UPPER CRETACEOUS SEQUENCE STRATIGRAPHY OF THE MISSISSIPPI-ALABAMA AREA

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Upper Cretaceous Sequence Stratigraphy of the Mississippi - Alabama Area

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Abstract

Three depositional sequences, associated with cycles of change in relative sea level and coastal onlap, can be identified in the Upper Cretaceous (Santonian, Campanian, and Maastrichtian) strata of the Mississippi-Alabama area. These depositional sequences have an event spacing of 2 to 11 million years and are herein designated the UZAGC-3.0 (Upper Zuni A, Gulf Coast), UZAGC-4.0, and UZAGC-5.0 sequences. The UZAGC-3.0 cycle comprises a lower type 1 sequence boundary (Tuscaloosa-Eutaw contact); lowstand systems tract (Eutaw Formation); first transgressive surface or disconformity (Eutaw-Tombigbee contact); transgressive systems tract (Tombigbee Sand Member of the Eutaw Formation and the lower Mooreville Chalk); surface of maximum transgression or submarine disconformity (within the Mooreville Chalk); and highstand systems tract (upper Mooreville Chalk and its Arcola Limestone Member, basal Demopolis sandy beds, Coffee Sand, Tupelo Tongue of the Coffee Sand). The UZAGC-4.0 cycle includes a lower type 2 sequence boundary (Coffee or Tupelo Tongue contact with the Demopolis or Sardis Formation or a contact recognized within the Demopolis), which is coincident with the first transgressive surface; transgressive systems tract (Demopolis marls, Sardis Formation); surface of maximum transgression within the Demopolis Chalk; and highstand systems tract (Demopolis Chalk and its Bluffport Marl Member, Coon Creek Formation, Ripley Formation, McNairy Sand). The UZAGC-5.0 cycle includes a lower sequence boundary (McNairy Sand contact with the Owl Creek Formation or Chiwapa Sandstone Member of the Ripley Formation or a disconformity recognized within the Ripley Formation), which can be coincident with the first transgressive surface; transgressive systems tract (Chiwapa or Ripley calcareous sands, Prairie Bluff or Owl Creek marls); surface of maximum transgression within the Prairie Bluff or Owl Creek; and highstand systems tract (Prairie Bluff or Owl Creek beds).

The component systems tracts and defining physical surfaces of these sequences have been recognized and traced from Selmer (Tennessee) to Selma (Alabama), a distance of about 420 km. The sequence boundaries and transgressive surfaces are diachronous along their traces. The transgressive systems tract deposits of a given sequence become progressively younger in age from the basin proper to the basin margin. Only the maximum flooding surfaces and/or condensed section strata have chronostratigraphic significance for regional and worldwide correlation. The synchronous nature of the maximum flooding surface is illustrated by the fact that from the basin proper to the basin margin the beds immediately above this surface rest with the same biostratigraphic zones. Therefore, depositional cycles should be dated by using the synchronous surface (maximum flooding surface) rather than the diachronous surface (sequence boundary or transgressive surface) associated with them. Three such maximum flooding events are evident in the Santonian through Maastrichtian strata of the Mississippi Embayment area. They occur in lower Campanian, upper Campanian, and middle Maastrichtian strata.

Introduction

The publication of the global coastal onlap cycle chart by Haq et al. (1988) stimulated much discussion regarding the validity of application of these proposed global cycles to Cretaceous strata. Miall (1992) suggested that a framework of sequence stratotypes, independent of the cycle chart of Haq et al. (1988), be established as a standard to test the applicability of sequence stratigraphy for global correlation. Along these lines, the purpose of this paper is to report the findings of our field mapping and correlation of Upper Cretaceous (Santonian to Maastrichtian) strata in the eastern Mississippi embayment area of the Gulf Coastal Plain to provide biostratigraphic and chronostratigraphic information for comparative studies on Upper Cretaceous sequence stratigraphy, depositional sequences, and their component systems tracts. The characteristics of the cycles, the duration of the cycles, and their chronostratigraphic significance are discussed. The area of study is principally the eastern Mississippi Embayment, encompassing the Gulf Coastal Plain from Selmer (Tennessee) to Selma (Alabama), a distance of about 420 km (Fig. 1).

Regional Setting

The Upper Cretaceous strata of the eastern Gulf Coastal Plain constitute a seaward-dipping, homoclinal wedge of sedimentary rocks that reflect the infilling of a differentially subsiding depositional basin on the passive southern margin of the North American continent. The Mississippi Embayment was a major structural trough throughout the Mesozoic (Murray, 1961; Wood and Walper, 1974) and was described by Murray as a broad, asymmetric synclinal structure. Wood and Walper (1974) interpreted the origin of this structural embayment as a megashear system associated with continental collision. The Upper Cretaceous strata thicken considerably from the basin margin (150 to 200 m) into the basin proper (300 to 350 m) in east-central Mississippi and west-central Alabama. The basin margin areas of south-central Tennessee and southeast Alabama are stable shelf platforms characterized by a thinner stratigraphic succession.

Stratigraphy and Biostratigraphy

The Upper Cretaceous (Santonian to Maastrichtian) stratigraphic succession of the eastern Gulf Coastal Plain consists of nonmarine, strandline, and marine siliciclastic and carbonate sediments (Russell and Keady, 1983). This section comprises the Eutaw Formation including the Tombigbee Sand Member, the Mooreville Chalk including its Arcola Limestone Member, the Coffee Sand including the Tupelo Tongue, the Demopolis Chalk including the Bluffport Marl Member, the Sardis Formation, the Coon Creek Formation, the McNairy Sand, the Ripley Formation including the Chiwapa Sandstone Member, the Prairie Bluff Chalk, and the Owl Creek Formation (Fig. 2). Throughout the area of investigation, the Eutaw Formation disconformably overlies the Tuscaloosa Group, and the Owl Creek Formation and Prairie Bluff Chalk are disconformably overlain by Paleogene strata.

