THE DEPARTMENT OF ENVIRONMENTAL QUALITY

mississippi geology

Office of Geology
P. O. Box 20307
Jackson, Mississippi 39289-1307

Volume 11, Number 4
June 1991

DETERIORATION AND RESTORATION OF THE GRANDE BATTURE ISLANDS, MISSISSIPPI

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ABSTRACT

The remnant shoals of the Grande Batture Islands comprise the seaward margins of a late Pleistocene/Holocene delta lobe of the Pascagoula-Escatawpa fluvial system. Sediment discharge into Mississippi Sound via the Bayou Cumbest distributary initiated phases of aggradation and progradation. As fluvial inputs decreased, wave action and longshore drift processes reworked the deltaic headland and produced the Grande Batture Islands. Historically, these islands sheltered the extensive nutrient-rich intertidal marshes as well as productive oyster beds in Pt. aux Chenes Bay and Grand Bay. An 1853 survey delineated about 450 acres of barrier island complex extending over 5 miles in length, yet by the 1950s it had been reduced to shoals. Shoreline erosion rates have averaged 15 ft/yr since 1853, and the remaining headland is presently retreating at even higher rates.

Proposed nourishment of the Grande Batture shoals with 6,000,000 cubic yards of dredged material would not only restore the former barrier chain, but would also slow rates of bayshore erosion and marsh deterioration. Optimal salinity regimes for oyster production might also be re-established. Preliminary indications are that the costs of island restoration and periodic renourishment would be offset by the benefits derived.

INTRODUCTION

Barrier islands and marshes have been receiving much attention in recent years, both for their value as recreational resources and also as integral components of estuarine ecosystems (Mitsch and Gosselink, 1986). Tidal marshes constitute nursery grounds for shrimp and finfish, and estuarine bays are valued for oyster production (Gosselink, 1984). Barrier island/tidal inlet complexes often shelter tidal marshes by acting as buffers against severe storms and high waves (van Beek and Meyer-Arendt, 1982). When these barriers disappear, marshes become exposed to increased marine forces (including wave erosion, enhanced tidal exchange, and saltwater intrusion), and the commercial and recreational resource base erodes away. These trends most likely will accelerate in the future if predictions of increasing sea level

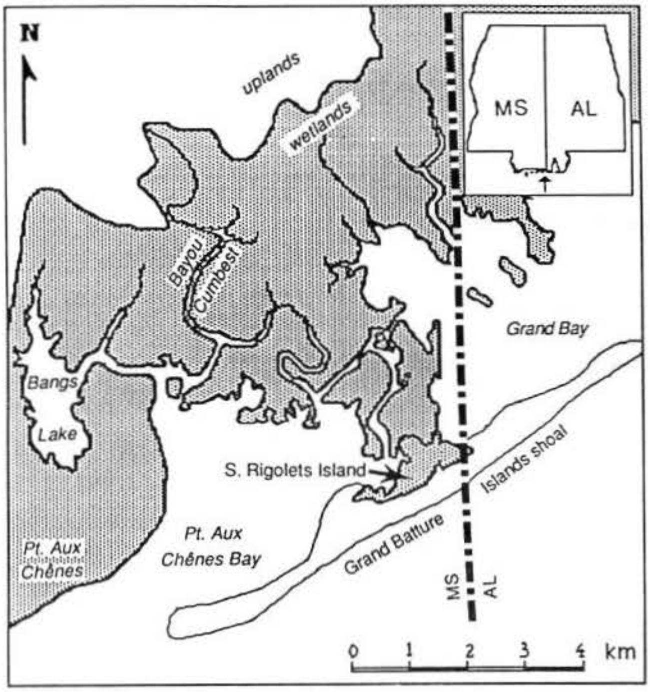

Figure 1. Grande Batture headland and vicinity, Mississippi/ Alabama.

rise rates become realized (National Research Council, 1987; Titus, 1988). In view of present trends and future scenarios, a dilemma arises: should a natural course of environmental degradation continue, or should humans intervene in natural processes to preserve a sustainable resource base? If preservation of habitat is the goal, then perhaps the latter is the optimal course to pursue if it can be done economically. One means by which environmental enhancement in one area can be relatively easily attained is by offsetting (i.e., mitigating) human-induced negative environmental impacts in another area (Kusler et al., 1988). These are the kinds of questions currently being raised in Jackson County, Mississippi, where: a) 4000 acres of the historically deteriorating Bayou Cumbest deltaic headland (also known as the Grande Batture headland) have been acquired under the Coastal Mississippi Wetlands Initiative and are slated to be incorporated into the 12,000 acre Grand Bay National Wildlife Refuge, and b) enlargement of the Pascagoula River ship channel and the Bayou Casotte Industrial Harbor will require the dredging and disposal of six million cubic yards of sediment. It is the purpose of this paper to: a) document the geologic evolution and environmental deterioration of the Grande Batture headland, and b) to evaluate the mechanics as well as the costs and benefits of island restoration via creative disposal of dredge spoil.

GEOLOGIC HISTORY

The remnant shoals of the Grande Batture Islands (Figure 1) and the retreating wetlands of the Grande Batture headland comprise the remaining seaward margins of a late Pleistocene/Holocene delta, which has been linked to the Pascagoula River by Gazzier (1977) and to the Escatawpa River by Otvos (1985). Sediment discharge of the Pascagoula/ Escatawpa fluvial system into Mississippi Sound via the Bayou Cumbest distributary initiated phases of aggradation and progradation (Kramer, 1990). A reduction in fluvial sedimentation coupled with an enhancement of coastal processes led to a sequence of geomorphic events similar to those seen in abandoned Mississippi River delta lobes in southeastern Louisiana. These events are described in a 3-stage model proposed by Penland and Boyd (1981), which may be applied to the Grande Batture area as follows:

1. As fluvial inputs diminished, shoreface processes transformed the delta into an erosional headland, and delta-front sands were reworked and redistributed by shore-parallel transport in the form of flanking barrier spits (Figure 2). This is seen on 1853 coastal survey charts which show the Grande Batture Islands as a continuous sand body attached to an erosional headland (USCGS, 1853).

2. The flanking barrier spits were fragmented into islands during storm events as seen on the 1920 coastal survey charts and 1940 aerial photographs (USCGS, 1933; Tobin Research Inc., 1940). Local transgression attributed to a combination of subsidence, sea level rise, storms, and lack of sediment influx caused the continued disintegration of the headland and the islands.

3. The final stage of the model is seen on modern 1985 color infrared aerial photographs in which the Grande Batture Islands have completely disappeared (USDA-ASCS, 1985). Bathymetric surveys revealed that the islands have been reduced to shoals (Kramer, 1990). The historic role of these islands in sheltering the extensive nutrient-rich deltaic marshes and productive oyster beds of Pt. aux Chenes Bay and Grand Bay has now also disappeared.

RECENT ACCELERATION OF EROSION RATES

The earliest accurate maps -- the 1853 United States Coast and Geodetic Survey maps -- delineated about 450 acres of the Grande Batture barrier island complex extending over 5 miles in length. By 1940, the area had been reduced to 120 acres, and by the 1950s the flanking islands had turned to shoals. From 1853 to 1988, the Grande Batture headland (a.k.a. South Rigolets Island) has witnessed shore retreat of over 2000 ft, or an average of 15 ft/yr. Comparison of 1988 aerial photos with 1977 imagery revealed retreat rates averaging 18 ft/yr, and exceeding 34 ft/yr in some reaches (Meyer-Arendt and Kramer, 1990).

