NEOGENE HISTORY OF THE CARAPITA FORMATION,
EASTERN VENEZUELA BASIN

By DENNIS ALBERTO SANCHEZ ZAMBRANO

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Professor Marie-Pierre Aubry
and approved by
W.A. Berggren
R. K. Olsson
R.D. Liska

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Thesis Director:
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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 sedimentologycal 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 (Codigo 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 MICROPALEONTOLOGICAL 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 stratigraphicaly 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 / Lenticulia 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 Midlle 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.

V-3. Scanning Electron Microscopy (SEM)

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 Venezuelian 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 inappropiate 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 Louisina 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 trochospiral, plano-convex trochospiral, milioline and biconvex trochospiral) 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 m). 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, Globoquadrina 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. altiapertutus* 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 assamblages 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 carapitana, U. rugosa, U. mexicana, Melonis pompilioides, Siphonina pozonensis, Dorothia 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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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

Anomalinoides globulosus (Chapman and Parr 1937)

Anomalinoides 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

Vaginulinopsis superbus (Cushman and Renz) 1941

**Valvulina flexilis* Cushman and Renz, 1941

**Vulvulina jarvisi* Cushman, 1932

**Vulvulina spinosa* Cushman 1932

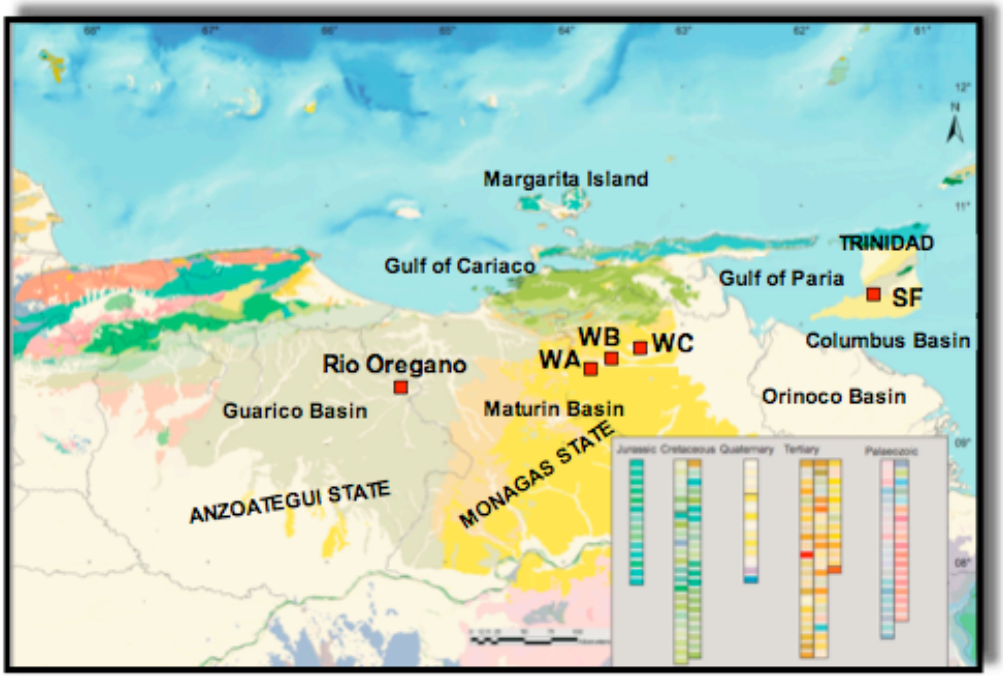


Figure 1. Geographical location of the study area. EVB and Trinidad (Modified from Di Croce, 1995).

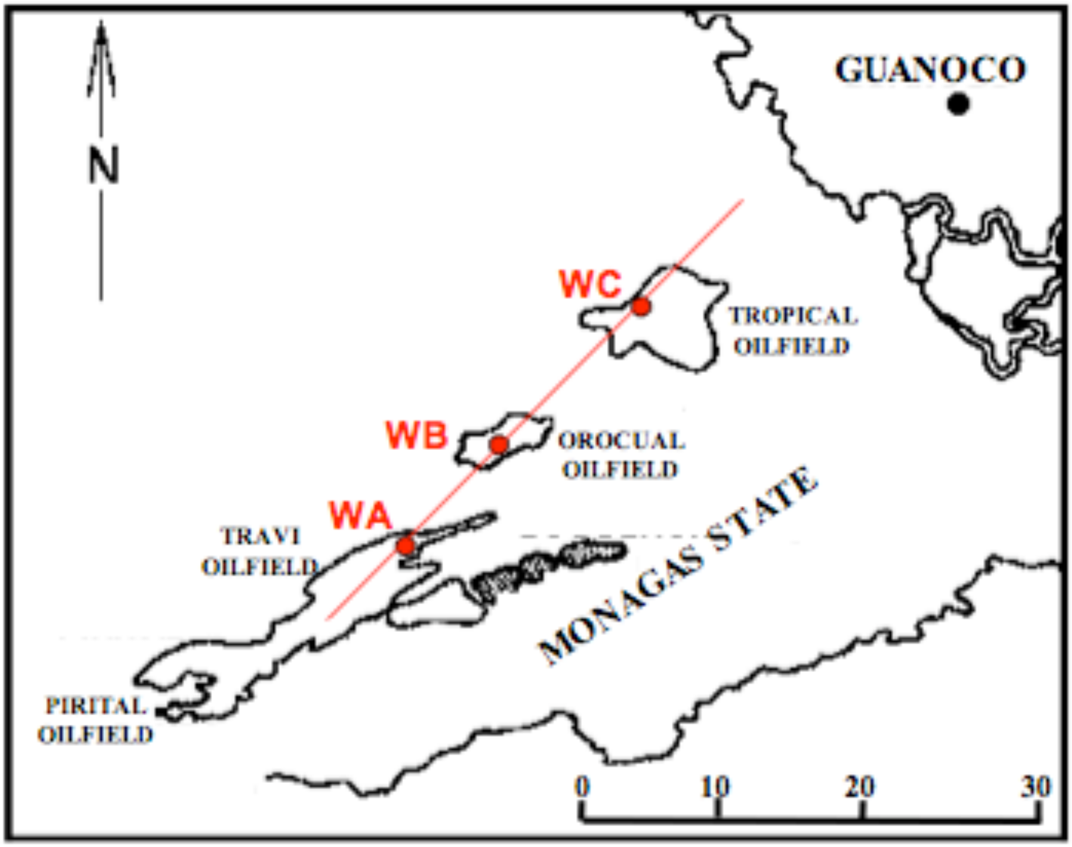


Figure 2. Geographical location of Wells: WA, WB and WC, Eastern Venezuela Basin (Modified from: Codigo Estratigrafico de Venezuela, PDVSA-INTEVEP, 2005).

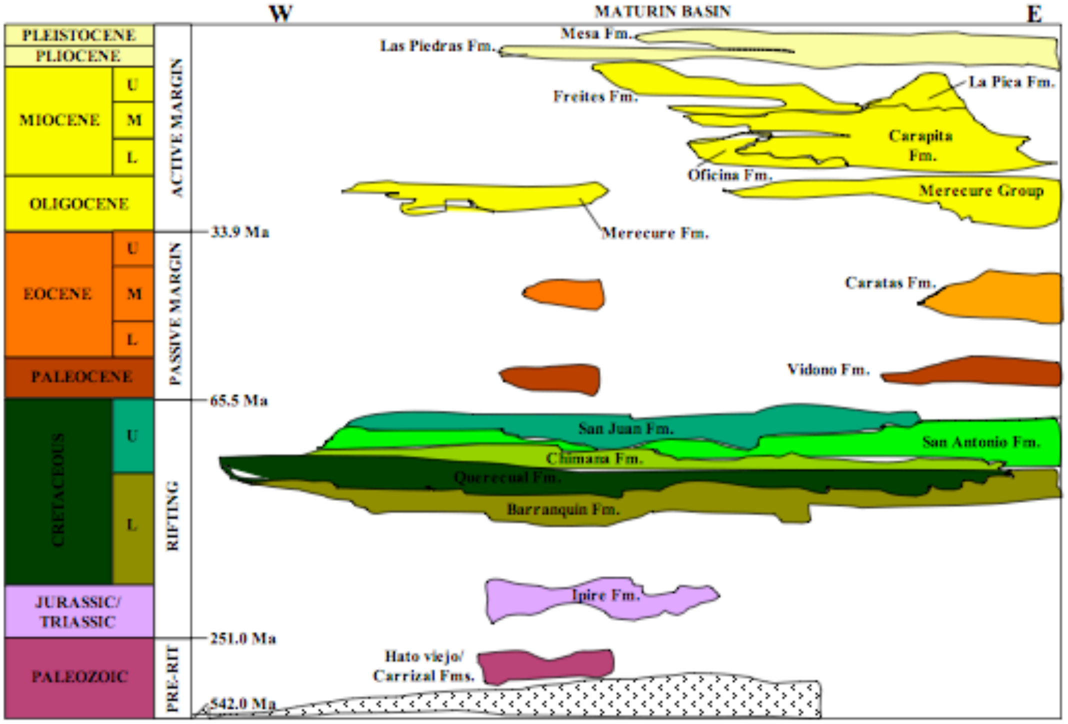


Figure 3. Simplified Chronostratigraphic Chart of the EVB (Modified from Di Croce et al. 2000).

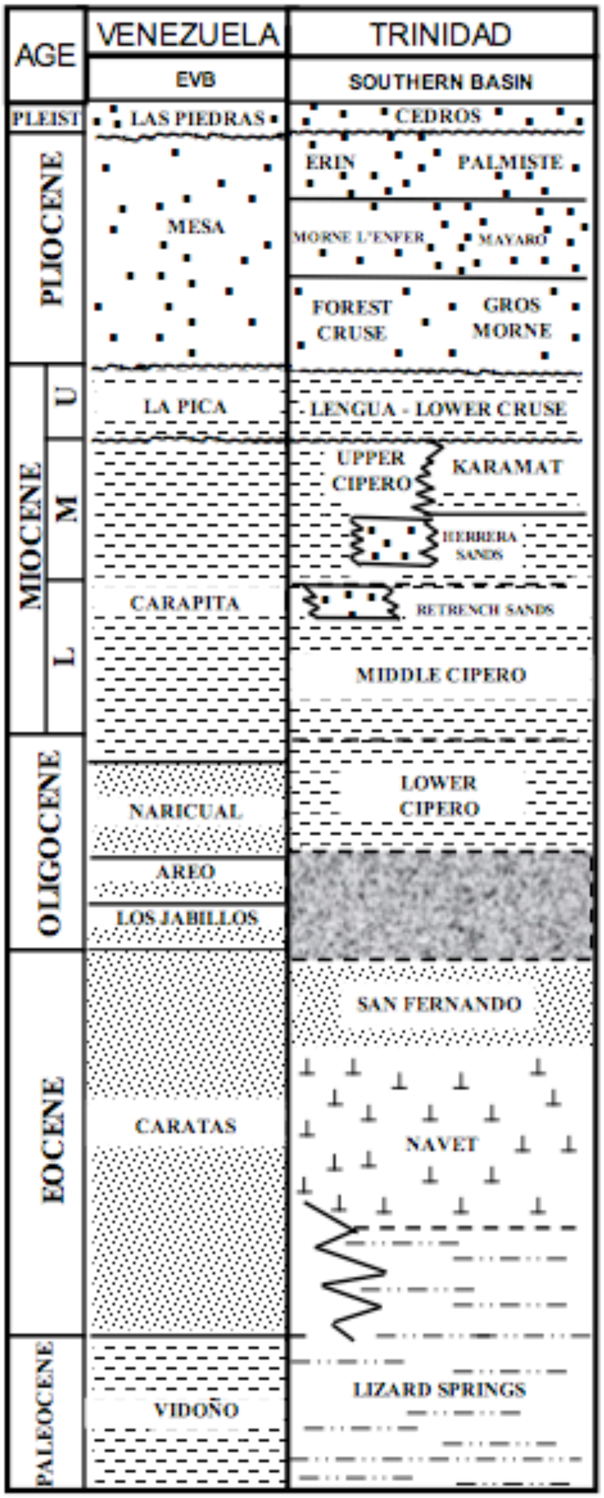


Figure 4. Correlation Chart of formations in Venezuela and Trinidad (Modified from Algar, 1991)

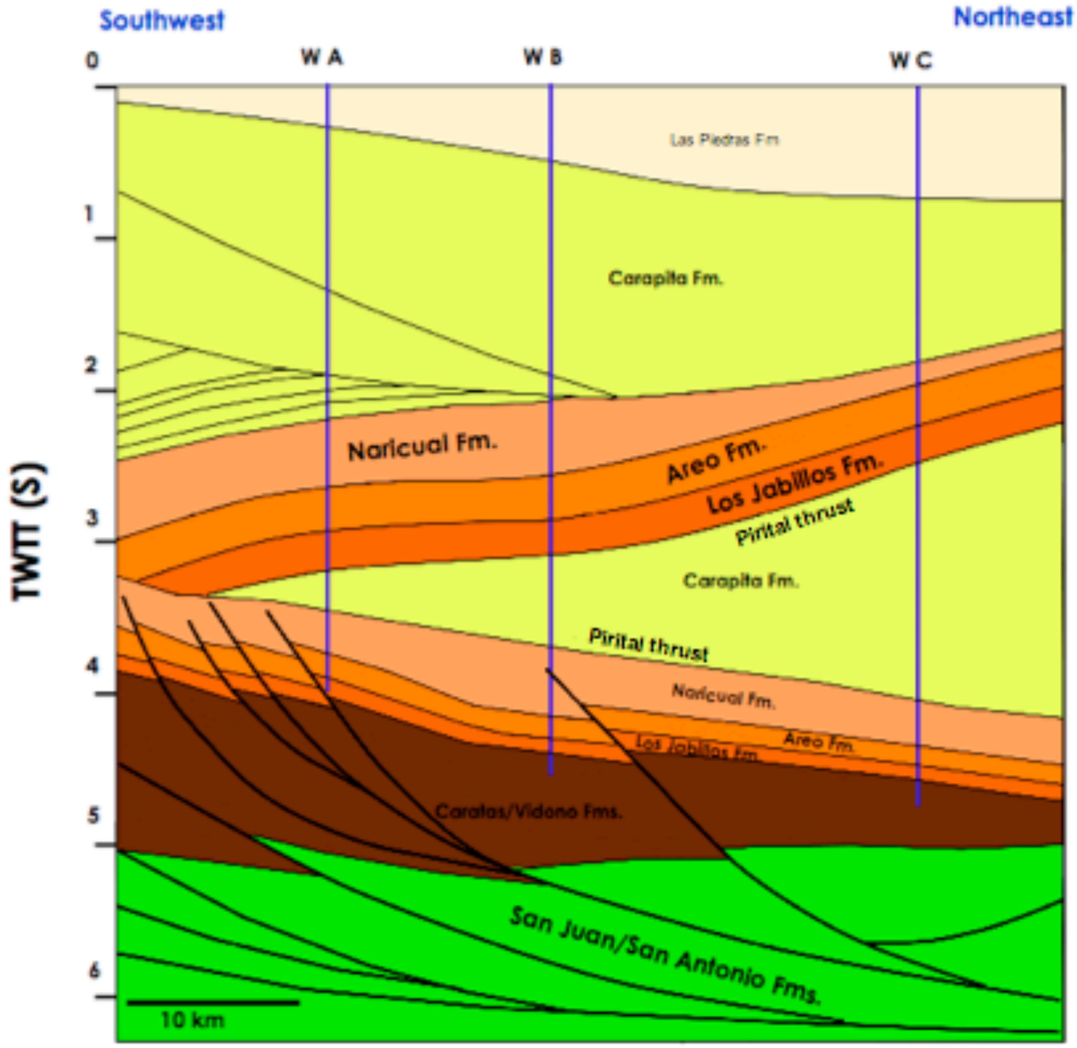


Figure 5. Structural geology of the studied area (Taken from PDVSA, Internal Report, 2009)