Lateral lithofacies changes from northwest to southeast indicate that depositional conditions in the Selmer area of Tennessee resulted from fluvio-deltaic, shoreline, and marginal marine sediment accumulation, whereas sedimentation in the Selma area of Alabama was dominated by marine shelf deposition (Fig. 1). This paleogeographic setting resulted in a siliciclastic-dominated succession in south-central Tennessee and northeastern Mississippi and a mixed carbonate and siliciclastic sequence in east-central Mississippi and west-central Alabama. Based on microfossil assemblages, Puckett (1991) determined water depths on the order of about 35 m for these marine shelf environments.

The Upper Cretaceous (Santonian to Maastrichtian) planktonic foraminiferal zonation used in this study is that of Caron (1985). The ostracode zonation of Hazel and Brouwers (1982) and Puckett (1994) and the calcareous nannofossil zonation of Perch-Nielsen (1985) are used herein. See Figure 2 for zone assignments. In this paper, the ranges of planktonic foraminifera are employed to define the Upper Cretaceous stage boundaries. The Santonian-Campanian Stage boundary is recognized by the last (highest) occurrence of *Dicarinella asymetrica* Sigal after the zonation of Caron (1985). *Globotruncanita elevata* (Brotzen) occurs concurrently with *D. asymetrica* at the top of the *D. asymetrica* Total Range Zone. The Campanian-Maastrichtian Stage boundary is recognized by the last (highest) occurrence of *Globotruncanita calcarata* (Cushman), and the Maastrichtian-Danian Stage boundary is defined by the first (lowest) occurrence of Danian planktonic foraminifera species, such as *Parvularugoglobigerina eugubina* Luterbacher and Premoli Silva or *Subbotina pseudobulloides* (Plummer).

Depositional Sequences

Cyclic changes in global sea level and associated relative changes in coastal onlap during the Cretaceous were proposed by Haq et al. (1988). These workers reported 10 global unconformities that were used to divide Santonian, Campanian, and Maastrichtian strata into 9 third-order depositional sequences with durations of 1 to 4 million years (Fig. 3). King and Skotnicki (1994) reported that they recognized each of these sequences in the Upper Cretaceous strata of the eastern Gulf Coastal Plain. On the other hand, Miall (1992) believed that the number of global events that can be attributed to eustasy is probably less than six for the entire Cretaceous Period and that these are probably second-order sequences with an event spacing of 10 to 100 million years rather than third-order sequences of 1 to 10 million years duration. In this study, three

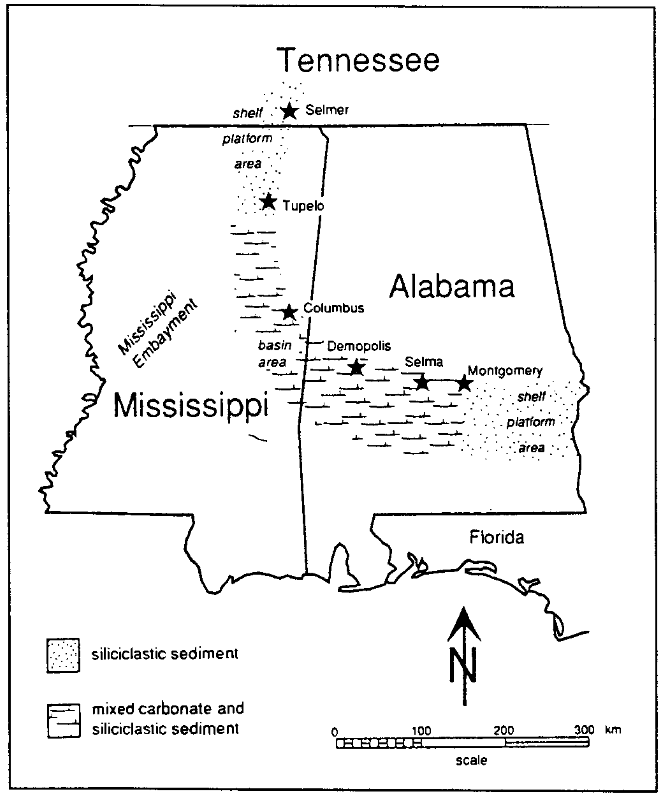

Figure 1. Upper Cretaceous paleogeography for the Mississippi Embayment area.

