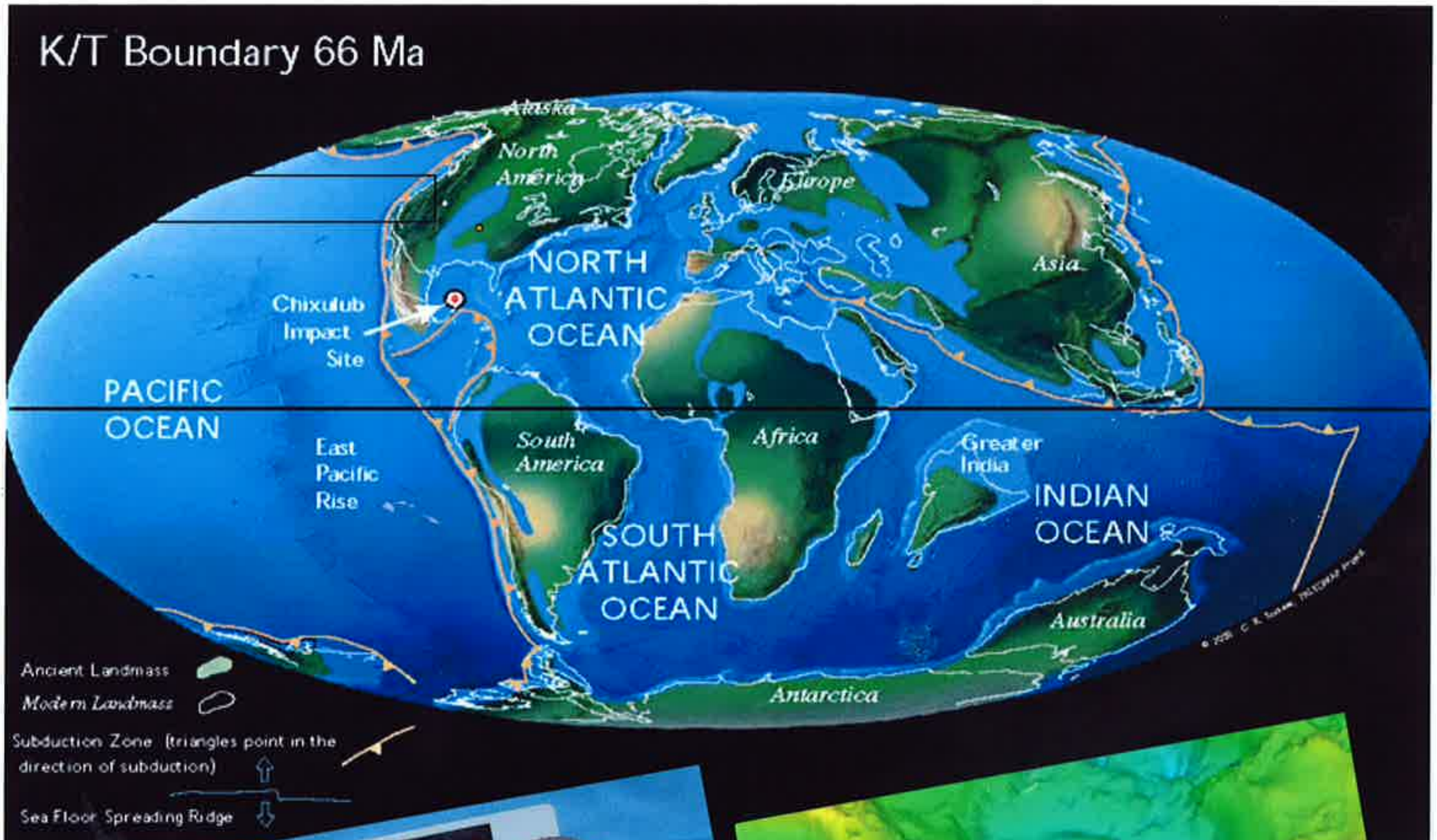
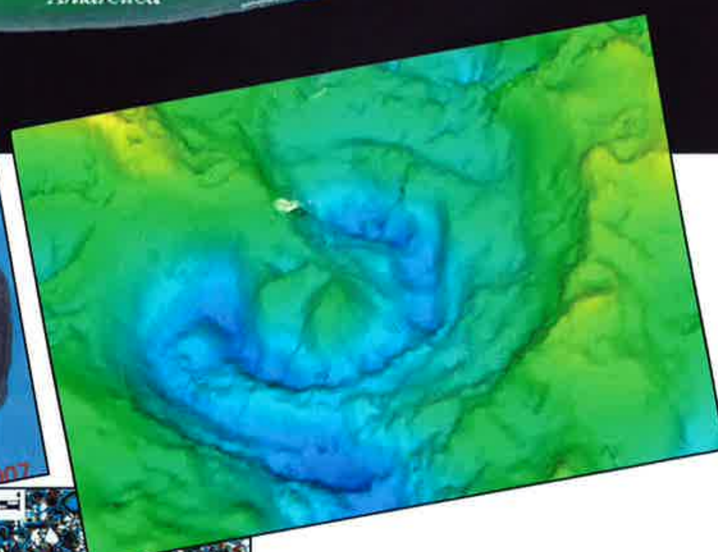
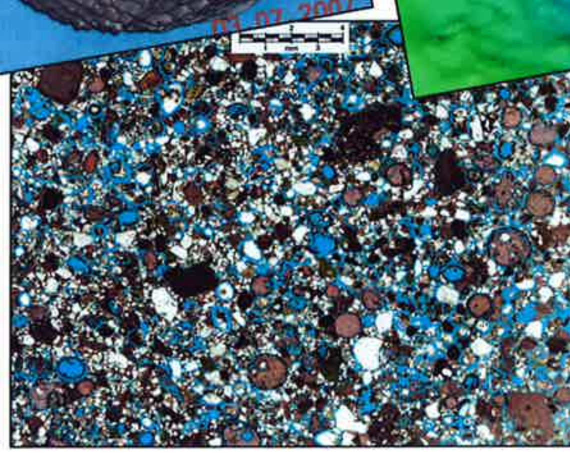
K/T Boundary and Paleogene Stratigraphy of Southwestern Alabama

