/NN5 zonal boundary occurs between 6,390 ft (1,947 m) and 6,240 ft (1,901 m). The HO of this taxon is thus close to the LOs of the planktonic foraminifera *Orbulina universa* and *Orbulina suturalis*, in agreement with correlation charts (Berggren et al. 1995).

Lower middle Miocene, Zone N8/M5

Sample interval: 6,240 ft (1,901 m) – 7,040 ft (2,145 m)

Cutting samples: 6

The HOs of *Globigerinoides bisphericus* and *Praeorbulina sicana* are at 6,390 ft (1,947 m), and their LOs at 7,040 ft (2,145 m). The lower boundary of Zone N8/N7 is thus placed between 7,040 ft (2,145 m) and 7,220 ft (2,200 m).

Lower Miocene, Zone N7/M4

Sample interval: 7,040 ft (2,145 m) – 7,380 ft (2,249 m)

Cutting samples: 3

The HO of *Globorotaloides stainforthi* at 7,380 ft (2,249 m) indicates the lower boundary of Zone N7/M4 (Figures 7). According to PDVSA Internal Report (2006) calcareous
nannofossil data for this interval are very poorly preserved and indicative of a broad lower to early Miocene age.

*Lower Miocene, Upper boundary of Zone N6/M3?*

Sample interval: 7,380 ft (2,249 m) – 7,820 ft (2,383 m)
Cutting samples: 4

Poor preservation and few planktonic foraminifera characterize this interval (Figure 7). The HO of *Globigerinoides altiaperturus* is at 7,380 ft (2,249 m), and its LO at 7,820 ft (2,383 m). The lower boundary of Zone N6/N3 is between 7,820 ft (2,383 m) and 8,150 ft (2,484 m) (Figure 7).

*Lower Miocene, Upper boundary of Zone N5/M2?*

Sample interval: 7,820 ft (2,383 m) – 9,740 ft (2,968 m)
Cutting samples: 14

Planktonic foraminifera assemblages are poorly to moderately preserved with low abundance and diversity (Figure 6). Between 9,340 ft (2,846 m) to 9,740 ft (2,968 m) the co-occurrence of *Globigerina ciperoensis* and *Cassigerinella chipolensis* (Figures 7) indicates that this interval is late Oligocene. According to Kennett and Srinivasan (1983), *Globigerina ciperoensis* is abundant in the upper Oligocene but rare in the lower Miocene. *Cassigerinella chipolensis* was used as a datum event (FAD, 33.65 Ma) by Berggren et al (1995). Only the calcareous nannofossil *Helicosphaera recta* (Upper Oligocene-lower Miocene) was reported from the interval 9,200 to 9,210 ft (2,806 to 2,809 m) (PDVSA Internal Report, 2006).

(ii) *Stratigraphic interpretation*

An intra-lower Miocene unconformity is inferred at level ~7,380 ft (2,250 m) (Figure 26) marked at this level by the juxtaposed HO of *G. altiaperturus* (LAD at 20.5 Ma), LO of
S. belemnos (FAD at 18.3 Ma) and the HO of G. stainforthi (LAD at 17.3 Ma). The NN3/NN4 and N6/M3-N7/M4 zonal contacts are thus unconformable.

The sedimentary interval below the unconformity, between 7,380 ft (2,250 m) and the 9,200 ft (2,806 m) is very difficult to interpret in the absence of stratigraphic markers. The HOs of G. ciperoensis and H. recta are recorded 420 ft (128 m) apart although the LADs of these taxa have almost the same age. This suggests reworking. (We note however that the LAD of the H. recta is not a reliable datum; Aubry, personal communication). The absence of markers may indicate that this stratigraphic interval is unconformable (Figure 26). If the sedimentary interval between 7,380 ft (2,250 m) and 5,900 ft (1,800 m) were continuous, it would have been deposited at a rate of 0.8 ft/1000 yr (25 cm/1000 yr). We infer the presence of an unconformity between the HO of H. ampliaperta (6390 ft (1,949 m); LAD at 15.6 Ma) and the LO of O. suturalis (6,240 ft (1,903 m); FAD at 15.1 Ma). Arbitrarily it is placed at ~6315 ft (1,926 m).

(iii) Temporal interpretation

The stratigraphic interpretation of WA is given in Figure 26. It is based mainly on planktonic foraminiferal and complemented by calcareous nannofossil stratigraphy. The lower to middle Miocene section comprises two unconformities (Figure 30). One in the lower middle Miocene, the other in the lower Miocene. The oldest unconformity occurs in the lowermost part of Zone M2/N5 and uppermost part of zones M2/N5 and NN2. The oldest hiatus is estimated to be 1.8 Myr long (Figures 26, 30). The lower surface of the unconformity (20.6 my) lies in zones M2/N5 and NN2 and was calculated using the HO of H. recta and the sedimentation rate curve of 0.71 ft/1000 yr (22.2 cm/1000 yr). The upper surface of the unconformity (18.8 Ma) is estimated using the LO of P. sicana and the HO of G. stainforthi with a sedimentation rate of 0.8 ft/1000 yr (25 cm/1000 yr).
The younger unconformity occurs in the lowermost part of Zone NN5 and the uppermost part of Zone M5/N8 (Figures 26, 30). The younger hiatus is estimated to be 0.5 Myr long. The lower surface of the unconformity (15.5 Ma) is calculated using the LO of *P. sicana* and the HO of *H. ampliaperta* with a sedimentation rate of 0.8 ft/1000 yr (25 cm/1000 yr). The age of upper surface is not precisely determined because it is estimated using only the LO of *O. suturalis*.

**VI-1-b. Well B (WB), Orocual Oilfield**

(i) **Zonal subdivision**

WB was drilled in 2008 and its bottom depth was 16,731 ft (5,103 m). The Carapita Formation is 9,760 ft (2,977 m) in this well. Nine (9) genera and fourteen (14) species of planktonic foraminifera were identified in WB (Figure 9), and three (3) genera and three (3) species of calcareous nannofossils were reported (PDVSA Internal Report, 2008). Planktonic foraminifera indicative of early Miocene to early Pliocene occur in WB between 2,100 ft (640 m) to 11,310 ft (3,450 m), such as: *Globigerinella obesa*, *?Neogloboquadrina siakensis*, *Dentoglobigerina venezuelana*, *D. altispira*D. altispira globosa, *Globoquadrina dehiscens* and *Globigerinoides trilobus* (Figure 8); the species *Globorotalia scitula* only occur between 2,100 ft (640 m) to 9,600 ft (2,926 m).

*Lower middle Miocene, Zone N9/M6*

Sample interval: 2,100 ft (640 m) – 7,410 ft (2,255 m)

Cutting samples: 22

In general, planktonic foraminifera exhibit poor preservation. The LO of *Orbulina universa* and *Orbulina suturalis* are located at 7,410 ft (2,255 m) (Figure 9). The lower boundary of Zone N9/M6 is thus placed between 7,410 ft (2,255 m) and 7,620 ft (2,322
The HO of the calcareous nannofossil *Helicosphaera ampliaperta* is at 7,410 ft (2,225 m), implying that the NN4/NN5 zonal boundary occurs between 7,410 ft (2,255 m) and 7,620 ft (2,322 m). The HO of this taxon is thus close to the LOs of the planktonic foraminifera *Orbulina universa* and *Orbulina suturalis*, in agreement with correlation charts (Berggren et al., 1995).

Lower middle Miocene, Zone N8/M5

Sample interval: 7,410 ft (2,255 m) – 8,210 ft (2,502 m)

Cutting samples: 3

Preservation of planktonic foraminifera is poor to moderate and their abundance is variable. The HOs of *Globigerinoides bisphericus* and *Praeorbulina sicana* are located at 7,620 ft (2,322 m), and their LOs at 8,210 ft (2,505 m) (Figure 9). The lower boundary of Zone N8/N7 is thus placed between 8,210 ft (2,505 m) and 8,380 ft (2,554 m).

Lower Miocene Zone N7/M4

Sample interval: 8,210 ft (2,505 m) – 9,600 ft (2,926 m)

Cutting samples: 8

The HO of *Globorotaloides stainforthi* is at 9,600 ft (2,926 m), implying that the lower boundary of Zone N7/M4 occurs between 9,600 ft (2,926 m) and 9,800 ft (2,987 m) (Figure 9). According to PDVSA Internal Report (2006) calcareous nannofossil data for this interval are very poor and indicative of an early to middle Miocene age.

Lower Miocene, Zones N6/M3? – N5/M2?

Sample interval: 9,600 ft (2,926 m) – 11,310 ft (3,447 m)

Cutting samples: 10

Poor to moderate preservation and low abundance of planktonic foraminifera characterize this interval (Figure 9). The HO of *Globigerina ciperoensis* is at 11,220 ft (3,419 m) and
the HO of the calcareous nannofossil *Sphenolithus belemnos* is at 11,310 ft (3,447 m) (Figure 9), implying that the NN3/NN4 zonal boundary occurs between 11,310 ft (3,447 m) and 11,400 ft (3,474 m); there is thus in good agreement with planktonic foraminiferal and calcareous nannofossil correlations (Berggren et al. 1995).

**(ii) Stratigraphic interpretation**

Two unconformities are inferred in WB (Figure 27). The lowest one, a lower Miocene unconformity is inferred between the HOs of *G. ciperoensis* (11,220 ft (3,419 m); LAD at 23.8 Ma) and *S. belemnos* (11,300 ft (3,444 m); LAD at 18.3 Ma), these species are recorded 80 ft (24 m) apart. Arbitrarily an unconformity is placed at ~11,260 ft (3,432 m).

The sedimentation rate curve between 11,260 ft (3,432 m) and 7,410 ft (2,258 m) was constructed using the HO of *G. stainforthi* (LAD at 17.3 Ma) and the LO of *P. sicana* (FAD at 16.4 Ma) with a sedimentation rate of ~ 1.5 ft/1000 yr (~47 cm/1000 yr) (Figures 9,27). The youngest unconformity is inferred at level ~7,410 ft (2,258 m). It is marked at this level by the juxtaposed HO of *H. ampliaperta* (LAD at 15.6 Ma) and LO of *O. suturalis* (FAD at 15.1 Ma). The NN4/NN5 and N8/M5-N9/M6 zonal contacts are thus unconformable (Figure 27). The sedimentary interval between 7,410 ft (2,258 m) and 3,620 ft (1,103 m) is very difficult to interpret and the sedimentation rate curve was established using the LO *O. suturalis* (7,410 ft (2,258 m); FAD at 15.1 Ma) and the HO of *S. heteromorphus* (3,620 ft (1,103 m); LAD at 13.6 Ma) with a sedimentation rate of ~ 2.5 ft/1000 yr (~77 cm/1000 yr) (Figure 27). Considering that rates of sedimentation of 5 to 50 cm are estimated for stratigraphically well-constrained intervals, a sedimentation rate of ~77 cm/1000 yr is high and supports our interpretation of a stratigraphic gap in the section.
(iii) Temporal interpretation

The stratigraphic interpretation of WB is given in figure 27. The lower to middle Miocene section contains two unconformities, one in the lower Miocene, the other in the lower middle Miocene. The hiatuses are estimated to be 5.6 Myr long for the older unconformity and 0.8 Myr long for the younger one. The oldest unconformity occurs in the lowermost part of the Zone NN4 and N6/M3. The lower surface of the unconformity was estimated using the HO of *G. ciperoensis* while the upper surface was estimated using the HO of *G. stainforthi*, the LO of *P. sicana* with a sedimentation rate of 1.5 ft/1000 yr (47 cm/1000 yr). The younger unconformity occurs in the lowermost part of Zones N9/M6 and NN5 and the uppermost Zones of N8/M5 and NN4. The upper surface was estimated using the LO of *O. suturalis*, the HO of *S. heteromorphus* with a sedimentation rate of 2.5 ft/1000 yr (77 cm/1000 yr) while the age of lower surface is calculated using the LO of *P. sicana* and the HO of *H. ampliaperta* (Figures 27, 30).

VI-1-c. Well C (WC), Tropical Oilfield

(i) Zonal subdivision

WC was drilled in 2008 and its bottom depth was 14,080 ft (4,291 m). The Carapita Formation is 6,490 ft (1,978 m) in this well. Nine (9) genera and fifteen (15) species of planktonic foraminifera were identified in WC (Figure 11), and three (3) genera and eight (8) species of calcareous nannofossils were reported (PDVSA Internal Report, 2006). Long-ranging, early Miocene to early Pliocene planktonic foraminifera occur in WC between 4,340 ft (1,322 m) and 9,200 ft (2,804 m), such as: *Globigerinella obesa, ?Neogloboquadrina siakensis, Dentoglobigerina venezuelana, Globorotalia scitula, and Globigerinoides trilobus* (Figure 11); the species *D. altispira globosa* occur only between
8,000 ft (2,438 m) to 11,410 ft (3,477 m) and *Globoquadrina dehiscens* between 8,000 ft (2,438 m) to 8,390 ft (2,557 m).

*Lower middle Miocene, Zone N9/M6*

Sample interval: 4,340 ft (1,322 m) – 8,000 ft (2,438 m)

Cutting samples: 21

The HOs of *Orbulina universa* and *O. suturalis* are located at 5,020 ft (1,530 m), and the LO of *O. universa* at 8,000 ft (2,438 m) (Figure 10). The lower boundary of Zone N9/M6 is thus placed between 8,000 ft (2,438 m) and 8,240 ft (2,511 m). The HO of the calcareous nannofossil *Helicosphaera ampliaperta* is at 8,240 ft (2,511 m), implying that the NN4/NN5 zonal boundary occurs between 8,000 ft (2,435 m) and 8,240 ft (2,511 m) (Figure 11); there is thus good agreement between planktonic foraminiferal and calcareous nannofossil correlations (Berggren, et al. 1995).

