SUPERFAMILY MILIOLACEA: A THREE-FOLD LAYERED WALL --- SUPERFAMILY MILIOLACEA EHRENBERG, 1839, EMENDED; NEW SUPERFAMILY HAUERINACEA

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I. ABSTRACT

The Superfamily Miliolacea Ehrenberg, 1839, is here restricted to the calcareous imperforate Foraminiferida that have a pitted exterior surface and a wall composed of three layers. Excluded are those Foraminiferida that have a smooth porcelaneous surface, as exhibited when viewed in reflected light.

Described herein as new are the genera *Hemimiliola, Heteromiliola,* and *Miliolacostata.* These three genera are distinguished by the texture of the outer wall of the test (smooth, ribbed, or costate), the chamber arrangement, and the distribution of pits (juxtaposed or separated). Five new subfamilies are here designated and described: the HEMIMILIOLINAE, HETEROMILIOLINAE, TEXININAE, HELENTAPPANELLINAE, and MILIOLACOSTATINAE, which include all of the known species of Miliolacea from the Gulf Coastal Plain.

The new Superfamily HAUERINACEA, here designated, is erected to accommodate all former species of Miliolacea with a smooth porcelaneous surface, as exhibited when viewed in reflected light.

II. INTRODUCTION

The layered structure in the wall of *Miliola* was brought to my attention by Earl Manning, then a graduate student at Louisiana State University, who was studying a foraminiferal assemblage from the Pacific Ocean. He recovered and photographed a specimen of *Miliola* he identified as "*Quinqueloculina semireticulosa* Cushman" (Figure 2). His photomicrograph revealed a three-fold wall structure, the outer a thin layer of tabular calcite with microscopic punctations that also lines the wall and bottom of the pits (Figures 3, 5). Between the pits, the outer layer can be seen to overlie an unconsolidated aggregate of rodlike structures or crystals that are randomly oriented and held in place by the inner lining or "ceiling" of the chambers. Further, a photomicrograph of "*Quinqueloculina tuberculata* Cushman and Todd" [= *Hemimiliola jacksonensis* Cushman] displays the same three-fold arrangement of calcite layers in the wall of the test (see Figure 4). Other photomicrographs reveal pores at the base of the pits in the genera *Miliola* and *Hemimiliola.*

Loeblich and Tappan, in describing the Suborder Miliolina Delage and Hérouard, 1896, state:

> "Test of porcelaneous high magnesium calcite, of fine randomly oriented rodlike crystals, 1.5 μm to 2.0 μm in length and 0.24 μm in diameter, seen only with the electron microscope, the random crystal orientation refracting light in all directions to result in the milky opacity or porcelaneous appearance in reflected light, wall appears brown and glassy in transmitted light, may have surface layer of variously arranged tabular rhombohedral crystals, commonly with organic lining and may have added adventitious material; true pores may occur in protoconch of some, generally imperforate in post embryonic stage, but may have pseudopores..." [see Loeblich and Tappan 1988, p. 309]

Evidently, these "randomly oriented rodlike crystals" are the elements observed in the *middle layer* in the wall of *Miliola* and its relatives and the "surface layer of variously arranged tabular rhombohedral crystals" describes the outer layer in the wall of *Miliola*. Tests with tabular crystals in the outer layer of the wall do not exhibit a porcelaneous appearance. Why, then, did Loeblich and Tappan describe the entire Suborder Miliolina Delage and Hérouard, 1896, as "Test of porcelaneous high magnesium calcite..." ?

In their remarks following the description of the Family Hauerinidae Schwager, 1876, Loeblich and Tappan (1988, p. 332) state: "The Miliolidae are recognized as a

separate family, characterized by the numerous perforations or pseudopores in the wall." Pseudopores are defined (*ibid.*, p. 739) as "Deep pits in the surface of some Miliolacea that do not completely penetrate the wall, as in *Miliola*; punctations." These pseudopores occur between the pits; however, at the base of the pits they penetrate the wall, becoming true pores.

This writer considers the characterization of the Miliolidae by Loeblich and Tappan in their remarks on the Hauerinidae as both revealing and noteworthy. The most important visible feature of the entire family Miliolidae is the pitted exterior wall of the tests. This characteristic, with the three-fold layered structure of the wall, is sufficient to restrict the Superfamily Miliolacea Ehrenberg, 1839, to the pitted wall genera as characterized by the genotype species *Miliolites saxorum* Lamarck, 1804 [= *Miliola saxorum* (Lamarck), 1804].

Taxonomic Note: In 1986, Loeblich and Tappan restricted the genus *Dentalina* to "those species with longitudinally costate surface" (quoted in 1988, p. 395) and erected *Laevidentalina* for those species "very finely perforate" with "surface smooth and unornamented" (see 1988, p. 396), illustrating the wall of a specimen from the Gulf of Mexico, SEM X7000 (pl. 439, fig. 24). This writer decided to investigate whether additional homogeny in the Miliolacea of the Gulf Coastal Plain would appear if costate miliolid species were separated from those with smooth surfaces. The result of this investigation is presented in Table I.

III. SYSTEMATIC DESCRIPTIONS AND EMENDATIONS

Superfamily MILIOLACEA Ehrenberg, 1839

Emended Diagnosis: Test free, coiled; outer wall with punctations; pits juxtaposed or irregularly dispersed; surface of test smooth, ribbed or costate; proloculus followed by coiled chambers, two per volution; wall of test consisting of three layers of calcite: a tabular layer of granular calcite that contains punctations, which overlies a mass of loosely stacked, randomly oriented calcite rods lying on the calcareous imperforate inner wall of the chamber; base of pits with pores; aperture terminal with or without trematophore on orifice. Eocene to Holocene.

Family MILIOLIDAE Ehrenberg, 1839

Emended Diagnosis: Test with chambers one-half coil in length added in one or more numerous planes; *wall smooth, ribbed or with costae.* Eocene to Holocene (cf. Loeblich and Tappan, 1988, p. 352).

Subfamily MILIOLINAE Ehrenberg, 1839

Emended Diagnosis: Test wall smooth, pits aligned or randomly disposed, elongate oval, proloculus followed by chambers one-half coil in length added in different planes. Eocene to Holocene. (cf. Loeblich and Tappan, 1988, p. 353).

