Pollen Biostratigraphy of Lower Tertiary Sediments from Five Cores from Screven and Burke Counties, Georgia

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ABSTRACT

Seventeen biostratigraphically useful lower Tertiary samples were examined for their pollen taxa from five test holes (Millhaven, Girard, Thompson Oak, Millers Pond, and McBean) in Screven and Burke Counties, Georgia. Ten biostratigraphically useful samples from the Ellenton Formation have earliest and latest possible ages of late early Paleocene and late Paleocene, respectively, but most or all of the samples are probably late early or early late Paleocene. One good sample from the Snapp Formation is no older than earliest late Paleocene and no younger than middle late Paleocene. Four productive samples from the Congaree Formation are not very well dated using pollen, but possible ages are generally from late early to middle middle Eocene. Two samples from the Santee Limestone are poorly dated from pollen within the late early Eocene to middle Eocene (or younger?) interval.

INTRODUCTION

The Savannah River Site (SRS) in Aiken, Barnwell, and Allendale Counties, S.C. (fig. 1), has manufactured, disposed of, and stored a variety of hazardous materials since the early 1950's. The U.S. Geological Survey, in cooperation with the U.S. Department of Energy and the Georgia Geologic Survey of the Georgia Department of Natural Resources, is conducting a study of the subsurface geology, hydrology, and water quality in the vicinity of the SRS. The goal of the study is to understand the present and possible future ground-water flow in the aquifers of the area. Many test holes have been drilled in Georgia and South Carolina to study the flow of ground water in the SRS region (Aadland, 1992; Harris and others, 1992; Strom and others, 1992; Clarke, 1993; Gellici and Logan, 1993; Clarke and others, 1994, 1996; Clarke and West, 1994; Leeth and others, 1996). The Cretaceous and Cenozoic aquifers are difficult to correlate from area to area because of structural movement and rapid facies changes. Some biostratigraphic research has been completed toward the goal of correlating aquifers between some of the test holes (Prowell and others, 1985; Edwards, 1992; Edwards and Clarke, 1992; Edwards and Frederiksen, 1992; Lucas-Clark, 1992; Falls and others, 1993, 1997; Clarke and others, 1994, 1996; Leeth and others, 1996; Edwards and others, 1997). However, much biostratigraphic study remains to be done in the region.

This paper uses Tertiary pollen grains in core samples from five Georgia test holes to provide biostratigraphic data on both marine and nonmarine sediments in the area. The five Georgia test holes (Millhaven, Girard, Thompson Oak, Millers Pond, and McBean) in Burke and Screven Counties, Ga., are directly across the Savannah River from the SRS. Details of the Tertiary geologic framework of the region are presented elsewhere (Falls and Prowell, this volume, chap. A). Table 1 summarizes the number of samples containing pollen and the number of samples barren of pollen from each stratigraphic unit in each core.

Pollen grains from terrestrial plants are frequently found in marine and terrestrial rocks. However, the palynological preparations of samples from cored strata in the SRS region commonly contained much more abundant dinoflagellates of marine to brackish-water origin (Edwards, this volume, chap. G) than pollen grains of terrestrial origin. This dinoflagellate dominance was particularly true of the Eocene rocks and the downdip Paleocene rocks in the Millhaven and Girard cores. Yet, some Paleocene samples from the cores contained abundant pollen grains, and some others contained sufficient pollen to make age determinations of these samples possible by using these fossils.

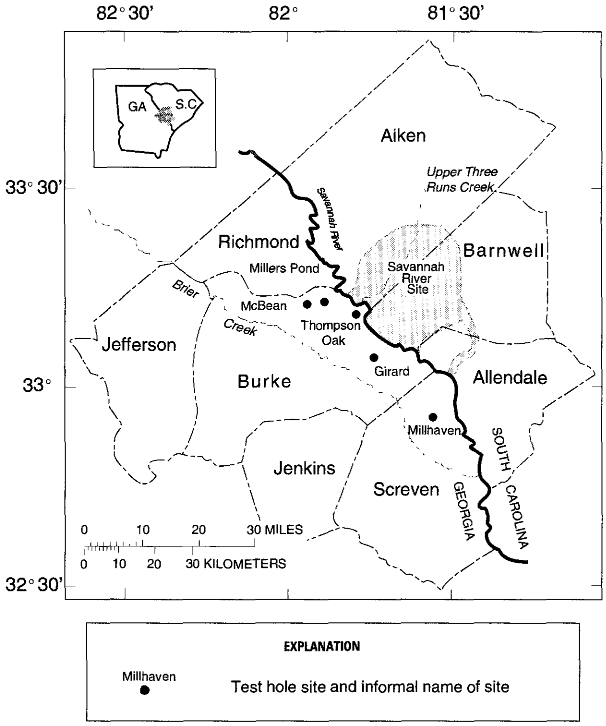

Figure 1. Index map showing the Savannah River Site and the location of test holes for this study.

ACKNOWLEDGMENTS

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MATERIAL AND METHODS

The samples discussed in this paper were processed by using normal palynological techniques involving treatment with hydrochloric, hydrofluoric, and nitric acids; short centrifugation with soapy water to remove fine material; removal of mineral grains by swirling; staining with Bismark brown; and screening on 8- or 10-micrometer (µm) sieves. The residues were mounted in glycerine jelly.

Table 2 shows the slide numbers and microscope coordinates of photographed pollen specimens; the slide designations show the sample number with the slide number in parentheses. The coordinates locate the specimens on Leitz microscope 871956 at the U.S. Geological Survey, Reston, Va. On this microscope, the coordinates for the center point of a standard 25.4x76.2-millimeter slide are 38.8 and 102.5 for the horizontal and vertical axes. The horizontal coordinates increase toward the right edge of the stage, and the vertical coordinates increase toward the front of the stage. Slides are stored at the U.S. Geological Survey, Reston, Va. The plates illustrate many of the pollen species found in the Tertiary samples. However, some of the species could not be usefully photomicrographed because of mediocre preservation or because the specimens were poorly oriented, crumpled, or partially covered with debris.

CORRELATIONS AND AGE DETERMINATIONS

Correlations and age determinations in this paper are based on many articles on spores and pollen grains from lower Tertiary strata in the Gulf Coast and the Mississippi embayment (Jones, 1962; Elsik, 1968a,b, 1974; Fairchild and Elsik, 1969; Nichols and Traverse, 1971; Nichols, 1973; Tschudy, 1973a,b, 1975; Potter, 1976; Frederiksen, 1978, 1980a, 1988, 1991, 1998; Jarzen, 1978; Christopher and others, 1980; Frederiksen and others, 1982), in the Southern Atlantic States (Frederiksen, 1978, 1980b, 1991; Frederiksen and Christopher, 1978; Prowell and others, 1985), and in the Middle Atlantic States (Frederiksen, 1979, 1984, 1991, 1998). The best pollen-stratigraphic control for the Paleocene and Eocene of eastern North America is in the eastern Gulf Coast. Therefore, in this paper, ages and correlations are made primarily by using ranges of pollen taxa in the eastern Gulf Coast. Most of the pollen taxa identified in this report (table 3) have been previously illustrated with photomicrographs in the papers listed, and many of the taxa are illustrated in plates 1 and 2.

Figure 2 shows the pollen zones that have been proposed for the Paleocene of the Eastern United States. No such zonation has been proposed for the Eocene of this region.

MILLHAVEN TEST HOLE

The Millhaven test hole (33X048) was drilled by the U.S. Geological Survey at lat 32°53'25" N., long 81°35'43" W., near Sylvania, Burtons Ferry 7.5 min quadrangle, Screven County, Ga. (fig. 1). The surface elevation is 110 ft above sea level. Sixteen Tertiary samples from this core were examined for pollen, from the depth interval of 639.5 to 105.0 ft. Seven contained biostratigraphically useful pollen assemblages.

ELLENTON FORMATION

Nine samples of the Ellenton Formation from 639.5 to 571.0 ft in the Millhaven core were examined for pollen, and six contained significant assemblages. Samples from 639.5, 632.0–632.2, and 577.0 ft were barren of pollen or recovered very poor assemblages. Distributions of pollen taxa in the six productive samples are shown in figure 3.

All of the pollen taxa in sample R4664 GD, from 620.8 ft, have long chronostratigraphic ranges within the Pale-

Table 1. Samples containing pollen and samples barren of pollen from each stratigraphic unit in each core.

[R numbers are U.S. Geological Survey paleobotanical numbers. Depths are in feet below the surface. P column: X = pollen grains are present, although not necessarily ones that are biostratigraphically important. B column: X = barren of pollen]

R number	Depth (ft)	Unit	P	B
Millhaven core				
R4664 AV-----	105	Barnwell	--	X
R4664 AT-----	195	Barnwell	--	X
R4664 AR-----	210	Barnwell	X	--
R4664 AL-----	260	Santee	--	X
R4664 K-------	490	Congaree	X	--
R4664 H-------	499	Congaree	--	X
R4664 E-------	564–565	Snapp	--	X
R4664 D-------	571	Ellenton	X	--
R4664 C-------	577	Ellenton	--	X
R4664 AW----	579.5	Ellenton	X	--
R4664 B-------	581	Ellenton	X	--
R4664 A-------	589	Ellenton	X	--
R4664 GE-----	599.5	Ellenton	X	--
R4664 GD ----	620.8	Ellenton	X	--
R4664 CH-----	632–632.2	Ellenton	--	X
R4664 GC-----	639.5	Ellenton	--	X
R4664 FG-----	755.0–755.3	Steel Creek	X	--
Girard core				
R4705 F-------	322.3–322.5	Santee	X	--
R4705 AE-----	415.2–415.5	Fourmile Br.	X	--
R4705 D-------	484.1–484.3	Ellenton	X	--
R4705 C-------	514–514.3	Ellenton	X	--
R4705 AD ----	517.9–518.1	Ellenton	X	--
R4705 B-------	521–521.2	Ellenton	X	--
R4705 A-------	532.5–532.7	Ellenton	X	--
Thompson Oak core				
R4836 O-------	172	Santee	X	--
R4836 N-------	174	Santee	X	--
R4836 M------	181.5	Santee	X	--
R4836 L-------	183	Congaree	X	--
R4836 K-------	192	Congaree	X	--
R4836 D-------	281	Ellenton	X	--
R4836 C-------	302	Ellenton	X	--
Millers Pond core				
R4581 Y-------	72–77	Barnwell	--	X
R4581 X-------	82–83	Santee	--	X
R4581 W------	120	Santee	--	X
R4581 V-------	124	Santee	--	X
R4581 U-------	148	Santee	X	--
R4581 S-------	165	Congaree	X	--
R4581 Q-------	252–257	Ellenton	X	--
McBean core				
R4663 G-------	181	Santee	X	--
R4663 F-------	210	Congaree	--	X
R4663 E-------	243	Snapp	--	X
R4663 D-------	264	Snapp	X	--
R4663 C-------	276	Ellenton	--	X
R4663 B-------	294	Ellenton	--	X

ocene except for the *Caryapollenites prodromus* group of Frederiksen (1991). This group has its range base near the top of the Naheola Formation in the eastern Gulf Coast (fig. 4), in the lower part of the upper Paleocene in calcareous nannofossil Zone NP 5 and, by definition, at the base of the *Caryapollenites prodromus* Interval Zone (fig. 2). Nannofossil evidence indicates that this sample lies within the lower part of Zone NP 5 (Bybell, this volume, chap. F).