Shoreline retreat appears to have been more severe in the 1977-1988 period than in the 1940-1977 period. Erosion rates along the western shore of Pt. aux Chenes Bay increased from 4-5 ft/yr to 7-8 ft/yr, and similar increases were observed along the northern shore of the bay. Even the Pt. aux Chenes headland, immediately to the east of the area known as the Tenneco marshes, saw retreat rates increase from under 10 ft/yr to over 13 ft/yr from the 1940-1977 to the 1977-1988 period (Meyer-Arendt and Gazzier, 1990).

The entire area is presently not only losing at least 7 acres of marsh annually, but Pt. aux Chenes Bay has witnessed such changes in tidal and salinity regimes that oyster production is no longer possible (USFWS, 1989). Further resource loss is anticipated as present trends continue.

DREDGED MATERIAL AS A NATURAL RESOURCE

In conjunction with expansion of the Ingalls shipyard, establishment of the Navy homeport in Pascagoula, and general port improvements, plans call for widening and deepening the Pascagoula River ship channel (which includes the Bayou Casotte industrial channel). The ship channel is to be deepened from 38 to 42 ft and widened from 225 to 300 ft. As mitigation for the various construction and industrial expansion projects which will negatively impact wetlands, archeological sites, and bay bottoms, it has been proposed by the U. S. Army Corps of Engineers to utilize dredged material for environmental enhancement. Instead of disposing of dredged spoil in deep water south of Mississippi Sound (as has historically been done), the Corps has proposed considering several alternatives for wetlands restoration and wetlands creation. These include: 1) several options for on-land disposal in the Tenneco marshes, 2) renourishment of Round Island, which is in danger of succumbing to shoreline erosion, and 3) reconstruction of the Grande Batture Islands (USFWS, 1989).

The idea of utilizing dredged material for natural resource creation has been around for decades. In 1973, the Dredged Material Research Program (DMRP) was initiated for exactly such purposes at the U.S. Army Engineer Waterways Experiment Station in Vicksburg (Walsh, 1977). Although direct barrier island beach nourishment has not been a specific focus of DMRP studies, considerable work has been done in evaluating the feasibility of spoil island creation and the enhancement of spoil habitats in marsh environments (Walsh, 1977; Saucier et al., 1978). Numerous DMRP publications outline the detailed steps in such procedures.

Although barrier island nourishment with dredged material was conducted on Mississippi's Ship Island in 1975 to keep Fort Massachusetts from crumbling into the sea, perhaps a better prototype for the Grande Batture area is Eastern Isle Derniere in Terrebonne Parish, Louisiana. The Isles Dernieres island chain is a typical deltaic headland barrier arc which has undergone considerable deterioration as a result of being in advanced stages of the Penland/Boyd model (Meyer-Arendt and Templet, 1983). Terrebonne Parish, recognizing the severity of the problem after several years of studies (Templet and Meyer-Arendt, 1982), embarked upon nourishing a critical section of Eastern Isle Derniere in 1984 (Jones and Edmonson, 1987). The $1 million project was quite successful, and the island suffered minimal erosion during the severe hurricane season of 1985 (Penland et al., 1986). Similar nourishment/breach closure projects have been proposed for other critically eroding segments of the Louisiana coast.

COSTS AND BENEFITS OF ISLAND RESTORATION

It has been proposed that to mitigate wetland losses associated with channel dredging (and perhaps with on-land

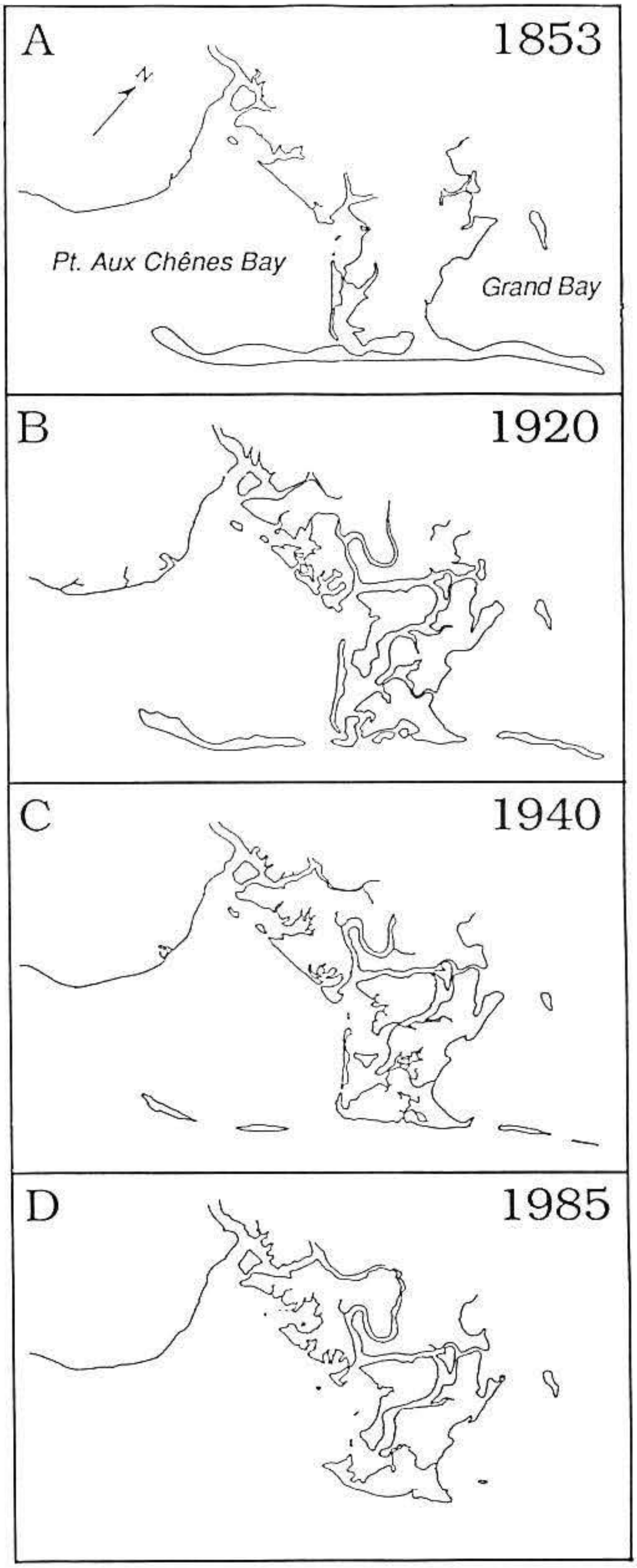

Figure 2. Deterioration of the Grande Batture headland, 1853-1985 (maps compiled from USCGS, 1853; USCGS, 1933; Tobin Research Inc., 1940; and USDA-ASCS, 1985).

