TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 21, Number 4 October 12, 1988

GULF COASTAL PLAIN PITTED MILIOLACEA AND RELATED SPECIES IN GRIGNON AND DAMERY, FRANCE

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I. ABSTRACT

Ten species of pitted Miliolacea from Grignon and Damery, France, are described and illustrated. These forms provide a model to which species from the Gulf Coastal Plain can be compared.

Twenty-four related species of foraminifera from the Gulf Coastal Plain are listed in Table I; fifteen of these are illustrated herein. The remaining nine species were described and illustrated by Andersen in 1984.

One new species, *Miliola alphillipsi*, from the type locality of the Byram Formation (Oligocene, Mississippi) is described.

The genus *Heterillina* Munier-Chalmas and Schlumberger is recognized as a form with a costate and pitted wall. The chamber arrangement is massiline and the aperture is cribrate.

Quinqueloculina stavensis Bandy, from the Yazoo Formation (Upper Eocene) at Little Stave Creek, Alabama, is regarded as a junior synonym of *Miliola saxorum* (Lamarck); *Massilina decorata* Cushman is placed in the genus *Neaguites* Andersen; and *Neaguites lamposus* (Hussey), from the Cane River Formation (Lower Eocene) in Louisiana, is considered a junior synonym of *Neaguites decoratus* (Cushman).

The concluding discussions pertaining to the pitted Miliolacea covers the following subjects: the enigmatic "knobs and doughnut-shaped elements" on the weathered wall of the test; the geological and geographical distribution of the genera;

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the environmental implications; and, the Paris Basin species also present in the Gulf Coastal Plain.

II. INTRODUCTION

Cushman reported the presence of *Miliola saxorum* (Lamarck) in the Upper Eocene of the Gulf Coastal Plain in 1935. This, the type species of *Miliola*, originally was reported from the Lutetian of the Paris Basin, France, where many additional species of the genus occur. It is remotely possible that species other than *Miliola saxorum* or its relatives might have been overlooked.

In order to test this thesis, ten specimens of Miliolacea from Grignon and Damery, France, with structural differences at the species level were photographed with a scanning electron microscope. This established a reference model that could be used to compare the Gulf Coastal Plain species with those reported from the Paris Basin in France.

For all genera here included, the chambers of the test are pitted with pores present either within the pits and/or elsewhere in the chamber walls. In addition, the aperture is cribrate (generally delicate and seldom preserved exhibiting more than a remnant) and the wall is costate. For example, if a quinqueloculine Paleogene foraminifer has pits and costae present, it should be assigned to *Miliola* even though the cribrate aperture can not be verified.

Chamber arrangement is considered of primary importance in defining genera. But in the present study, concerned primarily with foraminifera at the species level, shape and test size are relevant. However, it is advised that test size *per se* is useful only when comparing specimens from similar environments. As hostile environments may result in reduced average size in species, the length-width ratio becomes a more important parameter. For the present study (comparing pitted Gulf Coastal Plain species with pitted European species), it is proposed that the size, shape, and distribution patterns of pits in the chamber walls and the relation of the pits to costae when present constitute the most important features to differentiate species of pitted Mioliolacea. Enlarged electron photomicrographs revealing these features are stressed in the abridged descriptions of the Mioliolacea from the Paris Basin, France.

Lutetian Samples from the Paris Basin

Participation in the American Geological Institute Paris Basin Field Trip in 1965, conducted by Maurice Lys and Samuel P. Ellison, Jr., enabled this writer to collect samples from two Lutetian localities, at Grignon and Damery, France. The type species of many genera have been described from these two famous localities where the Lutetian "calcaire grossier", a thick Eocene limestone equivalent to Middle Eocene strata in the Gulf Coastal Plain, is exposed.

Charles Pomerol prepared the geological itinerary for the Grignon and Damery portion of the Paris Basin field trip. The Grignon locality (after A. F. de Lapparent) was described in the guidebook as follows:

> "A marl quarry located in the park of the National School of Agriculture at Grignon, 200 meters to the left of the buildings. Recent exploitation has passed beyond the most fossiliferous zone which has furnished more than 1,000 species. However, we can still collect numerous shells in a remarkable state of preservation. The cut of the marl mine shows three levels. The lower level is a glauconitic sandy limestone, very fossiliferous and belonging to the Lower Lutetien (Zone III)."

The sample collected is considered to be from the base of Zone III.

The locality at Damery, France, is upper marine Lutetian. It was described in the guidebook as follows:

> "The red Cuisian sands are directly covered by sandy limestone of a part of the the Upper Lutetien (Zone III). The sandy limestone contains an abundant microfauna, particularly rich in *Milioles*."

A sample of this sandy limestone was examined for this report.

Gulf Coastal Plain Samples Neither Examined nor Re-examined

The basal Jacksonian Inglis Formation of the Ocala Group (Upper Eocene, Florida) is the time equivalent of the Moodys Branch Formation (Upper Eocene, Mississippi). This limestone is exposed in various pits and quarries near Inglis, Levy County, Florida. In 1947, Puri recorded a tremendous invertebrate fauna from this limestone and described *Quinqueloculina ocalana* from cuttings in well 347. This species should have been placed in *Miliola* as the test surface is pitted and costate. *Miliola ocalana* (Puri) is included in Table I (Distribution of Pitted Miliolacea in the Gulf Coastal Plain).

Andersen (1984, p. 2) discussed and described sample collection localities in the Weches and Cane River formations (Claibornian, Middle Eocene) and the Moodys Branch Formation (Jacksonian, Upper Eocene). These stations were not re-examined for the present study, although the faunas from all three localities are included in Table I.

Gulf Coastal Plain Paleogene Samples Re-examined

Paleogene samples examined or re-examined for this report range from Upper Eocene through the Oligocene in age. The localities listed are in sequence from oldest to youngest (except when contemporaneous).

Crystal River Formation samples were supplied by Steve Windham, Bureau Chief, Bureau of Geology at Tallahassee, Florida. The sample studied is from the *Amusium* bed in a white chalky limestone, Locality PM-3, the Kendrick pit of the Cummer Lime and Manufacturing Company, Kendrick, Marion County, Florida (Puri, 1957, p. 2). At this outcrop, about forty feet of Crystal River Formation, Ocala Group, are exposed.

The Yazoo Formation (Upper Eocene) sample used is LSU Geoscience Museum No.-447, from Little Stave Creek (Sec. 21, T7N, R2E), Clarke County, Alabama. It was collected by Lewis Nichols from the basal clay of the Yazoo Formation, approximately five feet above the top of the Moodys Branch Formation.

The type section of the Shubuta Formation (Upper Eocene) is located in SW 1/4 Sec. 29, T10N, R5W, Wayne County, Mississippi. The sample was taken from a marl exposed along the west side of Shubuta Hill, eight to ten feet above high water level in the Chickasawhay River, east of Shubuta, Mississippi.

The Danville Landing section (Upper Eocene), consisting of two fossiliferous beds, was described by Veatch (1902, p. 167). Danville Landing is on the Ouachita River in Catahoula Parish, Louisiana, just south of the Caldwell-Catahoula parish line. The upper bed in this section, studied from samples available at LSU in the 1950's, was much more fossiliferous than the lower bed. This upper bed, consisting of light yellow fossiliferous clay, was lost to bank erosion by the Ouachita River fifty or more years ago.

The Red Bluff Formation (Oligocene) samples came from two localities. Most of the specimens studied here are from samples collected in the 1950's and 1960's from an outcrop located between the Hiwannee Railroad station and the Chickasawhay River. Today, the railroad station has been moved and the outcrop is covered and inaccessible. The second sample, Geology Museum Locality (GML) 447, is from the west bank of the Chickasawhay River in SW 1/4 Sec 28, T7N, R10W, Wayne County, Mississippi. This is close to the type locality of the Red Bluff Formation and in 1948, when the sample was collected, the section was considered better than the type section of the Red Bluff. The sample studied is from the glauconite ledge just above the disconformity separating the Red Bluff from the Upper Jackson.

The Rosefield Formation (Oligocene) sample is from Shell Branch, 2 1/2 miles south of Rosefield, Catahoula Parish, Louisiana.

The Glendon Formation (Oligocene) sample is from the type locality of the Byram Formation. The sample studied, a gray silty clay, is exposed beneath the indurated ledge at the base of the Byram Formation at extreme low water level in the Pearl River.