Genus MILIOLA Lamarck, 1804

Type species: *Miliolites saxorum* Lamarck, 1804.

Emended Diagnosis: Test narrow and elongate fusiform; chambers one-half coil in length, quinqueloculine, with separate floor; wall calcareous, *pitted, three-layered with a tabular surface layer bearing perforations or "pits," a middle layer of randomly oriented calcite rods, and an inner lining or "ceiling;"* surface of test may have longitudinal costae *or ribs*; aperture terminal on ultimate chamber with trematophore. [Emendation to diagnosis of Miliola by Loeblich and Tappan, 1988, p. 353.]

MILIOLA SAXORUM (Lamarck)
Figures 12-14

Miliolites saxorum LAMARCK, 1804, Annales Mus. Hist. Nat., vol. 5, p. 352.

Quinqueloculina saxorum (Lamarck). D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 301, no. 1, pl. 16, figs. 9-14.

Miliola saxorum (Lamarck). CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 12, pl. 3, figs. 1-3; BERGQUIST, 1942, Mississippi Geol. Surv., Bull. 49, p. 25, pl. 2, fig. 8; CUSHMAN and TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, pt. 4, p. 83; ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 5, figs. 5-16; ANDERSEN, 1988, Tulane Stud. Geol. Paleont.,

TABLE I

Wall and Chamber Arrangement of Pitted Miliolidae in the Gulf Coastal Plain

WALL	GENUS AND SPECIES	CHAMBERS
SMOOTH	Miliola alphillipsi Miliola chipolensis Miliola newberryensis Miliola saxorum	Quinqueloculine
	Hemimiliola jacksonensis	Quinqueloculine to Planispiral
	Neaguites byramensis * Neaguites inusitatus *	Planispiral
	Heteromiliola decorata **	
	Texina ferayi ***	
BROAD RIBS	Helentappanella punctatocostata	Quinqueloculine to Planispiral
COSTATE	Miliolacostata byramensis Miliolacostata jacksonensis Miliolacostata rolandi	Quinqueloculine
	Picouina mississippiensis	Triserial

* Pits juxtaposed.
** Outer wall white, granular calcite.
*** Pits not juxtaposed.

vol. 21, no. 4, p. 130, figs. 17, 18.

Miliola cf. *M. saxorum* (Lamarck). ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 132, fig. 19.

Emended Diagnosis: Test large, elongate, fusiform; chambers quinqueloculine, numerous, distinct and pitted; *wall three-fold with surface layer consisting of tabular, calcareous plates bearing perforations which extend into base of pits; middle layer consisting of a loose aggregate of calcite rods terminating at outer wall of pits;* aperture at end of a short neck with trematophore. Length 2.50 mm; breadth 0.69 mm.

Remarks: The distribution of the pits and the length-breadth ratio of *Miliola* cf. *M. saxorum*, from the Yazoo Formation, are comparable to the characteristic *Miliola saxorum* from the Moodys Branch Formation. However, the actual measurements of the former, 1.20 mm long and 0.34 mm wide, are much smaller than the latter, which is 2.50 mm in length and 0.69 mm in breadth. Both are mature specimens. The environments are different, which could account for the smaller size of the Red Bluff Formation specimen (see Environmental Implications below).

MILIOLA ALPHILLIPSI Andersen
Figures 6, 7

Miliola alphillipsi ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 136, fig. 28.

Emended Diagnosis: Test free, pitted, quinqueloculine chamber arrangement, slightly more than twice as long as wide, transverse section broadly triangular with periphery rounded; neck, *which extends above penultimate chamber, with surface covered by closely spaced costae randomly distributed at distal end;* pores present in each pit; *aperture simple.* Length of holotype: 0.49 mm; width 0.21 mm.

Remarks: All known specimens of this species were recovered from the type locality of the Byram Formation (Oligocene).

MILIOLA CHIPOLENSIS
(Cushman and Ponton)
Figures 8, 9

Quinqueloculina chipolensis CUSHMAN and PONTON, 1932, Florida Geol. Surv., Bull. 9, p. 45, figs. 1a, b, 2a, b, 3.

Miliola chipolensis (Cushman and Ponton) ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 132, figs. 22, 23.

Remarks: The description of this species was emended by Andersen in 1988.

MILIOLA NEWBERRYSENSIS (Puri)
Figures 10, 11

Quinqueloculina newberryensis PURI, 1957, Florida Geol. Surv., Bull. 38, p. 107, pl. 3, figs. 3a, b.

Miliola newberryensis (Puri). ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 134, fig. 26.

Remarks: This species is from the Crystal River Formation in Florida. All specimens recovered have weathered surfaces; however, rodlike calcite structures in the middle layer of the test were revealed with scanning electron microscope examination.

Subfamily HEMIMILIOLINAE Andersen, new subfamily

Diagnosis: Wall smooth, pitted but with pits not juxtaposed; quinqueloculine, followed by chambers one-half coil in length added at 180°. Eocene, North America.

Genus HEMIMILIOLA Andersen, new genus

Type species: *Massilina jacksonensis* Cushman, 1927.

Diagnosis: Wall smooth, pitted; quinqueloculine to planispiral; pores at base of pits; aperture on a short neck with trematophore; chambers rounded to carinate.

HEMIMILIOLA JACKSONENSIS (Cushman)
Figures 15-17

Massilina jacksonensis CUSHMAN, 1927, Journ. Paleontology, vol. 1, p. 150, pl. 23, figs. 5, 6; CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 13, pl. 3, figs. 7-10; CUSHMAN and TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, pt. 4, p. 82, pl. 13, fig. 17.

Massilina cf. *jacksonensis,* PURI, 1957, Florida Geol. Surv., Bull. 38, p. 108, pl. 3, figs. 2a, b.

Quinqueloculina tuberculata CUSHMAN and TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, pt. 4, p. 81, pl. 13, figs. 11, 12.

Tappanella jacksonensis (Cushman). ANDERSEN, 1984, (non *Tappanella* Gudina and Saidova, 1969), Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 12, figs. 30-33.