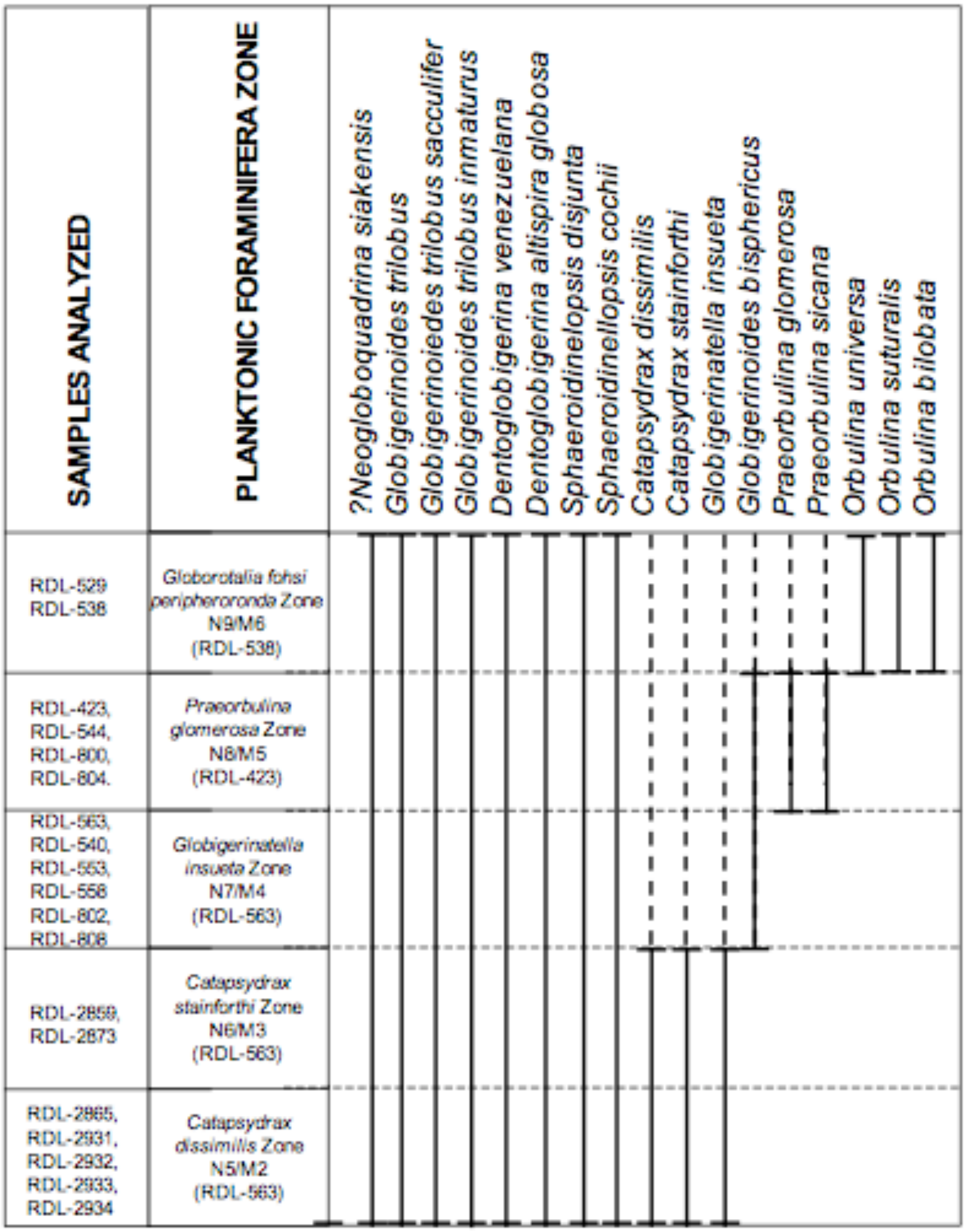


Figure 6. Distribution chart of selected taxa found in the Cipero Formation.

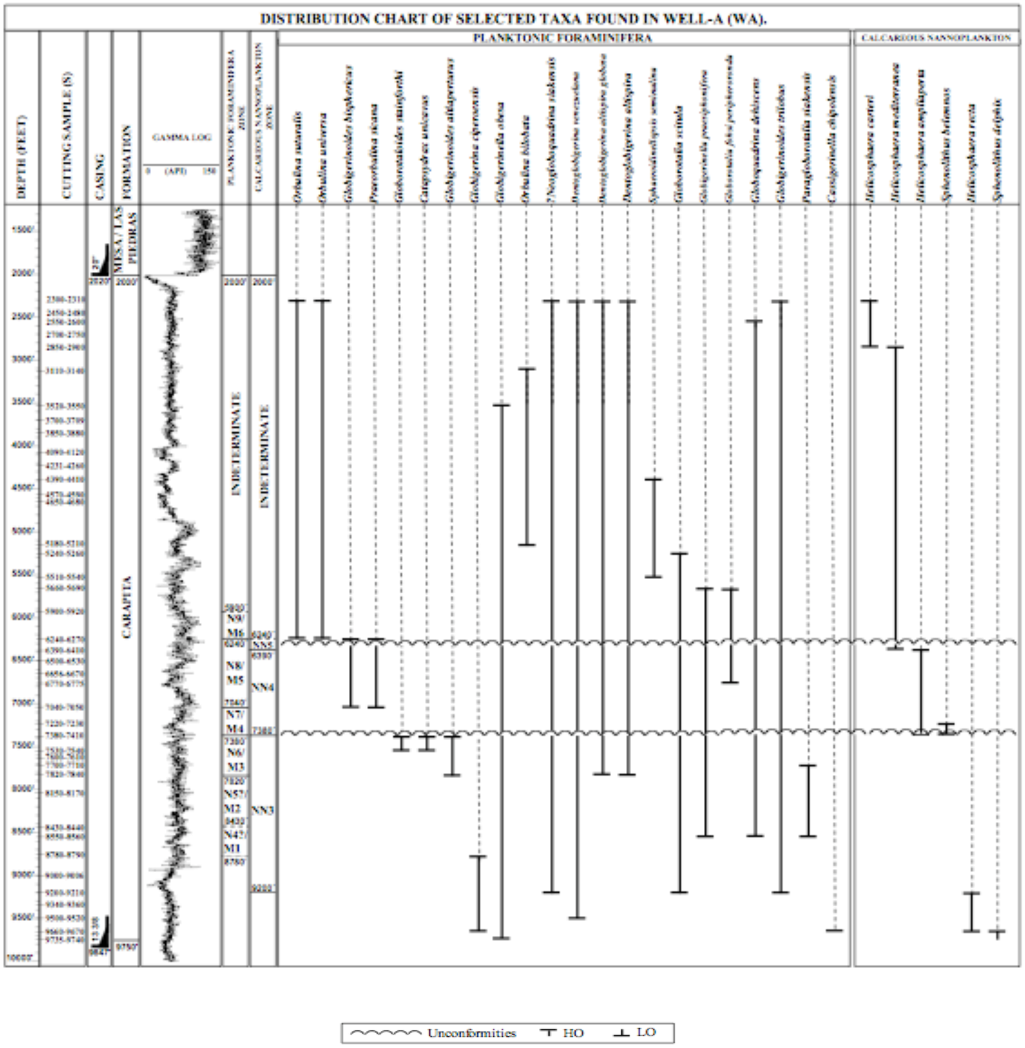


Figure 7. Distribution chart of taxa found in Well WA

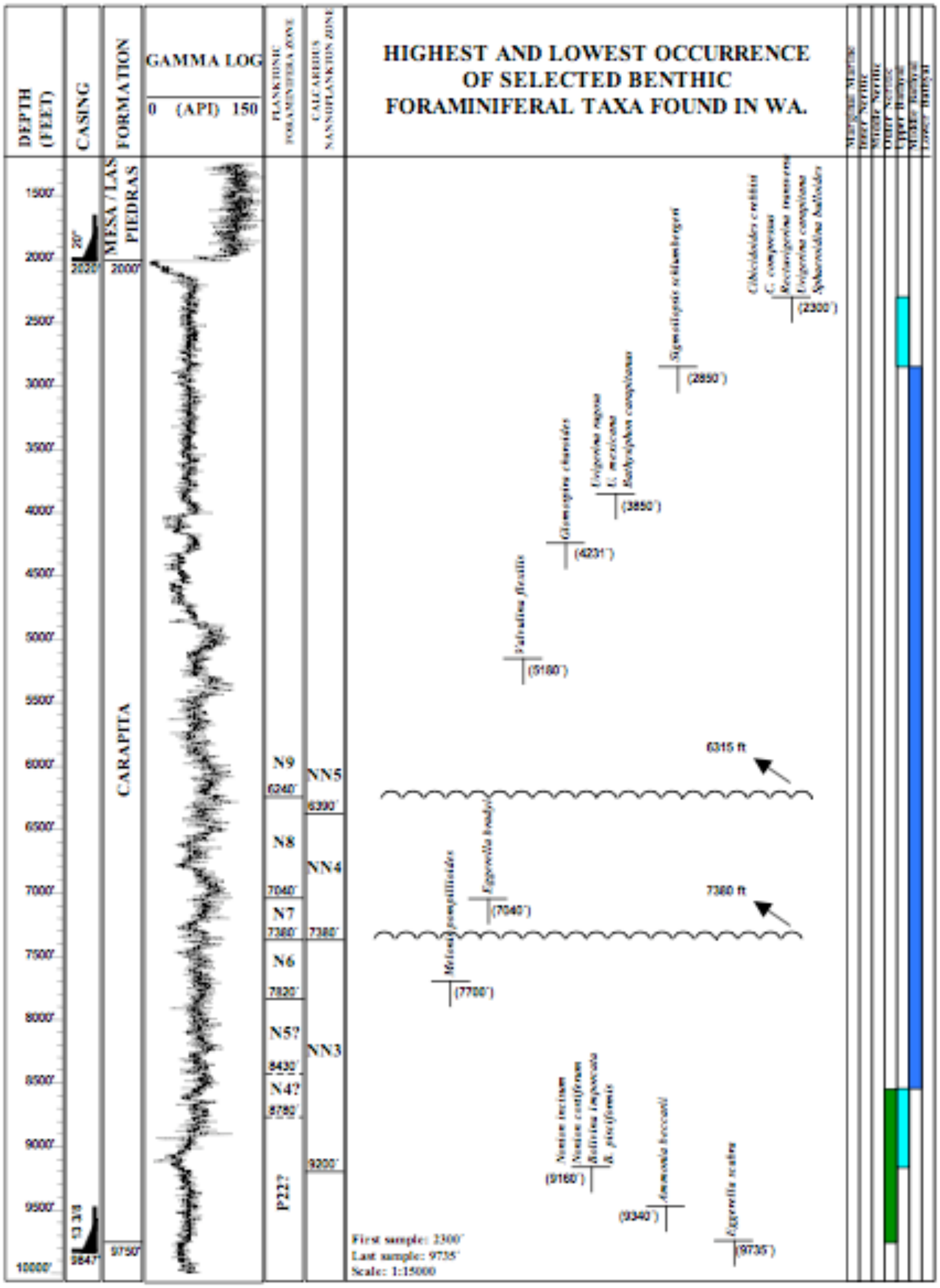


Figure 8. Highest and lowest occurrence of selected benthic foraminiferal found in WA.

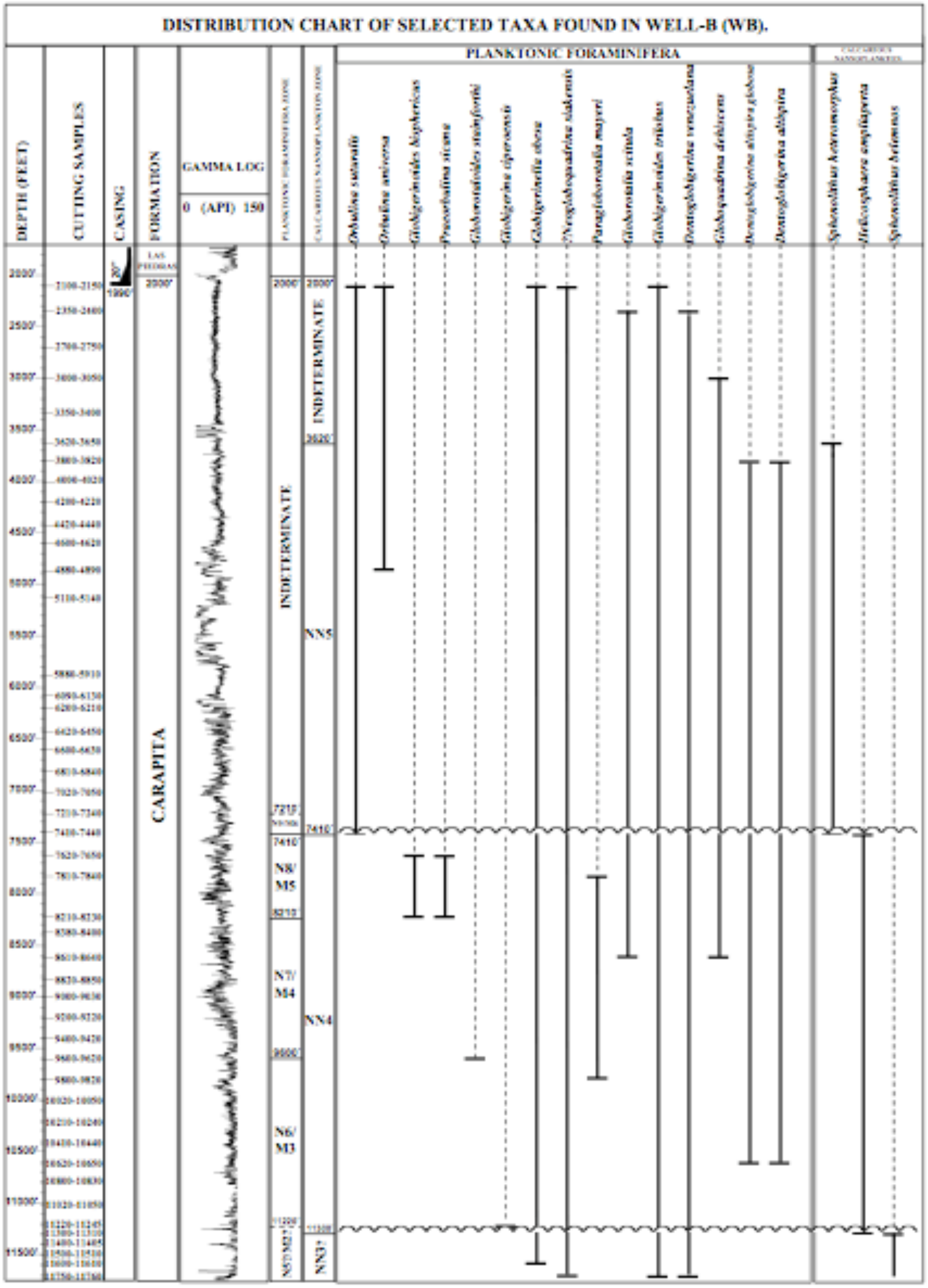


Figure 9. Distribution chart of taxa found in Well WB. Symbols as in figure 7.

