From Greenhouse to Icehouse

THE MARINE EOCENE-OLIGOCENE TRANSITION

EDITED BY

DONALD R. PROTHERO, LINDA C. IVANY, AND ELIZABETH A. NESBITT
CHAPTER 15

Palynological Patterns in the Uppermost Eocene to Lower Oligocene Sedimentary Rocks in the U.S. Gulf Coast

Francisca E. Oboh-Ikuenobe and Carlos A. Jaramillo

ABSTRACT
Climate, vegetation, sediment supply, and burial conditions play important roles in the diversity and abundance of palynomorphs transported into and preserved in depositional sequences. Preserved palynological assemblages (spores, pollen, dinoflagellate cysts, and palynofacies) can be used to recognize past vegetation patterns, climates, and sea-level fluctuations, and such a model is used here to interpret the upper Eocene to lowermost Oligocene Pachuta and Shubuta Members of the Yazoo Formation, and the lower Oligocene Vicksburg Group in southeastern Mississippi and southwestern Alabama. Of the 260 spore and pollen taxa identified, eleven groups representing about 50% of the taxa have been recognized on the basis of abundance, occurrence in most samples and ecological significance. The most prominent groups are *Sequoipollenites-Cupressacites, Momipites, Caryya, Quercoidites, Cupuliferoipollenites, Cyrillaceaeopollenites*, and *Stilaria*. Statistical analysis on presence-absence data produced five significant cluster groups that were dominated by species of the 11 groups, as well as by *Ulmipollenites thompsonianus* and *Salixipollenites parvus*. These cluster groups show some ecological significance because they appear to represent upland, swamp, and marsh taxa that were either preserved in the nearshore sediments or dispersed into the shallow-marine environment. The prominence of *Quercoidites, Sequoiapollenites, Cupressacites, and Cyrillaceaeopollenites* in the rich pollen assemblage, which contains some tropical to subtropical elements, such as *Pilatricolporites operculatus* and *Nyssapollenites pulvinus*, suggests a warm-temperate paleoclimate during the early Oligocene in the study area. Although *Momipites* was generally more abundant in the Eocene and *Quercoidites* increased during the Oligocene, there was no significant paleoecological change across the Eocene/Oligocene boundary. The major floral turnover along the Gulf Coast occurred well before the deposition of the Vicksburg units during the early Oligocene, probably in the middle Eocene. This observation is confirmed by dinoflagellate cyst (dino cyst) data that do not show any significant change in standing diversity, or in turnover rates across the Eocene/Oligocene boundary. A combination of dino cyst paleoecology, palynofacies, and lithofacies formed the basis of sequence stratigraphic interpretations. In southern Mississippi, we identified a latest Eocene maximum flooding surface in the middle of the Shubuta Clay, but this surface was identified at the top of the Shubuta Clay in southern Alabama, where the Eocene/Oligocene boundary was placed within a condensed interval. This condensation, which was identified at the Shubuta Clay–Vicksburg Group contact, is equivalent to the accumulation of the upper Shubuta Clay and Red Bluff Clay in southern Mississippi.

INTRODUCTION
The late Eocene to early Oligocene interval has received much attention because of a rapid cooling during the late Eocene, followed by a thermal minimum at the beginning of the Oligocene, as documented by microfaunas from deep-sea cores (Shackleton and Kennett, 1975; Wei, 1991). Fossil records of plant megafossils, pollen, and spores from the Gulf Coast and western North America have also
indicated changes in vegetation that could be associated with paleoclimatic cooling toward the end of the Eocene or the beginning of the Oligocene (Wolle, 1971, 1992, 1994; Elsk, 1974; Frederiksen, 1988). Outcrops of some of the most complete upper Eocene to lower Oligocene sedimentary rock sequences in North America are located in Mississippi and Alabama (figure 15.1) in the U.S. Gulf Coast. This study uses palynological information (pollen, spores, dinoflagellate cysts, and dispersed organic matter) from nine sections in southern Mississippi and southern Alabama to document paleoecological and paleofloristic patterns, and to make paleoclimatic inferences throughout the Eocene-Oligocene transition.

