BIOSTRATIGRAPHY OF PALEOCENE STRATA IN SOUTHWESTERN ALABAMA

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By

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ABSTRACT

In southwestern Alabama, the Paleocene consists of over 1400 ft of marginal marine and marine terrigenous sediments. The vertical change in planktic foraminiferal distribution in the Paleocene strata permits their assignment to an established world-wide zonation. Paleocene biostratigraphic *Subbotina pseudobulloides* and *S. trinidadensis* Interval Zones are represented in the Clayton Formation. Most of the Porters Creek clay is contained in the Paleocene *Morozovella uncinata* Interval Zone. Matthews Landing Marl Member of the Porters Creek Formation rests within the Paleocene *M. angulata* Interval Zone. Paleocene *M. pusilla pusilla* Interval Zone is most likely present in the Coal Bluff Marl Member of the Naheola Formation. "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation, as well as the lower Tuscahoma Sand, are contained within the Paleocene *Planorotalites pseudomenardii* Range Zone. Middle and upper parts of the Tuscahoma Sand are assigned to the Paleocene *M. velascoensis* Interval Zone. The Bashi Marl Member of the Hatchetigbee Formation is retained in the Eocene *M. subbotinae* Interval Zone. The Paleocene-Eocene boundary is near the base of the Bashi Marl Member of the Hatchetigbee Formation.

INTRODUCTION

The Paleocene of southwestern Alabama has been of particular interest to Gulf Coastal Plain stratigraphers over the years because these strata include marine terrigenous lithofacies which are locally fossiliferous. These shallow marine and marginal marine lithofacies of southwestern Alabama are transitional with the predominantly marginal marine and nonmarine Paleocene of Mississippi, Louisiana and Texas, the shallow marine to nonmarine Paleocene of southeastern Alabama and Georgia, and the Paleocene carbonates of peninsular Florida. Macrofossils contained in the marine beds have been used as biostratigraphic indicators for the definition of provincial stages in the Gulf Coastal Plain area and for the establishment of a biostratigraphic reference section for North America. The foraminifers associated with these formations have been studied by a number of micropaleontologists. Loeblich and Tappan (1957b), Berggren (1965a, 1965b), Smith (MS), Olsson (1970b), Kidd (MS), and Mancini and Oliver (1981) have used the distribution of the planktic foraminifers occurring in these units for local, regional, and world-wide biostratigraphic correlation.

The objectives of this paper are to identify the planktic foraminifers that occur in the Paleocene strata of southwestern Alabama and to determine the geologic age of each formation. Planktic foraminiferal zones present in these units are identified, compared with reported planktic foraminiferal zones for the Paleocene of Alabama, and integrated into an established world-wide planktic foraminiferal zonation.

These objectives are achieved by studying Paleocene formations that occur in the subsurface and in surface exposures in southwestern Alabama. Subsurface data are from two coreholes drilled near Butler, Choctaw County, Alabama. The Grampian Hills Member of the Nanafalia Formation through the middle beds of the Porters Creek Formation (707 ft of section) were cored in the OSM #1 Tuckabum Creek corehole, 7 mi northeast of Butler. The upper beds of the Hatchetigbee Formation through the upper part of the Oak Hill Member of the Naheola Formation (1027 ft of section) were cored in the OSM #2 Wahalak Creek corehole, 5 mi southwest of Butler. Surface samples were collected in Choctaw, Clarke, Dallas, Marengo, Monroe, Sumter, and Wilcox Counties, Alabama. Paleocene units that were sampled are represented by the Clayton Formation, Porters Creek Formation, Naheola Formation, Nanafalia Formation and Tuscahoma Sand. The lower Eocene Bashi Marl Member of the Hatchetigbee Formation was also sampled. Text-figure 1 is a map showing the sampled localities and location of the two coreholes.

LITHOSTRATIGRAPHY

The Clayton Formation, oldest Paleocene unit in southwestern Alabama, disconformably overlies the Upper Cretaceous Prairie Bluff Formation (text-fig. 2). In the type area near Clayton, Barbour County, in southeastern

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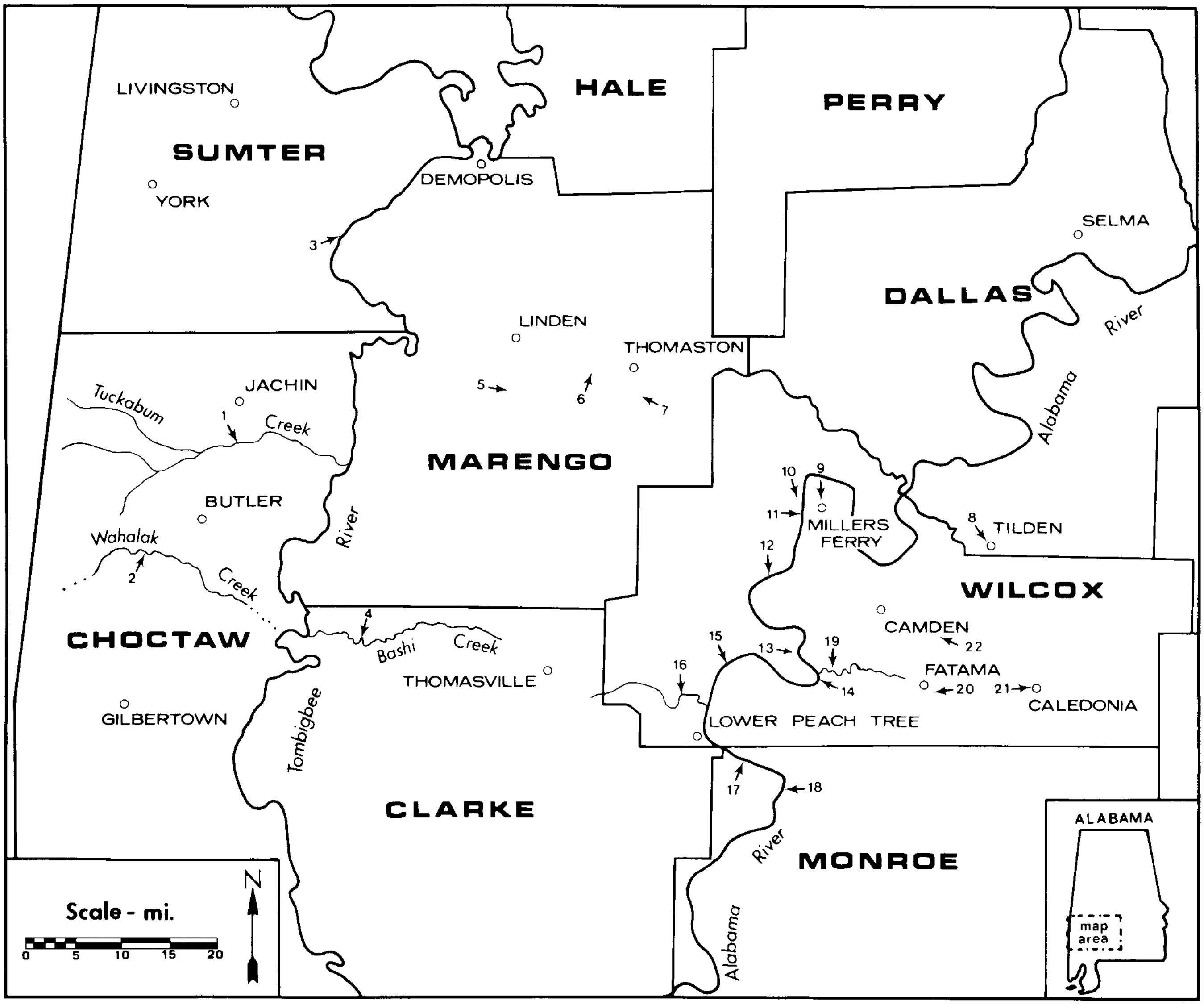
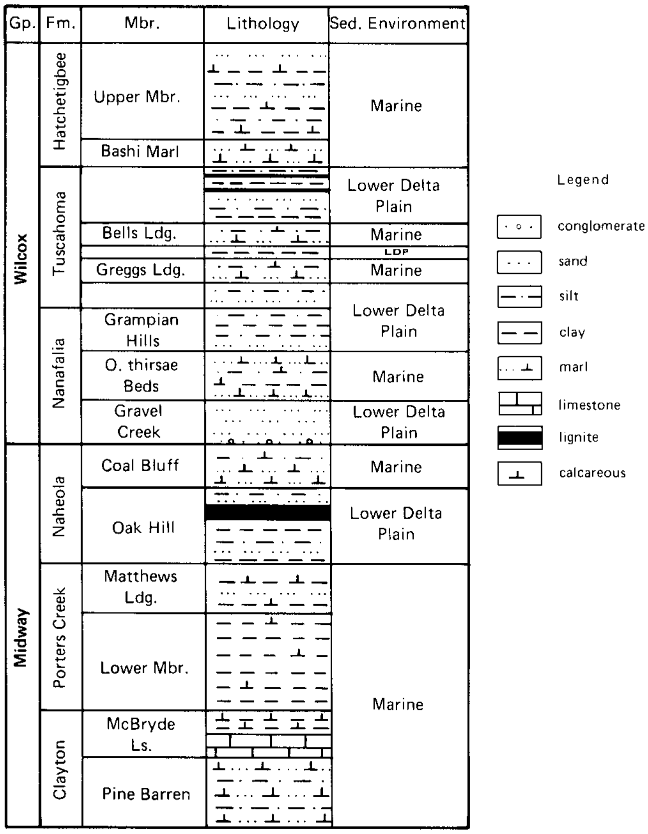


TEXT-FIGURE 1
Location map for coreholes and sections studied: (1) OSM #1 Tuckabum corehole, (2) OSM #2 Wahalak corehole, (3) Rooster Bridge, (4) Bashi Creek, (5) U.S. Route 43, (6) L&N Railroad, (7) Thomaston, (8) Tilden, (9) Millers Ferry corehole, (10) Lee Long Bridge, (11) Midway Landing, (12) Matthews Landing West, (13) Coal Bluff, (14) Gullettes Bluff, (15) Yellow Bluff, (16) Bear Creek, (17) Greggs Landing, (18) Bells Landing, (19) Gravel Creek, (20) Fatama, (21) Caledonia, and (22) Pursley Creek.

Alabama, the contact is marked by a basal coarse-grained sand which is overlain by calcareous clay (Cooke 1926). In Choctaw County, the Clayton includes less than 20 ft of marl and limestone (Toulmin et al. 1951) but the formation thickens to almost 200 ft in Wilcox County where it is divided into two members (LaMoreaux and Toulmin 1959). The lower Pine Barren Member consists of about 150 ft of calcareous silt, glauconitic sand, and sandy limestone at the type locality along Pine Barren Creek, Wilcox County, Alabama. The upper McBryde Limestone Member includes about 50 ft of sandy and argillaceous limestone in the type area near McBryde Station, Wilcox County, Alabama (LaMoreaux and Toulmin 1959). The Clayton was not penetrated by the coreholes drilled near Butler, Choctaw County.

The Porters Creek Formation conformably overlies the Clayton Formation in southwestern Alabama (text-fig. 2). The type locality for this formation is along Porters Creek west of Middleton, Hardeman County, Tennessee (Safford 1864). In Choctaw County, the Porters Creek consists of 350 to 450 ft of primarily black massive clay. The upper 3 to 6 ft of the formation are a gray to green, fossiliferous, glauconitic sand (Turner and Newton 1971).



TEXT-FIGURE 2
Geologic column and paleoenvironments of Paleocene and lower Eocene strata in southwestern Alabama.

This sand is recognized as the upper member of the Porters Creek and is referred to as the Matthews Landing Marl Member. The Porters Creek Formation decreases eastward to 150 to 200 ft in Wilcox County. The Matthews Landing Marl Member, however, increases in thickness eastward and is 20 ft thick at its type locality on the Alabama River in Wilcox County, Alabama (LaMoreaux and Toulmin 1959). A total of 275 ft of the Porters Creek Formation, including 5 ft of the Matthews Landing Member, was penetrated in the OSM #1 Tuckabum corehole drilling in Choctaw County.

The Naheola Formation conformably overlies the Porters Creek Formation (text-fig. 2). The type locality is at Naheola Bluff on the Tombigbee River, Choctaw County, Alabama (Toulmin et al. 1951). The formation is usually about 180 ft thick in Choctaw County and includes two members. The lower Oak Hill Member consists of 100 to 125 ft of gray, carbonaceous, micaceous, laminated silt and clay, interbedded with cross-bedded sand (Turner and Newton 1971). One or more beds of lignite usually occurs at the top of this member. The Oak Hill thins to 80 to 100 ft in its type area in Wilcox County, Alabama. In the type area, in roadcuts about 1 mi north and west of the Oakhill Post Office, Wilcox County, Alabama, the Oak Hill consists of laminated very fine-grained sand, silty clay and silt (LaMoreaux and Toulmin 1959). The upper Coal Bluff Marl Member disconformably overlies the Oak Hill. The Coal Bluff includes about 10 to 20 ft of fossiliferous, glauconitic, micaceous, fine- to medium-grained sand and thin layers of silt and clay in its type area in Wilcox County, Alabama (LaMoreaux and Toulmin 1959). The member increases in thickness from 40 to 60 ft in Choctaw County where the Coal Bluff consists of gray, carbonaceous clay and gray micaceous, sparsely glauconitic, fine- to medium-grained sand (Turner and Newton 1971). The Naheola Formation drilled in the OSM #1 Tuckabum corehole in Choctaw County includes 242 ft of section. It consists of 214.5 ft of Oak Hill, 7 of lignite and 27.5 ft of Coal Bluff. The Porters Creek-Naheola contact is conformable in the OSM #1 Tuckabum core. The Coal Bluff disconformably overlies a carbonaceous clay in this corehole. In the OSM #2 Wahalak core, where two lignite beds are present, 51 ft of Coal Bluff sediments disconformably overlie an upper 1-ft lignite bed. An 11-ft thick lignite bed occurs 23 ft below the upper lignite bed.