Only three pollen taxa were identified in sample R4664 GE, from 599.5 ft, and the only useful taxon was the *Caryapollenites prodromus* group. Nannofossil evidence indicates that this sample lies within the lower part of Zone NP 5 (Bybell, this volume, chap. F).

In sample R4664 A, from 589.0 ft, the only age-diagnostic species was *Choanopollenites* sp. cf. *C. consanguineus* Tschudy of Frederiksen (1979). This species was previously known only from the lowermost part of the Aquia Formation of Virginia, which belongs to the lower part of the *Carya* Interval Zone (Frederiksen, 1979, 1991) and which has been assigned to calcareous nannofossil Zone NP 5 (Bybell and Gibson, 1991) of early late Paleocene age. Sample R4664 A also belongs to nannofossil Zone NP 5 (Bybell, this volume, chap. F); therefore, scanty evidence suggests that *Choanopollenites* sp. cf. *C. consanguineus* Tschudy of Frederiksen (1979) may in fact be confined to rocks of NP 5 age. However, because nannofossil Zone NP 5 includes the upper part of the *Caryapollenites prodromus* Interval Zone as well as the lowermost part of the *Carya* Interval Zone, it is possible that *Choanopollenites* sp. cf. *C. consanguineus* Tschudy occurs in both of these pollen zones.

Sample R4664 B, from 581.0 ft, is no older than the upper part of the lower unnamed member of the Porters Creek Formation (latest early Paleocene) in the eastern Gulf Coast, according to the known range base of *Plicatopollis triradiatus* (Nichols) Frederiksen & Christopher. The sample from 581.0 ft is no younger than the Nanafalia Formation, which is late but not latest Thanetian (known range top of *Momipites dilatus* Fairchild; fig. 4). The chronostratigraphic range of the genus *Friedrichipollis* Krutzsch is poorly known because pollen of this genus is very rare. Nannofossil evidence indicates that this sample lies within the lower part of Zone NP 5 (Bybell, this volume, chap. F).

Sample R4664 AW, from 579.5 ft, contained only rare angiosperm pollen grains. Among the taxa present (fig. 3), the only one of biostratigraphic interest was *Spinaepollis spinosus* (Potonié) Krutzsch. This species has a range from near the NP 4–NP 5 calcareous nannofossil zone boundary (very low in the upper Paleocene) to the top of the Paleocene. Nannofossil evidence indicates that this sample lies within the lower part of Zone NP 5 (Bybell, this volume, chap. F).

Critical range bases and tops of taxa in sample R4664 D, from 571.0 ft, are displayed in figure 4. From these data, it is apparent that this sample can be assigned to the interval

Table 2. Slide numbers and microscope coordinates of photographed specimens.

[The slide designations show the sample number (table 1) followed by the slide number in parentheses. Coordinates are given for Leitz microscope 871956 at the U.S. Geological Survey, Reston, Va.]

Figure	Slide	Coordinates
Plate 1		
1	R4705 B(1)	58.7 × 95.0
2	R4836 K(1)	50.1 × 107.5
3	R4705 D(1)	61.8 × 111.3
4	R4663 D(1)	50.0 × 104.7
5	R4836 K(1)	56.3 × 109.0
6	R4664 D(1)	44.7 × 96.0
7, 8	R4664 K(1)	61.4 × 110.6
9, 10	R4664 FG(1)	58.7 × 111.7
11	R4664 K(1)	59.6 × 93.3
12	R4664 FG(1)	57.8 × 105.7
13	R4705 AE(1)	63.4 × 95.2
14	R4664 K(1)	56.1 × 96.8
15	R4663 D(1)	52.5 × 105.2
16	R4705 D(1)	62.0 × 109.4
17	R4705 D(1)	57.3 × 94.9
18	R4836 K(1)	58.1 × 104.6
19	R4664 AW(1)	57.4 × 102.5
20	R4836 K(1)	64.1 × 105.8
21, 22	R4836 N(1)	52.4 × 101.8
Plate 1—Continued		
23	R4836 D(1)	54.9 × 109.2
24	R4663 G(1)	45.8 × 99.2
Plate 2		
1	R4705 D(1)	55.9 × 106.3
2	R4705 A(1)	54.2 × 96.9
3	R4836 D(1)	50.9 × 105.4
4	R4663 G(1)	49.0 × 100.3
5	R4664 A(1)	42.0 × 109.9
6	R4663 D(1)	51.0 × 104.0
7	R4664 B(1)	42.2 × 95.0
8	R4581 Q(2)	55.5 × 99.8
9	R4836 C(1)	62.4 × 93.6
10	R4705 D(1)	61.0 × 101.0
11	R4581 U(1)	44.0 × 110.3
12	R4664 B(1)	42.2 × 95.0
13	R4581 Q(6)	45.7 × 93.8
14	R4664 D(1)	40.2 × 109.7
15	R4664 B(1)	44.4 × 102.0
16	R4836 L(1)	49.7 × 93.7

Table 3. List of pollen taxa mentioned in this report followed by the illustration location.

[Most pollen taxa have been previously illustrated by the authors listed]

Taxon	Plate	Figure
Aesculiidites circumstriatus (Fairchild *in* Stover and others, 1966) Elsik	1	23
Bombacacidites nacimientoensis (Anderson) Elsik	2	14
Bombacacidites reticulatus Krutzsch	2	13
Carya <29 μm	--	--
Carya >28 μm	--	--
Caryapollenites prodromus group of Frederiksen (1991)	--	--
Choanopollenites sp. cf. *C. consanguineus* Tschudy of Frederiksen (1979)	2	5
Eucommia type (tricolporate) of Frederiksen (1988)	1	20
Favitricolporites baculoferus (Pflug *in* Thomson and Pflug, 1953) Srivastava 1972	--	--
Friedrichipollis sp.	2	12
Holkopollenites chemardensis Fairchild *in* Stover and others (1966)	--	--
Holkopollenites sp. A	--	--
Ilexpollenites sp.	1	24
Insulapollenites rugulatus Leffingwell	2	6
Intratriporopollenites pseudinstructus Mai	--	--
Intratriporopollenites sp.	2	7
Lanagiopollis cribellatus (Srivastava) Frederiksen	2	15
Lanagiopollis sp., probably *L. hadrodictyus* Frederiksen	2	16

Table 3. List of pollen taxa mentioned in this report followed by the illustration location—Continued.

Taxon	Plate	Figure
Malvacipollis cf. *M. tschudyi* Frederiksen of Frederiksen (1988)	1	18
Milfordia hungarica (Kedves) Krutzsch & Vanhoorne *in* Krutzsch (1970)	1	2
Milfordia incerta (Pflug & Thomson *in* Thomson and Pflug, 1953) Krutzsch	1	3
Momipites actinus Nichols & Ott	--	--
Momipites coryloides Wodehouse	1	5
Momipites dilatus Fairchild *in* Stover and others (1966)	1	6
Momipites strictus Frederiksen & Christopher	--	--
Momipites tenuipolus group of Frederiksen and Christopher (1978)	1	4
Momipites-Plicatopollis-Platycaryapollenites complex of Frederiksen (1979)	1	14
Myrtaceidites sp.	--	--
Nudopollis terminalis (Pflug & Thomson *in* Thomson and Pflug, 1953) Pflug	2	2, 3
Nudopollis thiergartii (Thomson & Pflug) Pflug	--	--
Osculapollis? *colporatus* Frederiksen	2	9
Piolencipollis endocuspoides Frederiksen	--	--
Platycarya platycaryoides (Roche) Frederiksen & Christopher	1	7, 8
Platycarya sp. A of Frederiksen and Christopher (1978)	1	9, 10
Platycarya spp.	1	11–13
Platycaryapollenites sp. aff. *P. swasticoidus* (Elsik) Frederiksen & Christopher	--	--
Plicatopollis triorbicularis type of Frederiksen and Christopher (1978)	1	15
Plicatopollis triradiatus (Nichols) Frederiksen & Christopher	--	--
Porocolpopollenites ollivierae (Gruas-Cavagnetto) Frederiksen	--	--
Pseudolaesopollis ventosus (Potonié) Frederiksen	2	4
Pseudoplicapollis limitatus Frederiksen	2	1
Pseudoplicapollis serenus Tschudy	2	8
Retitrescolpites anguloluminosus (Anderson) Frederiksen	--	--
Rousea monilifera Frederiksen	--	--
Sparganiaceaepollenites sp.	1	1
Spinaepollis spinosus (Potonié) Krutzsch	1	19
Spinizonocolpites prominatus (McIntyre) Stover & Evans	1	21, 22
Subtriporopollenites anulatus Pflug & Thomson *in* Thomson and Pflug (1953)	--	--
Symplocos? sp. 1 of Frederiksen (1988)	--	--
Symplocos? sp. aff. *Symplocos*? sp. 1 of Frederiksen (1988)	2	11
"*Symplocospollenites* spp." of Tschudy (1973a)	--	--
Tetracolporopollenites lesquereuxianus (Traverse) Frederiksen	--	--
Tetracolporopollenites megadolium (Potonié) Frederiksen	--	--
Triatriopollenites sparsus group of Frederiksen (1988)	--	--
Tricolpites asper Frederiksen	--	--
Triporopollenites infrequens (Stanley) Frederiksen	--	--
Trudopollis plenus Tschudy	2	10
Trudopollis spp.	--	--
Ulmipollenites krempii (Anderson) Frederiksen	1	17
Ulmipollenites tricostatus (Anderson) Frederiksen	1	16

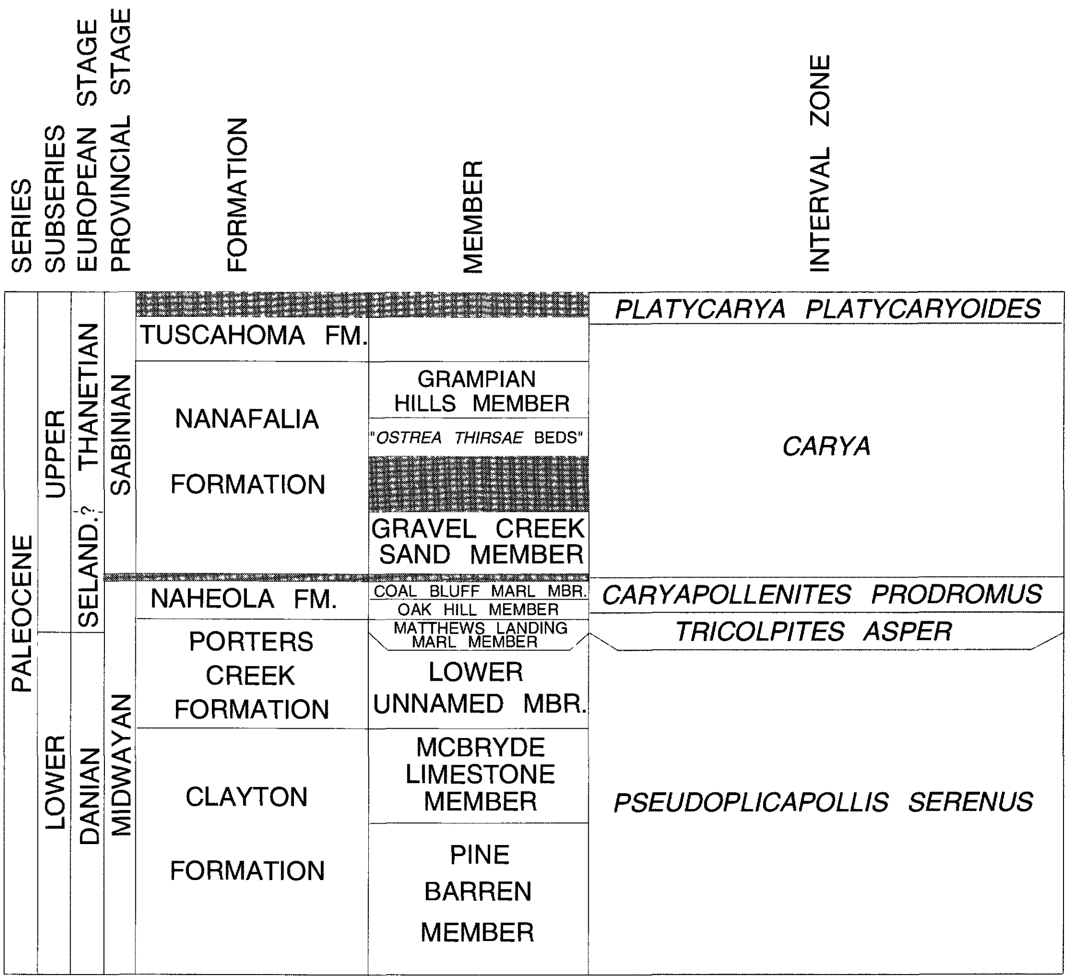

Figure 2. Pollen zonation chart for the Paleocene of the Eastern United States. Zones were proposed by Frederiksen (1991, 1998). Division of the Tertiary into European stages follows Berggren and others (1995).