The Mint Springs Marl (Oligocene) material, GML 131A - sample 1, was collected beneath a waterfall on Glass Bayou located across the street from a residence at 611 North Cherry Street, within the city of Vicksburg, Mississippi.

Most of the pitted Miliolacea figured in this report came from the type locality of

TABLE 1

Distribution of Pitted Miliolacea in the Gulf Coastal Plain

GULF COASTAL PLAIN SPECIES	EOCENE								OLIGOCENE						M
	Weches Formation	Cane River Fm.	Inglis Formation	Moodys Branch Fm.	Crystal River Fm.	Yazoo Formation	Shubuta Formation	Danville Landing	Chickasawhay Marl	Mint Springs Fm.	Rosefield Fm.	Red Bluff Fm.	Glendon Formation	Byram Formation	Chipola Formation
Miliola chipolensis (Cushman & Ponton)															O
" byramensis (Cushman)												O		●	O
" cf. M. chipolensis														O	
" rolandi Andersen												●			
" alphillipsi, new species														O	
" cf. M. saxorum					O							O			
" sp. A														O	
" sp. B														O	
" sp. C									O						
" cf. M. jacksonensis						O									
Quinqueloculina tessellata Cushman										O				O	
Picouina mississippiensis (Cushman)														●	
Neaguites byramensis (Cushman)														●	
" inusitatus Andersen												●			
" imprimatus (Cushman)														●	
" sp. A												O		O	
" decoratus (Cushman)*		●				O	O	O	O	O	O	O	O	O	
Miliola newberryensis (Puri)					O										
" saxorum (Lamarck)				●											
" jacksonensis (Cushman)				●											
" ocalana (Puri)			O												
Heterillina jacksonensis (Cushman)				●		?									
" punctatocostata (Cushman)				●											
Texina ferayi Andersen	●														

● Described and illustrated in Tulane Stud. Geol. Paleont., vol. 18, no. 1, October 31, 1984.

* Described as Neaguites lamposus (Hussey) by Andersen in 1984.

the Byram Formation, just north of the bridge on the Pearl River, east of Byram, Mississippi. Low water exposes an indurated ledge which may represent an unconformity between the Byram and the underlying Glendon Formation. The sample studied is from the glauconitic marl above the indurated ledge. It was very carefully washed by decantation to prevent destruction of the fragile tests of the pitted Miliolacea recovered from this sample.

The Chickasawhay Marl (Oligocene) sample studied is from one of the fossiliferous clays in an exposure on State Highway 29, 1.4 miles north of Millry, Washington County, Alabama.

Gulf Coastal Plain Neogene Samples Examined

The only Neogene material included in this report is from the Chipola Formation (Miocene) in peninsular Florida. The material studied, GML 852, is from an outcrop of the Chipola Formation (Alum Bluff Group) on Ten Mile Creek near Baileys Ferry on the Chipola River, Calhoun County, Florida.

Repository for Figured Specimens

All of the figured specimens are deposited in the Geoscience Museum collections at Louisiana State University (LSU GM).

III. DESCRIPTION OF LUTETIAN FORAMINFERS, PARIS BASIN, FRANCE

Family MILIOLIDAE Ehrenberg, 1839

Subfamily MILIOLINAE Ehrenberg, 1839

MILIOLA SAXORUM (Lamarck)
Figures 1-3

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

Quinqueloculina saxorum (Lamarck). D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 301, pl. 16, figs. 10-14; TERQUEM, 1882, Mem. Soc. Geol. France, ser. 3, vol. 2, p. 181, pl. 19, fig. 22.

Miliola saxorum (Lamarck). CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 12, 13, pl. 3, figs. 1-3; Y. LE CALVEZ, 1947, Mem. Expl. Carte Geol. France, pt. 1, p. 30; KAASSCHIETER, 1961, Inst. Royal Sci. Nat. Belgique, Mem. 147, p. 161, pl. 4, figs. 25-27, pl. 5, fig. 1; Y. LE CALVEZ, 1970, Centre Natl. Rech. Sci., Paris, p. 43, pl. 6, fig. 3.

Abridged Description: Quinqueloculine chamber arrangement; length slightly over two and one-half times width; periphery rounded; no costae; enlarged electron photomicrograph shows irregularly shaped pits aligned with the long axis of the test, distributed at about the diameter of one pit apart; pores visible in pits not filled with debris; aperture cribrate. Length of specimen No. 10,511 from Grignon (Figure 1), 1.5 mm; width 0.60 mm.

Remarks: An electron photomicrograph of the fractured and weathered wall on a specimen of *Miliola saxorum* from Damery shows the surface layer of the test wall overlying a mass of rodlike structures (crystals, enlarged in Figure 3), and two weathered pits. The orientation of crystals in the outer layer of the test (see left side, Figure 2) is not revealed; however, an electron photomicrograph of "*Quinqueloculina*" *tuberculata* (not figured) shows that it consists of a single layer of interlocked, elongate, flat crystals, aligned parallel to the contours of the test; the second or middle layer consists of a thick mass of short, rodlike crystals randomly oriented; and, the third or inner layer, possibly exposed at the base of the pits, appears to be similar to the surface layer. This three-layered test wall is believed to be characteristic of all members of the pitted Miliolacea lineage.

MILIOLA TERQUEMI Andersen, n. sp.
Figures, 4, 5

Miliola prisca (d'Orbigny) var. *terquemi* KAASSCHIETER, 1961, Inst. Royal Sci. Nat. Belgique, Mem. 147, p. 164, pl. 5, fig. 7a-c.

Abridged Description: Quinqueloculine chamber arrangement; length about one and one-half times width; chambers carinate; generally smooth except for one specimen (see No. 10,514, Figure 5) with a single costa on the chamber wall; enlarged wall of test shows that the pits are small, elliptical in outline and randomly distributed over the surface of the test, spaced about one-half to one pit diameter apart; pores not discernible in pits; aperture cribrate. Length of holotype (specimen No. 10,513), from Grignon, 0.63 mm; width 0.43 mm.

Remarks: After 1960, varieties have no standing in zoological nomenclature (see ICZN art. 16). Thus, the name designated by Kaasschieter for his "variety" is invalid as proposed. The species-group taxon *terquemi* is validated herein, is elevated to the species level, and is recognized as distinct from *Miliola prisca* (d'Orbigny).

MILIOLA cf. M. BIROSTRIS (Lamarck)
Figure 6

Miliolites birostris LAMARCK, 1804, Ann. Mus., Hist. Nat., vol. 5, p. 353.

Quinqueloculina birostris (Lamarck). TERQUEM, 1882, Mem. Soc. Geol. France, ser. 3, vol. 2, p. 181, pl. 19, fig. 23; Y. DE CALVEZ, 1947, Mem. Expl. Carte Geol. France, pt. 1, p. 8, pl. 1, figs. 4-6.

Miliola birostris (Lamarck). Y. LE CALVEZ, 1952, Mem. Expl. Carte del France, pt. 4, pl. 46; KAASSCHIETER, 1961, Inst. Royal Sci. Nat. Belgique, Mem. 147, p. 162, pl. 5, fig. 2.

Abridged Description: Quinqueloculine chamber arrangement; length about four times width; periphery rounded except at distal end of test, which is carinate; costate near proximal end of final chamber; enlarged surface of test wall shows that the pits are round, closely spaced, and longitudinally aligned; pores present in pits; aperture poorly preserved, probably cribrate. Length of specimen No. 10,515 from Grignon (Figure 6), 1.16 mm; width 0.30 mm.

MILIOLA sp. 1
Figure 7

Description: Quinqueloculine chamber arrangement; length about one and two-thirds times width; periphery rounded; costate; enlarged electron photomicrograph shows the surface of the test with transverse bridges between longitudinal costae compartmentalizing the single rows of elliptically shaped pits; pores not visible in pits; aperture cribrate. Length of specimen No. 10,516 from Grignon (Figure 7), 0.80 mm; width 0.50 mm.

Remarks: This specimen has the test shape of *Miliola prisca* (d'Orbigny) as illustrated by Kaasschieter (1961, pl. 5, fig. 4) and the striae described by Kaasschieter for *M. prisca strigilla* (d'Orbigny) (1961, pl. 5, fig. 6). However, his illustration of the subspecies is nearly as wide as long, which differs from *Miliola* sp. 1.