The diversity and abundance of palynomorphs and dispersed organic matter transported into and preserved in depositional sequences are dependent on climate, vegetation, sediment supply, and burial conditions. Paleovegetation patterns, paleoclimates, and sea-level fluctuations can be recognized from preserved palynological assemblages. These events have been reconstructed for the upper Eocene Pachuta and Shubuta Members of the Yazoo Formation, and the lower Oligocene Vicksburg Group in southeastern Mississippi and southwestern Alabama. We have also integrated dinocyst biostratigraphy, dinocyst paleoecology, and palynofacies, in order to obtain chronostatigraphic and paleobathymetric data to interpret the sequence stratigraphy and paleobathymetric fluctuations of upper Eocene to lower Oligocene strata in the area.

The few well-exposed Eocene to Oligocene sedimentary rocks in southern Mississippi and Alabama have been extensively studied. These units are more or less continuous and have provided field data for several paleogeographic and biostratigraphic studies (Hazel et al., 1980; Siesser, 1983; Tew and Mancini, 1995). The St. Stephens Quarry in southwestern Alabama has been the most studied, providing controversial information on the position of the Eocene/Oligocene boundary and its sequence stratigraphy (Mancini, 1979; Bybell and Poore, 1982; Siesser, 1983; Keller, 1985; Pasley and Hazel, 1990, 1995; Miller et al., 1993; Jaramillo and Obi-Iluenobe, 1999).

GEOLOGIC SETTING
The Cenozoic history of the Gulf of Mexico is characterized by a rapid sediment input and thick prograding depositional sequences that intertongue with interdeltic shelf-edge sediments (Galloway, 1989). These units were deposited in the shallow-marine to marginal-marine environments of a passive margin (Hazel et al., 1980; Pasley and Hazel, 1995; Tew and Mancini, 1995). Upper Eocene sediments are characterized by fine-grained sediment deposition, while the lower Oligocene sediments constitute one of the great progradational wedges in the region (Galloway, 1989). Latest Eocene time in southern Mississippi and Alabama is represented by two lithostratigraphic units, the Pachuta Marl and Shubuta Clay of the Jackson Group (figure 15.2). The lower Oligocene strata are composed of eight lithostratigraphic units, all of which have formation status in Mississippi. In
Alabama, four of them have only member status. In ascending order, the units are the Bumpnose Limestone, the Red Bluff Clay, the Forest Hill Sand, the Mint Spring Marl (or member of the Marianna Limestone), the Marianna Limestone, the Glenoldo Limestone (or member of the Byram Formation), the Byram Formation (or informal Byram “marl” member of the Byram Formation), and the Bucatunna Clay (or member of the Byram Formation). The Bumpnose Limestone, Red Bluff Clay and Forest Hill Sand are lateral equivalents of one another, although the Forest Hill Sand is thicker in Mississippi. The Bumpnose and Red Bluff intertongue in some areas in southwest Alabama (Tew and Mancini, 1995) (figure 15.2).

MATERIALS AND METHODS
We studied nine localities in Mississippi and Alabama. In southern Mississippi (figure 15.1) there were 3 coreholes: #1 Young, #1 Keter, #1 Wayne, and four outcrop sections: 0.4 km northeast of Bucatunna Creek (Bucatunna); Type Red Bluff (R2089); road cut east of Waynesboro, U.S. Route 84 (Waynesboro); and Mississippi Valley Portland Cement Quarry, Warren County (MVPC Quarry). Two outcrop sections, the St. Stephens Quarry and Milepost 54 on U.S. Rt. 84, east of Whatley, Clarke County, were studied in southwestern Alabama (figure 15.1). Approximately 160 palynological samples were used for this study. The R2089 and St. Stephens Quarry sections were analyzed for pollen, spores, and dinoflagellate contents. However, the #1 Young, #1 Keter, and #1 Wayne cores have dinocyst and palynofacies data, while the Bucatunna, Waynesboro, and Mississippi Valley Portland Cement Quarry sections have only pollen and spore data.

