MARINE PALEOENVIRONMENTS OF MIOCENE–PLIOCENE FORMATIONS OF NORTH-CENTRAL FALCÓN STATE, VENEZUELA

CARLY J. SMITH1, LAUREL S. COLLINS1,4, CARLOS JARAMILLO2 and LUIZ I. QUIROZ3

ABSTRACT

Late middle Miocene to middle or late Pliocene benthic foraminifera from north-central Falcón State, northwestern Venezuela, were used in determinations of the marine paleoenvironments of the Urumaco, Codore, Caujarao, La Vela and San Gregorio formations. From 121 collected samples, 31 that included a total of 126 taxa were applied to paleoenvironmental interpretations, and 20 well-preserved foraminiferal samples were analyzed with cluster analysis. In the Urumaco region, the upper middle to upper Miocene Urumaco Formation, which alternates among continental, marginal marine, and marine facies, was predominately inner shelf, and the taxa and very low diversities suggest highly variable, low-salinity conditions. Foraminifera of the upper Miocene–middle Pliocene Chignaja Member of the overlying Codore Formation indicate a deepening from inner to deeper-middle shelf. The middle to upper Pliocene San Gregorio Formation varies from estuarine in the lower Vergel Member to inner shelf in the overlying Cocuiza Member. In the Coro–La Vela region to the northeast, paleobathymetries are deeper, fluctuating from middle- to outer-neritic depths in the upper Miocene Taratara Member of the Caujarao Formation, and middle-neritic depths in the conformably overlying upper Miocene, basal part of the La Vela Formation. The relatively stable water depths of the Caujarao and lower La Vela formations support deposition on a stable marine platform. Overall, the shallower facies in the west and deeper facies in the east agree with the interpretation of an eastward progression of inversion of the Falcón basin from Miocene to Pliocene time. The middle Miocene–Pliocene shelf sequences of Falcón are compared to other formations of Venezuela and Colombia with similar paleoenvironments.

INTRODUCTION

The Cenozoic tectonic history of the northern margin of South America is complex. Interpretations of uplift, subsidence, and eustatic change have relied largely upon regional models, and assessments of petroleum potential are frequently based on seismic stratigraphy. Local paleoenvironmental studies based on the paleoecology of foraminifera provide additional information that can be used to supplement and test tectonic models and the results of seismic and eustatic studies. Neogene marine and terrestrial paleoenvironments of the Miocene–Pliocene Falcón basin of northwestern Venezuela (Fig. 1) were controlled by regional tectonics, basin subsidence, and sea-level fluctuations. This paleoenvironmental study includes the marine portions of the middle Miocene–Pliocene Urumaco, Codore, Caujarao, La Vela, and San Gregorio formations, with determinations based on their benthic foraminifera. The interpretations rely on modern distributions and preferred habitats of extant species in the tropical to subtropical region of the western Atlantic. Estimates of local paleobathymetries and marine conditions are used to construct a general depositional history that is compared to a previous model of Neogene tectonic uplift, and the formations are compared to similar sequences elsewhere in the Caribbean.

GEOLOGIC SETTING

The Cenozoic geologic history of northern Venezuela has been strongly influenced by the eastward advance of the Caribbean Plate relative to South America. The onset of the Caribbean-South American plate interactions began in the Paleogene along the northwestern corner of South America and progressed eastward, reaching the Falcón basin by the late Eocene (Lugo and Mann, 1995). The Sisquisique ophiolite and the metamorphic Lara Nappes were emplaced prior to the basin opening as a result of transpression (compressive-transcurrent regime), and formed the southwestern boundary of the incipient Falcón basin (Kellogg, 1984; Pindell and Barrett, 1990). Although studies agree that the Falcón basin (Fig. 1) formed during the late Eocene–early Oligocene, the mode of basin formation has been debated (e.g., Muessig, 1984; Boesi and Goddard, 1991; Macellari, 1995; Mann, 1999; Gorney and others, 2007). The stratigraphic sequence of the Falcón basin reflects its rapid subsidence during the Oligocene–early Miocene (Wheeler, 1963). Intense folding and inversion of the basin began in the middle Miocene, as evidenced by an unconformity at the base of the Socorro Formation (which underlies the Urumaco Formation) that is followed by strongly prograding strata characterized by clinoforms (Gorney and others, 2007). This unconformity marks a shift in the tectonic setting from basin subsidence to basin inversion, which is thought to have progressed during the Miocene and Pliocene from west to east (Boesi and Goddard, 1991), continuing until at least the Pleistocene (Audemard, 2001). Sedimentation during this time was characterized by marine to continental facies in the central region, and thicker deposits in the northeastern Falcón basin (Macellari, 1995).

Inversion of the basin has been attributed to either the oblique deformation between the Caribbean and South American plates (Audemard, 2001), or deformation related to the shallow underthrusting of the Caribbean slab (Kellogg, 1984; Gorney and others, 2007) that dips roughly S-SE, and parallel to the present ENE-trending Falcón Anticlinorium (van der Hilst and Mann, 1994). Sedimentation was restricted to the north flank of the anticlinorium, where sedimentary sequences generally became less marine.
and more continental. The tectonic uplift of the Falcón basin, along with a global sea level drop throughout the late Miocene and Pliocene (Haq and others, 1987) resulted in shallow-water deposition in central and northern Falcón.

**STUDY AREA**

Samples were collected from seven sections along the Urumaco River and several small, ephemeral creeks in Falcón State, Venezuela (Figs. 1, 2; Table 1; Appendix 1). The Miocene–Pliocene ages of the formations are somewhat poorly constrained due to their predominantly shallow paleobathymetries and consequent scarcity of well-preserved, adult planktic foraminifera. Fortunately, the formations in the Falcón basin have also yielded spectacular mammalian fossils that have been assigned chronostratigraphic ages based on paleomagnetostratigraphy (Aguilera and Rodrigues de Aguilera, 2003; Linares, 2004a; Aguilera and others, 2006), as described below.

In the Urumaco region, samples were collected from the marine-influenced sediments of the Urumaco and Codore formations that crop out along the Rio Urumaco (Fig. 3, Table 2). The upper-middle to upper Miocene Urumaco Formation has an approximate thickness of 2000 m in the Rio Urumaco section, and is informally divided into lower, middle and upper units; this study further distinguishes the basal part of the lower unit. The upper Miocene–middle Pliocene Codore Formation is subdivided into three members: the lower El Jebe Member, the middle Chiguaje Member, and the upper Algodones Member. Only the ~100-m-thick Chiguaje Member includes marine facies. Foraminifera in samples from the lower Vergel Member and middle Cocuiza Member of the middle to upper Pliocene San Gregorio Formation, sampled about 2 km east of the Urumaco River, are poorly preserved and only mentioned herein.