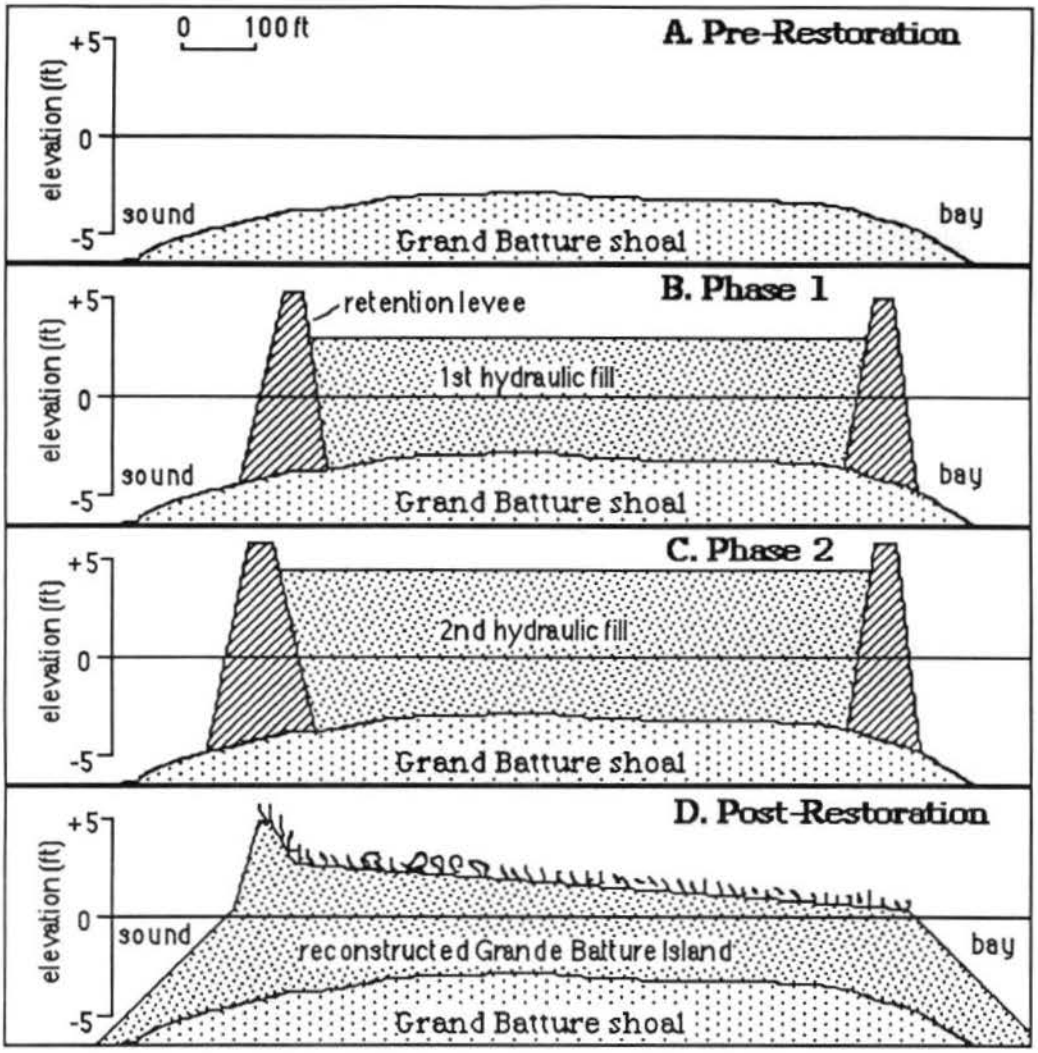

Figure 3. Schematic of Grande Batture Islands restoration process (scale approximate).

disposal of the spoil) the Grande Batture shoals be nourished with 6,000,000 cubic yards of dredged material. This would not only restore the former barrier chain, but would also slow rates of bayshore erosion and marsh deterioration because of decreased wave and tidal action. Although valuable waterbottoms will be lost in the island restoration process, resource gains will more than offset resource losses. The U. S. Fish and Wildlife Service, which endorses this proposal as the No. 1 mitigation option, estimates that land loss will be reduced by 5 acres per year. In terms of resource and recreation value, the Fish and Wildlife Service estimates an annual net benefit of $30,000 per acre, or $150,000 total. Perhaps even more importantly, preliminary studies show that optimal salinity regimes for oyster production would be re-established in Pt. aux Chenes Bay. Even if production in the bay only reaches 75% of that in nearby Bangs Lake, a resultant harvest of 375 sacks/acre at $25/sack over 4200 acres of bay yields $39 million/year (USFWS, 1989).

The pumping of the dredge spoil and technology of proper restoration will not come cheaply. The slurrying of spoil via pipeline over a distance of 5 to 8 miles will require barge-mounted or land-based booster stations spaced about every mile. Problems with bad weather and mechanical breakdown make realistic transport costs exceed $4/cubic yard. Once pumped into place, retention levees will need to be built for controlled dewatering of the slurried sediment. The use of hay bales for retention on the sound side, originally proposed by the Corps of Engineers, may not be sufficiently sturdy (USFWS, 1989). However, the construction of more solid retention walls will minimize turbidity and sediment infilling of the bay.

For a similar situation along Shell Island in Louisiana's Plaquemines Parish, where an 8000-ft long breach had developed, a restoration project called for construction of a 600-ft wide, 12,000-ft long sand barrier requiring about 1.3 million cubic yards of sediment fill. Because tidal exchange processes had become well established following the breaching of the island, potential problems with hydraulic forces were anticipated during the reconstruction effort and it was proposed that retention wall construction be conducted on a phased-in basis. (Due to various delays, the Shell Island project was never tested, however.)

The Grande Batture project, consisting of about 3 miles within Mississippi alone, may also require phased-in retention pond construction. Because of fewer anticipated problems with tidal hydraulics at the Grande Batture site, however, the number of segments could probably be lowered. The retention ponds would subsequently be filled in a two-step process, to allow sufficient settling and compaction (Figure 3). The second step of the fill process would leave plenty of subaerial sediment for subsequent sculpting into the proper barrier profile. The backbarrier zone should be planed off to barely above sea level (after compaction rates are calculated) to allow appropriate wetland species to take root. After completion of this initial phase of island restoration, a second phase -- in which additional beach nourishment is provided and vegetation planted in the dune and marsh environment -- is highly recommended to insure the stability of the project. Again, the various experiments conducted under the DMRP program of the U.S. Army Corps of Engineers will aid in the final design plan for island restoration.

Even at presently estimated total costs of perhaps $25 million, the expenses of restoration and periodic renourishment of the Grande Batture Islands would be more than offset by the direct and indirect resource benefits derived. Less expensive spoil disposal costs, such as dumping the spoil seaward of the barrier islands, will be much less beneficial -- in both the short-run and especially the long run -- to Mississippi's valuable coastal environment.

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CYPRAEACITES BLOWI N. SP.; FIRST OCCURRENCE OF THE GENUS IN THE NEW WORLD

STUDIES ON PALEOGENE CYPRAEOIDEA (MOLLUSCA: GASTROPODA) FROM THE GULF COAST BASIN - II

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Saint-Denis, France

INTRODUCTION

This is the second of a series of papers on Paleogene Cypraeoidea of the Gulf Coast. The first was by Dolin and Dolin (1981) entitled "*Sphaerocypraea jacksonensis* (Johnson) from the Moodys Branch Formation (Eocene), Mississippi." This series is undertaken with the ultimate goal of reviewing all published and unpublished Paleogene Cypraeoidea Rafinesque, 1815 (Mollusca: Gastropoda) of the North American Gulf Coast region.