from the lower part of the upper Paleocene (lower Selandian) to the upper part of the upper Paleocene (middle Thanetian). The sampled interval from the Ellenton Formation of this core contains the *Caryapollenites prodromus* group of Frederiksen (1991) but no specimens of *Carya* <29 µm were found. The latter taxon is common in samples above its range base at about the Midwayan-Sabinian Provincial Stage boundary (fig. 2), which is probably within calcareous nannofossil Zone NP 5. The apparent lack of this taxon in the Ellenton samples from the Millhaven core would suggest that this sampled interval belongs to the *Caryapollenites prodromus* Interval Zone. However, nannofossil evidence indicates that a sample from slightly deeper in this core, from 578.0 ft, is tentatively assignable to Zone NP 8 of middle Thanetian age, that is, within the upper half of the upper Paleocene (Bybell, this volume, chap. F), which is well within the range of *Carya* <29 µm. Thus, the apparent lack of this taxon in the sample from 571.0 ft is of no biostratigraphic significance. On the other hand, the lack of *Carya* <29 µm in the Ellenton samples assigned to the lower part of calcareous nannofossil Zone NP 5 in this core is thought to indicate a real absence of the taxon. *Carya* <29 µm is not known to range down to the lower part of Zone NP 5 in either the eastern Gulf Coast or South Carolina (Frederiksen, 1991).

SNAPP FORMATION

One sample, R4664 E, from 564.0–565.0 ft, was examined from the Snapp Formation in the Millhaven core. This sample contained rare dinoflagellates (Edwards, this volume, chap. G) but was barren of pollen grains.

CONGAREE FORMATION

Two samples were examined from the Congaree Formation in the Millhaven core. Sample R4664 H, from 499.0 ft, was barren of palynomorphs. Sample R4664 K, a fossiliferous sand from 490.0 ft, contained calcareous nannofossils of lower to middle Eocene Zone NP 14

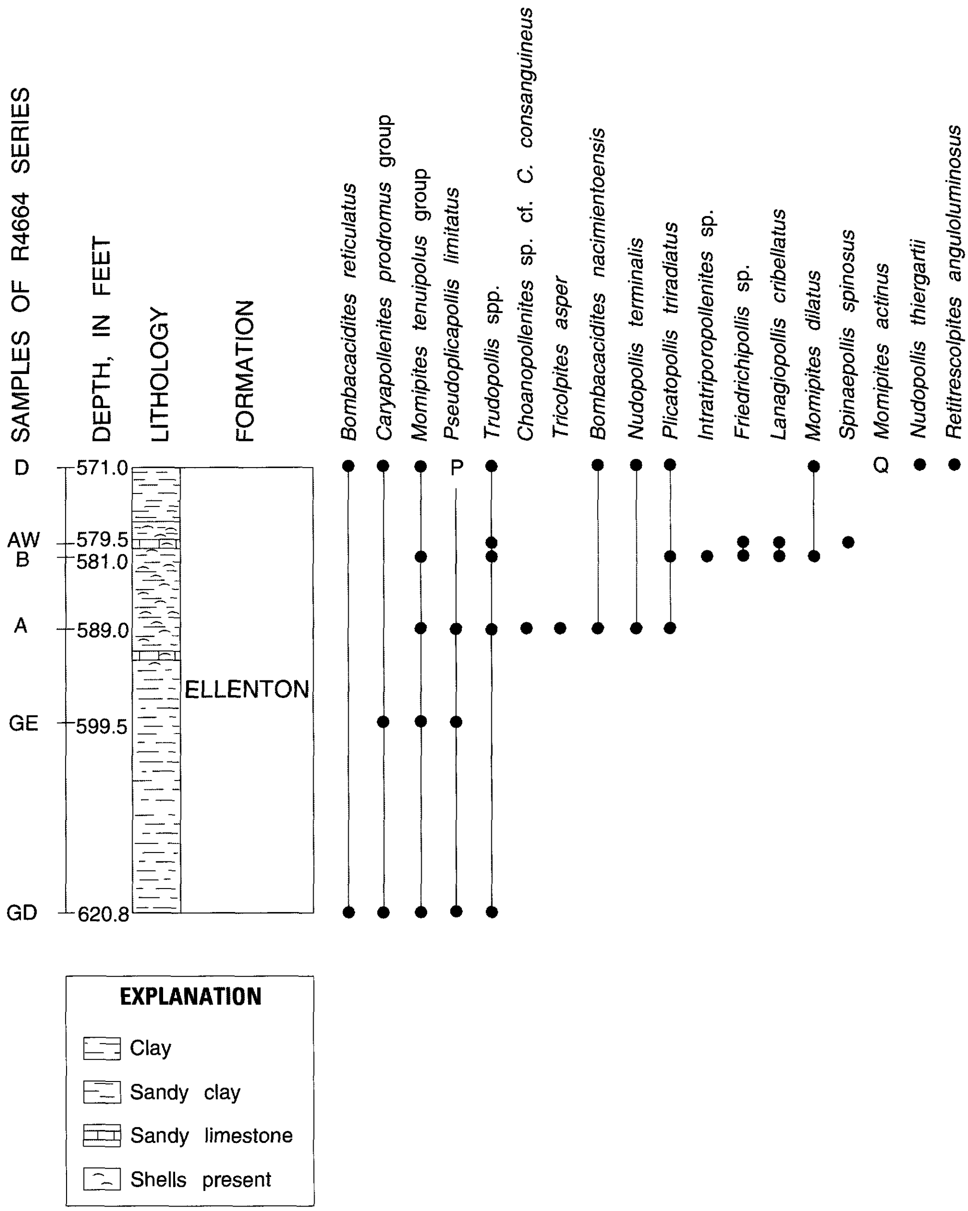

Figure 3. Chart showing pollen distributions in six samples from the Ellenton Formation in the Millhaven core. P indicates that the identification of the species was probable; Q indicates that the identification of the species was uncertain.

(Bybell, this volume, chap. F) and middle Eocene dinoflagellates (Edwards, this volume, chap. G) but only sparse pollen grains. Among the pollen taxa recovered were *Platycarya platycaryoides* (Roche) Frederiksen & Christopher and the *Momipites-Plicatopollis-Platycaryapollenites* complex of Frederiksen (1979). Both taxa have long chronostratigraphic ranges in the lower and middle Eocene, and both have their range bases a short stratigraphic distance below the top of the Paleocene.

WARLEY HILL FORMATION

No samples from the Warley Hill Formation in the Millhaven core were examined for pollen.

SANTEE LIMESTONE

One sample from the Santee Limestone in the Millhaven core, R4664 AL, from 260.0 ft, was examined for pollen. However, the sample was barren of these fossils.

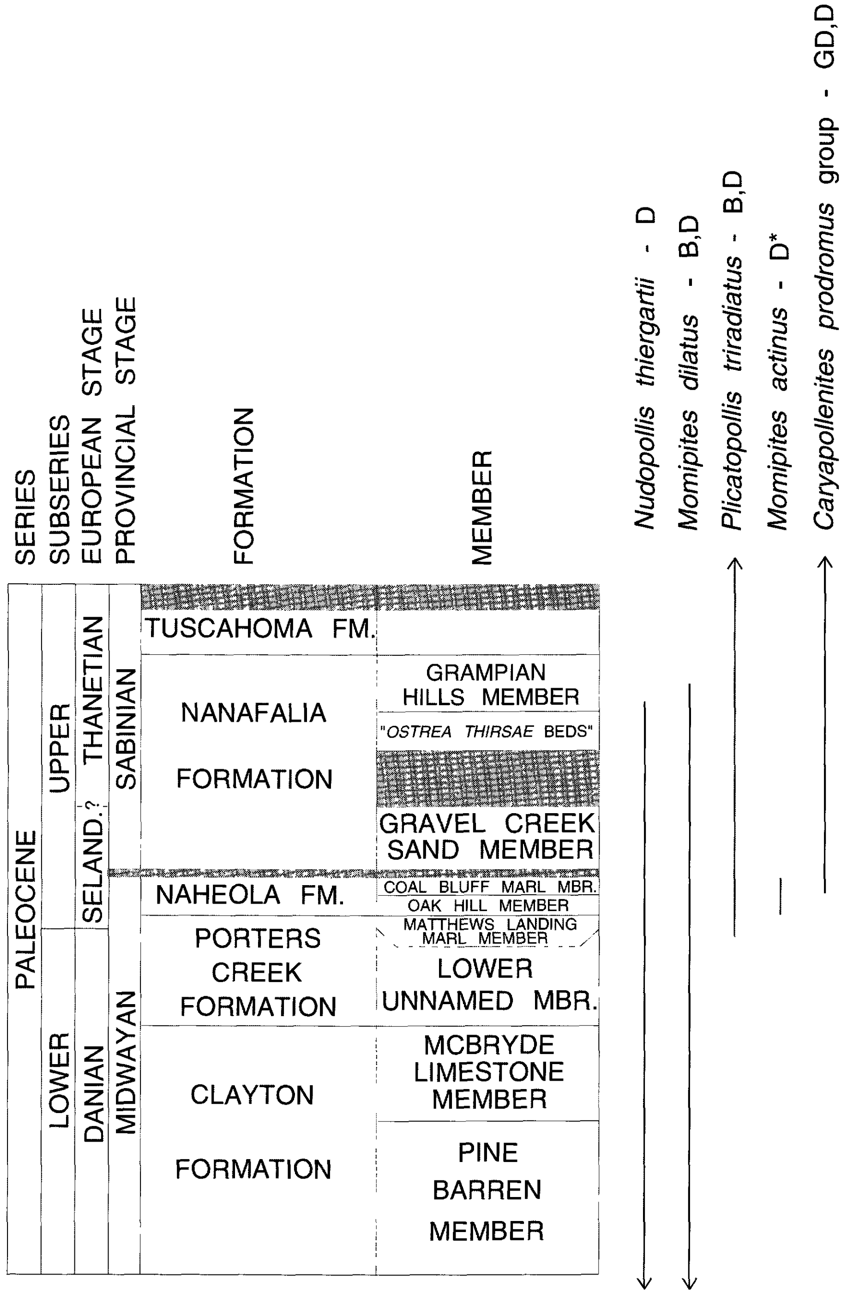

Figure 4. Chart showing known stratigraphic ranges in the eastern Gulf Coast of biostratigraphically important pollen species in samples R4664 GD, B, and D, from 620.8, 581.0, and 571.0 ft, respectively, in the Ellenton Formation in the Millhaven core. Samples in which each taxon was found are indicated by the sample initial following the taxon name; an asterisk following the name *Momipites actinus* indicates that this species was only tentatively identified.