The outcrop and core samples were prepared at the U.S. Geological Survey (Reston, Virginia) and by Global Geolab (Alberta, Canada), respectively, using standard palynological techniques, including mild oxidation in nitric acid or Shulzete solution, and heavy liquid separation in zinc chloride. The residues were sieved through 10 μm nylon meshes before permanent slides were made. Illustrations and count data of spores and pollen can be found in Oboh and Reeves Morris (1994, 1995) and Oboh et al. (1996), and those for the dinocysts are in Jaramillo and Oboh-Ikuenobe (1999). The slides from the outcrop samples will eventually be deposited at the U.S. Geological Survey (Reston, Virginia), and the Geological Museum of the University of California at Riverside.

Average linkage cluster analysis, using Euclidean distance on presence-absence palynomorph data, was used to analyze the pollen and spore data. We used presence-absence data instead of abundance data in order to reduce the effect of dominant taxa in the analysis. A nonmetric multidimensional scaling (MDS) analysis with Spearman rank-order coeffi-

![Figure 15.2. Simplified stratigraphic correlation chart of the Mississippi-Alabama region (modified from Galloway et al., 1991; Pasley and Hazel, 1995).](image-url)
cient was used to analyze the dinocyst distribution. This method is best suited to finding a major terrestrial-marginal marine gradient along the first and second axes, and seems to be least vulnerable to distortion from high data diversity, nonnormality, and nonlinearity (Pielou, 1984). A set of 32 dinocyst taxa with high abundances and those with recognized paleoenvironmental significance were selected for this analysis (Jaramillo and Oboh-Ikuenobe, 1999). A number of statistical techniques were also used to analyze dinocyst diversity patterns across the Eocene-Oligocene transition. We use the word "diversity" to indicate number of species. Most of the palynological analyses were performed using Systat 5.0 and MVSP 3.0 <www.kovcomp.co.uk/mvsp/ >.

Unoxidized dispersed organic matter of #1 Young samples provided the data set for the palynofacies analysis. At least 400 organic particles per sample were identified with a Zeiss transmitted-light microscope. Organic matter results were analyzed using a Euclidean-distance cluster analysis with average linkage (Jaramillo and Oboh-Ikuenobe, 1999). This method is useful because it averages all distances between pairs of objects in different clusters and decides how far apart they are (Sokal and Michener, 1958).

The chronostratigraphic framework used to date the sections was derived using graphic correlation on dinocyst distribution, and it was complemented by foraminifera and magnetic stratigraphy data. A detailed explanation can be found in Jaramillo and Oboh-Ikuenobe (1999).

POLLEN AND SPORE DISTRIBUTION

Two hundred and sixty spore and pollen taxa were identified. From the overall assemblage, eleven groups (50% of total taxa) were selected based upon a high relative abundance and recognized ecological significance. These groups were used to identify any relationship between pollen and spore distribution and the stratigraphy in the study area. These groups are spores, bisaccates, *Sequoiapollenites-Cupressautes, Momipites, Caryta, Quercoidites, Fraxinoipollenites, Cupuliferaipollenites, Cupuliferaipollenites, Cyrillacesipollenites*, and Siltaria (figure 15.3).

The Eocene/Oligocene boundary is associated with a slight increase in *Momipites and Quercoidites* whereas *Sequoiapollenites* decreases in abundance (figure 15.3). In the Vicksburg Group, increases up to the order of 7–30% were recorded for *Siltaria, Quercoidites, and Cyrillacesipollenites* over their abundances in the uppermost Eocene Shubuta Clay. With the exception of a slight increase in the Red Bluff Clay, *Momipites* is generally more abundant in the Shubuta Clay (Jackson Group) than the younger Vicksburg formations. Elsk (1974) and Frederiksen (1980; 1988) have shown that most of the taxa occurring in our data have their first occurrence datums before the deposition of the Shubuta Clay and ranged into the Oligocene. Therefore, in our study area, the palynoflora at the Eocene/Oligocene boundary did not experience any abrupt floristic change. The palynofloral patterns preserved in the strata were controlled by the stratal architecture of the stratigraphic sequence, the vegetation on adjacent land areas, an abundant production of certain species, and their easy dispersal into offshore environments.