MILIOLA sp. 2
Figure 8

Description: Quinqueloculine chamber arrangement; length a little more than twice width; periphery rounded; costae thin and slightly elevated above test surface; enlarged electron photomicrograph shows pits arranged

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FIGURES

1-3. *Miliola saxorum* (Lamarck)
    1. Lateral view, X 25 (LSU GM No. 10511)
    2. Layering within wall and weathered pits, X 1000 (LSU GM No. 10,512)
    3. Orientation of crystals within middle layer of wall, X 5000 (LSU GM No. 10,512)

4. *Miliola terquemi* Andersen, n. sp. (LSU GM No. 10,513)
   Lateral view, X 50
   Enlargement of pits, X 1000

5. *Miliola terquemi* Andersen, n. sp. (LSU GM No. 10,514)
   Lateral view, X 50

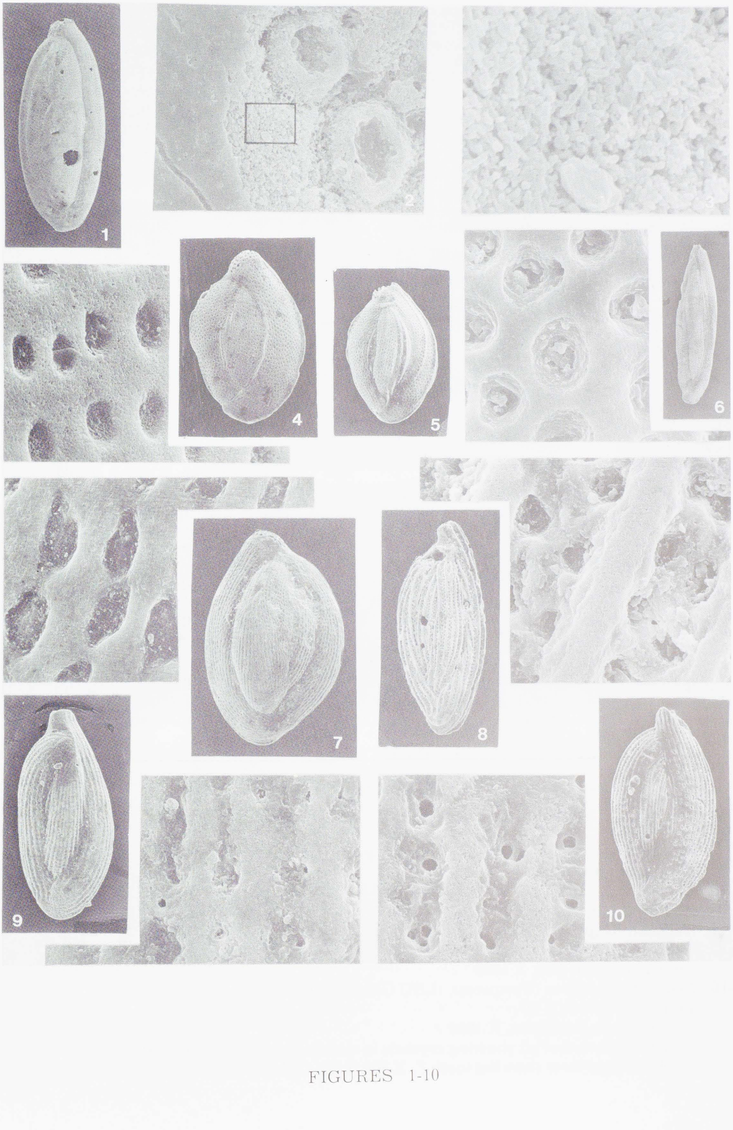
6. *Miliola* cf. *M. birostris* (Lamarck). (LSU GM No. 10,515)
   Lateral view, X 25
   Enlargement of pits, X 1000

7. *Miliola* sp. 1. (LSU GM No. 10,516)
   Lateral view, X 50
   Enlargement of pits, X 1000

8. *Miliola* sp. 2. (LSU GM No. 10,517)
   Lateral view, X 50
   Enlargement of pits, X 1000

9. *Miliola* sp. 3. (LSU GM No. 10,518)
   Lateral view, X 50
   Enlargement of pits, X 1000

10. *Miliola* sp. 3 ?. (LSU GM No. 10,519)
    Lateral view, X 50
    Enlargement of pits, X 1000



FIGURES 1-10

two abreast in longitudinal rows between costae; pores present in pits; aperture poorly preserved, probably cribrate. Length of specimen No. 10,517 from Grignon (Figure 8), 0.80 mm; width 0.35 mm.

MILIOLA sp. 3
Figures 9, 10

Description: Quinqueloculine chamber arrangement; length more than twice width; periphery rounded; costate; pores present in some pits; enlarged electron photomicrograph shows a single row of pits between costae with spacing not determinable due to weathering; aperture elevated on a neck extending above penultimate chansiline chamber arrangement and the pit distribution pattern (more clearly defined) is the same. Length of specimen No. 10,519, 0.76 mm; width 0.38 mm.

PICOUINA sp.
Figure 11

Description: Triloculine chamber arrangement; length about one and one third times width; periphery broadly angular; surface smooth; enlarged electron photomicrograph shows that the pits are elongated elliptical depressions aligned longitudinally; pores not apparent in pits; aperture cribrate. Length of specimen No. 10,520 from Grignon (Figure 11), 0.83 mm; width 0.58 mm.

HETERILLINA sp. 1
Figure 12

Description: Massiline chamber arrangement; length about one and two-thirds width; sides of test flattened; periphery rounded; costate; enlarged electro photomicrograph shows single row of pits between costae; pores present in pits; aperture flush with base of penultimate chamber; aperture poorly preserved, indeterminate. Length of specimen No. 10,521 from Damery (Figure 12), 0.90 mm; width 0.55 mm.

Remarks: This species differs from the abnormal specimen of *Miliola* sp. 3 in having an aperture flush with the base of the penultimate chamber and in the absence of transverse bridges connecting adjacent costae.

HETERILLINA sp. 2
Figure 13

Description: Massiline chamber arrangement; length slightly greater than width; test with flattened sides; periphery acute; not costate; enlarged electron photomicrograph shows that the pits are small, spaced about the diameter of one pit apart and aligned longitudinally; pores present in pits; aperture broken, but appears cribrate. Length of specimen No. 10,522 from Damery (Figure 13), 0.45 mm; width 0.38 mm.

NEAGUITES PERTUSUS (Terquem)
Figures 14-16

Spiroloculina pertusa TERQUEM, 1882, Mem. Soc. Geol. France, ser. 3, vol. 2, p. 160, pl. 16, figs. 27a, b.

Abridged Description: Spiroloculine chamber arrangement; length twice the width; sides of test flattened; periphery truncated; not costate; enlarged electron photomicrograph shows three rows of pits on the final chamber, parallel to the curvature of the test; pores in pits (see Figure 15); aperture with tooth (see Figure 16). Length of specimen No. 10,523 from Grignon (Figure 15), 0.63 mm; width 0.30 mm.

Remarks: The enlarged electron photomicrograph of a pit on *Neaguites pertusus* (Terquem) (see Figure 14) shows a single

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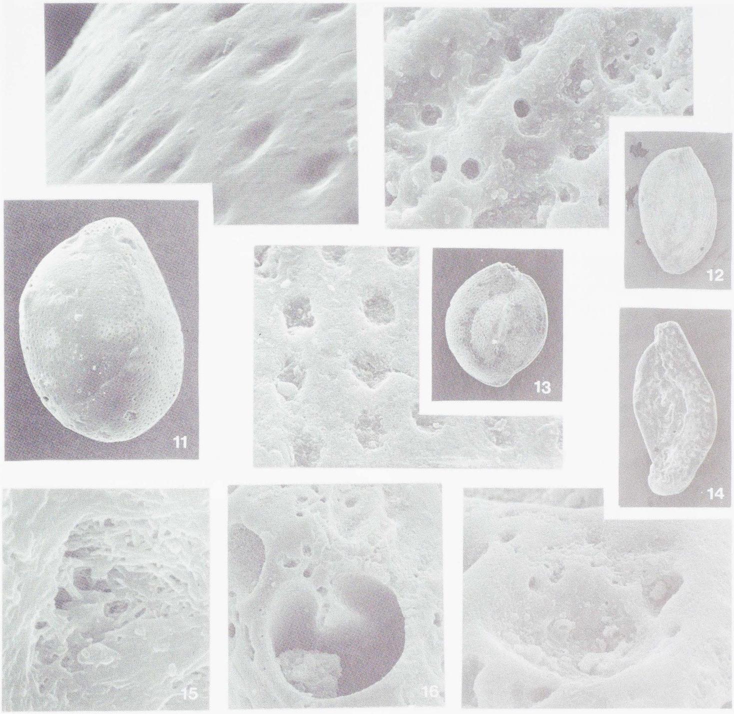
FIGURES

