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Ernest A. Mancini
State Geologist

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By

Ernest A. Mancini and David D. Soens

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Paleoenvironments of the Tombigbee Sand Member of the Eutaw Formation (Upper Cretaceous) of Eastern Mississippi and Western Alabama

Ernest A. Mancini[1,2] and **David D. Soens**[1]
[1]Department of Geology, University of Alabama, Tuscaloosa, AL 35486-9780
[2]Geological Survey of Alabama, Tuscaloosa, AL 35486-9780

Abstract

In eastern Mississippi and western Alabama, the Tombigbee Sand Member of the Eutaw Formation accumulated as part of a marine transgression during the Late Cretaceous (Santonian Stage). The Tombigbee includes glauconitic, fossiliferous, micaceous, bioturbated, massive-bedded, quartzose sandstone and siltstone deposited on a marine shelf. The inner to middle shelf sandstone and siltstone of the Tombigbee disconformably overlie thinly laminated to cross-bedded, tidally influenced, fine- to medium-grained, nearshore sandstone of the Eutaw Formation. *Ophiomorpha* burrows are common in the lower member of the Eutaw, and no calcareous microfossils were recovered from this member. In eastern Mississippi, the disconformable Eutaw-Tombigbee contact is marked by a 1- to 2-in (2.54- to 5.08-cm) sandstone bed containing phosphatic pebbles, shark teeth, and reworked fossils. The Tombigbee contains a diverse macrofauna, including echinoderms, gastropods, cephalopods, and bivalves, and a rich microfauna and microflora, including foraminifera, ostracodes, and calcareous nannoplankton. The foraminiferal assemblage consists of globotruncanids, heterohelicids, nodosariids, anomalinids, verneuilinids, globotextulariids, and textulariids. The middle shelf marls of the Mooreville Chalk conformably overlie the Tombigbee. These lower Mooreville marlstone beds have a diverse microfossil assemblage similar to the upper Tombigbee beds.

Introduction

The Upper Cretaceous strata of the eastern Gulf Coastal Plain represent a near-continuous section of Santonian through Maastrichtian siliciclastic and carbonate sediments. Of particular interest is the lowermost siliciclastic unit in this stratigraphic succession; that is, the Eutaw Formation and the associated Tombigbee Sand Member. Deposition of this unit signals the initiation of the highest post-Paleozoic rise in relative sea level for this area (Russell et al., 1983). The objective of this paper is to examine the lithofacies and foraminiferal biofacies changes evident in the Tombigbee Sand Member in eastern Mississippi and western Alabama (Fig. 1). Understanding the sedimentology and paleoecology of the Tombigbee deposits will aid in the interpretation of Late Cretaceous paleoenvironments and paleogeography of the eastern Gulf Coastal Plain.

Stratigraphy and Lithofacies

The Eutaw Formation includes a lower unnamed member and the upper Tombigbee Sand Member (Fig. 2). The lower member consists of 170 ft (51.82 m) of fine- to medium-grained, glauconitic, micaceous, cross-bedded sandstone containing clay laminae; thicker claystone layers are present in its type area near Eutaw, Greene County, Alabama (Wahl, 1966). *Ophiomorpha* structures are common. The Tombigbee Sand Member includes highly bioturbated, fossiliferous, glauconitic, micaceous, massive-bedded, very fine- to fine-grained sandstone and coarse siltstone. The Tombigbee Member attains a thickness of 50 ft (15.24 m) at the type section of the unit, Plymouth Bluff (Fig. 3) along the Tombigbee River, Lowndes County, Mississippi (Russell et al., 1983). The lower member of the Eutaw Formation disconformably underlies the Tombigbee Sand Member. In eastern Mississippi, the Eutaw-Tombigbee contact is marked by a 1- to 2-in (2.54- to 5.08-cm) bed containing phosphatic pebbles, shark teeth, and reworked fossils. The Mooreville Chalk conformably overlies the Tombigbee. The Tombigbee-Mooreville contact is lithologically gradational but is marked by phosphatic grains and sideritic mollusk molds.

Although the Tombigbee Sand Member appears to be relatively uniform in lithology, three lithofacies can be recognized from sedimentologic analyses (Table 1 and Fig. 4). Lithofacies one represents sediment from the uppermost part of the lower member of the Eutaw and lower part of the Tombigbee Sand Member. These sandstone units are characterized by tabular and trough cross-beds, rippled sandstone beds, and interbeds of parallel laminated silty sandstone and claystone. The cross-bed sets vary in thickness from 1 to 3 ft (0.3 to 0.9 m) and are usually separated by clay drapes. The bimodal nature of foreset directions indicates tidally influenced nearshore deposition. *Ophiomorpha* burrows typify these sediments. This lithofacies consists of fine-grained sandstone that is moderately to well