In southwestern Alabama and southeastern Mississippi, *Sequoiapollenites-Cupressautes* and *Quercoidites* are the most important components in the Vicksburg units. In southwest Alabama, *Sequoiapollenites-Cupressautes* are more prominent in the transgressive and highstand deposits of Mint Spring Marl, Marrianna Limestone, and Glendon Limestone (figures 15.1 and 15.3). The floristic pattern in the Mint Spring Marl and Glendon Limestone in southwestern Mississippi, where the Marrianna Limestone has been replaced laterally by the Mint Spring, is different from that in the eastern part of the study area: the *Sequoiapollenites-Cupressautes* group is a minor element whereas spores (figure 15.3) are more prominent in the assemblage. The Byram palynofloras are similar to those of the Bucatunna and Chickasawhay in southwestern Alabama. The coniferous pollen *Sequoiapollenites* is an ubiquitous element in the palynomorph assemblage. It is dominant (albeit in low numbers) in samples from the transgressive and highstand systems tracks of the Marrianna and Glendon Limestones in southeastern Mississippi and southwestern Alabama where other taxa are relatively few, probably as a result of diageneric alteration (Oboh and Reeves Morris, 1995). It is also dominant in the more palyniferous Mint Spring Marl in the area. The significance of *Sequoiapollenites* in these samples is purely ecological because it is not an important element in southwestern Mississippi, where spores, bisaccates, and other gymnosperms are more important. The genus probably experienced abundant production on adjacent land areas and was easily dispersed into the nearshore (Mint Spring) and offshore environments (Marrianna and Glendon) where it was preserved (Oboh et al., 1996).

Five cluster groups containing 18 taxa (or
Figure 15.3. Relative frequencies (in percent) of eleven groups of spores and pollen for five of the sections analyzed in this study: Mississippi Valley Portland Cement Quarry (MVSP Quarry); St. Stephens Quarry (SS Quarry); Milepost 54 on U.S. Route 84, Clarke County, Alabama (Milepost 54); Type Red Bluff Section (R2089); and east of Waynesboro, Mississippi (Waynesboro). Groups with less than 5% were not plotted. Bu, Bumpnose; CL, Chickasawhay Limestone; JG, Jackson Group; GL, Glendon Limestone; ML, Marianna Limestone; RB, Red Bluff; VG, Vicksburg Group. See lithology labels in figure 15.6.
approximately 7% of total assemblage), which are listed in Oboh and Reeves Morris (1994), were found in the presence-absence cluster analysis (figure 15.4). These 18 taxa contain mostly anemophilous taxa with a few zoophilous and hydrophilous elements. The five cluster groups are probably reflecting distinct plant assemblages. Group A (Sequoiapollenites species) probably represents an upland assemblage, group B contains both dry land taxa (Carya, Quercoidites microhenricii, Ulmipollenites) and a swamp taxon (Momipites coryloides) (Judith Gennett, written comm. 1994). Group C is dominated by such swamp taxa as Momipites microfoveolatus, Cupressacites, and Cupuliferoidaepollenites. Group D contains marsh elements such as Salixipollenites (Frederiksen, 1981). Group E contains only one taxon (Fraxinoipollenites) which is produced by several plant families (Frederiksen, 1980).

The rise in dominance of Quercoidites over Momipites was used by Elslík (1974) and Frederiksen (1988) to suggest a cooling and drying trend that took place either at the beginning of the Oligocene, or toward the end of the Eocene in the Gulf Coast. The prominence of pollen related to Quercus, Sequoia, Carya, Cyrrilla, Taxodium, Ulmus, and Fraxinus in this palynomorph assemblage, however, is indicative of a warm-temperate climate in the eastern Gulf during Vicksburgian time. This observation is supported by (1) the rarity of cool temperate to cold temperate palynomorphs related to Picea, Abies, Tsuga, and Betula, (2) the low abundance of Ephedra, Abies, Gramineae, and other pollen which are typical of dry environments, and (3) the presence of some tropical to subtropical palynomorphs such as Psilotricolporites operculatus, and Nyssapollenites pulvinus (Germeta et al., 1968; Groot, 1991). This early Oligocene warm-temperate paleoclimate was clearly cooler than the early and middle Eocene subtropical conditions in the Gulf Coast. However, the major floral turnover occurred well before the deposition of the lower Oligocene Vicksburg units.