In the Coro–La Vela region, the Caujarao and La Vela formations crop out to the northeast of the Urumaco region (Fig. 1, Table 2). The upper Miocene Caujarao Formation is ~300-m thick in the Carrizal Cemetery section (Fig. 4),
and is subdivided into the lower Muaco Member, the middle Mataruca Member, and the upper Taratara Member. Due to the very poor preservation and low abundance of foraminifera in the lower and middle members, only the Taratara Member was analyzed. Samples from the ~800-m-thick La Vela Formation were obtained from the base of the formation, just above its contact with the Caujarao Formation.

**METHODS**

**Specimen Preparation**

We collected 75 sedimentary rock samples (LC 429–504) in April, 2007. Most samples were barren or yielded only poorly preserved foraminifera, presumably because the humid but arid climate promotes intensive weathering but little erosion. Seventeen samples with common to abundant foraminifera that were fairly well preserved (i.e., minimal recrystallization, calcite overgrowths, or replacement) were selected for identification (Table 1) and quantitative study. In addition, 10 samples with poor preservation (i.e., reworked or flattened tests, or casts), including those from the San Gregorio Formation, were incorporated into the paleoenvironmental interpretation. Another four samples chosen for study were among the 46 samples previously collected by the Panama Paleontology Project (Collins and Coates, 2000).

Approximately 50 g of each selected sample were immersed in deionized water for two to three weeks to disaggregate the clays. Indurated samples with high clay content that remained consolidated after three weeks were subsequently soaked in paint thinner overnight. After decanting the solvent, the residue was mixed with deionized water and one tablespoon of washing soda (Na₂CO₃) for buffering foraminiferal calcite, and heated below boiling for 2–3 hours. The sediments were then washed through a 63-μm sieve, retaining all adult and nearly all juvenile foraminifera, and air-dried.

The washed residues were reduced with a sediment microsplitter to yield ≥300 randomly selected benthic foraminifera, a number adequate to represent proportional abundances of the taxa (Murray, 1991). Specimens were picked from the residue, sorted by species on microfaunal slides, and identified using comparative collections. Most of the species were compared with type specimens in the Cushman Collection of Foraminifera at the National Museum of Natural History, Smithsonian Institution, Washington, D.C. Common, well-preserved specimens of paleoenvironmental indicator taxa were photographed with a Leica DFC420 digital camera (5-megapixel resolution) mounted on a Leica MZ16 stereomicroscope.

**Paleoenvironmental Analysis**

Benthic foraminifera are the most commonly used paleoenvironmental indicators for marine settings because they are widespread, abundant, occur in virtually all marine-influenced sediments, and have unique habitat requirements. A bathymetric zonation of modern foraminifera was first proposed by Norton (1930). Soon thereafter, Natland (1933) used modern depth distributions of foraminifera to interpret regional strata, and this approach was developed further by Bandy (1953) and Natland (1957). Much subsequent research has confirmed the correlation of foraminiferal species distributions with water depth or, more specifically, with depth-related environmental parameters such as water mass and substratum (Murray, 1991). In paleoenvironmental interpretations based on fossils, the fossil taxa are assumed to have had the same limiting factors that their modern counterparts have. Paleoenvironmental and paleobathymetric reconstructions were based on the relative abundances of common benthic foraminiferal species and their preferred habitats, primarily in the Caribbean Sea and Gulf of Mexico. For extinct taxa, estimates were based on recurrent associations with extant species that have been documented in these regions.

Distributions of both live and total (live + dead) specimens were used in our paleoenvironmental interpretations. Whereas Murray (2000) stated that ecological studies should be based solely on living individuals, others have argued that total populations are superior as comparative data for interpreting fossil occurrences because they integrate small seasonal and spatial variations that more reliably reflect the general marine conditions that prevailed over longer periods of time (Scott and Medioli, 1980; Tobin and others, 2005). Although studies comparing live versus total assemblages from marshes (e.g., Vance and others, 2006) to bathyal depths (Heinz and others, 2008) note

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Formation</th>
<th>Member/Part</th>
<th>Samples</th>
<th>Geologic Age</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Urumaco</td>
<td>Basal</td>
<td>492, 493</td>
<td>Middle Miocene</td>
</tr>
<tr>
<td>2</td>
<td>Urumaco</td>
<td>Lower</td>
<td>437, 439, 440, 444</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td>3</td>
<td>Urumaco</td>
<td>Middle</td>
<td>483, 487, 2974, 2972</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td>4</td>
<td>Urumaco</td>
<td>Upper</td>
<td>489, 2977</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td>5</td>
<td>Codore</td>
<td>Chiquie Member</td>
<td>465, 464, 462, 461</td>
<td>Lower-middle Pliocene</td>
</tr>
<tr>
<td></td>
<td>San Gregorio</td>
<td>Cocuiza Member</td>
<td>470–472, 501, 502, 504</td>
<td>Middle-upper Pliocene</td>
</tr>
<tr>
<td>6</td>
<td>Caujarao</td>
<td>L. Taratara Member</td>
<td>446</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M. Taratara Member</td>
<td>450, 453</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U. Taratara Member</td>
<td>454, 456</td>
<td>Upper Miocene</td>
</tr>
<tr>
<td>7</td>
<td>La Vela</td>
<td>Basal</td>
<td>458, 460, 2532 **</td>
<td>Upper Miocene</td>
</tr>
</tbody>
</table>

* Tentatively assigned to the Urumaco Formation. Obtained from cobble float within the lower section.

**Collected by Panama Paleontology Project in 1997.**

**Collected by Panama Paleontology Project in 1995.**
FIGURE 3. Stratigraphic column of Urumaco and Codore formations sampled along the Urumaco River. Circled numbers correspond to stratigraphic sections of Figure 1. Adapted from Quiroz and Jaramillo (2010).
Table 2. Locality, general lithology, and age determinations of sampled stratigraphic units.

