

FLORIDA FOSSIL INVERTEBRATES

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LARGER FORAMINIFERA

Introduction, Biology, Ecology, Taxonomic and Stratigraphic Listings

Comments on Florida Fossil Assemblages

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FLORIDA FOSSIL INVERTEBRATES

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Florida Fossil Invertebrates is a publication of the Florida Paleontological Society, Inc., and is intended as a guide for identification of the many common invertebrate fossils found within the state. Two parts per year will be completed and each part will deal with a specific taxonomic group and contain a brief discussion of that group's life history along with the pertinent geological setting. This series deals solely with published taxa; no new species descriptions are included. Previously, five parts have been published [Part 1 (June 2001) Eocene echinoids, Part 2 (January 2002) Oligocene and Miocene echinoids, Part 3 (June 2002) Pliocene and Pleistocene echinoids, Part 4 (February 2004) Pliocene and Pleistocene decapod crustaceans, and Part 5 (September 2004) Eocene, Oligocene, and Miocene fossil decapod crustaceans. Part 6 (this issue) and Part 7 (December 2004) discuss larger Foraminifera. Each issue will be image-rich and, whenever possible, specimen images will be at natural size (1x). Some of the specimens figured in this series are on display at Powell Hall, the museum's Exhibit and Education Center. **This publication is made possible through the generous financial support of James and Lori Toomey.**

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INTRODUCTION

WHAT ARE LARGER FORAMINIFERA?

Foraminifera are a group of marine protists that are closely related to the familiar freshwater protozoan, *Amoeba*. But foraminifera (or, “forams”) are housed in a small shell called a *test* that is normally made of calcium carbonate (calcite— CaCO_3), but may also be constructed of organic material or a mosaic of tiny sediment particles that are cemented together. Extending through one or more openings in the foram test are long, thread-like extensions of protoplasm called *pseudopods* that gather food and assist in many other vital functions. Foraminifera may be *planktic* (floaters) or *benthic* (bottom dwellers) in habit. There are an estimated 10,000 species of extant (living) foraminifera.

Because of their great abundance in sedimentary rocks, foraminifera are one of the most useful of all fossil organisms to the geologist and paleontologist. They first appear in strata of the Cambrian Period and are found in abundance up to the present time. Forams can be used to identify specific geological time intervals, to reconstruct past environments, to decipher ancient climate changes, and to document evolutionary

patterns. Their small size, usually less than 1-2 millimeters (mm), ensures that fossil foraminifera can be preserved in rock cores, so they have been used extensively in the search for petroleum and in other subsurface geologic investigations. The study of fossil foraminifera and other skeletal protists generally falls under the branch of paleontology called *micropaleontology*.

Larger foraminifera are a subset of the foraminifera that are characterized by their relatively large tests (usually more than 3 cubic mm in test volume) and complex internal shell morphologies (Figures 1, 2) (Hottinger 1978, 1986). Some large forams, in fact, hardly seem to qualify as "microfossils." In the Permian Period, for example, some large forams called fusulinids (genus *Parafusulina*) reached 10 centimeters (cm) in length (Dunbar, 1963). Extinct *Lepidocyclina elephantina* reached 14 cm in length (Grell, 1973), and there are reports of *Nummulites* from the Eocene reaching 16 cm in diameter (Purton & Brasier, 1999), and perhaps even larger (specimens have been found reaching 19 cm or more according to Pavlovec, 1987). Modern *Cycloclypeus* from the Pacific can reach over 12 cm (Koba, 1978). In Florida, some fragments of *Lepidocyclina* found in Eocene and Oligocene strata approach 7 cm or more in diameter (Figure 3). Considering that these creatures are single-celled protozoa, these are extraordinary sizes. Most fossil species routinely found in Florida's Tertiary strata are between about 3-5 mm, with larger forms averaging up to 1-3 cm in size. Because they are sea bottom dwellers, larger foraminifera are frequently referred to as *larger benthic foraminifera*, or LBF for short.

BIOLOGY AND ECOLOGY OF LARGER FORAMINIFERA

With few exceptions, the relatively large and complex tests of extant species of larger foraminifera are related to algal symbiosis. The highly compartmentalized test contains multiple "greenhouses" for the shelter of single-celled algae. These symbiont-algae provide photosynthetic nutriment to the foram, and probably facilitate calcification of the foram test. In return, the foram provides shelter and some biochemical nutritive assistance to the algae (Hallock, 2002; Lee and Hallock, 1987; Leutenegger, 1984; Cowen, 1983). Algal symbionts in larger foraminifera include chlorophytes (green

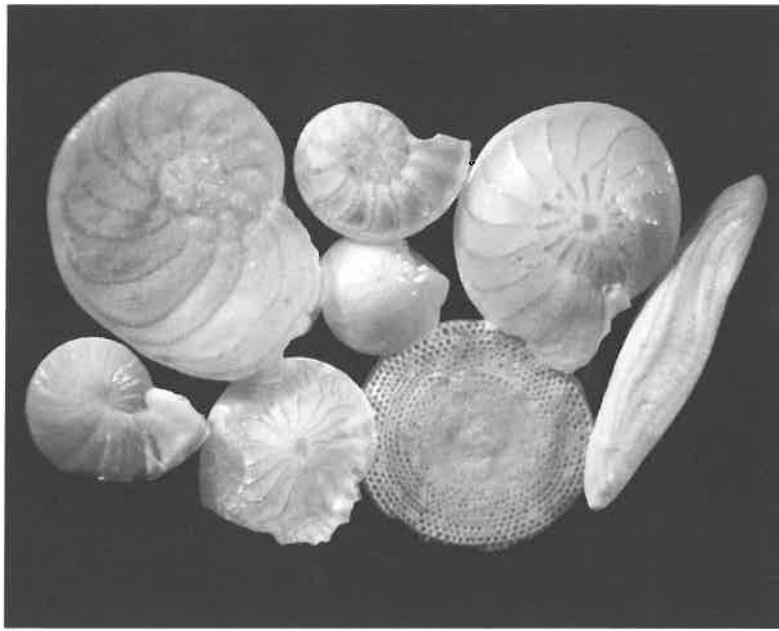


Figure 1. A variety of larger benthic foraminifera from the Philippines (magnification 14x).