**DINOCYST DIVERSITY**

We use the word "diversity" to denote number of species. Dinocyst diversity can be affected by three main factors: sample size (dinocysts per sample), sampling density for a given stratigraphic interval, and depositional environment. A number of techniques were used to take these factors into account: (1) The unbiased Simpson Index, or SI (Rosenzweig,
Figure 15.5. Detrended correspondence analysis (DCA), unbiased Simpson Index (SI) expressed as (-log₂(SI)), raw number of species, and standing diversity (after range-through method was applied) for the #1 Young core. Paleobathymetric curve, sequence stratigraphy, and dating of the section after Jaramillo and Oboh-Ikuenobe (1999). CE, coastal plain; I, inner neritic; M, middle neritic; O, outer neritic; HST, highstand systems tract; TST, transgressive systems tract; LST, lowstand systems tract; TS, transgressive surface; MFS, maximum flooding surface; SB, sequence boundary; CS, condensed section.

1995), was calculated to estimate underlying diversity independently of sample size. This index adequately estimates diversity of small samples regardless of sample size, and when used as (-log₂(SI)), it increases as the number of species increases (Rosenzweig, 1995); (2) The range-through method (Boltovskoy, 1988) was used to estimate standing diversity. This method assumes that a taxon is present in a sample if it is present below and above the sample examined, and it takes into account facies-related fossils and differences in capture probability for each taxon; (3) The overall dinocyst composition throughout the section was observed using detrended correspondence analysis, or DCA²(Hill and Gauch, 1980). DCA summarizes the variations in the composition of the assemblages in a small number of dimensions (Wing, 1998). The ordination was performed on the raw abundance data excluding samples with fewer than 40 dinocysts per sample. Dinocyst data from the #1 Young core were selected for the diversity study.
Figure 15.6. Comparison of dinocyst standing diversity patterns with lithofacies, paleobathymetry (derived from palynofacies and dinocyst paleobathymetric index), and sequence stratigraphy for the #1 Young core. Note how dinocyst diversity decreases as environments become shallower in the early Oligocene highstand system tract. Paleobathymetric curve, sequence stratigraphy, and dating of the section after Jaramillo and Oboh-Ikuenobe (1999). See label legends in figure 15.5.
because it is the section with the highest sampling density and best quality of recovery. Furthermore, it encompasses the Eocene-Oligocene transition.

The DCA, unbiased Simpson Index, and standing diversity show a constant dinocyst diversity throughout the Eocene-Oligocene transition (figure 15.5), although there is declining diversity later in the early Oligocene. This trend may be the product of the facies change toward more nearshore deposits (figures 15.5 and 15.6). This trend of decreasing diversity from middle offshore toward near-inshore deposits is observed in modern dinocyst distributions (e.g., Wall et al., 1977; Dale, 1996). The last and first occurrence patterns do not show any unusual event associated with the Eocene-Oligocene transition (figure 15.7). There is only one high first occurrence event that seems to be above background extinction and speciation rates (figure 15.7). However, this cluster of first occurrence datums at the maximum flooding surface is probably related to an artifact of sequence architecture (Holland, 1995), and does not indicate a true speciation event.

SEQUENCE STRATIGRAPHY

Paleobathymetric curves for each individual section, which constitute the basis for the sequence stratigraphic analysis, were derived from palynofacies analyses, dinocyst paleobathymetric indexes, and lithofacies. For a detailed explanation of techniques, results, and discussion of the curves, as well as sequence stratigraphy for each individual section, see Jaramillo and Oboh-Ikuenobe (1999). A correlation of all the studied sections (figure 15.8) shows that a maximum flooding surface in all the sections, except the St. Stephens Quarry, is isochronous and approximately 7.5 composite units (~0.1 Ma) older than the Eocene/Oligocene boundary. At the St. Stephens Quarry section, this surface is three composite units (~0.04 Ma) younger than the other sections. This maximum flooding surface occurs in the middle part of the Shubuta Clay in the four southern Mississippi sections and at the Shubuta-Bumpnose contact in the St. Stephens Quarry section. This contact represents a minor flooding surface in southern Mississippi. The Pachuta Marl and the lower Shubuta Clay (the entire Shubuta in Alabama) constitute a transgressive systems tract, with the upper Shubuta Clay and Bumpnose/Red Bluff/Forest Hill Formations representing the overlying highstand systems tract. The stratigraphic condensation at the St. Stephens Quarry section corresponds to the accumulation of the early Oligocene highstand in southern Mississippi. Figure 15.8 shows that the continuation of normal sedimentation in the St. Stephens Quarry area appears to correspond to the accumulation of the Forest Hill in southern Mississippi.