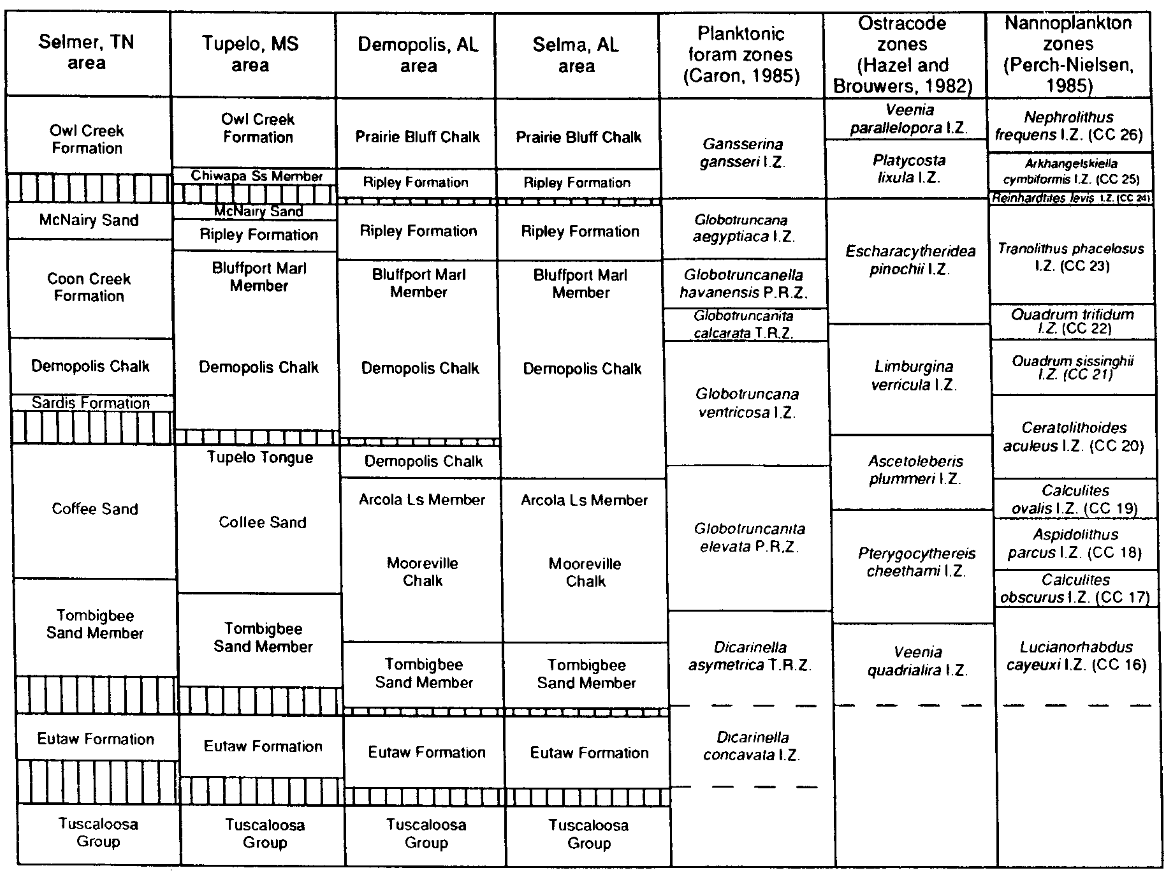

Figure 2. Upper Cretaceous (Santonian to Maastrichtian) lithostratigraphy and biostratigraphy of the Mississippi Embayment area.

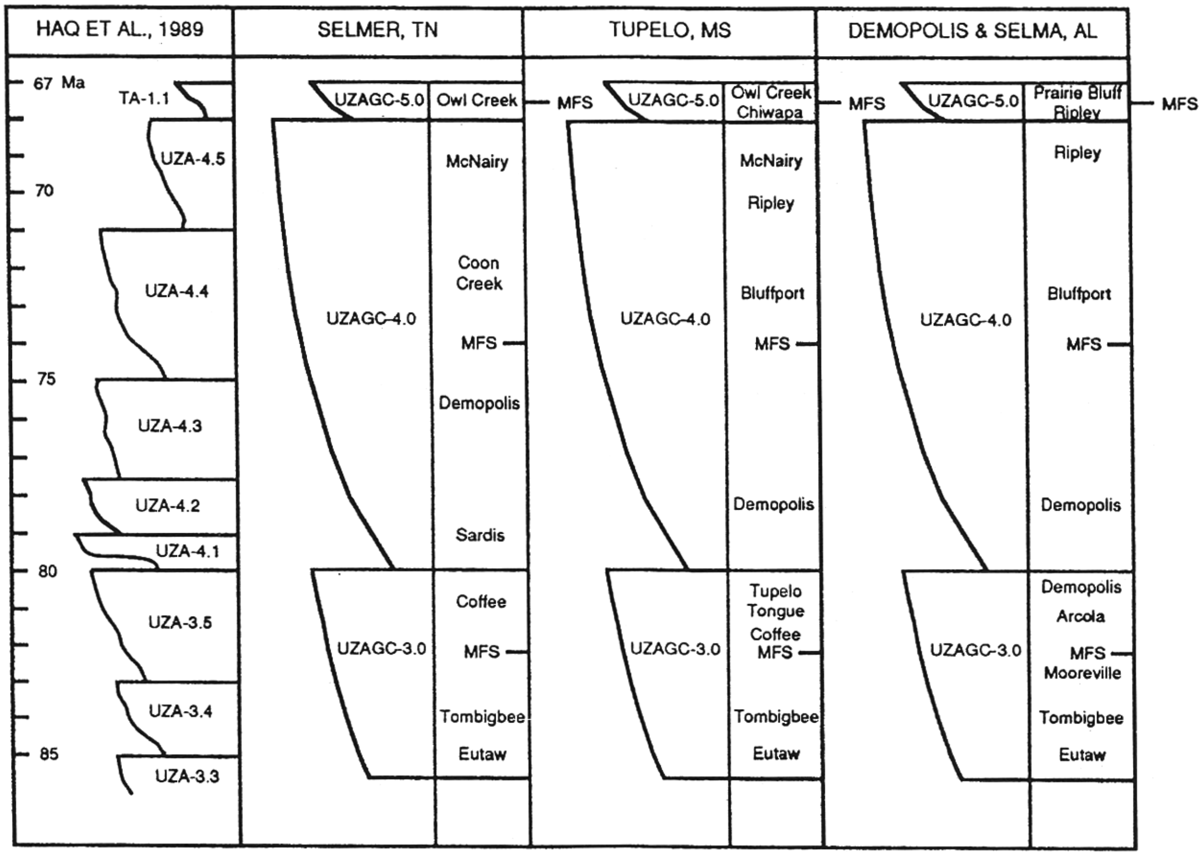

Figure 3. Comparison of Upper Cretaceous depositional sequences recognized for the Mississippi Embayment area to global cycles of Haq et al. (1988) for the equivalent strata. MFS=maximum flooding surface.

unconformity-bounded depositional sequences have been identified and mapped for the Santonian, Campanian, and Maastrichtian strata. These sequences have an event spacing of 2 to 11 million years. Presently, it would appear that insufficient data are available to determine the order of the cyclicity associated with these sequences based on the length of event spacing and that, in fact, it may be inappropriate to attempt to apply "orders" of cyclicity (in the sense of Haq et al., 1988) to Upper Cretaceous strata.