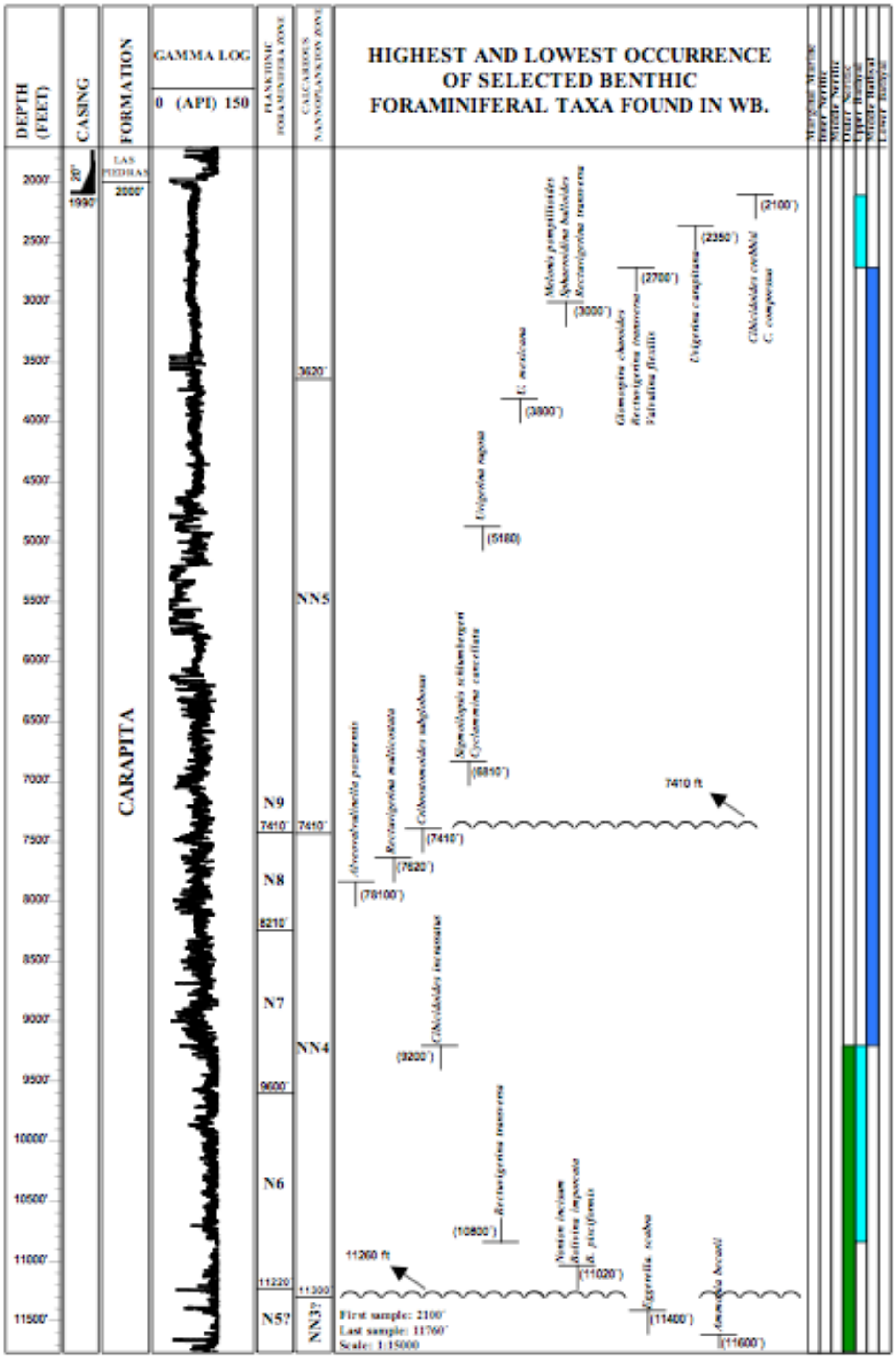


Figure 10. Highest and lowest occurrence of selected benthic foraminiferal taxa found in WB.

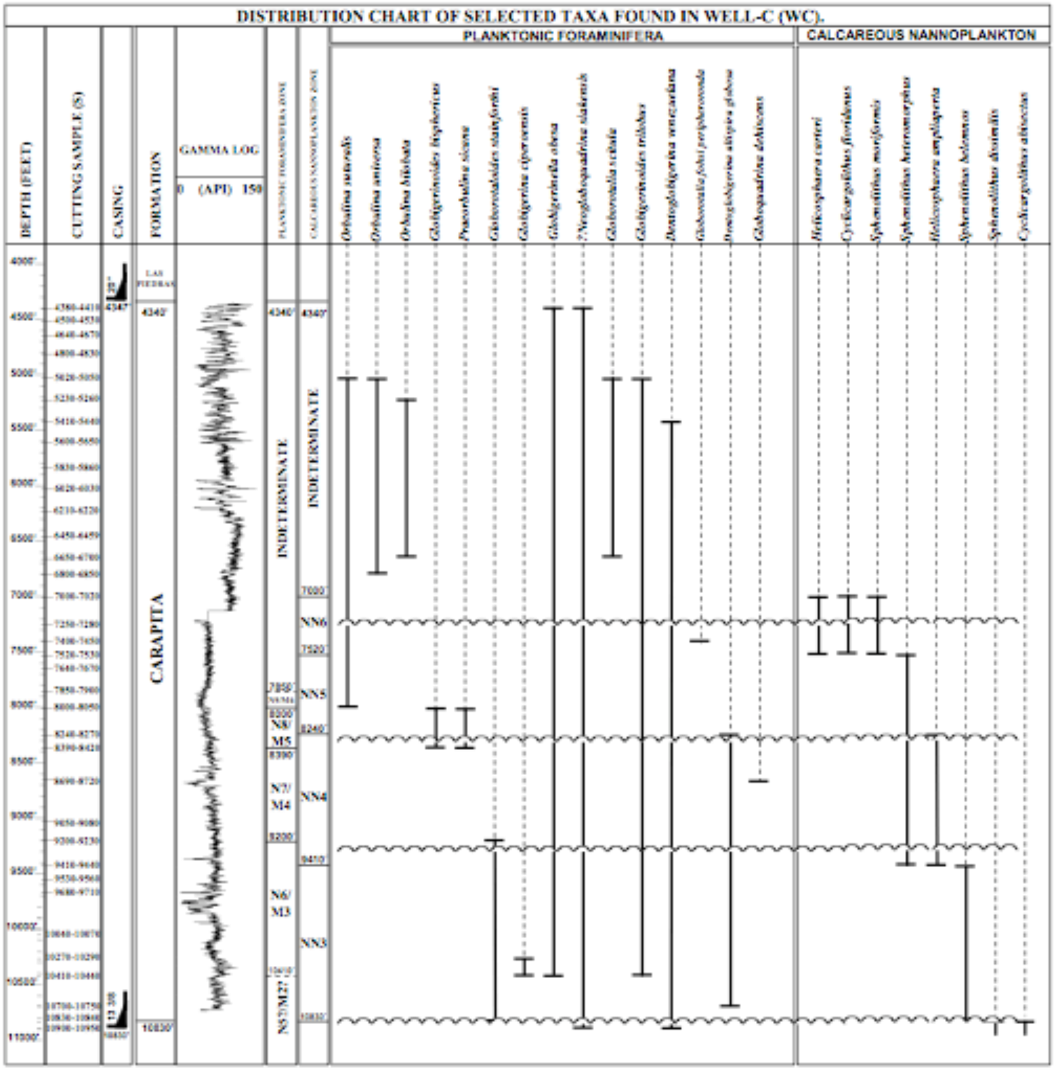


Figure 11. Distribution chart of taxa found in Well WC. Symbols as in figure 7.

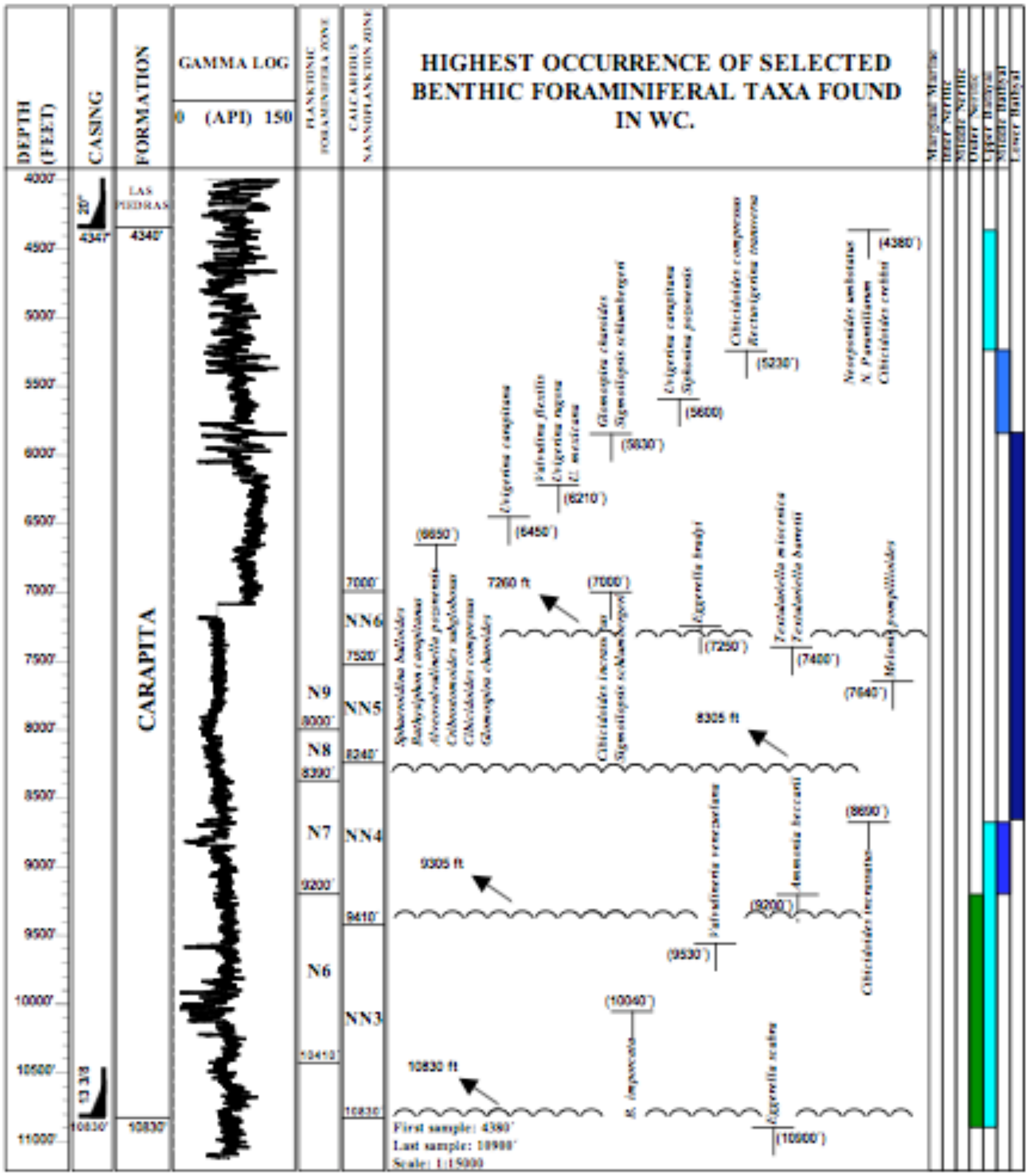


Figure 12. Highest and lowest occurrence of selected benthic foraminiferal taxa found in WC.

Figure 12. Highest and lowest occurrence of selected benthic foraminiferal taxa found in WC.