Up in the section, the Forest Hill-Mint Spring contact is interpreted as a sequence boundary that coincides with a transgressive surface. The Mint Spring Marl and Marianna Limestone represent a transgressive system tract. However, a possible lowstand deposit (forced regression) is interpreted in the #1 Wayne core section where sandy deposits occur in Mint Spring (figure 15.8).

Our interpretation of sequence stratigraphy is in general agreement with several previous studies (in particular, Tew and Mancini, 1995), although there are some distinct differences. First, the maximum flooding surface of the Shubuta-Forest Hill sequence occurs in the middle of the Shubuta Clay in southern Mississippi, but at the Shubuta-Bumpnose contact in the St. Stephens Quarry section. Second, the age of this maximum flooding surface is latest Eocene. Third, the lower 60 cm of the Bumpnose Limestone in the St. Stephens Quarry section constitute a condensed section that accumulated at the same time that the upper Shubuta and Red Bluff were being deposited in southern Mississippi. Fourth, the lowermost Oligocene sections constitute a highstand systems tract and not a lowstand systems tract as interpreted by Pasley and Hazel (1995).

REGIONAL AND GLOBAL PERSPECTIVES

The Eocene-Oligocene transition has received much attention because marine microfossils, most notably planktonic foraminifera and calcareous nannofossils, indicate thermal minimum at the boundary (Wei, 1991; Zachos et al., 1994). However, long-term cooling appears to have occurred long before the boundary itself, sometime during the middle to late Eocene. Several groups of organisms, such as mollusks in Oregon and Washington States (U.S.A.), document a decline in diversity and a shift from warm taxa to cold taxa during the late Eocene, just before the Eocene/Oligocene boundary (Hickman, this volume). In the U.S. Gulf Coast, our palynological data, which are limited to the Eocene-Oligocene transition, do not record distinct turnovers at the boundary itself, but note the dominance of the cooler-climate indicator *Querobidites over Momipites* in the palynofloral assemblage. *Momipites* pollen is more common in warmer climates and it was more dominant during the Eocene (Elsik, 1974; Frederiksen, 1988, 1991; Oboh et al., 1996). Frederiksen (1991) was
Figure 15.7. First and last occurrence datums per sample throughout the Eocene-Oligocene transition in the #1 Young core. Note how peak of first occurrence datum correlates with the maximum flooding surface, suggesting that the peak is an artifact of sequence architecture rather than an evolutionary event. Paleobathymetric curve, sequence stratigraphy, and dating of the section after Jaramillo and Oboh-Ikuenobe (1999). See label legends in figure 15.5.
Figure 15.8. Time (composite section) versus stratigraphic thickness and sequence stratigraphy for the studied sections containing dinocyst data. Each composite unit is equivalent to 0.014 My. The Eocene/Oligocene boundary in the #1 Wayne corehole is at 55.7 m, 1.9 m above the Shubuta-Red Bluff contact, while the C13n-C12r magnetostratigraphic boundary occurs at 7.1 m, 2 m above the Mint Spring-Marianna contact. In the #1 Ketter corehole, the Eocene/Oligocene boundary is located at 7.5 m, 3.7 m. above the Shubuta-Red Bluff contact. At the R2089 section, the Eocene/Oligocene boundary is located at 13.3 m, 0.1 m above the Shubuta-Red Bluff contact. At St. Stephens Quarry a 80 cm-condensed section containing the maximum flooding surface and the Eocene/Oligocene boundary begins 20 cm below the Shubuta-Bumpnose contact and ends 60 cm above the contact. See label description in legend of figure 15.5. MS, Mint Spring; RSL, relative sea level. Composite section after Jaramillo and Oboh-Ikuenobe (1999).