11. *Picouina* sp. (LSU GM No. 10,520)
    Lateral view, X 50
    Enlargement of pits, X 1000
12. *Heterillina* sp. 1. (LSU GM No. 10,521)
    Lateral view, X 25
    Enlargement of pits, X 1000
13. *Heterillina* sp. 2. (LSU GM No. 10,522)
    Lateral view, X 50
    Enlargement of pits, X 1000

14-16. *Neaguites pertusus* (Terquem). (LSU GM No. 10,523)
    14. Lateral view, X 50
        Enlargement of pits, X 1000
    15. Enlargement of pit showing crystals in middle layer of wall X 3750
    16. Apertural view showing tooth ?, X 500 (LSU GM No. 10,545)



FIGURES 11-16

"doughnut-shaped" element within the pit. Such features occur also on *Neaguites decoratus* (Cushman) (see figures 35, 37, and 38). This writer considers these elements to originate through weathering of the wall structure around the pores (see discussion in part V, this report).

IV. DESCRIPTION OF GULF COASTAL PLAIN PITTED MILIOLACEA

Family MILIOLIDAE Ehrenberg, 1839

Subfamily MILIOLINAE Ehrenberg, 1839

MILIOLA SAXORUM (Lamarck)
Figures 17, 18

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

Quinqueloculina saxorum (Lamarck). D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 301, no. 1, pl. 16, figs. 10-14.

Miliola saxorum (Lamarck). CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 12, 13, pl. 3, figs. 1-3; BERGQUIST, 1942, Mississippi Geol. Surv., Bull. 49, p. 25, pl. 2, fig. 8; CUSHMAN and TODD, 1945, Cushman Contr. Foram. Res., Contr., vol. 21, pt. 4, p. 83; ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 5, figs. 5-16.

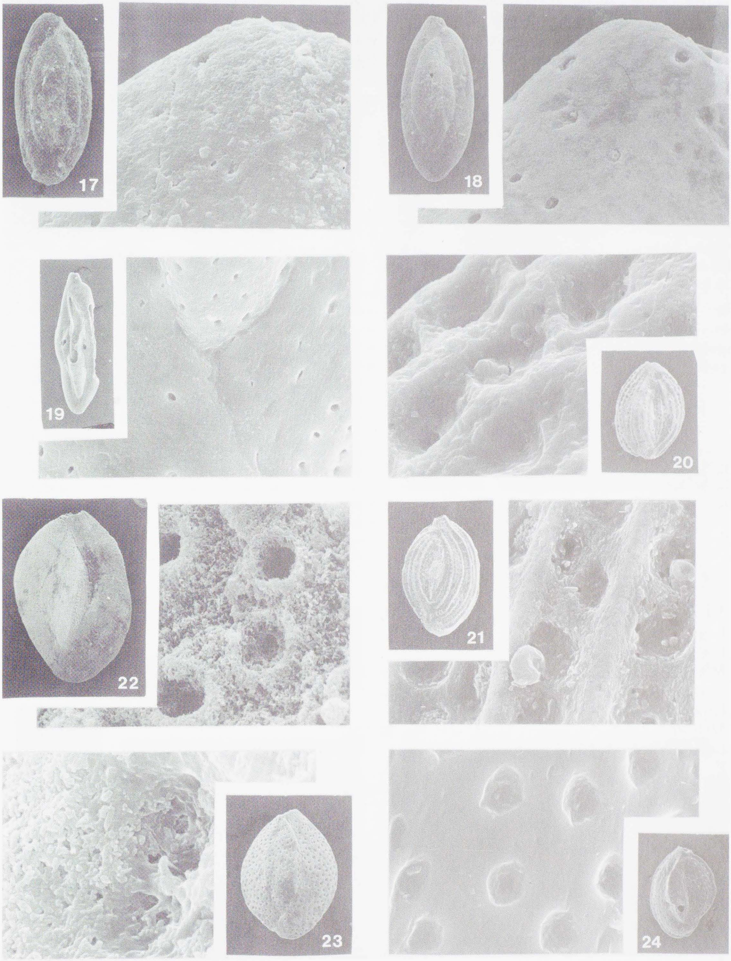
Quinqueloculina stavensis BANDY, 1949, Bulls. Amer. Paleontology, vol. 32, no. 131, p. 21, pl. 2, figs. 2a-c.

Remarks: Specimen No. 10,524 (Figure 17) was recovered from a sample collected by Lewis Nichols for the LSU Geology Department Museum, which duplicated as nearly as possible Bandy's Station 46, the basal clay in the Yazoo Formation. All of the foraminiferal tests recovered from this sample were replaced by silica, which obscured the structure of the wall. The diagenetic changes to which these Miliolacea were subjected left little more than test outlines upon which to base the identification of the species present.

Specimen No. 10,525 (Figure 18) from the Moodys Branch Formation at Riverside Park, Jackson, Mississippi, identified as *Miliola saxorum*, when compared to a topotype specimen (Figure 17) of *Quinqueloculina stavensis* Bandy, shows that the two specimens have identical shapes and identical distributions of pits near the apertures on both specimens. The conclusion reached is that Bandy's species is a junior synonym of *Miliola saxorum* (Lamarck). Length of specimen No. 10,524

FIGURES

17. *Miliola saxorum* (Lamarck). (LSU GM No. 10,524)
    Lateral view, X 25
    Enlargement of pits, X 1000
18. *Miliola saxorum* (Lamarck). (LSU GM No. 10,525)
    Lateral view, X 25
    Enlargement of pits, X 1000
19. *Miliola* cf. *M. saxorum* (Lamarck). (LSU GM No. 10,526)
    Lateral view, X 50
    Enlargement of pits, X 1000
20. *Miliola byramensis* (Cushman). (LSU GM No. 10,527)
    Lateral view, X 50
    Enlargement of pits, X 1000
21. *Miliola byramensis* (Cushman). (LSU GM No. 10,528)
    Lateral view, X 50
    Enlargement of pits, X 1000
22. *Miliola chipolensis* (Cushman and Ponton). (LSU GM No. 10,529)
    Lateral view, X 25
    Enlargement of pits, X 1000
23. *Miliola chipolensis* (Cushman and Ponton). (LSU GM No. 10,530)
    Lateral view of juvenile, X 50
    Enlargement of a pit showing crystals in middle layer of wall, X 3750
24. *Miliola* cf. *M. chipolensis* (Cushman and Ponton). (LSU GM No. 10,531)
    Lateral view, X 50
    Enlargement of pits, X 1000



FIGURES 17-24

from the Yazoo Formation (Figure 17), 1.26 mm; width 0.58 mm. Length of specimen No. 10,525 from the Moodys Branch Formation (Figure 18), 1.22 mm; width 0.56 mm.

MILIOLA cf. M. SAXORUM (Lamarck)
Figure 19

Description: Quinqueloculine chamber arrangement; length three times width; periphery rounded; surface of test smooth; pits extremely small, somewhat irregularly aligned with the long axis of the test; aperture poorly preserved, probably cribrate. Length of specimen No. 10,526 from the Red Bluff Formation, 1.02 mm; width 0.34 mm.

Remarks: The length-width ratio of this specimen does not fall within the normal range for *Miliola saxorum*, but in other respects it is similar.

MILIOLA BYRAMENSIS (Cushman)
Figures 20, 21

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.

Remarks: Specimen No. 10,527, from the Chipola Formation (Figure 20), is most typical of the species. Specimen No. 10,528 from the Red Bluff Formation (Figure 21), is less rugose but within an acceptable range of variation.