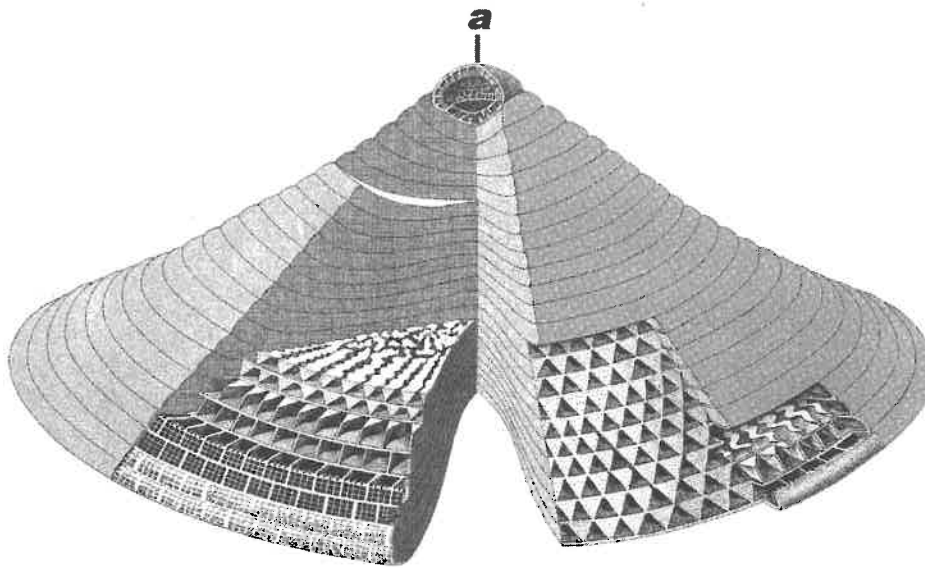


Figure 2. The Cretaceous larger foraminiferan, *Orbitolina*, with several planes cut away to show the internal complexity of the test. Shown are the megalospheric embryo (a), and a variety of chambers, partitions, and chamberlets (from Douglass, 1960).



Figure 3. A very large microspheric specimen of *Lepidocyclina* from the Eocene Ocala Limestone, collected at Marianna, Florida (magnification 1.4x).

algae), rhodophytes (red algae), diatoms (golden-brown algae), and dinoflagellates (yellow-green algae) (Leutenegger, 1984; Lee and Anderson, 1991).

Larger foraminifera have highly variable life cycles (Lee and Capriulo, 1990) that can extend up to one year or more (e.g., Ross, 1977; Lutze and Wefer, 1980). Most large forams are characterized by an alternation of generations in which a haploid *gamont* (gamete-producing) form (also called the A-generation) alternates with a diploid *agamont* (asexual) form (also called a *schizont*, or B-generation). The gamont normally has a smaller test than the agamont but a much larger *embryon* (the first two chambers of the test, also called *embryonic chambers*). The embryon of the gamont normally consists of two rather large chambers (*protoconch* and *deuteroconch*; or *proloculus* and *deuteroloculus* if they are part of a spire of chambers), and is designated *megalospheric* (Figure 4). These two, initial chambers housed the juvenile foraminifer when first released from the parent test during asexual reproduction. The larger, agamont has many nuclei (*multinucleate*) which control various vital functions of the cell. The agamont, formed by the fusion of gametes, has an extremely small initial chamber (*proloculus*), and is designated *microspheric* (Loeblich and Tappan, 1964; Lipps, 1982).

In living and fossil assemblages, megalospheric tests are always far more numerous than microspheric tests. This observation has led to the hypothesis of biologic *trimorphism*, in which it is thought that microspheric schizonts produce megalospheric schizonts, which produce megalospheric gamonts, which produce microspheric schizonts (Leutenegger, 1977). Several generations, in fact, of megalospheric schizonts are thought to precede gametogenesis in some cases. This life cycle has been observed in living *Heterostegina depressa* (Rottger et al., 1986, 1990).

Larger forams were particularly abundant during certain intervals of geologic history, particularly the Pennsylvanian, Permian, Cretaceous, and Tertiary Periods. During these times, LBF are usually associated with various types of reefs and other shallow water, tropical marine environments. It is the ecological strategy of hosting algal photosymbionts that has proven to be so advantageous for the larger foraminifera in these settings. Surprisingly, tropical, photic zone reefs normally grow in nutrient-poor