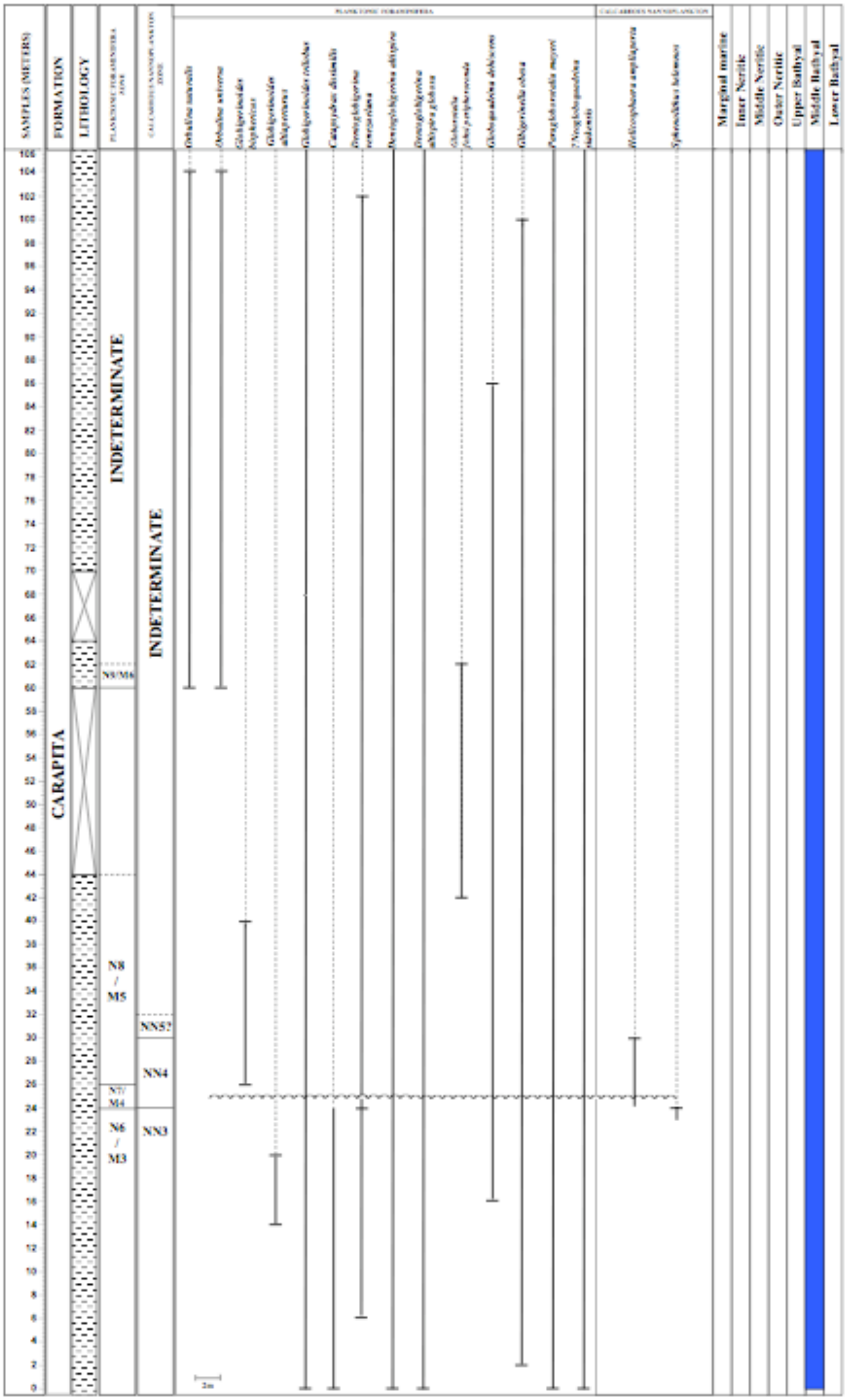


Figure 13. Distribution chart of taxa found in the Rio Oregano Outcrop. Symbols as in figure 7.

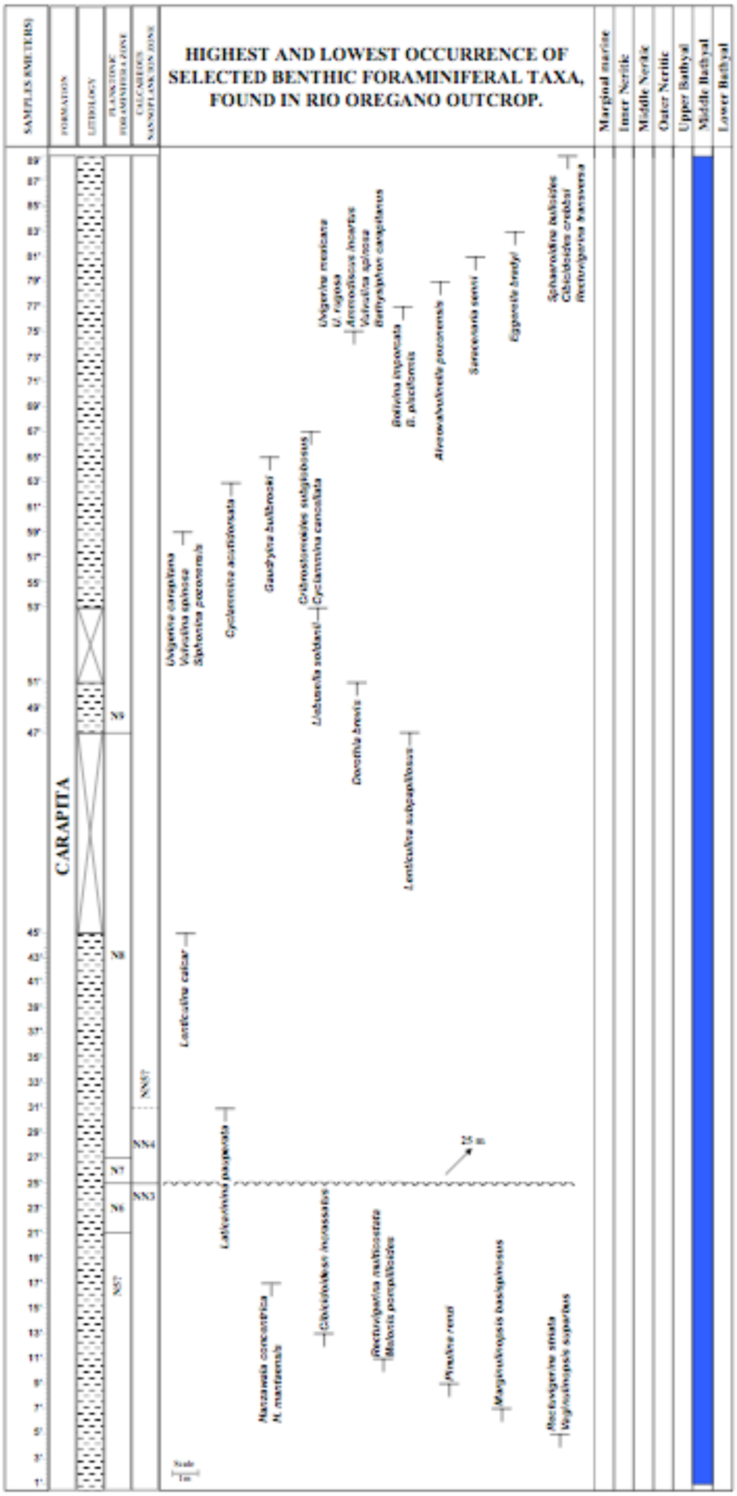


Figure 14. Highest and lowest occurrence of selected benthic foraminifera found in Rio Oregano Outcrop.

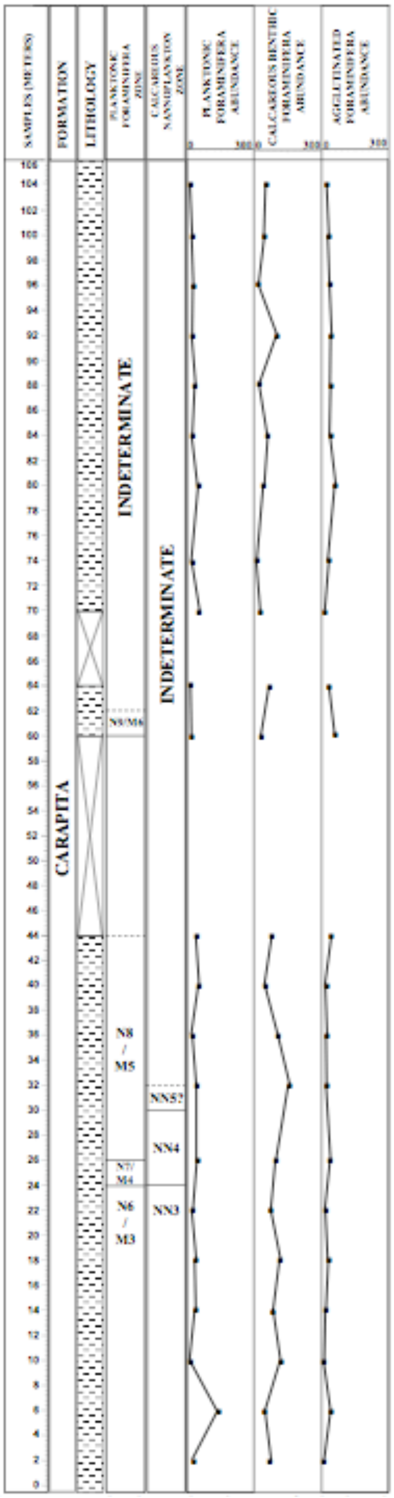
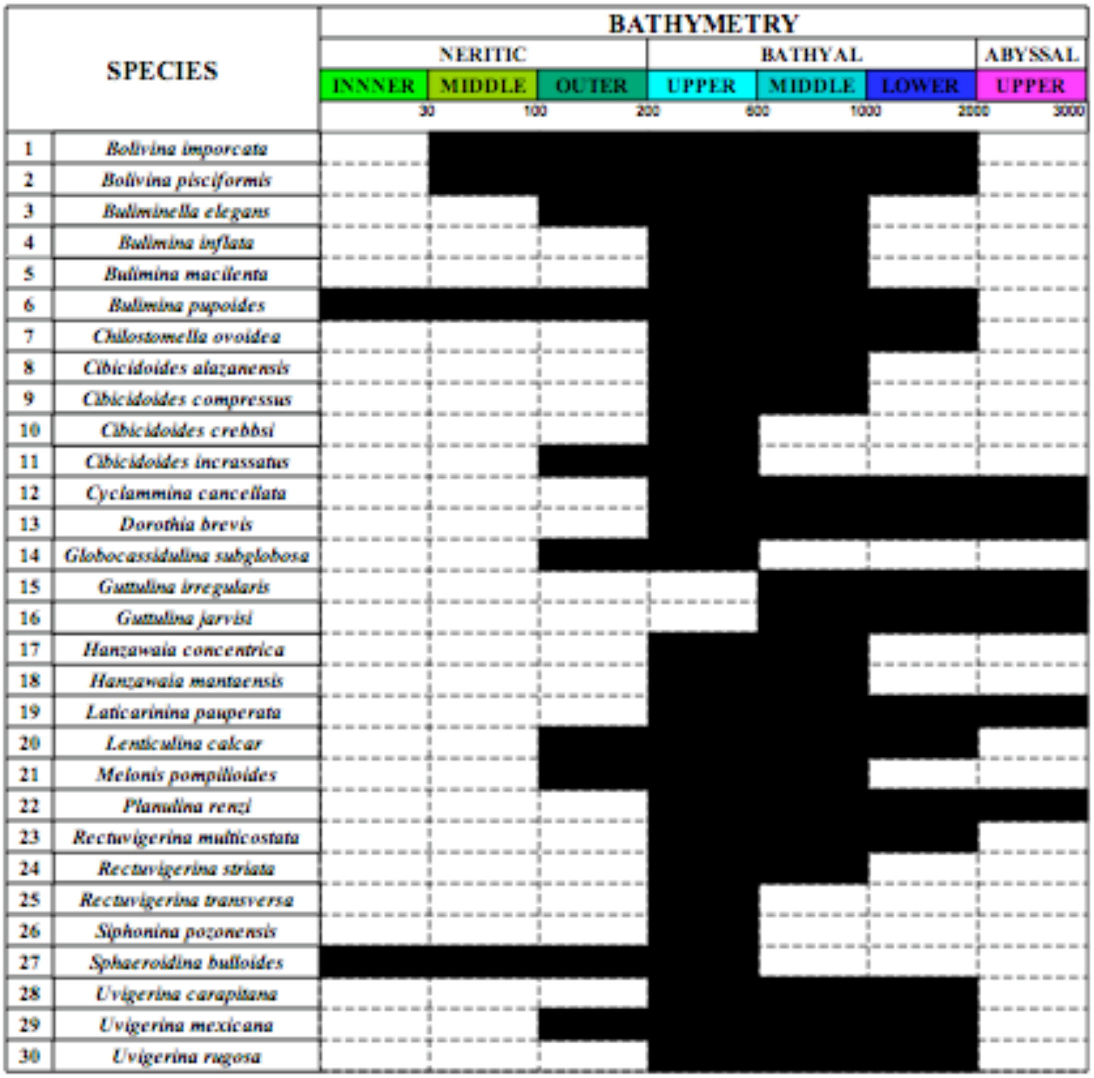
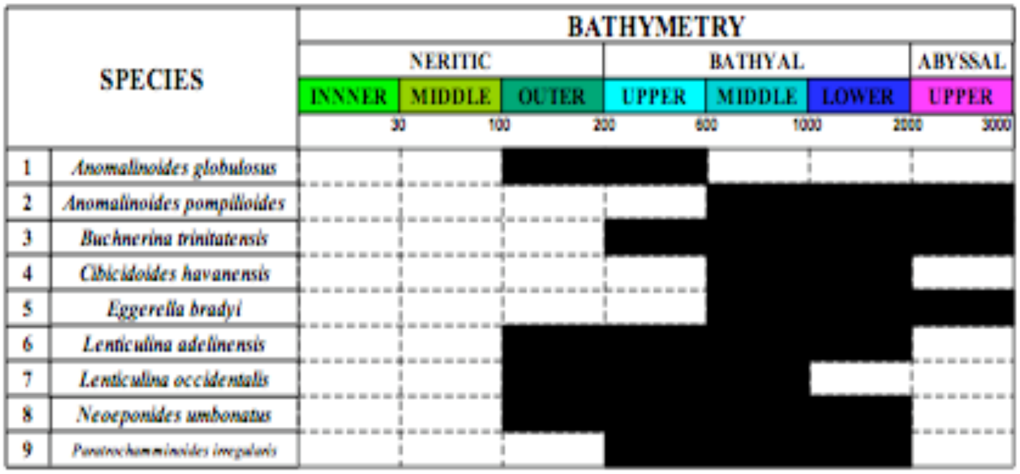


Figure 15. Absolute abundance of Planktonic, calcareous benthic and agglutinated foraminifera, 100 g samples from Rio Oregano Out crop.



	SPECIES	BATHYMETRY						
		NERITIC			BATHYAL			ABYSSAL
		INNNER	MIDDLE	OUTER	UPPER	MIDDLE	LOWER	UPPER
		30	100	200	600	1000	2000	3000
1	*Bolivina imporcata*		■	■	■	■	■	
2	*Bolivina pisciformis*		■	■	■	■	■	
3	*Buliminella elegans*			■	■	■		
4	*Bulimina inflata*				■	■		
5	*Bulimina macilenta*				■	■		
6	*Bulimina pupoides*	■	■	■	■	■	■	
7	*Chilostomella ovoidea*				■	■	■	
8	*Cibicidoides alazanensis*				■	■		
9	*Cibicidoides compressus*				■	■		
10	*Cibicidoides crebbsi*				■			
11	*Cibicidoides incrassatus*			■	■			
12	*Cyclammina cancellata*				■	■	■	■
13	*Dorothia brevis*				■	■	■	■
14	*Globocassidulina subglobosa*			■	■			
15	*Guttulina irregularis*					■	■	■
16	*Guttulina jarvisi*					■	■	■
17	*Hanzawaia concentrica*				■	■		
18	*Hanzawaia mantaensis*				■	■		
19	*Laticarinina pauperata*				■	■	■	■
20	*Lenticulina calcar*			■	■	■	■	
21	*Melonis pompilioides*			■	■	■		
22	*Planulina renzi*				■	■	■	■
23	*Rectuvigerina multicostata*				■	■	■	
24	*Rectuvigerina striata*				■	■		
25	*Rectuvigerina transversa*				■			
26	*Siphonina pozonensis*				■			
27	*Sphaeroidina bulloides*	■	■	■	■			
28	*Uvigerina carapitana*				■	■	■	
29	*Uvigerina mexicana*			■	■	■	■	
30	*Uvigerina rugosa*				■	■	■	

Figure 16. Bathymetry of selected benthic foraminifera species common to the Cipero and Carapita formations (Bathymetry from van Morkhoven et al. 1986).