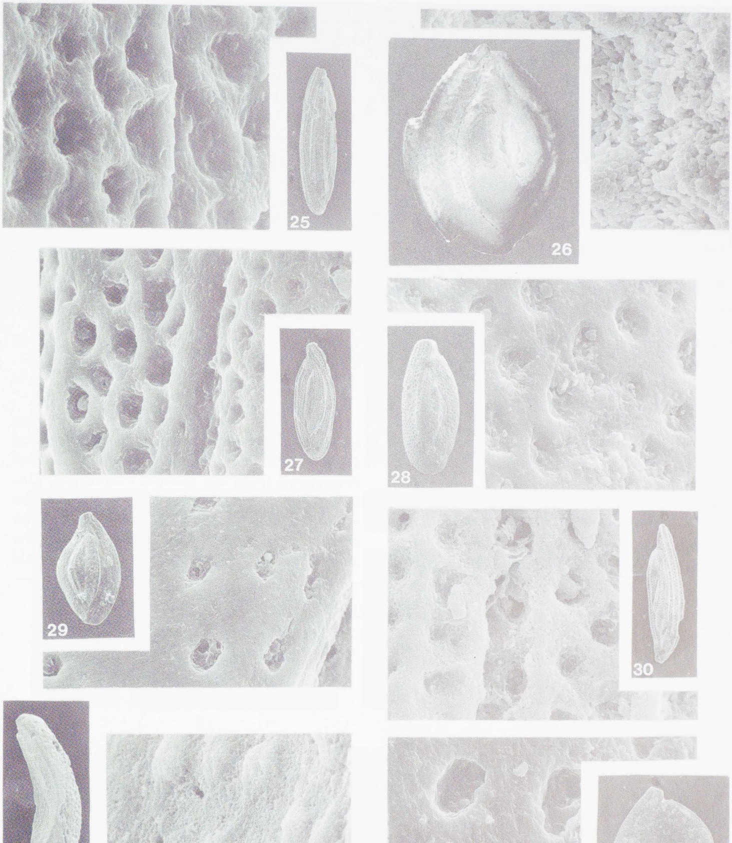
MILIOLA CHIPOLENSIS
(Cushman and Ponton)
Figures 22, 23

Quinqueloculina chipolensis CUSHMAN and PONTON, 1932, Florida Geol. Surv., Bull. 9, p. 45, pl. 3, figs. 1-3.

Abridged Description: Quinqueloculine chamber arrangement; length ranges from one and one-third times width in young specimens to one and one-half times width in the adult; periphery acutely angular, almost forming a keel in some specimens; test wall smooth; pits randomly distributed over test wall, spaced about one pit diameter apart; pores present in pits; crystals of calcite randomly oriented in the middle layer of the test wall (see Figure 23); aperture poorly preserved, probably cribrate. Length of specimen No. 10,529 from the Chipola Formation (Figure 22, an adult test), 1.22 mm; width 0.84mm. Length of specimen No. 10,530 also from the Chipola Formation (Figure 23, a juvenile test), 0.48 mm; width 0.35 mm.

FIGURES

25. *Miliola* cf. *M. jacksonensis* Cushman. (LSU GM No. 10,532)
    Lateral view, X 25
    Enlargement of pits, X 1000
26. *Miliola newberryensis* (Puri). (LSU GM No. 10,533)
    Lateral view, X 50
    Enlargement of pits, X 1000
27. *Miliola rolandi* Andersen. (LSU GM No. 10,534)
    Lateral view, X 50
    Enlargement of pits, X 1000
28. *Miliola alphillipsi* Andersen, n. sp. (LSU GM No. 10,535)
    Lateral view, X 50
    Enlargement of pits, X 1000
29. *Miliola* sp. A. (LSU GM No. 10,536)
    Lateral view, X 50
    Enlargement of pits, X 1000
30. *Miliola* sp. B. (LSU GM No. 10,537)
    Lateral view, X 50
    Enlargement of pits, X 1000
31. *Miliola* sp. C. (LSU GM No. 10,538)
    Lateral view, X 50
    Enlargement of pits, X 1000
32. *Heterillina jacksonensis* (Cushman). (LSU GM No. 10,540)
    Lateral view, X 25
    Enlargement of pits, X 1000



FIGURES 25-32

Remarks: None of the specimens recovered from the Chipola Formation samples exhibited a tooth as figured by Cushman and Ponton (1932, pl. 3, fig. 1) in their original definition of this species.

MILIOLA cf. M. CHIPOLENSIS
(Cushman and Ponton)
Figure 24

Remarks: The length of specimen No. 10,531 from the Red Bluff Formation (Figure 24) is 0.35 mm; the width is 0.24 mm. The length-width ratio of this specimen is similar to that for topotype specimen No. 10,529 from the Chipola samples (Figure 22), but the test is smaller. As it is the largest specimen recovered from the Red Bluff samples, it is regarded as an adult.

Although the surface, the distribution of pits on the test wall, and the absence of a tooth conform to identification of this form as *M. chipolensis*, absolute assignment to this species is withheld because of its smaller size.

MILIOLA cf. M. JACKSONENSIS Cushman
Figure 25

Remarks: This species was reported by Bandy (1949) from Station 46, a clay at the base of the Yazoo Formation in Little Stave Creek, Alabama. Bandy described the wall as siliceous because the wall of the test had been replaced with silica.

The length of specimen No. 10,532 (Figure 25) is 1.06 mm; the width is 0.28 mm. Its length-width ratio is close to that of topotypes of *Miliola jacksonensis* from the Moodys Branch Formation in Jackson, Mississipppi, but it does not have the costae extending well above the surface of the test wall nor the network of pores illustrated by Andersen in 1984 (fig. 19). This specimen is too large to be assigned to *Miliola rolandi* Andersen.

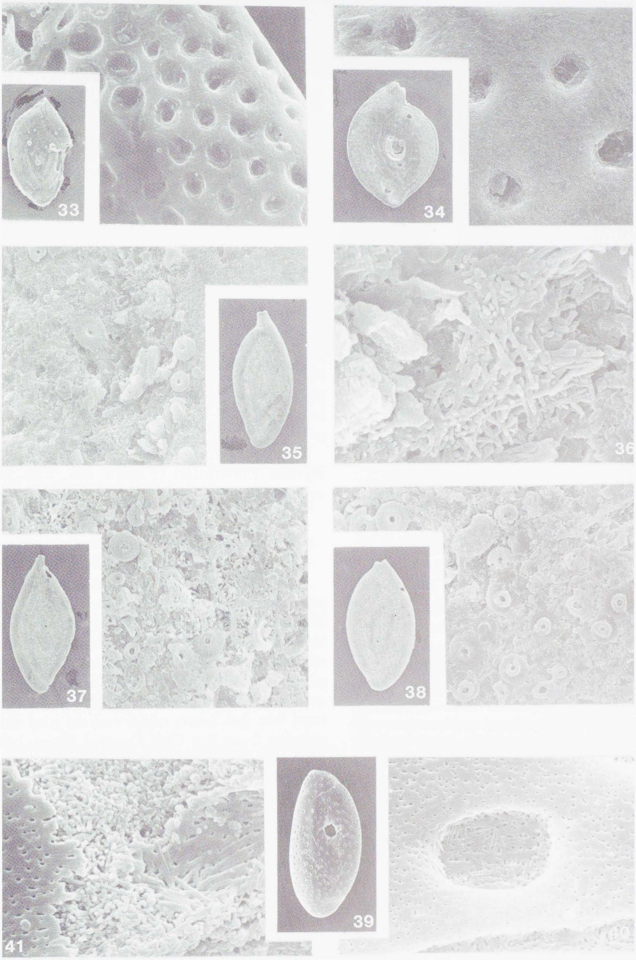
MILIOLA NEWBERRYENSIS (Puri)
Figure 26

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

Remarks: This is the most robust species of *Miliola* reported from the Gulf Coastal Plain and the figured specimen is the best recovered from the sample examined. Unfortunately, a detailed study could not be made of its weathered surface and the specimen was so badly damaged by the scanning electron microscope that it could

FIGURES

33. *Neaguites byramensis* (Cushman). (LSU GM No. 10,539)
Lateral view, X 50
Enlargement of pits, X 1000
34. *Neaguites* sp. A. (LSU GM No. 10,541)
Lateral view, X 50
Enlargement of pits, X 1000
35-36. *Neaguites decoratus* (Cushman). (LSU GM No. 10,542)
35. Lateral view with proloculus concealed, X 50
Enlargement of wall showing doughnut-shaped structures formed around perforations, X 3750
36. Enlargement of a pit showing crystals in middle layer of test wall, X 3750
37. *Neaguites decoratus* (Cushman). (LSU GM No. 10,543)
Lateral view with proloculus showing, X 50
Enlargement of wall showing doughnut-shaped structures formed around perforations X 1000
38. *Neaguites decoratus* (Cushman). (LSU GM No. 10,544)
Lateral view with proloculus concealed, X 50
Enlargement of wall showing doughnut-shaped structures formed around perforations, X 1000
39-41. *Quinqueloculina semireticulosa* Cushman.
39. Lateral view, X 75
40. Enlargement of a pit, X 2500
41. Section of wall showing layering, X 3750



FIGURES 33-41

not be saved.