*Lower middle Miocene, Zone N8/M5*

Sample interval: 8,000 ft (2,438 m) – 8,390 ft (2,557 m)

Cutting samples: 3

Abundance and preservation of planktonic foraminifera vary from poor to moderate. The HOs of *Globigerinoides bisphericus* and *Praeorbulina sicana* are located at 8,000 ft (2,438 m), and their LOs are at 8,390 ft (2,557 m) (Figure 11). The lower boundary of Zone N8/N7 is thus placed between 8,390 ft (2,557 m) and 8,690 ft (2,648 m).

*Lower Miocene Zone N7/M4*

Sample interval: 8,390 ft (2,557 m) – 9,200 ft (2,804 m)

Cutting samples: 4

The HO of *Globorotaloides stainforthi* is at 9,200 ft (2,804 m), implying that the lower boundary of Zone N7/M4 occurs between 9,050 ft (2,758 m) and 9,200 ft (2,804 m)
(Figure 11). The HO of the calcareous nannofossil *Sphenolithus belemnos* is at 9410 ft (2,868 m), implying that the NN3/NN4 zonal boundary occurs between 9,210 ft (2,807 m) and 9,410 ft (2,868 m) (Figure 11), there is thus good agreement between planktonic foraminiferal and calcareous nannofossil correlations (Berggren, et al., 1995).

**Lower Miocene, Zones N6/M3? – N5/M2?**

Sample interval: 9,200 ft (2,804 m) – 11,410 ft (3,477 m)

Cutting samples: 10

Planktonic foraminifera are poorly to moderately preserved. The HO of *Globigerina ciperoensis* is at 10,410 ft (3,172 m), implying that the lower boundary of Zone N6/N5 is placed between 10,270 ft (3,130 m) and 10,410 ft (3,172 m) (Figure 11).

**(ii) Stratigraphic interpretation**

Four unconformities are inferred in WC (Figure 28). The lowest one, a lower Miocene unconformity is inferred at level ~10,830 ft (3,300 m). It is marked at this level by the juxtaposed HOs of *C. abisectus* (LAD at 23.2 Ma) and *S. dissimilis* (LAD 19.2 Ma).

The sedimentary history between unconformities is difficult to determine because the sedimentation rate curve is poorly constrained with a sedimentation rate of ~1.5 ft/1000 yr (~48 cm/1000 yr). The second unconformity is arbitrarily placed at level ~9,305 ft (2,836 m) (Figure 28). It is identified using the HOs of *S. belemnos* (9,410 ft (2,868 m); LAD at 18.3 Ma) and *G. stainforthi* (9,200 ft (2,804 m); LAD at 17.3 Ma); these taxa are recorded 210 ft (64 m) apart. A third unconformity is inferred between the LO of *P. sicana* (8,390 ft (2,557 m); FAD at 16.4 Ma) and the HO of *H. ampliaperta* (8,240 ft (2,511 m); LAD at 15.6 Ma). An unconformity is also arbitrarily inferred at ~8,305 ft (2,531 m) (Figure 27). Based on the HOs of *S. heteromorphus* (LAD at 13.6 Ma) and *C.
*floridanus* (7,000 ft (2,133 m); LAD at 11.8 Ma). The unconformity is arbitrary placed at ~7,260 ft (2,212 m). Between 9,410 ft (2,868 m) and 8,305 ft (2,531 m) the NN3/NN4, NN4/NN5 and N7/M4-N8/M5 zonal contacts are thus unconformable.

(iii) **Temporal interpretation**

The lower to middle Miocene section comprises four unconformities (Figure 28); two in the lower Miocene and two in the middle Miocene. The oldest unconformity suggests that Zones M1/N4, NN1 and almost entirely M2/N5 and NN2 are absent; the lower surface of the unconformity (23.2 Ma) was placed using the HO of *C. abisectus* and the upper surface of the unconformity (19.0 Ma) was estimated using the HOs of *S. dissimilis* and *S. belemnos* with a sedimentation rate curve of 1.5 ft/1000 yr (48 cm/1000 yr) (Figures 28, 30).

The second unconformity occurs in the lowermost part of Zone NN4 and M3/N6 and the uppermost part of Zone M2/N5 with a hiatus estimated of 1.0 Myr long; the lower surface of the unconformity is estimated to be 18.1 Ma and the upper surface 17.1 Ma (Figure 30). The third unconformity occurs between Zones M4/N7 and M5/N8; the hiatus is about 1.4 Myr long with an lower surface of 16.7 Ma and an upper surface of 15.3 Ma (Figure 30). The younger unconformity suggests absence of Zones M9/N12, M8/N11 and M7/N10 in WC with a hiatus estimated of 2.6 Myr long; the upper surface (12.3 Ma) is estimated using the HO of *C. floridanus* with a sedimentation rate of 1.5 ft/1000 yr (48 cm/1000 yr) while the lower surface (14.9 Ma) is not precisely located because it was estimated using the LO of *O. suturalis* (Figure 30).

**VI-1-d. Rio Oregano Outcrop**

(i) **Zonal subdivision**
Seven (7) genera and fourteen (14) species of planktonic foraminifera were identified in Rio Oregano Outcrop (Figure 13), and two (2) genera and two (2) species of calcareous nannofossils were reported (PDVSA Internal Report, 2010). Planktonic foraminifera indicative of the early Miocene to early Pliocene occur in the Rio Oregano section between 0 to 104 m, such as: *Globigerinella obesa*, *?Neogloboquadrina siakensis*, *Dentoglobigerina venezuelana*, *D. altispira*, *D. altispira globosa*, *Globorotalia dehiscens* and *Globigerinoides trilobus* (Figure 12). *Globorotalia fohsi peripheroronda* occurs between 42 to 62 m.

**Lower middle Miocene, Zone N9/M6**

Sample interval: RO-89 to RO-47

Outcrop samples: 22

The HOs of *Orbulina universa* and *O. suturalis* are located at 104 m and the LOs at 60 m. The lower boundary of Zone N9/M6 is thus placed between samples 60 and 44 m (Figure 12).

**Lower middle Miocene, Zone N8/M5**

Sample interval: RO-47 to RO-27

Outcrop samples: 11

Planktonic foraminifera show poor to moderate preservation and their abundance is variable. The LO of *Globigerinoides bisphericus* is recorded at 26 m and its HO at 40 m, implying that the lower boundary of Zone N8/N7 lies between samples 26 and 24 m (Figure 13).

**Lower Miocene Zone N7/M4 and N6/M3**

Sample interval: RO-27 to RO-25

Outcrop samples: 2
The HO of *Globorotaloides dissimilis* is located at 24 m, implying that the lower boundary of Zone N7/M4 occurs between 24 and 26 m (Figure 13). The HO of the calcareous nannofossil *Sphenolithus belemnos* is also located at 24 m, suggesting that the NN3/NN4 zonal boundary occurs between samples 24 and 26 m. There is thus good agreement between planktonic foraminiferal and calcareous nannofossil biostratigraphy (Berggren et al. 1995).

**(ii) Stratigraphic interpretation**

An intra-lower Miocene unconformity is inferred at ~25 m marked by the HOs of *S. belemnos* (24 m; LAD at 18.3 Ma) and *C. dissimilis* (24 m; LAD at 17.3 Ma) and the LO of *G. bisphericus* (26 m; FAD at 16.4 Ma). The NN3/NN4 and N6/M3-N7/M4 zonal contacts are thus unconformable (Figure 29). The sedimentation rate curve above the unconformity (24 to 60 m) is constrained using the HO of *H. ampliaperta* (30 m; LAD at 15.6 Ma) and the LO of *O. universa* (60 m; FAD at 15.1 Ma) (Figure 29). The interval below (0 to 24 m) the unconformity was very difficult to interpret in the absence of stratigraphic markers; only *G. altiaperturus* is reported at 20 m (Figure 29).

**(iii) Temporal interpretation**

Figure 29 shows the stratigraphic interpretation of Rio Oregano Outcrop section; this lower to middle Miocene section comprises one unconformity in the upper lower Miocene (Figure 30). The hiatus is estimated to be 4.5 Myr long. The age of the upper surface (16.0 Ma) is estimated using the LO of *O. universa* and the HO of *H. ampliaperta* with a sedimentation rate curve of 0.06 m/1000yr (6 cm/1000 yr) and that of the lower surface is estimated using the HO of *G. altiaperturus* (Figure 30).
VI-2. Temporal correlations among sections

The four lower to middle Miocene sections studied here are discontinuous. In figure 30 the sections are arranged according to a depth transect, from shallower (Well WA) to deeper (Well WC) as determined by benthic foraminiferal assemblages (see below). The deeper section (WC) is the least continuous, whereas the shallower section is the more continuous.

Similar patterns have been described by Aubry (1991) who also showed that the same unconformities may be traceable from shallow (neritic) to deep sea (bathyal) setting. This suggests that some deep-sea unconformities may be indirectly related to sea level changes. Only deep water (bathyal) sections are available in this study and only limited interpretation is possible. However no clear relation exists between the unconformities in our wells and the sea level changes (Figure 31) described for the Neogene (Miller et al, 2005). There are no clear overlaps in the sections except in the lower Miocene with correlatives unconformities at ~25 m in the Rio Oregano, ~7,380 ft (2,249 m) in WA, ~11,260 ft (3,432 m) in WB and ~10,830 ft (3,300 m) in WC. This indicate that an important event occurred between ~20.6 Ma and ~19.0 Ma as constrained by the lower surface of the unconformity in WA and the upper surface of the unconformity in WC.

In WA and WB two correlative unconformities are associated with a short hiatus (0.5 Myr) with surface at the same age, 15.0 Ma for the upper surface and ~15.8 Ma for the lower surface.
VI-3. Implications for stratigraphic distribution of selective benthic foraminifera species

Benthic foraminiferal samples studied from the Carapita Formation in wells WA, WB and WC contain almost the same assemblages in the three wells. In general benthic foraminifera abundance varies from poor to moderate in all samples examined (Figure 15). The agglutinated foraminifera tend to be broken or distorted whereas in some cases calcareous benthic foraminifera are pyritized.

The ranges of selected species of calcareous benthic foraminifera and planktonic microfossils stratigraphy is given in figures 8, 10 and 12 (compare with figures 26-28).

Some HO/LO of some benthic foraminifera are real datums; but others result from truncation of benthic foraminifera ranges by unconformities. For instance in WB (Figure 10) the HO of *C. subglobosus* (~7,410 ft, 2,258 m)) occurs at the level of an unconformity. Similar situation occurs in WC (Figure 12) with the HO of *E. bradyi* (7,250 ft, 2,209 m)), which coincided with and unconformity inferred at the same level.

VII- PALEOBATHYMETRIC HISTORY OF THE CARAPITA AND CIPERO FORMATIONS

Benthic foraminifera are considered an excellent tool for both qualitative and quantitative ecology and paleoecology (Jones, 1996).

A total of 69 species of benthic foraminifera were identified in this study. The paleobathymetric ranges of these species are shown in figures 16 to 18. 1) Thirty species are common to both the Carapita and Cipero formations (Figure 16); 2) nine species are restricted to the Cipero Formation (Figure 17); and 3) thirty species are exclusive to the Carapita Formation (Figure 18). Based on the general bathymetric survey (see above) the
distributions of species suggest that both the Carapita (Rio Oregano, EVB) and the Cipero (Trinidad) formations were deposited at bathyal depths (Figures 16 to 18).

In the Carapita Formation from the *Praeorbulina glomerosa* Zone to *Globorotalia peripheroronda* Zone the infaunal morphotypes dominate over epifaunal ones (Figures 21 and 23). The dominant morphotypes (M) are M9 with values between 53.6 - 80 % followed by Morphotype M6 with values between 10.0 - 7 %. Table 5 shows that Morphotype M9 with values of 0 to 40 % belongs to water depths of 100 to 500 m while Morphotype M6 with values 0 – 30 % belongs to water depth of 1000 to 2000 m.

In contrast in the Cipero Formation (figures 20 and 22) the epifaunal morphotypes dominate in the *Praeorbulina glomerosa* Zone and *Globorotalia fohsi peripheroronda* Zone with values oscillating between 50 % (M3), 55 – 13.6 % (M2) and 22.7 – 12.5 % (M4). Morphotype M3 with values between 5 to 10 % (table 5) indicates water depths of 500 to 1000 m; this morphotype is rare or absent in water depths below 1000 m (Table 5). In addition to M3, Morphotype M2 (Table 5) reaches percentages between 0 to 10 % indicative of water depths of 100 to 1000 m. Morphotype M4 with percentage around 20 % indicates water depths between 100 to 500 m.

In general, epifaunal morphotypes are dominant in the Cipero Formation with values oscillating between 50.0 – 55.0 % and infaunal morphotypes are dominant in the Carapita Formation with values oscillating between 53.6 – 80.0 %.