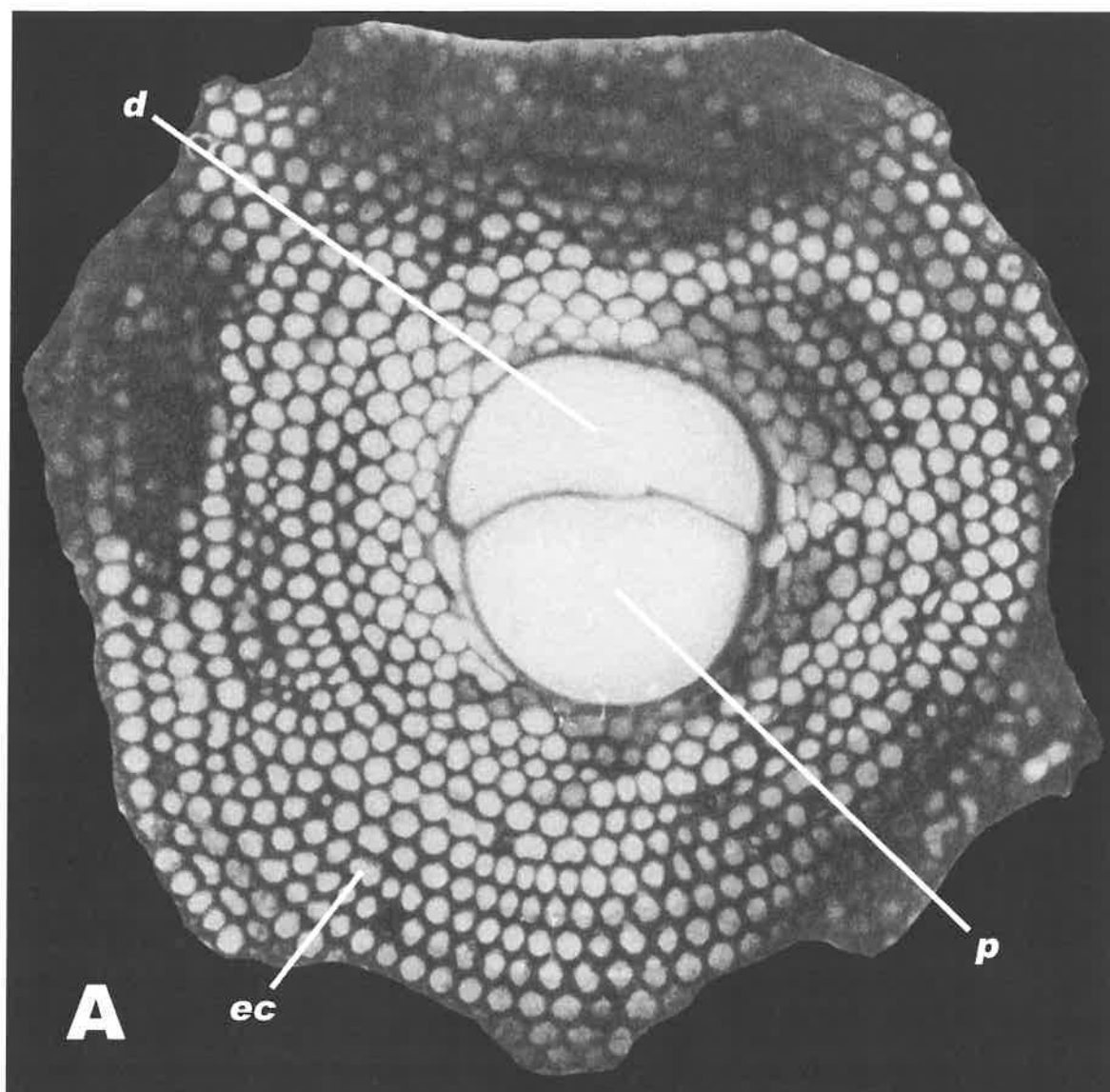
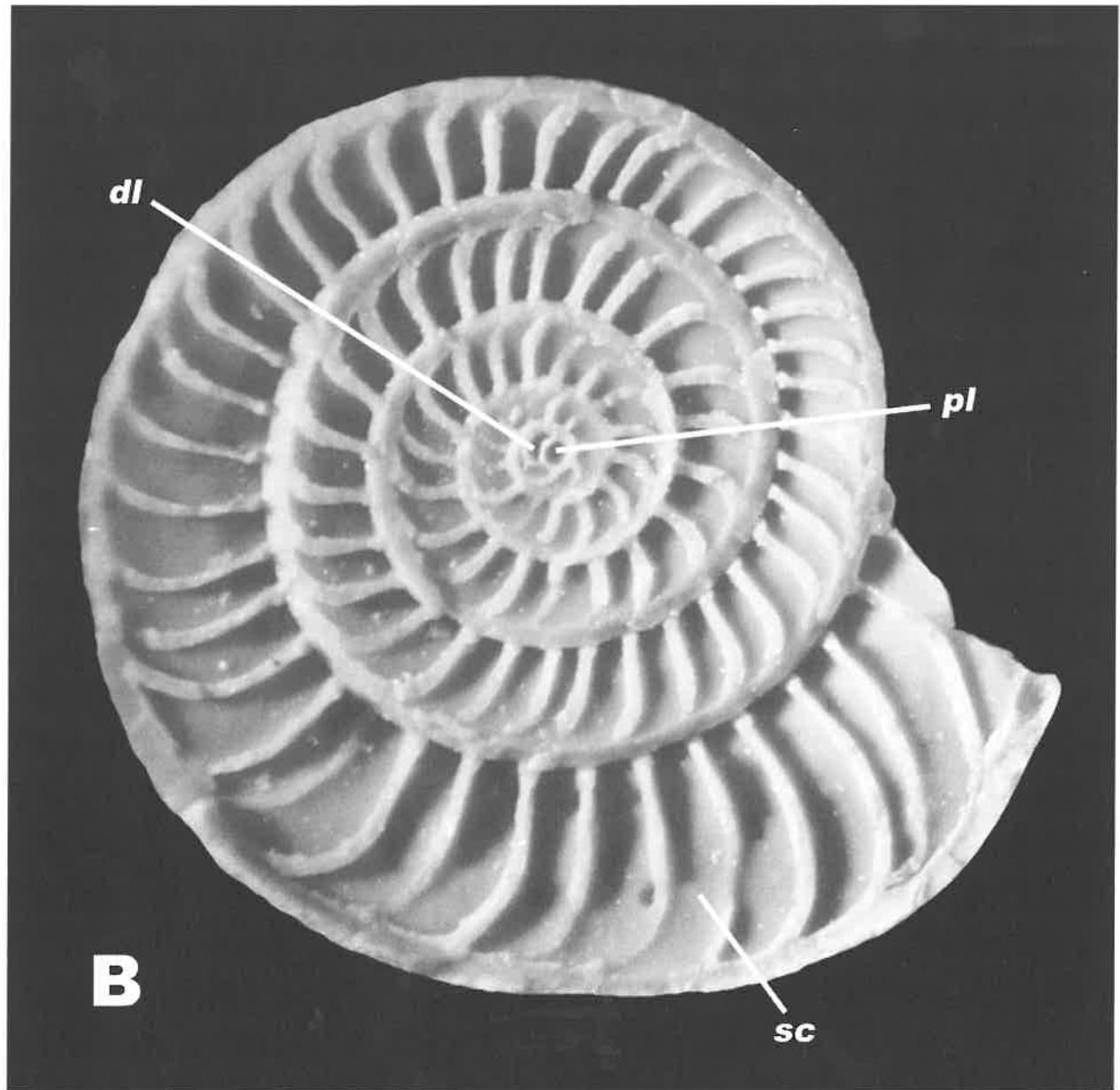


Figure 4. Equatorial (or, medial) views of two megalospheric gamonts, or A forms. *A. Lepidocyclina (Nephrolepidina) chaperi*, from the Upper Eocene/Early Oligocene Bumpnose Limestone, Chipola River, Marianna, Florida (x32; image from Cole, 1952). *B. Nummulites willcoxi*, from the Upper Eocene Ocala Limestone, Dixie County, Florida (x35). *p*, protoconch; *d*, deuterococh; *pl*, proloculus; *dl*, deuteroloculus; *ec*, equatorial chambers; *sc*, spiral chambers.



(*oligotrophic*) waters. In such marine environments, algal symbiosis is especially advantageous because the algae provide for much of the nutritional needs of the foram. Most modern LBF and reef corals also have algal symbionts (this gives corals their typical, golden-yellow color), and even some molluscs host algal symbionts (e.g., the giant reef clam, *Tridacna*). Reef ecosystems are, in fact, largely constructed by creatures that can take advantage of algal symbiosis and thereby thrive in what are otherwise nutrient-poor waters. Because extinct larger foraminifera are almost always associated with ancient tropical or subtropical marine environments, most are inferred to have had algal symbionts (Hallock, 1982; Hottinger, 1982).

Like many invertebrate organisms, LBF have *indeterminate growth*, which means they will continue to grow throughout their life, which normally ends at reproduction. During asexual reproduction, the parent distributes all of its protoplasm to its progeny by multiple fission. Under favorable conditions, LBF will mature and reproduce normally. However, if the population is stressed by low light (necessary for algal symbionts), low temperature, or other suboptimal conditions, the forams may delay reproduction and simply continue to grow. This occurs, for example, when LBF are washed into deeper water. Paradoxically, if a population contains many exceptionally large individuals, conditions for growth and reproduction may have been marginal (Hallock, 1985; Hallock and Glenn, 1986; Hallock et al., 1986).