The Nanafalia Formation disconformably overlies the Naheola Formation (text-fig. 2). The type locality for the Nanafalia is at Nanafalia Landing on the Tombigbee River, Marengo County, Alabama (Smith 1886). The Nanafalia is divided into three members and ranges in thickness from 100 to 130 ft in Choctaw County (Turner and Newton 1971). The lower Gravel Creek Sand Member consists of 40 ft of white to yellow, micaceous, medium- to coarse-grained, cross-bedded sand in Choctaw County (Toulmin et al. 1951). At its type locality along Gravel Creek, Wilcox County, Alabama, the member is approximately 50 ft thick (LaMoreaux and Toulmin 1959). Thirty-six ft of the middle member are exposed at the Nanafalia type section (Newton et al. 1961). This unit has been referred to informally as the "*Ostrea thirsae* beds" because of the abundance of the oyster *Odontogryphaea thirsae* (Gabb) in this calcareous, glauconitic, fossiliferous sand and silty clay (Turner and Newton 1971). The "*Ostrea thirsae* beds" are usually 35 to 45 ft thick in Wilcox County and 30 to 60 ft thick in Choctaw County (LaMoreaux and Toulmin 1959). The upper Grampian Hills Member is 80 to 110 ft thick in Wilcox County. At its type locality in roadcuts along Alabama Highway 41, 7.1 mi south of Camden, Wilcox County, Alabama, the Grampian Hills consists of green to gray, indurated clay interbedded with greenish gray, glauconitic sand (LaMoreaux and Toulmin 1959). In Choctaw County, this member includes 6 to 30 ft of gray, fossiliferous, carbonaceous, massive, blocky clay containing thin beds of glauconitic, fine-grained sand (Turner and Newton 1971). The Nanafalia Formation cored in the OSM #1 Tuckabum totals 195 ft, whereas in the OSM #2 Wahalak corehole, the formation is 160 ft thick. The Gravel Creek Sand Member is 37 ft in the OSM #1 Tuckabum core and 87 ft in the OSM #2 Wahalak core. The "*Ostrea thirsae* beds" are thicker in the OSM #1 Tuckabum core (71 ft) than the OSM #2 Wahalak core (40 ft). The Grampian Hills cored in the OSM #1 Tuckabum includes 87 ft. This member consists of 35 ft in the OSM #2 Wahalak core. The contact between the "*Ostrea thirsae* beds" and the Grampian Hills Member is gradational in both cores.

The Tuscahoma Sand conformably overlies the Nanafalia Formation (text-fig. 2). The formation was named for exposures at Tuscahoma Landing on the Tombigbee River, Choctaw County, Alabama (Smith et al. 1894). The Tuscahoma consists of 350 ft of interlaminated silty clays, silts, and fine-grained sands in Choctaw County (Toulmin et al. 1951). The formation thins to 275 ft in Wilcox County (LaMoreaux and Toulmin 1959). Calcareous, glauconitic, fossiliferous, fine-grained sands occur in the lower half of the formation. The lower sands are not named, whereas the middle two sands are referred to as the Greggs Landing Marl Member and the Bells Landing Marl Member. The Bells Landing Marl Member occurs near the middle of the formation. Its type section is at Bells Landing on the Alabama River, Monroe County, Alabama (Smith 1883). The Bells Landing is a highly fossiliferous, calcareous, glauconitic, quartzose, fine-grained sand about 9 ft thick. The Greggs Landing Marl Member is about 25 ft stratigraphically below the Bells Landing. This member was named for an exposure at Greggs Landing on the Alabama River in Monroe County, Alabama (Smith 1886). The member consists of a 6-ft bed of moderately fossiliferous, calcareous, quartzose, fine-grained sand with some glauconite and small particles of lignite. Several thin beds of lignite occur in the upper part of the formation. The Tuscahoma Sand penetrated in the OSM #2 Wahalak corehole is 505 ft thick. In this core, the Bells Landing Marl Member is 14 ft thick; and the Greggs Landing Marl Member, which occurs 33 ft stratigraphically below the Bells Landing, consists of 6 ft of sediment. Several other fossiliferous sands occur in the Tuscahoma above and below the Bells Landing Marl Member, but only two in the lower part of the formation are highly calcareous, glauconitic, fossiliferous, fine-grained sands. The Nanafalia-Tuscahoma contact in this corehole is conformable.

The Hatchetigbee Formation conformably overlies the Tuscahoma Sand (text-fig. 2). The formation is named from Hatchetigbee Bluff on the Tombigbee River, Washington County, Alabama (Smith 1886). The Hatchetigbee is usually 250 ft thick throughout southwestern Alabama and is divided into the lower Bashi Marl Member and an upper unnamed member (Toulmin et al. 1951). The Bashi is named from exposures along Bashi Creek, Clarke County, Alabama (Smith 1886). The Bashi consists of 6 to 35 ft of greenish gray, fossiliferous, glauconitic, calcareous sand (LaMoreaux and Toulmin 1959). The upper member is comprised of 215 to 245 ft of gray, carbonaceous, micaceous, laminated clay and silt and fine-grained, cross-bedded sand (Turner and Newton 1971). In the OSM #2 Wahalak corehole drilled in Choctaw County, 249 ft of Hatchetigbee was penetrated, including 21 ft of the Bashi Marl Member. The Tuscahoma-Hatchetigbee contact in the corehole is conformable.

The lithologies of the Paleocene lithostratigraphic units in the subsurface of Choctaw County, as observed in the OSM #1 Tuckabum and OSM #2 Wahalak cores, are similar to those for the respective units as described and observed from surface exposures in southwestern Alabama. However, the Paleocene section expands to over 1400 ft in the subsurface of Choctaw County as compared with a total thickness of 950 to 1000 ft for surface Paleocene strata in this county.

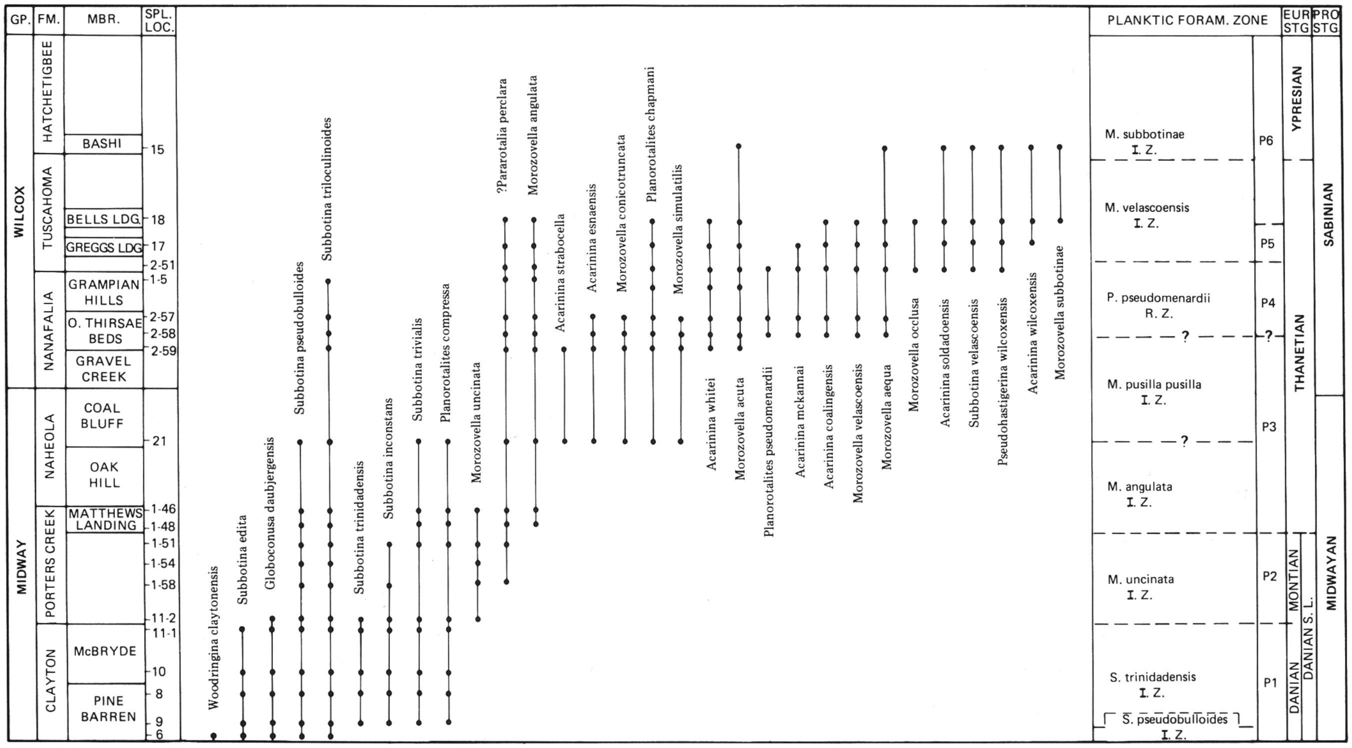
PLANKTIC FORAMINIFERAL BIOSTRATIGRAPHY

The Paleogene planktic foraminiferal zonation utilized in this study was first established by Bolli (1957, 1966) and later modified by Stainforth et al. (1975). This zonation has been used widely as an accepted biostratigraphic standard for warm-water areas of the world, including the Gulf Coastal Plain region.

The lower boundary of the *Subbotina pseudobulloides* Interval Zone of Leonov and Alimarina (1961) and Bolli (1966) is defined by the first occurrence of *Subbotina pseudobulloides* (Plummer) and the upper boundary is delineated by the first appearance of *Subbotina trinidadensis* (Bolli). *Subbotina pseudobulloides, Subbotina triloculinoides* (Plummer), and *Globoconusa daubjergensis* (Bronnimann) are characteristic of the zone. *Planorotalites compressa* (Plummer) occurs in the upper part of the zone (Stainforth et al. 1975).

The basal part of the Pine Barren Member of the Clayton Formation at Millers Ferry, Wilcox County, has been assigned by Olsson (1970b) to the *Subbotina pseudobulloides* Interval Zone (= *Globigerina edita* Zone). This interval zone is also recognized in the Clayton at Rooster Bridge on the Tombigbee River, Sumter County (Sect. 3; text-fig. 1) and in an exposure along the L&N Railroad near Highway 28, Marengo County (Sect. 6). The presence of *S. pseudobulloides* and the absence of *S. trinidadensis* in these beds place them in this interval zone (text-fig. 3). *Woodringina claytonensis* Loeblich and Tappan, *Subbotina edita* (Subbotina), *S. triloculinoides,* and *Globoconusa daubjergensis* are also common, while *Planorotalites compressa* was not observed.

The lower boundary of the *Subbotina trinidadensis* Interval Zone of Bolli (1957) is delimited by the first occurrence of *S. trinidadensis* and the upper boundary is marked by the first appearance of *Morozovella uncinata* (Bolli). *Subbotina trinidadensis, S. pseudobulloides, S. triloculi-*



TEXT-FIGURE 3

Paleocene and lower Eocene lithostratigraphy, biostratigraphy, and chronostratigraphy in southwestern Alabama. Section numbers refer to sections in text-figure 1.

noides, Globoconusa daubjergensis, and *Planorotalites compressa* typify the zone (Stainforth et al. 1975).

The lower Pine Barren at Millers Ferry, Wilcox County, has been reported by Olsson (1970b) to rest within the *Subbotina trinidadensis* Interval Zone. The zone is also recognized in the Pine Barren in a corehole drilled near Millers Ferry, Wilcox County (Sect. 9; text-fig. 1); the Pine Barren and McBryde Limestone Members of the Clayton Formation at Tilden, Dallas County (Sect. 8); the McBryde along Highway 10, west of the J. Lee Long Bridge (Sect. 10) and at Midway Landing on the Alabama River (Sect. 11), Wilcox County; and the lower part of the Porters Creek Formation, 2.1 mi south of Thomaston, Marengo County (Sect. 7). The occurrence of *S. trinidadensis* in the absence of *Morozovella uncinata* puts these beds in this Interval Zone (text-fig. 3). *Subbotina trivialis* (Subbotina), *S. edita, S. inconstans* (Subbotina), *S. pseudobulloides, Globoconusa daubjergensis,* and *Planorotalites compressa* are also found in these beds.

The lower boundary of the *Morozovella uncinata* Interval Zone of Bolli (1957, 1966) is marked by the first appearance of *M. uncinata* and the upper boundary is defined by the first occurrence of *Morozovella angulata* (White). *Subbotina trinidadensis* becomes extinct in the lower part of this interval zone (Stainforth et al. 1975).

Most of the Porters Creek clay is contained within the *Morozovella uncinata* Interval Zone as published by Berggren (1965a). However, Kidd (MS) has indicated that the lower part of the Porters Creek along Highway 12, Butler County, has a planktic foraminiferal assemblage characteristic of the *Subbotina trinidadensis* Interval Zone. As mentioned above, the lower part of the Porters Creek exposed in a roadcut south of Thomaston, Marengo County (Sect. 7) has been assigned to the *S. trinidadensis* Interval Zone. The lower Porters Creek occurring at Midway Landing on the Alabama River, Wilcox County (Sect. 11; text-fig. 1), however, contains *M. uncinata* and is placed in the *M. uncinata* Interval Zone. Thus, the lower Porters Creek exposed in Butler and Marengo Counties, and perhaps counties west of Marengo, may be age equivalent with a portion of the upper Clayton in Wilcox County. The 270 ft of Porters Creek clay cored in the OSM #1 Tuckabum corehole are put in the *M. uncinata* Interval Zone. The presence of *M. uncinata* and the absence of *M. angulata* place these beds in this zone (text-fig. 3). *Subbotina pseudobulloides, S. triloculinoides, S. inconstans, S. trivialis, Planorotalites compressa,* and *?Pararotalia perclara* (Loeblich and Tappan) are common constituents of the zone.

The lower boundary of the *Morozovella angulata* Interval

Zone of Alimarina (1963) and Hillebrandt (1965) is delineated by the first occurrence of *M. angulata* and the upper boundary is delimited by the first appearance of *Morozovella pusilla pusilla* (Bolli). *Morozovella conicotruncata* (Subbotina) occurs in the upper part of the zone (Stainforth et al. 1975).

The 5 ft of Matthews Landing Marl Member of the Porters Creek Formation cored in the OSM #1 Tuckabum corehole rests within the *Morozovella angulata* Interval Zone. The Matthews Landing Marl exposed near Matthews Landing on the Alabama River, Wilcox County (Sect. 12; text-fig. 1), on Pursley Creek near Estelle, Wilcox County (Sect. 22), and along U.S. Route 43, Marengo County (Sect. 5) is also placed in the zone. The occurrence of *M. angulata* and the absence of *M. pusilla pusilla* in this member put it in this interval zone (text-fig. 3). *Subbotina pseudobulloides, S. triloculinoides, S. trivialis, Planorotalites compressa, ?Pararotalia perclara,* and *M. uncinata* also occur in the Matthews Landing.

The lower boundary of the *Morozovella pusilla pusilla* Interval Zone of Bolli (1975) is defined by the first appearance of *M. pusilla pusilla* and the upper boundary is marked by the first occurrence of *Planorotalites pseudomenardii* (Bolli). *Morozovella conicotruncata* is the predominant species in this zone, and *Morozovella simulatilis* (Schwager), *Planorotalites chapmani* (Parr), and *Acarinina mckannai* (White) originate in the lower part of the zone (Stainforth et al., 1975).

The Coal Bluff Marl Member of the Naheola Formation has been assigned by Berggren (1965a, 1965b) to the *Morozovella pusilla pusilla* Interval Zone. Mancini (1981) placed the Coal Bluff exposed at Coal Bluff on the Alabama River (Sect. 13), along Gravel Creek (Sect. 19) and at Caledonia (Sect. 21), Wilcox County (text-fig. 1) in the upper part of the *M. angulata* Interval Zone based on the absence of *M. pusilla pusilla. Morozovella angulata, M. conicotruncata, Subbotina pseudobulloides, S. trivialis, S. triloculinoides, ?Pararotalia perclara, Acarinina esnaensis* (LeRoy), *A. strabocella* (Loeblich and Tappan), *Planorotalites compressa,* and *P. chapmani* were reported from these beds. Additional collecting and processing of samples from the Caledonia section has resulted in the recovery of *M. simulatilis* from the Coal Bluff. The presence of *M. simulatilis* with *M. conicotruncata* and *P. chapmani* indicates that the Coal Bluff should be placed in the *M. pusilla pusilla* Interval Zone. The Coal Bluff cored in the OSM #1 Tuckabum and OSM #2 Wahalak coreholes did not contain any planktic foraminifers. To date, no foraminifers have been recovered from the Oak Hill Member of the Naheola Formation; therefore, a planktic foraminiferal zone assignment of this member is not possible at this time.