| Stratigraphic Unit (Sections of Figure 1) | Locality Sampled | General Lithology (Figures 3, 4) | Age Determinations
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Urumaco Formation, basal unit (Section 1)</td>
<td>lower 200 m of section along Urumaco River, S of town of Urumaco</td>
<td>rhythmically bedded, dark grey claystone and siltstone, with bivalve and gastropod fragments, and organic-rich layers; caps of sandy limestone</td>
<td>Upper middle Miocene: Laventian land mammals. Contact with underlying Socorro Formation at Chrons C5A–C5A (13.4–12 Ma).</td>
</tr>
<tr>
<td>Urumaco Formation, lower unit above basal unit (Section 2)</td>
<td>Urumaco River, E of town of Urumaco</td>
<td>blue-grey, fine sandy siltstone with small, dispersed fragments of bivalves and gastropods, interbedded with claystones, coal seams and lithified shell hash</td>
<td>Upper Miocene (tentative): based on ages of underlying and overlying units</td>
</tr>
<tr>
<td>Urumaco Formation, middle unit (Section 3)</td>
<td>Urumaco River, N of town of Urumaco</td>
<td>dark grey, silty claystones with intermittent coal beds and sandstones; differentiated from lower unit by relatively thick limestones rich in mollusks and interbedded with sandstones</td>
<td>Upper Miocene: Chasican land mammals, ~Chron C4A (~8.6–7.6 Ma)</td>
</tr>
<tr>
<td>Urumaco Formation, upper unit (Section 4)</td>
<td>Urumaco River, W rim, N of town of Urumaco</td>
<td>dark grey, silty claystones with thin, intercalated, commonly bioturbated siltstones and sandstones; lacks diagnostic marine limestones of middle unit</td>
<td>Upper Miocene: Neogloboquadrina humerosa planktic foraminiferal zone (1 specimen) correlated with zones M13b/14; Huayquerian land mammals (~8.6–6.8 Ma).</td>
</tr>
<tr>
<td>Chiguaje Member, Codore Formation (Section 5)</td>
<td>Urumaco River, N of town of Urumaco and W–NW of town of El Chiguaje</td>
<td>blue-grey, fine sandy siltstones with scattered mollusks, sandstones, calcareous shales, intercalated coquinas</td>
<td>Upper Miocene–middle Pliocene: Montetherman land mammals in underlying Jebe Member; Urumaco Fm–Codore Fm contact at Chrons C3A–C3 (~6 Ma); planktic foraminifera Globorotalia marginatae and G. cf. G. miocenica are late Miocene-middle Pliocene.</td>
</tr>
<tr>
<td>Taratara Member, Caujarao Formation (Section 6)</td>
<td>Muaco Creek, NE of town of La Vela</td>
<td>weathered, dark grey to brown claystones and silty claystones with scattered mollusks</td>
<td>Upper Miocene: Neogloboquadrina dutertrei planktic foraminiferal zone = Globorotalia humerosa zone = zone N17 or M13b/14 (8.3–5.6 Ma).</td>
</tr>
<tr>
<td>La Vela Formation, base (Section 7), above Taratara Member</td>
<td>Muaco Creek, NE of town of La Vela</td>
<td>marine-terrestrial transitional lithology of cross-bedded sandstones, sandy siltstones and blue-grey shales with occasional marine limestone horizons</td>
<td>basal unit uppermost Miocene and most of section in Pliocene Globorotalia marginatae zone = zones N18–19 and M14–PL2</td>
</tr>
</tbody>
</table>

1 Bolli and others, 1985
2 Diaz de Gamero, 1997
3 Diaz de Gamero and Linares, 1989
4 Egleé and others, 2001
5 Gradstein and others, 2004
6 Linares, 2004a
7 Linares, 2004b
8 Rey, 1990
9 Wozniak and Wozniak, 1987

Taphonomic changes, they have generally found them similar. This study takes into account the distributions of both live and total populations, emphasizing the deepest-dwelling species and their shallowest occurrences to minimize any possible effects of down-shelf or down-slope transport.

R-mode cluster analysis determined the level of similarity between samples by comparing the proportions of species in their assemblages. Three sets of analyses were performed on species in each sample: 1) 118 species with >1 occurrence, 2) 66 species with ≥1% abundance, and 3) 45 species with ≥2% abundance in any sample. Eliminating single occurrences and species with low frequencies reduces “noise” in grouping samples from similar paleoenvironments. The proportions of species were first transformed with the relationship 2 arcsin √P, where P = percentage of a species in a sample (Collins, 1993), and then standardized by the calculation of z values (Wilkinson, 1989). This standardization gives equal weight to all species in calculations of similarity. Each cluster analysis produced a dendrogram, which is a hierarchical representation of the successive groupings. The analyses were run with six linkage methods (Wilkinson, 1989): Ward’s, average, single, complete, median, and centroid.

The diversity of each assemblage was measured with Fisher’s alpha (α), an index that assumes the proportions of species within samples to be distributed in a log series (Murray, 1991). Calculations for Fisher’s α use the number of taxa and the number of specimens simultaneously, and the iterative solutions were obtained from Hayek and Buzas (1997).

RESULTS

The most common or diagnostic indicator species (Figs. 5 and 6) and their modern environmental distributions are discussed below for each geologic section in the
Urumaco and Coro–La Vela regions (Tables 3–6). For each species we cite only a few studies from the region supporting the bathymetric distribution, although most of the taxa are well known and many more (paleo)ecological references could be given. One hundred twenty-six species were identified (Appendices 2 and 3) and their relative abundances in the 20 most well-preserved samples were calculated (App. 2). Below, in the paleoenvironmental determinations for the formations, the citations within brackets that follow taxonomic names refer to analogous modern or fossil distributions rather than authorship.

**Samples from the basal unit of the Urumaco Formation (Table 3) indicate a nearshore, inner-shelf facies ≤40 m deep. Common inner-shelf species in the lowest sample include Ammonia parkinsoniana gr. (25%), Elphidium poeyanum [Havach and Collins, 1997] and Haynesina depressula [Scott and others, 2001]; and the lesser presence of deeper-inner to middle shelf Hanzawaia concentrica [Murray, 1991; Havach and Collins, 1997], Buccella hannai [Phleger and Parker, 1951], Nonionella basiloba [Phleger and Parker 1951 (as N. cf. opima); Drooger and Kaasschieter, 1958] and Bolivina vaughani [Sellier de Civrieux, 1976] suggest a deep inner-shelf habitat, 20–40 m. The dominance of A. parkinsoniana gr. and E. poeyanum along with Textularia panamensis and Textulariella miocenica? further suggest low salinity (Renz, 1948), as agglutinated taxa are more common in brackish waters (Murray, 1991). An exceptionally low diversity in the overlying sample LC493 (α = 2), along with the strong dominance of A. parkinsoniana gr. (~78%) indicate a decrease in water depth and suggest the extreme environment of a mangrove swamp or marsh (Scott and others, 2001; Murray, 1991).