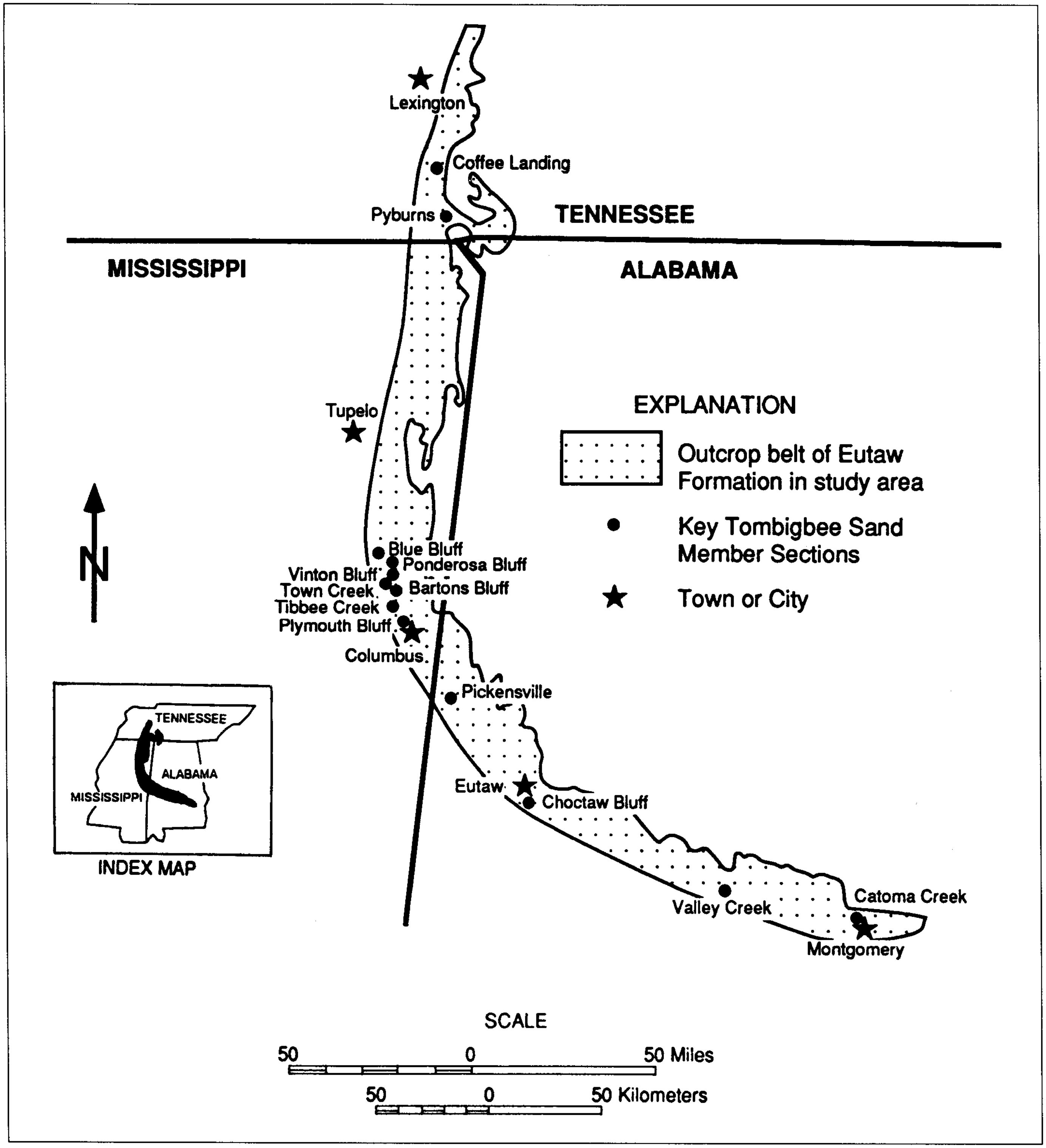

Figure 1. Map showing outcrop belt of Upper Cretaceous Eutaw Formation and key Tombigbee Sand Member sections.

sorted, coarse to strongly fine skewed, and made up of more than 96% sand-size grains (Table 1).

Lithofacies two represents "typical" Tombigbee Sand Member strata. This lithofacies is massive bedded, bioturbated, and glauconitic and contains *Thalassinoides* and *Ophiomorpha* structures. Middle Tombigbee sediment is fine sandstone to coarse siltstone, moderately to very poorly sorted, strongly fine skewed, and has moderate amounts of carbonate content. The sedimentary characteristics of this lithofacies indicates that it accumulated in more offshore marine shelf environments than the tidally influenced environments of lithofacies one (Table 1).