The single specimen of *Cypraeacites blowi* n. sp. described here was noted by the author in the collection of the National Museum of Natural History, Smithsonian Institution.

ACKNOWLEDGMENTS

I wish to thank particularly Warren Blow and the staff of the U.S. National Museum who gave me the opportunity to study this material. My warmest gratitude goes also to Mary and David Dockery for their support in July of 1989. My thanks are extended to the Director and other members of the Mississippi Office of Geology for their help; it is hoped that this work will be a modest reward for their efforts. I wish to thank Lindsey Groves (Natural History Museum, Los Angeles) for his helpful comments and for reading the manuscript.

SYSTEMATICS

Family CYPRAEIDAE Gray, 1824
Subfamily EROSARIINAE Schilder, 1924
Genus *Cypraeacites* Schlotheim, 1820

Cypraeacites Schlotheim, 1820, Petrefactenkunde, v. 1, p. 117. - Bottger, 1883, Ber. Offenb. Ver., v. 22/23, p. 222 (as *Cypraeites*).

Type-species: *Cypraeacites inflatus* Schlotheim (= *meyeri* Bottger) by original designation.

Cypraea subgenus *Conocypraea* Oppenheim, 1901, Paleontologica, v. 47, p. 235.

Type-species: *Conocypraea persona* Oppenheim (? = *anhaltina* Giebel) by original designation.

Schilder and Schilder (1971, p. 58) listed under the name *Proadusta* Sacco, 1894, the Eocene species complex of "*Proadusta*" *subrostrata* (Gray, 1824) and Oligocene species complex of "*P.*" *meyeri* (Bottger, 1883). *Proadusta splendens* (Grateloup, 1827), the type-species, and allied species of the West European Oligocene were added to New World *Cypraeorbis* (Schilder and Schilder, 1971, p. 28-29). Real *Proadusta* have no relationship with *Cypraeacites* or *Cypraeorbis* Conrad, 1865. That is why I prefer use here of the name *Cypraeacites* as Schilder used himself (1931a, p. 17; 1931b, p. 86) for the group.

Cypraeacites blowi n. sp.
Figures 1a-c

Holotype: USNM 112072; height 24.5 mm, maximum diameter 16.8 mm, dorsoventral diameter 12.9 mm, 16 columellar teeth, 20 labral teeth. L. C. Johnston collector.

Type locality: U.S. Geological Survey locality 2003; Creole Bluff, Grant Parish, Louisiana.

Stratigraphic distribution: Moodys Branch Formation, basal unit of the Jackson Group (Upper Eocene), at Montgomery Landing (= Creole Bluff) on the Red River at Montgomery, Louisiana. Uppermost Middle/earliest Late Eocene (R. Squires, personal communication).

Description: Shell medium sized, almond shaped, heavy, with slightly flattened ventral area, developed margins and acuminate extremities. Multiwhorl spire protruding but embedded in the anal channel callus; spire and callus together form an apical pseudo-umbilicus. The aperture is narrow, straight along the first two thirds, adaxially curved in the last adapical third. The ventral side of the inner and outer lips is flattened. Lateral margins calloused, expanded and bent up. The inner lip terminates in a smooth, triangular, adapical ridge that projects from the deep anal channel; there are 16 major columellar teeth, which are short and regularly placed; the angulation is pronounced but obtuse. There are 20 short labral teeth - the posterior-most five terminate abruptly at the ventral area, but the others are prolonged on the ventral area of the outer lip by tooth-like ribs; adaxial labral peristome parasigmoidal; the first adapical third of the outer lip is elevated relative to the ventral area and is more

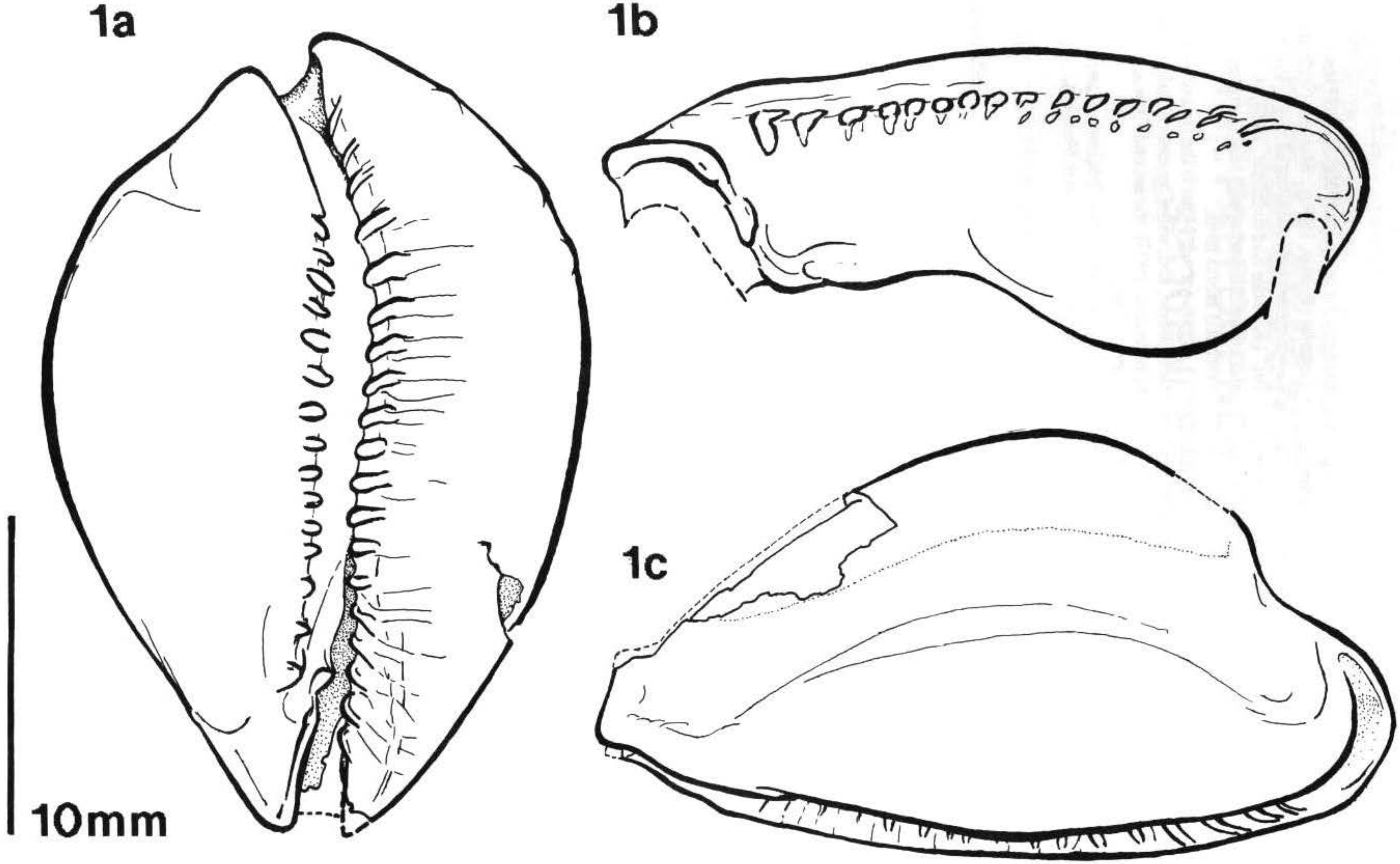

Figure 1. *Cypraeacites blowi* n. sp. Height 24.5 mm, maximum diameter 16.8 mm, dorsoventral diameter 12.9 mm, 16 columellar teeth, 20 labral teeth; Moodys Branch Formation, Creole Bluff, Montgomery, Louisiana. Holotype USNM 112072, L. C. Johnston collector.