Larger foraminifera are often so abundant that their tests comprise a substantial volume of calcium carbonate sediment, rivaling corals and calcareous algae in their volumetric contribution (Hallock and Glenn, 1986; Hallock, 1981; Ross, 1977). Thus larger forams, corals, and algae are some of the primary limestone-producing organisms found in tropical, shallow marine environments. Many fossiliferous limestones are composed of nearly 100% larger foraminifera. Such limestone may be called a *coquina*. LBF-rich limestones and coquinas are common in the Ocala Limestone and other Florida formations (Figure 5). The Middle Eocene Giza Limestone of Egypt, for example, is rich in LBF called *Nummulites*. This limestone comprises much of the building stone for the great pyramids (Figure 6). Egyptian nummulites were recognized as curiosities as early as the fifth century B.C., and were considered to be



Figure 5. Larger foraminiferal limestone/coquina, containing *Nummulites* and *Lepidocyclina*. Upper Eocene Ocala Limestone, Haile Quarries, near Gainesville, Florida (magnification 1.7x).



Figure 6. *Nummulites gizenesis*, from the Middle Eocene Giza Limestone of Egypt (magnification 3.5x).

the remains of petrified lentils left over from the rations given to the slaves who build the Great Pyramids. Fossil nummulitids have also been nicknamed “mermaid’s pennies.”

Larger foraminifera in general have distinctive environmental tolerances, and individual species may be restricted to particular habitats. This habitat-specific association is largely a function of the light tolerances of algal symbionts. LBF that host chlorophyte (green) algal symbionts for example, such as the modern Floridan species *Laevipeneroplis proteus* and *Archaias angulatus*, require very shallow waters and are typically found in backreef and seagrass habitats. Other LBF, such as Indo-Pacific nummulitids *Nummulites venosus* and *Heterostegina operculinoides*, host algae that can carry out photosynthesis in deeper photic zone waters with restricted light penetration. But modern algal-symbiont-hosting LBF rarely live in waters exceeding 100 meters (m) depth.

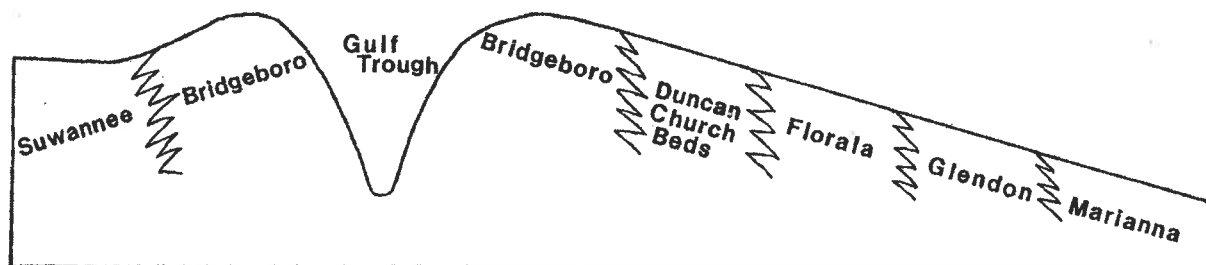
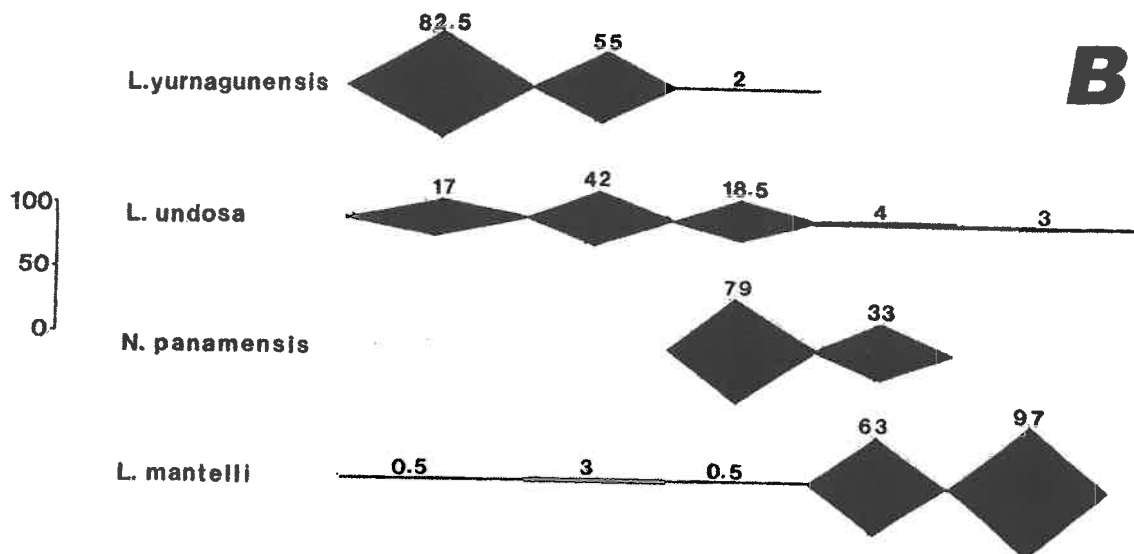
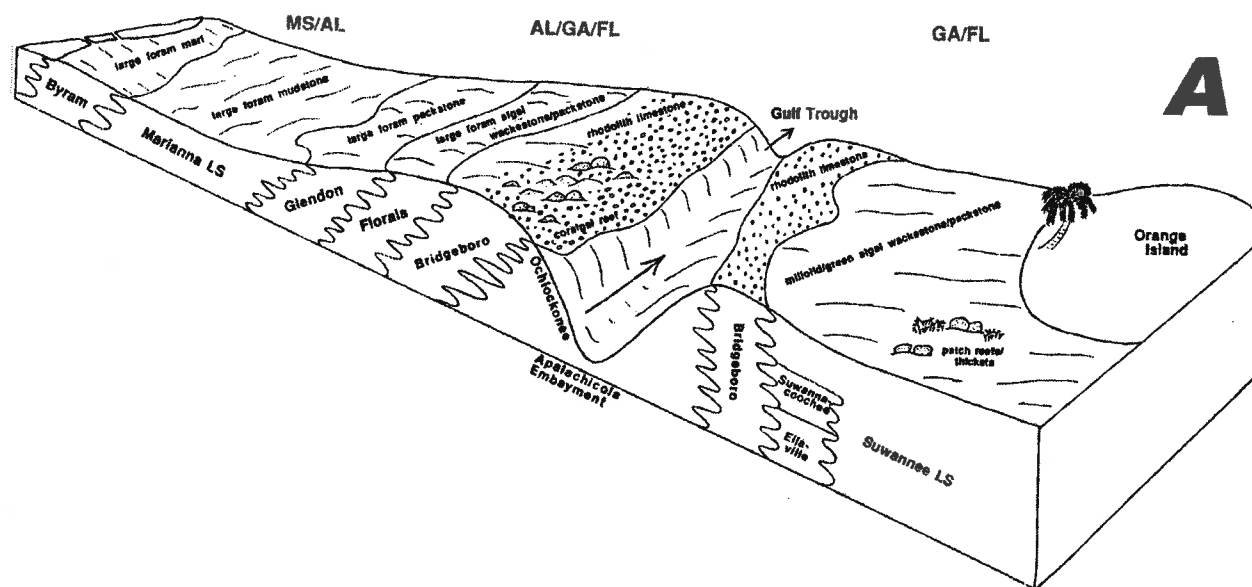
Similar habitat associations can be reasonably inferred for fossil LBF, making them extremely valuable in the reconstruction of past marine environments. Many studies have documented the paleoenvironmental (*biofacies*) distributions of LBF (Drooger, 1983; Hottinger, 1977, 1983, 1997). It is common, for example to map the ecologic zonation of LBF along a shallow-to-deep transect within reef-associated limestones (Figure 7).