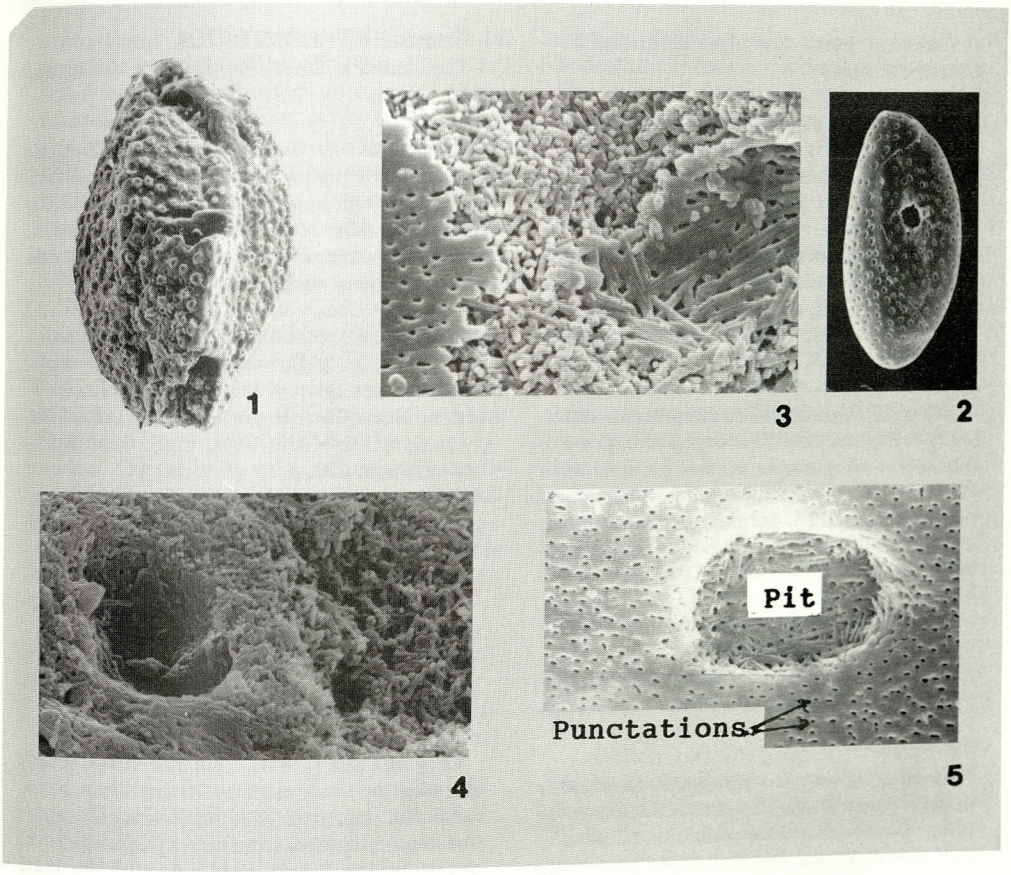
Heterellina jacksonensis (Cushman). ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 138, fig. 32.

Emended Diagnosis: Test *free,* broadly oval or elliptical, compressed; chambers acute to slightly rounded, ultimate chamber extending slightly beyond penultimate chamber; pits randomly distributed over smooth chamber wall; early chambers quinqueloculine, later chambers added at 180° in a single plane; aperture on a short neck with trematophore. Length 1.40 mm; breadth 1.00 mm; thickness 0.20 mm.

Remarks: Figured specimens 15 and 17, LSU Geoscience Museum numbers 11548 and 11549, are from the Moodys Branch Formation in Jackson Park, Jackson, Mississippi. Four genera of the family Miliolidae are present in abundance at this locality (see Table II).

Subfamily NEAGUITESINAE Andersen, 1984

Emended Diagnosis: Wall smooth, pitted with



Figures 1-5

1. "*Quinqueloculina tuberculata* Cushman and Todd"
   Weathered specimen X 75
2. "*Quinqueloculina semireticulosa* Cushman"
   Lateral view X 75
3. "*Quinqueloculina semireticulosa* Cushman"
   Section of wall showing layering X 3750
4. "*Quinqueloculina tuberculata* Cushman and Todd"
   View showing rod-like elements in middle layer X 2500
5. "*Quinqueloculina semireticulosa* Cushman"
   View identifying "pit" and "punctations" X 3750

pits juxtaposed; chambers planispirally coiled. Eocene and Oligocene, North America.

Genus NEAGUITES Andersen, 1984

Type species: *Spiroloculina byramensis* Cushman, 1922.

Emended Diagnosis: Test elliptical, sides flattened to slightly concave; *wall* pitted with pits juxtaposed; chamber arrangement consisting of two chambers per volution added at 180°; aperture terminal, simple.

Remarks: Removal of the outer wall in weathered specimens reveals the rodlike, calcite elements of the middle layer in the wall of the test (see Andersen, 1984, Figure 40). Weathered specimens also

reveal that pores are present in the bottom of each pit.

NEAGUITES BYRAMENSIS (Cushman)
Figures 18, 19

Spiroloculina byramensis CUSHMAN, 1922, U. S. Geol. Surv., Prof. Paper 129, p. 101, pl. 25, figs. 4a, b.

Neaguites byramensis (Cushman). ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 15, figs. 39, 40; ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 138, fig. 33.

Emended Diagnosis: Test compressed, elliptical *to nearly round; wall with pits juxtaposed to the extent that test is almost covered with adjoining pits;* proloculus and early chambers normally concealed; periphery rounded; *aperture simple* at end of a short neck. Figured specimen: length 9.55 mm; breadth 0.51 mm.

NEAGUITES INUSITATUS Andersen
Figures 20, 21

Neaguites inusitatus ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 15, figs. 37, 38.

Original Diagnosis: "Test small, elliptical in outline, twice as long as broad; flat, megalospheric form with visible proloculus followed by two chambers per volution added in a single plane, microspheric form with early chambers at an angle to the plane of coiling; periphery rounded to broadly acute; aperture end extends beyond the penultimate chamber, final chamber frequently forming an eyelet at the base of the test by not remaining in juxtaposition with the preceding chamber; chambers with a frosted appearance produced by its intensely pitted surface wherein there are perforations; aperture on a slight neck. Length of holotype 0.60 mm; breadth 0.30 mm." (Andersen, 1984)

Remarks: In this species, the pits are closely juxtaposed as in *Neaguites byramensis.*

Subfamily HETEROMILIOLINAE
Andersen, new subfamily

Diagnosis: Wall smooth, pitted; external portion of three-layered wall composed of white, granular calcite; chambers planispiral in arrangement. Eocene and Oligocene, North America.