Above the basal section, the rest of the lower unit of the Urumaco Formation (Table 3) is also characterized by many of the same inner-shelf samples, with the exception of sample LC444, float from a muddy, possibly low-oxygen, shallow-middle-shelf setting. Sample LC437 has a low diversity and is dominated by A. parkinsoniana gr. (~45%) and H. depressula (~33%), which suggest the intertidal to shallow subtidal zone (Scott and others, 2001) and perhaps low-salinity conditions. Samples LC439 and LC440 have the typical inner-shelf indicator species of the basal unit, but at relatively higher diversities (α = 17 and 13, respectively), and the deeper-water taxa such as H. concentrica [Murray, 1991], Cibicides pachyderma, and Bolivina paula [Havach and Collins, 1997] in LC449, as well as Cassidulina laevigata [Renz, 1948; Parker, 1954] in LC440, suggest a deep-inner-shelf setting. Sample LC439 is a mixed siliciclastic-carbonate sample, indicated by the relatively high diversity of miliolids, the presence of carbonate indicator species such as Rotorbinella umbonata, Asterigerina carinata, Discorbina patelliformis and Amphistegina gibbosa [Havach and Collins, 1997], along with a higher frequency of Pararotalia sarmientoi, associated with nearshore siliciclastic facies (Manning, 1985).

Samples of the middle unit of the Urumaco Formation (Table 3) range from nearshore to outer shelf. The two lowermost samples are dominated by A. parkinsoniana gr. and Buliminella elegantissima, indicating a muddy nearshore environment. In overlying sample LC487, the increase in α diversity from 2 to 7 suggests an increase in water depth and a normal marine setting (Murray, 1991), and the sample above it (PPP2974) is clearly shallow-middle shelf. Typical inner-shelf species are joined by high frequencies of middle-shelf B. hannai and Epistomellina vitrea [Poag, 1981] and deeper Gyroidina umbonata [Phleger and Parker, 1951]. Overlying sample PPP2972 reflects another depth increase to outer shelf with a more open-ocean influence as indicated.
by the abundance of *C. laevigata* [Phleger and Parker, 1951; Drooger and Kaasschieter, 1958; Havach and Collins, 1997]. Deepest outer-shelf taxa include *Bolivina subaenariensis* var. *mexicana* [Phleger and Parker, 1951], *Bolivina imporcata* [Kohl, 1985], *Gyroidina regularis* [Pflum and Frerichs, 1976], and *Plectofrondicularia* spp. [van Morkhoven and others, 1986].

The upper part of the Urumaco Formation (Table 3) indicates a return to inner-neritic depths. The extremely low-diversity samples include typical inner-shelf species *A.*
FIGURE 6. Common Neogene paleoenvironmental indicator taxa of the Falcón basin, with sample numbers: 1, 2 Cancris sagra, LC446, Caujarao Formation; 3, 4 Haynesina depressula, LC465, Codore Formation; 5, 6 Pararotalia sarmientoi, LC439, Urumaco Formation; 7, 8 Ammonia parkinsoniana gr., Urumaco Formation; 9, 10 Hanzawaia concentrica, LC446, Caujarao Formation; 11, 12 Hanzawaia isidroensa, LC453, Caujarao Formation; 13–15 Nonionella obducta, LC493, Urumaco Formation; 20–22 Nonionella obducta, LC493, Urumaco Formation. All scale bars = 0.5 mm.
parkinsoniana gr. and E. poeyanum. The stratigraphically highest sample reflects a muddy substratum, as indicated by the dominance of B. elegantissima.

Pliocene samples from the marine Chiguaje Member of the Codore Formation (Table 4) indicate increasing water depth over time, from inner neritic to deep middle neritic. Near the base, inner-shelf samples with extremely low diversity ($\alpha = 2$) are dominated by A. parkinsoniana gr., E. poeyanum and B. elegantissima, suggesting highly variable, possibly low-salinity conditions (Renz, 1948). The same nearshore taxa in overlying sample LC462 are found with deeper-water Bolivina imporciata [Kohl, 1985] and Uvigerina peregrina gr. [Phleger and Parker, 1951], but very worn tests indicate some reworking. The highest sample combines inner-shelf and deeper species such as Bolivina imporciata [Renz, 1948; Ingle, 1980] and Oridorsalis unbonatus [Phleger and Parker, 1951; van Morkhoven and others, 1986] for an open-ocean, deep-middle-shelf assignment, $\sim$65–100 m.

Benthic foraminifera of the two lower members of the San Gregorio Formation (Table 1) are from the shallowest facies of the study. A sample from the lower Vergel Member contained only a few specimens of Ammodiscus and small, thin-shelled Ammonia tepida gr., suggesting a low-salinity, estuarine setting. Six samples from the overlying Cocuiza Member had higher diversity and included mostly Ammonia parkinsoniana gr. with Elphidium poeyanum, E. spp., Quinquiloculina spp. and a few textulariids, indicating a nearshore habitat with carbonate influence.

**Paleoenvironments of the Coro–La Vela Region**

Paleobathymetries of the upper Miocene Taratara Member (Table 5) fluctuated between shallow-middle and outer neritic, and taxa are distinctly different from those of the middle to upper Miocene Urumaco Formation. Middle-shelf samples from the lower section with Cancris sagra and Epistominella vitrea [Havach and Collins, 1997] are overlain

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**Table 3.** Paleoenvironments and their diagnostic foraminifera, Urumaco Formation.

<table>
<thead>
<tr>
<th>Section</th>
<th>Sample No.</th>
<th>Paleobathymetry</th>
<th>Indicator species</th>
<th>$\alpha^*$</th>
<th>Additional descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>2977</td>
<td>Inner neritic</td>
<td>Ammonia parkinsoniana gr., Elphidium poeyanum, Buliminella elegantissima</td>
<td>2</td>
<td>Muddy</td>
</tr>
<tr>
<td>Upper</td>
<td>489</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., Haynesia depressula, E. poeyanum, E. cariacoeensis?</td>
<td>1</td>
<td>Low-salinity zone?</td>
</tr>
<tr>
<td>Middle</td>
<td>2972</td>
<td>Outer neritic</td>
<td>Hanzawaia isdroensis, Cassidulina laevigata, Bolivina subaenariensis var. mexicana, Bolivina imporciata, Uvigerina peregrina gr., Buliminella curta gr.</td>
<td>24</td>
<td>Open-ocean influence</td>
</tr>
<tr>
<td>Middle</td>
<td>2974</td>
<td>Shallow middle neritic</td>
<td>Buccella hannai, Nonionella obducta, E. poeyanum, Gyroidina umbonata; B. elegantissima</td>
<td>12</td>
<td>Muddy</td>
</tr>
<tr>
<td>Middle</td>
<td>487</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., H. depressula, B. elegantissima</td>
<td>7</td>
<td>Muddy</td>
</tr>
<tr>
<td>Middle</td>
<td>483</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., H. hannai, B. elegantissima</td>
<td>2</td>
<td>Muddy</td>
</tr>
<tr>
<td>Lower?</td>
<td>444</td>
<td>Shallow middle neritic</td>
<td>N. obducta, Cancris sagra, Textularia panamensis, B. elegantissima</td>
<td>3</td>
<td>Muddy; low O$_2$</td>
</tr>
<tr>
<td>Lower</td>
<td>440</td>
<td>Deep inner neritic</td>
<td>A. parkinsoniana gr., H. depressula, E. poeyanum, Pararotalia sarmiento, Cibicides pachyderma, Cassidulina laevigata, B. elegantissima</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>439</td>
<td>Deep inner neritic</td>
<td>A. parkinsoniana gr., H. depressula, E. poeyanum, P. sarmiento, Rotorhinella umbonata, Quinquiloculina spp., B. elegantissima</td>
<td>17</td>
<td>Muddy; mixed siliciclastic-carbonate sample</td>
</tr>
<tr>
<td>Lower</td>
<td>437</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., H. depressula, Nonionella atlantica, T. panamensis, B. elegantissima</td>
<td>2</td>
<td>Low-salinity zone?</td>
</tr>
<tr>
<td>Lowermost</td>
<td>493</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., N. obducta, T. panamensis</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Lowermost</td>
<td>492</td>
<td>Deep inner neritic</td>
<td>A. parkinsoniana gr., H. depressula, E. poeyanum, Hanzawaia concentrica, T. panamensis, Textularia miocenic?, B. elegantissima</td>
<td>4</td>
<td>Muddy; possibly subject to salinity fluctuations</td>
</tr>
</tbody>
</table>