The depositional sequences recognized in this study are herein designated the UZAGC-3.0 (Upper Zuni A, Gulf Coast), UZAGC-4.0, and UZAGC-5.0 sequences (Fig. 3). The use of the term "depositional sequence" in this paper is after the definition of sequence by Mitchum et al. (1977). Thus, a depositional sequence is "a stratigraphic unit composed of a relatively conformable succession of genetically related strata and bounded at its top and base by unconformities or their correlative conformities" (Mitchum et al., 1977).

The UZAGC-3.0 is interpreted as a type 1 sequence bounded at the base by a type 1 sequence boundary. A sequence boundary is considered a type 1 unconformity if field mapping reveals regionally extensive valley incision along the boundary with subsequent lowstand fill of the incised topography, such as at the Tuscaloosa Group-Eutaw Formation contact. The component systems tracts and associated surfaces for the UZAGC-3.0 cycle (Fig. 4c) include the sequence boundary (Tuscaloosa-Eutaw contact), lowstand systems tract (Eutaw Formation), first transgressive surface or disconformity (Eutaw-Tombigbee contact), transgressive systems tract (Tombigbee Sand Member of the Eutaw and the lower Mooreville Chalk), surface of maximum transgression or submarine disconformity (within the Mooreville Chalk), and highstand systems tract (upper Mooreville Chalk and its Arcola Limestone Member, basal Demopolis sandy beds, Coffee Sand, Tupelo Tongue of the Coffee Sand).

The UZAGC-4.0 is a type 2 sequence having a type 2 lower bounding unconformity. Extensive valley incision with subsequent lowstand fill of this incised topography has not been observed along this boundary. The component systems tracts and associated surfaces for the UZAGC-4.0 cycle (Fig. 4b) include a lower type 2 sequence boundary (Coffee or Tupelo Tongue contact with the Demopolis or Sardis Formation or a contact recognized within the Demopolis), which is coincident with the first transgressive surface; transgressive systems tract (Demopolis marls, Sardis Formation); surface of maximum transgression within the Demopolis Chalk; and highstand systems tract (Demopolis Chalk beds, Bluffport Marl Member, Coon Creek Formation, Ripley Formation, McNairy Sand).

The component systems tracts and associated surfaces for the UZAGC-5.0 cycle (Fig. 4a) include a lower sequence boundary (McNairy Sand contact with the Owl Creek Formation or Chiwapa Sandstone Member of the Ripley Sand or a disconformity recognized within the Ripley Formation), which can be coincident with the first transgressive surface; transgressive systems tract (Chiwapa or Ripley calcareous sands, Prairie Bluff or Owl Creek marls); surface of maximum transgression within the Prairie Bluff or Owl Creek; and highstand systems tract (Prairie Bluff or Owl Creek beds).

Parasequences are recognized in these depositional sequences, such as in the transgressive systems tract deposits of the Mooreville Chalk and in the highstand systems tract deposits of the Mooreville Chalk and Demopolis Chalk (Fig. 5). Although these parasequences lack distinct bounding surfaces and component systems tracts, they are unique and traceable over reasonable distances. The mechanism