Genus HETEROMILIOLA, new genus

Type species: *Massilina decorata* Cushman, 1922.

Diagnosis: Test free, flattened and elliptical; pits randomly distributed on the surface of test, not juxtaposed; outer wall composed of white, granular calcite; two chambers per volution, added at 180°; proloculus rarely visible on side of test; aperture simple.

HETEROMILIOLA DECORATA (Cushman)
Figures 22-24

Massilina decorata CUSHMAN, 1922, U. S. Geol. Surv., Prof. Paper 129-F, p. 143, pl. 34, fig. 7; CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 13, pl. 3, fig. 14.

Spiroloculina lamposa HUSSEY, 1949, Journ. Paleontology, vol. 23, no. 2, p. 121, pl. 26, fig. 6.

Neaguites lamposus (Hussey). ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, p. 16, figs. 41, 42.

Neaguites decoratus (Cushman). ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 1, p. 138, figs. 35-38.

Original Diagnosis: "Test much flattened, elliptical or oval, slightly longer than wide, basal and apertural ends projecting, the apertural end narrowed to a small cylindrical neck, nearly in the longitudinal axis of the test; sutures rather indistinct; surface dull white; periphery rounded, the sides ornamented by very fine pits, giving a finely granular appearance to the test. Length 1 millimeter or less." (Cushman, 1922). In 1935, Cushman added that the finely granular surface gave the test a "matte appearance."

Remarks: Heteromiliola decorata is not admissible to any genus presently assigned to the Miliolidae. It satisfies the basic requirements of the family because the test wall is composed of three layers and is pitted (see Andersen, 1988, Figure 36). However, the pits are not juxtaposed (Andersen, 1988, Figure 38), thus this species cannot be placed in the genus *Neaguites.*

All of the other smooth-walled genera in the Miliolacea appear to have an outer test wall similar to the Holocene genus *Miliola,* as demonstrated by Earl Manning (see Introduction, above). In Figures 22 and 23 (herein), it can be noted that the

outer layer of the wall of *Heteromiliola decorata* consists of interlocked, elongate, flat sheets of calcite with numerous perforations. The granular, outer wall of this species, therefore, is unique to the Miliolidae. In addition, the pits as seen on weathered specimens appear as "reel-shaped" elements. Coccolith plates are commonly present among the debris adhering to the wall of the test.

Tests of *Heteromiliola decorata,* examined and analyzed with an X-ray diffraction unit by Professor Ray E. Ferrell, Jr., Louisiana State University, are composed of calcite, negating the possibility that *Heteromiliola* is related to the porcelaneous Foraminiferida, which are composed of aragonite. This difference in composition could explain the fact that the surfaces of all recovered tests of this genus are strongly weathered.

Subfamily TEXININAE Andersen, new subfamily

Diagnosis: Wall pitted, but pits not juxtaposed, planispirally coiled, aperture terminal with trematophore. Eocene, North America.

Genus TEXINA Andersen, 1984

Type species: *Texina ferayi* Andersen, 1984.

Emended Diagnosis: Test free, pitted with pits not juxtaposed, sides flattened, periphery rounded; wall three-layered with rods in middle layer exposed on the surface of the wall; planispirally coiled with two chambers per volution; aperture with trematophore.

TEXINA FERAYI Andersen
Figures 25-27

Spiroloculina smithvillensis FERAY, 1948, Dissertation, University of Wisconsin, 1948 *[nomen nudum].*

Texina ferayi ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 17, figs. 43-46.

Neaguites ferayi (Andersen). LOEBLICH and TAPPAN, 1988, Foraminiferal Genera and Their Classification: Van Nostrand Reinhold Co., Inc., vol. 1, p. 352, pl. 360, figs. 12-15.

Emended Diagnosis: Test planispiral, nearly round in outline, compressed; apertural end nearly flush with periphery; pits randomly distributed over unornamented chambers; *white spots appearing on outer wall between pits are ends of calcite rods in middle layer of test;* aperture at end of a short neck, with trematophore. Length of holotype: 0.48 mm; breadth 0.45 mm.

Remarks: A taxonomic mistake occurred when the genus *Texina* was described in 1984, four years before the discovery of the three-fold arrangement of the calcite in the walls of the Miliolacea. Loeblich and Tappan (1988, p. 352-353) placed *Texina* in synonymy with *Neaguites* because the "possible inclusions in the wall of *Texina*" might be the "result of secondary overgrowth due to diagenesis rather than an intrinsic part of the test structure." These "possible inclusions," appearing as round, white spots on the test wall, actually are the ends of calcite rods in the middle layer of the wall and, thus, are an intrinsic part of the structure of the test. These "spots" occur also in the wall of *Helentappanella punctatocostata* (Cushman) from the Moodys Branch Formation (see Figure 30), and *Miliola saxorum* (Lamarck) from Damery, France (see Figure 14).

Loeblich and Tappan, in their remarks on the genus *Texina*, state "*Neaguites* was described as having a simple aperture and *Texina* as having a cribrate one. However, the last chamber of the holotype is broken, hence the apertural characters are not shown in the original figures." (1988, p. 353). The first feature destroyed, when such a specimen is subjected to wear or weathering, commonly is the cribrate aperture. The holotype (Andersen, 1984, fig. 43) was selected for the well-preserved chambers. The paratype (*ibid.*, Figure 44), with a partially preserved aperture, reveals that *Texina* does have a cribrate aperture (see Figure 27 herein).

Subfamily HELENTAPPANELLINAE Andersen, new subfamily

Diagnosis: Wall ribbed with pits on ribs and in valleys between ribs; early chambers quinqueloculine, later added at 180°; aperture with trematophore. Eocene, North America.

Genus HELENTAPPANELLA Andersen, 1985

Type species: *Massilina jacksonensis* Cushman var. *punctatocostata* Cushman, 1933.

Emended Diagnosis: Test free, pitted, early chambers quinqueloculine, later chambers added at 180°, elliptical, compressed; periphery angular or rounded; wall three-layered with broad, pitted ribs.

HELENTAPPANELLA PUNCTATOCOSTATA
(Cushman)
Figures 28-30

Massilina jacksonensis Cushman var. *punctatocostata* CUSHMAN, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 1, p. 3, figs. 5, 6.