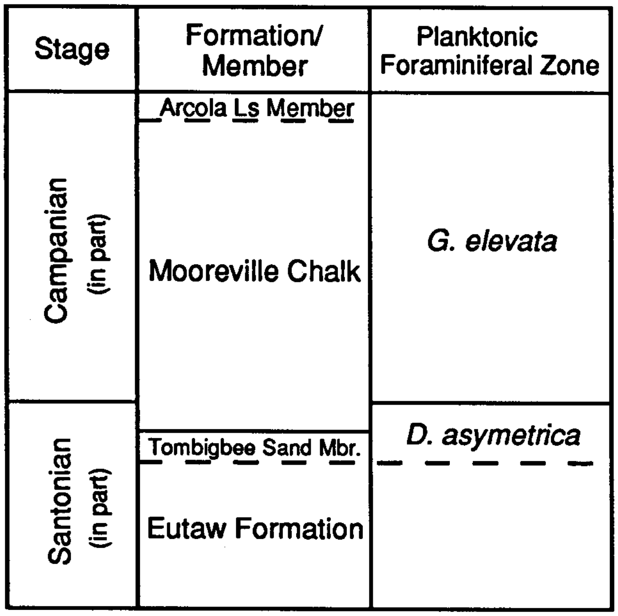

Figure 2. Lithostratigraphy and biostratigraphy of the Tombigbee Sand Member of the Eutaw Formation and associated strata in the area of study.

Lithofacies three represents sediment from the upper Tombigbee Sand Member and lowermost part of the Mooreville Chalk and silty claystone beds in the middle part of the Tombigbee interval. This sediment is thin to massive bedded, moderately bioturbated, calcareous, and weathers to a blocky appearance. This lithofacies is very poorly sorted, fine to strongly fine skewed, and contains chiefly silt and clay-size particles. Carbonate content ranges from 3 to 42% in this coarse siltstone and claystone. The sedimentary characteristics of lithofacies three indicates that it accumulated in a lower energy and more offshore marine shelf environment than lithofacies two (Table 1).

Overall, the Tombigbee Sand Member represents an upward-fining sequence. The sandstone percent decreases upward from the disconformable Eutaw-Tombigbee contact to the transitional Tombigbee-Mooreville contact, whereas the silt, clay, and carbonate contents generally increase upward through the Tombigbee (Fig. 4). The Tombigbee vertical sequence records a change in paleoenvironmental conditions from higher energy, tidally influenced nearshore environments at the base through marine shelf environments deposited below wave base to more offshore lower energy marine shelf environments.

Biostratigraphy

Using the last (highest stratigraphic) occurrence of the planktonic foraminifer *Dicarinella asymetrica* Sigal (*Dicarinella concavata carinata* of many authors) rather than the first (lowest stratigraphic) occurrence of single-keeled globotruncanids (*Globotruncanita elevata* [Brotzen] and *G. stuartiformis* [Dalbiez]), the Tombigbee Sand Member is Santonian in age (Fig. 2). The Tombigbee is assigned to the *Dicarinella asymetrica* Taxon Range Zone as defined by Caron (1985). The last (highest stratigraphic) occurrence of *Dicarinella asymetrica* is in the Mooreville Chalk; therefore, the Santonian-Campanian Stage boundary is in the Mooreville.

Because of the presence of the single-keeled *Globotruncanita stuartiformis* in the Tombigbee, Smith and Mancini (1983) determined that the Tombigbee was Campanian in age. Dalbiez (1959), Pessagno (1969), and Postuma (1971) recognized the base of the Campanian as the first occurrence of single-keeled globotruncanids, and *Globotruncanita stuartiformis* occurs in the Tombigbee. This determination is consistent with the work of Smith (1975). In this paper, however, the Tombigbee is assigned a late Santonian age following the work of Caron (1985). Caron (1985) recognized the base of the Campanian by the absence of *Dicarinella asymetrica*. In the Tombigbee and lower Mooreville in eastern Mississippi and western Alabama, the ranges of *G. stuartiformis* and *D. asymetrica* overlap. This range overlap was recognized by Caron (1985), and the

Table 1. Characteristics of lithofacies.

Lithofacies	Grain size mean (ϕ)	Sorting (ϕ)	Skewness SKI	Sand (%)	Silt (%)	Clay (%)	$CaCO_3$ (%)
uppermost Eutaw-lower Tombigbee 1	2.04–2.67 fine sand	0.37–0.59 moderately to well	-0.29–1.33 coarse to strongly fine	96–100	0.05–4	0	0–4
middle Tombigbee 2	2.68–4.64 fine to very fine sand to coarse silt	0.77–2.22 moderately to very poorly	0.79–6.54 strongly fine	24-96	3–66	0.1–13	1–13
upper Tombigbee-lowermost Mooreville 3	4.16–8.19 coarse silt to clay	2.07–3.12 very poorly	0.15–1.38 fine to strongly fine	3- 68	15–46	17–69	3–42