constricted than declivous in front. The anal channel is tubular, adaxially curved, deep and open, and dorsally turned up. The siphonal canal area of the type is broken and a little piece is missing; this area seems to be perfectly delineated and forms a bridge-like neck that is separated from and elevated in relation to the ventral area. The terminal ridge is thin, horizontal, adaxially transverse and slightly curvilinear; it is truncated by a short, denticuliform, vertical, inner edge. The fossula is shallow, particularly flat, and has a light calloused border along its inner margin; it is poorly separated from the columellar area, globular, and constricts the aperture.

The color pattern is not visible, but the excellently preserved type may reveal a pattern under ultraviolet light. The mat-textured brown varnish of the dorsal surface contrasts strongly with the shiny white varnish of the ventral and marginal surfaces.

Discussion: *Cypraeacites blowi* is easily distinguished from Eocene and Oligocene species of *Cypraeorbis*. They both have the same elevation of the siphonal canal in relation to the ventral area and they have the same short denticulation of the inner lip, which is limited to the first mm of the columellar area by the slightly obtuse angulation with the ventral surface. However, *Cypraeacites blowi* differs radically from *Cypraeorbis* by its general outline (close to that of the Erosariinae/Erroneinae, but not of the *Cypraeorbis* and allied genera), by its terminal ridge, which does follow the shell axis, its fossula, and by the first third of its outer lip, which is "constricted" and not "declivous" (Schilder and Schilder, 1938, p. 125).

Cypraeacites blowi resembles the European Cenozoic group of "*Proadusta*" sensu Schilder and Schilder (1971, p. 58) in its general flattened *Erosaria* (Troschel, 1863)-like shape, its terminal ridge and inner edge, its shallow, marginated fossula, and in the adapical extension of its inner and outer lip, which forms a narrow anal channel that skirts around the apex. *Cypraeacites blowi* differs from the Eocene *C. subrostrata* (Gray, 1824) species complex by the triangular (and not plate) shape of its adapical ridge. It is not so marginated as either the Eocene species figured as *Proadusta moloni* (Bayan, 1870) and *Proadusta subrostrata* (= *C. subrostrata*) (Gray, 1824) in Dolin et Dolin (1983, fig. 10, and fig. 11-12, respectively), or the Oligocene *Cypraeacites meyeri* species complex. In the last two aspects, *Cypraeacites blowi* appears similar to the living Indo-Pacific species *Cribrarula esontropia* (Duclos, 1833) and *Cribrarula gaskoini gaskoini* (Reeve, 1846). Modern *Cribrarula* Strand (1929) have a more evolved terminal ridge "bordering the outlet and slit" (Schilder and Schilder, 1938, p. 125), a ribbed fossula and columellar area, and less numerous, stronger and more extended labral teeth.

Cypraeacites blowi is the first report of this genus in the New World, and, with *Cypraeorbis alabamensis ventripotens* (Cossmann, 1903), the second Cypraeidae from the Moodys Branch Formation.

Etymology: This species is named in honor of Warren Blow of the U.S. National Museum.

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THE TUSCAHOMA-BASHI SECTION AT MERIDIAN, MISSISSIPPI: FIRST NOTICE OF LOWSTAND DEPOSITS ABOVE THE PALEOCENE-EOCENE TP2/TE1 SEQUENCE BOUNDARY

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INTRODUCTION

The fossiliferous outcrops behind the Red Hot Truck Stop at Meridian, Mississippi, have been long known by area fossil collectors as a site for collecting shark teeth. The Red Hot Truck Stop locality, Mississippi Geological Survey (MGS) locality 19, is just off Interstate 20 on the south frontage road, between the exits at highways 19 and 45, in NW corner, NW 1/4, NE 1/4, Section 20, T6N, R16E, Lauderdale County, Mississippi (Figure 1). The Tuscahoma, Bashi, and Hatchetigbee formations are exposed here along the ditch and slope in the wooded area behind the restaurant. However, just the lower part of the Hatchetigbee Formation is present due to local surface erosion, and only the upper beds of the Tuscahoma are visible in the ditch wall. The Bashi Formation crops out along the slope above the ditch wall and consists of a transgressive marine unit and the first recognized surface exposure of Baum and Vail's (1988) "missing" TE1.1 lowstand deposits. This discovery expands the Bashi at this locality so that all components of a Type 1 sequence are present in the exposure. The Paleocene-Eocene boundary has been defined based on pollen and dinocyst data (Frederiksen and Edwards, personal communication) at the Red Hot Truck Stop locality and separates the Eocene TE1.1 deposits of the Hatchetigbee-Bashi interval from the Paleocene TP2.3 Tuscahoma unit below.

Several significant paleontologic findings have been made at this locality. From both the Tuscahoma and Bashi formations, eleven species of bony fish and 22 species of shark, skate, ray, and sawfish have been recognized (Case, 1986). Four species of estuarine snakes have been collected, one from the Bashi and three from the Tuscahoma (Holman et al., 1991). An omomyid primate tooth and jaw fragment was recovered from the Bashi Formation (Beard and Tabrum, 1991), and the teeth of at least 13 different land mammal species have been identified from an estuarine channel sand (designated the T4 channel sand) in the Tuscahoma Formation (Beard and Tabrum, personal communication).

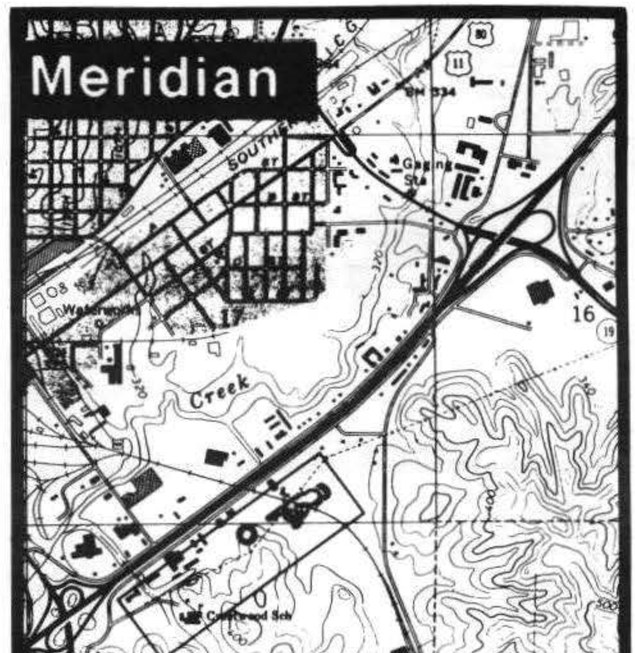

Figure 1. MGS Locality 19; portion of Meridian South 7.5 Minute Quadrangle.