Tappanella punctatocostata (Cushman). ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 12, figs. 26-29.

Helentappanella punctatocostata (Cushman). ANDERSEN, 1985, Micropaleontology, vol. 31, p. 67 [new name for *Tappanella* Andersen *non* Gudina and Saidova, 1969.

Emended Diagnosis: Test broadly elliptical to nearly round, much compressed, periphery ranging from acute to slightly rounded depending on position of *pitted ribs* relative to periphery; apertural end extending slightly beyond penultimate chamber; early chambers quinqueloculine, later ones added at 180° in a single plane; surface ornamented with low, flat, *wide ribs* oriented either parallel to long axis of chamber or cutting diagonally across chamber; sutures difficult to discern because of *ribs;* aperture with trematophore at end of a short neck. Length of figured specimen: 2.95 mm; breadth 2.05 mm.

Subfamily MILIOLACOSTATINAE Andersen, new subfamily

Diagnosis: Wall pitted, costate; pits aligned between acute costae; aperture simple. Eocene and Oligocene, North America.

Genus MILIOLIACOSTATA, new genus

Type species: *Miliola jacksonensis* Cushman, 1933.

Diagnosis: Wall with longitudinal costae, pits juxtaposed in valleys between costae; quinqueloculine chamber arrangement; test fusiform with base rounded; aperture terminal, simple, and elevated on a short neck which extends above penultimate chamber.

MILIOLACOSTATA JACKSONENSIS (Cushman)
Figures 33, 34

Miliola jacksonensis CUSHMAN, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. l, p. 2, pl. 1, figs. 2, 3; CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 13, pl. 3, figs. 4-6; CUSHMAN and TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, pt. 4, p. 83, pl. 13, fig. 13; BANDY, 1949, Bull. Amer. Paleontology, vol. 32, no. 131, p. 22, pl. 2, figs.

Figures 6-17

Subfamily MILIOLINAE Ehrenberg, 1839

Miliola alphillipsi Andersen
6. Lateral view X 50
7. Enlargement of pits X 1000

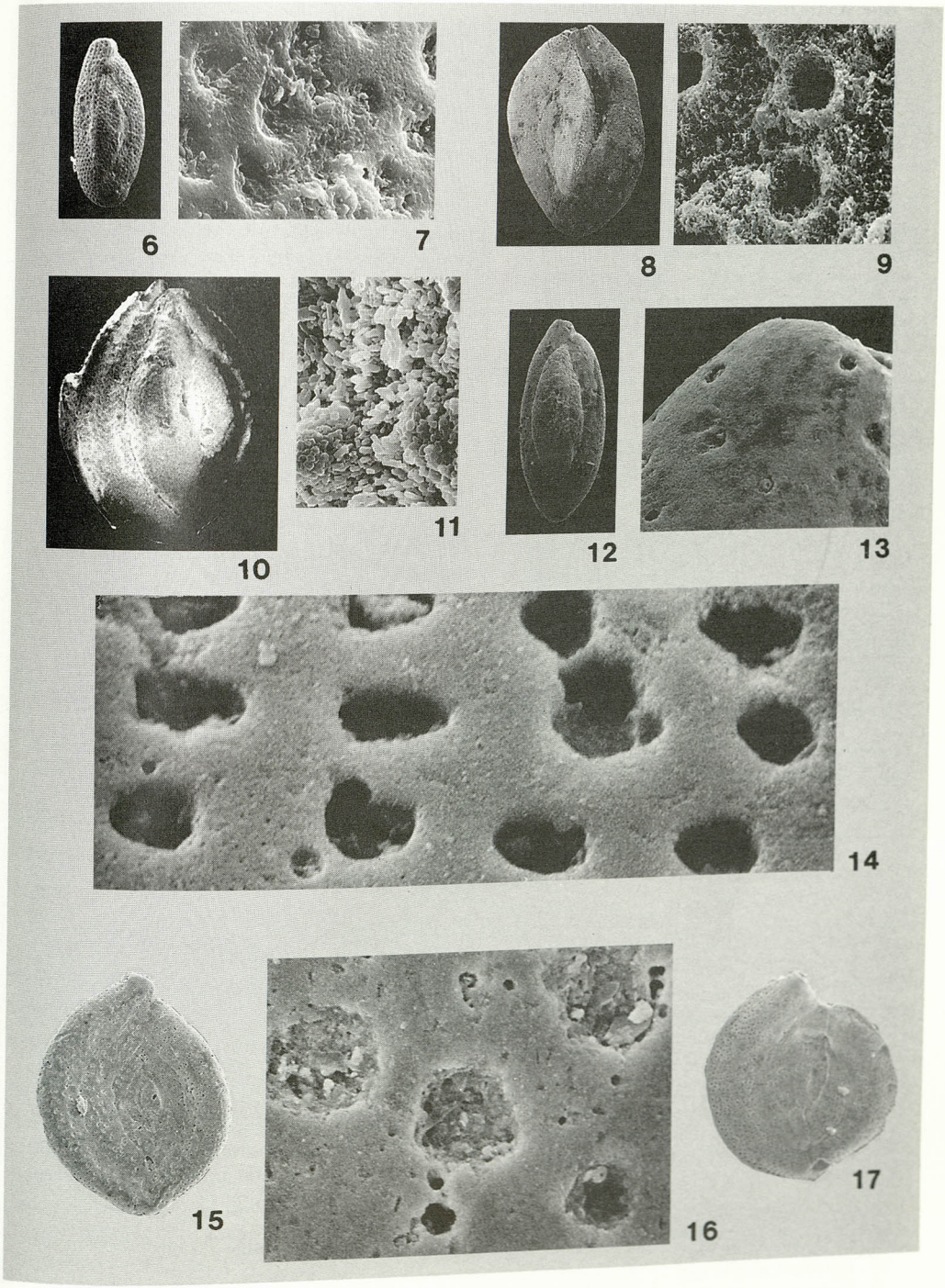
Miliola chipolensis (Cushman and Ponton)
8. Lateral view X 75
9. Enlargement of pits X 1000

Miliola newberryensis (Puri)
10. Lateral view X 50
11. Enlargement of pits X 1000

Miliola saxorum (Lamarck)
12. Lateral view X 33
13. Enlargement of pits X 1000
14. Calcite rods from middle layer of wall exposed on surface of the test X 2000

Subfamily HEMIMILIOLINAE Andersen, new subfamily

Hemimiliola jacksonensis (Cushman)
15. Lateral view X 25
16. Enlargement of pits X 1500
17. Lateral view of carinate form X 25



Figures 6-17

6a-c; ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 5, figs. 17-19.
Miliola cf. *M. jacksonensis* FRANKLIN, 1944, Journ. Paleontology, vol. 18, pl. 45, fig. 6; ANDERSEN, 1988, Tulane Stud. Geol. Paleont., vol. 21, no. 4, p. 134, fig. 25.