BARNWELL UNIT

Sample R4664 AR, a fossiliferous sand from 210.0 ft in the Millhaven core, is from the Barnwell unit; the sample contained calcareous nannofossils of upper Eocene Zone NP 19/20 (Bybell, this volume, chap. F) and typical Eocene to Oligocene pollen species such as *Momipites coryloides* Wodehouse, *Pseudolaesopollis ventosus* (Potonié) Frederiksen, and *Tetracolporopollenites lesquereuxianus* (Traverse) Frederiksen. However, all of these pollen taxa have such long chronostratigraphic ranges that they are not useful for age determinations. Two additional samples of the Barnwell unit, from 195.0 and 105.0 ft, were barren of pollen.

GIRARD TEST HOLE

The Girard test hole was drilled by the U.S. Geological Survey in southern Burke County at the lookout tower on Griffins Landing Road, 2 miles north of the town of Girard, at lat 33°03'54" N., long 81°43'13" W., Girard 7.5 min quadrangle (fig. 1). The surface elevation is 250 ft above sea level. Seven Tertiary samples from this core were examined for pollen, from the depth interval of 532.7 to 322.3 ft.

ELLENTON FORMATION

Five samples from the Ellenton Formation of the Girard core were examined for pollen. One of these, sample R4705 A, from 532.5–532.7 ft, contained only two taxa (fig. 5), both long ranging. The second sample, R4705 C, from 514.0–514.3 ft (not shown in fig. 5), had only very rare pollen grains.

Samples R4705 B, from 521.0–521.2 ft, and AD, from 517.9–518.1 ft, included taxa listed in figure 5. Stratigraphic ranges of the key pollen taxa in the two samples are shown in figure 6. The overlap of ranges of *Osculapollis*? *colporatus* Frederiksen and *Caryapollenites prodromus* group of Frederiksen (1991) might suggest that the samples correlate with the Naheola Formation of the eastern Gulf Coast and are early late Paleocene in age. However, two specimens were found in the sample from 521.0–521.2 ft that might belong to the early Paleocene species *Pseudoplicapollis serenus* Tschudy. If *P. serenus* Tschudy actually is present, that might complicate the age interpretation because this species is not known to coexist with the late Paleocene taxon *Caryapollenites prodromus* group of Frederiksen (1991). However, *P. serenus* Tschudy ranges down into the Cretaceous (fig. 6) and, therefore, might be reworked.

Sparganiaceaepollenites sp. is an upper Paleocene to Holocene(?) species that is probably a result of drilling mud contamination of the sample. *Myrtaceidites* is a mainly Eocene to Oligocene genus in southeastern North America and is extremely rare below the Eocene. Therefore, this specimen also is probably a result of drilling mud contamination of the sample. Dinoflagellates in the samples from 521.0–521.2 ft and 517.9–518.1 ft indicate an early Paleocene, Danian age (Edwards, this volume, chap. G). Leeth and others (1996) interpreted the data as indicating that these samples are late Paleocene and contain reworked early Paleocene palynomorphs. However, it now seems more likely that *Myrtaceidites* sp., *Caryapollenites prodromus* group, and *Sparganiaceaepollenites* sp. are all contaminants from uphole, and that the samples from 521.0–521.2 ft and 517.9–518.1 ft are early Paleocene in age and assignable to the *Pseudoplicapollis serenus* Interval Zone (fig. 2).

Sample R4705 D, from 484.1–484.3 ft, contained a variety of pollen taxa (fig. 5), but all of them are long ranging within the Paleocene. Dinoflagellates in the sample were interpreted by Leeth and others (1996) and Edwards (this volume, chap. G) as indicating an early late Paleocene (Selandian) age.

SNAPP FORMATION

No pollen samples were examined from the Snapp Formation in the Girard core.

FOURMILE BRANCH FORMATION

Sample R4705 AE, from 415.2–415.5 ft in the Girard core, is from the Fourmile Branch Formation; the sample contained very rare pollen grains. However, two of the specimens identified were of *Platycaryapollenites* sp. aff. *P. swasticoidus* (Elsik) Frederiksen & Christopher and, therefore, are Eocene. These two specimens are probably of early Eocene or possibly early middle Eocene age.

CONGAREE FORMATION

No pollen samples were examined from the Congaree Formation in the Girard core.

SANTEE LIMESTONE

One sample of the Santee Limestone, R4705 F, from 322.3–322.5 ft in the Girard core, was examined, but the sample contained only rare pollen grains.

BARNWELL UNIT

No pollen samples were examined from the Barnwell unit in the Girard core.

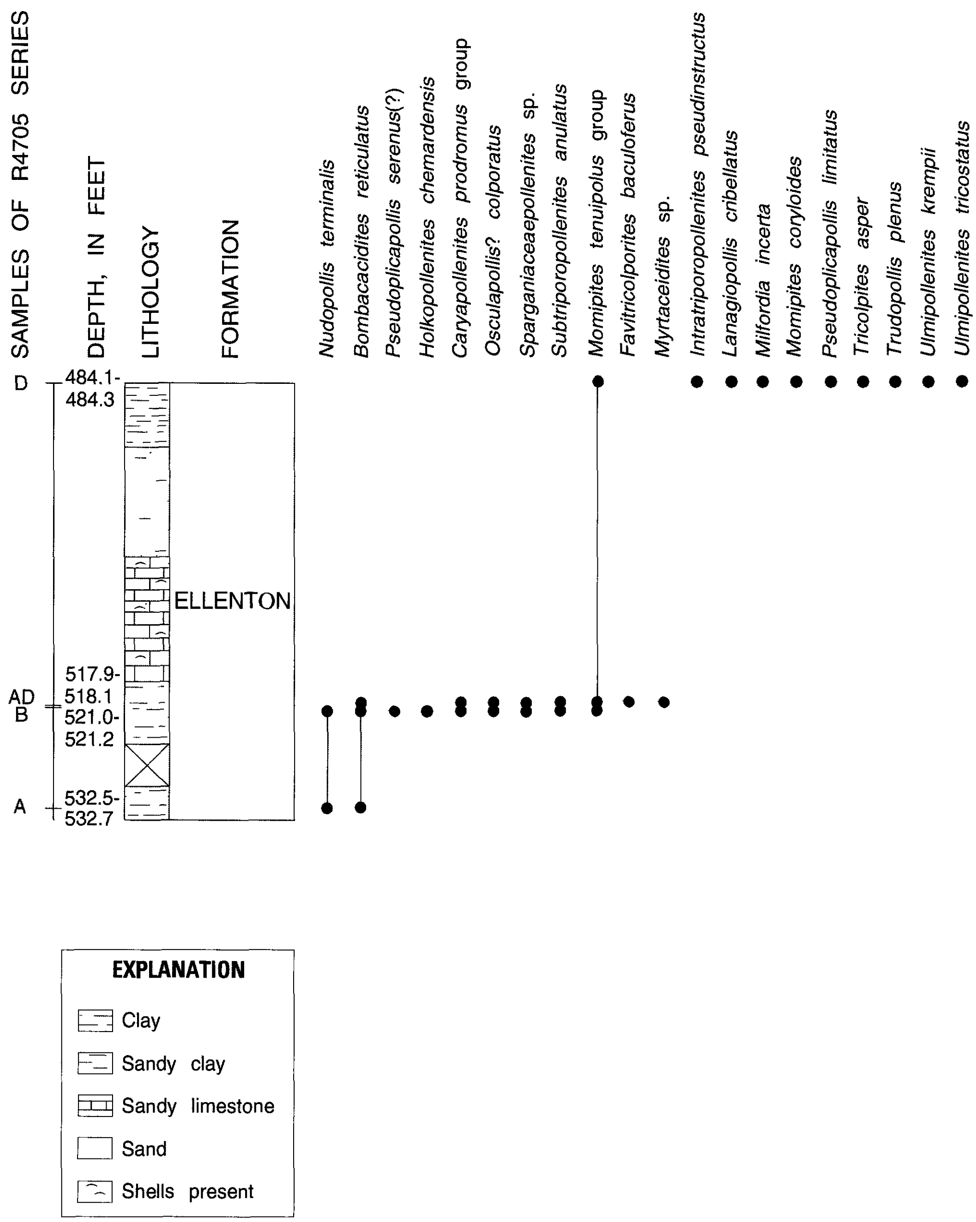

Figure 5. Chart showing pollen distributions in four of the five samples from the Ellenton Formation of the Girard core. A fifth sample, not shown, contained only very rare pollen grains.

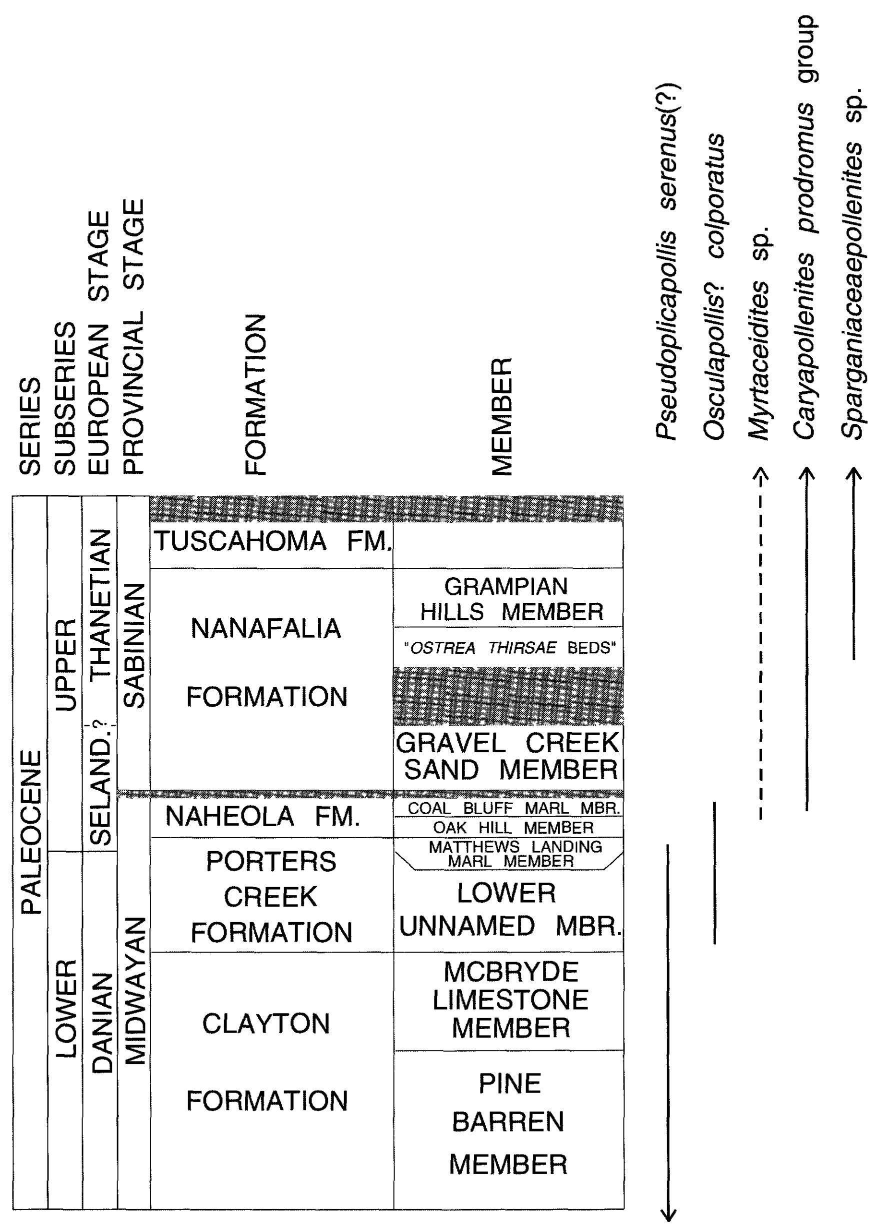

Figure 6. Chart showing known stratigraphic ranges in the eastern Gulf Coast of biostratigraphically important pollen species in sample R4705 B (from 521.0–521.2 ft) and AD (from 517.9–518.1 ft) from the Ellenton Formation in the Girard core.