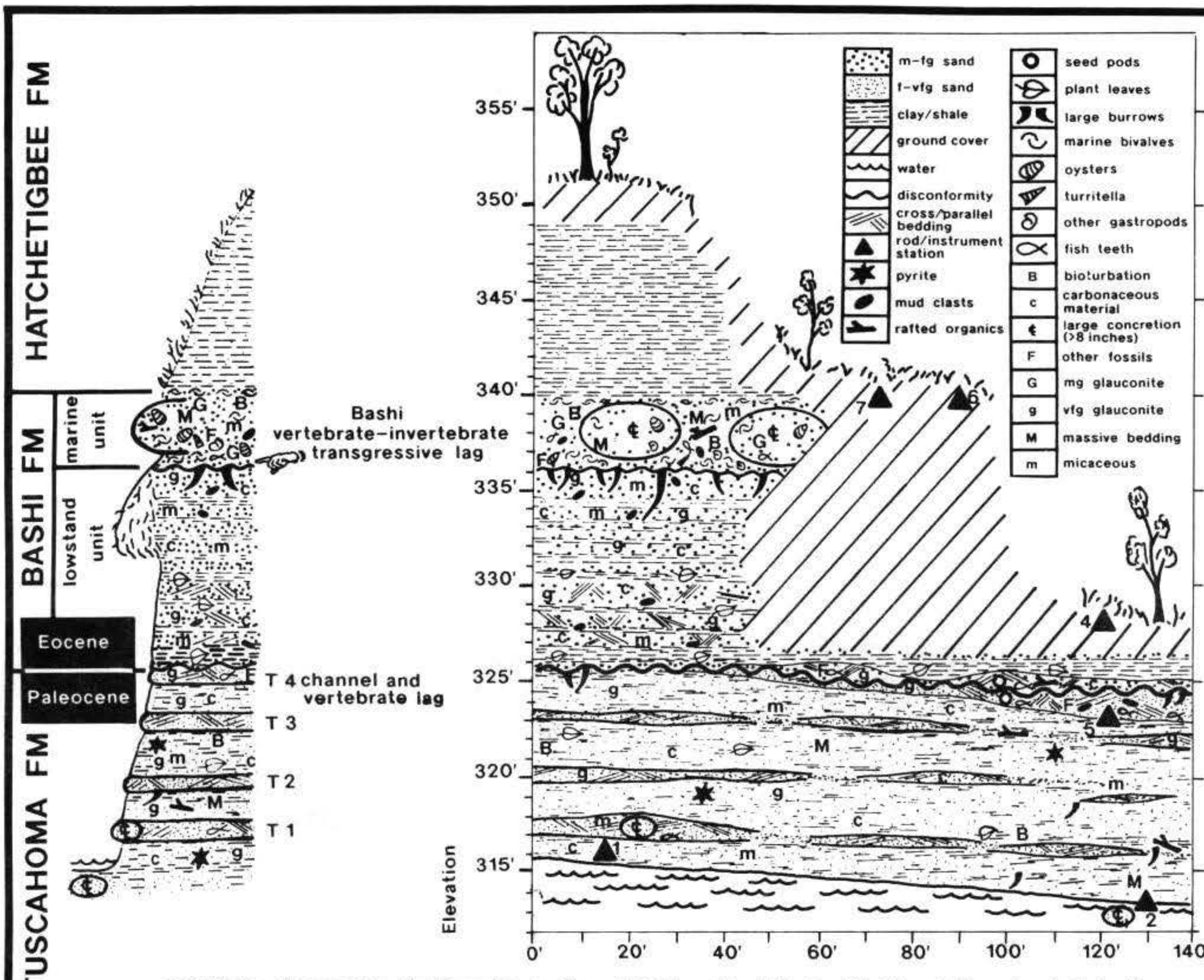

FIGURE 2. Composite stratigraphic section: MGS Locality #19, Red Hot Truck Stop (scale in feet).

STRATIGRAPHY

Tuscahoma Formation

Only the upper ten feet of the Tuscahoma Formation are exposed at the Red Hot Truck Stop site. The sediments are green to gray, glauconitic, micaceous, fine- to very fine-grained quartz sands, silts, and clays. Sand and silt lenses are laminar to cross-bedded, varying from 0.1 foot to 1.5 feet in thickness. Fossiliferous lag deposits occur at or near the base of the larger sand lenses, but this appears to be the exception and not the rule. In places these lenses are disrupted by bioturbation resulting in intercalation of sands, silts, and clays. Callianassid burrow casts and other trace fossils are found randomly throughout. Masticated plant fragments are present in the sediments and are usually carbonized or pyritized; however, well preserved fragments can be recovered for analysis. Other rafted organics include woody parts and seed pods. The glauconite is fine-grained, peloidal, and strikingly similar to the reworked pellets present in the overlying Bashi lowstand unit. There are a few small, 1- to 2-foot thick concretions present. Two examined at this section were restricted to those portions of the sand lenses that had not been disturbed by bioturbation.

Four glauconitic sand lenses in the Tuscahoma Formation are over eight inches thick and are laterally continuous. These sand units are here designated in ascending order as T1-T4 (Figure 2). The sands are composed of fine- to very fine-grained quartz, abundant fine-grained glauconite, and are micaceous and carbonaceous. The sand lenses are cross-bedded and graded. Rafted materials are found at or near the bases of some sand lenses and consist of leaf fragments of