Emended Diagnosis: Test large, *elongate,* fusiform, *quinqueloculine chamber arrangement;* chambers numerous, distinct, pitted; *base of pits with one or more pores; acute costae with uniformly spaced transverse ridges that separate juxtaposed pits between costae;* aperture at end of a very short neck, cribrate. Length 2.00 mm; breadth 0.55 mm.

MILIOLACOSTATA BYRAMENSIS (Cushman)
Figures 31, 32

Quinqueloculina byramensis CUSHMAN, 1923, U. S. Geol. Surv., Prof. Paper 133, p. 54, pl. 8, fig. 3.
Miliola byramensis (Cushman). ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 8, figs. 20-22.

Emended Diagnosis: Test quinqueloculine, approximately twice as long as broad, final chamber projecting slightly beyond penultimate chamber at both ends of test; *wall with acute* elevated costae longitudinally disposed; *pits forming a single line in valley between costae with eyelets in costae occupying space between pores;* aperture simple, on a short neck. Length 0.3 mm to 0.4 mm.

MILIOLACOSTATA ROLANDI (Andersen)
Figures 35, 36

Miliola rolandi ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 8, figs. 24, 25.

Emended Diagnosis: Test small, *costate,* elongate, approximately 2.5 times as long as broad, quinqueloculine; base rounded, final chamber extending above penultimate chamber; periphery rounded; *single row of pits in each valley between costae with each pit occupying position of space between pits in the adjacent valley;* aperture simple, at end of a very short neck. Length of figured specimen: 0.54 mm; breadth 0.20 mm.

Genus PICOUINA Andersen, 1984

Type species: *Triloculina mississippiensis* Cushman, 1935.

Original Diagnosis: "Test free, triloculine chamber arrangement; wall calcareous perforate; chambers with a series of pits with single perforation extending into the chamber; aperture cribrate." (Andersen, 1984)

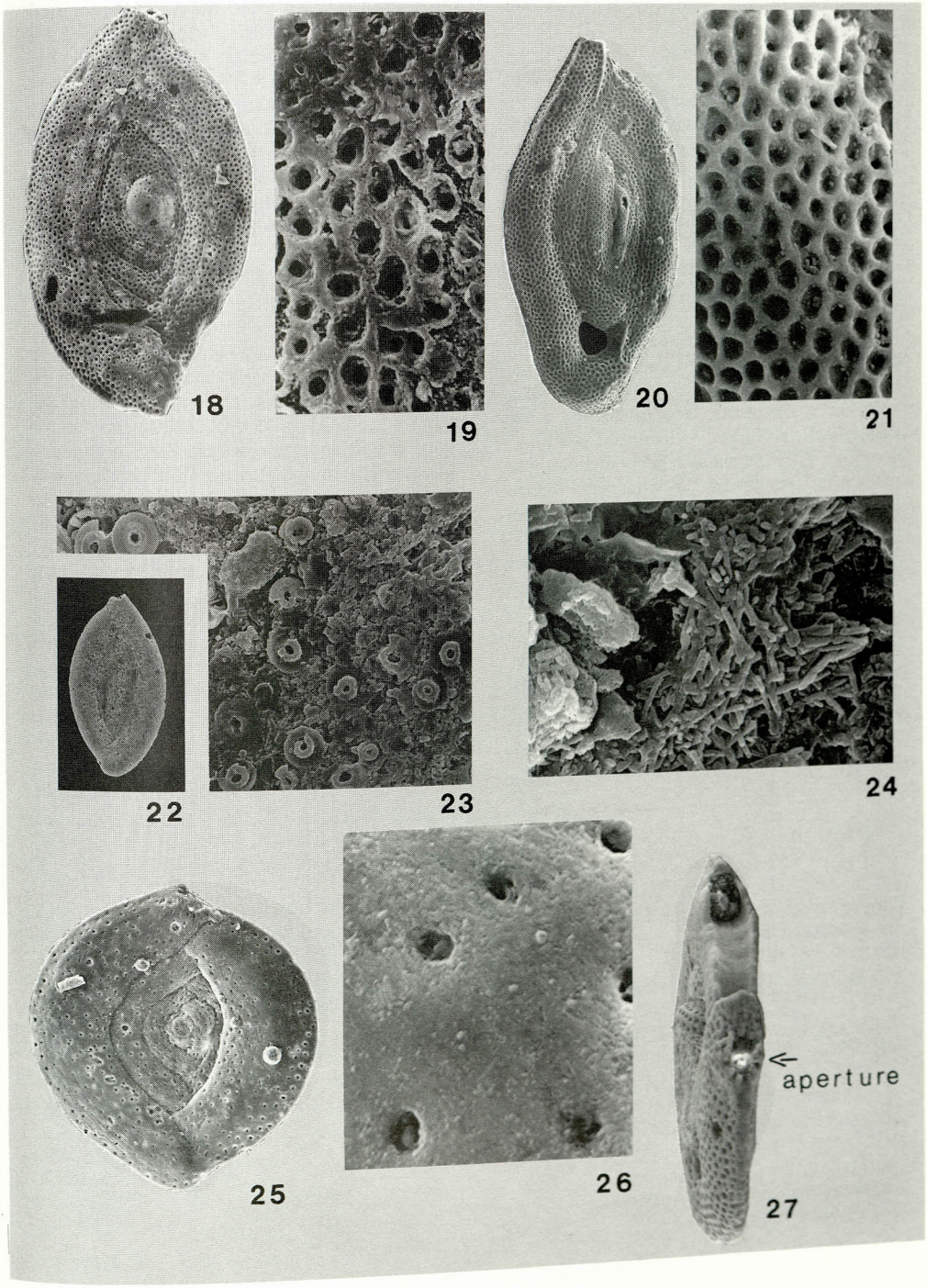
PICOUINA MISSISSIPPIENSIS (Cushman)
Figures 37, 38