PREPARATION OF FOSSIL LARGER FORAMINIFERA

The study of larger foraminifera requires a variety of special preparation techniques. If the forams are preserved in hard, well-cemented limestones, then individual specimens can be nearly impossible to remove. In such cases, polished thin-sections of the rock must be made to observe the forams through transmitted light with a petrographic microscope. A variety of special saws and other equipment is generally needed to prepare petrographic thin sections. Fortunately, most fossil LBF in Florida are preserved in soft limestones or other loosely consolidated sediments, so simpler and more cost-effective methods can be employed to prepare specimens.

The first step in preparing LBF is to isolate a sufficient number of quality specimens for study from the rest of the rock or sediment. Most LBF-rich limestones can be carefully broken several times with a rock hammer until sufficient loosened

Figure 7. Larger foraminiferal zonation across an Early Oligocene reef tract and associated environments. A. block diagram reconstruction of shallow marine environments extending from Mississippi, southeastward to Florida (rock formations are shown in side panel). The Bridgboro Limestone is a reef deposit rich in coralline algae. The Gulf Trough was a current-swept channel that extended from the eastern Florida panhandle through southern Georgia. The Florida peninsula is represented by the Suwannee Limestone. B. Distribution (percent) of four species of Shelf Assemblage larger foraminifera from the reef to deeper shelf. Not shown are abundant *Fallotella cookei* and *Fallotella floridana*, representing the Bank Assemblage of the Suwannee Limestone (from Bryan, 1995).



matrix has been freed from the rock. After removing larger, unbroken fragments, this matrix should be washed over an 80 mesh (177 micron diameter) screen sieve to remove fine fraction dust. Larger mesh sizes can be used, but an 80 mesh sieve will catch even juvenile larger foraminifera. Identification of most LBF, in fact, requires that the smaller A-forms (megalspheres) be used. Identification of the larger B-forms (microspheres) is more difficult.

After the matrix is gently washed in the sieve, it must be dried. Depending on the size of the sample, it can be placed in an oven at 100° F for a couple of hours, or set over very low heat on a hot plate. If the LBF are preserved in a white or pale-yellow limestone (such as the Ocala or Suwannee limestones), the specimens may be bleach-white and difficult to distinguish from the rest of the sediment. In this case, the sample may be dipped in a shallow pan of diluted blue or green food dye before drying. When dry, the sample may be observed in a microfossil tray under a binocular dissecting microscope at a comfortable magnification. The stained LBF will be especially evident.

To identify individual specimens to the species level (and sometimes even the genus level) normally requires that the test be split in two, or that the surface layer of the test be carefully ground away to reveal the arrangement of the internal chambers. The following specimen preparation methods will apply for many fossil LBF found in Florida.

Nummulites. Preparation of nummulitids for study requires a simple, but unusual procedure. Nummulites have a natural, equatorial plane of weakness through the edge of the test, a region called the *marginal cord*. The marginal cord is a complex system of canals and furrows that contain pseudopods. Because of this plane of weakness in the shell, the specimen can be easily split across its equatorial plane by heating the test over an alcohol lamp flame until red-hot, then plunging the foram into a shallow dish of water. This causes the nummulite to split into two equal halves, both of which show the internal test chamber (see Figure 4B). Each half (or the one that best survives this violent technique) is mounted on a labeled microfossil slide (with white glue or gum tragacanth) for study. A cover slide over the microfossil slide will ensure safe storage.

***Lepidocyclina*.** Preparation of specimens of *Lepidocyclina* and similar forms (*Pseudophragmina*, *Asterocyclina*) requires that the surface of at least one side of the individual specimen be ground away until the equatorial and embryonic chambers become fully visible. This can be difficult because, unless the specimens are exceptionally large, they cannot be manipulated without some aid to hold them during preparation. This may be done by mounting each individual specimen on a standard 1x3" biological glass slide using a small chip of Lakeside-70 resin on the slide, holding the slide over an alcohol lamp flame until the resin melts (10-15 seconds), then placing the foram on the drop of melted resin. The resin hardens in approximately 60 seconds. It is also possible to mount the LBF test on the tip of a *dop stick* using *dop wax* (a technique used by lapidary hobbyists when holding small stones for grinding and polishing), or to mount the specimen on top of a small, flat-head nail with epoxy resin.

The specimen is now ready for grinding to reveal the internal chambers. If mounted on a glass slide, the specimen is ground on a coarse-frosted glass plate, using a few drops of water and a bit of blue or green food dye (to enhance the visibility of the specimen). Regularly examine the specimen under a binocular microscope to ensure that the grinding has not gone beyond the equatorial plane (see Figure 4A). A more finely frosted glass plate may be used for fine polishing (I use a 120 silicon carbide grit to frost the coarse plate, and a 600 grit for the finer plate). If the specimens are mounted on a dop stick or nail, a small lap wheel may be used for grinding, and the mounted specimens can be stored in a square of foam or cardboard (as with insect collections). There are various other methods that have been described in the literature for the preparation of larger foraminifera. One must find the technique that best suits.