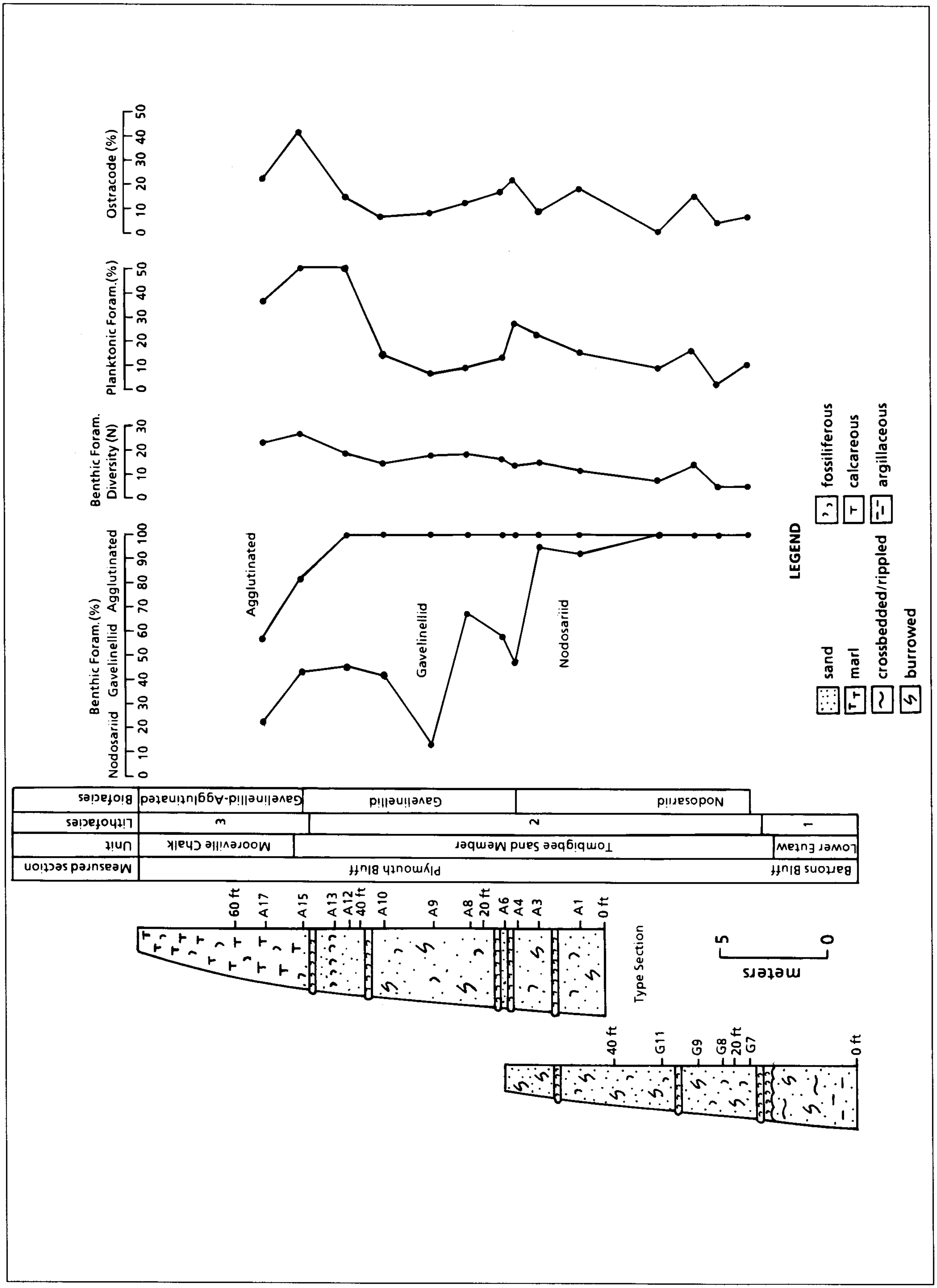

Figure 3. Composite section of the Tombigbee Sand Member, including the type section at Plymouth Bluff near Columbus, Mississippi, illustrating vertical trends in microfaunal diversity and composition in the area of study. See Figure 1 for location of Tombigbee sections.