The lower part of the "*Ostrea thirsae* beds" of the Nanafalia Formation cored in the OSM #1 Tuckabum and OSM #2 Wahalak coreholes and exposed at Gullettes Bluff on the Alabama River, Wilcox County (Sect. 14; text-fig. 1) may rest either within the *Morozovella pusilla pusilla* Interval Zone or the *Planorotalites pseudomenardii* Range Zone. Neither *M. pusilla pusilla* nor *P. pseudomenardii* was observed in these beds. *Morozovella acuta* (Toulmin), *M. conicotruncata, M. simulatilis, M. angulata, Acarinina whitei* (Weiss), *A. strabocella, A. esnaensis, Planorotalites chapmani, ?Pararotalia perclara,* and *Subbotina triloculinoides* are present, but these species can occur in either zone. The absence of *Morozovella aequa* (Cushman and Renz) and *Morozovella velascoensis* (Cushman) suggests that the lower part of the "*Ostrea thirsae* beds" should be placed in the *M. pusilla pusilla* Interval Zone; however, the calcareous nannofossil assemblage contained within these beds indicates a zone assignment comparable to the *P. pseudomenardii* Range Zone (Gibson et al. 1982). No calcareous microfossils have yet been found in the Gravel Creek Sand Member of the Nanafalia Formation so it cannot be placed in a planktic foraminiferal zone at this time.

The *Planorotalites pseudomenardii* Range Zone of Bolli (1957) is defined by the total range of *P. pseudomenardii. Morozovella occlusa* (Loeblich and Tappan), *M. aequa,* and *M. velascoensis* appear at the base of the zone, while *M. acuta* originates immediately below the base (Stainforth et al. 1975).

The "*Ostrea thirsae* beds" of the Nanafalia Formation exposed at Nanafalia Landing on the Tombigbee River, and in a roadcut north of Vineland, Marengo County, as reported by Smith (MS), and the unnamed lower Tuscahoma marls occurring near Fatama (Sect. 20) and along Bear Creek (Sect. 16), Wilcox County (text-fig. 1), as published by Mancini and Oliver (1981), contain *Planorotalites pseudomenardii* and therefore were assigned to the *P. pseudomenardii* Range Zone by these authors. The upper part of the "*Ostrea thirsae* beds" and the Grampian Hills Member of the Nanafalia Formation, as well as the lower Tuscahoma, penetrated in the OSM #1 Tuckabum and the OSM #2 Wahalak coreholes and the upper part of the "*Ostrea thirsae* beds" of the Nanafalia at Gullettes Bluff (Sect. 14) also rest within this range zone. The presence of *P. pseudomenardii* places these beds in this zone (text-fig. 3). *Morozovella acuta, M. aequa, M. angulata, M. velascoensis, Acarinina coalingensis* (Cushman and Hanna), *A. mckannai, A. whitei, P. chapmani,* and *?Pararotalia perclara* are common constituents of the assemblage. *Morozovella conicotruncata, M. simulatilis, Acarinina esnaensis,* and *Subbotina triloculinoides* occur in the lower part of the zone, while *M. occlusa, Pseudohastigerina wilcoxensis* (Cushman and Ponton), *Acarinina soldadoensis* (Bronnimann), and *Subbotina velascoensis* (Cushman) are present in the upper part of the range zone.

The lower boundary of the *Morozovella velascoensis* Interval Zone of Bolli (1957) is delineated by the extinction of *Planorotalites pseudomenardii*, and the upper boundary is delimited by the last occurrence of *M. velascoensis*. *Acarinina mckannai* becomes extinct in the zone, and *Morozovella subbotinae* (Morozova) originates in the upper part of this interval zone.

The Greggs Landing and Bells Landing Marl Members of the Tuscahoma Sand at their respective type sections on the Alabama River, Monroe County (Sect. 17 and 18; text-fig. 1) have been put in the *Morozovella velascoensis* Interval Zone by Mancini and Oliver (1981). *Morozovella velascoensis* occurs in both of the members, while *Planorotalites pseudomenardii* is absent. *Morozovella occlusa* and *M. subbotinae* were found in the Bells Landing Marl Member, and *Acarinina mckannai* is restricted to the Greggs Landing Marl Member (text-fig. 3). *Acarinina wilcoxensis* (Cushman and Ponton), *A. coalingensis, A. soldadoensis, A. whitei, Morozovella aequa, M. angulata, M. acuta, Planorotalites chapmani, Pseudohastigerina wilcoxensis,* ?*Pararotalia perclara,* and *Subbotina velascoensis* occur in both of these members (Mancini and Oliver 1981). The Greggs Landing and Bells Landing Marl Members in the OSM #2 Wahalak corehole did not contain an age diagnostic planktic foraminiferal assemblage. *Planorotalites pseudomenardii* was not observed in either member, but *Acarinina coalingensis, A. whitei,* ?*Pararotalia perclara,* and *Subbotina velascoensis* are present in the Bells Landing Marl Member.

The lower boundary of the *Morozovella subbotinae* Interval Zone of Bolli (1957, 1966) is marked by the last occurrence of *M. velascoensis* and the upper boundary is defined by the first occurrence of *Morozovella aragonensis* (Nuttall). *Morozovella aequa* and *M. acuta* became extinct in the lower part of this zone (Stainforth et al. 1975).

The Bashi Marl Member of the Hatchetigbee Formation has been placed in the *Morozovella subbotinae* Interval Zone by Berggren (1965b). *Morozovella subbotinae, M. acuta, M. aequa, Acarinina wilcoxensis, Subbotina velascoensis,* and *Pseudohastigerina wilcoxensis* have been reported by Mancini and Oliver (1981) from this member at Yellow Bluff along the Alabama River, Wilcox County (Sect. 15; text-fig. 1). *Morozovella velascoensis* and *M. occlusa* were not observed in samples from Yellow Bluff (text-fig. 3). A similar assemblage is present in exposures in the type area of the Bashi along Bashi Creek (Sect. 4), Clarke County. The Hatchetigbee Formation penetrated in the OSM #2 Wahalak corehole did not contain any planktic foraminifers.

Utilizing the planktic foraminiferal zones recognized in the Paleocene surface and subsurface strata in southwestern Alabama, relative geologic age determinations can be made for the respective formations. The Clayton Formation and Porters Creek clay are Danian in age (text-fig. 3). The Matthews Landing Marl Member of the Porters Creek Formation, the Oak Hill and Coal Bluff Marl Members of the Naheola Formation, and possibly the Gravel Creek Sand Member of the Nanafalia Formation are early Thanetian. The "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation and the Tuscahoma Sand are late Thanetian. The Bashi Marl Member of the Hatchetigbee is primarily Ypresian in age.

Employing the stratigraphic distribution of the planktic foraminifers recovered from these shallow to marginal marine formations, the Paleocene-Eocene boundary in southwestern Alabama is judged to be above the top of the Bells Landing Marl Member of the Tuscahoma Sand and near the base of the Bashi Marl Member of the Hatchetigbee Formation (text-fig. 3). The Bells Landing Marl Member has been put in the *Morozovella velascoensis* Interval Zone by Mancini and Oliver (1981), and the Bashi Marl Member has been assigned to the *M. subbotinae* Interval Zone by Berggren (1965b). Many planktic foraminiferal biostratigraphers place the boundary between the Paleocene and Eocene at the top of the *M. velascoensis* Interval Zone. At this horizon, large and heavily ornamented species, like *M. velascoensis*, become extinct and are replaced by simpler forms, such as *M. subbotinae* (Stainforth et al. 1975). Based on the distribution of sporomorphs in the Tuscahoma and Hatchetigbee Formations, the Paleocene-Eocene boundary in Alabama corresponds with the Tuscahoma-Hatchetigbee formational contact with a minor hiatus apparent between the two units (Frederiksen et al. 1982; Gibson et al. 1982).

Berggren et al. (1967) and Berggren (1971) have defined the Paleocene-Eocene boundary by the occurrence of the first Tertiary planispiral planktic foraminifer, *Pseudohastigerina wilcoxensis,* and have referred to this level as the "*Pseudohastigerina* datum." Specimens of *P. wilcoxensis* have been described from the Tuscahoma marls by Mancini and Oliver (1981). The occurrence of this species in the unnamed lower Tuscahoma marls (*Planorotalites pseudomenardii* Range Zone) and the Greggs Landing and Bells Landing Members of the Tuscahoma Sand (*Morozovella velascoensis* Interval Zone) suggests that the "*Pseudohastigerina* datum" may not be applicable to the northeastern Gulf Coast region. Stainforth et al. (1975) also have reported *P. wilcoxensis* from the *Planorotalites pseudomenardii* Range Zone in the eastern Mediterranean. Although *Pseudohastigerina wilcoxensis* originally was described from the Bashi (Berggren et al. 1967), it probably evolved from *Planorotalites chapmani* during the Late Paleocene. Most specimens of *Pseudohastigerina wilcoxensis* from the unnamed lower Tuscahoma marls are atypical in having a low trochospiral rather than a planispiral test, whereas many of the individuals recovered from the Greggs Landing and Bells

Landing Marl Members attain a more planispiral morphology typical of the species (Mancini and Oliver 1981).

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERIDA Eichwald 1830
Genus ACARININA Subbotina 1953

Acarinina coalingensis (Cushman and Hanna 1927)

Globigerina coalingensis CUSHMAN and HANNA 1927, p. 219, pl. 14, figs. 4a-b.
Acarinina coalingensis (Cushman and Hanna).—BERGGREN 1977, pp. 251-253, Chart X.—MANCINI and OLIVER 1981, p. 210, pl. 1, figs. 1-2.

Remarks: Acarinina coalingensis is recognized by its strongly spinose to papillate surface and by having three or four compressed chambers in the final whorl. Although surface texture varies considerably, high magnification will permit recognition of the spines on most specimens.

Stratigraphic distribution: This species has a world-wide distribution from the Late Paleocene *Planorotalites pseudomenardii* Range Zone through the Middle Eocene (Berggren 1977). In this study, it was found to be rare to common in the "*Ostrea thirsae* beds" of the Nanafalia Formation and in the Tuscahoma marls.

Acarinina esnaensis (LeRoy 1953)

Globigerina esnaensis LEROY 1953, p. 31, pl. 6, figs. 8-10.
Globorotalia esnaensis (LeRoy).—LOEBLICH and TAPPAN 1957b, pp. 189-190, pl. 61, figs. 1a-2c, 9a-c.
Acarinina esnaensis (LeRoy).—BERGGREN 1977, pp. 249-250, Chart X.

Remarks: This species is characterized by a nearly quadrate outline, a periphery that is broadly rounded, and by having four chambers in the final whorl. It has a spinose surface texture.

Stratigraphic distribution: Acarinina esnaensis has a world-wide range from the Late Paleocene *Planorotalites pseudomenardii* Range Zone to the Early Eocene *Morozovella subbotinae* Interval Zone (Berggren 1977). Loeblich and Tappan (1957b) and Smith (MS) have reported this species from the "*Ostrea thirsae* beds" of the Nanafalia Formation of Alabama. It was observed to be rare to common in the present study in the Coal Bluff Marl Member of the Naheola Formation and the "*Ostrea thirsae* beds" of the Nanafalia Formation.

Acarinina mckannai (White 1928)

Globigerina mckannai WHITE 1928, p. 194, pl. 27, fig. 16.—LOEBLICH and TAPPAN 1957b, pp. 181-182, pl. 47, figs. 7a-c; pl. 53, figs. 1a-2c; pl. 57, figs. 8a-c; pl. 62, figs. 5a-7c.—STAINFORTH ET AL. 1975, p. 205, fig. 66.
Acarinina mckannai (White).—BERGGREN 1977, pp. 253-254, Chart XI.—MANCINI and OLIVER 1981, p. 212, pl. 1, figs. 3, 6.

Remarks: Acarinina mckannai is recognized by its nearly circular equatorial outline and its five to seven globose chambers in the last whorl. The surface is extremely spinose.

Stratigraphic distribution: This species ranges world-wide from the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone to within the lower part of the Late Paleocene *Morozovella velascoensis* Interval Zone (Stainforth et al. 1975; Berggren 1977). *Acarinina mckannai* has been reported from the Salt Mountain Limestone (Loeblich and Tappan 1957b) and the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS) of Alabama. In the present study, it was found to be rare in the "*Ostrea thirsae* beds" of the Nanafalia Formation, the unnamed lower Tuscahoma marls and the Greggs Landing Marl Member of the Tuscahoma Sand.

Acarinina soldadoensis (Bronnimann 1952)

Globigerina soldadoensis BRONNIMANN 1952, pp. 9-11, pl. 1, figs. 1-9.
Globigerina soldadoensis soldadoensis Bronnimann.—STAINFORTH ET AL. 1975, pp. 229-230, fig. 87.
Acarinina soldadoensis (Bronnimann).—BERGGREN 1977, pp. 257-258, Chart XI.—MANCINI and OLIVER 1981, p. 212, pl. 1, figs. 4-5; pl. 3, fig. 1.

Remarks: Acarinina soldadoensis is distinguished by its four or five imbricate, ovate, axially elongate chambers in the final whorl. The species has a more open umbilicus and is less spinose than *A. mckannai.* The ultimate chamber often is one-third the size of the penultimate chamber.

Stratigraphic distribution: This species first appears in the Late Paleocene *Morozovella velascoensis* Interval Zone and becomes extinct at the base of the Middle Eocene *Hantkenina aragonensis* Interval Zone (Stainforth et al. 1975; Berggren 1977). In this study, it was observed to be rare in the Tuscahoma marls and the Bashi Marl Member of the Hatchetigbee Formation.

Acarinina strabocella (Loeblich and Tappan 1957b)

Globorotalia strabocella LOEBLICH and TAPPAN 1957b, p. 195, pl. 61, figs. 6a-c.
Acarinina strabocella (Loeblich and Tappan).—OLSSON 1970a, pp. 591-593.

Remarks: This species is characterized by having five or six chambers in the final whorl and a moderately spinose surface. The chambers increase gradually in size and are generally of greater width than height.

Stratigraphic distribution: Acarinina strabocella was first described from the Nanafalia Formation of Alabama by Loeblich and Tappan (1957b). This species was observed to be rare in the present study in the Coal Bluff Marl Member of the Naheola Formation and in the lower portion of the "*Ostrea thirsae* beds" of the Nanafalia Formation.

Acarinina whitei (Weiss 1955)

Globorotalia whitei WEISS 1955, pp. 18–19, pl. 6, figs. 1-3.
Acarinina whitei (Weiss).—MANCINI and OLIVER 1981, p. 212, pl. 2, figs. 1-3.