---

**Table 4.** Paleoenvironments and their diagnostic foraminifera, Chiguaje Member, Codore Formation.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Paleobathymetry</th>
<th>Indicator species</th>
<th>$\alpha^*$</th>
<th>Additional descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>461</td>
<td>Deep middle neritic</td>
<td>Ammonia parkinsoniana gr., Pararotalia sarmiento, Elphidium poeyanum, Hanzawaia concentrica, Oridorsalis unbonatus, Cassidulina laevigata, Bolivina subaenariensis var. mexicana, B. floridiana, Buliminella elegantissima</td>
<td>14</td>
<td>Open ocean</td>
</tr>
<tr>
<td>462</td>
<td>Middle neritic</td>
<td>A. parkinsoniana gr., E. poeyanum, Haynesia depressula, C. laevigata, B. subaenariensis var. mexicana, Bolivina imporciata, B. elegantissima</td>
<td>12</td>
<td>Poor preservation; some taxa such as B. imporciata reworked</td>
</tr>
<tr>
<td>464</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., E. poeyanum, B. elegantissima</td>
<td>2</td>
<td>Muddy</td>
</tr>
<tr>
<td>465</td>
<td>Inner neritic</td>
<td>A. parkinsoniana gr., E. poeyanum, Discorbis cf. D. bulbosa, B. elegantissima</td>
<td>2</td>
<td>Muddy</td>
</tr>
</tbody>
</table>

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$^*$ Fisher’s alpha
by outer-shelf sediments of the middle section as indicated by *Bolivina subaenariensis* var. *mexicana* [Phleger and Parker, 1951; Drooger and Kaasschieter, 1958; Pflum and Frerichs, 1976], and higher frequencies of *Cassidulina subglobosa* [Parker, 1954; Drooger and Kaasschieter, 1958] and *C. norcrossi australis* [Havach and Collins, 1997]. In the upper section, high frequencies of *Epistominella vitrea*, *B. subaenariensis* var. *mexicana*, and *Ammonia parkinsoniana* var. *a* show a return to middle-neritic depths, and the small, thin-walled specimens suggest low-oxygen conditions.

Samples of the late Miocene basal part of the La Vela Formation (Table 6) reflect middle neritic paleodepths. The lowermost sample with abundant *Ammonia parkinsoniana* gr., *Haynesina depressula*, *Pararotalia sarmientoi*, and *Elphidium poeyanum*, and lesser frequencies of *Buliminella curta* gr. and *Epistominella vitrea* suggest shallow-middle-neritic depths, and relatively small, thin-shelled specimens indicate lower levels of dissolved oxygen. Overlying sample LC460 with a higher diversity (α = 22) and typical middle-shelf taxa such as *Bolivina vaughani* (e.g., Sellier de Civrieux, 1976) reflect a more normal middle-shelf setting. The highest sample contains both reworked and well-preserved specimens from a middle-shelf, carbonate-influenced environment, as shown by abundant *Amphistegina gibbosa*, *Quinqueloculina compta*, and *Q. lamarckiana* (e.g., Havach and Collins, 1997).

### Table 5. Paleoenvironments and their diagnostic foraminifera, Taratara Member, Caujarao Formation.

<table>
<thead>
<tr>
<th>Section</th>
<th>Sample No.</th>
<th>Paleobathymetry</th>
<th>Indicator species</th>
<th>α'</th>
<th>Additional descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>456</td>
<td>Shallow middle neritic</td>
<td><em>Ammonia parkinsoniana</em> gr., <em>Pararotalia sarmientoi</em>, <em>Haynesina depressula</em>,</td>
<td>16</td>
<td>Low O₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Gyroidina cf. G. turgidus</em>, <em>Bolivina subaenariensis</em> var. <em>mexicana</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>454</td>
<td>Middle neritic</td>
<td><em>Epistominella vitrea</em>, <em>B. subaenariensis</em> var. <em>mexicana</em>, <em>B. curta</em> gr., <em>Uvigerina peregrina</em> gr.,</td>
<td>5*</td>
<td>Poor preservation: flattened tests, Open ocean influence</td>
</tr>
<tr>
<td>Middle</td>
<td>453</td>
<td>Outer neritic</td>
<td><em>E. vitrea</em>, <em>Rotalia garveyensis</em>, <em>Hanzawaia isidroensis</em>, <em>Cassidulina subglobosa</em>, <em>C. minuta</em>, <em>B. subaenariensis</em> var. <em>mexicana</em>, <em>U. peregrina</em> gr.</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>450</td>
<td>Shallow outer neritic</td>
<td><em>R. garveyensis</em>, <em>Hanzawaia concentrica</em>, <em>B. subaenariensis</em> var. <em>mexicana</em>, <em>B. imporcuta</em>, <em>Fursenkoina mexicana</em>, <em>Bulimina tessellata</em>, <em>Gutalina spp.</em></td>
<td>10*</td>
<td>Poor preservation: mostly casts</td>
</tr>
<tr>
<td>Lower</td>
<td>446</td>
<td>Middle neritic</td>
<td><em>Nonionella pizarrensis</em>, <em>Cameris sagra</em>, <em>H. concentrica</em>, <em>Textularia panamensis</em>, <em>B. curta</em> gr., <em>U. peregrina</em> gr.</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

*Fisher’s alpha*  
*Poor preservation may have lowered value*

### Cluster Analysis

Ward’s method, which calculates the distance between two clusters as the sum of squares between the two clusters added up over all the variables (i.e., species in this study), produced the best dendrogram of the six algorithms tested. The other five algorithms either showed results similar to Ward’s method or produced stringy dendrograms of little use. The localities clustered primarily by paleobathymetry and secondarily by formation and geographic region (Fig. 7). Cluster 1 comprises the inner-shelf samples plus one shallow-middle-shelf sample (PPP2974). The deeper facies of Cluster 2 join a deep-inner-shelf group with a middle-shelf group, which are differentiated from a cluster of middle- and outer-shelf samples. The Chiguaje Member of the Codore Formation is of late Miocene–middle Pliocene age and younger than the underlying Urumaco Formation of middle to late Miocene age, but their samples cluster most closely by paleoenvironment rather than age.