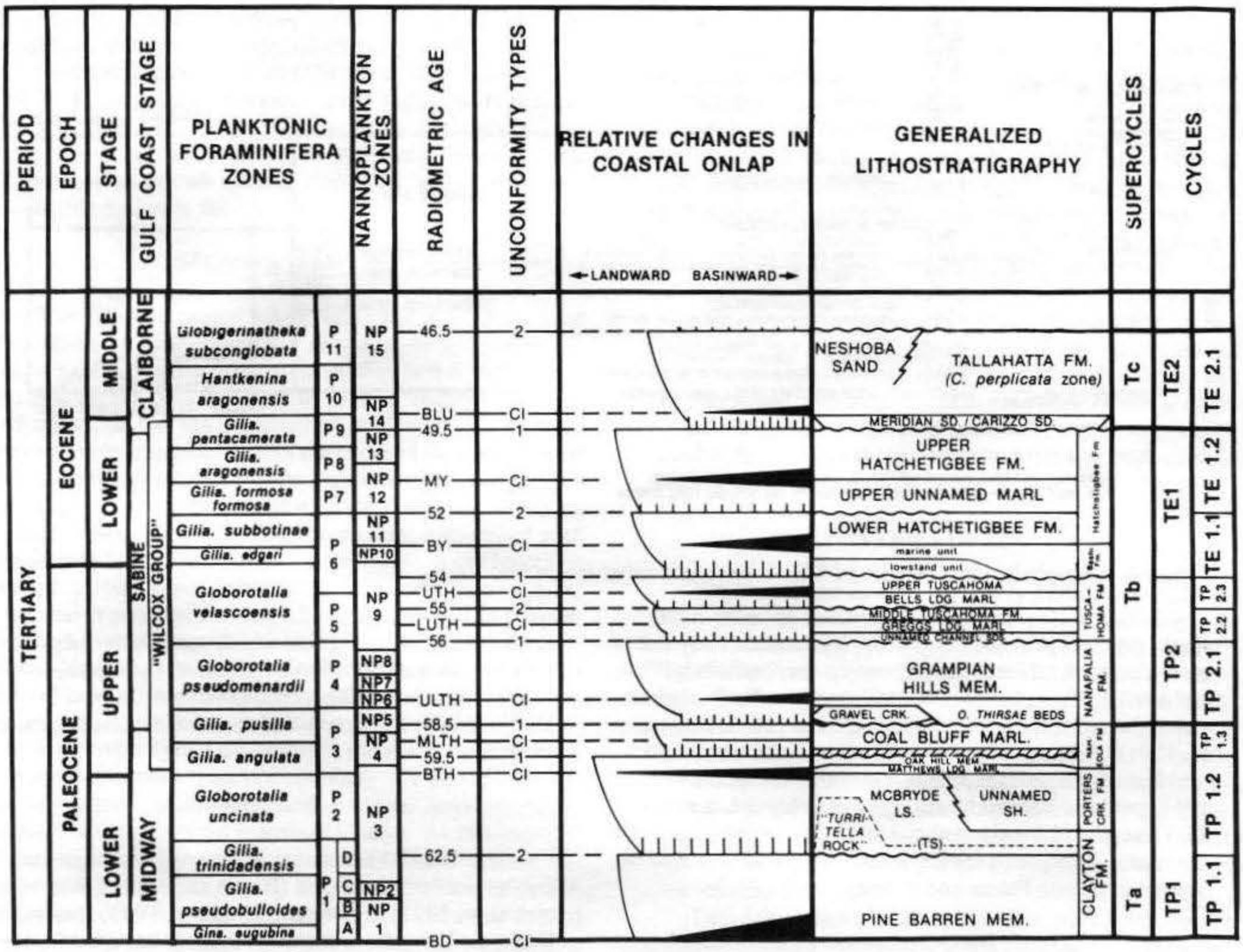

Figure 3. Coastal-onlap chart (from Baum and Vail, 1988; modified by Ingram).

masticated marsh grasses, terrestrial plant stems, limbs, and fruit pods. Other lag materials include bone fragments, teeth of marine-estuarine sharks and fish, and rarely the teeth of land mammals. The above sedimentary characteristics imply two things. One, the grain size, grading, cross-bedding, and rafted materials show an environment with a moderately high energy flow regime; and two, the glauconite and mica indicate periods of low energy and sediment transport from marine environments. Therefore, these sands were probably deposited as estuarine tidal channels associated with a bay or lagoon near a delta.

The T4 Channel Sand

The T4 channel sand occurs just below the Tuscahoma-Bashi, Paleocene-Eocene boundary. This sand body has been the primary focus of ongoing excavations by Chris Beard and Alan Tabrum of the Carnegie Museum of Natural History, funded in part by the National Geographic Society. It is jade-green and composed of fine- to very fine-grained quartz sand, fine-grained glauconite, and mica. It is cross-bedded with multiple, cross-cutting scours evidencing the cut-and-fill depositional characteristics associated with estuarine channel facies. These sands are unconsolidated and friable. At the base of the T4 channel sand is a lag deposit composed of vertebrate teeth and other fossil fragments. To date, it has exhibited the richest vertebrate fauna of the stratigraphic section at MGS locality 19. Beard and Tabrum have identified mammals of nine different orders, ten families, and thirteen species from this bed with some of the fossil remains possibly depicting new species (Beard and Tabrum, 1991, personal communication). Other faunal elements include

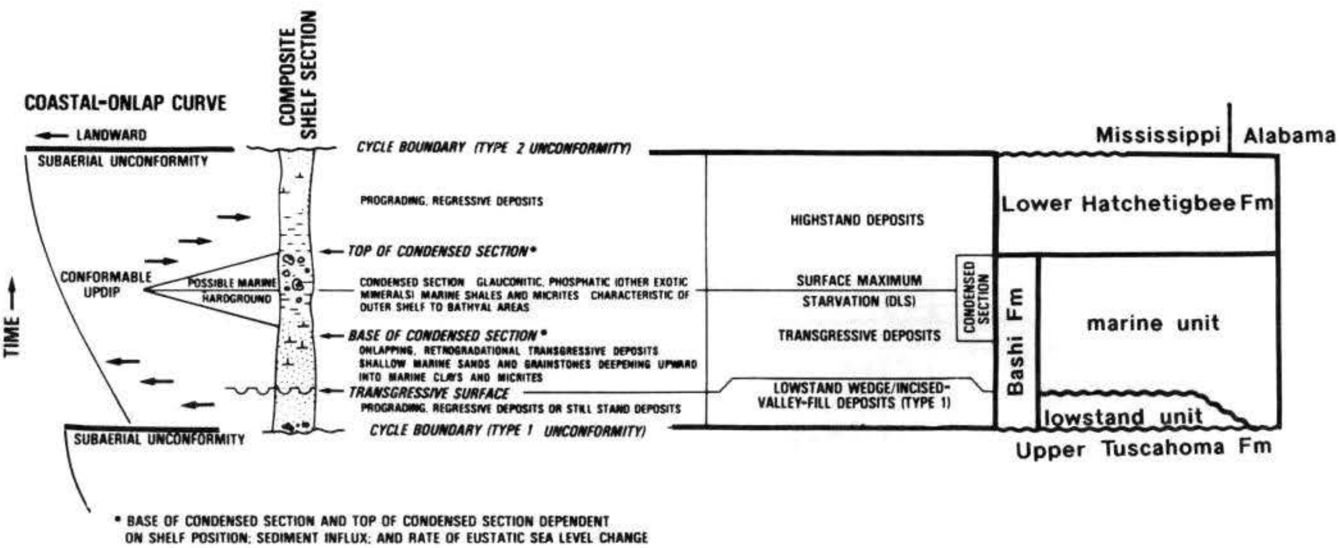

Figure 4. Composite shelf section of TE1.1 Sequence (after Baum and Vail, 1988).

shark, ray, and skate (Case, 1986). Numerous bony fishes have also been collected representing gar, catfish, billfish, and sawfish (Case, 1986). Crocodile teeth, turtle shell plates, and snake vertebrae have been found (Case, 1986; Holman et al., 1991). Additionally, several fruit pods have been recovered from this basal lag. Frederiksen and Edwards (1990 and 1991, personal communication) have analyzed samples of the T4 sand and the clays above and below it for pollen and dinocysts. Their analyses show the T4 channel sand and lag deposit to be late Paleocene in age.