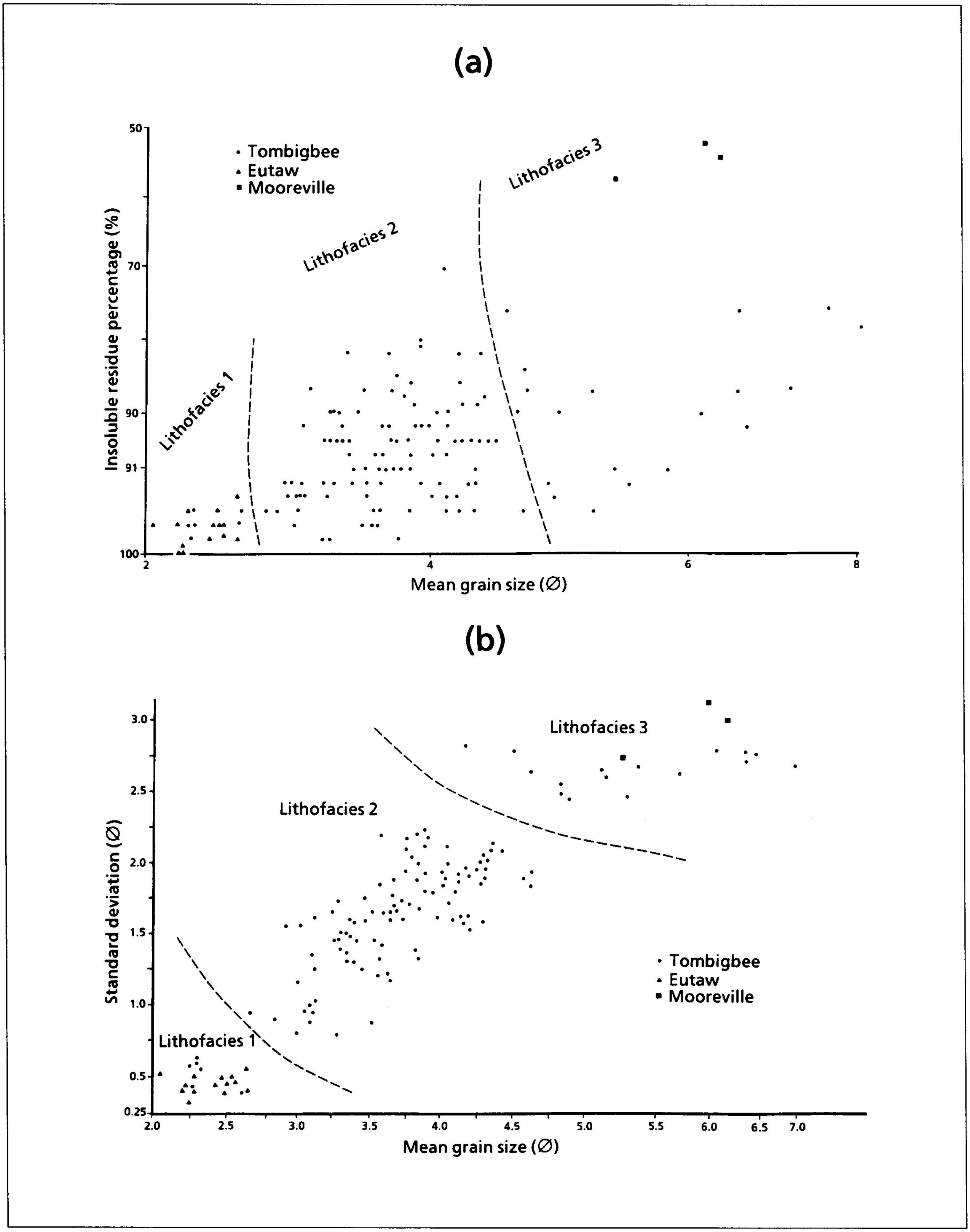

Figure 4. Cross plots depicting sediment changes in the Tombigbee lithofacies: (a) mean grain size versus insoluble residue and (b) mean grain size versus standard deviation.

Table 2. Characteristics of biofacies.

Biofacies	Benthonic foraminifera diversity (N)[1]	Benthonic foraminifera abundance (N)[2]	Planktonic foraminifera (%)	Calcareous benthonic foraminifera (%)	Agglutinated benthonic foraminifera (%)	Benthonic foraminifera (%)	Ostracodes (%)
Marginulinid	2–17	0.05–1.47	0–83	17–100	0–21	15–100	0–46
Lenticulinid	5–21	0.13–3.14	0–74	26–100	0–7	26–100	0–16
Gavelinellid	4–22	0.11–4.31	0–50	42–100	0–23	48–100	0–21
Other	3–26	0.1–2	0–72	25–36	0–64	19–100	0–32

[1]Diversity is measured as the total number of benthic foraminiferal genera present in a sediment sample.

[2]Abundance is measured as the number of benthic foraminiferal specimens per gram of sediment. Calculated by dividing the number of specimens counted by the weight of the sediment sample (~200 grams).

strata in which these species occur concurrently were assigned a late Santonian age. This age assignment is consistent with the determination by Dowsett (1989), working with calcareous microfossils, and Kennedy and Cobban (1991), working with ammonites, that the Tombigbee is Santonian in age.

The planktonic foraminiferal assemblage of the Tombigbee Sand Member includes *Archaeoglobigerina blowi* Pessagno, *A. cretacea* d'Orbigny, *Rugoglobigerina rugosa* (Plummer), *Heterohelix globulosa* (Ehrenberg), *Pseudotextularia elegans* (Rzehek), *Ventilabrella glabrata* Cushman, *Globigerinelloides prairiehillensis* Pessagno, *G. multispina* (Lalicker), *Dicarinella asymetrica*, *Rosita fornicata* (Plummer), *Globotruncana bulloides* Volger, *G. arca* (Cushman), *G. lapparenti* Brotzen, and *Globotruncanita stuartiformis*. No foraminifera were recovered from the lower member of the Eutaw.