### Discussion

The depositional setting for the thick sequence of Urumaco Formation sediments has been described as a prograding delta (Saavedra and Velez, 1987). The extremely low diversities (α < 5) of most inner-shelf assemblages in the Urumaco and Codore formations suggest marginal-marine environments subject to great variability, including
The extremely variable lithology of the Urumaco and Codore formations of the Urumaco trough (Fig. 3) attests to a dynamic interplay of transgression and regression. Our interpretation of a brackish inner shelf for the depositional setting of the Urumaco Formation agrees with previous studies which explained it as a complex of barrier islands, marshes, swamps, lagoons, and lower alluvial plain (Díaz de Gamero and Linares, 1989). The lithology shows variability between more terrestrially influenced beds such as coal seams, and marine influenced facies including cross-bedded sandstones, marine limestones and shales. These continental and marine facies are repeated throughout the entire section, illustrating fluctuations in the local sea level. The repetition of these presumably high-frequency sequences may have been controlled by high subsidence rates in the basin, as they were in the Maracaibo basin in far-western Venezuela (Milano and Steel, 2002).

Foraminiferal assemblages were present in some of the poorer preserved samples (e.g., PPP2523, La Vela Formation). The extremely variable lithology of the Urumaco and Codore formations of the Urumaco trough (Fig. 3) attests to a dynamic interplay of transgression and regression. Our interpretation of a brackish inner shelf for the depositional setting of the Urumaco Formation agrees with previous studies which explained it as a complex of barrier islands, marshes, swamps, lagoons, and lower alluvial plain (Díaz de Gamero and Linares, 1989). The lithology shows variability between more terrestrially influenced beds such as coal seams, and marine influenced facies including cross-bedded sandstones, marine limestones and shales. These continental and marine facies are repeated throughout the entire section, illustrating fluctuations in the local sea level. The repetition of these presumably high-frequency sequences may have been controlled by high subsidence rates in the basin, as they were in the Maracaibo basin in far-western Venezuela (Milano and Steel, 2002).

The Chiguaje Member of the Codore Formation, which overlies the Urumaco Formation, is sandwiched between two other members of terrestrial (fluvial) origin (Rey, 1990). Thus, the Chiguaje Member was deposited during a transgression that was followed by a regression. As exposed along the banks of the Urumaco River, the benthic foraminiferal samples trace a transgression from shallow-estuarine to middle-neritic depths. The ages of these units are not constrained enough to relate the deepening to specific tectonic events or global eustatic cycles.

Above the Codore Formation and exposed to the northeast, the lower Vergel Member of the San Gregorio Formation yielded sparse foraminifera, including the agglutinant Ammodiscus and small, thin-shelled Ammonia tepida, which suggest very low-salinity estuarine conditions. This agrees with a previous interpretation of the Vergel Member as an alluvial plain based on sedimentology (Rey, 1990). The overlying Cocuiza Member contains a more diverse fauna with abundant miliolids that indicates nearshore marine conditions, and it, in turn, is succeeded by the alluvial Rio Seco Member (Rey, 1990).
Paleoenvironments of the upper Miocene Chiguaje Member of the Caujarao Formation and basal La Vela Formation were mostly deeper than those of the Urumaco, Codore and San Gregorio formations to the west. Samples of the two members that underlie the Taratara Member of the Caujarao Formation were barren, but a previous study that yielded mollusks and foraminifera indicates marine deposition (Wozniak and Wozniak, 1987). The overlying Taratara Member consists of middle- to outer-shelf deposits, and its conformity with the overlying mid-shelf basal unit of the La Vela Formation indicates continued marine deposition. Thus, the paleobathymetries of the three formations suggest a stable depositional setting, which agrees with the interpretation by Petzall (1959) of a marine platform.

During the middle Miocene—Pliocene, inversion and shoaling of the Falcón basin progressed from west to east (Boesi and Goddard, 1991). Our foraminiferal study supports this interpretation, as it indicates shallower facies in the Urumaco region and the deeper facies in the Coro–La Vela region to the northeast (Fig. 1).

There are numerous siliciclastic shelf sequences of Neogene age in the Caribbean region (Maurrasse, 1990) that are comparable in thickness and fossil content to the Chiguaje Member (Codore Formation), San Gregorio Formation, Taratara Member (Caujarao Formation) and La Vela Formation. However, Venezuela seems unique in the Caribbean region in having thick, marginal-marine, Neogene sequences such as the 2000-m-thick Urumaco Formation from which most of our samples were collected. The Maracaibo basin of northwestern Venezuela contains a 10,000-m-thick, deltaic-to-estuarine succession that includes intervals of subaerial exposure (Milano and Steel, 2002; Guzmán and Fisher, 2006). The Oligocene–lower Miocene Castillo Formation of northwestern Venezuela is also a complex of marginal-marine sediments that contains vertebrate and invertebrate fossils, but is only 1500 m thick (Wheeler, 1963; Sánchez-Villagra and others, 2000). To the east, in Colombia, several sections have less extensive, nearshore, marginal-marine deposits, including the middle part of a 169-m-thick Pliocene section of the Tubara Formation (Molinares and others, 2007), part of the 150-m-thick El Floral Formation (Duque-Caro, 1968), and part of the 350-m-thick El Cerrito Formation (Petters and Sarmento, 1956; Duque-Caro, 1968). Inner-shelf sedimentary sequences of Central America typically contain more diverse foraminiferal faunas than does the Urumaco Formation (Collins, 2006). For example, the middle–upper Miocene Gatun Formation of Panama varies from deep-inner shelf to shallow-middle shelf, and contains relatively high-diversity assemblages (Collins and others, 1996b). Likewise, the Pliocene Cayo Agua Formation (Bocas del Toro basin, northwestern Panama) and Rio Banano Formation (Limón basin, northeastern Costa Rica) vary from deep-inner to middle shelf (Collins, 1993; Collins and others, 1995). However, in the San Carlos basin of north-central Costa Rica, the Miocene Venado Formation includes shallow, nearshore foraminifera (e.g., *Ammonia* and *Elphidium*) that lived in an Atlantic-Pacific strait (Sen Gupta and others, 1986).