Isotopic analysis was not possible because of poor preservation of the tests of foraminifera. However the greater abundance of infaunal taxa in the Carapita Formation compared with the Cipero Formation may reflect low oxygen conditions in the EVB, perhaps as a result of high accumulation rates.
In the wells WA, WB and WC the upper stratigraphic interval was deposited at upper to middle bathyal depths (Figures 8, 10 and 12; bathymetry from van Morkhoven et al, 1986) characterized by the following benthic foraminiferal taxa *Cibicidoides crebbsi, C. compressus, C. incrassatus, Rectuvigerina transversa, R. multicostata, R. striata, Uvigerina carapatana, U. rugosa, U. mexicana, Melonis pompilioides, Siphonina pozonensis, Dorothis brevis, Cyclammina cancellata, Valvulina flexilis, Alveovalvulinella pozonensis, Glomospira charoides, Bathysiphon carapitanus, Sigmoilopsis schlumbergeri, and N. parantillarum*. Figures 8, 10 and 12 show that the lower stratigraphic interval in WA, WB and WC changes from outer neritic to bathyal based on the following assemblage: *Nonion incisum, N. costiferum, Bolivina imporcata, B. pisciformis, Eggerella scabra* and *Ammonia beccarii* (Figures 16-18).

Benthic foraminiferal distribution patterns reveal a comprehensive bathymetric history of the EVB (Figure 32). The shallower sites (WA, WB) were outer neritic to upper bathyal during the early Miocene (24.0 to 20.5 Ma), deepened to middle bathyal during the late early Miocene from 18.8 to 15.5 and shallowed from middle to upper bathyal in the early middle Miocene (15.0 to 11.7 Ma).

The intermediate site (Rio Oregano) remained at lower bathyal depths through early to middle Miocene (24 to 11.7 Ma). The deeper site (WC) was outer neritic / upper bathyal during the early Miocene (24 to 23.2 Ma) deepened to upper to middle bathyal between 19.0 to 18.1 Ma, deepened to lower bathyal between 17.1 to 14.9 Ma and then shallowed slightly to lower to middle bathyal in the early middle Miocene (11.7 to 11 Ma). It is remarkable that changes in water depths as determined from the benthic foraminifera are associated with stratigraphic gaps. This suggests that changes in
paleobathymetry and developments of stratigraphic gaps were controlled by tectonic in
a tectonically active (Di Croce et al, 2000).

VIII- DISCUSSION AND CONCLUSIONS

The Carapita Formation in the area of study span lower Miocene (Zone N6/M3)
to middle Miocene (Zone N9/M6) between the HO of *G. stainforthi* (17.3 Ma) and the
LO of *O. suturalis* (15.1 Ma).

The four lower to middle Miocene sections studied are highly discontinuous. A
lower Miocene unconformity was identified in the outcrop of the Carapita Formation
(Rio Oregano) with a hiatus of 4.5 Myr. In Well WA two unconformities are estimated,
the oldest hiatus is 1.8 Myr and the youngest 0.5 Myr. Two unconformities have been
identified in Well WB with hiatuses of 5.6 Myr long for the oldest and 0.8 Myr long for
the youngest one. Four unconformities were identified in Well WC, the oldest one with a
hiatus of 4.2 Myr long; the second unconformity with a hiatus of 1.0 Myr; the third
unconformity with a hiatus of 1.4 Myr long and the youngest unconformity with the
hiatus of 3.2 Myr.

According to the general survey and morphotypes analysis, paleobathymetric
interpretation suggests that the Carapita Formation in the outcrop was deposited at middle
bathyal depths (≥ 600-1,000 m) and the Cipero Formation ranges from middle to lower
bathyal depths (≥ 600-2,000 m). In wells WA, WB and WC, paleobathymetry ranges
from outer neritic to lower bahyal depths (≥ 100-2,000 m).

Bathymetric changes are associated with several unconformities in all studied
area, suggesting that both were tectonically induced.
Finally, comparison made by Scanning Electronic Microscope (SEM) of planktonic and benthic foraminifera from the Carapita Formation (Venezuela) and the Cipero Formation (Trinidad) will definitely improve taxonomic identification in future subsurface exploration studies in the EVB.

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Loeblich, A. R and Tappan, H. (1957a). Planktonic Foraminifera of Paleocene and Early Eocene Age from the Gulf and Atlantic Coastal Plains. In A. R. Loeblich, Jr., and


TAXONOMIC INDEX

Planktonic Foraminifera

Catapsydrax dissimilis dissimilis (Cushman and Bermudez) 1937

Dentoglobigerina altispira globosa Bolli 1957

“Dentoglobigerina” venezuelana Hedberg 1937

Globigerina ciperoensis Bolli 1954

Globigerinatella insueta Cushman and Stainforth 1945

Globigerinella obesa (Bolli) 1957

Globigerinoides altiaperturus Bolli 1957

Globigerinoides bisphericus Todd, 1954

Globigerinoides trilobus (Reuss) 1850

Globoquadrina dehiscens (Chapman, Parr, and Collins) 1934

Globorotalia scitula Brady 1882

Globorotaloides stainforthi (Bolli, Loeblich, and Tappan) 1957

Globorotaloides suteri Bolli 1957

?Neogloboquadrina siakensis (Le Roy) 1939

Orbulina bilobata d’Orbigny 1846

Orbulina universa d’Orbigny 1839

Praeorbulina glomerosa (group) Blow 1956

Praeorbulina sicana De Stefani 1950

Sphaeroidinellopsis disjuncta Finlay 1940

Sphaeroidinellopsis seminulina seminulina

Agglutinated* and calcareous benthic foraminifera
*Alveovalvulinella pozonensis* Cushman and Renz 1941

*Anomalainoides globulosus* (Chapman and Parr 1937)

*Anomalainoides pompilioides* Galloway and Heminway 1941

*Bolivina imporcata* Cushman and Renz 1941

*Bolivina pisciformis* Galloway and Morrey 1929

*Buchnerina trinitatensis* (Cushman and Stainforth) 1945

*Cibicidoides crebbsi* (Hedberg) 1937

*Cibicidoides incrassatus* (Fichtel and Moll) 1978

*Cyclammina cancellata* Brady, 1879

*Dorothia brevis* Cushman and Renz, 1945

*Gaudryina bullbrooki* Cushman, 1936

*Glomospira charoides* (Jones and Parker, 1860)

*Gyroidinoides altiformis* (Stewart and Stewart) 1930

*Hanzawaia concentrica* (Cushman) 1964

*Hanzawaia mantaensis* (Galloway and Morrey) 1971

*Laticarinina pauperata* (Parker and Jones, 1865)

*Lenticulina adelinensis* Keijzer 1945

*Lenticulina calcar* (Linnaeus) 1758

*Lenticulina hedbergi* Cushman and Renz, 1941

*Lenticulina occidentalis* (Cushman) var. *torridus* (Cushman, 1923)

*Lenticulina subpapillosus* (Nuttall) 1932

*Marginulinopsis basispinosus* (Cushman and Renz) 1941

*Melonis pompilioides* (Fichtel and Moll, 1798)

*Neoeponides campester* (Palmer and Bermudez, 1941)
Neoeponides parantillarum (Galloway and Heminway, 1941)

Neoeponides umbonatus (Reuss, 1851)

*Paratrochamminoides irregularis* White 1928

Planularia venezuelana Hedberg, 1937

Planulina renzi Cushman and Stainforth, 1945

Rectuvigerina multicostata (Cushman and Jarvis, 1929)

Rectuvigerina striata (Schwager) 1866

Rectuvigerina transversa (Cushman) 1918

Saracenaria senni Hedberg 1937

Sigmoilopsis schlumbergeri (Silvestri, 1904)

Siphonina pozonensis Cushman and Renz 1941

Sphaeroidina bulloides d’Orbigny, 1826.

*Textularia tatumi* Cushman and Ellisor, 1939

Uvigerina carapitana Hedberg, 1937.

Uvigerina mexicana Nuttall 1932

Uvigerina rugosa Schwager, 1866

Vaginitulinopis superbus (Cushman and Renz) 1941

*Valvulina flexilis* Cushman and Renz, 1941

*Valvulina jarvisi* Cushman, 1932

*Valvulina spinosa* Cushman 1932
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<td>RO-81</td>
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<tr>
<td>42</td>
<td>11600-11610</td>
<td></td>
<td></td>
<td>RO-83</td>
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</tr>
<tr>
<td>43</td>
<td>11750-11760</td>
<td></td>
<td></td>
<td>RO-85</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td></td>
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<td></td>
<td>RO-87</td>
<td></td>
</tr>
<tr>
<td>45</td>
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<td></td>
<td></td>
<td>RO-89</td>
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**Table 1.** Samples analyzed.
<table>
<thead>
<tr>
<th>Planktonic Foraminiferal Datums</th>
<th>Calcareous Nannofossils Datums (From O. Rodriguez, 2010)</th>
<th>Age (Ma)</th>
<th>WA (ft)</th>
<th>WB (ft)</th>
<th>WC (ft)</th>
<th>Carapita Outcrop (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD H. carteri</td>
<td></td>
<td>11.8</td>
<td>7000</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>LAD C. floridanus</td>
<td></td>
<td>11.8</td>
<td>7000</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>LAD H. euphratis</td>
<td></td>
<td>11.8</td>
<td>7000</td>
<td></td>
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<tr>
<td>LAD S. heteromorphus</td>
<td></td>
<td>13.6</td>
<td>3620</td>
<td>7520</td>
<td></td>
<td></td>
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<tr>
<td>FAD O. suturalis</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>FAD O. universa</td>
<td></td>
<td>15.1</td>
<td>6240</td>
<td>7410</td>
<td>8000</td>
<td>60</td>
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<tr>
<td>LAD H. ampliaperta</td>
<td></td>
<td>15.6</td>
<td>6390</td>
<td>7410</td>
<td>8240</td>
<td>30</td>
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<tr>
<td>FAD P. sicana</td>
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<td>16.4</td>
<td>7040</td>
<td>8210</td>
<td>8390</td>
<td></td>
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<td>FAD G. bisphericus</td>
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<td>16.4</td>
<td>7040</td>
<td>8210</td>
<td>9200</td>
<td>26</td>
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<td>LAD G. stainforthi</td>
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<td>17.3</td>
<td>7380</td>
<td>9600</td>
<td>9200</td>
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</tr>
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<tr>
<td>LAD S. belemnos</td>
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<td>18.3</td>
<td>7380</td>
<td>11300</td>
<td>9410</td>
<td>24</td>
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<td>LAD S. dissimilis</td>
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<td>19.2</td>
<td>7380</td>
<td>11300</td>
<td>10830</td>
<td>24</td>
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<td>LAD G. altiaperturus</td>
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<td>20.5</td>
<td>7380</td>
<td></td>
<td>10830</td>
<td>20</td>
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<td>LAD H. recta</td>
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<td>23.2</td>
<td>9200</td>
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<td></td>
<td></td>
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<tr>
<td>LAD C. abisectus</td>
<td></td>
<td>23.2</td>
<td>9200</td>
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<tr>
<td>LAD G. ciperoensis</td>
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<td>23.8</td>
<td>8780</td>
<td>11220</td>
<td>10410</td>
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Table 2. Datums (FAD and LAD) of selected planktonic foraminifera and calcareous nannofossil used in this study. Ages are from Berggren and others (1995).

<table>
<thead>
<tr>
<th>Rounded trochospiral (M1)</th>
<th>Plano-convex, trochospiral (M2)</th>
<th>Milioline (M3)</th>
<th>Biconvex, trochospiral (M4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyroidinoides altiformis</td>
<td>Cibicidoides alazanensis</td>
<td>Quinqueloculina lamarckiana</td>
<td>Neoeponides campester</td>
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<tr>
<td>Gyroidinoides soldanii</td>
<td>Cibicidoides compressus</td>
<td>Quinqueloculina seminula</td>
<td>Neoeponides parantillarum</td>
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<td></td>
<td>Cibicidoides crebisi</td>
<td>Sigmoidopsis schlumbergeri</td>
<td>Neoeponides umbonatus</td>
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<tr>
<td></td>
<td>Cibicidoides incrassatus</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Planulina martalana</td>
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<td></td>
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<tr>
<td></td>
<td>Planulina renzi</td>
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<tr>
<td></td>
<td>Planulina subtenuissima</td>
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Table 3. Epifaunal morphotype classification on benthic foraminifera from the Cipero (Trinidad) and the Carapita (EVB) formations (Morphotype designation from Corliss and Fois, 1991).
<table>
<thead>
<tr>
<th>Rounded planispiral (M5)</th>
<th>Tapered/cylindrical (M6)</th>
<th>Flattened tapered (M7)</th>
<th>Spherical (M8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melonis pompiliodes</td>
<td>Buliminella elegans</td>
<td>Bolivina cuadriae</td>
<td>Globocassidulina subglobosa</td>
</tr>
<tr>
<td>Nonion costiferum</td>
<td>Bulimina inflata</td>
<td>Bolivina imporcata</td>
<td>Pullenia bulboides</td>
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<td>Nonion incisum</td>
<td>Bulimina jarvisi</td>
<td>Bolivina isidroensis</td>
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<td>Bulimina macilenta</td>
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<tr>
<td>Bulimina pupoides</td>
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<tr>
<td>Marginulina subbullata</td>
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<tr>
<td>Uvigerina carapatana</td>
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<tr>
<td>Uvigerina mexicana</td>
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<tr>
<td>Uvigerina rugosa</td>
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Table 4. Infaunal morphotype classification on benthic foraminifera from the Cipero (Trinidad) and the Carapita (EVB) formations (Morphotype designation from Corliss and Fois, 1991).
<table>
<thead>
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<th>Flattened ovoid (M9)</th>
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<tr>
<td>Cassidulina carapitana</td>
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<td>Cassidulina tricamerata</td>
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<td>Lenticulina adelinensis</td>
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<td>Lenticulina americana</td>
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<td>Lenticulina calcar</td>
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<td>Lenticulina clericii</td>
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<td>Lenticulina formosa</td>
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<tr>
<td>Lenticulina hedbergi</td>
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<tr>
<td>Lenticulina nutalli</td>
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<tr>
<td>Lenticulina occidentalis</td>
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<tr>
<td>Lenticulina senni</td>
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<tr>
<td>Lenticulina subaculeata</td>
</tr>
<tr>
<td>Lenticulina subpapillosa</td>
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<tr>
<td>Lenticulina suteri</td>
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<tr>
<td>Lenticulina wallacei</td>
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<tr>
<td>Siphonina pozonensis</td>
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Table 4. Continued
Table 5. Water depths vs % of morphotypes (Taken from Corliss and Fois, 1991)