Paleoenvironments and Biofacies

Three benthic foraminiferal assemblages are recognized in the Tombigbee Sand Member and lowermost Mooreville Chalk (Table 2 and Figs. 3, 5, and 6). These include the nodosariid, gavelinellid, and gavelinellid-agglutinated assemblages. The nodosariid assemblage principally consists of species of the genera *Lenticulina*, *Marginulina*, *Vaginulina*, *Nodosaria*, *Dentalina*, *Frondicularia*, *Kyphopyxa*, *Lagena*, and *Marginulinopsis*. This biofacies has lower benthic foraminiferal diversity and abundance and the highest counts of ostracodes (Table 2 and Fig. 5). Such a foraminiferal assemblage predominated by hyaline benthic foraminifera of the nodosariid group typically occurs in present-day normal marine inner to middle neritic environments (Bandy, 1964; Walton, 1964; Loep, 1965; Phleger, 1965; Murray, 1973). Nodosariids have been described as being typically characteristic of Cretaceous inner to middle shelf environments by Burnaby (1962), Sliter and Baker (1972), Mancini (1978, 1982), and Nyong and Olsson (1984).

The gavelinellid assemblage principally consists of species of the genus *Gavelinella* (anomalinid). This biofacies has moderate benthic foraminiferal diversity and abundance and moderate counts of ostracodes. Anomalinids have been described from present-day neritic environments (Murray, 1973). Gavelinellids have been reported from Cretaceous shelf to slope environments (Sliter and Baker, 1972; Nyong and Olsson, 1984).

The gavelinellid-agglutinated assemblage principally consists of species of the genus *Gavelinella* and agglutinated benthic foraminifera. This biofacies has higher benthic foraminiferal diversity and abundance and high counts of ostracodes. The agglutinated benthic forms (*Textularia*, *Dorothia*, and *Gaudryina*) present in this assemblage are species characteristic of shelf environments (Burnaby, 1962; Sliter and Baker, 1972; Mancini, 1978, 1982). Species of the genera *Valvulineria* (discorbid) and *Gyroidinoides* (osangulariid), which are typical neritic to bathyal present-day forms (Murray, 1973), are a consistent part of this assemblage.

Overall, the composition and diversity of the microfaunal populations indicate that the Tombigbee sediments accumulated under normal marine inner to middle shelf conditions (Fig. 5). The predominance of nodosariids and gavelinellids supports this interpretation. The low counts of polymorphinids (*Guttulina* and *Globulina*) (Table 2) and the absence of miliolids in the Tombigbee suggest an outermost inner to middle shelf environment rather than an innermost inner shelf environment as these forms are most abundant in nearshore normal marine environments (Sliter and Baker, 1972; Murray, 1973). The predominant agglutinated benthic foraminifera that occur in the Tombigbee are not hyposaline types but rather are textulariids, globotextulariids, and verneuilinids characteristic of Cretaceous shelf environments (Burnaby, 1962; Sliter and Baker, 1972; Mancini, 1978, 1982). Planktonic fora-