SPECIES		BATHYMETRY						
		NERITIC			BATHYAL			ABYSSAL
		INNNER	MIDDLE	OUTER	UPPER	MIDDLE	LOWER	UPPER
		30	100	200	600	1000	2000	3000
1	*Anomalinoides globulosus*			■	■			
2	*Anomalinoides pompilioides*					■	■	■
3	*Buchnerina trinitatensis*				■	■	■	■
4	*Cibicidoides havanensis*					■	■	
5	*Eggerella bradyi*					■	■	■
6	*Lenticulina adelinensis*			■	■	■	■	
7	*Lenticulina occidentalis*			■	■	■		
8	*Neoeponides umbonatus*			■	■	■	■	
9	*Paratrochamminoides irregularis*				■	■	■	

Figure 17. Bathymetry of selected benthic foraminifera species restricted to the Cipero Formation (Bathymetry from van Morkhoven et al. 1986).

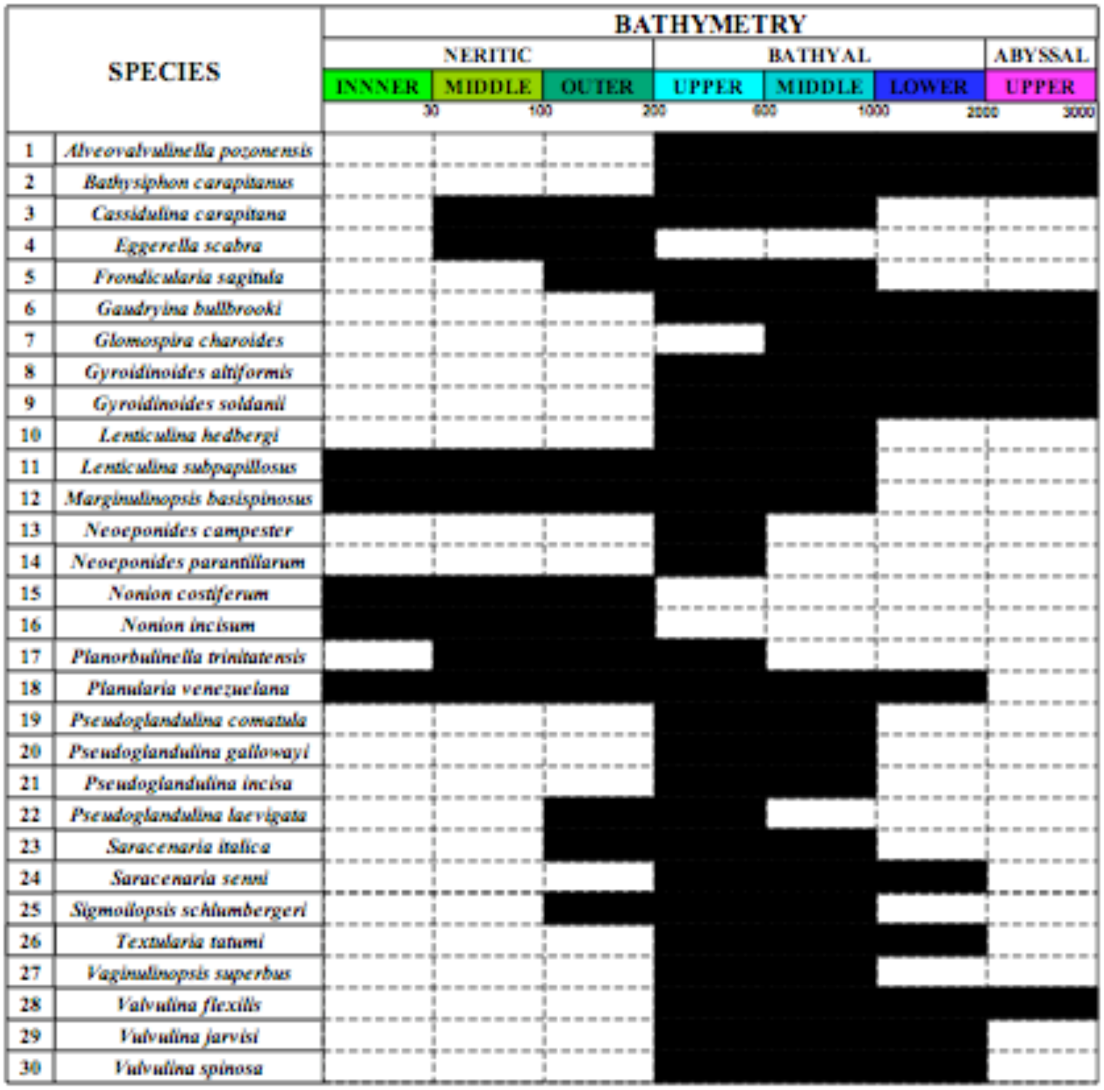


Figure 18. Bathymetry of selected benthic foraminifera species restricted to the Carapita Formation (Bathymetry from van Morkhoven et al. 1986).

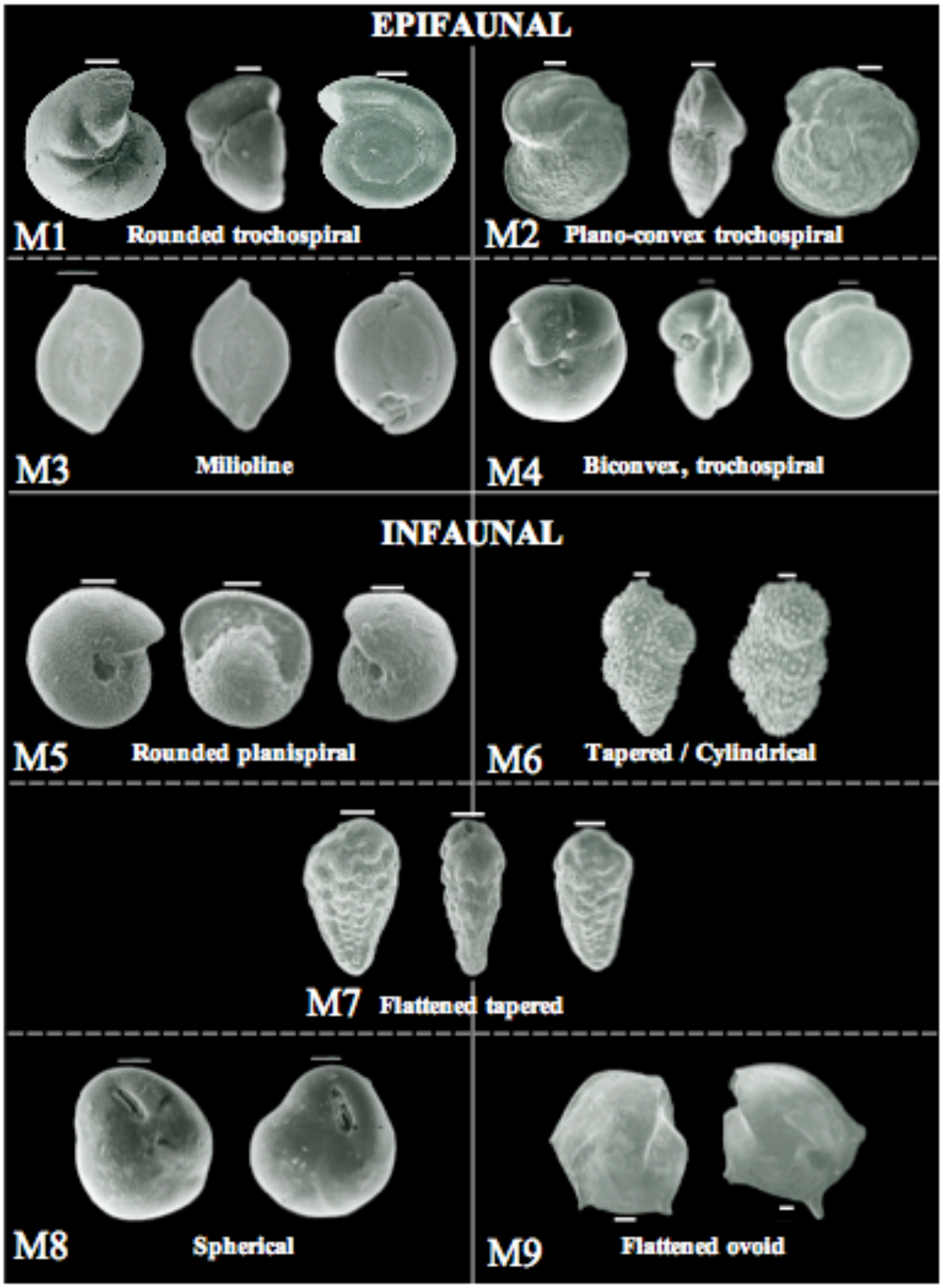


Figure 19. Benthic foraminifera morphotype recognized in the Cipero and Carapita formations (Following Corliss and Chen, 1988 and Corliss and Fois, 1993).

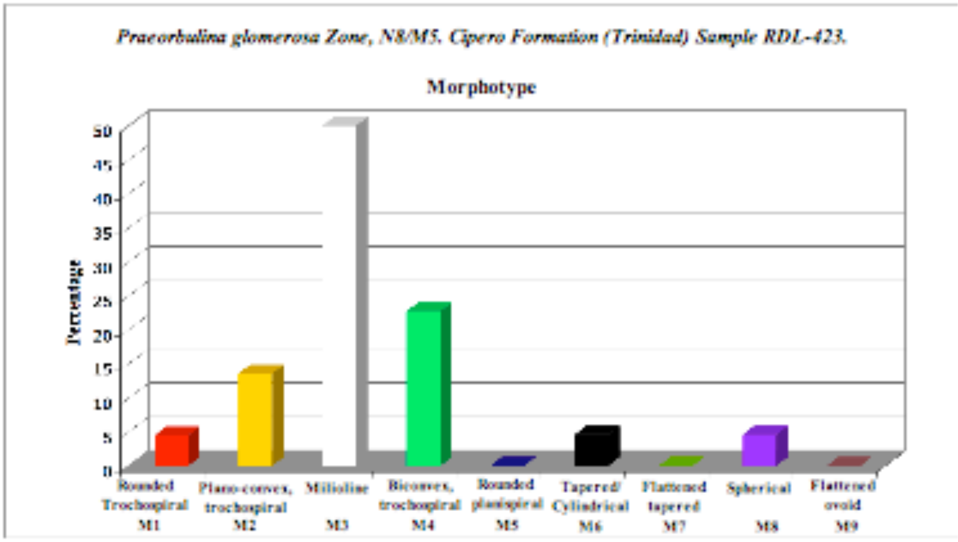


Figure 20. Morphotype analysis; *Praeorbulina glomerosa* Zone, N8/M5. Cipero Formation (Trinidad).

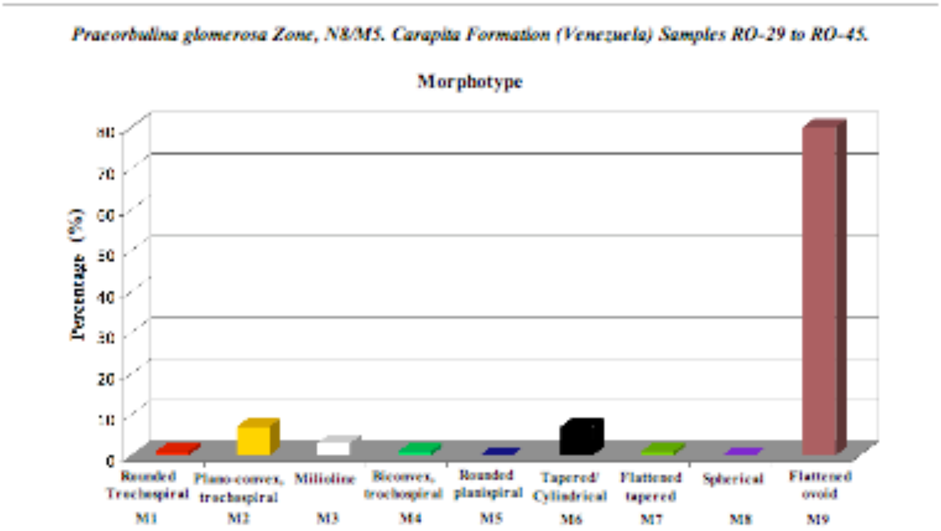


Figure 21. Morphotype analysis, *Praeorbulina glomerosa* Zone, N8/M5. Carapita Formation (Venezuela).

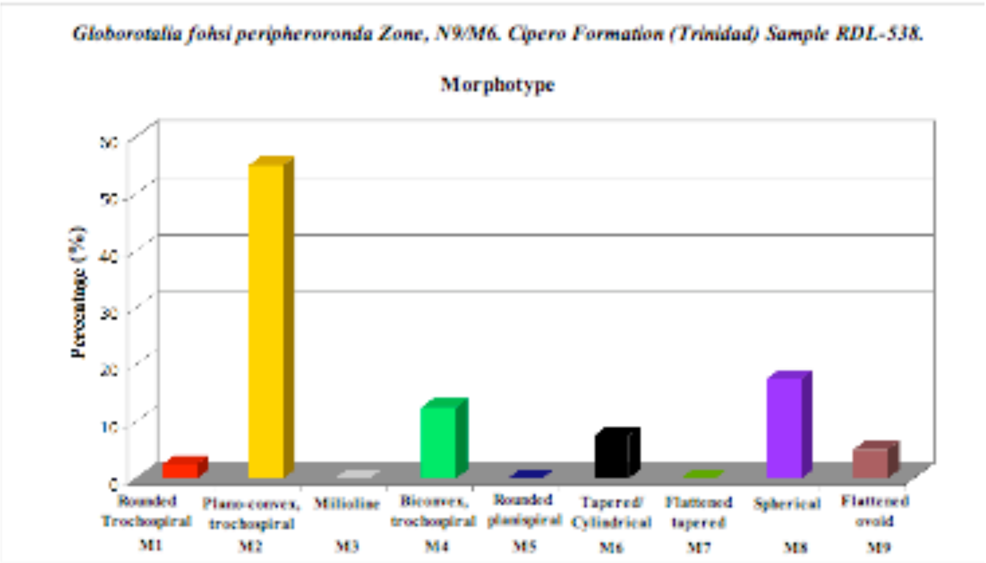


Figure 22. Morphotype analysis, *Globorotalia fohsi peripheroronda* Zone, N9/M6. Cipero Formation (Trinidad).