Remarks: This species is recognized by its four or five inflated, slightly compressed chambers in the last whorl and by its finely spinose surface. It is distinguished from *A. wilcoxensis* by its smaller size and less acute periphery.

Stratigraphic distribution: Acarinina whitei ranges from the lower part of the Late Paleocene *Planorotalites pseudomenardii* Range Zone through the *Morozovella velascoensis* Interval Zone (Bolli 1957). This species was found to be rare to common in this study in the "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation and the Tuscahoma marls.

Acarinina wilcoxensis (Cushman and Ponton 1932)
Plate 1, figures 1–3

Globorotalia wilcoxensis CUSHMAN and PONTON 1932, p. 71, pl. 9, figs. 10a–c.—STAINFORTH ET AL. 1975, p. 243, fig. 98.
Acarinina wilcoxensis (Cushman and Ponton).—BERGGREN 1977, pp. 250–251, Chart X.—MANCINI and OLIVER 1981, pp. 212–214, pl. 2, figs. 4–6.

Remarks: Acarinina wilcoxensis is characterized by its four or five moderately globose subangular-conical chambers in the final whorl, which is moderately tightly coiled. The surface is spinose.

Stratigraphic distribution: This species ranges from the Late Paleocene *Morozovella velascoensis* Interval Zone through the Early Eocene *Morozovella formosa formosa* Interval Zone (Stainforth et al. 1975). Berggren (1977) restricted *A. wilcoxensis* to the Early Eocene *Morozovella subbotinae* Interval Zone. In Alabama, it was described from the Tuscahoma Sand and Bashi Marl Member of the Hatchetigbee Formation by Cushman (1944a). In the present study, *A. wilcoxensis* was observed to be common in the Greggs Landing Marl and Bells Landing Marl Members of the Tuscahoma Sand and the Bashi Marl Member of the Hatchetigbee Formation.

Genus GLOBOCONUSA Khalilov 1956

Globoconusa daubjergensis (Bronnimann 1953)
Plate 1, figures 4–6

Globigerina daubjergensis BRONNIMANN 1953, p. 340, fig. 1.—STAINFORTH ET AL. 1975, p. 181, fig. 45.
Globigerinoides daubjergensis (Bronnimann).—LOEBLICH and TAPPAN 1957b, pp. 184–185, pl. 40, figs. 1a–c, 8a–c; pl. 41, figs. 9a–c; pl. 42, figs. 6a–7c; pl. 43, figs. 1a–c; pl. 44, figs. 8a–c.
Globoconusa daubjergensis (Bronnimann).—OLSSON 1970a, p. 593.

Remarks: Globoconusa daubjergensis is recognized by its small, highly trochospiral test. It has three or four spherical chambers in the final whorl which increase rather rapidly in size. The surface is hispid. Specimens occurring in the upper McBryde Member of the Clayton Formation and lower Porters Creek beds are characterized as being larger in diameter, acquiring well-developed sutural openings on the spiral side, and by having a more significant increase in the height of the spire compared with those forms found in the lower Pine Barren Member of the Clayton Formation. As recommended by Stainforth et al. (1975), these later evolutionary stage forms are best assigned to *G. daubjergensis* rather than *G. kozlowskii* Brotzen and Pozaryska.

Stratigraphic distribution: This species ranges world-wide from the Early Paleocene *Subbotina pseudobulloides* Interval Zone through the Early Paleocene *Subbotina trinidadensis* Interval Zone (Stainforth et al. 1975). *Globoconusa daubjergensis* has been reported from the Pine Barren (Olsson 1970b) and McBryde Limestone (Loeblich and Tappan 1957b) Members of the Clayton Formation. It was observed from the Pine Barren and McBryde Limestone Members of the Clayton Formation, as well as the basal Porters Creek beds in the present study.

Genus MOROZOVELLA McGowran 1968

Morozovella acuta (Toulmin 1941)

Globorotalia wilcoxensis Cushman and Ponton var. *acuta* TOULMIN 1941, p. 608, pl. 82, figs. 6–8.
Globorotalia acuta Toulmin.—LOEBLICH and TAPPAN 1957b, pp. 185–186, pl. 47, figs. 5a–c; pl. 55, figs. 4a-5c; pl. 58, figs. 5a–c.—STAINFORTH ET AL. 1975, p. 163, fig. 30.
Morozovella acuta (Toulmin).—BERGGREN 1977, p. 234, Chart VI.—MANCINI and OLIVER 1981, p. 214, pl. 3, figs. 3–4, 6.

Remarks: Morozovella acuta is recognized by its four or five angular-conical chambers in the final whorl, a keeled periphery, and a generally smooth last chamber which comprises one-fifth to one-third of the final whorl. It is distinguished from *M. velascoensis* by its less pronounced ornamentation, fewer chambers, and a narrower umbilicus.

Stratigraphic distribution: This species has a world-wide distribution from the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone to within the Early Eocene *Morozovella subbotinae* Interval Zone (Stainforth et al. 1975; Berggren 1977). In Alabama, *M. acuta* has been reported from the Matthews Landing Marl Member of the Porters Creek Formation (Cushman 1951), the Coal Bluff Marl Member of the Naheola Formation (Cushman 1944b), the Salt Mountain Limestone (Toulmin 1941; Loeblich and Tappan 1957b), the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS), and the Bashi Marl Member of the Hatchetigbee Formation (Cushman 1944a). It was found to occur in this study in the "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation, the Tuscahoma marls, and the Bashi Marl Member of the Hatchetigbee Formation. *Morozovella acuta* was not observed in samples from the Matthews Landing Marl Member of the Porters Creek Formation or the Coal Bluff Marl Member of the Naheola Formation.

Morozovella aequa (Cushman and Renz 1942)

Globorotalia crassata Cushman var. *aequa* CUSHMAN and RENZ 1942, p. 12, pl. 3, figs. 3a-c.
Globorotalia aequa Cushman and Renz.—LOEBLICH and TAPPAN 1957b, p. 186, pl. 50, figs. 6a-c; pl. 55, figs. 8a-c; pl. 59, figs. 6a-c; pl. 60, figs. 3a-c; pl. 64, figs. 4a-c.—STAINFORTH ET AL. 1975, pp. 163-164, fig. 31.
Morozovella aequa (Cushman and Renz).—BERGGREN 1977, pp. 228-230, Chart IV.—MANCINI and OLIVER 1981, p. 216, pl. 4, figs. 1-3.

Remarks: This species is characterized by usually having four angular-conical chambers which increase rapidly in size in the last whorl with the final chamber comprising one-third to one-half of the last whorl. The periphery usually has a faint keel. *Morozovella aequa* is similar to *M. subbotinae* but lacks a distinct keel and is less tightly coiled. It has fewer chambers and is less convex umbilically than *M. angulata*.

Stratigraphic distribution: Morozovella aequa ranges world-wide from the Late Paleocene *Planorotalites pseudomenardii* Range Zone to the Early Eocene *Morozovella subbotinae* Interval Zone (Stainforth et al. 1975; Berggren 1977). It has been reported from the Matthews Landing Marl Member of the Porters Creek Formation (Cushman 1951), the Coal Bluff Marl Member of the Naheola Formation (Cushman and Todd 1942; Loeblich and Tappan 1957b), the "*Ostrea thirsae* beds" of the Nanafalia Formation (Loeblich and Tappan 1957b; Smith MS), and the Bashi Marl Member of the Hatchetigbee Formation (Gibson 1980) of Alabama. It was found in the "*Ostrea thirsae* beds" of the Nanafalia Formation, the Tuscahoma marls, and the Bashi Marl Member of the Hatchetigbee Formation in this study. *Morozovella aequa* was not observed in the Matthews Landing Marl Member of the Porters Creek Formation or the Coal Bluff Marl Member of the Naheola Formation.

Morozovella angulata (White 1928)
Plate 2, figures 1-3

Globigerina angulata WHITE 1928, pp. 191-192, pl. 27, fig. 13.
Globorotalia angulata (White).—LOEBLICH and TAPPAN 1957b, p. 187, pl. 45, figs. 7a-c; pl. 48, figs. 2a-c; pl. 50, figs. 4a-c; pl. 55, figs. 2a-c, 6a-7c; pl. 58, figs. 2a-c; pl. 64, figs. 5a-c.—STAINFORTH ET AL. 1975, p. 167, fig. 34.
Morozovella angulata (White).—BERGGREN 1977, pp. 230-231, Chart V.—MANCINI and OLIVER 1981, p. 216, pl. 4, figs. 4-6.

Remarks: Morozovella angulata is recognized by usually having five or six angular-conical chambers which increase rapidly in size with the last chamber comprising about one-third of the whorl. The periphery is lobate and has a keel. The test is umbilico-convex with the spiral side usually flat.

Stratigraphic distribution: This species has a world-wide distribution from the Middle Paleocene *Morozovella angulata* Interval Zone (Stainforth et al. 1975) to within the Late Paleocene *Planorotalites pseudomenardii* Range Zone (Stainforth et al. 1975; Berggren 1977). *Morozovella angulata* has been described from the Matthews Landing Marl Member of the Porters Creek Formation, the Salt Mountain Limestone (Loeblich and Tappan 1957b), and the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS) in Alabama. In this study, the species was found to occur in the Matthews Landing Marl Member of the Porters Creek Formation, the Coal Bluff Marl Member of the Naheola Formation, the "*Ostrea thirsae* beds" and the Grampian Hills Member of the Nanafalia Formation, and the Tuscahoma marls.

Morozovella conicotruncata (Subbotina 1947)
Plate 2, figures 4-6

Globorotalia conicotruncata SUBBOTINA 1947, pp. 115-116, pl. 4, figs. 11-13; pl. 9, figs. 9-11.—STAINFORTH ET AL. 1975, p. 178, fig. 44.
Morozovella conicotruncata (Subbotina).—BERGGREN 1977, pp. 231-232, Chart V.

Remarks: This species is similar to *M. angulata* but is distinguished by having more angular-conical chambers (6 to 8) in the last whorl that are closely spaced and increase slowly in size. The periphery is subcircular and usually has a faint keel.

Stratigraphic distribution: Morozovella conicotruncata ranges from within the Middle Paleocene *Morozovella angulata* Interval Zone (Stainforth et al. 1975) to within the Late Paleocene *Planorotalites pseudomenardii* Range Zone (Stainforth et al. 1975; Berggren 1977). It has been reported from the "*Ostrea thirsae* beds" of the Nanafalia Formation in Alabama (Smith MS). The species was observed in this study in the Coal Bluff Marl Member of the Naheola Formation and the "*Ostrea thirsae* beds" of the Nanafalia Formation.

Morozovella occlusa (Loeblich and Tappan 1957b)

Globorotalia occlusa LOEBLICH and TAPPAN 1957b, p. 191, pl. 55, figs. 3a-c; pl. 64, figs. 3a-c.—STAINFORTH ET AL. 1975, pp. 208-210, fig. 70.
Morozovella occlusa (Loeblich and Tappan).—BERGGREN 1977, pp. 234-235, Chart VII.

Remarks: Morozovella occlusa is distinguished from *M. velascoensis* by having less distinct ornamentation and a more closed umbilicus. It has five to eight angular-rhomboid chambers that increase slowly in size and a circular periphery that is distinctly keeled.

Stratigraphic distribution: This species ranges from the *Planorotalites pseudomenardii* Range Zone to the *Morozovella velascoensis* Interval Zone of the Late Paleocene (Stainforth et al. 1975; Berggren 1977). In Alabama, *M. occlusa* has been reported from the Salt Mountain Limestone (Loeblich and Tappan 1957b). In this study, it was found to be rare in one of the unnamed lower Tuscahoma marls and the Bells Landing Marl Member of the Tuscahoma Sand.

Morozovella simulatilis (Schwager 1883)
Plate 3, figures 1–3

Discorbina simulatilis SCHWAGER 1883, p. 120, pl. 29, figs. 15a–d.
Globorotalia simulatilis (Schwager).—STAINFORTH ET AL. 1975, pp. 226–228, fig. 85.
Morozovella simulatilis (Schwager).—BERGGREN 1977, p. 236, Chart VII.

Remarks: This species is characterized by its five or six angular-rhomboid chambers that increase uniformly in size in the final whorl and by having a circular periphery with an indistinct keel. It differs from *M. angulata* and *M. conicotruncata* by having a biconvex lenticular test.

Stratigraphic range: Morozovella simulatilis ranges from the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone to the Late Paleocene *Planorotalites pseudomenardii* Range Zone (Stainforth et al. 1975; Berggren 1977). It has been reported from the "*Ostrea thirsae* beds" of the Nanafalia Formation in Alabama (Smith MS). In this study, this species was observed to be rare in the Coal Bluff Marl Member of the Naheola Formation and the "*Ostrea thirsae* beds" of the Nanafalia Formation.

Morozovella subbotinae (Morozova 1939)

Globorotalia subbotinae MOROZOVA 1939, pp. 80–81, pl. 2, fig. 16.—STAINFORTH ET AL. 1975, p. 230, fig. 89.
Globorotalia rex MARTIN 1943, p. 117, pl. 8, figs. 2a–c.—LOEBLICH and TAPPAN 1957b, p. 195, pl. 60, figs. 1a–c.
Morozovella subbotinae (Morozova).—BERGGREN 1977, pp. 239–242, Chart VIII.—MANCINI and OLIVER 1981, p. 218, pl. 5, figs. 4–6.

Remarks: Morozovella subbotinae has four or five rhomboidal chambers in the final whorl which increase rapidly in size and an acute periphery with a distinct keel. It is distinguished from *M. acuta* and *M. velascoensis* by having a more closed umbilicus, a less elevated umbilical side and less distinct chamber shoulders. It is not as tightly coiled as *M. aequa* and has a distinct keel.

Stratigraphic distribution: This species originates in the latest Paleocene *Morozovella velascoensis* Interval Zone and ranges into the Early Eocene *Morozovella aragonensis* Interval Zone (Stainforth et al. 1975). Berggren (1977) reported its range from the *Morozovella subbotinae* Interval Zone to the *Morozovella formosa* Interval Zone of the Early Eocene. In Alabama, *M. subbotinae* has been reported from the Bashi Marl Member of the Hatchetigbee Formation (Berggren 1965b). In the present study, it has been found in the Bells Landing Marl Member of the Tuscahoma Sand, the Bashi Marl Member of the Hatchetigbee Formation, and upper Hatchetigbee marls at Hatchetigbee Bluff on the Tombigbee River, Washington County.

Morozovella uncinata (Bolli 1957)
Plate 3, figures 4–6

Globorotalia uncinata BOLLI 1957, p. 74, pl. 17, figs. 13–15.—STAINFORTH ET AL. 1975, p. 239, fig. 95.
Morozovella uncinata (Bolli).—BERGGREN 1977, pp. 225–226, Chart I.

Remarks: This species is characterized by its five or six chambers, which increase moderately in size in the final whorl. The chambers are subangular-conical except for the last one, which is usually globular. The side of the test is flat or slightly convex and has sharply curved sutures, while the umbilical side is inflated and has radial sutures. The periphery is subangular and later becomes rounded. *Morozovella uncinata* is distinguished from its ancestors *Subbotina pseudobulloides* and *S. inconstans* by its subangular-conical test, flat spiral side, and the strong backward curvature of the sutures on the spiral side. It differs from *M. angulata* by its somewhat more rounded test and strongly inflated umbilical side.