TAXONOMIC AND STRATIGRAPHIC LISTING

LARGER BENTHIC FORAMINIFERA OF FLORIDA

The classification of foraminifera continues to change as we learn more of the genetic similarities among extant taxa, their evolutionary relationships, and acquire yet more anatomical detail of the organism. For the purposes of this paper, I have used the higher classification (to genus level) of Loeblich and Tappan (1987), and have

attempted to include all LBF taxa that have been mentioned in the literature as occurring in Florida from Cretaceous to Holocene age. It should be noted that the designation of some taxa as *larger* foraminifera, may be a bit arbitrary, in some cases. There are a wide variety of sizes. Also, it must be remembered that the association of large size with algal symbiosis is an inference. Some large modern species do not harbor symbionts, and some small ones do, so precise definitions are not always possible. Therefore, some judgment had to be made whether or not to include certain species in this list. Some problematic listings and undescribed species in the literature were omitted. As with any species list, the following will continue to change and improve as fossils are reexamined. In any case, all of the species listed below are benthic foraminifera, most are relatively large or have complex tests compared to other foraminifera, and most are primarily shallow water in occurrence.

Systematic Paleontology

Order Foraminiferida Eichwald, 1830

FloridaGeologic Range¹

Suborder Textulariina Delage & Herouard, 1896

Family **Lituolidae** de Blainville, 1827

Flabellamina brachylocula Tappan, 1941

mCretaceous

Flabellamina denisonensis Tappan, 1941

mCretaceous

Lituola subgoodlandensis (Vandepool, 1933)

mCretaceous

Family **Cyclamminidae** Marie, 1941

Choffatella decipiens Schlumberger, 1905

uJur?-l-mCret

Cyclammina watersi Appin & Jordan, 1945

mEocene

Pseudocyclammina hedbergi Maync, 1953

mCretaceous

Family **Cuneolinidae** Saidova, 1981

Cuneolina walteri Cushman & Applin, 1947

uCretaceous

Family **Dicyclinidae** Loeblich & Tappan, 1964

Dicyclina cf. *D. schlumbergeri* Munier-Chalmas, 1887

mCretaceous

Family **Coskinolinidae** Moullade, 1965

Coleiconus zansi Robinson, 1993

mEocene

Coskinolina elegans (Cole, 1942)

mEocene

Family **Orbitolinidae** Martin, 1980

Coskinolinoides texanus Keijzer, 1942

mCretaceous

Cushmania americana (Cushman, 1919)

mEocene

Dictyoconus floridanus (Cole, 1941)

mCretaceous

Fallotella cookei (Moberg, 1928)

mEoc-lOlig

Fallotella floridana (Cole, 1941)

mEoc-lOlig

Paracoskinolina sunnilandensis (Maync, 1955)

mCretaceous

Orbitolina minuta Douglas, 1960

mCretaceous

<i>Orbitolina texana</i> (Roemer, 1849)	mCretaceous
Family Valvulaminidae Loeblich & Tappan, 1986	
<i>Arenagula floridana</i> (Cole, 1942)	mEocene
<i>Discorinopsis gunteri</i> Cole, 1941	m-uEoc-Olig
<i>Valvulammina minuta</i> Applin & Jordan, 1945	mEocene
<i>Valvulammina nassauensis</i> Applin & Jordan, 1945	Paleocene
Family Valvulinidae Berthelin, 1880	
<i>Cribobulimina cushmani</i> Applin & Jordan, 1945	mEocene
<i>Valvulina avonparkensis</i> Applin & Jordan, 1945	mEocene
<i>Valvulina floridana</i> Cole, 1941	mEocene
<i>Valvulina intermedia</i> Applin & Jordan, 1945	mEocene
<i>Valvulina martii</i> Cushman & Bermudez, 1937	mEocene
<i>Valvulina ocalana</i> Cushman, 1926	uEocene
<i>Valvulina oviedoiana</i> d'Orbigny, 1839	Holocene
Family Chrysalidinidae Neagu, 1968	
<i>Pseudochrysalidina floridana</i> Cole, 1941	mEocene
Family Involutinidae Butschli, 1880	
<i>Trocholina floridana</i> Cushman and Applin, 1947	uCretaceous
Suborder Miliolina Delage & Herouard 1896	
Family Fabulariidae Ehrenberg, 1830	
<i>Fabularia gunteri</i> Applin & Jordan, 1945	mEocene
<i>Fabularia vauhani</i> Cole & Ponton, 1934	mEocene
Family Rhapydioninidae Keijzer, 1945	
<i>Chubbina macgillavryi</i> Robinson, 1968	uCretaceous
Family Alveolinidae Ehrenberg, 1839	
<i>Borelis floridanus</i> Cole, 1944	Pal-mEoc
<i>Borelis gunteri</i> Cole, 1941	Paleocene
<i>Borelis pulchra</i> (d'Orbigny, 1839)	Holocene
Family Peneroplidae Schultze, 1854	
<i>Dendritina antillarum</i> d'Orbigny, 1846	Holocene
<i>Dendritina elegans</i> d'Orbigny, 1846	Holocene
<i>Laevipeneroplis bradyi</i> (Cushman, 1930)	Holocene
<i>Laevipeneroplis proteus</i> (d'Orbigny, 1839)	?Plio-Holo
<i>Laevipeneroplis elegans</i> (d'Orbigny, 1839)	Holocene
<i>Peneroplis pertusus</i> (Forskal, 1775)	Holocene
<i>Spirolina coryensis</i> Cole, 1941	mEocene
Family Soritidae Ehrenberg, 1839	
<i>Androsina lucasi</i> Levy, 1977	Holocene
<i>Amphisorus hemprichii</i> Ehrenberg, 1839	?Mio-Holo
<i>Archaias angulatus</i> (Fichtel & Moll, 1798)	?Plio-Holo
<i>Archais columbianensis</i> Applin & Jordan, 1945	mEocene
<i>Archais withlacoochensis</i> Puri, 1957	m-lEocene
<i>Cycloputeolina discoidea</i> (Flynt, 1971)	Holocene
<i>Cyclorbiculina compressa</i> (d'Orbigny, 1839)	Holocene
<i>Keramosphaerina</i> (?) sp. (= " <i>Oligostegina</i> " of Applin & Applin, 1967)	uCretaceous
<i>Miarchaias floridanus</i> (Conrad, 1846)	Miocene
<i>Miosorites americanus</i> (Cushman, 1918)	Mio-?Plio
<i>Parasorites orbitolitoides</i> (Hofker, 1930)	Holocene
<i>Sorites marginalis</i> (Lamarck, 1816)	?Mio-Holo
<i>Sorites orbiculatus</i> (Forskal, 1775)	Holocene
Suborder Rotaliina Delage & Herouard 1896	