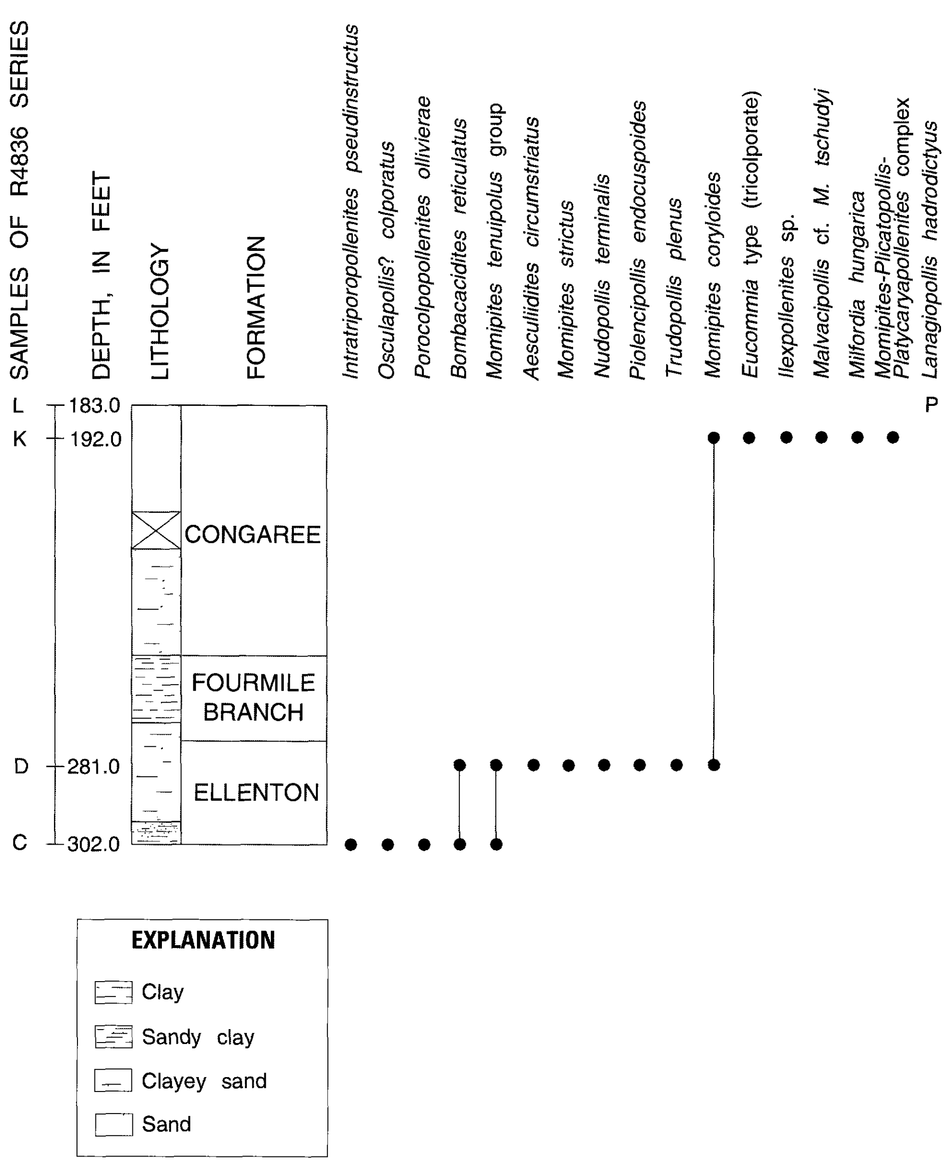

Figure 7. Chart showing pollen distributions in four samples, from 302.0 to 183.0 ft, of the Ellenton and Congaree Formations in the Thompson Oak core. P indicates that the identification of the species was probable.

THOMPSON OAK TEST HOLE

The Thompson Oak test hole was drilled by the Georgia Geologic Survey at lat 33°10'42" N., long 81°47'10" W., Shell Bluff Landing 7.5-min quadrangle, Burke County, Ga. (fig. 1). The surface elevation is 240 ft. Seven Tertiary samples from this core were examined for pollen, from a depth interval of 302.0 to 172.0 ft. Pollen distributions in four productive samples from this core are shown in figure 7.

ELLENTON FORMATION

Two pollen samples were examined from the Ellenton Formation in the Thompson Oak core. Sample R4836 C, from 302.0 ft, contained mainly long-ranging taxa. However, several specimens were observed of *Osculapollis*? *colporatus* Frederiksen, whose range in the eastern Gulf Coast is from the upper part of the lower Paleocene to very low in the upper Paleocene (fig. 6).

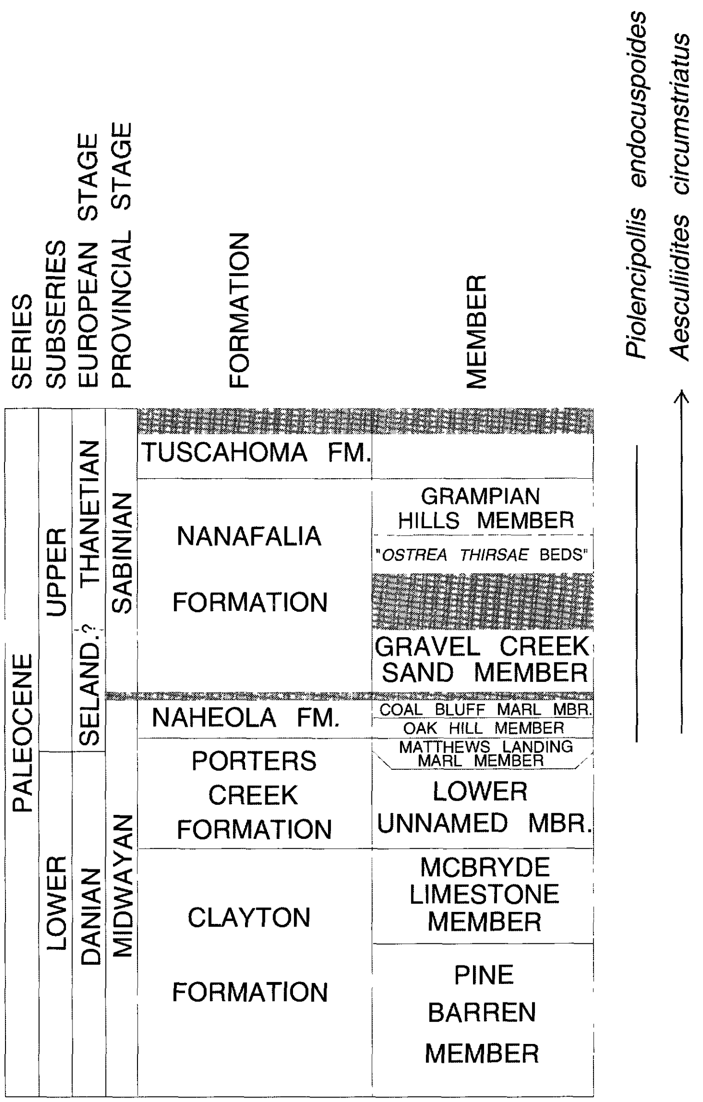

Figure 8. Chart showing known stratigraphic ranges in the eastern Gulf Coast of two biostratigraphically important pollen species found in sample R4836 D, from 281.0 ft, in the Ellenton Formation in the Thompson Oak core.

Most of the taxa in sample R4836 D, from 281.0 ft, have long stratigraphic ranges within the Paleocene. The presence of *Aesculiidites circumstriatus* (Fairchild) Elsik and *Piolencipollis endocuspoides* Frederiksen indicates that the sample could be any age within the late Paleocene (fig. 8).

FOURMILE BRANCH FORMATION

No pollen samples were examined from the Fourmile Branch Formation in the Thompson Oak core.

CONGAREE FORMATION

Two pollen samples were examined from the Congaree Formation in the Thompson Oak core. Sample R4836 K, from 192.0 ft, contained several pollen taxa having somewhat restricted ranges (figs. 7, 9). The known range of *Malvacipollis* cf. *M. tschudyi* Frederiksen of Frederiksen (1988), the most age-definitive species in the sample, is from the lower part of the Tallahatta Formation (Zone NP 12, middle lower Eocene) to the lower part of the Lisbon Formation (Zone NP 15 or lowermost Zone NP 16, lower

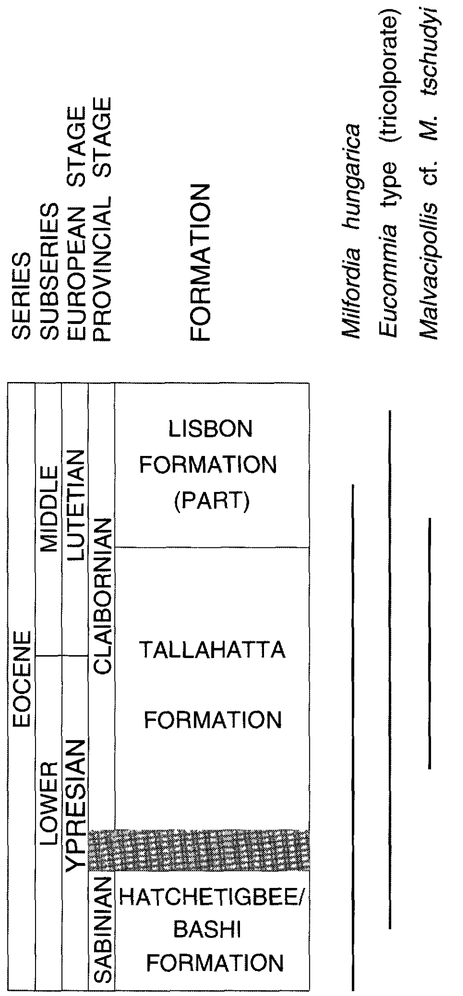

Figure 9. Chart showing known stratigraphic ranges in the eastern Gulf Coast of biostratigraphically important pollen species in sample R4836 K, from 192.0 ft, in the Congaree Formation in the Thompson Oak core.

middle Eocene) in the eastern Gulf Coast. Dinoflagellates in the sample indicate that it is probably correlative with the lower part of the Lisbon Formation (Edwards, this volume, chap. G).