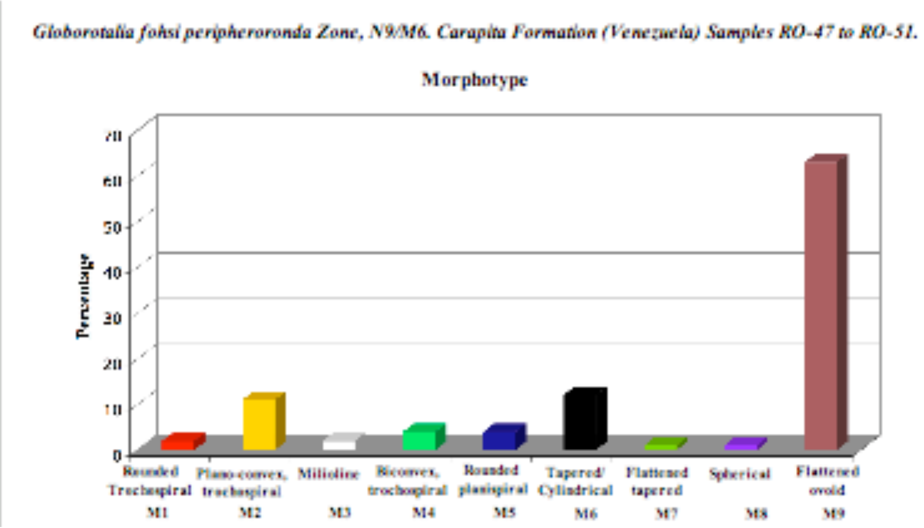


Figure 23. Morphotype analysis; *Globorotalia fohsi peripheroronda* Zone, N9/M6. Carapita Formation (Venezuela).

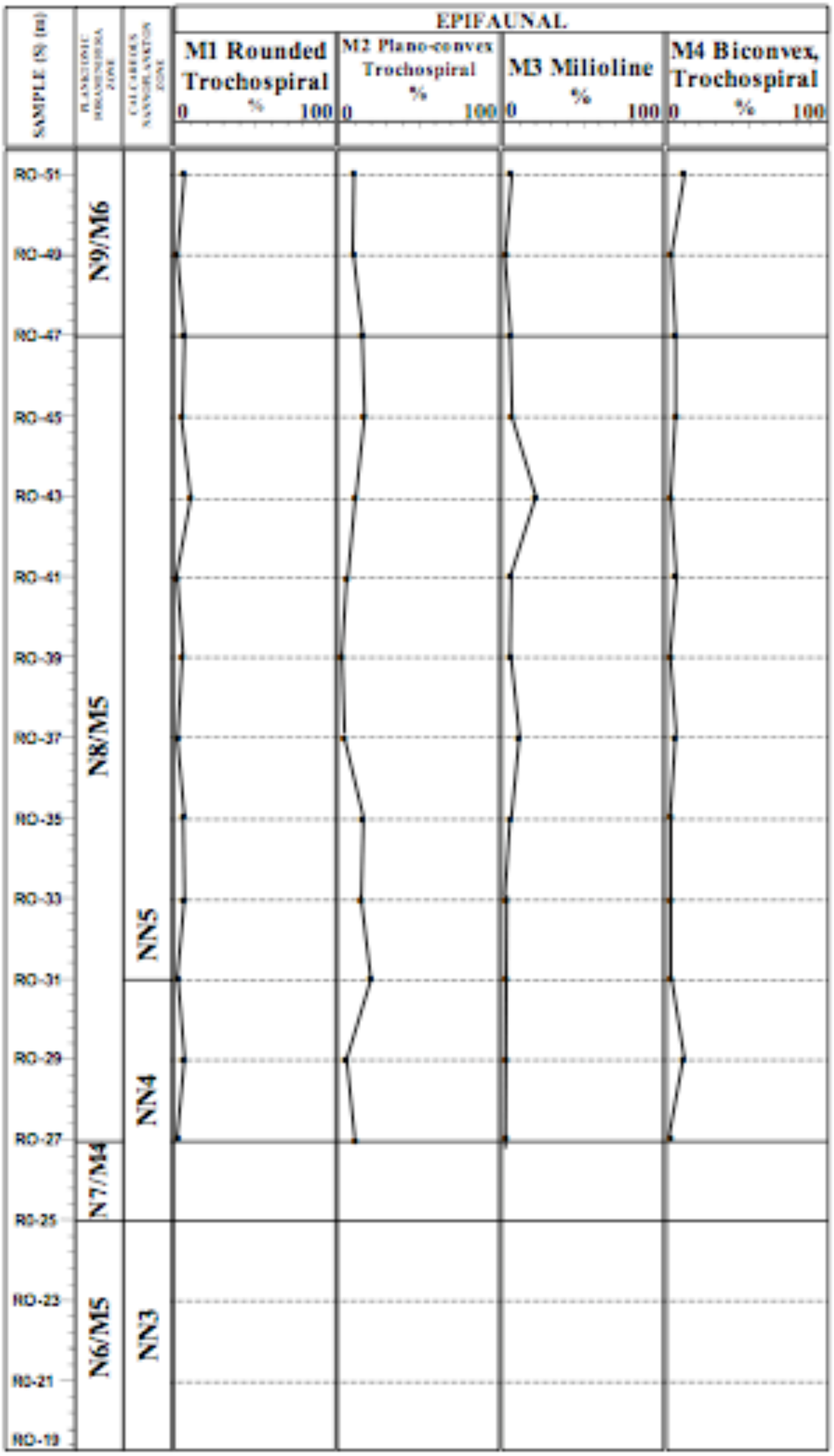


Figure 24. Epifaunal morphotypes recognized in the Carapita Formation.

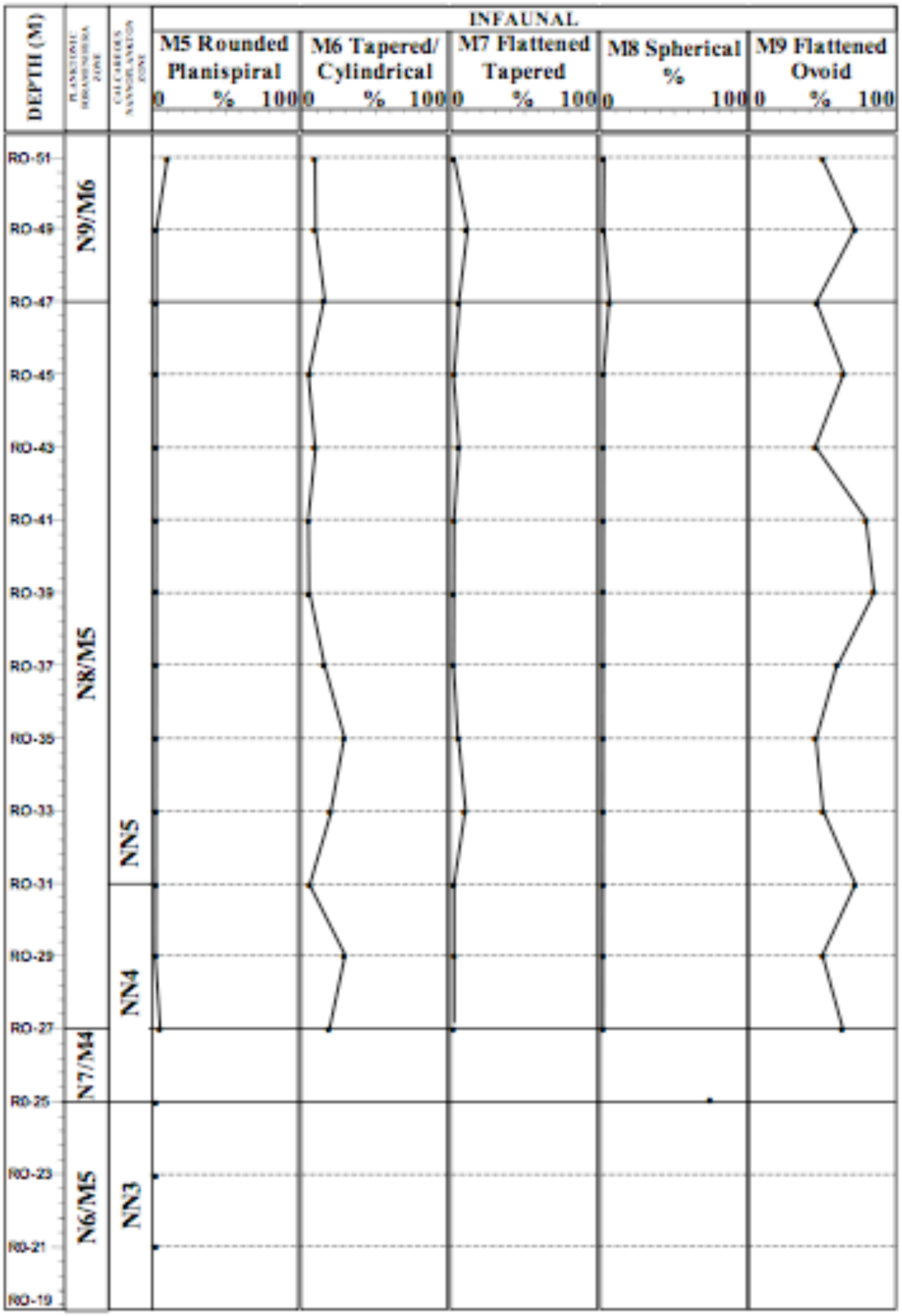


Figure 25. Infaunal morphotypes recognized in the Carapita Formation.

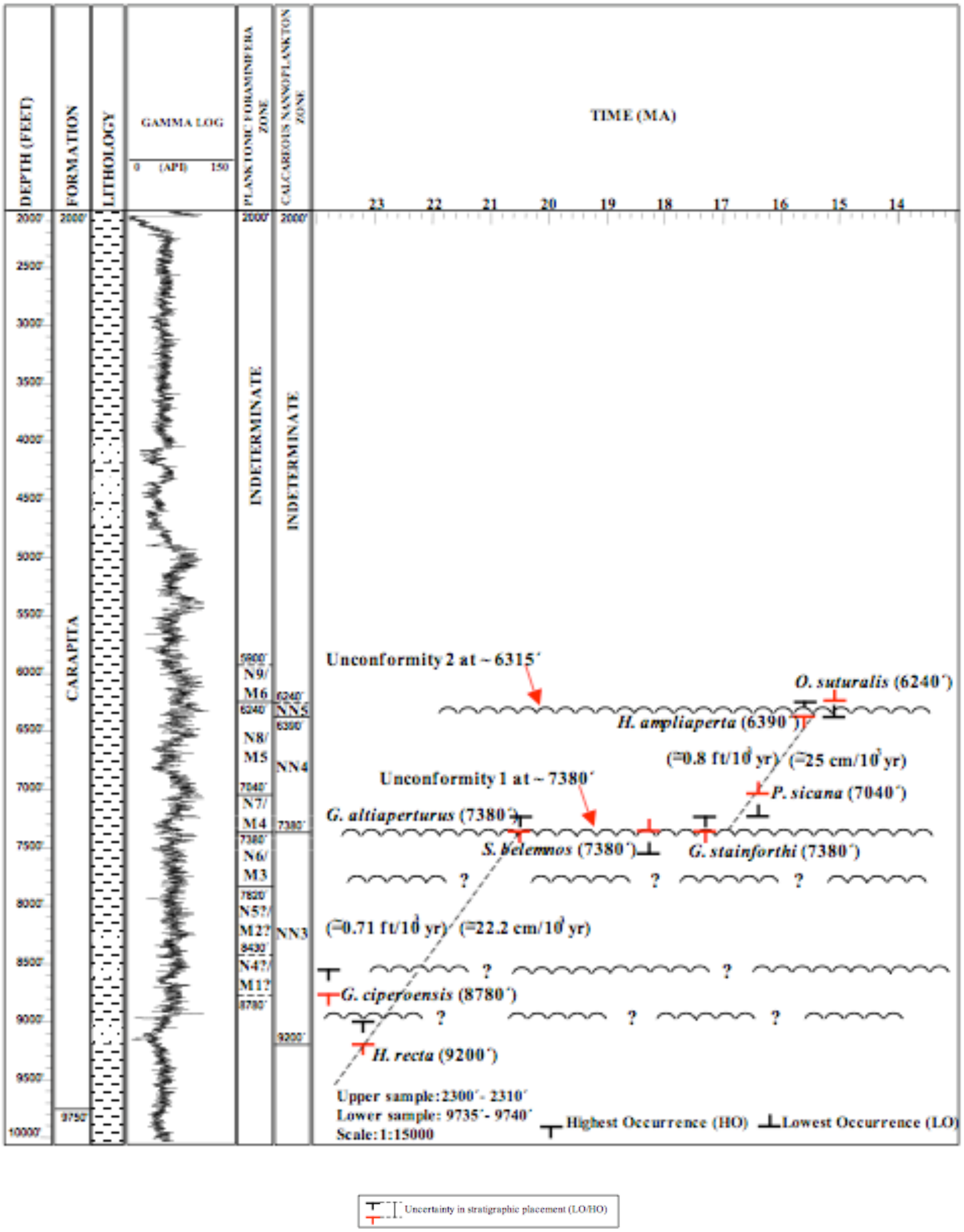


Figure 26. Stratigraphic interpretation of the lower to middle Miocene section from Well WA. Travi Oilfield. Symbols as in figure 7.