Stratigraphic distribution: Morozovella uncinata ranges world-wide from the base of the *Morozovella uncinata* Interval Zone to within the *Morozovella angulata* Interval Zone of the Middle Paleocene (Stainforth et al. 1975; Berggren 1977). It has been reported from the Porters Creek Formation of Alabama (Berggren 1965a; Kidd MS). In this study, this species was found in the Porters Creek clay and the Matthews Landing Marl Member of the Porters Creek Formation.

Morozovella velascoensis (Cushman 1925)

Pulvinulina velascoensis Cushman 1925, p. 19, pl. 3, figs. 5a–c.
Globorotalia velascoensis (Cushman).—LOEBLICH and TAPPAN 1957b,

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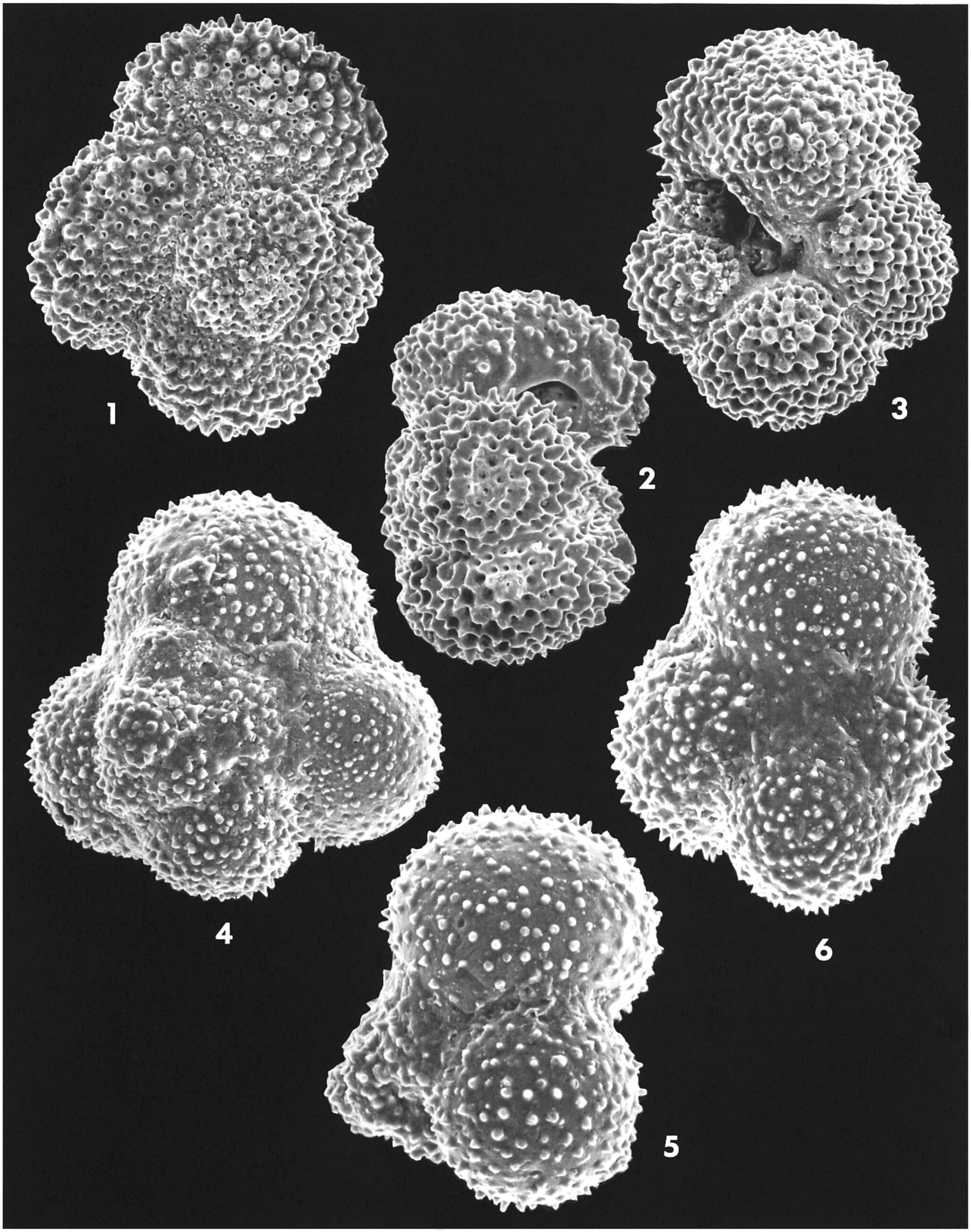
PLATE 1

1–3 *Acarinina wilcoxensis* (Cushman and Ponton)
1, spiral view; 2, edge view; 3, umbilical view, from the Bells Landing Marl Member of the Tuscahoma Sand, measured section 18. × 270.

4–6 *Globoconusa daubjergensis* (Bronnimann)
4, spiral view, × 360; 5, edge view, × 450; 6, umbilical view, × 360, from the McBryde Limestone Member of the Clayton Formation, measured section 10.


1
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pp. 196–197, pl. 64, figs. 1a-2c.—STAINFORTH ET AL. 1975, pp. 240–241, fig. 97.

Morozovella velascoensis (Cushman).—BERGGREN 1977, pp. 232–234, Chart VI.—MANCINI and OLIVER 1981, p. 218, pl. 6, figs. 1-3.

Remarks: Morozovella velascoensis is characterized by its six to eight angular-conical chambers, which increase moderately in size in the last whorl. The periphery is acute and has a strongly developed keel. It differs from *M. acuta* by having more chambers in the final whorl, by possessing more distinct and beaded sutures on the spiral side, and in having more ornamented umbilical shoulders.

Stratigraphic distribution: This species ranges from the *Planorotalites pseudomenardii* Range Zone through the *Morozovella velascoensis* Interval Zone of the Late Paleocene (Stainforth et al. 1975). Berggren (1977) reported its presence from the upper part of the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone to the basal part of the Early Eocene *Morozovella subbotinae* Interval Zone. In Alabama, this species has been described from the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS) and the Bashi Marl Member of the Hatchetigbee Formation (Berggren 1977). In this study, *M. velascoensis* was found to be rare in the "*Ostrea thirsae* beds" of the Nanafalia Formation and the Tuscahoma marls. It was not recovered from the Bashi Marl Member of the Hatchetigbee Formation.

Genus PARAROTALIA Le Calvez 1949

?Pararotalia perclara (Loeblich and Tappan 1957b)

Globorotalia perclara LOEBLICH and TAPPAN 1957b, pp. 191–192, pl. 42, figs. 4a–c; pl. 45, figs. 11a–c; pl. 46, figs. 3a–c; pl. 50, figs. 1a–c; pl. 54, figs. 6a–7c; pl. 60, figs. 5a–c.

Pararotalia? *perclara* (Loeblich and Tappan).—OLSSON 1971, pp. 502–503.

?*Pararotalia perclara* (Loeblich and Tappan).—MANCINI and OLIVER 1981, pp. 218–220, pl. 5, figs. 1–3.

Remarks: Because of its morphologic affinities with pararotaliids, Olsson (1971) assigned this species to *Pararotalia,* a benthic foraminifer. Mancini and Oliver (1981) reported that the chamber walls of ?*P. perclara* are not so porous as the morozovellids nor so spinose as the acarinids but still thought the species was a planktic foraminifer based on its stratigraphic occurrence. This species is recognized by its small test, and by its five or six low, rounded to ovate chambers in the final whorl.

Stratigraphic distribution: This species ranges from the Early Paleocene *Subbotina trinidadensis* Interval Zone to the Late Paleocene *Planorotalites pseudomenardii* Range Zone (Loeblich and Tappan 1957b). It has been recovered from the Clayton Formation, the Matthews Landing Marl Member of the Porters Creek Formation, the Coal Bluff Marl Member of the Naheola Formation, the Salt Mountain Limestone and the Nanafalia Formation in Alabama (Loeblich and Tappan 1957b). In the present study ?*P. perclara* was found to be rare to common in the Porters Creek clay, the Matthews Landing Marl Member of the Porters Creek Formation, the Coal Bluff Marl Member of the Naheola Formation, the "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation, and the Tuscahoma marls. It was not found in the Clayton Formation.

Genus PLANOROTALITES Morozova 1957

Planorotalites chapmani (Parr 1938)
Plate 4, figures 1–3

Globorotalia chapmani PARR 1938, p. 87, pl. 3, figs. 8a–b.—STAINFORTH ET AL. 1975, pp. 176–178, fig. 42.

Globorotalia elongata Glaessner.—LOEBLICH and TAPPAN 1957b, p. 189, pl. 45, figs. 5a–c; pl. 46, figs. 5a–c; pl. 48, figs. 5a–c; pl. 49, figs. 7a–c; pl. 54, figs. 1a–5c; pl. 59, figs. 4a–c; pl. 60, figs. 9a–c; pl. 63, figs. 2a–c.

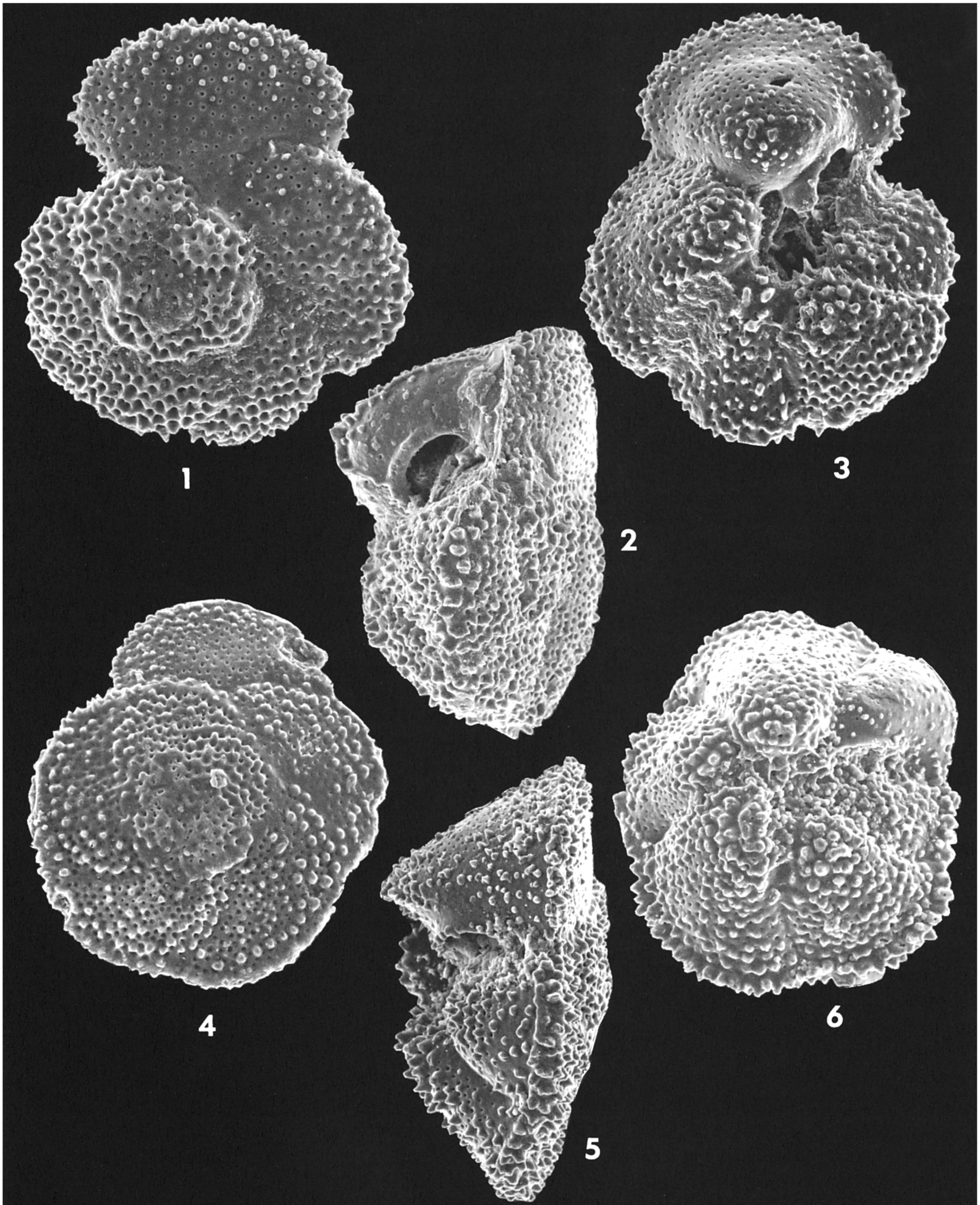
Planorotalites chapmani (Parr).—BERGGREN 1977, pp. 221–222, Chart II.

Remarks: Planorotalites chapmani has four to six angular-rhomboid chambers which increase moderately in size in the final whorl. The last chamber comprises about one-third of the whorl. The test is biconvex and almost equilateral. The periphery is lobate and lacks a true keel, although it does have an imperforate marginal band which resembles a keel. The test surface is finely perforate and smooth, and the last chamber is usually radially elongate. *Planorotalites compressa,* its ancestor, usually lacks a strong imperforate band, while *P. pseudomenardii,* its descendant, has a true keel.

PLATE 2

1–3 *Morozovella angulata* (White)
1, spiral view; 2, edge view; 3, umbilical view, from the Matthews Landing Marl Member of the Porters Creek Formation, Tuckabum Corehole 1. × 270.

4–6 *Morozovella conicotruncata* (Subbotina)
4, spiral view; 5, edge view; 6, umbilical view, from the "*Ostrea thirsae* beds" of the Nanafalia Formation, measured section 14. × 270.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Stratigraphic distribution: This species has a world-wide distribution from the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone (Stainforth et al. 1975) through the Early Eocene *Morozovella subbotinae* Interval Zone (Stainforth et al. 1975; Berggren 1977). In Alabama, *P. chapmani* has been reported from the Matthews Landing Marl Member of the Porters Creek Formation, the Coal Bluff Marl Member of the Naheola Formation, the Salt Mountain Limestone (Loeblich and Tappan 1957b), the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS), and the Bashi Marl Member of the Hatchetigbee Formation (Berggren 1977). It was found to be rare in this study in the Coal Bluff Marl Member of the Naheola Formation, the "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation, and the Tuscahoma marls. This species was not observed in the Matthews Landing Marl of the Porters Creek Formation.

Planorotalites compressa (Plummer 1926)
Plate 4, figures 4–6

Globigerina compressa PLUMMER 1926, p. 135, pl. 8, figs. 11a–c.
Globorotalia compressa (Plummer).—LOEBLICH and TAPPAN 1957b, p. 188, pl. 40, figs. 5a–c; pl. 41, figs. 5a–c; pl. 42, figs. 5a–c; pl. 44, figs. 9a–10c.—STAINFORTH ET AL. 1975, p. 178, fig. 43.
Planorotalites compressa (Plummer).—BERGGREN 1977, pp. 218–219, Chart II.