Triloculina mississippiensis CUSHMAN, 1935, Cushman Lab. Foram. Res., Contr., vol. 11, pt. 2, p. 25.
Picouina mississippiensis (Cushman). ANDER-

Figures 18-27

Subfamily NEAGUITINAE Andersen, 1984
Neaguites byramensis (Cushman)
18. Lateral view X 113
19. Enlargement of pits X 1000
Neaguites inusitatus Andersen
20. Lateral view X 150
21. Enlargement of pits X 1000
Heteromiliola decorata (Cushman)
22. Lateral view X 50
23. Enlargement of wall showing "reel-shaped" structures and adherent coccoliths X 1000
24. Enlargement showing the rodlike structures or crystals in the middle layer of test wall X 3750

Subfamily TEXININAE Andersen, new subfamily
Texina ferayi Andersen
25. Lateral view X 125
26. Enlargement of pits X 1000
27. Apertural view of paratype showing residual segment of cribrate aperture X 225



Figures 18-27

SEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 14, figs. 34, 35.

Original Diagnosis: "Test elongate, fusiform, broadly rounded in end view, both ends of the chambers extending well beyond the previous ones; chambers fairly distinct, very elongate, semicircular in transverse section, periphery broadly rounded; sutures rather indistinct; wall ornamented with numerous, 10-12, longitudinal costae running the entire length of the chamber, with fine rectangular pits in the grooves between the costae, of uniform size and regular position; aperture small, nearly circular, with a slight, rounded lip. Length 0.60-0.65 mm; breadth 0.15 mm; thickness 0.12 mm." (Cushman, 1935)

Emended Diagnosis: "Test calcareous, perforate, small, elongate, triloculine; periphery broadly rounded; chambers fairly distinct, interior simple, semicircular in transverse section; final chamber extending well beyond the penultimate chamber, apertural end pointed; wall ornamented with numerous longitudinal costae extending the entire length of the chamber, very fine, circular, uniform sized pits in grooves between costae; sutures indistinct due to the costate ornamentation; aperture cribrate." (Andersen, 1984). Figured specimen: Length 0.60-0.65 mm; breadth 0.15 mm; thickness 0.15 mm.

Remarks: The holotype of *Triloculina mississippiensis* Cushman, as described and figured in 1935, has an "aperture small, nearly circular, with a slight, rounded lip." Our figured specimen of *Picouina mississippiensis* (Cushman) exhibits a cribrate aperture; thus, our specimen does not agree with Cushman's interpretation of this species.

IV. NEW SUPERFAMILY

Superfamily HAUERINACEA Andersen, new superfamily

Diagnosis: Wall calcareous, porcelaneous in reflected light; test coiled, with two or more chambers per volution in varying planes about the longitudinal axis, may become involute or may uncoil; some forms may have secondary partitions within the chambers; aperture with trematophore or simple. Upper Triassic to Holocene.

Remarks: The emendation of the Superfamily Miliolacea [see above] to include only those forms with punctations and pores within the wall structure makes necessary the establishment of a new superfamily to accommodate those forms formerly included in the Superfamily Miliolacea which have a calcareous porcelaneous wall and lack perforations or pores. Thus, this division will eliminate

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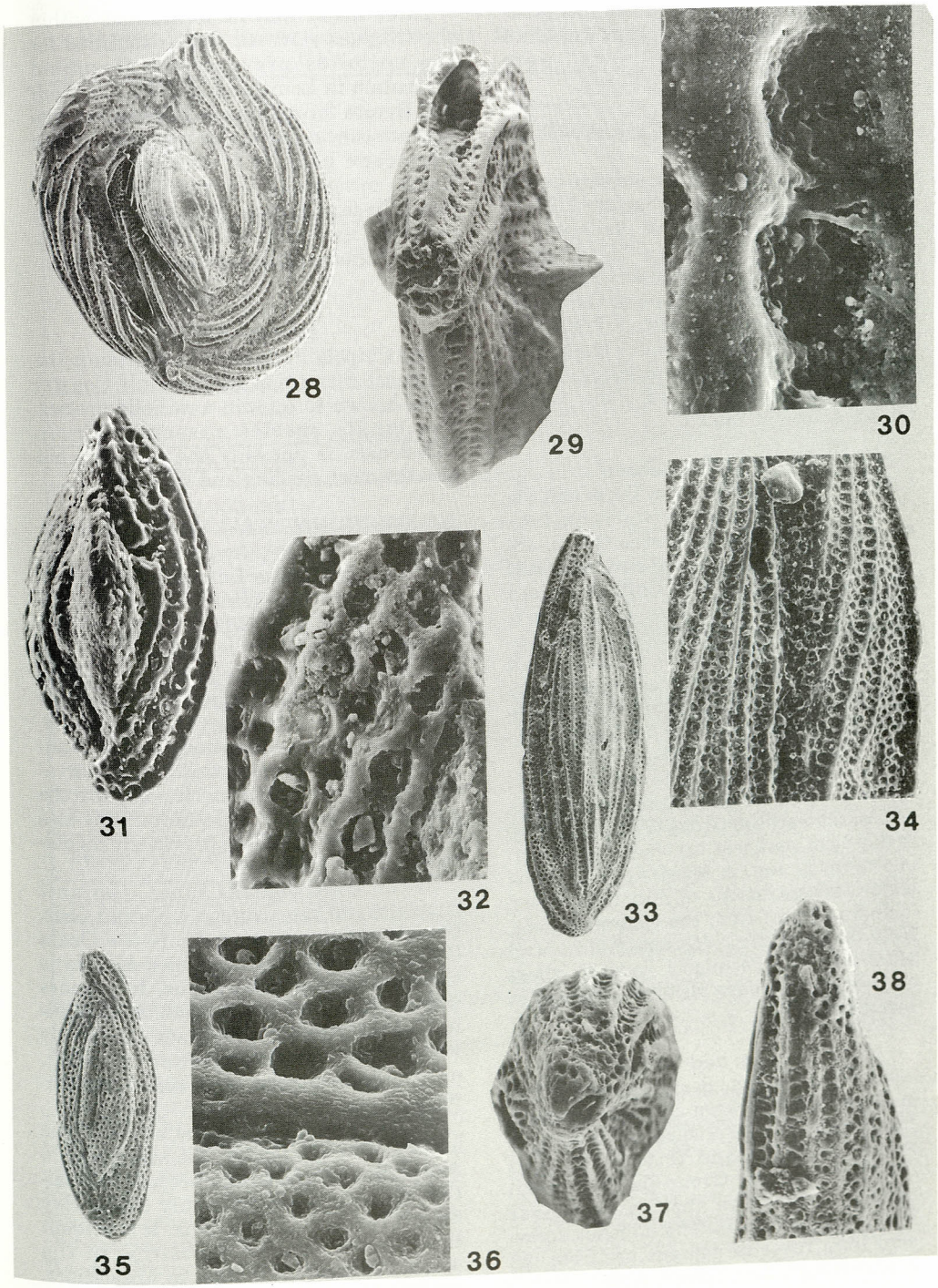
Figures 28-38