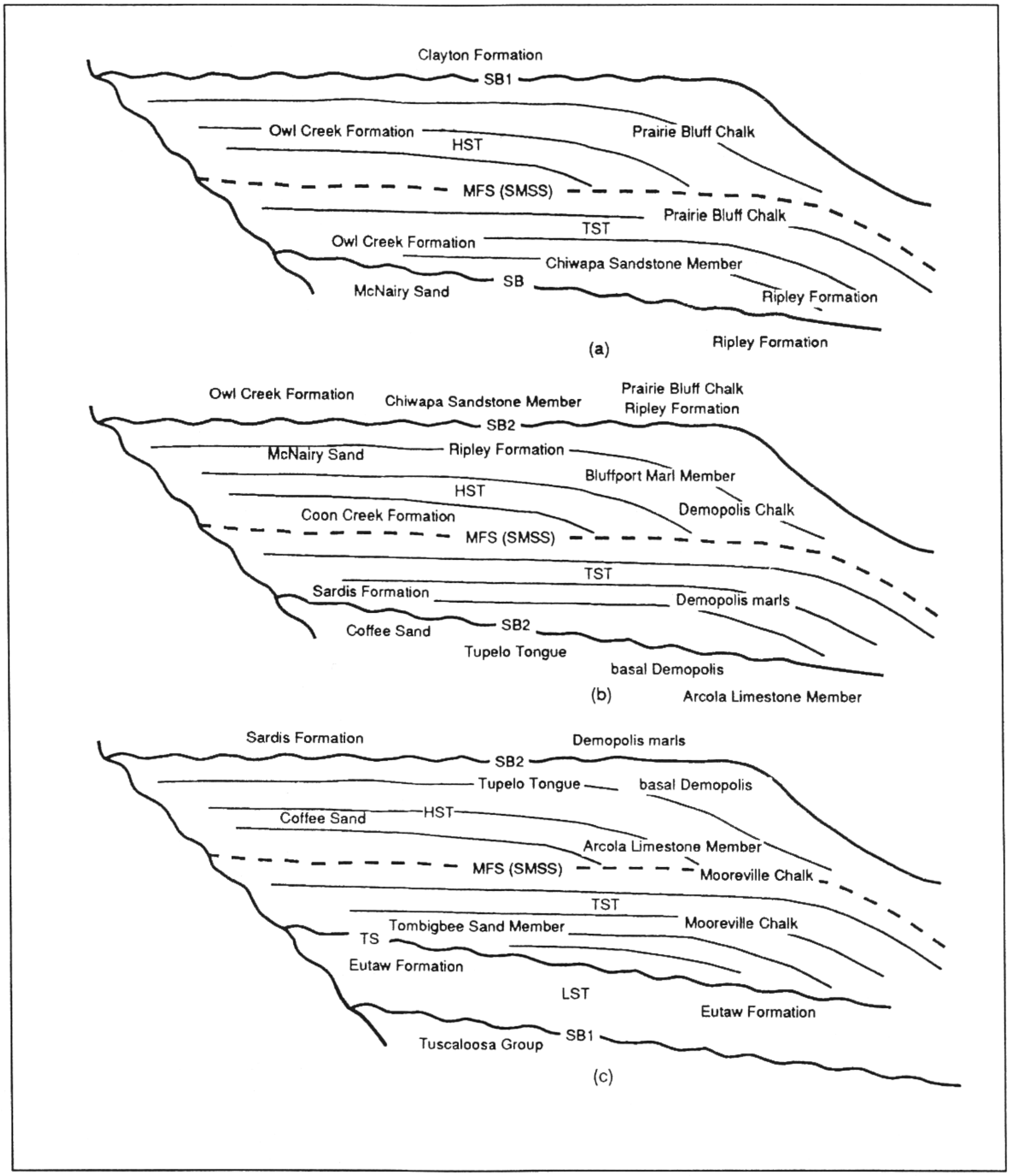

Figure 4. Upper Cretaceous depositional sequences: (a) Ripley-Prairie Bluff-Owl Creek sequence, (b) Demopolis-Sardis-Ripley-Coon Creek-McNairy type 2 sequence, and (c) Eutaw-Tombigbee-Mooreville-Coffee type 1 sequence. SB1=type 1 sequence boundary, SB2=type 2 sequence boundary, TS=transgressive surface, MFS(SMSS)=maximum flooding surface (surface of maximum sediment starvation), LST=lowstand systems tract, HST=highstand systems tract.

driving the development of parasequences appears to be the episodic introduction of siliciclastic sediment into the embayment area.

Discussion

Clearly, genetically related, unconformity-bounded, depositional sequences of 2 to 11 million years' duration, their component systems tracts and their defining physical surfaces, such as type 1 and type 2 unconformities, first transgressive surfaces and surfaces of maximum transgression, can be recognized and mapped in Upper Cretaceous (Santonian to Maastrichtian) strata of the eastern Mississippi Embayment area. In addition, these depositional sequences, when integrated with biostratigraphy, are useful for regional correlation and provide a chronostratigraphic framework for deciphering the depositional history and paleogeography of the area during the Late Cretaceous. This section represents a near continuous record of late Cretaceous events and, therefore, has the potential to be a standard for Santonian through Maastrichtian sequence stratigraphy.

The lateral lithofacies changes in the Upper Cretaceous strata from Selmer (Tennessee) to Selma (Alabama) reflect the variable depositional conditions of the eastern Mississippi Embayment area. That is, siliciclastic sediment accumulation dominated south-central Tennessee and northeastern Mississippi, whereas mixed carbonate and siliciclastic deposition characterized east-central Mississippi and west-central Alabama. Further, sedimentation in the area of east-central Mississippi and west-central Alabama was influenced by a differentially subsiding basin. Subsidence rates in the stable shelf platform areas located in south-central Tennessee and southeast Alabama are estimated to have been half as much as the subsidence rates in the basin proper. The fact that depositional sequences and their component systems tracts can be recognized and traced across a distance of about 420 km, considering significant differences in sedimentation and subsidence rates and overall similarity in climate, indicates that some factor other than climate, subsidence rates, or sediment supply controls the cyclicity in these sequences of 2 to 11 million years' durations. Eustasy is a strong candidate as that controlling factor. The mechanism driving eustatic sea level fluctuations during deposition of these Upper Cretaceous strata has not been discerned from this study.

Although the sequence boundaries for the UZAGC-3.0, UZAGC-4.0, and UZAGC-5.0 cycles (Tuscaloosa-Eutaw, Demopolis/Coffee/Tupelo Tongue-Demopolis/Sardis, Ripley/McNairy-Ripley/Prairie Bluff/Owl Creek disconformable contacts) are diachronous along their traces (Fig. 5), these physical correlation surfaces are event markers and separate older rocks below from younger rocks above, as indicated for sequence boundaries in general by Van Wagoner et al. (1988). These disconformities typically are marked by sediment clasts, quartz pebbles, phosphate grains, steinkerns, fossilized wood, shark teeth, and other vertebrate fossils (Mancini and Tew, 1993).

Mapping of the initial or first transgressive surface for the UZAGC-3.0 cycle, in conjunction with the biostratigraphy of the strata across this surface, reveals a Santonian age (lower part of the *Dicarinella asymetrica* Total Range Zone with the absence of *Globotruncanita elevata*, and the *Lucianorhabdus cayeuxii* Interval Zone, CC16) for the strata above this disconformity downdip (in the basin proper) and a late Santonian age (upper part of the *Dicarinella asymetrica* Total Range Zone with the presence of *G. elevata,* and *Calculites obscurus* Interval Zone, CC17) updip (near the basin margin) (Fig. 5). In the basin proper, the strata above the first transgressive surface of the UZAGC-4.0 cycle are late early Campanian in age (*Globotruncana ventricosa* Interval Zone and *Ceratolithoides aculeus* Interval Zone, CC20), and near the basin margin these strata are late Campanian in age (*Globotruncana ventricosa* Interval Zone and *Quadrum sissinghii* Interval Zone, CC21). In the basin proper, a disconformity is not evident at the base of the UZAGC-4.0 sequence. The strata above the first transgressive surface of the UZAGC-5.0 cycle in the basin are late early Maastrichtian in age (Gansserina gansseri Interval Zone and *Reinhardtites levis* Interval Zone, CC24), and near the basin margin these strata are middle Maastrichtian in age (*Arkhangelskiella cymbiformis* Interval Zone, CC25). Ostracode biostratigraphy (Fig. 5) confirms the time transgressive, diachronous trace of the first transgressive surface of these cycles.