The only species of interest found in sample R4836 L, from 183.0 ft, was a specimen probably belonging to *Lanagiopollis hadrodictyus* Frederiksen. In the eastern Gulf Coast, the known range of this species is from the lower part of the Tallahatta Formation, NP 12, to the lower part of the Lisbon Formation, lower NP 16, and possibly as high as the Moodys Branch Formation, NP 17.

SANTEE LIMESTONE

Samples R4836 M (181.5 ft), R4836 N (174.0 ft), and R4836 O (172.0 ft) were examined for pollen from the Santee Limestone in the Thompson Oak core, but they contained no biostratigraphically useful taxa. *Spinizonocolpites prominatus* (McIntyre) Stover & Evans was found in the sample from 174.0 ft (pl. 1, figs. 21, 22), but this species ranges throughout the Eocene.

BARNWELL UNIT

No pollen samples were examined from the Barnwell unit in the Thompson Oak core.

MILLERS POND TEST HOLE

The Millers Pond test hole was drilled by the Georgia Geologic Survey (Burke 2, GGS–3758) near Shell Bluff Landing on the Savannah River, lat 33°13'48" N., long 81°52'44" W., McBean 7.5-min quadrangle, Burke County, Ga. (fig. 1). The surface elevation is 245 ft above sea level. A lithologic description of the cored section was provided by Clarke and others (1994). Seven Tertiary samples from this core were examined for pollen, from the depth interval of 257.0 to 72.0 ft, and two contained pollen assemblages that conveyed useful information. Pollen distributions in three of the samples are shown in figure 10.

ELLENTON FORMATION

One sample from the Ellenton Formation in the Millers Pond core was examined for pollen—sample R4581 Q from 252.0–257.0 ft. Known Gulf Coast ranges of critical species in this sample are displayed in figure 11. It appears on the basis of the overlapping ranges of *Pseudoplicapollis serenus* and *Momipites coryloides* that this sample is from the upper part of the lower Paleocene (upper Danian). The sample is from the upper part of the *Pseudoplicapollis serenus* Interval Zone (fig. 2). This age determination is supported by a Danian (early Paleocene) dinoflagellate age for the sample (Edwards, this volume, chap. G).

SNAPP FORMATION

No pollen samples were examined from the Snapp Formation in the Millers Pond core.

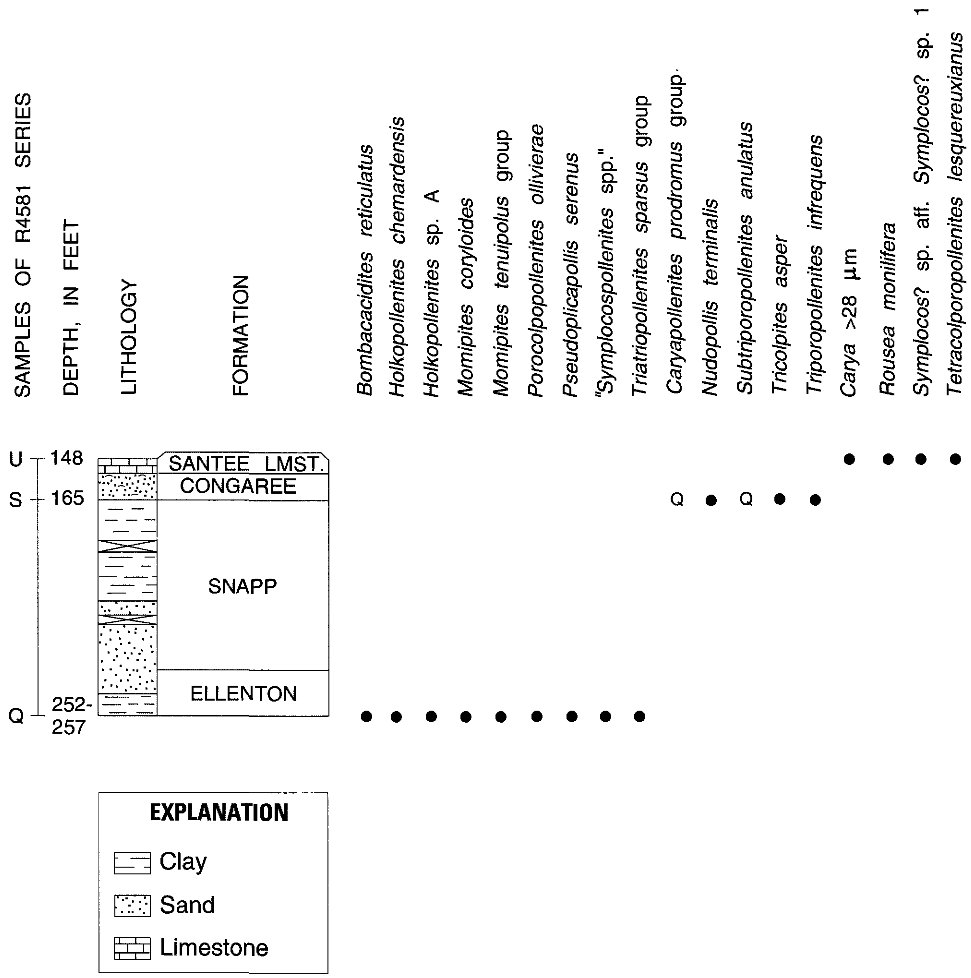

Figure 10. Chart showing pollen distributions in three samples between 257.0 and 148.0 ft in the Millers Pond core. Q indicates that the identification of the species was uncertain.

CONGAREE FORMATION

Sample R4581 S, from 165.0 ft, is just above the contact of the Snapp and Congaree Formations in the Millers Pond core. The sample contained only a few pollen taxa (fig. 10). Either these taxa are long ranging, or else the identification of the taxa was uncertain.

SANTEE LIMESTONE

Sample R4581 U, from 148.0 ft in the Santee Limestone of the Millers Pond core, had two pollen taxa that do not range below the lower Eocene part of the Tallahatta Formation in the eastern Gulf Coast (fig. 12). *Symplocos*? sp. 1 of Frederiksen (1988) is a rare species that has previously been found only in the lower part of the Lisbon Formation (lower middle Eocene, lower Lutetian) in Alabama and Georgia. However, the true range of this species is poorly known. Dinoflagellates in the sample indicate correlation with the upper part of the Lisbon Formation (middle part of the middle Eocene; Edwards, this volume, chap. G). Three additional samples of the Santee Limestone, from 124.0, 120.0, and 82.0–83.0 ft, were also examined, but they were either barren of pollen or else did not contain any biostratigraphically useful taxa.

BARNWELL UNIT

One sample from the Barnwell unit in the Millers Pond core was examined for pollen—sample R4581Y from 72.0–77.0 ft, but it was barren of palynomorphs.

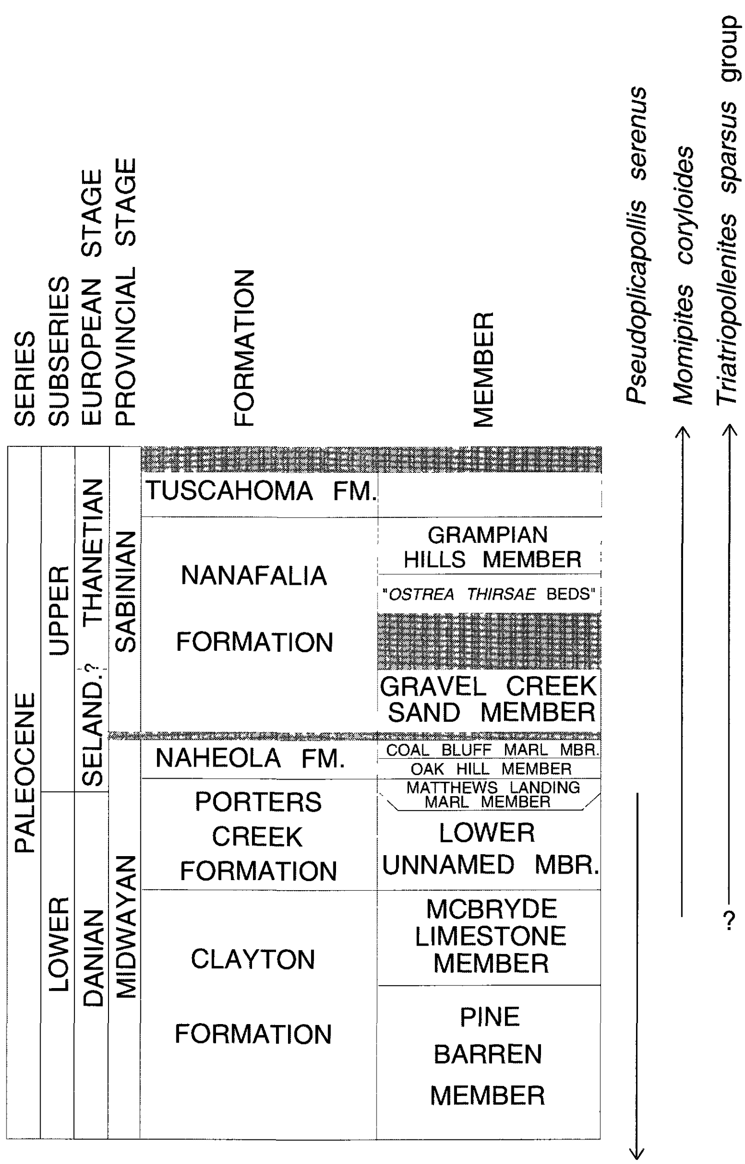

Figure 11. Chart showing known stratigraphic ranges in the eastern Gulf Coast of biostratigraphically important pollen species in sample R4581 Q, from 252.0–257.0 ft, in the Ellenton Formation in the Millers Pond core.

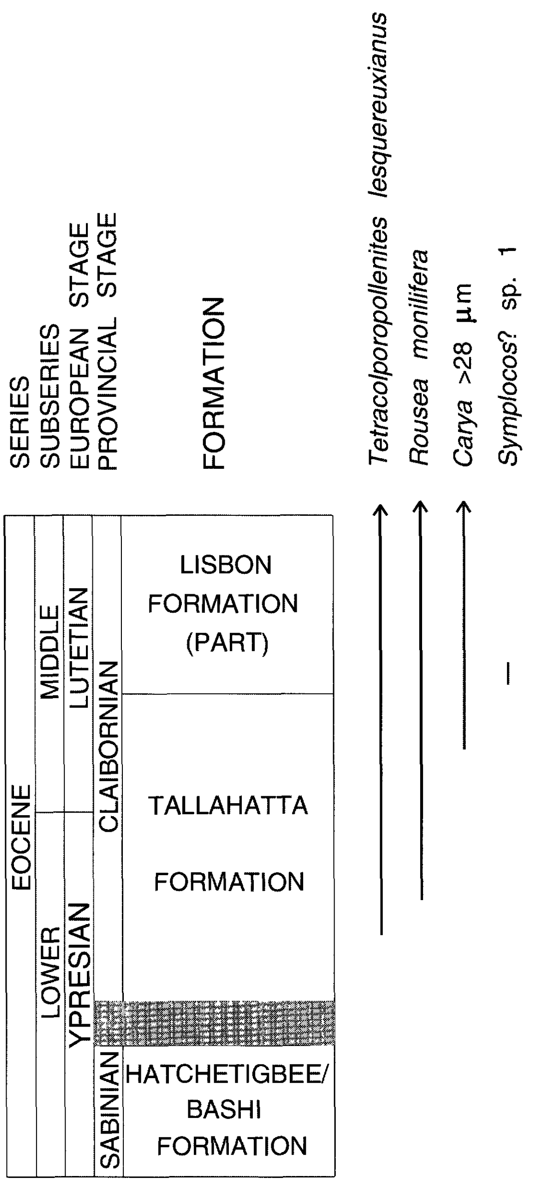

Figure 12. Chart showing known stratigraphic ranges in the eastern Gulf Coast of biostratigraphically important pollen species in sample R4581 U, from 148.0 ft, in the Santee Limestone in the Millers Pond core.