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<thead>
<tr>
<th>MORPHOTYPE</th>
<th>WATER DEPTHS</th>
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<tbody>
<tr>
<td></td>
<td>100-500 m</td>
<td>500-1000 m</td>
<td>1000-2000 m</td>
<td></td>
</tr>
<tr>
<td>EPIFAunal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1 Rounded trochospiral</td>
<td>0-5 %</td>
<td>0-10 %</td>
<td>Rare or absent</td>
<td></td>
</tr>
<tr>
<td>M2 Plano-convex</td>
<td>0-10 %</td>
<td>0-10 %</td>
<td>Rare or absent</td>
<td></td>
</tr>
<tr>
<td>M3 Milioline</td>
<td>0-5 %</td>
<td>5-10 %</td>
<td>Rare or absent</td>
<td></td>
</tr>
<tr>
<td>M4 Biconvex trochospiral</td>
<td>20 %</td>
<td>40 %</td>
<td>Rare or absent</td>
<td></td>
</tr>
<tr>
<td>INFANAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M5 Rounded planispiral</td>
<td>0-5 %</td>
<td>0-5 %</td>
<td>Rare or absent</td>
<td></td>
</tr>
<tr>
<td>M6 Tapered/cylindrical</td>
<td>40-50 %</td>
<td>40-50 %</td>
<td>0-50%</td>
<td></td>
</tr>
<tr>
<td>M7 Flattened tapered</td>
<td>0-90 %</td>
<td>0-90 %</td>
<td>&gt; 30%</td>
<td></td>
</tr>
<tr>
<td>M8 Spherical</td>
<td>&gt; 10 %</td>
<td>&gt; 20 %</td>
<td>&gt; 10%</td>
<td></td>
</tr>
<tr>
<td>M9 Flattened ovoid</td>
<td>0-40 %</td>
<td>0-10 %</td>
<td>Rare or absent</td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Morphotype data based on faunal data of the Cipero (Trinidad) and the Carapita (Rio Oregano section) formations.
Plate 3. 1-8. *Globigerina ciperoensis* group; Sample BO-287, Cipero Formation. 9-12. *Globigerina ciperoensis*; Sample WA 8780'-8790', Carapita Formation. Figures 1-3,5-7,9-11: bars= 200 µm; Figures 4,8,12: bars= 100 µm.
Plate 4. 1-8. *Globigerinella obesa*; Sample RO-3 (LO), Carapita Formation. Figures 1-3,6-8: bars=200 µm; Figures 4-5: bars=100 µm.
Plate 7. 1-3. *Globigerinoides bisphericus*; Sample RDL-423, Cipero Formation. 4-7. *Globigerinoides bisphericus*; Sample RO-27 (LO), Carapita Formation. Figures 1-2,4-5: bars= 200 μm; Figures 3,6,7: bars= 100 μm.
Planktonic foraminifera found in the Cipero and Carapita Formation.

Plate 8. 1-6. Praeorbulina glomerosa group; Sample RDL-423, Cipero Formation. 7-12. Praeorbulina glomerosa circularis; Sample RDL-423, Cipero Formation. Figures 1-2, 4-12: bars = 200 µm; Figures 3: bars = 100 µm.
Plate 9. 1-3. Praeorbulina sicana; Sample RDL-423, Cipero Formation. 4-6. Praeorbulina sicana; Sample WC 7040’-7050’, Carapita Formation. 7-9. Orbulina bilobata; Sample RDL-538, Cipero Formation. 10-12. Orbulina bilobata; Sample WC 5230’-5260’(HO), Carapita Formation. Figures 1-2,4,5,7-9,11-12: bars= 200 µm; Figures 3,6,10: bars= 100 µm.
Plate 10. 1-6. *Orbulina universa*; Sample RDL-538, Cipero Formation. 7-12. *Praeorbulina glomerosa circularis*; Sample RO-47 (LO), Carapita Formation. Figures 1-5, 7-10: bars= 200 µm; Figures 6, 11-12: bars= 100 µm.
Plate 15. 1-4. *Globoquadrina dehiscens*; Sample BO-287, Cipero Formation. 5-8. *Globoquadrina dehiscens*; Sample RO-15 (LO), Carapita Formation. Figures 1-3,5-7: bars = 200 µm; Figures 4,8: bars = 100 µm.
Planktonic foraminifera found in the Cipero and Carapita Formations.

Planktonic foraminifera found in the Cipero and Carapita Formations.

Plate 18. **Globigerinatella insueta**; Sample RDL-563, Cipero Formation. Figures 1-3, 5-6: bars = 200 µm; Figures 4, 7-8: bars = 100 µm.
APPENDIX I—Planktonic Foraminifera from the Carapita and the Cipero formations

Basis for classification of planktonic foraminifera: from morphological / phylogenetic / to wall texture classification

Between mid 1930s to end 1950s most planktonic foraminiferal research (Plummer, 1931; Thalmann, 1934; Renz, 1935; Glaessner’s, 1937; Gandolfi, 1942; Bolli, 1945; Subbotina, 1947; Cita, 1948; Sigal, 1948; Grinsdale, 1951; Bronnimann, 1952b, Loeblich and Tappan, 1957a and Morozova, 1959) around the world were emphasized in mere morphological criteria (type and position of aperture, presence or absence of keels, shape of chambers, basic coiling mode, shape ornamentation and others features) and their biostratigraphic use.

In Trinidad and the Caribbean Region planktonic foraminifera have been used since mid 1960s in connection with the oil exploration industries. However, were Renz (1942, 1948), Cushman and Stainforth (1945), Cushman and Renz (1947) and Bermudez (1949) whose initiated surface studies in Venezuela and Trinidad in conjunction with Mene Grande Oil Company, Caribbean Petroleum and Creole Petroleum Corporation. Bolli (1957a; modified in 1966) developed a detailed zonation for the Paleocene and lower Eocene of Trinidad.

In mid 1960s to 1980s planktonic foraminifera studies turn from simple morphological classification to phylogenetic classification (Parker, 1962; Berggren, 1968; Steineck, 1971; Bandy, 1972, 1975; Fleisher, 1974 and Srinivasan and Kennett 1981a, 1981b) based on relationship of ancestor-descendent. For this job we have adopted wall texture classification and phylogeny (Murray, 1897; Lipps, 1966; Steineck and Fleisher, 1978; Premoli Silva and Boersma, 1989; Spezzaferri, 1994; Olsson et al.,
1999 and Pearson et al., 2006) into two different categories: spinose and non-spinose surface and distribution of taxa is presented in terms of the N-zonation of Blow (1969, 1979) and M-zonation (BKSA 95), Neogene and Berggren and Pearson (2005), Paleogene. Plates 1 and 2 show the main features in spinose and non-spinose wall texture identified in the studied section. Plate 1, figures 1-8; show gametogenic calcification. Plate 1, figure 1 show well preserved pustules in *Globigerinatella insueta* wall texture. Plate 2, show smooth surface and non-spinose wall texture in *Neogloboquadrina siakensis*.

**Species inventory**

The following species of planktonic foraminifera have been arranged using the wall texture features (Murray, 1897; Lipps, 1966; Fleisher, 1974; Steineck and Fleisher, 1978; Premoli Silva and Boersma, 1989; Spezzaferri, 1994; Olsson et al., 1999 and Pearson et al., 2006) into two different categories. Category 1: spinose surface (*Globigerina. ciperoensis, Globigerinella obesa, Sphaeroidinellopsis disjuncta, Ss. seminulina seminulina, Globigerinoides trilobus, G. altiaperturus, G. bisphericus, Praeorbulina glomerosa, P. sicana, Orbulina bilobata, O. universa, Catapsydrax dissimilis dissimilis, Globorotaloides stainforthi* and *G. suteri*). Category 2: non-spinose surface (*Dentoglobigerina altispira globosa, D. venezuelana, Globoquadrina dehiscens, *?Neogloboquadrina siakensis, Globorotalia scitula* and *Globigerinatella insueta*). Distribution of taxa is presented in terms of the N-zonation of Blow (1969, 1979) and M-zonation (BKSA 95), Neogene and Berggren and Pearson (2005), Paleogene.

**Category 1: Spinose**

Genus *Globigerina* d’Orbigny 1836
**Globigerina ciperoensis** Bolli 1954

(Plate 3, Figures 6-9)

**Diagnostic Features:** Test small to medium size, surface cancellate, spinose, low trochospiral, five spherical chambers in the last whorl, peripheral outline rounded; radial and depressed sutures in both sides, large umbilical aperture.

**Remarks:** Differs from *Globigerina angustiumbilicata* in having a larger umbilicus.

**Known Stratigraphic Range:** Upper Oligocene Zone P19 to lower Miocene N4B.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Carapita Formation in Zone N4/M1 (Sample WA 8780’-8790’, WB 11220’-11240’ and WC 10410’-10440’).

Genus *Globigerinella* Cushman 1927

*Globigerinella obesa* (Bolli) 1957

(Plate 4, Figures 1-8)

**Diagnostic Features:** Test small to medium, smooth and spinose, low trochospiral, peripheral outline rounded, four to four and one-half inflated chambers in the last whorl; sutures radial and depressed in both sides, umbilical-extraumbilical aperture.


**Known Stratigraphic Range:** Upper Oligocene P22 to Recent.

**Occurrences in Venezuela and Trinidad:** In the studied section occurs in the lower Miocene to lower middle Miocene of the Cipero Formation (Trinidad) from Zones N5/M2 (sample BO-287, *Catapsydrax dissimilis* Zone) to N9/M6 (sample RDL-538,
Globorotalia fohsi peripheroronda Zone). Recorded in the Carapita Formation in Zone N5/M2 to N9/M6, from samples WA 3520’-3550’ to 9735’-9740’, WB 2100’-2150’ to 11600’-11610’, WC 4380’-4410’ to 10410’-10440’ and RO-3 to RO-83.

Genus Sphaeroidinellopsis Banner and Blow 1959

(Plate 5, Figures 1-8)

*Sphaeroidinellopsis disjuncta* Finlay 1940

**Diagnostic Features:** Test large, thick, low trochospiral, surface cancellate and finely perforate, with four subspherical chambers in the last whorl, peripheral outline rounded; sutures depressed on both sides, aperture umbilical bordered by a thick rim.

**Remarks:** Its ultrastructure is intermediate between *Globoturborotalita woodi* and *Sphaeroidinellopsis*. Considered as a synonym of *Sphaeroidinellopsis seminulina* by Banner and Blow (1959).

**Known Stratigraphic Range:** Lower Miocene Zone N4/M1 to middle Miocene N11/M8.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Cipero Formation in Zones N7/M4-N9/M6, from sample RDL-563 (*Globigerinatella insueta* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

*Sphaeroidinellopsis seminulina seminulina*

(Plate 5, Figures 9-11)

**Diagnostic Features:** Test ovate, medium to large, low trochospiral; surface cancellate and densely perforate, three chambers in the final whorl; low arched and elongate umbilical aperture.
Remarks: Differs from *Sphaeroidinellopsis subdehiscens* by having three chambers in the final whorl.

Known Stratigraphic Range: Lower Miocene Zone N7/M4 to upper Pliocene Zone PL3/4 boundary.

Occurrences in Venezuela and Trinidad: Recorded in this study in the Cipero Formation in Zones N7/M4-N9/M6, from sample RDL-563 (*Globigerinatella insueta* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone) and in the Carapita Formation in Zone N9/M6, from samples WA 5510’-5540’ to 4570’-4590’.

Genus *Globigerinoides* Cushman 1927

*Globigerinoides trilobus* (Reuss) 1850

(Plate 6, Figures 1-8)

Diagnostic Features: Test medium to large, distinctly cancellate, spinose, from with three spherical chambers in the last whorl, peripheral outline rounded; curved and depressed apertures in both sides, low umbilical-extraumbilical primary aperture.

Remarks: Differs from *Globigerinoides inmaturus* in having final larger chamber.

Known Stratigraphic Range: Lower Miocene Zone N4B/M1 to Recent.

Occurrences in Venezuela and Trinidad: Recorded in this study in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone) and in the Carapita Formation in Zones N4/M1-N9/M6, from samples WA 2300’-2310’ to 9735’-9740’, WB 2100’-2150’ to 11750’-11760’, WC 4380’-4410’ to 10900’-10950’ and RO-1 to RO-89.