The synchronous nature of the maximum flooding surface is illustrated by its biostratigraphic consistency (Loutit et al, 1988). In the case of the UZAGC-3.0 cycle, this event is of early Campanian age and is near the top of the Mooreville Chalk (near the top of the *Globotruncanita elevata* Partial Range Zone and top of the *Calculites ovalis* Interval Zone, CC19) from the basin proper to near the basin margin. The maximum flooding surface of the UZAGC-4.0 cycle occurs in the middle part of the Demopolis Chalk and this surface is also synchronous, marking a late Campanian event that is located near the top of the *Globotruncana ventricosa* Interval Zone and the top of the *Quadrum sissinghii* Interval Zone, CC21, immediately below the base of the *Globotruncanita calcarata* Total Range Zone and the *Quadrum trifidum* Interval Zone, CC22. In the case of the UZAGC-5.0 cycle, the maximum flooding event is of middle Maastrichtian age and is near the middle of the *Gansserina gansseri* Interval Zone (at the base of the *Racemiguembelina fructicosa* Zonule of Smith and Pessagno, 1973) and the top of the *Arkhangelskiella cymbiformis* Interval Zone, CC25. These synchronous beds are remarkable in that they can be physically identified and mapped from a basinward position near Selma (Alabama) to near the basin margin near Selmer (Tennessee). The maximum flooding surface is marked by a distinctive mappable surface in the UZAGC-5.0 cycle (Mancini et al., 1989); however, in the UZAGC-3.0 and UZAGC-4.0 cycles, this event is recognized by a change in microfossil assemblages, principally maximum planktonic to benthic foraminiferal ratios. The trace of the surface of maximum transgression (maximum flooding surface) within a depositional sequence represents the time of greatest accommodation on the shelf, maximum landward encroachment of the shoreline, and is the turnaround point in sedimentation from retrogradation or aggradation to progradation (Posamentier et al., 1988). The maximum flooding surface is also the surface of maximum sediment starvation and often delineates a submarine hiatus that represents a period of extremely slow deposition or erosion within a condensed section; this is described as a marine disconformity or discontinuity (Loutit et al., 1988).

The utility of the point of maximum transgression in a particular cycle was noted by Israelsky (1949), who used the maximum depth in bathymetric cycles, as determined by analysis of foraminifera, for correlation. This practice is currently employed by geologists mapping subsurface strata in the Gulf of Mexico area; however, these workers refer to this datum as the maximum flooding surface (Armentrout et al., 1990; Vail and Wornhardt, 1990). Krumbein and Sloss (1963) also indicated that the point of change from transgression to regression can be used for "correlation by position in the bathymetric cycle" and that the turnaround point is regionally correlative and essentially synchronous.

As mentioned previously, the UZAGC-3.0 type 1 sequence boundary is a significant unconformity that can be recognized and mapped regionally. The tidally influenced lowstand deposits of the Eutaw are regionally extensive. The marine transgressive deposits of the Tombigbee and Mooreville are time transgressive with the glauconitic sands of the Tombigbee being best developed updip and the marls of the Mooreville being the more offshore basinal facies. Updip, the basal Mooreville beds are assigned to the *Aspidolithus parcus* Interval Zone (CC18), and the basal Mooreville beds basinward rest within the *Lucianorhabdus cayeuxii* Interval Zone (CC16). The chalk beds of the Mooreville, the Arcola, and the basal sandy Demopolis beds represent the highstand deposits of the UZAGC-3.0 sequence basinward. More extensive highstand deposits are present updip, north of Tupelo (Mississippi). This siliciclastic succession includes the Coffee Sand and Tupelo Tongue and is, in part, time equivalent to the upper Mooreville Chalk, the Arcola, and basal Demopolis beds.

The maximum flooding event of the UZAGC-3.0 sequence is marked by a change in the microfossil assemblages in the Mooreville-specifically, the highest planktonic to benthic foraminiferal ratios are present in these beds. No distinct physical surface was observed in the Mooreville delineating this event. The Arcola represents the upper portion of the condensed section (lower highstand) deposits of this depositional sequence. The geographically widespread and lithologically consistent nature of the Arcola has long been recognized. The Arcola can be physically traced from southeast of Montgomery (Alabama) to near Tupelo (Mississippi). These beds lie in the same biostratigraphic zones (*Globotruncanita elevata* Partial Range Zone, *Calculites ovalis* Interval Zone, CC19, and *Ascetoleberis plummeri* Interval Zone) throughout their extent.

There was a significant increase in water depth during deposition of the lower Demopolis marls of the UZAGC-4.0 cycle that overlie the Arcola and the basal sandy Demopolis beds, as indicated by the composition of the microfossil assemblages. Near Selma (Alabama) this disconformity above the Arcola limestone beds in the basal Demopolis is not evident, and there are four limestone beds in an expanded Arcola section rather than the usual two beds, indicating that the type 2 sequence boundary overlying the basal sandy Demopolis beds at this locality is conformable. Updip, however, a distinct unconformity defines the Coffee-Sardis/Demopolis contact north of Tupelo (Mississippi). The distinct disconformable contact of the Sardis/Demopolis with the Coffee represents the lower