Subfamily HELENTAPPANELLINAE Andersen, new subfamily
Helentappanella punctatocostata (Cushman)
28. Lateral view X 25
29. Apertural view X 100
30. Enlargement of pits, showing pores at base of pits X 1000

Subfamily MILIOLACOSTATINAE Andersen, new subfamily
Miliolacostata byramensis (Cushman)
31. Lateral view X 150
32. Eyelets in costae X 500
Miliolacostata jacksonensis (Cushman)
33. Lateral view X 33
34. Enlargement of costae and pits X 80
Miliolacostata rolandi (Andersen)
35. Lateral view X 50
36. Enlargement of pits X 1000
Picouina mississippiensis (Cushman)
37. Apertural view X 300
38. Side view of aperture X 200



Figures 28-38

the anomalous dichotomy which has existed within the Superfamily Miliolacea since the first "perforate miliolids" were described.

V. STRATIGRAPHIC OCCURRENCES

With the exclusion of imperforate porcelaneous Foraminiferida from the Miliolidae, the geological range of the family in the marine deposits of the Gulf Coastal Plain is from the lower Claiborne [Eocene] to the Miocene strata. None of the pitted forms have been reported from the Holocene of the Gulf of Mexico. The known distribution of genera and species from representative Gulf Coastal Plain formations is shown in Table II.

Basal Claiborne Group

The Weches Formation in Texas and the Cane River Formation in Louisiana, both from the base of the Claiborne Group, are the oldest lithologic units in the Gulf Coastal Plain known to contain genera from the Family Miliolidae. *Texina ferayi* Andersen is one of the miliolid species present in the Weches Formation and *Heteromiliola decorata* (Cushman) is the only miliolid species reported from the Cane River Formation (see Table II).

Basal Jackson Group

The Moodys Branch Formation, at the base of the Jackson Group [Eocene Series], is the next youngest lithologic unit bearing miliolids and, in Mississippi, contains major concentrations of miliolid species, including forms from the genera *Miliola, Helentappanella, Hemimiliola,* and *Miliolacostata.* Peculiarly, however, there are none in Moodys Branch outcrops in Louisiana.

Upper Jackson and Ocala Groups

The Upper Eocene Series consists of formations in the Jackson and Ocala groups. The lithologic units studied for this report are the Shubuta and Yazoo formations from the Jackson Group in Mississippi and Alabama, and the Crystal River Formation in Florida. The miliolids recovered from these formations are from the genera *Miliola* and *Heteromiliola.*

Oligocene Series

Three major marine formations within the Oligocene strata were examined for the miliolids present: the Rosefield Formation in Louisiana and the Red Bluff and Byram formations in Mississippi. The highest concentration of miliolids in the Oligocene beds is from the Glendon-Byram outcrop on the right bank of the Pearl River at Byram, Mississippi. Genera present include: *Miliola, Neaguites, Heteromiliola, Miliolacostata,* and *Picouina.*

Miocene Series

The Chipola Formation in Florida is the youngest formation in the Gulf Coastal Plain known to contain a miliolid species. The single species present, *Miliola chipolensis,* is not only the youngest but also the most striking and different.

VI. ENVIRONMENTAL IMPLICATIONS

The upper marine Lutetian outcrops in France are the type area for the Miliolidae and the beds from which the genotype species, *Miliola saxorum,* was described by Lamarck in 1804. Samples collected at the park of the National School of Agriculture at Grignon, France, are from a friable, sandy limestone renowned for the numbers of species present and the preservation of these microfossils. Not only are the true Miliolidae well represented but also the porcelaneous genera previously included within the miliolids.

In the Gulf Coastal Plain, the unit equivalent to the Grignon Lutetian beds, though not quite as sandy, is the Ocala Group in Florida within which *Miliola* is the dominant miliolid genus. It appears that the preferred environment where miliolids flourished, thus, is a relatively warm and shallow [inner neritic], extremely calcareous, near reefal environment.

West of Florida, along the strike of the Jackson Group outcrops, the sediments in Alabama and Mississippi become less calcareous with essentially only marly clay deposits present in Louisiana. It is evident that, at the time of deposition of the Moodys Branch Formation in Mississippi, the waters were not sufficiently calcareous to accommodate the presence of *Neaguites, Heteromiliola, Miliolacostata,* and

TABLE II

Miliolidae Genera and Species in the Gulf Coastal Plain

GENERA AND SPECIES	EOCENE					OLIGOCENE			MIOCENE
	Weches Fm.	Cane River Fm.	Moodys Branch Fm.	Yazoo Fm.	Crystal River Fm.	Rosefield Fm.	Red Bluff Fm.	Byram Fm.	Chipola Fm.
Miliola alphillipsi								●	
" chipolensis								?	●
" newberryensis					●				
" saxorum			●	●					
Hemimiliola jacksonensis			●						
Neaguites byramensis								●	
" inusitatus							●		
Heteromiliola decorata		●		●		●	●	●	
Texina ferayi	●								
Helentappanella punctatocostata			●						
Miliolides byramensis								●	
" jacksonensis			●						
" rolandi								●	
Picouina mississippiensis								●	

Picouina. These four genera, based upon their association with pelagic genera, are adapted to life in the middle to outer neritic zones. It is curious that the Moodys Branch Formation in Louisiana lacks miliolid species though the lithologies of the Moodys Branch Formation in Louisiana and Mississippi are essentially the same.

VII. ACKNOWLEDGMENTS

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