- Family **Planorbulinidae** Schwager, 1877
Planorbulina acervalis (Brady, 1884) Holocene
- Family **Cymbaloporidae** Cushman, 1927
Fabiana cassis (Oppenheim, 1896) m-uEoc-I/Olig
Gunteria floridana Cushman & Ponton, 1933 mEocene
- Family **Victoriellidae** Chapman and Crespin, 1930
Rupertina floridana Cushman, 1933 uEocene
- Family **Acervulinidae** Schultze, 1854
Discogypsina vesicularis A. Silvestri, 1937 Holocene
Sphaerogypsina globulus (Reuss, 1848) m-uEoc-Olig
- Family **Homotrematidae** Cushman, 1927
Homotrema rubrum (Lamarck, 1816) Holocene
- Family **Asterigerinidae** d'Orbigny, 1839
Asterigerina carinata d'Orbigny, 1839 Holocene
Asterigerina cedarkeysensis Cole, 1942 mEocene
Asterigerina primaria heligma Levin, 1957 mEocene
Asterigerina subacuta floridensis Applin & Applin, 1944 Oligocene
Asterigerina texana (Stadnichenko, 1927) mEocene
- Family **Amphisteginidae** Cushman, 1927
Amphistegina alabamensis Applin & Jordan, 1945 uEocene
Amphistegina chipolensis Cushman & Ponton, 1932 IMiocene
Amphistegina floridana Cushman & Ponton, 1932 Miocene
Amphistegina gibossa d'Orbigny, 1839 Plio-Holo
Amphistegina nassauensis Applin & Jordan, 1945 mEocene
Amphistegina pinarensis cosdeni Applin & Applin, 1944 m-uEocene
Eoconuloides lopeztrigoi (D.K. Palmer, 1934) mEocene
- Family **Lepidocyclinidae** Scheffen, 1932
Helicostegina gyralis Barker & Grimsdale, 1936 mEocene
Helicostegina paucispira (Barker & Grimsdale, 1936) uEoc-I/Olig
Lepidocyclina (Pliolepidina) cedarkeysensis Cole, 1942 mEocene
Lepidocyclina (Polylepidina) antillea Cushman, 1919 mEocene
Lepidocyclina (Lepidocyclina) macdonaldi Cushman, 1918 mEoc-?I/Olig
Lepidocyclina (Lepidocyclina) mantelli (Morton, 1833) IOligocene
Lepidocyclina (Lepidocyclina) mortoni Cushman, 1920 uEocene
Lepidocyclina (Lepidocyclina) ocalana Cushman, 1920 uEocene
Lepidocyclina (Nephrolepidina) chaperi Lemoine & R. Douville, 1904 uEoc-I/Olig
Lepidocyclina (Nephrolepidina) yurnagunensis Cushman, 1919 IOligocene
Lepidocyclina (Eulepidina) undosa Cushman, 1919 IOligocene
- Family **Linderinidae** Loeblich & Tappan, 1984
Linderina floridensis Cole, 1942 mEocene
- Family **Orbitoididae** Schwager, 1876
Orbitoides browni (Ellis, 1932) uCretaceous
Torreina torrei D.K. Palmer, 1934 uCretaceous
- Family **Lepidorbitoididae** Vaughan, 1933
Lepidorbitoides floridensis Cole, 1942 uCretaceous
Sulcoperculina cosdeni (Applin & Jordan, 1945) uCretaceous
Sulcoperculina dickersoni (D.K. Palmer, 1934) uCretaceous
- Family **Pseudorbitoididae** M.G. Rutten, 1935
Asterorbis aquayoi (D.K. Palmer, 1934) uCretaceous

<i>Asterorbis rooki</i> Vaughan & Cole, 1932	uCretaceous
<i>Orbitocyclina minima</i> (H. Douville, 1927)	uCretaceous
<i>Pseudorbitoides trenchmanni</i> H. Douville, 1922	uCretaceous
<i>Sulcorbitoides pardo</i> Bornnemann, 1954	uCretaceous
<i>Vaughanina cubensis</i> D.K. Palmer, 1934	uCretaceous
Family Rotaliidae Ehrenberg, 1839	
<i>Camagueyia perplexa</i> Cole & Bermudez, 1944	mEocene
<i>Lockhartia cushmani</i> Applin & Jordan, 1945	mEocene
<i>Lockhartia gyropapulosa</i> Levin, 1957	mEocene
<i>Lockhartia praealta</i> Levin, 1957	mEocene
<i>Neorotalia mexicana</i> (Nuttall, 1928)	IOligocene
<i>Rotalia avonparkensis</i> Applin & Jordan, 1945	mEocene
<i>Rotalia byramensis</i> Cushman, 1922	IOligocene
<i>Rotalia cushmani</i> Applin & Jordan, 1945	uEocene
<i>Rotalia trochidiformis</i> (Lamarck, 1804)	mEocene
<i>Smoutina cruysi</i> Drooger, 1960	uCretaceous
Family Miogypsinidae Vaughan, 1928	
<i>Miogypsina panamensis</i> (Cushman, 1918)	uOligocene
<i>Miogypsina antillea</i> (Cushman, 1919)	uOligocene
Family Nummulitidae de Blainville, 1827	
<i>Nummulites floridensis</i> (Heilprin, 1885)	m-uEocene
<i>Nummulites gravelli</i> Cole, 1944	mEocene
<i>Nummulites heilprini</i> (Hantken, 1886)	uEocene
<i>Nummulites mariannensis</i> (Vaughan, 1928)	uEocene
<i>Nummulites panamensis</i> Cushman, 1918	IOligocene
<i>Nummulites striatoreticulatus</i> (?) L. Rutten, 1928	uEocene
<i>Nummulites willcoxi</i> Heilprin, 1882	uEocene
<i>Heterostegina ocalana</i> Cushman 1921	uEocene
<i>Heterostegina antillea</i> Cushman, 1919	uOlig-?IMio
<i>Heterostegina antillarum</i> d'Orbigny, 1839	Holocene
Family Asterocyclinidae Bronnemann, 1951	
<i>Asterocyclina americana</i> (Cushman, 1917)	uEocene
<i>Asterocyclina chipolensis</i> (Vaughan, 1928)	uEocene
<i>Asterocyclina georgiana</i> (Cushman, 1917)	uEocene
<i>Asterocyclina mariannensis</i> (Cushman, 1917)	uEocene
<i>Asterocyclina monticellensis</i> Cole & Ponton, 1934)	mEocene
<i>Asterocyclina nassauensis</i> (Cole, 1944)	uEocene
<i>Asterocyclina vauhani</i> (Cushman, 1917)	uEocene
<i>Pseudophragmina bainbridgensis</i> (Vaughan, 1928)	uEocene
<i>Pseudophragmina cedarkeyensis</i> Cole, 1944	mEocene
<i>Pseudophragmina flintensis</i> (Cushman, 1917)	uEocene
<i>Pseudophragmina floridana</i> (Cushman, 1917)	uEocene
<i>Pseudophragmina stvensoni</i> (Vaughan, 1929)	uPal-IEoc

¹ l = Lower, m = Middle, u = Upper, Jur = Jurassic, Cret = Cretaceous, Pal = Paleocene, Eoc = Eocene, Olig = Oligocene, Mio = Miocene, Plio = Pliocene, Holo = Holocene.