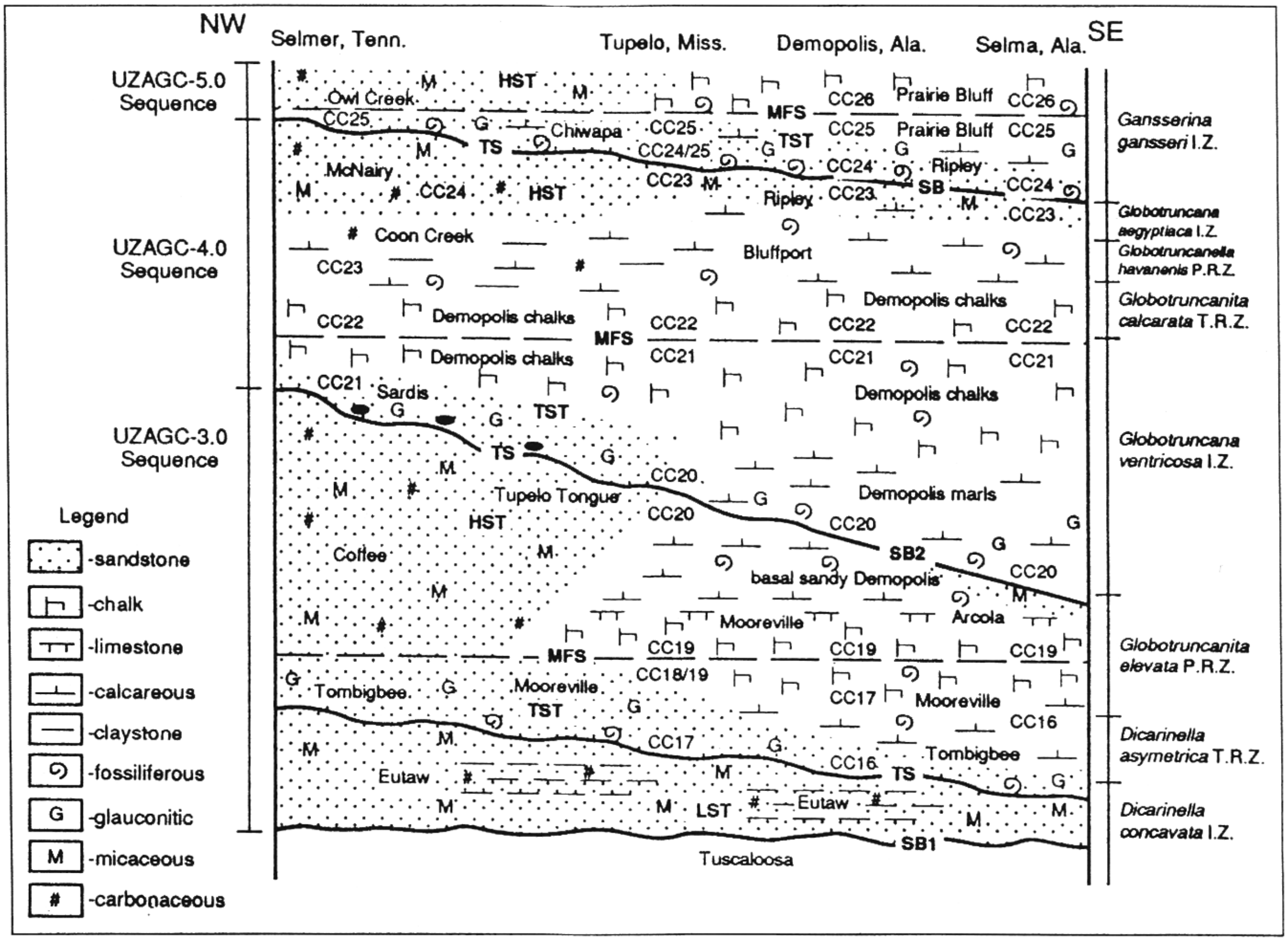

Figure 5. Schematic cross section illustrating lithofacies relationships, planktonic foraminifera and calcareous nannoplankton zones, and unconformity bounded depositional sequences. SB1=type 1 sequence boundary, SB2=type 2 sequence boundary, TS=transgressive surface, MFS=maximum flooding surface, LST=lowstand systems tract, HST=highstand systems tract, CC16=calcareous nannoplankton zone.

boundary of the UZAGC-4.0 type 2 sequence. Although diachronous, this disconformity is the same surface that can be mapped south of Tupelo. In this area, the basal sandy Demopolis beds immediately overlying the Arcola are disconformably overlain by Demopolis marls. The transgressive deposits of the UZAGC-4.0 sequence (Demopolis marls) are well developed in east-central Mississippi and west-central Alabama. These transgressive deposits thin rapidly northward towards Selmer (Tennessee), where the first transgressive surface and maximum flooding surface appear to merge. Updip, the Demopolis marls are assigned to the *Quadrum sissinghii* Interval Zone (CC21), and the Demopolis marls basinward rest within the *Ceratolithoides aculeus* Interval Zone (CC20). The maximum flooding surface for this sequence, like that of the UZAGC-3.0 sequence, is not marked by a physical surface in the Demopolis but rather is recognizable by a change in the microfossil assemblages. The pure chalk beds in the massive Demopolis Chalk represent the condensed section of the UZAGC-4.0 cycle. The consistent lithology and widespread geographic occurrence of these chalk beds have been used for surface and subsurface correlation throughout east-central Mississippi. These chalk beds can be physically traced from west-central Alabama to northeastern Mississippi. These chalks lie in the same biostratigraphic zones (*Globotruncana ventricosa* Interval Zone, *Quadrum sissinghii*, Interval Zone (CC21), and *Limburgina verricula* Interval Zone) throughout their extent. Key biostratigraphic zones occur immediately above the maximum flooding surface-the *Globotruncanita calcarata* Total Range Zone and the *Quadrum trifidum* Interval Zone, CC22. The chalk beds of the Demopolis, the Bluffport, and the lower and middle Ripley represent the highstand systems tract of this sequence in the basin proper and the Coon Creek, Ripley, and McNairy are the highstand units at the basin margin.