able to correlate similar pollen events in the Gulf Coast with those in southern California. However, Yancey et al. (this volume) document that *Quercoidites* abundance occurred earlier in Texas, during the late Eocene as opposed to the early Oligocene in the eastern Gulf Coast. Our early Oligocene palynofloral assemblage is indicative of a warm temperate climate in comparison with more tropical elements in early and middle Eocene assemblages. A similar observation was also made in Australia by Gammon et al. (this volume) in his study of Southern Hemisphere biosiliceous deposits. Our dinocyst diversity data (figure 15.5) do not record a rapid decline at the Eocene-Oligocene transition, and therefore support the spore and pollen data. The slight decrease in dinocyst diversity during the early Oligocene was
likely due to a facies change from marine sediments to nearshore sediments.

Intensive debates have been going on for several years about the synchronicity of the sequence boundaries of the Haq et al. (1988) curve and its use for worldwide chronostratigraphic correlation (e.g., Miall, 1992). The Haq curve shows a sequence boundary at the Eocene/Oligocene boundary (TA 4.3/4.4 sequence boundary), which some people have argued should be used to define the Eocene/Oligocene boundary worldwide (e.g., Brinkhuis and Visscher, 1995). The 1992 Kyoto International Geological Congress defined the Eocene/Oligocene boundary by the last occurrence of the foraminifera Hankenina spp. at the Massignano section in Italy (Berggren et al., 1995). This datum is located in the youngest part of the magnetostratigraphic C13r (C13r.14) Chron (Berggren et al., 1995). In the Priabonian type section, Brinkhuis (1994) indicated that the Eocene/Oligocene boundary (as defined by the last occurrence of Hankenina) would be located 15 m below the lithostratigraphic position of a sequence boundary that is interpreted as the TA4.3/TA4.4 sequence boundary of the Haq et al. (1988) curve. Furthermore, this sequence boundary in the Priabonian type section is in the lower part of Chron C13n (Brinkhuis and Visscher, 1995:298, figure 4). The correlation of the Priabonian sequence boundary with the sequence boundary at the Forest Hill-Mint Spring contact is not possible because the sequence boundary in the U.S. Gulf Coast occurs at the C13n-C12r boundary (figure 15.8). Therefore, the Priabonian and Forest Hill-Mint Spring sequence boundaries are not coeval, and the TA 4.3/TA4.4 sequence boundary of the Haq et al. (1988) curve may not be worldwide in occurrence and should not be used as a time line.

CONCLUSIONS
The prominence of Quercidites, Sequoiapollenites, Cupressacites, and Cylindraceapollenites in the rich pollen assemblage, which contains some tropical to subtropical elements, and lacks indicators of cool-temperate to cold-temperate or dry conditions, suggests a warm temperate paleoclimate during the beginning of the early Oligocene in the study area. Although Monotrites was generally more abundant in the Eocene, and Quercidites increased during the Oligocene, there was no significant paleofloristic change across the Eocene/Oligocene boundary. The major floral turnover along the Gulf Coast occurred well before the deposition of the Vicksburg units during the early Oligocene, probably at the end of the middle Eocene. Dinocyst data also do not show evidence of either a major species turnover or a change in standing diversity, suggesting that major changes in sea surface water in the area did not occur at the Eocene/Oligocene boundary. Sequence stratigraphic interpretations are in agreement with most previous studies.

ACKNOWLEDGMENTS
We thank Norman Frederiksen and Thomas Yancey for a detailed review of this paper. We also thank Norman Frederiksen and Lucy Edwards (U.S. Geological Survey) for loan of the outcrop samples, Larry Fearn and Mobil Exploration and Producing for providing the Mississippi corehole samples, and Mobil for permission to publish the results from the Mississippi coreholes. Lisa Reeves-Morris and Oscar Yepes contributed data to this study. This research was funded by the Petroleum Research Fund, administered by the American Chemical Society, and by NSF Grant No. EAR-9405154 to FEO. Carlos Jaramillo thanks Colciencias for its support.

REFERENCES