*Globigerinoides altiaperturus* Bolli 1957
(Plate 6, Figures 9-15)

**Diagnostic Features:** Test small to medium, cancellate, smooth and spinose, low trochospiral, peripheral outline rounded, three and a half spherical chambers in the last whorl; sutures depressed on both sides, very high umbilical primary aperture bordered by a sinuous rim.

**Remarks:** Differs from *Globigerinoides trilobus trilobus* in having distinctly higher primary aperture.

**Known Stratigraphic Range:** Lower Miocene zones N5/M2 to N7/M4.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo-Miocene Cipero and Lengua formations of Trinidad from Zone P20 to middle Miocene N14-M11. Recorded in this study in the Carapita Formation in Zone N6/M3, from samples WA 7380’-7410’ to 7820’-7840’ and RO-15 to RO-21.

*Globigerinoides bisphericus* Todd,

(Plate 7, Figures 1-7)

**Diagnostic Features:** Test small to medium, three and a half spherical chambers in the last whorl, peripheral outline broadly rounded, sutures depressed and radial in both sides, several apertures from with two (less commonly) to four between the last and earlier chambers.

**Remarks:** Regarded as the ancestor of *Praeorbulina* and *Orbulina*.

**Known Stratigraphic Range:** Lower Miocene to lower middle Miocene zones N7/M4 to N9/M6.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Cipero Formation in Zone N8/M5, sample RDL-423 (*Praeorbulina glomerosa* Zone) and in the
Carapita Formation in Zone N8/M5, from samples WA 6240’-6270’ to 7040’-7050’,
WB 7620’-7650’ to 8210’-8230’, WC 8000’-8050’ to 8390’-8420’ and RO-27 to RO-41.

Genus *Praeorbulina* Olsson, 1964

*Praeorbulina glomerosa* (group) Blow 1956

(Plate 8, Figures 1-12 and Plate 10, Figures 7-12)

**Diagnostic Features:** test ovoid to nearly circular, surface distinctly cancellate, spinose, chambers spherical, sutures slightly depressed with several small supplementary apertures along the suture on the spiral side.

**Known Stratigraphic Range:** lower middle Miocene zones N8/M5 to N9/M6.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Cipero Formation in Zone N8/M5, sample RDL-423 (*Praeorbulina glomerosa* Zone).

*Praeorbulina sicana* De Stefani 1950

(Plate 9, Figures 1-6)

**Diagnostic Features:** Test subcircular to circular, surface distinctly cancellate, spinose, two and one-half chambers in the final whorl; sutures depressed, aperture irregular elongate slit between the last and the penultimate chamber.

**Remarks:** According to Kennett and Srinivasan (1983) this taxon developed from *Globigerinoides trilobus* and is the ancestor of *Praeorbulina/Orbulina.*

**Known Stratigraphic Range:** Lower middle Miocene zones N8/M5 to N9/M6.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Cipero Formation in Zone N8/M5, sample RDL-423 (*Praeorbulina glomerosa* Zone) and in the
Carapita Formation in Zone N8/M5, from samples WA 6240’-6270’ to 7040’-7050’, WB 7620’-7650’ to 8210’-8230’ and WC 8000’-8050’ to 8390’-8420’.

Genus *Orbulina* d’Orbigny 1839

*Orbulina bilobata* d’Orbigny 1846

(Plate 9, Figures 7-12)

**Diagnostic Features:** Test large, bilobate, surface distinctly perforate, spinose, chambers spherical; aperture areal with several openings on the final chamber and along the sutures.

**Remarks:** According to Blow (1956) *O. bilobata* evolved from *Praeorbulina sicana*.

**Known Stratigraphic Range:** lower middle Miocene Zone N9/M6 to Recent.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Cipero Formation in Zone N9/M6, sample RDL-538 (*Globorotalia fohsi peripheroronda* Zone) and in the Carapita Formation in Zone N9/M6, from samples WC 5230’-5260’ to 6650’.

*Orbulina universa* d’Orbigny 1839

(Plate 10, Figures 1-6)

**Diagnostic Features:** Test globular, surface distinctly and densely perforate, spinose, spherical chamber; aperture aereal with several small openings on the surface.

**Remarks:** Bolli and Saunders (1985) consider that *Orbulina bilobata* is a variant of *Orbulina universa*.

**Known Stratigraphic Range:** lower middle Miocene Zone N9/M6 to Recent.

**Occurrences in Venezuela and Trinidad:** Recorded in this study in the Cipero Formation in Zone N9/M6, sample RDL-538 (*Globorotalia fohsi peripheroronda* Zone)
and in the Carapita Formation in Zone N9/M6, from samples WA 2300’-2310’ to 6240’-6270’, WB 2100’-2150’ to 4880’-4890’, WC 5020’-5050’ to 6800’-6850’ and RO-47 to RO-87.

Genus *Catapsydrax* Bolli, Loeblich, and Tappan 1957

*Catapsydrax dissimilis dissimilis* (Cushman and Bermudez) 1937

(Plate 11, Figures 1-11)

**Diagnostic Features:** Robust, surface cancellate, probably spinose, with four chambers in last whorl, peripheral outline subcircular; aperture low arch covered by an umbilical bulla with one or more supplementary apertures.

**Remarks:** Spinosity in *Catapsydrax* was suspected but not proven, by the Eocene Planktonic Foraminifera Working Group (Pearson et al., 2006, p 69). Generally occurs with *Catapsydrax dissimilis ciperoensis*, which has more than one aperture.

**Known Stratigraphic Range:** Upper Eocene Zone P13 to lower Miocene N6/M3.

**Occurrences in Venezuela and Trinidad:** In the studied section occurs in the lower Miocene of the Cipero Formation (Trinidad), Zone N5/M2 (sample BO-287, *Catapsydrax dissimilis* Zone). Recorded in Carapita Formation from samples RO-25 to RO-1 (Zones N6/M3 to N7/M4).

Genus *Globorotaloides* Bolli 1957

*Globorotaloides stainforthi* (Bolli, Loeblich, and Tappan) 1957

(Plate 12, Figures 1-6)

**Diagnostic Features:** Test small to medium, surface distinctly cancellate, probably spinose, low trochospiral, four inflated to subglobular chambers in the final whorl,
peripheral outline lobulate to rounded; sutures depressed on both sides, primary
aperture interiomarginal umbilical and supplementary aperture on the final whorl.

**Remarks:** Included earlier in the genus *Catapsydrax* but Spezzaferri (1994) included it in the
genus *Globorotaloides* for having initially globorotaliiform and successively
globigeriniform coiling mode.

**Known Stratigraphic Range:** Lower Miocene Zones N4B/M1 to N7/M4.

**Occurrences in Venezuela and Trinidad:** In the studied section occurs in the lower
Miocene to lower middle Miocene of the Cipero Formation (Trinidad) from Zones
N5/M2 (sample BO-287, *Catapsydrax dissimilis* Zone). Recorded in the Carapita
Formation in Zone N6/M3, from samples WA 7380’-7410’ to 7530’-7540’, WB 9600’-
9620’ and WC 9200’-9230’ to 10830’-10840’.

*Globorotaloides suteri* Bolli 1957

(Plate 12, Figures 7-12)

**Diagnostic Features:** Test medium to large, surface strongly cancellate, probably
spinose, low trochospiral, three to four inflated globular chambers in the final whorl;
spiral sutures slightly curved and umbilical sutures radial and depressed, low aperture
umbilical-extraumbilical.

**Remarks:** Differs from *Catapsydrax unicavus* in having initially globorotaliiform coiling
mode and from *Globorotaloides variabilis* in having fewer chamber in the final whorl.

**Known Stratigraphic Range:** Lower Eocene (~P9) to lower Miocene Zone N7/M4.

**Occurrences in Venezuela and Trinidad:** In the studied section occurs in the lower
Miocene of the Cipero Formation (Trinidad) from Zones N5/M2 (sample BO-287,
*Catapsydrax dissimilis* Zone).
Category 2: Non-Spinose

Genus *Dentoglobigerina* Blow 1979

*Dentoglobigerina altispira globosa* Bolli 1957

(Plate 13, Figures 1-11)

**Diagnostic Features:** Robust, surface distinctly cancellate, non-spinose, from five to six chambers in the final whorl, peripheral outline subcircular, radial sutures on both spiral and umbilical sides; aperture broad, umbilicus covered by tooth like projections.

**Remarks:** Differs from *D. altispira altispira* in the absence of a high trochospire.

**Known Stratigraphic Range:** Lower Miocene Zone N4B/M1 to mid Pliocene Zone ~PL4.

**Occurrences in Venezuela and Trinidad:** Occurs in Trinidad in the Oligo-Miocene of the Cipero and Lengua formations. In the studied section occurs in the lower Miocene to lower middle Miocene of the Cipero Formation (Trinidad) from Zones N5/M2 (sample BO-287, *Catapsydrax dissimilis* Zone) to N9/M6 (*Globorotalia fohsi peripheroronda* Zone). Recorded in the Carapita Formation in Zone N6/M3 to N9/M6, from samples WA 2300’-2310’ to 7820’-7840’, WB 3620’-3650’ to 10800’-10830’, WC 8240’-8270’ to 10700’-10750’ and RO-1 to RO-89.

“*Dentoglobigerina* venezuelana” Hedberg 1937

(Plate 14, Figures 1-12)

**Diagnostic Features:** Robust, surface distinctly cancellate, non-spinose, low trochospiral, with three to four chambers in the final whorl, peripheral outline rounded,
sutures radial on umbilical side and depressed and slightly curved on spiral side; aperture umbilical and low arched.

**Remarks:** Assigned to *Globigerina* by Blow (1969), Postuma (1971) and Stainforth et al. (1975) and to *Globoquadrina* by Kennett and Srinivasan (1983) based on lack of umbilical tooth by definition (Spezzaferri, 1994). Placed provisionally here in “*Dentoglobigerina*” pending ongoing investigations by the Oligocene Planktonic Foraminifera Working Group (OPFWG).

**Known Stratigraphic Range:** Lower Oligocene (~) to lower Pliocene (PL4/5).

**Occurrences in Venezuela and Trinidad:** In the studied section occurs in the lower Miocene to lower middle Miocene of the Cipero Formation (Trinidad) from Zones N5/M2 (sample BO-287, *Catapsydrax dissimilis* Zone) to N9/M6 (sample RDL-538, *Globorotalia fohsi peripheroronda* Zone). Recorded in the Carapita Formation in Zone N6/M3 to N9/M6, from samples WA 2300’-2310’ to 9340’-9360’, WB 2350’-2400’ to 11750’-11760’, WC 5410’-5440’ to 10900’-10950’ and RO-1 to RO-85.

Genus *Globoquadrina* Finlay 1947

*Globoquadrina dehiscens* (Chapman, Parr, and Collins) 1934

(Plate 15, Figures 1-8)

**Diagnostic Features:** Test medium to large, surface distinctly cancellate, non-spinose, with four inflated chambers in the last whorl, peripheral outline rounded; sutures depressed in both sides, low arched aperture covered by an umbilical tooth.

**Remarks:** Differs from its ancestor *Globoquadrina praedehiscens* in having four chambers in the last whorl and quadrate outline.
Known Stratigraphic Range: Lower Miocene Zone N4B/M1 to Late Miocene Zone N18/PL1a.

Occurrences in Venezuela and Trinidad: In the studied section occurs in the lower Miocene to lower middle Miocene of the Cipero Formation (Trinidad) from Zones N5/M2 (sample BO-287, Catapsydrax dissimilis Zone) to N9/M6 (sample RDL-538, Globorotalia fohsi peripheroronda Zone). Recorded in the Carapita Formation in Zone N5/M2 to N9/M6, from samples WA 2300’-2310’ to 8550’-8560’, WB 3000’-3050’ to 8610’-8640’, WC 8690’-8720’ and RO-17 to RO-69.

Genus Neogloboquadrina Bandy, Frerichs and Vincent 1967

?Neogloboquadrina siakensis (Le Roy) 1939

(Plate 16, Figures 1-16)

Diagnostic Features: Test medium to large, surface cancellate, ?non-spinose, five to seven chambers in the final whorl, peripheral outline rounded, sutures depressed in both sides, primary aperture umbilical-extraumbilical bordered by a distinct lip.

Remarks:

Paragloborotalia vs. Neogloboquadrina

The genus Paragloborotalia was introduced by Cifelli (1982) to designate groups of species with cancellate surface and spinose wall texture. Recently studies of the holotype and near topotypes of the species siakensis (Central Sumatra and Java, Indonesia) by Zachariasse (2010) suggest the absence of spines. In addition, this study shows the same behavior in siakensis in the Cipero Formation (sample BO-287, Catapsydrax dissimilis Zone) of Trinidad, i.e., cancellate surface and no clear evidence of spines (See Pl 13, Fig 1-16). Therefore, I assign siakensis provisionally to the non-spinose Neogloboquadrina.
Known Stratigraphic Range: Lower Oligocene (P22) to middle Miocene (N14/M11).

Occurrences in Venezuela and Trinidad: In the studied section occurs in the lower Miocene to lower middle Miocene of the Cipero Formation (Trinidad) from Zones N5/M2 (sample BO-287, Catapsydrax dissimilis Zone) to N9/M6 (sample RDL-538, Globorotalia fohsi peripheroronda Zone). Recorded in the Carapita Formation in Zone N5/M2 to N9/M6, from samples WA 2300’-2310’ to 9200’-9210’, WB 2100’-2150’ to 11750’-11760’, WC 4380’-4410’ to 10900’-10950’ and RO-1 to RO-89.