Length of specimen No. 10,533 from the Crystal River Formation (Figure 26), 0.72 mm; width 0.60 mm.

MILIOLA OCALANA (Puri)

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

Remarks: This costate and pitted species, with an average length of 1.5 mm, is common in the Ingles Formation (Lower Jackson Group of Florida), according to Puri (1957, p. 24). No samples or specimens of this species were available for this investigation.

MILIOLA ROLANDI Andersen
Figure 27

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

Remarks: The holotype of *Miliola rolandi*, incorrectly reported by Andersen (1984) to be from the Moodys Branch Formation, is from the Red Bluff Formation, the same locality as specimen No. 10,534 (Figure 27), length 0.42 mm; width 0.15 mm.

MILIOLA ALPHILLIPSI, n. sp.
Figure 28

Description: Quinqueloculine chamber arrangement; slightly more than twice as long as wide; transverse section of test broadly triangular with periphery rounded; neck extending above penultimate chamber; surface covered with closely spaced pits randomly distributed at distal end of final chamber, aligned between costae that are parallel to long axis of test near aperture; pores present in each pit; aperture without tooth, probably cribrate but incomplete. Length of holotype, specimen No. 10,535 from the type locality of the Byram Formation (Figure 28), 0.49 mm; width 0.21 mm.

Remarks: The figured specimen is considered an adult as no other in the sample was appreciably larger. It is the most abundant pitted species.

This species is named for Alvin Phillips, Curator of Foraminifera, School of Geoscience Museum, Louisiana State University, whose assistance in the preparation of this paper is greatly appreciated.

MILIOLA sp. A
Figure 29

Remarks: This quinqueloculine specimen differs from *Miliola chipolensis* in the less carinate periphery, smaller and more closely spaced pits, and in the presence of an apertural neck.

Length of specimen No. 10,536 from the Byram Formation (Figure 29), 0.41 mm; width 0.23 mm.

MILIOLA sp. B
Figure 30

Remarks: This specimen is one of several examples of Miliolacea with the length-width ratio about 4:1 recovered from samples collected in the Paris Basin and in the Gulf Coastal Plain. Its shape is similar to *Miliola jacksonensis* but an electron photomicrograph of the wall shows that it lacks the lace-like network of pores that is present in that species.

Length of specimen No. 10,537 from the Byram Formation (Figure 30), 0.50 mm; width 0.14 mm.

MILIOLA sp. C
Figure 31

Remarks: The specimens of *Miliola* recovered from the Chickasawhay Marl near Millry, Alabama, consist of single chambers with casts of pits on the outer surface of the chamber floor. These casts are aligned with the long axis of the chamber and appear elliptical in outline. This pattern has not been observed on any other species from the Gulf Coastal Plain, but is present on *Miliola* sp. 1 from the Paris Basin.

Length of specimen No. 10,538 (Figure 31), 0.79 mm.

"QUINQUELOCULINA" TESSELLATA Cushman

Quinquloculia tessellata CUSHMAN, 1922, U. S. Geol. Surv. Prof. Paper 129-F, p. 142, pl. 33, fig. 8 and pl. 34, fig. 1; CUSHMAN, 1923, U. S. Geol. Surv. Prof. Paper 133, p. 54, not figured; CUSHMAN and McGLAMERY, 1942, U. S. Geol. Surv., Prof. Paper 197-B, p. 66, pl. 4, fig. 1; BERGQUIST, 1942, Mississippi Geol. Surv., Bull. 49, pl. 2, figs. 11, 14; TODD, 1952, U. S. Geol. Surv., Prof. Paper 241, p. 7, not figured.

Remarks: Quinqueloculina tessellata Cushman, reported originally from the Glass Bayou and Mint Springs Bayou calcareous marls exposed in Vicksburg, Mississippi, was described as follows:

> "Test elongate, fusiform, in transverse section much angled; periphery rather sharply angled, sides flat and slightly convex, apertural end very little extended; sutures not very distinct; surface ornamented by longitudinal rows of rather large pits, five or six rows on each side of the largest chamber. Length 1.25 millimeters, breadth 0.5 millimeter."

Of the two figures illustrated, figure 8 was designated the type specimen.

Cushman's statement that the test of "*Quinqueloculina*" *tessellata* was "ornamented by longitudinal rows of rather large pits" is adequate evidence that his species belongs to the *Miliola* lineage. His statement that the sides are "flat and slightly convex" is strong evidence that it is neither *Quinqueloculina* nor *Miliola*. Possibly, with its chamber arrangement, it should be placed in *Heterillina*.

The specimen figured by Cushman and McGlamery (1942) as *Quinqueloculina tessellata* is definitely a *Miliola*. However, it does not appear to have the flat sides described for Cushman's species (1922).

The specimens figured by Bergquist (1942) do not agree with his description of the species in which he quoted Cushman's original diagnosis verbatim. His Figure 11 on Plate 2 could be *Miliola byramensis*; Figure 14 on Plate 2 cannot be identified.

HETERILLINA Munier-Chalmas and Schlumberger, 1905

Heterillina MUNIER-CHALMAS and SCHLUMBERGER, 1905, Soc. Geol. France, Bull., (Ser. 4) vol. 5, p. 131

Tappanella ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 10; *non* GUIDINA and SUIDOVA, 1969, Doklady Akademii Nauk SSSR, vol. 185, no. 5, p. 1109-1111.

Helentappanella ANDERSEN, 1985, Micropaleontology, vol. 31, No. 1, p. 67.

Remarks: Andersen (1984, p. 10) made the following statement:

> "Both *Heterillina* and *Tappanella* have a massiline chamber arrangement; however, neither the description nor the illustrated specimen of *Heterillina* in Loeblich and Tappan's *Treatise on Foraminifera* (1964, p. C470, fig. 357, 7a-c) accommodates *Tappanella punctatocostata* (Cushman) with its pitted chambers, costae, and perforated test."

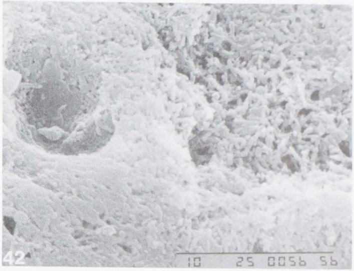


Figure 42. *Heterillina jacksonensis* (Cushman) showing the rodlike crystals of the middle layer.

The section herein on the Lutetian Miliolacea required a more thorough study of the foraminiferal literature from France than the paper written in 1984. Yolande Le Calvez (1970), in her study of the Paleogene foraminifers, described a species of *Heterillina* with a massiline chamber arrangement, costae, pits, and a cribrate aperture. Thus, Le Calvez is in agreement with Cushman, who designated the genotype of *Heterillina* in 1928. In his 1948 edition of *Foraminifera and their Economic Use* he states (p. 183), "This genus *(Heterellina)* has evidently developed from *Miliola*, as *Massilina* has come from *Quinqueloculina*." Also, a close examination of Loeblich and Tappan's Figure 357 (1964, p. C469), reproducing Munier-Chalmas and Schlumberger's original figure (1905), shows a transverse section of the chamber arrangement in *Heterillina*, in which every chamber on the exterior of the test has a serrated margin. These serrations have to indicate the presence of costae or pits; therefore, all available evidence leads to the conclusion that species attributed to *Heterillina*, an Eocene genus with costae and a cribrate aperture, must have pits on the wall of the test.

HETERELLINA JACKSONENSIS (Cushman)
Figure 32

Massilina jacksonensis CUSHMAN, 1927, Jour. Paleontology, vol. 1, p. 150, pl. 23, figs. 5, 6.
Quinqueloculina tuberculata CUSHMAN and TODD, 1945, Cushman Lab. Foram. Res., Contr., vol. 21, p. 81, pl. 13, fig. 17.
Tappanella jacksonensis (Cushman). ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 12, figs. 30-33.