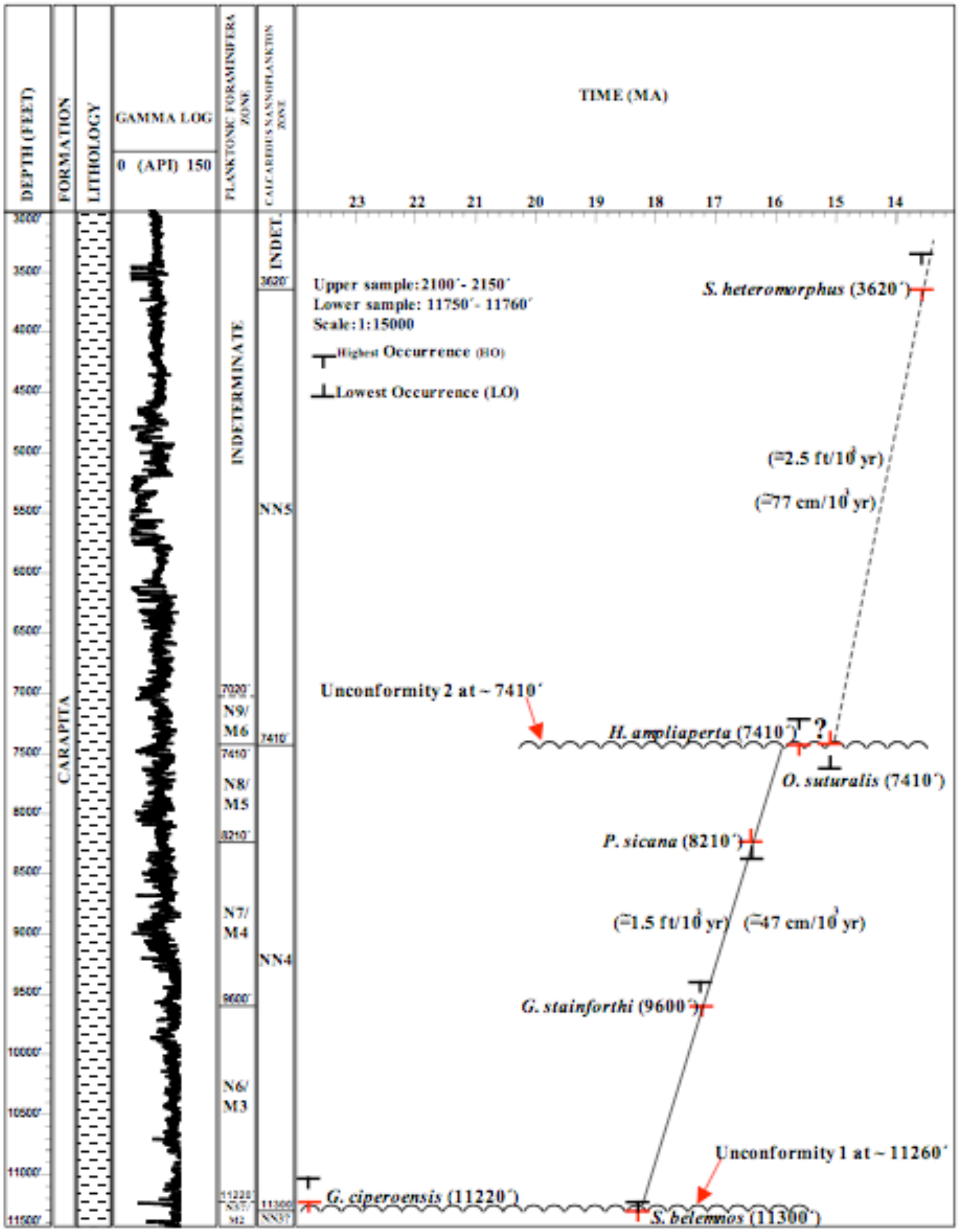


Figure 27. Stratigraphic interpretation of the lower to middle Miocene section from Well WB. Orocual Oilfield. Symbols as in figures 7 and 26.

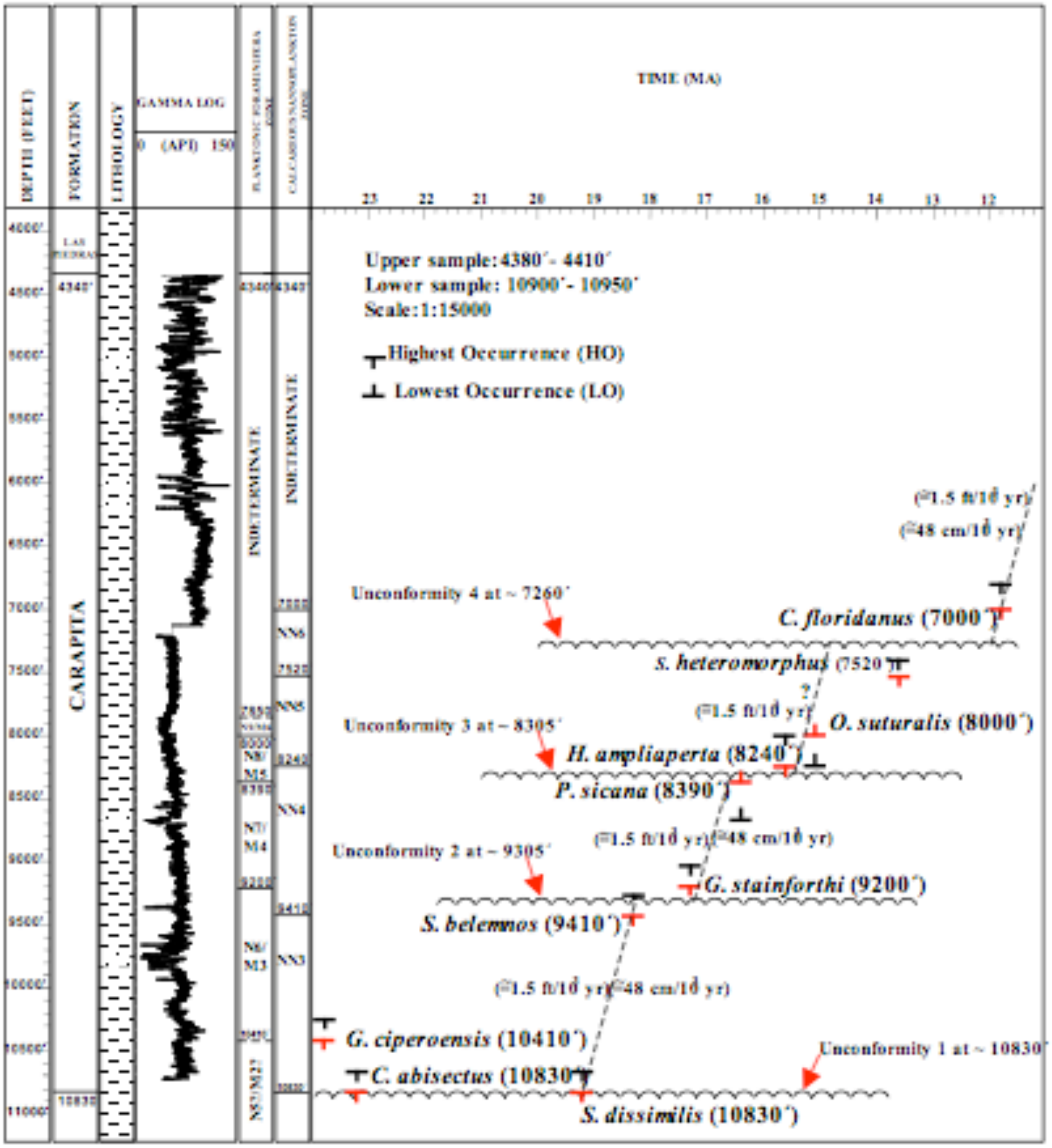


Figure 28. Stratigraphic interpretation of the lower to middle Miocene section from Well WC. Tropical Oilfield. Symbols as in figures 7 and 26.

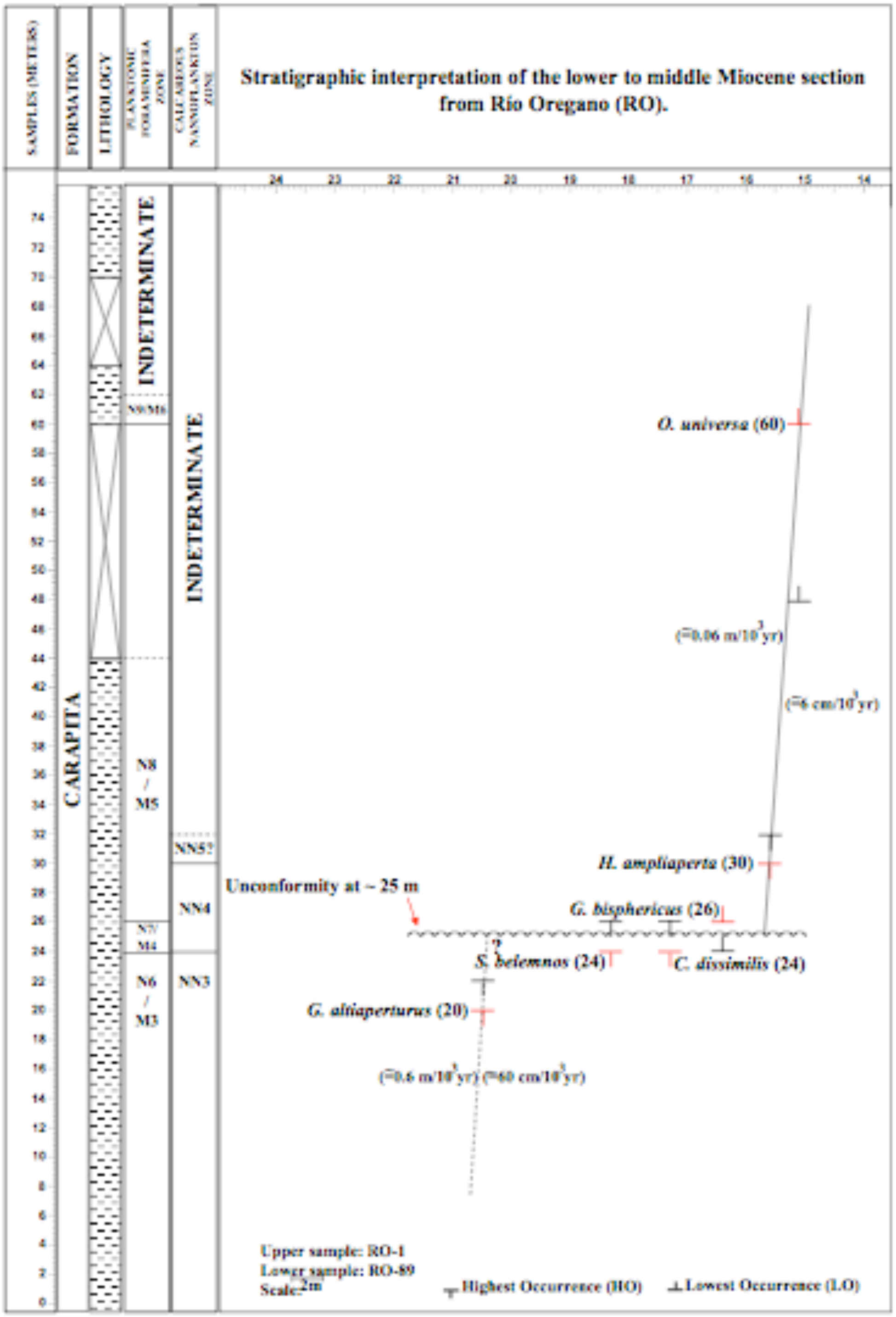


Figure 29. Stratigraphic interpretation of the lower to middle Miocene section, Rio Oregano Outcrop. Symbols as in figures 7 and 26.

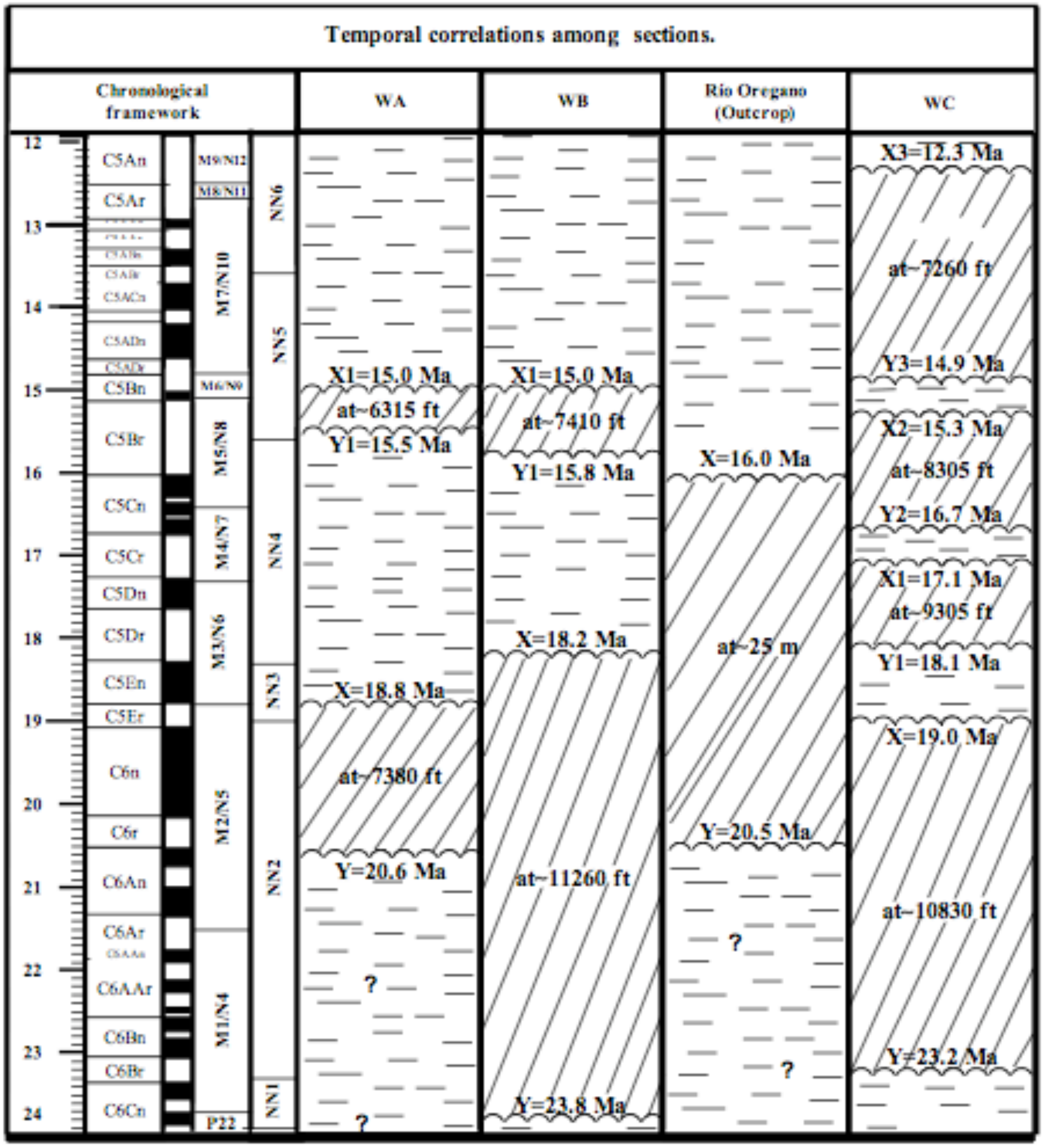


Figure 30. Temporal correlations among sections.