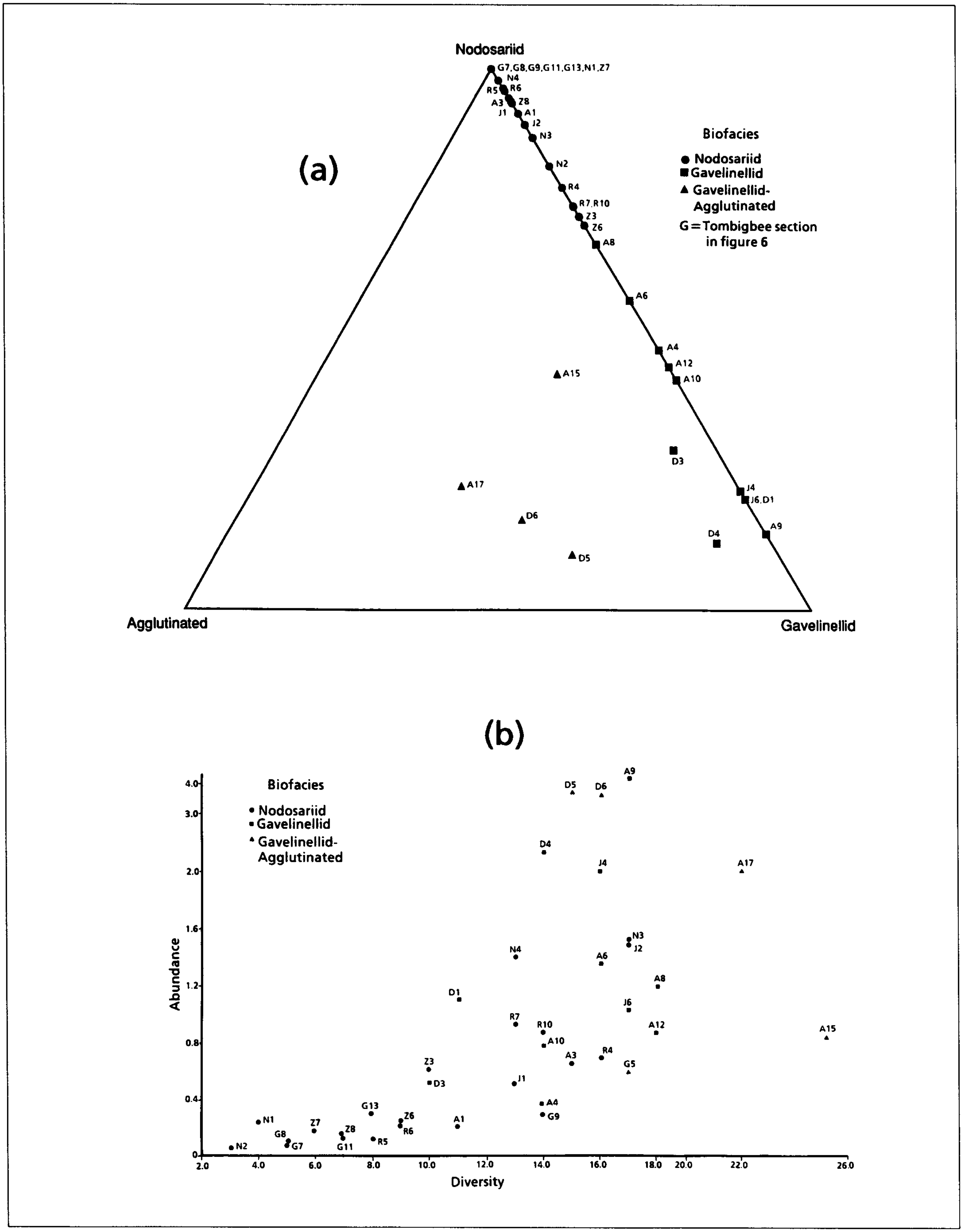

Figure 5. Triangle diagram and cross plot depicting changes in the Tombigbee benthic foraminiferal biofacies: (a) composition of foraminiferal populations and (b) diversity versus abundance. See Figure 1 for location of Tombigbee sections.