Remarks: This species is characterized by a small, biconvex test, which has a lobate periphery that lacks a keel or a strong, imperforate marginal band. It has four or five ovate angular-rhomboid chambers which increase moderately in size in the last whorl. The last chamber usually is elongate radially. It is distinguished from *Subbotina pseudobulloides* by its angular-rhomboid chambers, somewhat compressed biconvex test, and finely perforate, smooth test surface rather than a reticulate wall pattern.

Stratigraphic distribution: Planorotalites compressa originates in the Early Paleocene *Subbotina pseudobulloides* Interval Zone and ranges into the Middle Paleocene *Morozovella angulata* Interval Zone (Stainforth et al. 1975). Berggren (1977) reported the range of this species to be from the base of the Early Paleocene *Subbotina trinidadensis* Interval Zone to the lower part of the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone. In Alabama, *P. compressa* has been described from the McBryde Limestone Member of the Clayton Formation and the Matthews Landing Marl Member of the Porters Creek Formation (Loeblich and Tappan 1957b). In this study, it was observed to be rare to common in the Pine Barren and McBryde Limestone Members of the Clayton Formation, the Porters Creek clay, the Matthews Landing Marl Member of the Porters Creek Formation, and the Coal Bluff Marl Member of the Naheola Formation.

Planorotalites pseudomenardii (Bolli 1957)
Plate 5, figures 1–3

Globorotalia pseudomenardii BOLLI 1957, p. 77, pl. 20, figs. 14–17.—LOEBLICH and TAPPAN 1957b, p. 193, pl. 45, figs. 10a–c; pl. 47, figs. 4a–c; pl. 49, figs. 6a–c; pl. 54, figs. 10a–13c; pl. 59, figs. 3a–c; pl. 60, figs. 8a–c; pl. 63, figs. 1a–c.—STAINFORTH ET AL. 1975, p. 217, fig. 77.
Planorotalites pseudomenardii (Bolli).—BERGGREN 1977, pp. 220–221, Chart II.—MANCINI and OLIVER 1981, pp. 220–222, pl. 6, figs. 4–6.

Remarks: Planorotalites pseudomenardii has a distinct test characterized by five crescent-shaped chambers spirally and a finely perforate, smooth test surface. It has a strong imperforate keel.

Stratigraphic distribution: This species is restricted to the Late Paleocene *Planorotalites pseudomenardii* Range Zone (Stainforth et al. 1975; Berggren 1977). It has been reported from the Matthews Landing Marl Member of the Porters Creek Formation, the Salt Mountain Limestone (Loeblich and Tappan 1957b) and the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS) in Alabama. In the present study, *P. pseudomenardii* was observed to be rare in the "*Ostrea thirsae* beds" of the Nanafalia Formation and the unnamed lower Tuscahoma marls. It was not observed in the Matthews Landing Marl of the Porters Creek Formation.

Genus PSEUDOHASTIGERINA Banner and Blow 1959

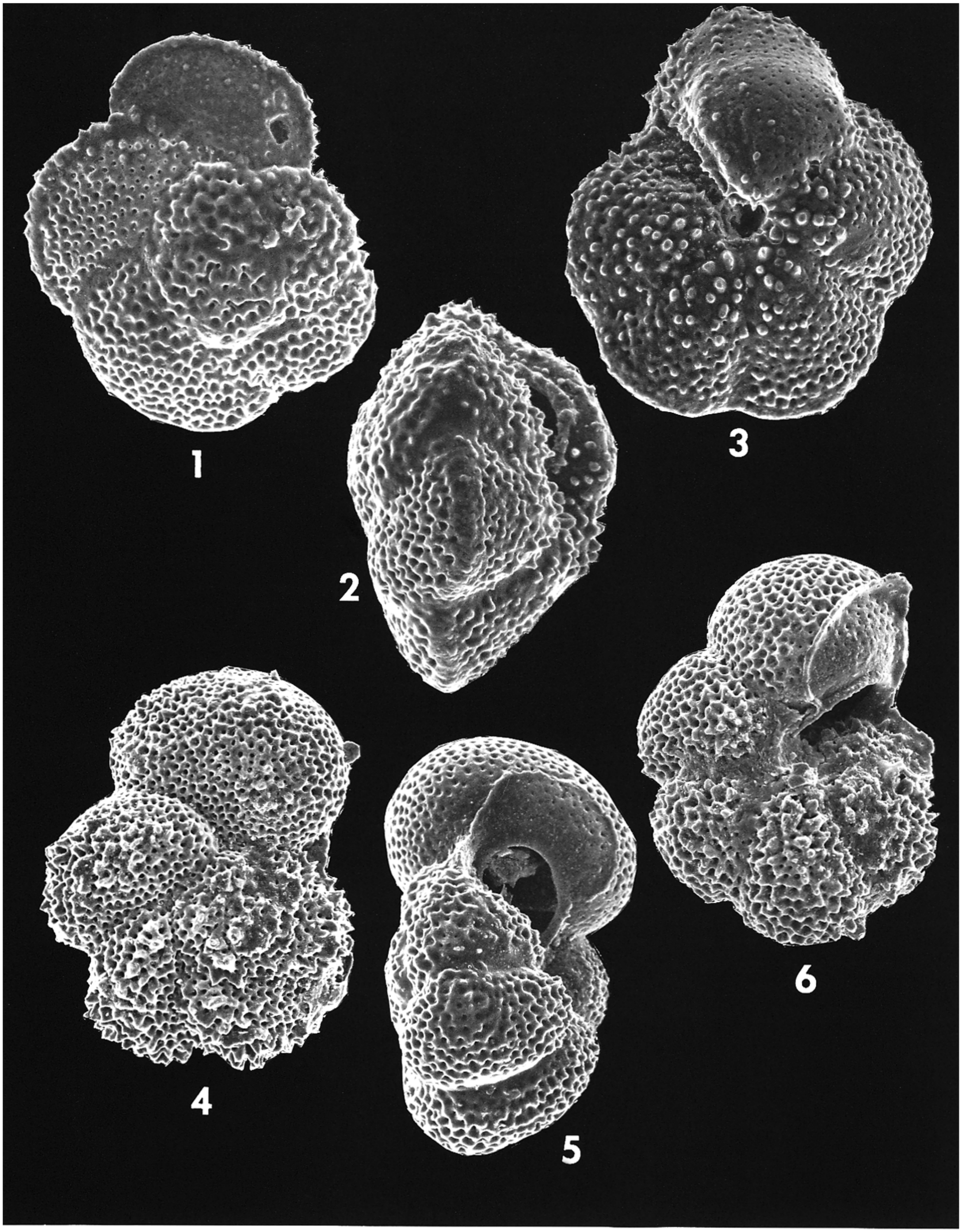
Pseudohastigerina wilcoxensis (Cushman and Ponton 1932)
Plate 5, figures 4–6

Nonion wilcoxensis CUSHMAN and PONTON 1932, p. 64, pl. 8, fig. 11.

PLATE 3

1–3 *Morozovella simulatilis* (Schwager)
1, spiral view; 2, edge view; 3, umbilical view, from the Coal Bluff Marl Member of the Naheola Formation, measured section 21. × 360.

4–6 *Morozovella uncinata* (Bolli)
4, spiral view, × 180; 5, edge view, × 270; 6, umbilical view, × 270, from the Matthews Landing Marl Member of the Porters Creek Formation, Tuckabum Corehole 1.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Pseudohastigerina wilcoxensis (Cushman and Ponton).—BERGGREN ET AL. 1967, pp. 278-280, text-fig. 2, figs. a-v; text-fig. 3, figs. 2a-5c; text-fig. 4, figs. 2a-5c; text-fig. 5, figs. 1a-9c; text-fig. 6, figs. 1a-6c.—STAINFORTH ET AL. 1975, pp. 243-244, fig. 99.—MANCINI and OLIVER 1981, p. 222, pl. 7, figs. 1-3.

Remarks: This species is a nearly planispiral, evolute form with five to seven inflated chambers that increase regularly in size. The periphery is moderately lobate, and the test surface is finely perforate, smooth.

Stratigraphic distribution: The range of *P. wilcoxensis* is from the Late Paleocene *Planorotalites pseudomenardii* Range Zone to the Middle Eocene *Globorotalia lehneri* Interval Zone (Stainforth et al. 1975). Berggren et al. (1967) reported its first occurrence from the Early Eocene *Morozovella subbotinae* Interval Zone. In Alabama, *P. wilcoxensis* has been reported from the Bashi Marl Member of the Hatchetigbee Formation (Berggren et al. 1967). This species was found to be common in the Tuscahoma marls and the Bashi Marl Member of the Hatchetigbee Formation in this study.

Genus SUBBOTINA Brotzen and Pozaryska 1961

Subbotina edita (Subbotina 1953)

Globigerina edita SUBBOTINA 1953, p. 54, pl. 2, figs. 1a-c.—OLSSON 1970b, p. 598.
Eoglobigerina edita edita (Subbotina).—BLOW 1979, pp. 1210-1212, pl. 61, figs. 2-3; pl. 66, fig. 1; pl. 69, fig. 6; pl. 72, figs. 6, 8; pl. 79, fig. 3.
Subbotina edita (Subbotina).—MANCINI 1981, p. 365.

Remarks: Subbotina edita is recognized by its five subglobular chambers which increase gradually in size in the final whorl, a reticulate wall pattern and a fairly tightly coiled test. The aperture generally is low.

Stratigraphic distribution: This species ranges from below the Early Paleocene *Subbotina pseudobulloides* Zone to within the Middle Paleocene *Morozovella uncinata* Interval Zone (Blow 1979). In Alabama, it has been reported from the Pine Barren Member of the Clayton Formation (Olsson 1970b). In this study, *S. edita* was observed to be rare in the Pine Barren and McBryde Limestone Members of the Clayton Formation.

Subbotina inconstans (Subbotina 1953)

Globigerina inconstans SUBBOTINA 1953, p. 58, pl. 3, figs. 1-2.
Globorotalia inconstans (Subbotina).—STAINFORTH ET AL. 1975, p. 193, fig. 55.
Subbotina inconstans (Subbotina).—BERGGREN 1977, pp. 217-218, Chart I.

Remarks: This species has five or six globular, ovate chambers which increase gradually in size in the last whorl, a moderately reticulate to smooth surface, and a somewhat flattened spiral side. It differs from its ancestor *S. trinidadensis* by having fewer chambers in the final whorl and a smoother test surface.

Stratigraphic distribution: The range of *S. inconstans* is from the Early Paleocene *Subbotina pseudobulloides* Interval Zone to the Middle Paleocene *Morozovella uncinata* Interval Zone (Stainforth et al. 1975). In Alabama, the species has been reported from the Pine Barren Member of the Clayton Formation (Olsson 1970b) and the Porters Creek Formation (Berggren 1977). It was found to be rare to common in this study in the Pine Barren and McBryde Limestone Members of the Clayton Formation and the Porters Creek clay.

Subbotina pseudobulloides (Plummer 1926)
Plate 6, figures 1-3

Globigerina pseudobulloides PLUMMER 1926, p. 33, pl. 8, fig. 9.
Globorotalia pseudobulloides (Plummer).—LOEBLICH and TAPPAN 1957b, pp. 192-193, pl. 40, figs. 3a-c; pl. 41, figs. 1a-c; pl. 42, figs. 3a-c; pl. 43, figs. 3a-c; pl. 44, figs. 6a-c; pl. 45, figs. 1a-2c; pl. 46, figs. 6a-c.—STAINFORTH ET AL. 1975, pp. 216-217, fig. 76.
Subbotina pseudobulloides (Plummer).—BERGGREN 1977, p. 218.

Remarks: Subbotina pseudobulloides is recognized by generally having five globular, ovate chambers that increase rapidly in size in the final whorl, and a reticulate wall pattern. The aperture is a low arch and usually has a faint lip.

Stratigraphic distribution: This species ranges from the Early Paleocene *Subbotina pseudobulloides* Interval Zone to the Middle Paleocene *Morozovella angulata* Interval Zone (Stainforth et al. 1975). In Alabama, it has been reported from the Pine Barren and McBryde Limestone Members of the Clayton Formation, the Matthews Landing Marl Member of the Porters Creek Formation, and the

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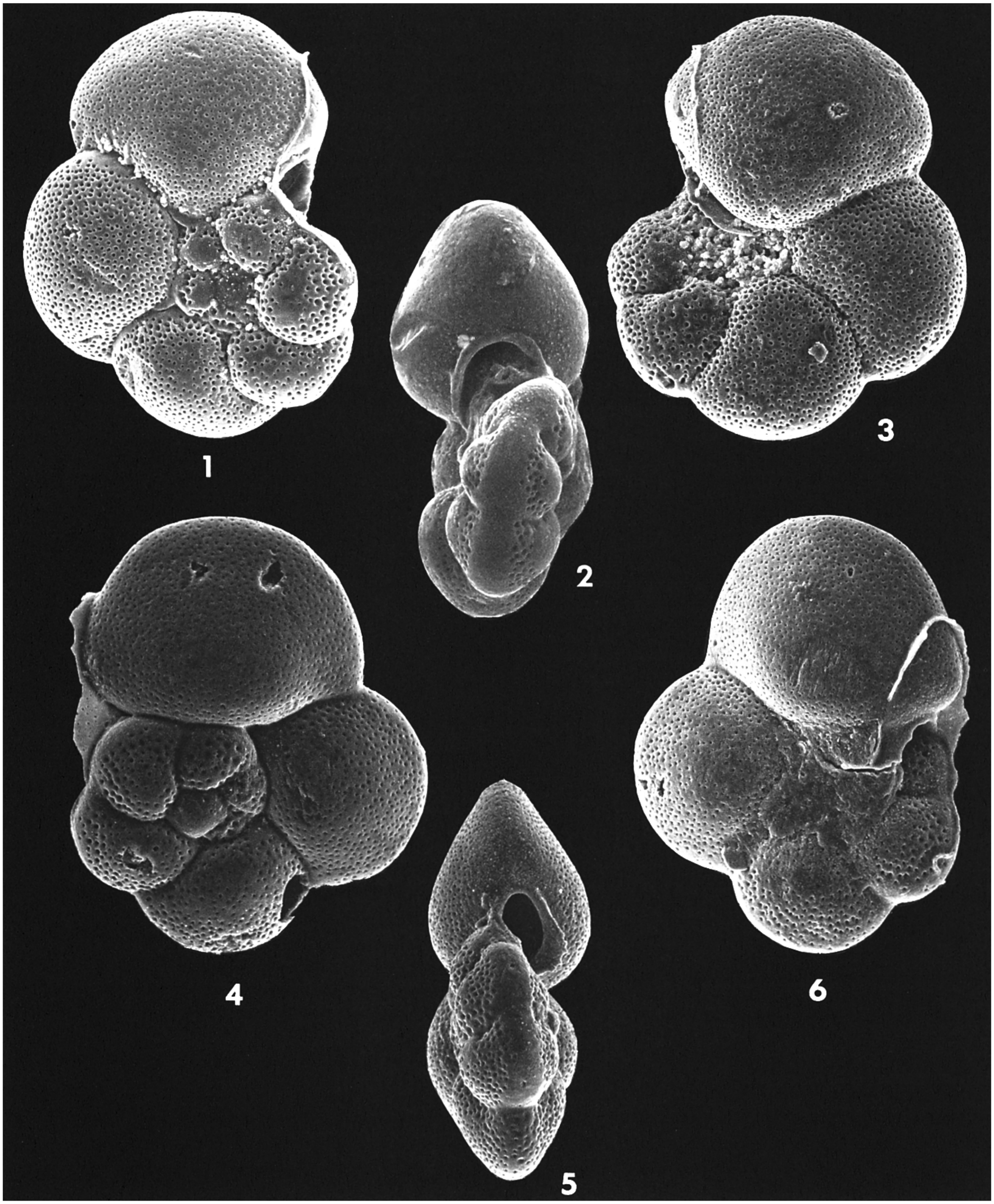
PLATE 4

1-3 *Planorotalites chapmani* (Parr)
1, spiral view; 2, edge view; 3, umbilical view, from the Coal Bluff Marl Member of the Naheola Formation, measured section 21. × 270.