Remarks: The calcium carbonate test of the single recovered specimen of this species, and that of all others from the Yazoo Formation in Little Stave Creek, Alabama, has been replaced with silica, which has altered the surface features. The pits are enlarged and are more irregularly shaped than those on specimens from the Moodys Branch Formation in Jackson, Mississippi. This single specimen is interpreted as megalospheric as the sides are only slightly convex.

Length of specimen No. 10,540 (Figure 32), 1.12 mm; width 0.78 mm.

Subfamily NEAGUITESINAE Andersen, 1984

NEAGUITES BYRAMENSIS (Cushman)
Figure 33

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.

Remarks: This specimen has the closely interlocked perforations figured by Andersen (1984, fig. 40). During the early stages of weathering the "doughnut-shaped" structures form attached to the inner layer of the wall (see discussion in Part V).

Length of specimen No. 10,539 from the Red Bluff Formation (Figure 33), 0.40 mm; width 0.23 mm.

NEAGUITES sp. A

Description: Spiroloculine chamber arrangement; length slightly less than one and one-half times width; periphery carinate; neck extends beyond the penultimate chamber; surface of test smooth; one row of pits next to the carinate periphery aligned parallel to the chamber outline, the rest more-or-less randomly disposed and spaced two or three pit diameters apart; pores in each pit; aperture poorly preserved, probably cribrate. Length of specimen No. 10,541 from the Byram Formation type locality (Figure 34), 0.45 mm; width 0.33 mm.

Remarks: The planispiral chamber arrangement of this specimen satisfies the morphological requirements for the genus *Neaguites*, but the interlocking perforations on the test surface, the second most distinctive characteristic, are missing.

NEAGUITES DECORATUS (Cushman)
Figures 35-38

Massilina decorata CUSHMAN, 1922, U. S. Geol. Surv., Prof. Paper 129-F, p. 143, pl. 34, fig. 7; CUSHMAN, 1923, U. S. Geol. Surv., Prof. Paper 133, p. 55, 56; COLE and PONTON, 1930, Florida Geol. Surv., Bull. 5, pl. 10, fig. 5; HOWE and WALLACE, 1932, Louisiana Geol. Surv., Geol. Bull. 2, p. 20, 21, pl. 2, fig. 6; CUSHMAN, 1935, U. S. Geol. Surv., Prof. Paper 181, p. 13, pl. 3, figs. 14-16; CUSHMAN, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, pt. 3, pl. 9, fig. 13; BERGQUIST, 1942, Mississippi Geol. Surv., Bull. 49, p. 22, pl. 10, fig. 26; C 1946, Cushman Lab. Foram. Res., Spec. Pub. 16, p. 5, 6; pl. 1, fig. 11; CUSHMAN and STONE, 1949, Cushman Lab. Foram. Res., Contr., vol. 25, pt. 4, p. 78, pl. 13, fig. 29; BANDY, 1949, Bulls. Amer. Paleontology, vol. 32, no. 131, pl. 2, figs. 7a, b; CUSHMAN, 1942, Cushman Lab. Foram. Res., Contr., vol. 5, pt. 2, p. 40, pl. 7, fig. 1.
Spiroloculina lamposa HUSSEY, 1949, Jour. Paleontology, vol. 23, pl. 26, fig. 6.
Neaguites lamposus (Hussey). ANDERSEN, 1984, Tulane Stud. Geol. Paleont., vol. 18, no. 1, p. 16, figs. 41, 42.

Remarks: Until 1984, with the exception of *Spiroloculina lamposa* Hussey, almost every small, smooth, flat-sided, spiroloculine specimen from the Eocene and Oligocene of the Gulf Coastal Plain, either with an exposed proloculus or with the proloculus concealed by the rotation of the initial coil, was identified as *Massilina decorata* Cushman. In 1984, Andersen introduced the genus *Neaguites* and referred these spiroloculine forms to *Neaguites lamposus*; here revised to *Neaguites decoratus* (Cushman).

In Cushman's original description, he described the sides of the test as "ornamented by very fine pits giving a granular appearance to the test." This writer examined specimens of this species from the Rosefield, Shubuta, and Red Bluff formations with the scanning electron microscope. The electron photomicrographs (Figures 35-38) reveal that:

1) the test has a granular appearance due to weathering even in the best preserved specimens recovered;

2) the middle layer in the test wall consists of rodlike crystals loosely bound and randomly oriented similar to that of *Miliola saxorum* and "*Quinqueloculina*" *tuberculata*;

3) the "fine pits" perceived by Cushman with the binocular microscope were openings at the centers of "doughnut-shaped" elements, not present in any other genus of pitted Miliolacea studied; and,

4) In Figures 35, 36, and 37, the "doughnut-shaped" structures appear to be randomly distributed over the test surface, but in Figure 38, an enlarged section of the wall shows these structures to have a rational distribution pattern (see discussion in Part V).

The main purpose for examining specimens of *Neaguites decoratus* from a variety of localities was to verify the presence of the pits that must be present in this species as it has the three-layered test wall characteristic of the pitted *Miliola* lineage. The only observed "pits" are the holes at the center of the "doughnut-shaped" elements. Most were in clusters among the debris on the wall of the test and bore a single flange with the trace of a circle between the central hole and the perimeter of the element. In the lower left hand corner of Figure 38, the "doughnut-shaped" elements are: 1) somewhat uniformly distributed over wall of the test; 2) bear two unequal sized flanges with the upper smaller than the lower; and 3) have none of the rodlike crystals of the middle layer separating the two flanges. These two-flanged elements, the writer believes, are the original pits on the wall of the test weathered *in situ*. The two "doughnut-shaped" elements above the test in Figure 38 may be coccoliths in the weathered debris on the surface of the test. If not, then secondary deposition of calcite in the double-flanged elements caused coalescence of the two flanges with the outline of the upper flange superposed on the lower flange. After coalescence, the double-flanged "doughnut-shaped" structure becomes a coccolith-like element randomly dispersed within the debris on the surface of the test.

Neaguites decoratus differs from the type species of the genus, *Neaguites byramensis* (Figure 33), which has obvious pits that weather into flanged "doughnut-shaped" structures attached to the inner layer of the wall. As the "doughnut-shaped" elements are present on the weathered surface of *Neaguites lamposus* (Hussey), as shown by Andersen (1984, fig. 42), and because Hussey's type specimen strongly resembles *Neaguites decoratus*, it is considered a junior synonym of *Neaguites decoratus* (Cushman).

Figures 35 and 36 are from the Rosefield Formation (LSU GM 10,542); Figure 37 is from the Shubuta Formation (LSU GM 10,543); and Figure 38 is from the Red Bluff Formation (LSU GM 10,544).

V. DISCUSSION

The Enigmatic Knobs on Pitted Genera of Miliolacea

It has been demonstrated (see Figure 2), that *Miliola saxorum* (Lamarck) has a three-layered test wall. An electron photomicrograph of a slightly weathered specimen of "*Quinqueloculina*" *tuberculata* [=*Heterillina jacksonensis* (Cushman)] (see Figure 42), confirms the threefold subdivision of the wall in the *Miliola*-lineage, and more clearly depicts the structure and orientation of the calcite crystals in the wall of the test. Flat, interlocked crystals of calcite form the outer layer of the test and line the walls of the pits; a thick mass of short, rodlike, randomly oriented crystals forms the middle layer; and, though the inner layer is not visible in the electron photomicrograph, it is considered to be similar to the surface layer.

As the end product of weathering of the test wall is a series of knobs; differences in the material in the wall provide a residue of unweathered material that converts the pit into a knob. It is possible that the foraminifer concurrently secreted both ordinary calcite and magnesium-enriched calcite, with magnesium-free calcite deposited around the pits. This possibility may have been resolved by the work of Earl Manning, a graduate student at Louisiana State University, who has studied a foraminiferal assemblage from the

Holocene deposits off the coast of southeastern Nicaragua. He recovered a single specimen of "*Quinqueloculina*" *semireticulosa* Cushman from these deposits which was coated for electron microphotography. The coating, unfortunately, prevents determining the composition of the test. However, his results (see Figures 39-41) did reveal the three-layered structure of the pitted test wall, which has been shown to be present also in *Miliola saxorum* (compare Figures 41 with Figure 2), but with a greater number of perforations in the test than in the type species. Thus, his specimen should be placed in the genus *Miliola* and the range of the genus must be extended into the Holocene. Manning kindly granted permission to include his photographs in the plates (Figures 39-41).