Genus Globorotalia Cushman 1927

Globorotalia scitula Brady 1882

(Plate 17, Figures 1-16)

Diagnostic Features: Test medium to large, surface smooth and low to moderately perforate, non-spinose, low trochospiral, peripheral outline subcircular, with four to five compressed chamber in the final whorl; spiral side with sutures strongly curved and radial to slightly curved on the umbilical side, several pustule on umbilical side and aperture umbilical- extraumbilical with slit.

Remarks: Differs from Globorotalia praescitula in having peripheral outline subcircular.

Known Stratigraphic Range: Middle Miocene Zone N9/M6 to Recent.

Occurrences in Venezuela and Trinidad: In the studied section occurs in the lower middle Miocene of the Cipero Formation (Trinidad), Zone N9/M6 (sample RDL-538, Globorotalia fohsi peripheroronda Zone). Recorded in the Carapita Formation in Zone N9/M6, from samples WA 5600’-5690’ to 6240’-6270’, WB 2350’-2150’ to 7410’-7440’ and WC 5020’-5050’ to 6650’-6700’.
Genus *Globigerinatella* Cushman and Stainforth 1945

*Globigerinatella insueta* Cushman and Stainforth 1945

(Plate 18, Figures 1-8)

**Diagnostic Features:** Robust and large, test subcircular to circular, non-spinose, chambers spherical with irregular pustule-like bullae; peripheral outline circular, sutures radial, primary aperture umbilical and multiple supplementary apertures.

**Remarks:** Differs from its ancestor *Globigerinita glutinata* in having several aereal supplementary apertures.

**Known Stratigraphic Range:** Lower Miocene N6/M3 to lower middle Miocene Zone N9/M6.

**Occurrences in Venezuela and Trinidad:** In the studied section occurs in the lower Miocene of the Cipero Formation (Trinidad) Zone N7/M4 (sample RDL-563, *Globigerinatella insueta* Zone).
Calcareous benthic foraminifera found in the Cipero and Carapita formations

Genus *Cibicidoides* Thalmann, 1939.

(Plate 19, Figures 1-6)

*Cibicidoides crebbsi* (Hedberg) 1937

**Diagnostic Features**: The broad, strongly sinuous sutures on umbilical side fusing to glossy umbilical boss a curved and tangential to the periphery on spiral side most adequately distinguishes *crebbsi* from other biconvex, coarsely puncatate, cibicidoidids. Sutures of early whorls usually fuse/merge and obscure initial chambers.

**Paleobathymetry**: Predominantly upper bathyal.

**Known Stratigraphic Range**: Upper Oligocene (P21) through Middle Miocene (N15/M12).

Remarks: This is one of the most characteristic benthic species in the Miocene and appears to be a useful marker for upper bathyal depths (van Morkhoven et al., 1986)

*Cibicidoides incrassatus* (Fichtel and Moll) 1978

(Plate 19, Figures 7-12)

Diagnostic Features: Test free, large and robust, perforate and subcircular, slightly lobulate in outline, periphery rounded, small to moderate size umbonal boss; at least twelve chambers in final whorl. Sutures broad, curved, slightly limbate on trochospiral side and slightly curved on umbilical side. Aperture interiomrginal extending onto the spiral side.

Paleobathymetry: Common in outer neritic and upper bathyal depths.

Known Stratigraphic Range: Lower Oligocene (P18) through Pleistocene (N23/Pt2).

Occurrences in Venezuela and Trinidad: As *Anomalinoides trinitatensis*, this form has been reported in the Upper Acostian and scarce in Lower Araguatian and Lucian (Lower zone) in the Agua Salada Group, Falcon Basin of Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste. Croix and Brasso Formations) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-89 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

Genus *Hanzawaia* Asano, 1944.

*Hanzawaia concentrica* (Cushman) 1964

(Plate 20, Figures 1-6)
**Diagnostic Features:** Wall calcareous, hyaline and finely perforate; test free, trochospiral, planoconvex, elongate in outline, flattened spiral side and convex ventral side; at least nine chambers in final whorl, umbilical side involute and sutures strongly curved; aperture an arch on the periphery with a slight lip.

**Paleobathymetry:** Upper to middle bathyal.

**Known Stratigraphic Range:** Lower Oligocene to Holocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Carapita Formation) of the Eastern Venezuela Basin (Hedberg, 1937), in the Upper Araguatian and Lucian (Lower zone) of the Agua Salada Group, Falcon Basin, Venezuela and Oligo/Miocene (Brasso Formation) of Trinidad. Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-11 to RO-89 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

*Hanzawaia mantaensis* (Galloway and Morrey) 1971

(Plate 20, Figures 7-12)

**Diagnostic Features:** Test free, trochospiral, biconvex, flat spiral side and partially involute, wall calcareous, hyaline and finely perforate; between ten to eleven chambers in final whorl, apertural face surrounded by triangular keel

**Paleobathymetry:** Upper to middle bathyal.

**Known Stratigraphic Range:** Lower Oligocene to upper Miocene (N16/M13).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Carapita Formation) of the Eastern Venezuela Basin (Hedberg, 1937), also occurs scarce in the *Uvigerinella sparsicostata* Zone and common throughout Acostian and Lower
Araguatian in the Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste. Croix Formation) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-7 to RO-89 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-2865 (Catapsydrax dissimilis Zone) to RDL-538 (Globorotalia fohsi peripheroronda Zone).

**Remarks:** Differ from *Cibicides americanus* because its smaller, less inflated and has large umbilicus.

Genus *Laticarinina* Galloway and Wissler, 1927.

*Laticarinina pauperata* (Parker and Jones, 1865)  
(Plate 21, Figures 1-4)

**Diagnostic Features:** Test free, slightly trochoid, discoidal, flattened rounded to oval in outline, compressed, biconvex to planoconvex, periphery with a broad and thin transparent keel. Chambers numerous, ten to eleven in the final whorl, slightly radial sutures on ventral side and flush on spiral side; small rounded aperture on ventral side.

**Paleobathymetry:** Predominantly bathyal to abyssal.

**Known Stratigraphic Range:** Lower Oligocene (P19) through Pleistocene (N23/Pt2).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Carapita Formation) of the Eastern Venezuela Basin (Hedberg, 1937), also occurs scarce in the Acostian and Lucian (Lower zone) in the Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste. Croix and Brasso Formations) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Cipero Formation in Zones N5/M2-N9/M, from
Remarks: *L. pauperata* occurs at different depths but is predominantly bathyal. Discussions about its mode of life has been given by different authors (Loeblich and Tappan, 1964, Galloway and Wissler, 1927) but it is still unresolved whether it is attached or free-living in life position. Phleger and Parker (1951) reported upper depth limits of 500 m for *L. pauperata* in the Norwest Gulf of Mexico.

**Genus** *Lenticulina* Lamarck 1804.

*Lenticulina calcar* (Linnaeus) 1758

(Plate 21, Figures 5-10)

**Diagnostic Features:** Test free, planispiral, biconvex, five to seven chambers in the final whorl, periphery keeled with radial spines, each single spine generally opposite each chamber in final whorl; chambers inflated increasing gradually in size as added, some chambers without spines, sutures limbate slightly curved, wall calcareous, hyaline, smooth, finely perforate; aperture radiate.

**Paleobathymetry:** Outer neritic to lower bathyal.

**Known Stratigraphic Range:** Upper Eocene to Recent.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Carapita Formation) of the Eastern Venezuela Basin (Hedberg, 1937), also occurs common in the Acostian, Araguanian and Lucian (Lower zone) in the Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste. Croix and Brasso Formations) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-7 to RO-5 (Zones N6/M3-N8/M5) and in the Cipero
Formation in Zones N5/M2-N9/M6, from sample RDL-2865 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

Genus *Melonis* de Montfort, 1808.

*Melonis pompilioides* (Fichtel and Moll, 1798)

(Plate 22, Figures 1-6)

**Diagnostic Features:** Test free, planispiral, biumbilicate, slightly compressed, involute; periphery broadly rounded; chambers increasing in size as added, usually nine to eleven in the final whorl; sutures straight, radiating, smooth. Wall coarsely perforate; aperture an interiomarginal equatorial slit.

**Paleobathymetry:** Outer neritic to middle bathyal.

**Known Stratigraphic Range:** Upper Oligocene (P22) through Holocene (Pt2).

**Occurrences in Venezuela and Trinidad:** Occurs in the *Uvigerinella sparsicostata* Zone, common in the Acostian and Lower Araguatian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948), also occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-75 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

**Remarks:** Differs from *M. spharoides* in having less inflated chambers; also *M. spharoides* has a different peripheral outline and more chambers (10-11) than *M. pompilioides* (See van Morkhoven et al., 1986). The morphologic difference between *M. pompilioides* (outer neritic to middle bathyal) and *M. spharoides* (lower bathyal to
abyssal) would appear useful in paleobathymetric distribution. Whittaker (1988) suggests that *M. pompilioides* is synonymous with *Nonionina pompilioides*.

Genus *Sphaeroidina* d’Orbigny, 1826.

*Sphaeroidina bulloides* d’Orbigny, 1826.

(Plate 22, Figures 7-12)

**Diagnostic Features:** Test free, subglobular, initial portion trochospiral, later streptospiral, four to six inflated chambers, increasing in size as added; sutures thin, depressed, aperture interiomarginal surrounded by a lip. Wall calcareous, hyaline and finely perforate.

**Paleobathmetry:** Neritic to upper bathyal depths.

**Known Stratigraphic Range:** Lower Oligocene (P19) through Pleistocene (N23/Pt2).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) also occurs in the *Uvigerinella sparsicostata* Zone, Acostian Araguatian and Lucian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-89 (Zones N6/M3-N9/M6).

Genus *Planulina* d’Orbigny, 1826.

*Planulina renzi* Cushman and Stainforth, 1945.

(Plate 23, Figures 7-12)
**Diagnostic Features:** Test free, robust, compressed, large, peripheral margin acute, with thin and delicate keel; involute on both spiral and umbilical side, umbilical side more convex than spiral, between fifteen to eighteen chambers in final whorl, increasing gradually in size as added; sutures limbate; wall surface coarsely perforate giving a granular appearance; aperture equatorial slit, slightly arched, extending from the periphery to the dorsal side.

**Paleobathymetry:** Bathyal through abyssal.

**Known Stratigraphic Range:** Oligocene (P18) through upper Miocene (N17/M14).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) and in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-9 to RO-87 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M, from sample RDL-2865 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

**Remarks:** van Morkhoven et al., (1986) recognized specimens similar to *P. renzi* with larger umbos in the upper Eocene, less ornamented during the Oligocene, transitional forms near the Oligo/Miocene boundary and strongly ornamented during the Miocene. Also they include *Planulina marialana* var. gigas as a synonym of *renzi*.

Genus *Siphonina* Reuss, 1850.

*Siphonina pozonensis* Cushman and Renz 1941

(Plate 23, Figures 1-6)
**Diagnostic Features:** Test free, trochospiral, biconvex, periphery strongly keeled, acute, slightly lobulate; five chambers inflated in last whorl, sutures oblique on the spiral side and radial to curved on umbilical side, aperture areal with short neck and phialine lip. Wall calcareous, hyaline, smooth and coarsely perforate.

**Paleobathymetry:** Upper bathyal deposits

**Known Stratigraphic Range:** Lower Miocene (N5/M3) through middle Miocene (N14/M11).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) also occurs in the *Uvigerinella sparsicostata* Zone, Acostian Araguatian and Lucian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-11 to RO-59 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

**Remarks:** Differs from *S. tenuicarinata* in having less coarsely perforate, more convex test and strongly keeled periphery.

Genus *Bolivina* d’Orbigny 1839.

*Bolivina imporcata* Cushman and Renz 1941

(Plate 24, Figures 1-6)

**Diagnostic Features:** Test slightly inflated, biserial, elongate in outline, wall calcareous with coarse perforations and distinctly crenulated appearance, aperture ovate in final
chamber; periphery broadly rounded: at least six pairs of chambers, increasing gradually in size; sutures strongly curved, frequently with lobe shaped ornamentation.

**Paleobathymetry:** Middle neritic to bathyal.

**Known Stratigraphic Range:** Lower Oligocene (P18) through upper Miocene (N16/M13a).

**Occurrences in Venezuela and Trinidad:** Common in the upper Acostian, Araguatian and Lucian (lower and upper zones) in the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-77 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample RDL-2865 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

*Bolivina pisciformis* Galloway and Morrey 1929

(Plate 24, Figures 7-12)

**Diagnostic Features:** Test slightly inflated, free biserial and elongate; periphery broadly rounded, at least six pairs of chambers, wall calcareous finely perforate with sutures strongly curved, aperture terminal, elongate slit.

**Paleobathymetry:** Middle neritic to bathyal.

**Known Stratigraphic Range:** Lower Oligocene (P18) through upper Miocene (N16/M13).

**Occurrences in Venezuela and Trinidad:** Common in the Acostian and lower Araguatian in the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Typically in Ste. Croix and Brasso Formation (Esmeralda member) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop)
from sample RO-5 to RO-89 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

Genus *Uvigerina* d’Orbigny, 1826.

*Uvigerina carapitana* Hedberg, 1937.