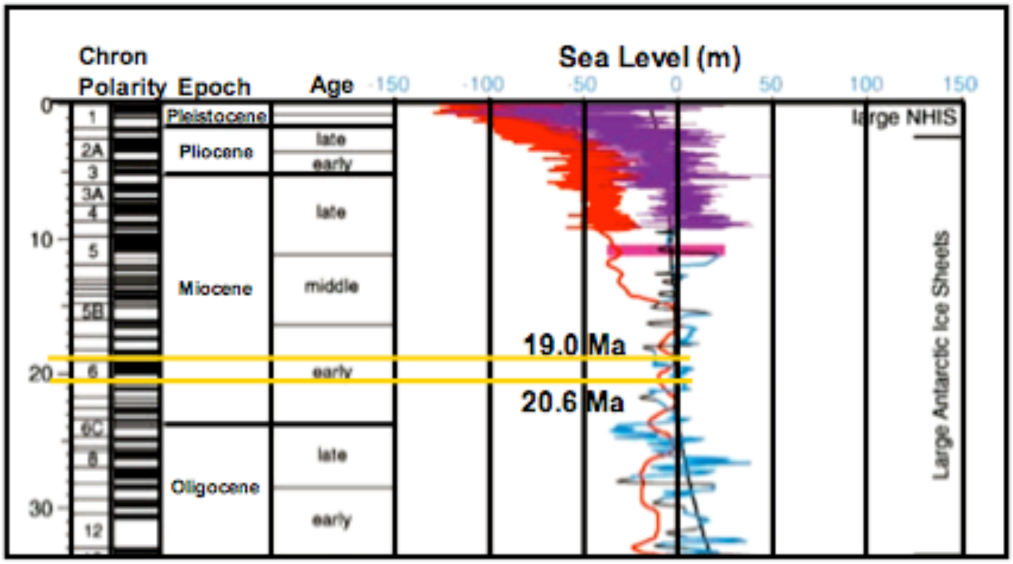


Figure 31. Global Sea Level (Modified from Miller et al. 2005).

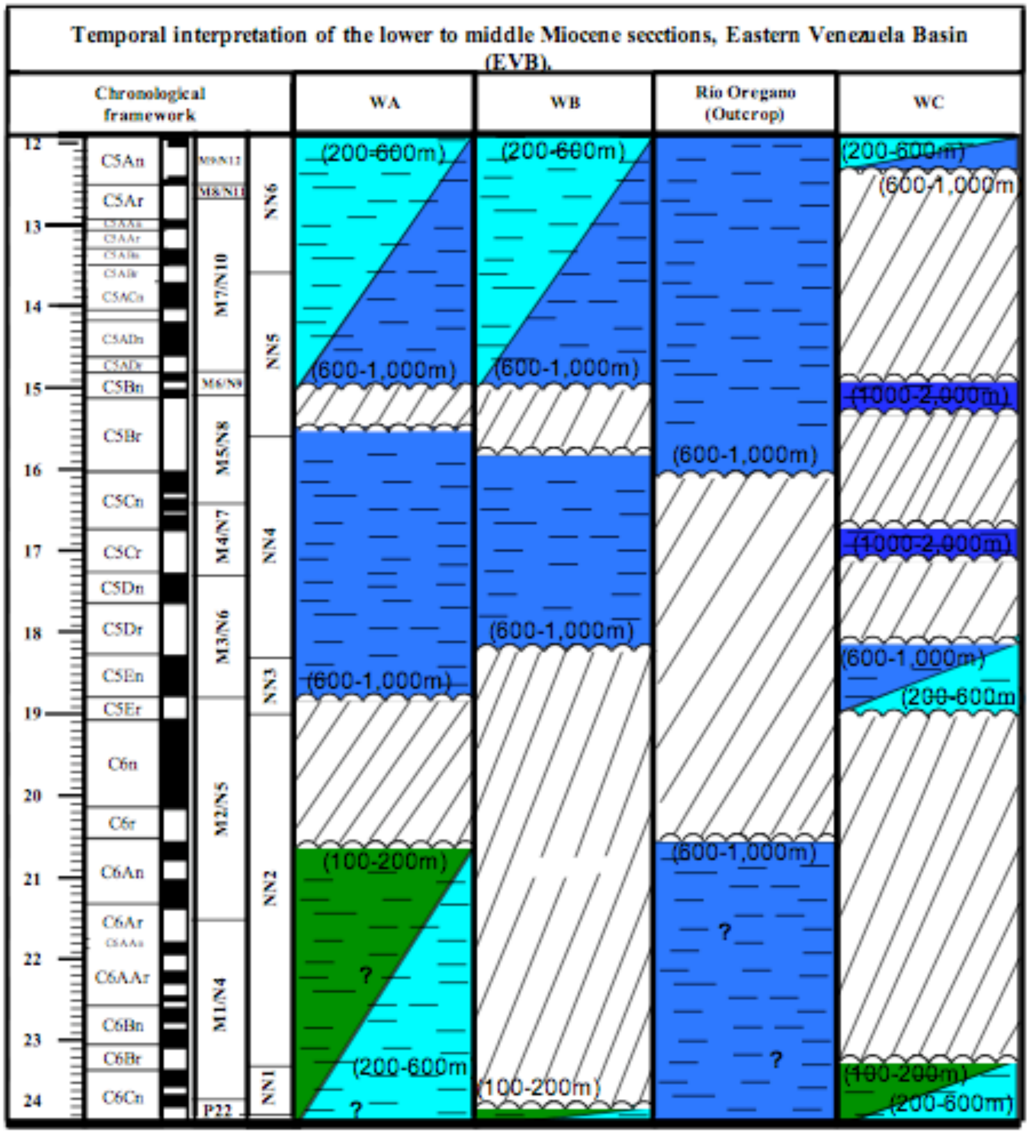


Figure 32. Temporal interpretation of the lower to middle Miocene sections, Eastern Venezuela Basin (EVB).

No	**Well-1 (ft)**	**Well-2 (ft)**	**Well-3 (ft)**	**Carapita Outcrop (m)**	**Cipero Outcrop**
1	2300-2310	2100-2150	4380-4410	RO-1	RDL-529
2	2450-2480	2350-2400	4500-4530	RO-3	RDL-538
3	2550-2600	2700-2750	4640-4670	RO-5	RDL-423
4	2700-2750	3000-3050	4800-4830	RO-7	RDL-544
5	2850-2900	3350-3400	5020-5050	RO-9	RDL-800
6	3110-3140	3620-3650	5230-5260	RO-11	RDL-804
7	3520-3550	3800-3820	5410-5440	RO-13	RDL-563
8	3700-3709	4000-4020	5600-5650	RO-15	RDL-540
9	3850-3880	4200-4220	5830-5860	RO-17	RDL-553
10	4090-4120	4600-4620	6020-6030	RO-19	RDL-558
11	4231-4260	4880-4890	6210-6220	RO-21	RDL-802
12	4390-4410	5110-5140	6450-6459	RO-23	RDL-808
13	4570-4590	5880-5910	6650-6700	RO-25	RDL-2859
14	4650-4680	6090-6130	6800-6850	RO-27	RDL-2873
15	5180-5210	6200-6210	7000-7020	RO-29	RDL-2865
16	5240-5260	6600-6630	7250-7280	RO-31	RDL-2931
17	5510-5540	6810-6840	7400-7450	RO-33	RDL-2932
18	5660-5690	7020-7050	7520-7530	RO-35	RDL-2933
19	5900-5920	7210-7240	7640-7670	RO-37	RDL-2934
20	6240-6270	7410-7440	7880-7900	RO-39	
21	6390-6410	7620-7650	8000-8050	RO-41	
22	6500-6530	7810-7840	8240-8270	RO-43	
23	6656-6670	8210-8230	8390-8420	RO-45	
24	6770-6775	8380-8400	8690-8720	RO-47	
25	7040-7050	8610-8640	8690-8720	RO-49	
26	7220-7230	8820-8850	9050-9080	RO-51	
27	7380-7410	9000-9030	9200-9230	RO-53	
28	7530-7540	9200-9220	9410-9440	RO-55	
29	7600-7610	9400-9420	9680-9710	RO-57	
30	7700-7710	9600-9620	10040-10070	RO-59	
31	7820-7840	9800-9820	10270-10290	RO-61	
32	8150-8170	10020-10050	10410-10440	RO-63	
33	8430-8440	10210-10240	10700-10750	RO-65	
34	8550-8560	10410-10440	10830-10840	RO-67	
35	8780-8790	10620-10650	10900-10950	RO-69	
36	9000-9006	10800-10830		RO-71	
37	9200-9210	11020-11050		RO-73	
38	9340-9360	11220-11240		RO-75	
39	9500-9520	11300-11310		RO-77	
40	9660-9670	11400-11405		RO-79	
41	9735-9740	11500-11510		RO-81	
42		11600-11610		RO-83	
43		11750-11760		RO-85	
44				RO-87	
45				RO-89	

Table 1. Samples analyzed.

Planktonic Foraminiferal Datums	**Calcareous Nannofossils Datums** **(From O. Rodriguez, 2010)**	**Age (Ma)**	**WA (ft)**	**WB (ft)**	**WC (ft)**	**Carapita Outcrop (m)**
	LAD *H.carteri*	11.8			7000	
	LAD *C. floridanus*	11.8			7000	
	LAD *H. euphratis*	11.8			7000	
	LAD *S. heteromorphus*	13.6		3620	7520	
FAD *O. suturalis O. universa*		15.1	6240	7410	8000	60
	LAD *H. ampliaperta*	15.6	6390	7410	8240	30
FAD *P. sicana*		16.4	7040	8210	8390	
FAD *G. bisphericus*		16.4	7040	8210		26
LAD *G. stainforthi C. dissimilis*		17.3	7380	9600	9200	24
	LAD *S. belemnos*	18.3	7380	11300	9410	24
	LAD *S. dissimilis*	19.2			10830	
LAD *G. altiaperturus*		20.5	7380			20
	LAD *H. recta*	23.2	9200			
	LAD *C. abisectus*	23.2			10830	
LAD *G. ciperoensis*		23.8	8780	11220	10410	

Table 2. Datums (FAD and LAD) of selected planktonic foraminifera and calcareous nannofossil used in this study. Ages are from Berggren and others (1995).

Rounded trochospiral (M1)	**Plano-convex, trochospiral (M2)**	**Milioline (M3)**	**Biconvex, trochospiral (M4)**
Gyroidinoides altiformis	*Cibicidoides alazanensis*	*Quinqueloculina lamarckiana*	*Neoeponides campester*
Gyroidinoides soldanii	*Cibicidoides compressus*	*Quinqueloculina seminula*	*Neoeponides parantillarum*
	Cibicidoides crebbsi	*Sigmoilopsis schlumbergeri*	*Neoeponides umbonatus*
	Cibicidoides incrassatus		
	Planulina marialana		
	Planulina renzi		
	Planulina subtenuissima		

Table 3. Epifaunal morphotype classification on benthic foraminifera from the Cipero (Trinidad) and the Carapita (EVB) formations (Morphotype designation from Corliss and Fois, 1991).

Rounded planispiral (M5)	**Tapered/cylindrical (M6)**	**Flattened tapered (M7)**	**Spherical (M8)**
Melonis pompiliodes	*Buliminella elegans*	*Bolivina cuadriae*	*Globocassidulina subglobosa*
Nonion costiferum	*Bulimina inflata*	*Bolivina imporcata*	*Pullenia bulloides*
Nonion incisum	*Bulimina jarvisi*	*Bolivina isidroensis*	
	Bulimina macilenta	*Bolivina pisciformis*	
	Bulimina pupoides	*Bolivina simplex*	
	Marginulina subbullata		
	Uvigerina carapitana		
	Uvigerina mexicana		
	Uvigerina rugosa		

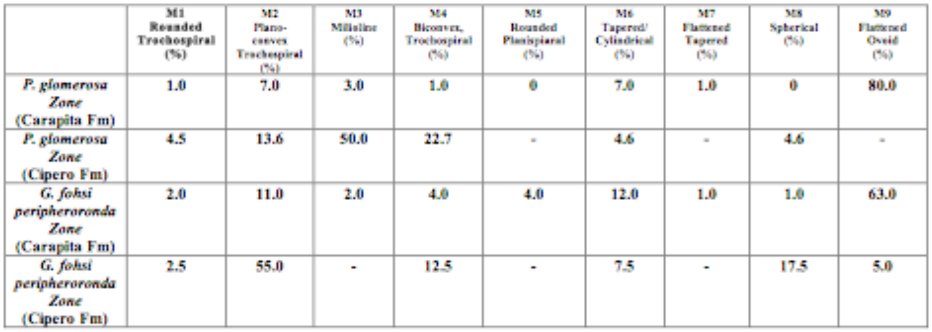
Table 4. Infaunal morphotype classification on benthic foraminifera from the Cipero (Trinidad) and the Carapita (EVB) formations (Morphotype designation from Corliss and Fois, 1991).

Flattened ovoid (M9)
Cassidulina carapitana
Cassidulina tricamerata
Lenticulina adelinensis
Lenticulina americana
Lenticulina calcar
Lenticulina clericii
Lenticulina formosa
Lenticulina hedbergi
Lenticulina nutalli
Lenticulina occidentalis
Lenticulina senni
Lenticulina subaculeata
Lenticulina subpapillosa
Lenticulina suteri
Lenticulina wallacei
Siphonina pozonensis

Table 4. Continued

MORPHOTYPE		WATER DEPTHS		
		100-500 m	500-1000 m	1000-2000 m
EPIFAUNAL	M1 Rounded trochospiral	0-5 %	0-10 %	Rare or absent
	M2 Plano-convex	0-10 %	0-10 %	Rare or absent
	M3 Milioline	0-5 %	5-10 %	Rare or absent
	M4 Biconvex trochospiral	20 %	40 %	Rare or absent
INFAUNAL	M5 Rounded planispiral	0-5 %	0-5 %	Rare or absent
	M6 Tapered/cylindrical	40-50 %	40-50 %	0-30%
	M7 Flattened tapered	0-90 %	0-90 %	> 30%
	M8 Spherical	> 10 %	> 20 %	> 10%
	M 9Flattened ovoid	0-40 %	0-10 %	Rare or absent

Table 5. . Water depths vs % of morphotypes (Taken from Corliss and Fois, 1991)



	M1 Rounded Trochospiral (%)	M2 Plano-convex Trochospiral (%)	M3 Milioline (%)	M4 Biconvex, Trochospiral (%)	M5 Rounded Planispiaral (%)	M6 Tapered/ Cylindrical (%)	M7 Flattened Tapered (%)	M8 Spherical (%)	M9 Flattened Ovoid (%)
P. glomerosa Zone (Carapita Fm)	1.0	7.0	3.0	1.0	0	7.0	1.0	0	80.0
P. glomerosa Zone (Cipero Fm)	4.5	13.6	50.0	22.7	-	4.6	-	4.6	-
G. fohsi peripheroronda Zone (Carapita Fm)	2.0	11.0	2.0	4.0	4.0	12.0	1.0	1.0	63.0
G. fohsi peripheroronda Zone (Cipero Fm)	2.5	55.0	-	12.5	-	7.5	-	17.5	5.0

Table 6. Morphotype data based on faunal data of the Cipero (Trinidad) and the Carapita (Rio Oregano section) formations.