MCBEAN TEST HOLE

The McBean test hole (GGS–3757) was drilled by the Georgia Geologic Survey at lat 33°13'38" N., long 81°55'50" W., in the McBean 7.5-min quadrangle, Burke County, Ga. (fig. 1). The surface elevation is 297 ft above sea level. Six Tertiary samples from this core were examined for pollen, from the depth interval of 294.0 to 181.0 ft. Two samples contained more than rare pollen grains. These two samples were from 264.0 and 181.0 ft (fig. 13).

ELLENTON FORMATION

Two samples were examined from the Ellenton Formation (R4663 B and C, from 294.0 and 276.0 ft, respectively) in the McBean core, but they were barren or nearly barren of pollen grains.

SNAPP FORMATION

No dinocysts were found in sample R4663 D, from 264.0 ft in the Snapp Formation of the McBean core. The critical pollen taxa in this sample (fig. 14) were *Momipites dilatus* Fairchild and *Caryapollenites prodromus* group of Frederiksen (1991), whose overlapping ranges indicate that the sample is no older than earliest late Paleocene and no younger than middle late Paleocene. The sample belongs somewhere within the *Caryapollenites prodromus* or *Carya* Interval Zones (fig. 2). Sample R4663 E, from 243.0 ft, was barren or nearly barren of pollen grains.

CONGAREE FORMATION

Sample R4663 F, from 210.0 ft in the Congaree Formation of the McBean core, was barren or nearly barren of pollen grains.

SANTEE LIMESTONE

Sample R4663 G, from 181.0 ft in the Santee Limestone of the McBean core, contained few pollen taxa (fig. 13); however, *Ilexpollenites* Potonié and *Tetracolporopollenites megadolium* (Potonié) Frederiksen are known only from Eocene and younger strata.

BARNWELL UNIT

No pollen samples were examined from the Barnwell unit in the McBean core.

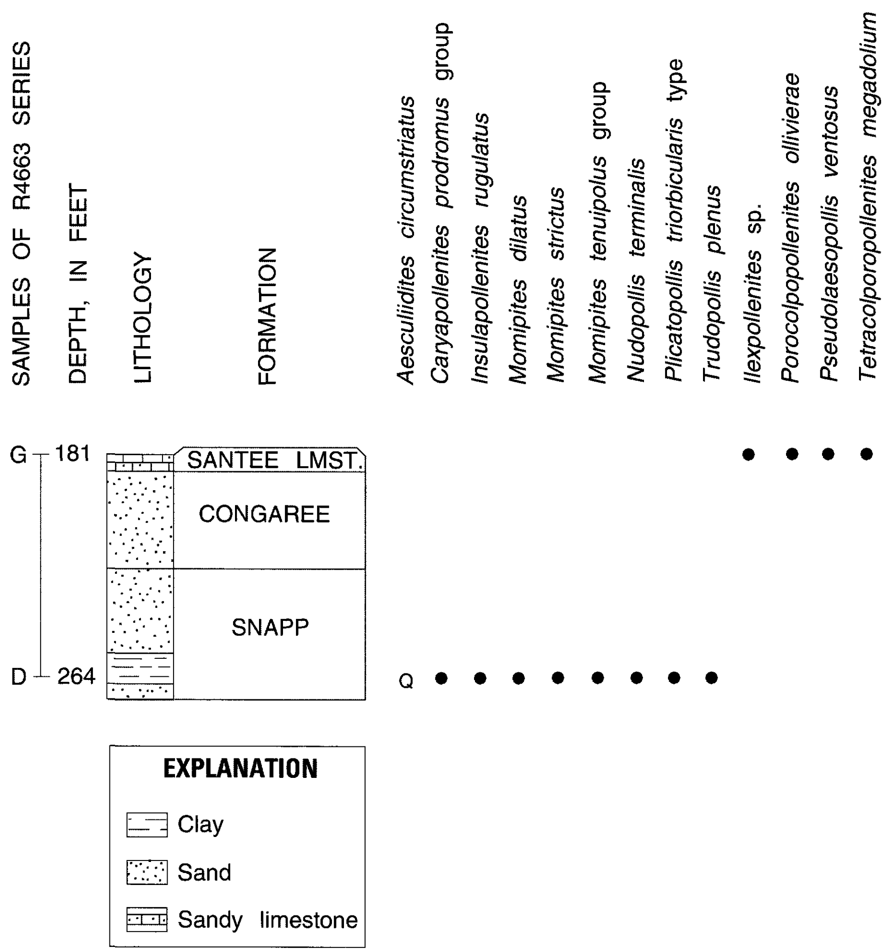

Figure 13. Chart showing pollen distributions in two samples, from 264.0 and 181.0 ft, in the Snapp Formation and Santee Limestone in the McBean core. Q indicates that the identification of the species was uncertain.

SUMMARY

Seventeen biostratigraphically useful lower Tertiary samples were examined for pollen from five cores (Millhaven, Girard, Thompson Oak, Millers Pond, and McBean) in Screven and Burke Counties, Ga. Ten biostratigraphically useful samples from the Ellenton Formation were analyzed, from the Millhaven, Girard, Thompson Oak, and Millers Pond cores. Most samples are not older than early late Paleocene, but one or two of them are older—late early Paleocene in age. The youngest possible age for some of the Ellenton samples is more difficult to establish. On the basis of pollen evidence, several of the Ellenton samples might be as young as middle late or even late late Paleocene. However, most of the samples are probably not younger than the *Caryapollenites prodromus* Interval Zone of early late Paleocene age.

Only one productive sample was obtained from the Snapp Formation; it was from the McBean core. This sample is no older than earliest late Paleocene and no younger than middle late Paleocene.

One productive sample was obtained from the Fourmile Branch Formation, from the Girard core. The sample appears to be early Eocene or possibly early middle Eocene in age.

Three productive samples were obtained from the Congaree Formation from the Millhaven and Thompson Oak cores. The pollen taxa in these samples mainly have long stratigraphic ranges within the lower and middle Eocene. However, one of the samples from the Thompson Oak core appears to be late early to early middle Eocene in age.

Two productive samples were examined from the Santee Limestone from the Millers Pond and McBean cores. These are poorly dated within the late early Eocene to middle Eocene (or younger?) interval.

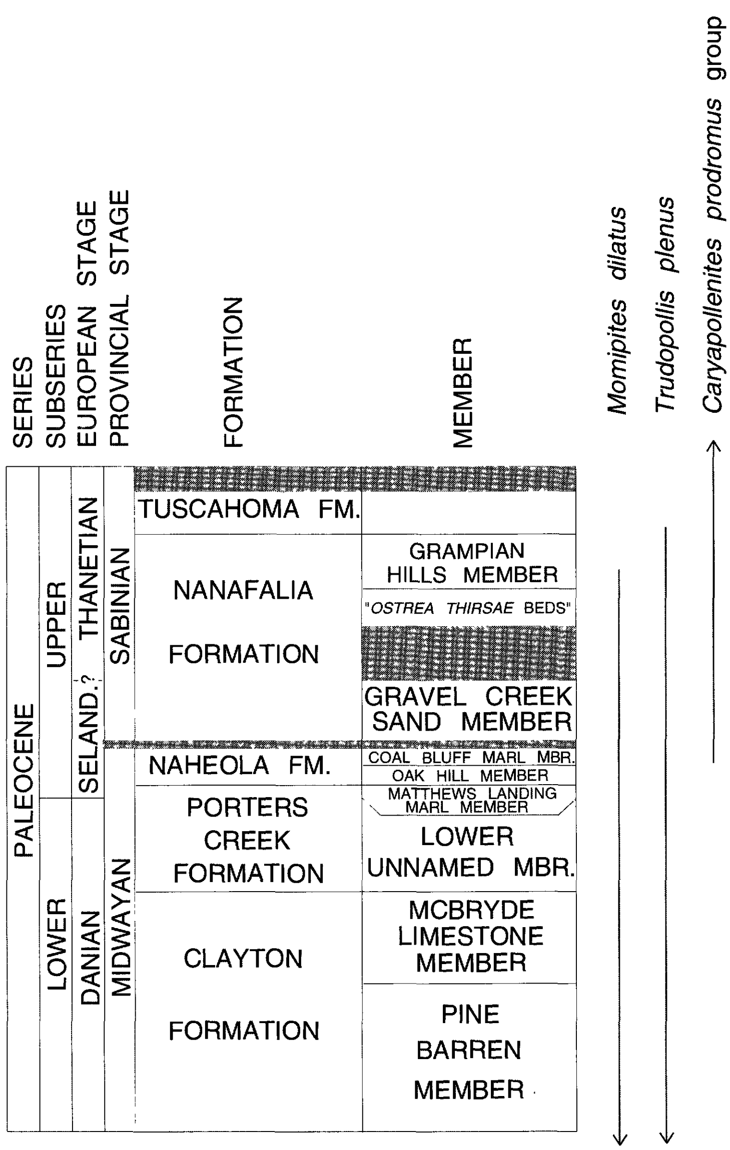

Figure 14. Chart showing known stratigraphic ranges in the eastern Gulf Coast of biostratigraphically important pollen species in sample R4663 D, from 264.0 ft, in the Snapp Formation in the McBean core.

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PLATES 1, 2

PLATE 1

[All specimens are from Screven and Burke Counties, Georgia]

Figure 1. *Sparganiaceaepollenites* sp., Ellenton Formation, Girard core (521.0–521.2 ft), Burke County.

2. *Milfordia hungarica* (Kedves) Krutzsch & Vanhoorne *in* Krutzsch (1970), Congaree Formation, Thompson Oak core (192.0 ft), Burke County.

3. *Milfordia incerta* (Pflug & Thomson *in* Thomson and Pflug, 1953) Krutzsch, Ellenton Formation, Girard core (484.1–484.3 ft), Burke County.

4. *Momipites tenuipolus* group of Frederiksen and Christopher (1978), Snapp Formation, McBean core (264.0 ft), Burke County.

5. *Momipites coryloides* Wodehouse, Congaree Formation, Thompson Oak core (192.0 ft), Burke County.

6. *Momipites dilatus* Fairchild *in* Stover and others (1966), Ellenton Formation, Millhaven core (571.0 ft), Screven County.

7, 8. *Platycarya platycaryoides* (Roche) Frederiksen & Christopher, Congaree Formation, Millhaven core (490.0 ft), Screven County. Interference contrast.

9, 10. *Platycarya* sp. A of Frederiksen and Christopher (1978) (from drilling mud contamination), Steel Creek Formation (Cretaceous), Millhaven core (755.0–755.3 ft), Screven County.

11. *Platycarya* sp., Congaree Formation, Millhaven core (490.0 ft), Screven County. The specimen has several irregular pseudocolpi; interference contrast.

12. *Platycarya* sp. (from drilling mud contamination), Steel Creek Formation (Cretaceous), Millhaven core (755.0–755.3 ft), Screven County.

13. *Platycarya* sp., Fourmile Branch Formation, Girard core (415.2–415.5 ft), Burke County.