COMMENTS ON LARGER FORAMINIFERAL ASSEMBLAGES OF FLORIDA

During most of the Cretaceous Period, much of Florida was submerged beneath a shallow, lime-producing sea. In the middle of the Cretaceous, many larger foraminifera such as *Paracoskinolina sunnilandensis* and *Orbitolina texana* are associated with the oil-producing Sunniland Limestone of the southern portion of the peninsula. The Sunniland contains a rudist bivalve reef or shoal and other fossiliferous shallow water deposits. Other common middle Cretaceous LBF of Florida are *Coskinolinoides texanus* and *Orbitolina minuta*. In the upper Cretaceous, most LBF are found in the Lawson Limestone, a chalky to nodular limestone, with abundant calcareous algae, rudists, and other fossils indicating shoal water conditions. Common LBF in the Lawson include *Lepidorbitoides floridensis*, *Lepidorbitoides minima*, *Chubbina macgillavryi*, *Vaughanina cubensis* and many others.

In much of the Cenozoic of Florida, certain textulariid and miliolid LBF (such as *Fallotella*, *Discorinopsis*, and *Borelis*) inhabited backreef/lagoonal or otherwise very shallow waters. The common presence of calcareous green algae, sea grasses, and other unique sediments indicate extremely shallow water, from the shoreline to perhaps 10 m depth. This recurring association of LBF may be called the *Bank Assemblage*, referring to the shallow-water, flat-topped, limestone-producing plateau or *bank*, in which the LBF live (much like the present day Bahama Bank). Larger, flat coiled or discoid rotaliids (such as *Nummulites*, *Lepidocyclina*, and *Pseudophragmina*) typically inhabit forereef and deeper photic zone areas on the gently inclined continental shelf, with water depths reaching up to perhaps 50 m or more. This association may be called the *Shelf Assemblage*. These two assemblages have long been recognized in Florida and elsewhere. Although rarely this simple, it is usually an accurate first approximation to classify LBF assemblages as either a Bank Assemblage or a Shelf Assemblage. The Bank Assemblage appears to be dominant throughout most of the Paleocene to Middle Eocene, and during the Early Oligocene of the peninsula. The Shelf Assemblage is most evident in the Late Eocene, and in the Oligocene of northwestern Florida.

Relatively few larger foraminifera are known from the subsurface Paleocene strata of Florida, but environmental conditions for LBF were favorable. A large reef-like

structure (Rebecca Shoals Dolomite) surrounded much of the peninsula. Two species of the alveolinid, *Borelis* (*B. floridanus* and *B. gunteri*), representing the Bank Assemblage, have been reported from the Cedar Keys Formation, a dolostone rich in evaporate minerals (viz., the salts gypsum and anhydrite). The presence of dolomite and salts indicates very shallow waters over the peninsula with restricted water circulation, perhaps in a broad lagoon behind the Rebecca Shoals reef. The asterocyclinid, *Pseudophragmina stevensoni*, representing the Shelf Assemblage, has been reported from the subsurface of Jackson and Nassau counties from the Salt Mountain Limestone, a formation more commonly known from Alabama, where it is a coral-algal-sponge reef (Bryan 1997a, b; 1991).

The Eocene of Florida was very much like the Paleocene, with shallow bank and slightly deeper shelf environments fluctuating over the peninsula. Larger foraminifera reflect these shifting sea levels. The Middle Eocene Oldsmar Limestone contains both Bank and Shelf Assemblages species, but has a dominant Shelf Assemblage near the top of the formation, including *Helicostegina gyralis* and *Pseudophragmina cedarkeyensis*. The lower part of the Middle Eocene Avon Park Formation (including the former "Lake City Limestone") appears to be a Shelf Assemblage, but the upper part of the Avon Park (representing the oldest exposed rocks in Florida) contains rare fossil sea grasses and Bank Assemblage species such as *Fallotella*. The lower part of the Ocala Limestone (formerly the Inglis Limestone) also has a good Bank Assemblage deposited in high energy, nearshore waters. It is almost certain that there were low islands across much of the peninsula during various times in the Cenozoic, and certainly during the Middle Eocene.

The upper part of the Ocala Limestone clearly contains a Shelf Assemblage, dominated by *Nummulites* and *Lepidocyclina*, usually preserved in muddy limestones. Pure coquinas of *Nummulites* are often found in the Ocala, and represent gravelly shoals or bars that formed in the shallow end of the Shelf environment. In slightly deeper shelf waters, *Lepidocyclina*, *Pseudophragmina* and *Asterocyclina* become more common. Only very small patch reefs are found in the Ocala, but there is evidence of a larger Eocene reef structure along the eastern margin of the peninsula. In the Early Oligocene, the Bank Assemblage returns to the Florida peninsula in the Suwannee

Limestone, with an assemblage that looks very much like a Middle Eocene fauna (*Fallotella*, *Discorinopsis*, and other species). Patch coral reefs were common, and much of the peninsula was an island (or islands)—affectionately called *Orange Island* by T.W. Vaughan in 1910. Across the Florida panhandle, a distinct Shelf Assemblage is present in the Marianna and Bridgeboro limestones, with abundant *Lepidocyclina mantelli*, *Lepidocyclina yurnagunensis*, and *Lepidocyclina undosa*. In the Late Oligocene, *Miogypsina* is found in some subsurface samples.

By the Miocene Epoch, the Florida peninsula was becoming progressively more exposed, as indicated by the abundant terrestrial mammals that appear in the record at this time. But fluctuating sea levels still created shallow marine environments. Larger foraminifera are present in the Miocene, but have a very different aspect than earlier assemblages. With the extinction of most nummulitids, lepidocyclinids, and other forms, Miocene LBF are much like modern forms. Common genera in the Chipola, Tampa, or Chattahoochee formations include *Archaias*, *Amphistegina*, and various soritids. Few LBF have been documented from the Pliocene. Pleistocene LBF appear to be essentially modern in aspect, but they have not been adequately studied. The modern LBF fauna is primarily associated with the Florida Reef Tract, and includes such common species as *Amphistegina lessoni*, *Androsina lucasi*, *Archaias angulatus*, *Cyclorbiculina compressa*, *Laevipeneroplis bradyi*, *Laevipeneroplis proteus*, and *Parasorites orbitolitoides*.

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