(Plate 26, Figures 1-6)

**Diagnostic Features:** Test free, robust, triserial with about three to four whorls, chambers strongly inflated; periphery smoothly rounded; aperture tubular over the long neck in the margin of last chamber. Wall thick, calcareous, hyaline, finely perforate, sometimes ornamented with longitudinal striae.

**Paleobathymetry:** Bathyal.

**Known Stratigraphic Range:** Lower Miocene (N6/M3) through upper Miocene (N17/M15).

**Occurrences in Venezuela and Trinidad:** This form occurs in the lower to middle Miocene of the Carapita Formation, Eastern Venezuela Basin (Hedberg, 1937); in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) also occurs (scarce) in the *Uvigerinella sparsicostata* Zone and (common) in the Acostian Araguatian and Lucian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-59 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N6/M2-N9/M6, from sample RDL-2859 (*Catapsydrax stainforthi* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).
Remarks: The nearly smooth test is almost unique and differentiates it from the other Neogene species (See van Morkhoven et al., 1986).

_Uvigerina mexicana_ Nuttall 1932

(Plate 25, Figures 1-6)

**Diagnostic Features:** Test free, triserial, short, strongly ornamented with longitudinal costae; chambers slightly inflated, sutures curved, depressed; apertural end flattened in both forms, at the end of short neck in final chamber.

**Paleobathymetry:** Outer neritic and bathyal.

**Known Stratigraphic Range:** Upper Eocene (P16) through Recent.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene of the Carapita Formation, Eastern Venezuela Basin (Franklin, 1944) and in the Oligo/Miocene (Ste Croix Formation) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-75 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample RDL-2865 (_Catapsydrax dissimilis_ Zone) to RDL-538 (_Globoportalia fohsi peripheroronda_ Zone).

_Uvigerina rugosa_ Schwager, 1866.

(Plate 25, Figures 7-12)

**Diagnostic Features:** Test free, triserial; elongate, periphery lobulate, chambers increasing gradually in size, strongly ornamented with papillae on each chamber, aperture terminal at the end of a short neck, with lip.

**Paleobathymetry:** Bathyal depths.
Known Stratigraphic Range: Upper Oligocene (P21) through Pleistocene (N23/Pt2).

Occurrences in Venezuela and Trinidad: This form occurs in the Acostian Araguatian and Lucian (Lower zone) of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste Croix Formation) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-9 to RO-75 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample RDL-2865 (Catapsydrax dissimilis Zone) to RDL-538 (Globorotalia fohsi peripheroronda Zone).

Remarks:

_U. hispida_ vs _U. rugosa_

Both species exhibit similarities or likeness such as; shape, size, and in being densely covered with spines on the surface. However, _U. rugosa_ is characterized by its distinct eccentric aperture across the final whorl and less coarse ornament (Boersma, 1984). According to Whittaker (1988), _U. rugosa_ differs from _U. hispida_ in having more and longer spines. Lamb and Miller (1984) placed an upper-depth limit of 1000 m for _U. rugosa._

Genus _Rectuvigerina_ Mathews 1945

(Rectuvigerina multicostata (Cushman and Jarvis, 1929)

(Plate 26, Figures 7-16)

Diagnostic Features: Test free, elongate, length three times the width, triserial in the early portion follow by biserial and uniserial; chambers slightly inflated and increasing
gradually in size, sutures depressed, aperture terminal circular produced with a cylindrical neck with lip. Wall ornamented with several costae and in some cases spines.

**Paleobathymetry:** Bathyal depths.

**Known Stratigraphic Range:** Upper Oligocene (P21) through Pliocene (N20/PL4-5).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) and in the Acostian and Araguantian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-11 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N8/M5, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-423 (*Praeorbulina glomerosa* Zone).

*Rectuvigerina striata* (Schwager) 1866

(Plate 27, Figures 11-16)

**Diagnostic Features:** Test free; elongate, triserial in the early portion later ones biserial to uniserial; periphery lobulate, four to five inflated chambers in uniserial portion, increasing gradually in size; sutures deeply depressed. Aperture terminal on a neck with distinct lip. Wall thin, finely perforate, ornamented with fine striae, an some individuals ending as spines.

**Paleobathymetry:** Upper to middle bathyal.

**Known Stratigraphic Range:** Lower middle Miocene (N9/M6) through middle Pliocene (N20/PL5).

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) and in the Upper
Acostian and Lower Araguatian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-49 to RO-75 (Zone N9/M6) and in the Cipero Formation in Zones N8/M2-N9/M6, from sample BO-287 (Catapsydrax dissimilis Zone) to RDL-423 (Praeorbulina glomerosa Zone).

*Rectuvigerina transversa* (Cushman) 1918

(Plate 27, Figures 1-10)

**Diagnostic Features:** Test free, elongate, triserial in the early portion later short biserial stage and finally uniserial; sutures arched, indented with costae; aperture with a short cylindrical neck.

**Paleobathymetry:** Upper bathyal.

**Known Stratigraphic Range:** Lower Miocene (N4/M1) to middle Miocene (N11/M8).

**Occurrences in Venezuela and Trinidad:** This form occurs in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Hedberg, 1937) and in the *Uvigerinella sparsicostata* Zone in the Lower and Upper Acostian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Also occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-89 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (Catapsydrax dissimilis Zone) to RDL-538 (Globorotalia foehsi peripheroronda Zone).

**Remarks:** van Morkhoven et al., (1986) found this species restricted to the lower to upper Miocene and also characteristic of upper bathyal depths.
Calcareous benthic foraminifera found in the Cipero Formation

Genus *Anomalinoides* Brotzen, 1942.

*Anomalinoides globulosus* (Chapman and Parr 1937)

(Plate 29, Figures 1-3)

**Diagnostic Features:** Test almost planispiral, elongate in outline, sutures straight on umbilical side and curved on umbilical side, six to eight chambers inflated in final whorl, increasing in size: wall calcareous; umbilical surface smooth, with sparsely distributed pores, spiral side densely perforate.

**Paleobathymetry:** Outer neritic and upper bathyal.

**Known Stratigraphic Range:** Oligocene through Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the of the Ste. Croix Formation of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Cipero Formation in Zones N5/M2-N8/M5, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-423 (lower *Globigerinatella insueta* Zone).

**Remarks:** Differs from *A. semicribratus* in having its aperture extending to the periphery; in having a nearly planispiral coil and more coarsely perforate spiral side (See van Morkhoven et al., 1986).

*Anomalinoides pompilioides* Galloway and Heminway 1941

(Plate 29, Figures 4-6)

**Diagnostic Features:** Test low trochospiral, strongly involute, and nearly circular in outline, chambers inflated, five to seven in the last whorl, wall calcareous and strongly
perforate on both sides but more common on umbilical side, sutures straight on umbilical side and curved on spiral side.

**Paleobathymetry:** Middle bathyal through abyssal.

**Known Stratigraphic Range:** Middle Eocene (P12) through middle Miocene (N9/M6).

**Occurrences in Venezuela and Trinidad:** Common in the Oligo/Miocene of the Cipero Formation of Trinidad (Cushman and Stainforth, 1945). Recorded in this study in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

Genus *Neoeponides* Reis, 1960.

*Neoeponides umbonatus* (Reuss, 1851)

(Plate 29, Figures 7-9)

**Diagnostic Features:** Test free, trochospiral, biconvex, periphery with a circular thin keel, six to seven chambers slightly inflated in the last whorl, increasing gradually in size as added; sutures limbate on the spiral side and curved to radial in the umbilical side; aperture an interiomarginal slit with a thin lip extending from the umbilical to the periphery area; small supplemental apertures on the spiral side. Wall calcareous, hyaline and finely perforate.

**Paleobathymetry:** Outer neritic through lower bathyal.

**Known Stratigraphic Range:** Upper Oligocene to Recent.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986) and in the *Uvigerinella sparsicostata* Zone, through the Acostian, Araguatian and Lucian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Also occurs in the
Oligo/Miocene (Ste Croix, Brasso and Cipero formations) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Cipero Formation in Zones N5/M2-N9/M, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

Genus *Buchnerina* R. W. Jones 1984

*Buchnerina trinitatensis* (Cushman and Stainforth) 1945

(Plate 30, Figures 1-3)

**Diagnostic Features:** Test free, finely perforate, wall calcareous, hyaline, aperture terminal, oval on long neck, keels forming a band around the total test.

**Paleobathymetry:** Bathyal through abyssal.

**Known Stratigraphic Range:** Upper Oligocene to Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs commonly in the Oligo/Miocene (Cipero Formation) of Trinidad (Cushman and Stainforth, 1945). Recorded in this study in the Cipero Formation in Zones N5/M2-N9/M, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

**Remarks:** This species was described by Cushman and Stainforth (1945) in the Oligo/Miocene of Cipero and Ste. Croix formations of Trinidad as *Lagena trinitatensis*. Robertson (1998) included in the genus *Buchnerina*.

Genus *Lenticulina* Lamarck 1804.

*Lenticulina adelinensis* Keijzer 1945

(Plate 30, Figures 4-6)
Diagnostic Features: Test free, large, and stout, planispiral; circular in outline, periphery acute and smooth with a narrow thin keel, four chambers in final whorl, increasing gradually in size, sutures flush with surface. Aperture elliptical and concave over face in final chamber; wall calcareous, hyaline, smooth and finely perforate.

Paleobathymetry: Neritic to lower bathyal.

Known Stratigraphic Range: Lower Oligocene to Miocene.

Occurrences in Venezuela and Trinidad: Occurs in the Upper Oligocene (Sombrerito Formation), Falcon Basin of Venezuela (Bermudez, 1949) Recorded in this study in the Cipero Formation in Zone N5/M2 BO-287 (Catapsydrax dissimilis Zone).

*Lenticulina occidentalis* (Cushman) var. torridus (Cushman, 1923)

(Plate 30, Figures 7-9)

Diagnostic Features: Test free, planispiral, circular to slightly angular in outline, with a narrow thin keel, seven to eight chambers in final whorl, increasing gradually in size, sutures thin and slightly curved aperture radiate; wall calcareous, hyaline, smooth, and finely perforate.

Paleobathymetry: Neritic to middle bathyal.

Known Stratigraphy Range: Lower Oligocene (P8) to upper Miocene (N18/Pl1).

Occurrences in Venezuela and Trinidad: Occurs in the Upper Oligocene (Sombrerito Formation), Falcon Basin of Venezuela (Bermudez, 1949). Recorded in this study in the Cipero Formation in Zone N5/M2, sample BO-287 (Catapsydrax dissimilis Zone).

Calcareous benthic foraminifera found in the Carapita Formation

Genus *Neoeponides* Reis, 1960.
Neoeponides campester (Palmer and Bermudez, 1941)

(Plate 31, Figures 1-3)

**Diagnostic Features:** Test free, large, trochospiral, biconvex; periphery angular, acute, bordered by a limbate keel, seven to ten chambers in final whorl, dorsal sutures strongly oblique and ventral sutures radial, aperture interiomarginal between the periphery and the umbilicus; wall calcareous, hyaline and finely perforate.

**Paleobathymetry:** Upper bathyal.

**Known Stratigraphic Range:** Lower Oligocene (P18) through middle Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene of Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-89 (Zones N6/M3-N9/M6).

Neoeponides parantillarum (Galloway and Heminway, 1941)

(Plate 31, Figures 4-6)

**Diagnostic Features:** Test free, trochospiral, biconvex, spiral sized more convex that umbilical side, periphery subacute to rounded, seven to eight chambers in the last whorl, increasing gradually in size as added; sutures curved on spiral side and radial on umbilical side; wall calcareous, hyaline and finely perforate, aperture an interiomarginal slit with a distinct thickened lip.

**Paleobathymetry:** Upper bathyal.

**Known Stratigraphic Range:** Lower Oligocene to Recent.

**Occurrences in Venezuela and Trinidad:** Occurs in the Lucian (*Vaginulinopsis superbus* Zone) of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948), also
occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-89 (Zones N6/M3-N9/M6).

Genus *Gyroidinoides* Brotzen, 1942.

*Gyroidinoides altiformis* (Stewart and Stewart) 1930 (Plate 31, Figures 7-9)

**Diagnostic Features:** Wall calcareous and finely perforate, test free, trochospiral, planoconvex, circular in outline, spiral side flat to convex, umbilical side convex with deep umbilicus, eight to ten chambers in the last whorl, inflated on the umbilical side and slightly depressed on the spiral side: aperture extending from periphery to umbilicus.

**Paleobathymetry:** Upper bathyal to abyssal.

**Known Stratigraphic Range:** Upper Eocene to Recent.

**Occurrences in Venezuela and Trinidad:** This form occurs in the Oligo/Miocene (Carapita Formation) of the Eastern Venezuela Basin (Hedberg, 1937), also occurs common in the Acostian and scarce in the Araguatian and Lucian (lower zone) in the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste. Croix and Brasso formations) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-45 (Zones N6/M3-N8/M5).

Genus *Planularia* Defrance, in de Blainville 1826

*Planularia venezuelana* Hedberg, 1937.

(Plate 31, Figures 10-12)
**Diagnostic Features:** Test large, compressed, slightly longer than broad, thin, sides almost parallel, early portion closely coiled; two to three whorls. Peripheral margin truncate with a broad thin and delicate keel. Chambers inflated increasing gradually in size as added; six in last whorl. Sutures strongly curved, distinct radiate aperture; wall calcareous, hyaline and finely perforate.