An increase in water depth during the deposition of the upper Ripley marls, Chiwapa sands, and lower Owl Creek beds of the UZAGC-5.0 cycle that overlie the McNairy or lower Ripley highstand deposits is indicated by the vertical lithologic changes and the composition of the microfossil assemblages. Although diachronous, this disconformity is recognized throughout the area of study. Updip, the lower Owl Creek beds are assigned to the *Arkhangelskiella cymbiformis* Interval Zone (CC25), and basinward, the upper Ripley beds overlying this surface are assigned to the *Reinhardtites levis* Interval Zone (CC24). The maximum flooding surface for this sequence is marked by a physical surface in the Prairie Bluff. The pure chalk beds of the Prairie Bluff represent the condensed section of the UZAGC-5.0 cycle. These chalks lie in the same biostratigraphic zones (near the middle of the *Gansserina gansseri* Interval Zone and the top of the *Arkhangelskiella cymbiformis* Interval Zone, CC25).

The importance of using a facies independent species for correlating Upper Cretaceous lithofacies is illustrated by the occurrence of the *Globotruncanita calcarata* Total Range Zone in the massive chalk beds of the Demopolis Chalk from west-central Alabama to south of Tupelo, in the mixed siliciclastic and carbonate beds of the Demopolis (Bluffport) north of Tupelo, and in the siliciclastic Demopolis beds near Selmer (Tennessee). Interestingly, *Exogyra cancellata* Stephenson, an oyster whose first occurrence has been considered to mark the beginning of the Maastrichtian, does not occur in the *G. calcarata* Total Range Zone south of Tupelo, but it does occur in the zone north of Tupelo. The occurrence of *E. cancellata* is restricted to the mixed siliciclastic and carbonate beds of the Demopolis (Bluffport). Clearly, the occurrence or absence of *E. cancellata* in the Demopolis is environmentally controlled and therefore should not be used as a geologic time event marker. The highest occurrence of *G. calcarata*, a planktonic foraminifera, is the preferred event to mark the top of the Campanian, as is the highest occurrence of *D. asymetrica* to delineate the top of the Santonian.

Conclusions

Three unconformity-bounded depositional sequences of 2 to 11 million years' duration can be mapped in Santonian through Maastrichtian strata of the eastern Mississippi Embayment area of the Gulf Coastal Plain along the passive southern margin of the North American continent. The component systems tracts and defining physical surfaces are recognizable and traceable from Selmer (Tennessee) to Selma (Alabama), a distance of about 420 km. Eustasy is postulated as the major controlling factor for the cyclicity recorded in these strata, but the mechanism driving the development of parasequences within particular systems tracts of the depositional sequences appears to be the episodic introduction of siliciclastics into the embayment area.

Key biostratigraphic microfossil species are present in these deposits and their continuous ranges indicate that these strata represent a near complete stratigraphic section which documents the significant sedimentologic and paleontologic events that punctuated late Cretaceous times. Therefore, this section is recommended as a standard for comparative sequence stratigraphic studies of Santonian through Maastrichtian strata. The importance of integrating high resolution biostratigraphy in sequence stratigraphic analyses in a standard stratigraphic section is illustrated by the following observations from this study.

Sequence boundaries and transgressive surfaces are diachronous along their traces. Our field work not only supports this finding but also demonstrates that the transgressive systems tract deposits for the UZAGC-3.0, UZAGC-4.0, and UZAGC-5.0 cycles become progressively younger in age from the basin proper to the basin margin. With the UZAGC-3.0 cycle, these deposits have been assigned to the nannofossil zones CC16 in south-central Alabama (Selma), CC17 in western Alabama, and CC18 in east-central Mississippi. The transgressive deposits of the UZAGC-4.0 cycle rest within nannofossil zone CC20 in the basin and CC21 at the basin margin. Interestingly, the lower boundary of this type 2 sequence is conformable near Selma and is disconformable near Selmer. In the UZAGC-5.0 cycle, the transgressive deposits have been assigned to the nannofossil zone CC24 in the basin proper and the CC25 Zone at the basin margin. In each sequence, the highstand systems tract deposits that prograde into the basin postdate the transgressive deposits.

The synchronous nature of the condensed section deposits and the maximum flooding surface is illustrated by the fact that throughout the study area the beds above the maximum flooding surface for the UZAGC-3.0, UZAGC-4.0, and UZAGC-5.0 cycles rest within the same planktonic foraminiferal and calcareous nannoplankton zones. The maximum flooding surface can be marked by a distinctive mappable surface as in the UZAGC-5.0 cycle, but often is recognized by a change in microfossil assemblages as in the UZAGC-3.0 and UZAGC-4.0 cycles. Importantly, condensed section deposits consist of characteristic lithologies that also can be mapped throughout the embayment area: nearly pure limestone beds (Mooreville and Arcola) of the UZAGC-3.0 sequence, pure chalk beds (Demopolis) of the UZAGC-4.0 sequence, and nearly pure chalk beds (Prairie Bluff) of the UZAGC-5.0 sequence. The dominance of carbonate in these beds reflects maximum accommodation and highest relative sea level with minimum siliciclastic sediment influx.

The major implications of this work are as follows: (1) only the essentially synchronous maximum flooding surface and associated condensed section strata have chronostratigraphic significance for regional and worldwide correlation; (2) sequence boundaries and transgressive surfaces are diachronous and the transgressive deposits and their associated fauna and flora are greatly impacted by local events; (3) using these diachronous surfaces for regional or global correlation will produce conflicting results, and therefore, depositional cycles should be dated by the synchronous event (maximum flooding surface or regional marine flooding event of Galloway, 1989) not by diachronous events (sequence boundary or transgressive surface); (4) three such maximum flooding events are evident in the Santonian to Maastrichtian strata of the Mississippi Embayment area, and they occur in lower Campanian, upper Campanian, and middle Maastrichtian strata; (5) the availability of high resolution biostratigraphy is vital to sequence stratigraphic analysis; and (6) the time duration of the depositional cycles does not seem important in that the component systems tracts can be recognized in all of the sequences observed in this study, regardless of duration, and the use of second and third orders should be evaluated before their use is continued for Cretaceous strata.

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