Bashi Formation

Lowstand unit

The Bashi Formation at the Red Hot Truck Stop locality is here expanded to include a ten-foot basal section, which corresponds to the "missing" TE1.1 lowstand deposits of Baum and Vail's (1988) coastal onlap cycle (Figures 2-4). Previously, these beds had been placed in the Tuscahoma Formation (Dockery et al., 1991; Ingram and Dockery, 1991). However, re-evaluation of the lithostratigraphy and micropaleontology indicates that the sand and shale beds immediately below the Bashi marine unit are genetically related to the Bashi rather than the Tuscahoma Formation. This Bashi lowstand unit is comprised of interbedded sand and shale. The shales vary in color from gray to brown and the lowermost shales contain whole and masticated carbonized leaves of forest and marsh vegetation. Frederiksen (1991, personal communication) dated these basal shales as Early Eocene based on pollen analyses. The sand in this unit is composed of white fine- to medium-grained quartz sand, is sparingly micaceous, has reworked lignite fragments and reworked fine-grained glauconite. The lowermost sand, which unconformably overlies the Tuscahoma T4 channel sand, is cross-bedded and contains a lag deposit at its base consisting of rafted lignitic woody material, seed pods, clay pebbles, corroded and broken shark and ray teeth, and other fossil material. This lag deposit marks the base of Baum and Vail's (1988) Sequence TE1.1 and the Paleocene-Eocene boundary.

Marine unit

The Bashi Formation, as generally recognized, is a transgressive marine unit (Baum and Vail, 1988; Mancini and Tew, 1991; Ingram and Dockery, 1991) that varies in thickness between four and five feet in eastern Mississippi. Boulder-size concretions characterize this unit, and outcrops of the Bashi Formation in Mississippi and western Alabama are easily recognized by their presence. At the Red Hot Truck Stop locality, the Bashi marine unit is composed of white fine- to medium-grained quartz sand, and medium-grained glauconite. It is fossiliferous, micaceous, highly glauconitic, and the boulder-size concretions (4 feet in diameter) are present. In places, a very fossiliferous sand is present below the concretions. This concentration of fossils occurs at the base of the Bashi marine unit and is considered to be a lag deposit above the transgressive surface of the TE1.1 Coastal Onlap Sequence (Figures 2-4). This transgressive surface can be seen at the Red Hot Truck Stop locality where fossiliferous marine sands disconformably overlie lowstand sediments. The contact is abrupt and undulates, showing that it was an active scouring surface which truncated the underlying beds. Extending below this surface are numerous callianassid shrimp burrows of the trace fossil form taxon *Ophiomorpha*.

Hatchetigbee Formation

Only the lower ten feet or so of the Hatchetigbee Formation crop out on the upper slopes of the Red Hot Truck

Stop locality. Erosion has removed much of the section. The basal Hatchetigbee is composed of gray, fissile, silty clay. According to Baum and Vail (1988) and Mancini and Tew (1991), these sediments represent the highstand regressive deposits of the TE1.1 cycle. The contact with the underlying Bashi Formation is conformable and sharp. Bivalve fossil imprints and medium-grained glauconite mixed with gray clayey silt delineate the boundary.

SEQUENCE MODEL

The TE1.1 sequence began with a fall in sea level after deposition of Late Paleocene estuarine sediments in the upper Tuscahoma Formation. In the Baum and Vail (1988) model (Figure 3), TE1.1 is a Type 1 sequence, which indicates that the sea retreated to or near the outer shelf margin. Subsequent erosion of the exposed shelf and coastal environments produced a Type 1 unconformity and a channeled upper Tuscahoma surface. As sea level began to rise, incised valleys above the Tuscahoma were back-filled with fluvial and estuarine deposits. A progressive sea level rise caused barrier islands to retreat landward, overstepping lowstand deposits of fluvial and estuarine origin and exposing them to wave erosion. In western Alabama and easternmost Mississippi, wave erosion completely stripped away Bashi lowstand sediments deposited above the Tuscahoma Formation. Here the transgressive surface cut down to or below the basal Type 1 unconformity of the TE1.1 Sequence and forms the basal sequence boundary. Updip to the north, in the vicinity of Meridian, Mississippi, Bashi lowstand deposits were preserved in incised valleys. As illustrated in Figure 4, all the components of a Type 1 sequence are preserved in the stratigraphic section at MGS locality 19, including incised valley-fill deposits (the Bashi lowstand unit), transgressive deposits and condensed section (the Bashi marine unit), and highstand regressive deposits (the lower Hatchetigbee Formation).

DISCUSSION

Similar lithologies of shales, interbedded sands and shales, and glauconitic sands occur in both the upper Tuscahoma and lower Hatchetigbee formations in eastern Mississippi (Ingram and Dockery, 1991). These units are distinguished in the field by recognizing their position relative to the boulder-size concretions and fossiliferous sands of the Bashi Formation. The Bashi lowstand and marine units of the Meridian area differ in grain size (fine- to medium-grained sands) from those of the underlying and overlying formations (very fine- to fine-grained sands of the Tuscahoma and Hatchetigbee formations). The coarsest terrigenous clastics in the outcrops behind the Red Hot Truck Stop are found in the Bashi section, as would be predicted for the updip lowstand and transgressive units of a Type 1 coastal onlap sequence (Figure 4). The coarser-grained lithology of the Bashi Formation is bounded above and below by finer grained sediments in the upper Tuscahoma highstand regressive deposits (sequence TP2.3) and lower Hatchetigbee highstand regressive deposits (sequence TE1.1), respectively.

To date, the state's most diverse Paleogene land mammal fauna is from an estuarine channel sand at the top of the Tuscahoma Formation behind the Red Hot Truck Stop (Figure 2). Thirteen different mammalian species have been identified from the lag deposit at the base of the T4 channel sand. In another important find at MGS locality 19, a primate tooth and jaw fragment was recovered from the marine unit of the Bashi Formation. These recent discoveries of land mammal fossils in coastal plain sediments provide a basis for correlating the North American Land Mammal Ages with the Gulf Coast marine stages and with international marine zonations. Additionally, the occurrence of land mammal fossils in the highstand regressive deposits of the Tuscahoma Formation and the transgressive marine deposits of the Bashi Formation suggests that land mammal fossils may also be found in the highstand regressive and transgressive components of other coastal onlap sequences in the Gulf region.

CONCLUSION

The Paleocene-Eocene boundary behind the Red Hot Truck Stop, as determined by fossil pollen and dinocysts analyses, falls at a Type 1 sequence boundary between the Tuscahoma Formation of Sequence TP2.3 and a lowstand unit in the Bashi Formation of Sequence TE1.1. The Bashi lowstand unit is recognized here for the first time in the Meridian, Mississippi, area, MGS locality 19. Here the TE1.1 Sequence of Baum and Vail (1988) is complete with incised valley-fill deposits (the Bashi lowstand unit), transgressive deposits and condensed section (the Bashi marine unit), and highstand regressive deposits (the lower Hatchetigbee Formation).

Two lag deposits containing vertebrate teeth overlie erosional surfaces within the Red Hot Truck Stop Tuscahoma-Bashi section. The most important of these contains numerous mammalian taxa, occurs above a diastem at the base of the T4 channel sand at the top of the Tuscahoma Formation, and is Late Paleocene in age. The other occurs above the transgressive surface underlying the Bashi marine unit and is Early Eocene in age.

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