### CONCLUSIONS

1. Benthic foraminifera reveal that late-middle Miocene to middle-late Pliocene marine paleoenvironments of the Falcón basin varied from estuarine to outer shelf (<200 m). Its upper Miocene siliciclastic sediments had less carbonate influence than paleobathymetrically similar deposits in the middle-late Pliocene and in most modern Caribbean settings.

2. The taxa and very low diversity of inner-shelf foraminiferal assemblages from the Urumaco and Codore formations indicate low, fluctuating salinities, suggestive of a lagoon or bay.

3. Marine facies of the Urumaco trough were generally shallower than those of the Coro–La Vela region, which agrees with an eastward progression of basin inversion during the Miocene—Pliocene.

4. The thick, Neogene marine facies of the Urumaco Formation are comparable to other marginal-marine sequences of northern Venezuela and Colombia. The significant geographic and stratigraphic extent of these South American sequences reflects deposition along a continental coastal plain, in contrast to the less extensive marginal marine sequences found throughout most of the Caribbean basin.

### ACKNOWLEDGMENTS

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Duque-Caro, H., 1968, Observaciones generales a la biostratigrafía y geología regional en los Departamentos de Bolívar y Córdoba: Boletín de Geología, Universidad Industrial de Santander, no. 24, p. 11–37.


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APPENDIX 1

Detailed maps of sample localities in northwestern Venezuela that were identified in this study.

Anomia parkinsoniana gr. (d’Orbigny) = Rosalina parkinsoniana d’Orbigny, 1839
Anphistegina gibbosa d’Orbigny, 1839
Asterigerina carinata d’Orbigny, 1839
Astronomon stelligerum (d’Orbigny) = Nonionina stelligerum d’Orbigny, 1839
Bolivina cochei Cushman and Adams, 1935
Bolivina eckisi (Natland) = Saguunda eckisi Natland, 1950 Bolivina floridana Cushman, 1918
Bolivina imporata Cushman and Renz = Bolivina floridana Cushman var. imporata Cushman and Renz, 1944
Bolivina inflata Heron-Allen and Earland, 1913
Bolivina multistella? Cushman = Bolivina aenariensis (Costa) Brady var. multistella Cushman, 1918
Bolivina paula Cushman and Cahill, 1932
Bolivina cf. B. paula Cushman and Cahill, 1932
Bolivina subaenariensis var. mexicana Cushman, 1922a
Bolivina subexcavata Cushman and Wickenden, 1929
Bolivina tortuosa Brady = Bulimina (Bolivina) tortuosa Brady, 1881
Bolivina vaughani Natland, 1938
Buccella hannai (Phleger and Parker) = Eponides hannai Phleger and Parker, 1951
Bulimina tessellata Cushman and Todd = Bulimina marginata d’Orbigny var. tessellata Cushman and Todd, 1945
Bulimina curta Cushman, 1925 gr.
Bulimina elegans (d’Orbigny) = Bulimina elegans d’Orbigny, 1839
Cancris sagra (d’Orbigny) = Rotalina (Rotalina) sagra d’Orbigny, 1839
Cassidulina aff. C. carapitana Hedberg, 1937
Cassidulina laevigata d’Orbigny, 1826
Cassidulina mimata Cushman, 1933
Cassidulina norcrossi Cushman, 1933 var. australis Phleger and Parker, 1951
Cassidulina subglobosa Brady, 1881
Cibicides pachyderma (Rzehak) = Truncatulina pachyderma Rzehak, 1886
Cymbaloporetta taboagensis (Brönnimann) = Cymbalopora taboagensis Brönnimann, 1949
Discorbina patelliformis Brady, 1884
Discorbis bulbosa Parker, 1954
Discorbis cf. D. bulbosa Parker, 1954
Dyocibicides biserialis Cushman and Valentine, 1930
Elphidium cariaucense? Bermúdez and Seigle, 1963
Elphidium mexicanum Kornfeld = Elphidium incertum (Williamson) var. mexicanum Kornfeld, 1931
Elphidium poeyanum (d’Orbigny) = Polystomella poeyanum d’Orbigny, 1839
Epistominella pacifica (Hofker) = Epistominella pacifica Hofker, 1951
Epistominella vitrea Parker, 1953
Fissurina diaphana Seguenza, 1880
Fissurina laevigata Reuss, 1850
Fissurina sicilensis Loeblich and Tappan, 1954 (new name for F. marginata Seguenza, 1852)
Farsenokina pontoni (Cushman) = Virgulina pontoni Cushman, 1932
Farsenokina mexicana? (Cushman) = Virgulina mexicana Cushman, 1922
Gyroidina cf. G. turgida (Phleger and Parker) = Eponides turgida Phleger and Parker, 1951
Gyroidina regularis (Phleger and Parker) = Eponides regularis Phleger and Parker, 1951
Gyroidina umbonata Silvestri = Rotalia soldanii d’Orbigny var. umbonata Silvestri, 1898
Hanzawaia concentrica (Cushman) = Truncatulina concentrica Cushman, 1918
Hanzawaia isidroensis (Cushman and Renz) = Cibicides isidroensis Cushman and Renz, 1941
Hauerina fragilissima (Brady) = Spiroloculina fragilissima Brady, 1884
Haynesina depressula (Walker and Jacob) = Nautilus depressulum Walker and Jacob, 1798
Lagena amphora? Reuss, 1863
Lagena ciperensis? Cushman and Stainforth, 1945
Lenticulina calcar (Linnaeus) = Nautilus calcar Linnaeus, 1758
Milionella california Rhumbler, 1936
Neoconorbina parkeri (Natland) = Discorbis parkeri Natland, 1950
Nodobaculariella cassis (d’Orbigny) = Vertebralinia cassis d’Orbigny, 1839
Nonionella atlantica Cushman, 1947
Nonionella basiloba Cushman and McCulloch, 1940
Nonionella cf. N. miocenea Cushman, 1926
Nonionella obducta (Cushman and Stevenson) = Nonion obductus Cushman and Stevenson, 1948
Nonionella pizarrensis (Berry) = Nonion pizarrensis Berry, 1928
Oridorsalis umbonatus (Reuss) = Rotalina umbonatus Reuss, 1851
Pararotalia sarmientoi (Redmond) = Rotalia sarmientoi Redmond, 1953
Patellina corrugata Williamson, 1858
Plectonodocella calcariformis Cushman and Stewart, 1926
Plectonodocella floridana Cushman, 1930
Quinqueloculina comptata Cushman, 1947
Quinqueloculina horrida? Cushman, 1947
Quinqueloculina lamarkiana d’Orbigny, 1839
Reussella spinulosa (Reuss) = Verneuillina spinulosa Reuss, 1850
Rosalina concinna (Brady) = Discorbina concinna Brady, 1884
Rosalina subarcaucana (Cushman) = Discorbis subarcaucana Cushman, 1922
Rotalina garveyensis Natland, 1938
Rotalinella umbonata Sellier de Civrieux, 1977
Sagrina pulchella (d’Orbigny) = Bulimina pulchella d’Orbigny, 1839
Spiroloculina antillarum d’Orbigny, 1839
### APPENDIX 3