**Paleobathymetry:** Neritic to bathyal.

**Known Stratigraphic Range:** Lower to upper Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Hedberg, 1937) and in the Lower and Upper Acostian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Also occurs in the Oligo/Miocene (Ste Croix, Brasso and Cipero formations) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-7 to RO-89 (Zones N6/M3-N9/M6).

Genus *Vaginulinopsis* Silvestri, 1904

*Vaginulinopsis superbus* (Cushman and Renz) 1941

(Plate 32, Figures 1-3)

**Diagnostic Features:** Test free, early portion closely coiled and compressed, planispiral, evolute, later portion uncoiled, periphery keeled; six to nine compressed chambers, increasing gradually in size, sutures distinct, with round knoblike beads on the sutures; aperture terminal, radiate, at the end of elongate terminal chamber, with distinct neck. Wall calcareous, hyaline, smooth and finely perforate.

**Paleobathymetry:** Outer neritic to bathyal.

**Known Stratigraphic Range:** Upper Oligocene through Miocene.
**Occurrences in Venezuela and Trinidad:** This form occurs in the Lucian (Upper zone) and in the *Vaginulinopsis superbus*/*Trochammina* cf. *pacifica* zonule of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Brasso Formation) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-5 (Zone N6/M3).

Genus *Marginulinopsis* Silvestri, 1904

*Marginulinopsis basispinosus* (Cushman and Renz) 1941

(Plate 32, Figures 4-6)

**Diagnostic Features:** Test free, short, stout, elongate; early portion closely coiled, later uncoiled to rectilinear, periphery angular with a distinct keel with basal spines, six to eight compressed chambers in the coiled portion, two to three in the uncoiled portion, terminal chamber inflated, sutures ornamented with distinct beads in the coiled portion, aperture terminal, at the end of a short neck.

**Paleobathymetry:** Neritic to middle bathyal.

**Known Stratigraphic Range:** Lower Oligocene to Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the *Marginulinopsis basispinosus* Zone of the Lower Lucian in the Agua Salada Group, Falcon Basin of Venezuela (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-15 (Zone N6/M3).

Genus *Lenticulina* Lamarck 1804.

*Lenticulina hedbergi* Cushman and Renz, 1941.

(Plate 32, Figures 7-9)
**Diagnostic Features:** Test free, planispiral, involute, biconvex, periphery keeled with small spines; chambers inflated increasing gradually in size as added, some chambers without spines, six to seven chambers in the final whorl, sutures limbate with distinctly pustules, slightly curved, wall calcareous, hyaline, smooth, finely perforate; aperture radiate.

**Paleobathymetry:** Range from upper to middle bathyal depths.

**Known Stratigraphy Range:** Lower Oligocene (P18) to upper Miocene (N16/M13).

**Occurrences in Venezuela and Trinidad:** This form occurs common in the Lower Acostian and scarce in Upper Acostian in the Falcon Basin, Venezuela (Renz, 1948) and in the Oligo/Miocene (Ste. Croix and Brasso Formations) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-15 (Zone N6/M3).

*Lenticulina subpapillosus* (Nuttall) 1932

(Plate 32, Figures 10-12)

**Diagnostic Features:** Test free, biconvex, subcircular peripheral margin with thin keel, chambers inflated increasing gradually in size as added, five to seven chambers in the final whorl, sutures limbate slightly curved, wall calcareous with papillose ornamentation, hyaline, smooth, finely perforate; aperture radiate.

**Paleobathymetry:** Neritic to middle bathyal.

**Known Stratigraphic Range:** Lower Oligocene to Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Upper Oligocene (Sombrerito Formation), Falcon Basin of Venezuela (Bermudez, 1949). Recorded in this study in the
Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-89 (Zones N6/M3-N9/M6).

Genus *Saracenaria* Defrance 1824

*Saracenaria senni* Hedberg 1937

(Plate 32, Figures 13-14)

**Diagnostic Features:** Test free, small, initial portion close coiled, later portion uncoiling and curved; seven chambers, increasing gradually in size. Periphery keeled, sometimes with stout spines and the end but not on all chambers; sutures curved, radiate aperture. Wall calcareous, hyaline, smooth and finely perforate.

**Paleobathymetry:** Bathyal depths.

**Known Stratigraphic Range:** Oligocene to Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Hedberg, 1937) and in the *Uvigerinella sparsicosta* Zone in the Lower Acostian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Also occurs in the Oligo/Miocene (*Ste Croix and Brasso Formations*) of Trinidad (Cushman and Stainforth, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-7 to RO-53 (Zones N6/M3-N9/M6).
Agglutinated benthic foraminifera from the Cipero and Carapita formations

Genus *Cyclammina* H. B. Brady, 1876.

*Cyclammina cancellata* Brady, 1879

(Plate 28, Figures 1-8)

**Diagnostic Features:** Test free, large, robust, planispiral, biconvex, involute, circular to oval in outline, periphery rounded, subcircular; wall finely agglutinated, nine to twelve chambers in the final whorl, slightly inflated, gradually increasing in size, sutures radial, depressed; aperture multiple with interiomarginal slit and several rounded pores on the apertural face.

**Paleobathymetry:** Range from upper bathyal to abyssal.

**Known Stratigraphic Range:** Upper Eocene to Recent.

**Occurrences in Venezuela and Trinidad:** Occurs in *Uvigerinella sparsicostata* Zone, Acostian, Araguatian and Lucian (Lower and Upper zones) in the Agua Salada Group, Falcon Basin of Venezuela (Renz, 1948). In the Oligo/Miocene (Carapita Formation) of the Eastern Venezuela Basin (Hedberg, 1937) and in the Oligo/Miocene (Ste. Croix and Brasso formations) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-67 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Globorotalia fohsi peripheroronda* Zone).

Genus *Dorothia* Plummer, 1931.

*Dorothia brevis* Cushman and Renz, 1945.
Diagnostic Features: Test free, robust, chambers strongly inflated, gradually increasing in size, sutures depressed, wall finely to moderate agglutinated, aperture over the final chamber covered by a thin lip.

Paleobathymetry: Bathyal to abyssal.

Known Stratigraphic Range: Oligocene to Miocene.

Occurrences in Venezuela and Trinidad: Occurs in the Oligo/Miocene (Ste. Croix and Brasso formations) of Trinidad (Cushman and Renz, 1947). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-89 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M6, from sample BO-287 (Catapsydrax dissimilis Zone) to RDL-538 (Globorotalia fohsi peripheroronda Zone).

Agglutinated foraminifera from the Cipero Formation

Genus Paratrochamminoides Cushman 1910

Paratrochamminoides irregularis White 1928

(Plate 30, Figures 10-12)

Diagnostic Features: Test robust, large, coiling glomospiral, chambers globular, elongate, aperture a simple terminal opening. Wall finely agglutinated.

Paleobathymetry: Bathyal

Known Stratigraphic Range: ?Oligocene to Miocene.

Occurrences in Venezuela and Trinidad: This form occurs in the Oligo/Miocene (Cipero Formation) of Trinidad (Cushman and Stainforth, 1945). Recorded in the Cipero Formation in Zone N5/M2, sample BO-287 (Catapsydrax dissimilis Zone).
Agglutinated foraminifera from the Carapita Formation

Genus *Valvulina* d’Orbigny, 1826.

*Valvulina flexilis* Cushman and Renz, 1941.

(Plate 33, Figures 1-3)

**Diagnostic Features:** Test free, early portion triserial after biserial in adult stage. Chambers strongly deformed, wall agglutinated.

**Paleobathymetry:** Bathyal through abyssal depths.

**Known Stratigraphic Range:** Upper Oligocene to middle Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Ste Croix Formation) of Trinidad (Cushman and Stainforth, 1947) and scarce in the *Uvigerinella sparsicostata* Zone, Acostian and Araguatian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948) also in the Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-75 (Zones N6/M3-N9/M6).

Genus *Sigmoilopsis* Finlay, 1947.

*Sigmoilopsis schlumbergeri* (Silvestri, 1904)

(Plate 33, Figures 4-6)

**Diagnostic Features:** Test free, ovate, biconvex; chambers indistinct and slightly inflated, periphery subacute to rounded. Wall finely agglutinated, terminal rounded aperture on a short neck with a bifid tooth, surrounded by a lip.

**Paleobathymetry:** Outer neritic to middle bathyal depths.

**Known Stratigraphic Range:** Lower middle Miocene (N8/M5) through Pleistocene (N23/Pt2).
**Occurrences in Venezuela and Trinidad:** This form occurs in the Oligo/Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-49 (Zones N6/M3-N9/M6).

Genus *Alveovalvulinella* Cushman 1933

*Alveovalvulinella pozonensis* Cushman and Renz 1941

(Plate 33, Figures 7-9)

**Diagnostic Features:** Test free, elongate, periphery cylindrical in outline, robust; initial portion trochospiral, later becoming uniserial, alveolar inflated chambers, increasing rapidly in size in uniserial portion, sutures depressed, indistinct, wall thick strongly agglutinated, terminal aperture.

**Paleobathymetry:** Upper bathyal to abyssal.

**Known Stratigraphic Range:** Lower Oligocene (P18) through upper Miocene (N16/M13).

**Occurrences in Venezuela and Trinidad:** Common in the Acostian and Araguatian in the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Also occurs in the Oligocene Nariva Formation of Trinidad. Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-79 (Zones N6/M3-N9/M6) and in the Cipero Formation in Zones N5/M2-N9/M, from sample BO-287 (*Catapsydrax dissimilis* Zone) to RDL-538 (*Glororotalia fohsi peripheroronda* Zone).

Genus *Glomospira* Rzehak, 1885.

*Glomospira charoides* (Jones and Parker, 1860)
Diagnostic Features: Test irregularly with tubular streptospirally enrolled chamber, wall finely to moderate agglutinated and aperture at the open end of the tubular chamber.

Paleobathymetry: Middle bathyal through abyssal depths.

Known Stratgraphic Range: Cretaceous to Recent.

Occurrences in Venezuela and Trinidad: Occurs in the Oligo/Miocene (Carapita Formation) Eastern Venezuela Basin (Hedberg, 1937), also occurs in the Upper Acostian and Lucian (Lower zone) of the Agua Salada Group, Falcon Basin, Venezuela and in the Oligo/Miocene (Ste. Croix and Brasso formations) of Trinidad (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-45 (Zones N6/M3-N8/M5).

Remarks: This is a cosmopolitan species, often found in deep-sea environments; however in the Gulf of Mexico it occurs at shallower depths. Its variability in the abundance in different environments can be useful as paleoecological indicator (See Kaminski and Gradstein, 2005).

Genus *Textularia* Defrance, in de Blaineville 1824

*Textularia tatumi* Cushman and Ellisor, 1939

(Plate 34, Figures 1-3)

Diagnostic Features: Test free, small, biserial in adult portion, at least four pairs of chambers in biserial portion, somewhat indistinct, increasing rapidly in size, apertural depression at base of apertural face. Wall finely agglutinated

Paleobathymetry: Bathyal

Known Stratgraphic Range: Miocene
**Occurrences in Venezuela and Trinidad:** This form occurs in the Miocene of the Carapita Formation in the Eastern Venezuela Basin (Jouval and Villain, 1986). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-7 to RO-49 (Zones N6/M3-N9/M6).

Genus *Vulvulina* d’Orbigny 1826

*Vulvulina jarvisi* Cushman, 1932

(Plate 34, Figures 4-6)

**Diagnostic Features:** Test free, early portion planispiral follow by biserial and finally single terminal chamber, periphery acute and keeled, sutures limbate and slightly curved, aperture interiomarginal slit in terminal chamber. Wall finely agglutinated.

**Paleobathymetry:** Bathyal.

**Known Stratigraphic Range:** Eocene to upper Miocene.

**Occurrences in Venezuela and Trinidad:** Occurs in the Oligo/Miocene (Cipero Formation) of Trinidad (Cushman and Stainforth, 1945). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-5 to RO-75 (Zones N6/M3-N9/M6).

*Vulvulina spinosa* Cushman 1932

(Plate 34, Figures 7-9)

**Diagnostic Features:** Test free, large, initial portion coiled, later chamber triserial becoming uniserial, at least seven pairs in the biserial portion with a projecting spine at the outer margin; aperture terminal and elongate. Wall finely agglutinated.

**Paleobathymetry:** Bathyal.
Known Stratigraphic Range: Lower Oligocene to Pleistocene.

Occurrences in Venezuela and Trinidad: This form occurs in the Oligo/Miocene (Ste Croix and Brasso Formations) of Trinidad (Cushman and Stainforth, 1947) and in the upper Acostian of the Agua Salada Group, Falcon Basin, Venezuela (Renz, 1948). Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-7 to RO-75 (Zones N6/M3-N9/M6).

Genus *Gaudryina* d’Orbigny, in de la Sagra 1839

*Gaudryina bullbrooki* Cushman, 1936.

(Plate 34, Figures 10-12)

Diagnostic Features: Test free, large and robust, elongate, early portion triserial and sharply triangular; the last pair of chambers biserial: wall strongly agglutinated with a large amount of calcareous sands, aperture at the inner margin of the last chamber.

Paleobathymetry: Bathyal to abyssal.

Known Stratigraphic Range: Oligocene to Miocene.

Occurrences in Venezuela and Trinidad: Occurs in the Acostian, Upper Araguatian and Lucian (Lower zone) of the Agua Salada Group, Falcon Basin, Venezuela. Recorded in this study in the Carapita Formation (Rio Oregano outcrop) from sample RO-1 to RO-45 (Zones N6/M3-N8/M5).