A second possibility, favored by this writer, is that the formation of knobs can be attributed to the structure and orientation of the calcite crystals in the test wall. The loosely bound, rodlike crystals of the middle layer (see Figure 42) would be more readily dissolved or eroded, but the interlocked crystals of the outer and inner walls would be more resistant. In time, chemical and/or mechanical weathering could remove the outer and middle layers of the wall between the pits, but a few of the rodlike crystals from the middle layer weld the pit to the inner wall of the test, converting the pits into knobs. Concurrently or later, additional calcite could have been deposited in the pits enhancing the knobs. Laboratory washing procedures may affect the ornamentation and the weathered surface of the test. The nature or amount of such alteration is not known.

The presence of knobs has been noted in some species of pitted Miliolacea. Knobs characterize the species "*Quinqueloculina*" *tuberculata* Cushman and Todd from the Moodys Branch Formation at its type locality in Jackson, Mississippi. Doughnut-shaped structures characterize the species "*Massilina*" *decorata* Cushman, which occurs in almost every neritic foraminiferal assemblage in Louisiana, Mississippi, and Alabama sediments. Two questions are to be considered: 1) what set of circumstances produced the knobs; and, 2) are the "doughnut-shaped" structures the product of diagenetic alteration of the test wall.

The original description of "*Quinqueloculina*" *tuberculata* (Cushman and Todd, 1945) includes the following statement: "wall ornamented with raised knobs arranged in longitudinal rows, in well preserved specimens each knob having a pit on its summit and appearing to be perforated, in eroded specimens the knobs may be worn off leaving only rows of pits and faint longitudinal costae...This species is very distinctive with its striking raised ornamentation and should be a good index fossil for the Moodys marl." The above-quoted description stating that "knobs may be worn off leaving only rows of pits" is one of the principal reasons the present study was initiated. If their interpretation is correct, then erosion could convent knobs into pits on specimens of other species of Miliolacea.

Geological and Geographical Distribution of the Pitted Miliolacea

The distribution of the pitted Miliolacea, other than the genus *Neaguites*, remains essentially as described previously (Andersen, 1984). The oldest recognized genus, *Texina*, is reported only from the Claibornian (Middle Eocene) Weches Formation of Texas. A geologically younger, mature *Miliola* and *Heterillina* assemblage (see Table I) is present in the Moodys Branch Formation at Jackson, Mississippi, but is missing from the excellent and lithologically similar outcrop of Moodys Branch at Montgomery Landing, Grant Parish, Louisiana, and from the overlying Yazoo Formation.

During Upper Jacksonian (Upper Eocene) time, the pitted Miliolacea appear to have migrated southward into deeper water clastics as exposed at Little Stave Creek, Alabama, and eastward into the carbonate-rich deposits of the Ocala Group in Florida, where Puri (1957) reports *Miliola* in certain zones. The extent to which the pitted Miliolacea are present in the foraminiferal assemblages of Florida may never be fully recognized due to conditions unfavorable for good preservation of miliolid tests.

Oligocene pitted assemblages are best studied in the Bryam Formation of Mississippi where almost every known pitted Oligocene species is present (see Table I). Two pitted species, *Miliola byramensis* and *Miliola chipolensis* are reported from the Neogene of Florida. Thus, the range of the pitted Miliolacea extends into the Miocene, but no higher. No Holocene species with pitted tests are reported from the Gulf of Mexico area.

The genus *Neaguites* requires special consideration. It is distinguished by its planispiral coil, generally with the proloculus exposed on both flat sides of the test; the lack of a cribrate aperture; and its length which rarely exceeds 0.60 mm. *Neaguites decoratus* (Cushman) occurs in every Upper Jacksonian and Oligocene sample examined (see Table I), and in some samples, such as the Rosefield Formation in Louisiana, it is the dominant miliolacean in the assemblage. Only in the Byram and Red Bluff formations does *Neaguites* occur with an appreciable number of other miliolaceans.

The geological range of *Neaguites* extends from the Lower Jacksonian (Upper Eocene) through the Oligocene; its geographical distribution includes Louisiana, Mississippi, and Alabama. It has not been recorded from the Jacksonian of Florida. The morphological equivalent of *Neaguites*, but with an adventitious test and widely spaced pits is *Texina*, from the Weches Formation (Lower Eocene) of Texas.

Environmental Implications

The apparent environment in which most of the pitted Miliolacea thrived (attained their maximum growth), as previously reported by Andersen (1984, p. 18), is in warm, shallow water. Lending credence to this observation is the number of pitted species present in the Ocala Group (Eocene) of Florida, which certainly represented a warm, shallow water environment.

A problem which may have environmental implications, however, is the reduction in size and rare occurrence of the pitted Miliolacea in the Byram and Red Bluff formations. In these two Oligocene formation, most of the pitted Miliolacea are so small that only the largest individuals are retained on the 60 mesh sieve; so rare that one is most fortunate to recover a single specimen per tray of sample examined. Their association with pelagic foraminifera indicates that the depth environment has shifted from inner neritic waters at Jackson, Mississippi, to middle or outer neritic at Byram, Mississippi, a distance of only about 10 miles and covering a time span of millions of years. Either a shift in environment or advancing time has brought about the changes observed in the assemblages.

The time span of a species may result in reduction in size and/or distortion in the shape of the test. One specimen recovered from the Red Bluff Formation is identified as *Miliola* cf. *M. saxorum* (figure 19) on the basis of the distribution of the pits on the wall of the test. The specimen is small, slightly distorted, and has a length-width ratio greater than the norm for *M. saxorum*. If this species assignment is correct, this specimen could be regarded as evidence of senility in this species.

Time is considered the factor least likely to produce dwarf specimens in the Byram and Red Bluff formations. The many small members of these assemblages appear to be robust specimens of undescribed species or small representatives of large pitted forms which occur in the overlying Miocene strata. It is possible that the deeper water environment may have favored early maturity and reproduction, resulting in the small test size. In many species of foraminifera, it is known that very large individuals result from delayed reproduction, not from favorable environmental conditions.

Relationship of Gulf Coastal Plain and Paris Basin Miliolacea

Cushman's identification in 1935 of *Miliola saxorum* (Lamarck) from the Jackson Group of the Gulf Coastal Plain is correct. It is unequivocally the same as the Lamarck's species from the Paris Basin.

One group of foraminifera in the Lutetian, however, causes some concern–the small pitted forms with a length-width ratio of 3 or 4 to 1, which have isomorphs in the Gulf Coastal Plain. The specimens from Grignon and Damery, France, have a distinguishing feature in the keel on the distal end of the final chamber. One pitted specimen recovered from the Byram Formation appears to have this feature, but it is not observable in other specimens from the same sample because they were all fragmentary with the crucial portion of the test missing. Thus, *Miliola birostris* (Lamarck), or some other closely related species from the Paris Basin, may occur also in the Gulf Coastal Plain.

VI. ACKNOWLEDGMENTS

I wish to thank the following people for their contributions to this report: Dr. James Coleman, Chairman,, and Dr. Rex Pilger, Acting Chairman of the Louisiana State University School of Geology, for granting permission to use the School of Geology's scanning electron microscope; Ezat Atydari, LSU graduate student, for the excellent work he did in operating the microscope and processing the electron photomicrographs for this paper; Lewis Nichols for supplying needed materials; Dr. Clyde Moore, Jr., Professor of Geology at LSU, whose departmental support is appreciated; Alvin Phillips, Jr., curator of the LSU micropaleontology collections and library who supplied many of the samples and much pertinent literature not in my personal library; Earl Manning, LSU graduate student, who permitted me to publish three electron photomicrographs of a foraminiferan from his three electron photomicrographs of a foraminiferan from his master's thesis; and my partner, Harry L. Roland, Jr., who gave me a leave of absence to complete this report.

I again wish to express my appreciation to my friends and former students for the binocular microscope used in this study. Also, I especially wish to thank Dr. Willem van den Bold for the time spent in reviewing this paper.

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Manuscript received December 30, 1985.