4-6 *Planorotalites compressa* (Plummer)
4, spiral view; 5, edge view; 6, umbilical view, from the basal Porters Creek clay, measured section 7. × 270.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Coal Bluff Marl Member of the Naheola Formation (Loeblich and Tappan 1957b). In the present study, this species was found to be common in the Pine Barren and McBryde Limestone Members of the Clayton Formation, the Porters Creek clay, the Matthews Landing Marl Member of the Porters Creek Formation and the Coal Bluff Marl Member of the Naheola Formation.

Subbotina triloculinoides (Plummer 1926)

Globigerina triloculinoides PLUMMER 1926, p. 134, pl. 8, fig. 10.—LOEBLICH and TAPPAN 1957b, pp. 183-184, pl. 40, figs. 4a-c; pl. 43, figs. 9a-c; pl. 45, figs. 3a-c.—STAINFORTH ET AL. 1975, p. 234, fig. 92.
Subbotina triloculinoides (Plummer).—OLSSON 1970b, p. 598.

Remarks: This species is characterized by its 3 to 3.5 globular chambers in the last whorl which increase rapidly in size, and by its distinctly reticulate test surface. The test is tightly coiled and trilobate in outline.

Stratigraphic distribution: The range of *S. triloculinoides* is from the Early Paleocene *Subbotina pseudobulloides* Interval Zone into the Late Paleocene *Planorotalites pseudomenardii* Range Zone (Stainforth et al. 1975). In Alabama it has been reported from the Pine Barren (Olsson 1970b) and McBryde Limestone Members of the Clayton Formation, the Matthews Landing Marl Member of the Porters Creek Formation, the Coal Bluff Marl Member of the Naheola Formation, the Salt Mountain Limestone (Loeblich and Tappan 1957b), and the "*Ostrea thirsae* beds" of the Nanafalia Formation (Smith MS). This species was found to be rare to common in this study in the Pine Barren and McBryde Limestone Members of the Clayton Formation, the Porters Creek clay, the Matthews Landing Marl Member of the Porters Creek Formation, the Coal Bluff Marl Member of the Naheola Formation, and the "*Ostrea thirsae* beds" and Grampian Hills Member of the Nanafalia Formation.

Subbotina trinidadensis (Bolli 1957)
Plate 6, figures 4-6

Globorotalia trinidadensis BOLLI 1957, p. 73, pl. 16, figs. 19-23.—STAINFORTH ET AL. 1975, pp. 235-237, fig. 93.
Subbotina trinidadensis (Bolli).—MANCINI 1981, p. 365.

Remarks: Subbotina trinidadensis has six to eight globular chambers which increase gradually in size in the final whorl, a flattened spiral side and a reticulate surface. The last chamber is usually detached.

Stratigraphic distribution: This species ranges from the Early Paleocene *Subbotina trinidadensis* Interval Zone to the Middle Paleocene *Morozovella uncinata* Interval Zone (Stainforth et al. 1975). In Alabama, *S. trinidadensis* has been reported from the Pine Barren Member of the Clayton Formation (Olsson 1970b) and the Porters Creek Formation (Berggren 1977). This species was found to be rare to common in this study in the Pine Barren and McBryde Limestone Members of the Clayton Formation and the Porters Creek clay.

Subbotina trivialis (Subbotina 1953)

Globigerina trivialis SUBBOTINA 1953, p. 64, pl. 4, figs. 4a-c, 6a-c, 7a-c.
Globigerina triloculinoides Plummer.—LOEBLICH and TAPPAN 1957b, pl. 41, figs. 2a-c; pl. 42, figs. 2a-c; pl. 43, figs. 5a-c, 8a-b.
Subbotina trivialis (Subbotina).—OLSSON 1970a, p. 592.
Eoglobigerina trivialis (Subbotina).—BLOW 1979, pp. 1224-1228, pl. 65, figs. 1-3; pl. 66, figs. 4, 7; pl. 69, fig. 9; pl. 70, fig. 8; pl. 74, figs. 3, 5; pl. 79, figs. 1-2.

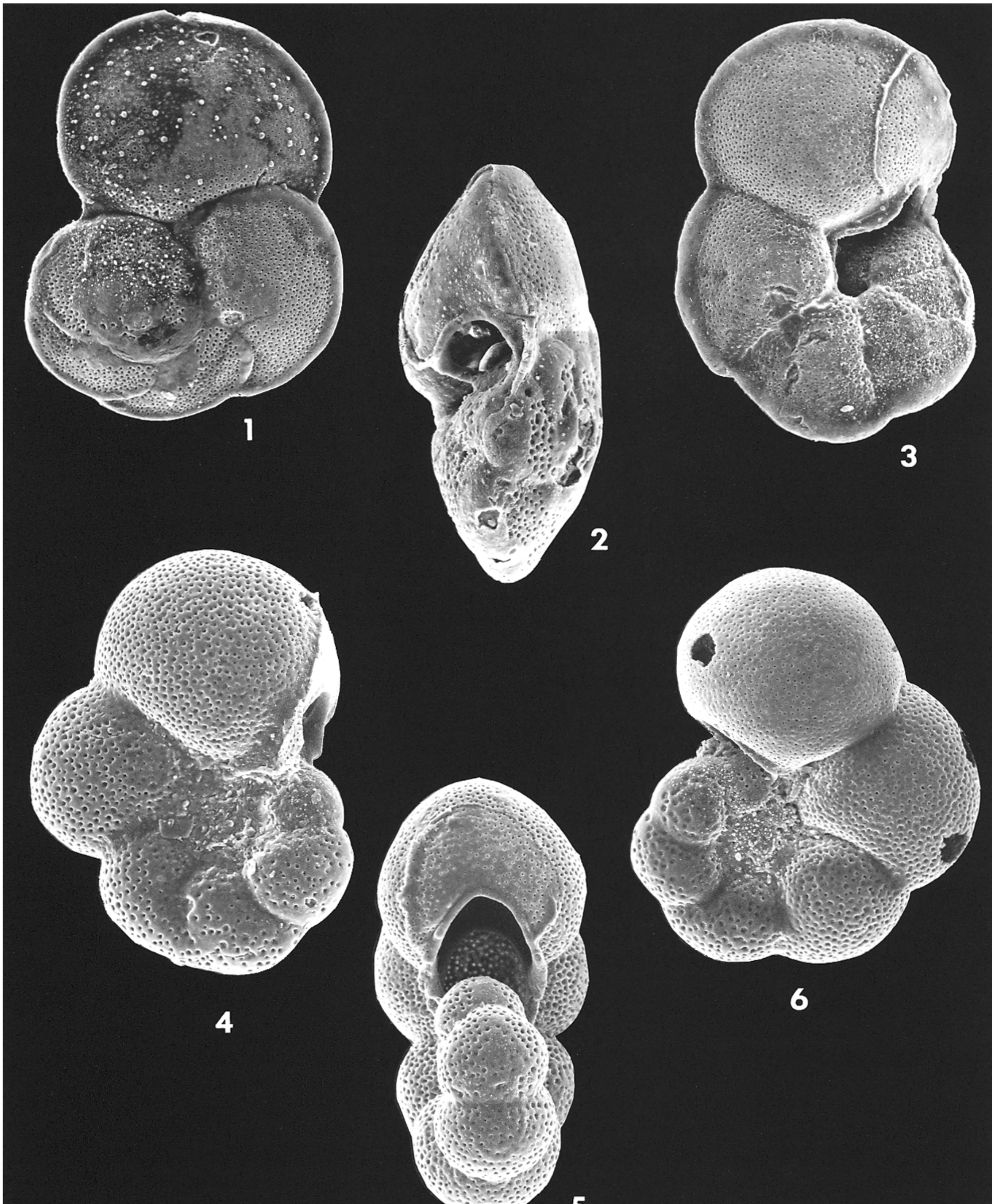
Remarks: This species is characterized by having four globular chambers in the last whorl which increase slowly in size, and by its reticulate test surface. *Subbotina trivialis* differs from *S. triloculinoides* by having a quadrilobed test, a more raised dorsal spire, more strongly separated chambers in the last whorl, and a more open and centrally located aperture.

Stratigraphic distribution: The range of *S. trivialis* is from below the Early Paleocene *Subbotina pseudobulloides* Interval Zone to within the lower part of the Middle Paleocene *Morozovella angulata* Interval Zone (Blow 1979). In this study, it is rare to common in the Pine Barren and McBryde Limestone Members of the Clayton Formation, the Porters Creek clay, the Matthews Landing Marl Member of the Porters Creek Formation, and the Coal Bluff Marl Member of the Naheola Formation.

PLATE 5

1-3 *Planorotalites pseudomenardii* (Bolli)
1, spiral view, × 180; 2, edge view, × 270; 3, umbilical view, × 180, from the unnamed lower Tuscahoma marls, measured sections 16 and 20.

4-6 *Pseudohastigerina wilcoxensis* (Cushman and Ponton)
4, spiral view; 5, edge view; 6, umbilical view, from the Bashi Marl Member of the Hatchetigbee Formation, measured section 15. × 270.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Subbotina velascoensis (Cushman 1925)

Globigerina velascoensis CUSHMAN 1925, p. 19, pl. 3, figs. 6a–c.—STAINFORTH ET AL. 1975, pp. 239–240, fig. 96.
Subbotina velascoensis (Cushman).—MANCINI and OLIVER 1981, p. 222, pl. 7, figs. 4–5.

Remarks: This species has four laterally compressed chambers, which increase rapidly in size in the final whorl, and a reticulate surface. Its laterally compressed chambers and lobate equatorial outline distinguish *S. velascoensis* from *S. triloculinoides* and *S. trivialis.*

Stratigraphic distribution: Subbotina velascoensis ranges from the Middle Paleocene *Morozovella pusilla pusilla* Interval Zone to the Early Eocene *Morozovella subbotinae* Interval Zone (Stainforth et al. 1975). In Alabama it is common in the Tuscahoma marls and the Bashi Marl Member of the Hatchetigbee Formation.

Genus WOODRINGINA Loeblich and Tappan 1957a

Woodringina claytonensis Loeblich and Tappan 1957a

Woodringina claytonensis LOEBLICH and TAPPAN 1957a, p. 39, figs. 1a–d.

Remarks: This heterohelicid consists of a small test which is initially triserial and later becomes biserial. The chambers are subglobular and increase rapidly in size. The surface of *W. claytonensis* is hispid and the aperture is a low, arched slit which is asymmetrical in position.

Stratigraphic distribution: This species has been previously described from the Pine Barren Member of the Clayton Formation (Loeblich and Tappan 1957a) of the Early Paleocene *Subbotina pseudobulloides* Interval Zone. It was found to be rare in the basal Pine Barren beds of the Clayton Formation in this study.

CONCLUSIONS

1. The Paleocene *Subbotina pseudobulloides* Interval Zone, *S. trinidadensis* Interval Zone, *Morozovella uncinata* Interval Zone, *M. angulata* Interval Zone, *Planorotalites pseudomenardii* Range Zone, *M. velascoensis* Interval Zone, and Eocene *M. subbotinae* Interval Zone are represented in the Paleogene strata of southwestern Alabama. The Paleocene *M. pusilla pusilla* Interval Zone is present but more difficult to delineate.

2. The Clayton Formation and Porters Creek clay are Danian in age. The Matthews Landing Marl Member of the Porters Creek Formation, the Naheola Formation and possibly the Gravel Creek Sand Member of the Nanafalia Formation are assignable to the early Thanetian. The "*Ostrea thirsae* beds" and the Grampian Hills Member of the Nanafalia Formation, as well as the Tuscahoma Sand, are late Thanetian, and the Bashi Marl Member of the Hatchetigbee Formation is primarily Ypresian in age. The Paleocene-Eocene boundary is near the base of the Bashi Marl Member of the Hatchetigbee Formation.

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REFERENCES

ALIMARINA, V. P., 1963. Nekotorye osobennosti razvitiya planktonnykh foraminifer v svyazi s zonalnym ras'cheleniem nizhnego paleogena severnogo kavkasa. [Some peculiarities in the development of planktonic foraminifers in connection with the zonal subdivision of the lower Paleogene in the northern Caucasus.] Akad. Nauk SSSR, Voprosy Mikropal., 7:158–195. [Russian]

BANNER, F. T., and BLOW, W. H., 1959. The classification and stratigraphical distribution of the Globigerinaceae. Palaeontology, 2(1):1–27, pls. 1–3.

BERGGREN, W. A., 1965a. The recognition of the *Globorotalia uncinata* Zone (Lower Paleocene) in the Gulf Coast. Micropaleontology, 11(1): 111–113.

———, 1965b. Some problems of Paleocene-Lower Eocene planktonic foraminiferal correlations. Micropaleontology, 11(3):278–300, pl. 1.

———, 1971. Tertiary boundaries and correlations. In: Funnell, B. M., and Riedel, W. R., Eds., Micropaleontology of the oceans. Cambridge: Cambridge Univ. Press, 693–809.