14. *Momipites-Plicatopollis-Platycaryapollenites* complex of Frederiksen (1979), Congaree Formation, Millhaven core (490.0 ft), Screven County.

15. *Plicatopollis triorbicularis* type of Frederiksen and Christopher (1978), Snapp Formation, McBean core (264.0 ft), Burke County.

16. *Ulmipollenites tricostatus* (Anderson) Frederiksen, Ellenton Formation, Girard core (484.1–484.3 ft), Burke County.

17. *Ulmipollenites krempii* (Anderson) Frederiksen, Ellenton Formation, Girard core (484.1–484.3 ft), Burke County.

18. *Malvacipollis* cf. *M. tschudyi* Frederiksen of Frederiksen (1988), Congaree Formation, Thompson Oak core (192.0 ft), Burke County.

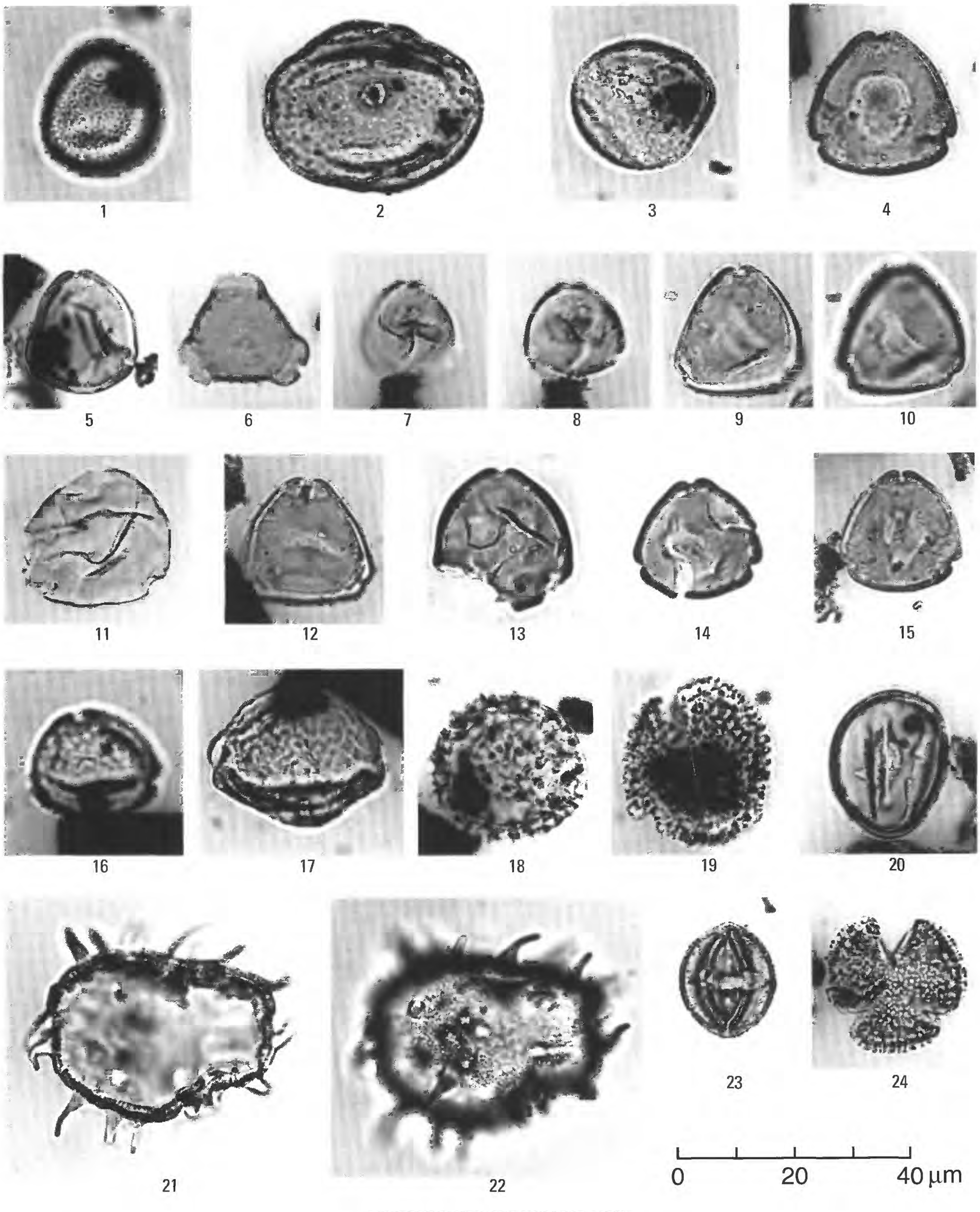
19. *Spinaepollis spinosus* (Potonié) Krutzsch, Ellenton Formation, Millhaven core (579.5 ft), Screven County.

20. *Eucommia* type (tricolporate) of Frederiksen (1988), Congaree Formation, Thompson Oak core (192.0 ft), Burke County.

21, 22. *Spinizonocolpites prominatus* (McIntyre) Stover & Evans, Santee Limestone, Thompson Oak core (174.0 ft), Burke County.

23. *Aesculiidites circumstriatus* (Fairchild *in* Stover and others, 1966) Elsik, Ellenton Formation, Thompson Oak core (281.0 ft), Burke County.

24. *Ilexpollenites* sp., Santee Limestone, McBean core (181.0 ft), Burke County.



ANGIOSPERM POLLEN GRAINS

PLATE 2

[All specimens are from Screven and Burke Counties, Georgia]

Figure 1. *Pseudoplicapollis limitatus* Frederiksen, Ellenton Formation, Girard core (484.1–484.3 ft), Burke County.

2, 3. *Nudopollis terminalis* (Pflug & Thomson *in* Thomson and Pflug, 1953) Pflug, Ellenton Formation. 2, Girard core (532.5–532.7 ft), Burke County; 3, Thompson Oak core (281.0 ft), Burke County.

4. *Pseudolaesopollis ventosus* (Potonié) Frederiksen, Santee Limestone, McBean core (181.0 ft), Burke County.

5. *Choanopollenites* sp. cf. *C. consanguineus* Tschudy of Frederiksen (1979), Ellenton Formation, Millhaven core (589.0 ft), Screven County.

6. *Insulapollenites rugulatus* Leffingwell, Snapp Formation, McBean core (264.0 ft), Burke County.

7. *Intratriporopollenites* sp., Ellenton Formation, Millhaven core (581.0 ft), Screven County.

8. *Pseudoplicapollis serenus* Tschudy, Ellenton Formation, Millers Pond core (252.0–257.0 ft), Burke County.

9. *Osculapollis*? *colporatus* Frederiksen, Ellenton Formation, Thompson Oak core (302.0 ft), Burke County.

10. *Trudopollis plenus* Tschudy, Ellenton Formation, Girard core (484.1–484.3 ft), Burke County.

11. *Symplocos*? sp. aff. *Symplocos*? sp. 1 of Frederiksen (1988), Santee Limestone, Millers Pond core (148.0 ft), Burke County.

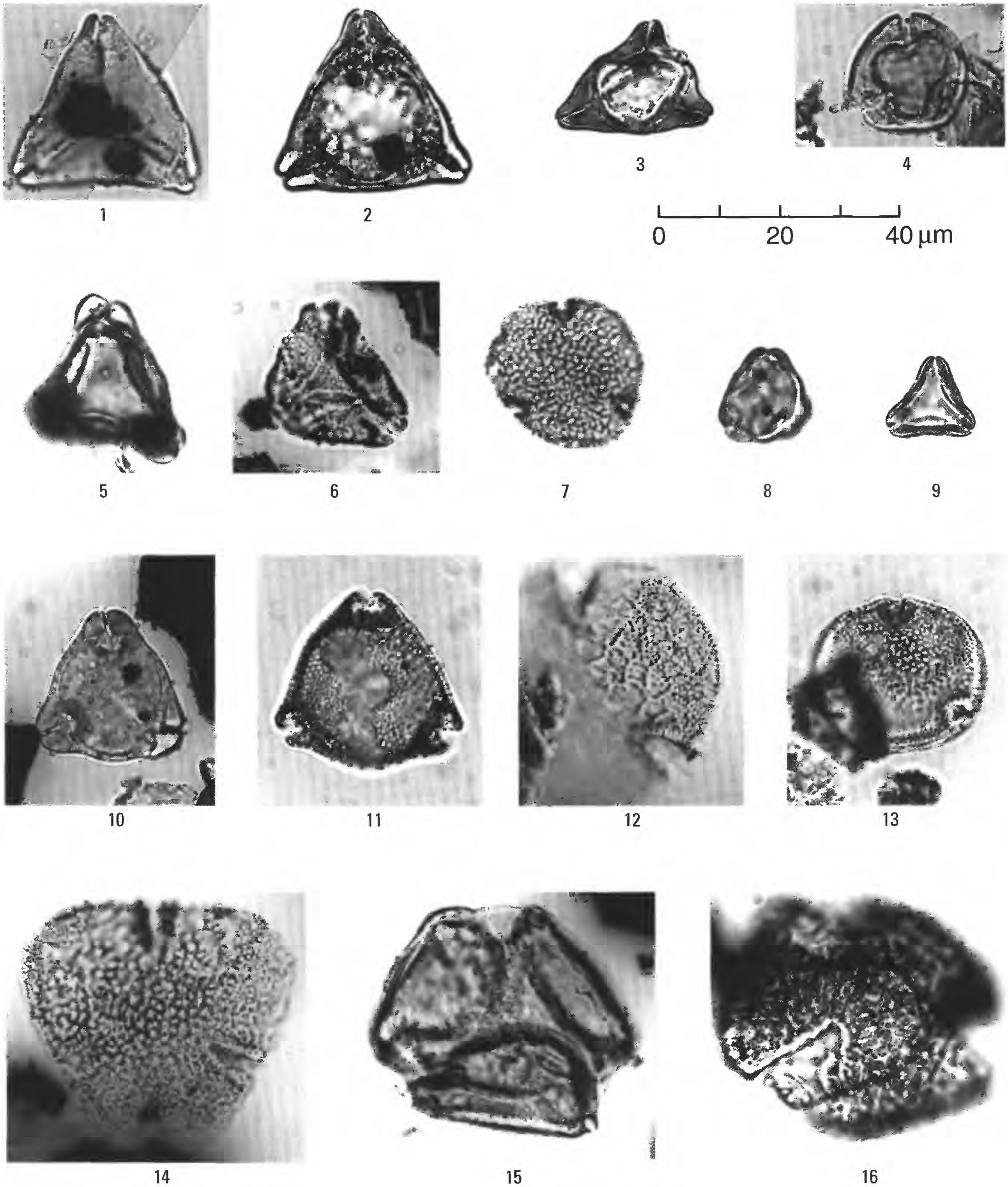
12. *Friedrichipollis* sp., interference contrast. Ellenton Formation, Millhaven core (581.0 ft), Screven County.

13. *Bombacacidites reticulatus* Krutzsch, Ellenton Formation, Millers Pond core (252.0–257.0 ft), Burke County.

14. *Bombacacidites nacimientoensis* (Anderson) Elsik, Ellenton Formation, Millhaven core (571.0 ft), Screven County.

15. *Lanagiopollis cribellatus* (Srivastava) Frederiksen, Ellenton Formation, Millhaven core (581.0 ft), Screven County.

16. *Lanagiopollis* sp., probably *L. hadrodictyus* Frederiksen, Congaree Formation, Thompson Oak core (183 ft), Burke County.



ANGIOSPERM POLLEN GRAINS