Relative abundance (%) of middle Miocene to middle Pliocene benthic foraminifera from northwestern Venezuela. All taxa with at least one occurrence in any sample are included.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>LC 492</th>
<th>LC 493</th>
<th>LC 437</th>
<th>LC 439</th>
<th>LC 444</th>
<th>LC 440</th>
<th>PPP 2972</th>
<th>PPP 2974</th>
<th>PPP 2977</th>
<th>LC 483</th>
<th>LC 487</th>
<th>LC 489</th>
<th>LC 446</th>
<th>LC 453</th>
<th>LC 456</th>
<th>LC 461</th>
<th>LC 464</th>
<th>LC 465</th>
<th>LC 458</th>
<th>LC 460</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia parkinsoniana gr.</td>
<td>24.7</td>
<td>77.7</td>
<td>45.2</td>
<td>18.7</td>
<td>29.8</td>
<td>6.1</td>
<td>2.7</td>
<td>4.5</td>
<td>58.8</td>
<td>16.6</td>
<td>78.8</td>
<td>9.7</td>
<td>14.4</td>
<td>54.1</td>
<td>55.1</td>
<td>28.0</td>
<td>7.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphistegina gibbosa</td>
<td>0.3</td>
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<tr>
<td>Anomalanooides sp.</td>
<td>0.3</td>
<td>0.3</td>
<td>15.3</td>
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<td>Asterigerina carinata</td>
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<tr>
<td>Astrononion stelligerum</td>
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<tr>
<td>Bolivina cf. B. paula</td>
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</tr>
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<td>Fissurina laevigata</td>
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<td>Fissurina siciliensis</td>
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Fissurina sp. A  0.5
Fissurina sp. B  0.3
Fursenkoina pontoni  0.5  0.3  0.3
Fursenkoina mexicana?  0.8
Fursenkoina sp.  0.3
Genus 1 sp.  3.1
Genus 2 sp.  0.3
Genus 3 sp.  0.3
Glabratella spp.  1.0
Gyroidea cf. G. turgida  0.2
Gyroidea regularis  1.7  0.3  0.3  0.3  0.7  0.6
Gyroidea sp. A  0.2
Gyroidea sp. B  0.5
Gyroidea umbonatus  0.3  0.9  5.9  0.2  1.3  1.0  0.7  0.3
Hanzawaia concentrica  4.2  1.3  2.8  1.4  0.2  2.6
Hanzawaia isidroensis  1.9  13.7  0.9
Hanzawaia cf. H. isidroensis  2.3
Hauerina fragilissima  0.4
Haynesina depressa  8.4  32.5  8.4  7.4  0.5  0.4  1.0  0.3  0.7  0.6
Lagena amphora?  0.5
Lagena eiperensis?  0.7
Lagena striata  0.2  1.5
Lagena sp.  0.5
Lenticulina calcar  3.1  0.2  0.5  0.7
Lenticulina spp.  1.0
Melonis sp.  0.7
Miliolinella californica  0.3
Neoconorbina parkeriae  0.3  1.0
Nodobaculariella cassisi  0.3  0.6
Nonion sp.  0.5
Nonionella atlantica  4.1  1.6  0.3  0.5  0.4  1.3  0.1
Nonionella basiloba  0.7  0.5  0.4  0.2  0.5  0.3
Nonionella cf. N. miocenea  1.5
Nonionella obducta  2.9  15.2  54.2  2.1  7.1
Nonionella pizarrensis  0.6  16.5
Oridorsalis umbo natus  1.6
Pararotalia sarmentoi  6.3  9.9  9.9  0.2  8.7  3.6  6.5  3.4
Patellina corrugata  0.8
Plectofrondicularia californica  0.7
Plectofrondicularia floridanana  0.3  0.2  0.3
Quinqueloculina compta  0.5  0.7  1.0
Quinqueloculina horrida?  0.8
Quinqueloculina sp. A  1.1
Quinqueloculina sp. B  0.5
Quinqueloculina sp. C  0.5
Quinqueloculina sp. D  0.4
Quinqueloculina sp. E  0.6
Quinqueloculina spp.  0.2  0.5  1.6  0.7  0.2  0.3  1.0
Reussella spinulosa  0.3  0.3  0.2  0.2  0.8  0.2  0.6
Rosalia concina  0.8  0.2  0.6
Rosalia cf. R. concina  0.8
Rosalia subarauca na  1.8  1.4  3.4
Rosalia spp.  3.9  11.9  1.6  5.9  3.8  8.8
Rotula garveyensis  0.8  11.3
Rotorbinella umbonata  3.9  0.2
Sagrina pulchella  0.7
Spiroloculina antillarum  0.3
Spiroloculina depressa  0.3  0.6
Textulariella miocenea?  1.5
Textularia panamensis  33.3  2.2  8.0  5.0  2.9  8.0  7.5  1.0  0.4  27.6  24.3  0.3  0.3
Textularia schencki  0.5  1.0  0.3  0.3
Triarina eximia  0.2
Triarina occidentalis  0.2  1.6  0.5  0.8  0.5  0.6
Uvigerina carapitana?  0.2  0.3  0.6  11.1  0.4  0.4  3.2  16.3  3.3  7.2  0.6  0.0  1.4  0.6
Uvigerina peregrina gr. Valvulina?  1.1
Valva linera? sp. A  0.2
Valva linera? sp. B  0.6
TOTAL (%)  98.9  99.2  100.3  95.7  96.7  97.9  96.3  95.3  99.8  100.1  99.3  99.5  96.5  82.2  94.9  94.1  99.4  100.0  96.3  95.3
TOTAL INDIVIDUALS  453  408  588  380  312  426  423  478  622  551  547  424  370  608  392  30  5  342  702  418  319

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**APPENDIX Continued.**