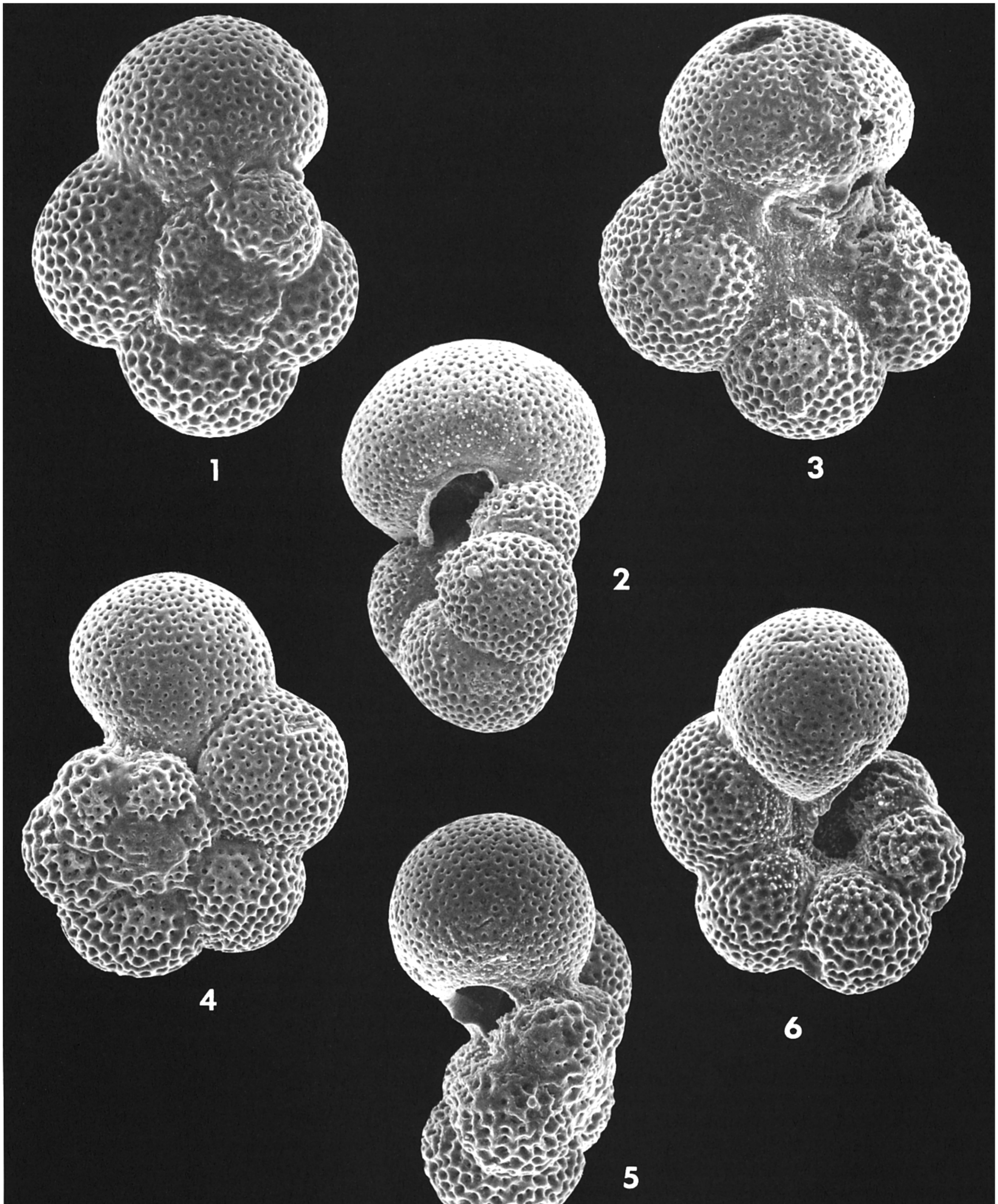
———, 1977. Atlas of Palaeogene planktonic foraminifera. In: Ramsey, A. T. S., Ed., Oceanic micropaleontology. New York: Academic Press, 1:205–299, charts I–XII.

BERGGREN, W. A., OLSSON, R. K., and REYMENT, R. A., 1967. Origin and development of the foraminiferal genus *Pseudohastigerina* Banner and Blow, 1959. Micropaleontology, 13(3):265–288, pl. 1.

PLATE 6

1–3 *Subbotina pseudobulloides* (Plummer)
1, spiral view; 2, edge view; 3, umbilical view, from the basal Porters Creek clay, measured section 7. × 180.

4–6 *Subbotina trinidadensis* (Bolli)
4, spiral view; 5, edge view; 6, umbilical view, from the McBryde Limestone Member of the Clayton Formation, measured section 10. × 270.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BLOW, W. H., 1979. The Cainozoic Globigerinida. Leiden: E. J. Brill, 1413 pp., pls. 1-264.

BOLLI, H. M., 1957. The genera *Globigerina* and *Globorotalia* in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad, B.W.I. U.S. Natl. Mus., Bull., 215:61-81, pls. 15-20.

———, 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. Assoc. Venezolana Geol., Min. Petrol. Bol. Inf., 9:3-32.

BRONNIMANN, P., 1952. Trinidad Paleocene and lower Eocene Globigerinidae. Bulls. Amer. Pal., 34(143):34 pp., pls. 1-3.

———, 1953. Note on planktonic foraminifera from Danian localities of Jutland, Denmark. Eclogae Geol. Helvetiae, 45:339-341, text-fig. 1.

BROTZEN, F., and POZARYSKA, K., 1961. Foraminifères du paléocene et de l'éocene inférieur en Pologne septentrionale, remarques paleogeographiques. Rev. Micropal., 4:155-166, pls. 1-4.

COOKE, C. W., 1926. The Cenozoic formations. In: Adams, G. I., Butts, C., Stephenson, L. W., and Cooke, C. W., Eds., Geology of Alabama. Alabama Geol. Surv., Spec. Rept., 14:251-297.

CUSHMAN, J. A., 1925. Some new foraminifera from the Velasco Shale of Mexico. Cushman Lab. Foram. Res. Contr., 1:18-23, pl. 3.

———, 1944a. A foraminiferal fauna of the Wilcox Eocene, Bashi Formation, from near Yellow Bluff, Alabama. Amer. Jour. Sci., 242:7-18, pls. 1, 2.

———, 1944b. A Paleocene foraminiferal fauna from the Coal Bluff Marl Member of the Naheola Formation of Alabama. Cushman Lab. Foram. Res. Contr., 20:29-50, pls. 5-8.

———, 1951. Paleocene foraminifera of the Gulf Coastal region of the United States and adjacent areas. U.S. Geol. Surv., Prof. Paper, 232: 1-75, pls. 1-24.

CUSHMAN, J. A., and HANNA, G. D., 1927. Foraminifera from the Eocene near Coalinga, California. California Acad. Sci., Proc., ser. 4, 16:205-228, pls. 13, 14.

CUSHMAN, J. A., and PONTON, G. M., 1932. An Eocene foraminiferal fauna of Wilcox age from Alabama. Cushman Lab. Foram. Res. Contr., 8:51-72, pls. 7-9.

CUSHMAN, J. A., and RENZ, H. H., 1942. Eocene, Midway, foraminifera from Soldado Rock, Trinidad. Cushman Lab. Foram. Res. Contr., 18: 1-14, pls. 1-3.

CUSHMAN, J. A., and TODD, R., 1942. The foraminifera of the type locality of the Naheola Formation. Cushman Lab. Foram. Res. Contr., 18:23-46, pls. 5-8.

FREDERIKSEN, N. O., GIBSON, T. G., and BYBELL, L. M., 1982. Paleocene-Eocene boundary in the eastern Gulf Coast. Gulf Coast Assoc. Geol. Socs., Trans., 32:289-294.

GIBSON, T. G., 1980. Molluscan and foraminiferal biostratigraphy of lower Paleogene strata. In: Reinhardt, J., and Gibson, T. G., Eds., Upper Cretaceous and lower Tertiary geology of the Chattahoochee River valley, western Georgia and eastern Alabama. Excursions in southeastern geology, 2:411-416, pls. 5-6.

GIBSON, T. G., MANCINI, E. A., and BYBELL, L. M., 1982. Paleocene to middle Eocene stratigraphy of Alabama. Gulf Coast Assoc. Geol. Socs., Trans., 32:449-458.

HILLEBRANDT, AXEL VON, 1965. Foraminiferen-stratigraphie im Alttertiär von Zumaya (Provinz Guipuzcoa, NW Spanien) und ein vergleich mit anderen Tethys-Gebieten. Bayerische Akad. Wiss. Abh., Math.-Naturw. Kl., 123:62 pp.

KHALILOV, D. M., 1956. O pelagicheskoi faune foraminifer paleogenovykh otlozhenii Azerbaydzhana [Pelagic foraminifers of the Paleogene deposits of Azerbaidzhan.] Akad. Nauk Azerbaydzhan, SSSR Inst. Geol., Trudy, 17:234-261, pls. 1-5. [Russian]

KIDD, J. T., MS. Foraminifera of the Porters Creek Formation in Butler County, Alabama. Unpublished Master's Thesis, 1971, University of Alabama, 92 pp., pls. 1-8.

LAMOREAUX, P. E., and TOULMIN, L. D., 1959. Geology and groundwater resources of Wilcox County, Alabama. Alabama Geol. Surv., Co. Rept., 4:280 pp.

LE CALVEZ, Y., 1949. Revision des foraminifères Lutétiens du Bassin de Paris. II. Rotaliidae et familles affinés. Carte Geol. Détaillée France, Mém., 54 pp., pls. 1-6.

LEONOV, G. P., and ALIMARINA, V. P., 1961. Stratigrafiya i planktonnye foraminifery "perekhodnykh" ot mela k paleogenu sloev tsentralnova predkavkasya. [Stratigraphy and planktonic foraminifera of the Cretaceous-Paleocene transition beds of the central part of the north Caucasus.] Moskov. Univ. Trudov Geol. Fak. Sborn., Moskov. Univ. Izd., 29-60. [Russian]

LEROY, L. W., 1953. Biostratigraphy of Maqfi Section, Egypt. Geol. Soc. Amer., Mem., 54:73 pp., pls. 1-13.

LOEBLICH, A. R., JR., and TAPPAN, H., 1957a. *Woodringina,* a new foraminiferal genus (Heterohelicidae) from the Paleocene of Alabama. Washington Acad. Sci., Jour., 47:39-40, text-fig. 1.

———, 1957b. Planktonic foraminifera of Paleocene and Early Eocene age from the Gulf and Atlantic Coastal Plains. U.S. Natl. Mus., Bull., 215:173-198, pls. 40-64.

MANCINI, E. A., 1981. Lithostratigraphy and biostratigraphy of Paleocene subsurface strata in southwest Alabama. Gulf Coast Assoc. Geol. Socs., Trans., 31:359-367.

MANCINI, E. A., and OLIVER, G. E., 1981. Planktic foraminifers from the Tuscahoma Sand (upper Paleocene) of southwest Alabama. Micropaleontology, 27(2):204-225, pls. 1-7.

MARTIN, L. T., 1943. Eocene foraminifera from the type Lodo Formation, Fresno County, California. Stanford Univ. Publ., Geol. Sci., 3(3):93-125, pls. 5-9.

MCGOWRAN, B., 1968. Reclassification of Early Tertiary *Globorotalia.* Micropaleontology, 14(2):179-198, pls. 1-4.

MOROZOVA, V. G., 1939. K stratigrafii verkhnego mela i paleogena Embenskoi oblasti po faune foraminifer. [On the stratigraphy of the Upper Cretaceous and Paleogene of the Emba region according to the foraminiferal faunas.] Moskov. Obshch. Ispytateley Prirody Byull., Otdel. Geol., 17(4,5):59-86, pls. 1, 2. [Russian]

———, 1957. Nadsemeistro foraminifer Globigerinidea superfam nova i nekotorye ego predstaviteli. [Foraminiferal superfamily Globigerinidea, superfam. nov., and some of its representatives.] Akad. Nauk SSSR, Doklady, 114(5):1109-1111, text-fig. 1. [Russian]

NEWTON, J. G., SUTCLIFFE, HORACE, JR., and LAMOREAUX, P. E., 1961. Geology and ground-water resources of Marengo County, Alabama. Alabama Geol. Surv., Co. Rept., 5:443 pp.

OLSSON, R. K., 1970a. Paleocene planktonic foraminiferal biostratigraphy and paleozoogeography of New Jersey. Jour. Pal., 44(4):589-597.

———, 1970b. Planktonic foraminifera from base of Tertiary, Millers Ferry, Alabama. Jour. Pal., 44(4):598-604, pls. 91-93.

———, 1971. Early Tertiary planktonic foraminiferal zonation of New Jersey. In: Farinacci, A., Ed., Proc. II Plankt. Conf., 1970. Rome: Tecnoscienza, 493-504, pls. I, II.

PARR, W. J., 1938. Upper Eocene foraminifera from the deep borings in King's Park, Perth, Western Australia. Roy. Soc. Western Australia, Jour., 24(8):69–101, pls. 1–3.

PLUMMER, H. J., 1926. Foraminifera of the Midway Formation in Texas. Texas, Univ., Bur. Econ. Geol., Bull., 2644:206 pp., pls. 1–15.

SAFFORD, J. M., 1864. On the Cretaceous and Superior formations of west Tennessee. Amer. Jour. Sci., 37(87):360–372.

SCHWAGER, C., 1883. Die Foraminiferen aus den Eocaen-Ablagerungen der Lybischen Wüste und Ägyptens. Palaeontographica, 30:79–154, pls. 24–29.

SMITH, C. C., MS. Foraminifera, paleoecology, and biostratigraphy of the Paleocene "*Ostrea thirsae* beds," Nanafalia Formation, west-central Alabama. Unpublished Master's Thesis, 1967, University of Houston, 205 pp., pls. 1–7.

SMITH, E. A., 1883. Report of progress for the years 1881 and 1882. Alabama Geol. Surv., 615 pp.

———, 1886. Summary of the lithological and stratigraphical features and subdivision of the Tertiary of Alabama. In: Aldrich, T. H., Ed., Preliminary report on the Tertiary fossils of Alabama and Mississippi. Alabama Geol. Surv., Bull., 1:7–14.

SMITH, E. A., JOHNSON, L. C., and LANGDON, D. W., JR., 1894. Report on the geology of the Coastal Plain of Alabama. Alabama Geol. Surv., Spec. Rept., 6:759 pp.

STAINFORTH, R. M., LAMB, J. L., LUTERBACHER, H., BEARD, J. H., AND JEFFORDS, R. M., 1975. Cenozoic planktonic foraminiferal zonation and characteristics of index forms. Univ. Kansas Pal. Contr., art. 62:425 pp., text-figs. 1–213.

SUBBOTINA, N. N., 1947. Foraminifery datskikh i paleogenovikh otlozhenii severnogo Karhaza. [Foraminifers of the Danian and Paleogene deposits of the northern Caucasus.] Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst., Trudy, 39–160, pls. 1–9. [Russian]

———, 1953. Iskopaemye foraminifery SSSR; Globigerinidae, Hantkeninidae i Globorotaliidae. [Fossil foraminifers of the USSR; Globigerinidae, Hantkeninidae, and Globorotaliidae.] Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst. (VNIGRI), Trudy, n. ser., 76:1–296, pls. 1–41. [Russian]

TOULMIN, L. D., 1941. Eocene smaller foraminifera from the Salt Mountain Limestone of Alabama. Jour. Pal., 15(6):567–611, pls. 78–82.

TOULMIN, L. D., LAMOREAUX, P. E., and LANPHERE, C. R., 1951. Geology and ground water resources of Choctaw County. Alabama Geol. Surv., Spec. Rept. 21, Co. Rept., 2:197 pp.

TURNER, J. D., and NEWTON, J. G., 1971. Geology of Choctaw County, Alabama. Alabama Geol. Surv. Map 102:15 pp.

WEISS, L., 1955. Foraminifera from the Paleocene Pale Greda Formation of Peru. Jour. Pal., 29(1):1–21, pls. 1–6.

WHITE, M. P., 1928. Some index foraminifera of the Tampico Embayment area of Mexico. Part I. Jour. Pal., 2(3):177–215, pls. 27–29.

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