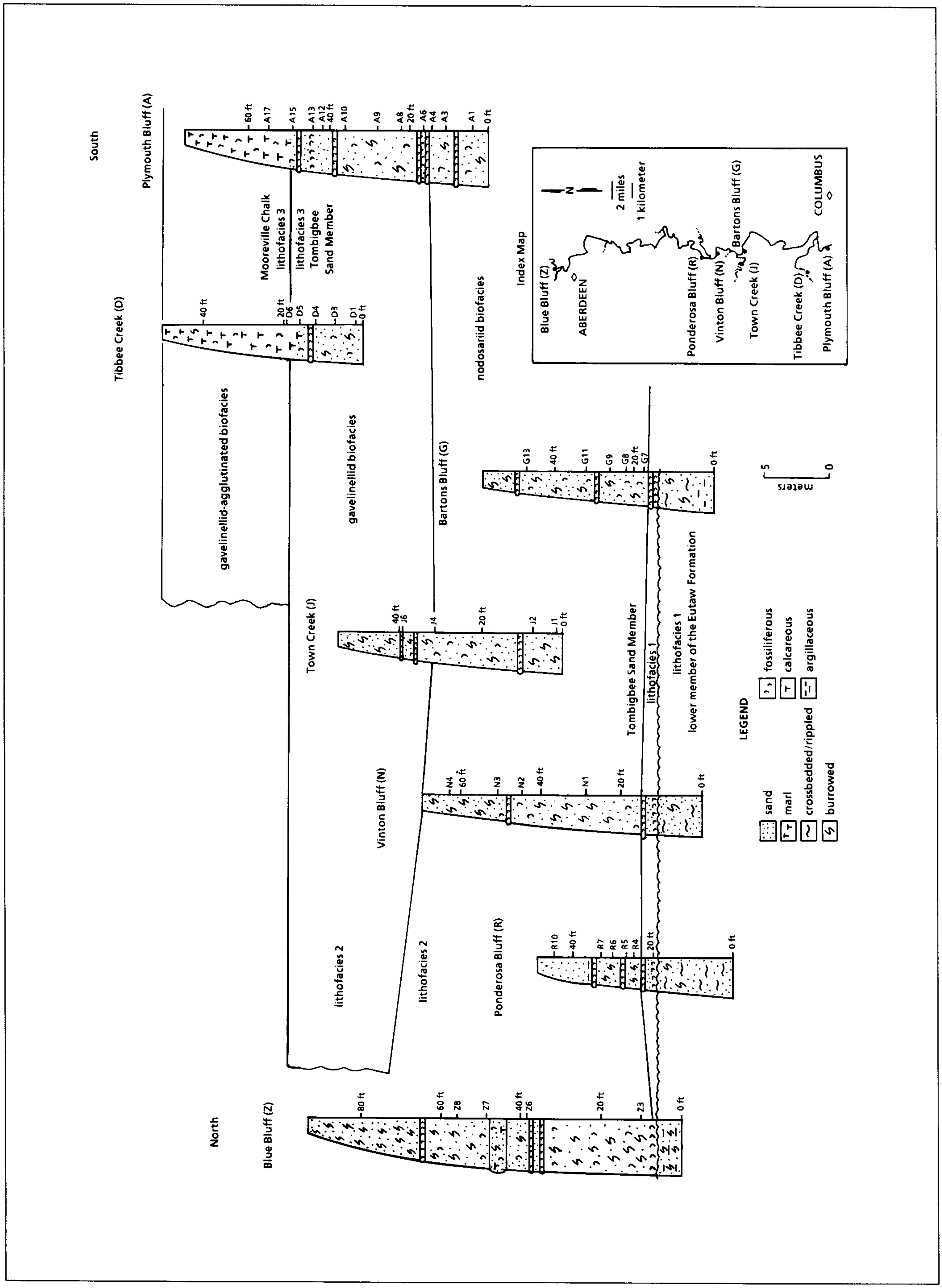

Figure 6. Cross section illustrating lithofacies and biofacies changes in the Tombigbee Sand Member in the study area. See Figure 1 for location of Tombigbee sections.

minifera are common but not abundant in the middle Tombigbee beds, suggesting shelf environments rather than deeper marine environments (Upshaw and Stehli, 1962; Phleger, 1965). Planktonic foraminifera are more abundant in the upper Tombigbee and Mooreville beds (Fig. 3). The Tombigbee ostracode assemblage, consisting of brachycytherids, cythereids, and cytherellids, is predominated by forms that commonly occur in present-day marine shelf environments (Puri and Hulings, 1957; Benson, 1961). The preservation and ornamentation of the foraminifera and ostracodes indicate a paleoenvironment characterized by low to moderate energy levels. The macrofauna are diverse and are characterized by echinoderms, gastropods, cephalopods, and bivalves (especially species of *Exogyra*, *Pycnodonte*, *Ostrea*, *Inoceramus*, and *Anomia*), suggesting that the Tombigbee paleoenvironment was optimal for normal marine shelf organisms.

Vertical trends in microfaunal diversity and composition in the Tombigbee are very subtle (Fig. 3); however, the following generalizations can be made. The lower member of the Eutaw Formation and lowermost beds of the Tombigbee (lithofacies one) accumulated in a marginal marine nearshore paleoenvironment; this is supported by the fact that this unit is barren of calcareous microfossils. The middle Tombigbee sandstone and siltstone deposits (lithofacies two) were deposited in an upward-deepening setting associated with a rise in sea level. Initially the nodosariid biofacies and then the gavelinellid biofacies predominated these inner to middle shelf deposits (Fig. 5). With continued sea-level rise, lithofacies three (upper Tombigbee and lowermost Mooreville) accumulated in an environment predominated by middle shelf gavelinellid-agglutinated biofacies. This Santonian transgression continued with the deposition of the lower sediments of the Mooreville Chalk.

Conclusions

1. In eastern Mississippi and western Alabama, the shelf sandstone and siltstone of the Tombigbee Sand Member of the Eutaw Formation accumulated as part of a marine transgression initiated during the Santonian Stage. The Tombigbee disconformably overlies the lower member of the Eutaw Formation and is conformably overlain by the Mooreville Chalk.

2. Three lithofacies can be recognized in the Tombigbee Sand Member from sedimentologic analyses. Overall, the Tombigbee interval represents an upward-fining sequence exhibiting an upward decrease in sand percent and an increase upward in silt, clay, and carbonate contents.

3. Three benthic foraminiferal assemblages can be discerned in the Tombigbee sediments. These include a nodosariid assemblage, a gavelinellid assemblage, and a gavelinellid-agglutinated assemblage. Overall, the microfaunal composition and diversity indicate that the Tombigbee sediments principally accumulated under normal marine inner to middle shelf conditions.

4. The Tombigbee Sand Member is assigned to the upper Santonian *Dicarinella asymetrica* Taxon Range Zone of Caron (1985) based on the presence of the nominal taxon. This species co-occurs with the single-keeled *Globotruncanita stuartiformis* in the Tombigbee deposits. The Santonian-Campanian Stage boundary is placed in the Mooreville Chalk.

Acknowledgments

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