Lafayette Geological Society Field Trip
March 23-25, 2007







Barry E. Wawak
editor

Lafayette Geological Society
Founded December 1958
Lafayette, Louisiana

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Acknowledgements

I would like to thank *Core Laboratories* for sponsoring the printing of the guidebook and Ron Cormier of *Core Laboratories* in assisting the compiling the guidebook and on the reconnaissance trip where we logged most of the route we will be traveling. I would also like to thank Mr. James Long, Jr., director of the St. Stephens Historical Commission for providing permission to visit the northern quarry at the St. Stephens.

Core Lab
RESERVOIR OPTIMIZATION

Front Cover:

1) K/T map from the PaleoMap Project (Scotese, C.R., 2002, http://www.scotese.com, PALEOMAP website). 2) *Exogyra costata*, Prairie Bluff Formation. 3) Three-dimensional Bouguer gravity anomaly map over the Chicxulub crater. Note that this image is not showing the shape of the crater; the negative gravity anomaly of the crater corresponds to the relatively low densities of the rocks within the crater (breccias and the melt sheet) and the Tertiary sediments filling the crater. The double humped central gravity high corresponds to the central uplift buried deep within the crater. The Chicxulub crater has no central topographic feature - the central peak characteristic of smaller complex craters. Chicxulub is a peak-ring crater with a poorly known topographic ring occurring at 24 to 27 mile radius from the crater's center. Subsequent erosion probably substantially removed the rim of Chicxulub before it was buried (Image courtesy Geological Survey of Canada, http://miac.uqac.ca/MIAC/chicxulub.htm). 4) Thin section photo of basal Clayton sand, Shell Creek.

Back Cover:

1) Alabama State Highway map (2007 edition) showing field trip stops. 2) *Lepidocyclina mantelli*, Marianna limestone, St. Stephens Quarry. 3) Large burrow, Moscow Landing. 4) *Protoscutella mississippiensis*, Winona Sand.

Agaronia alabamensis, Gosport Formation,
Clarke Co., Alabama

Cubitostrea lisbonensis, Lisbon Formation,
Choctaw Co., Alabama

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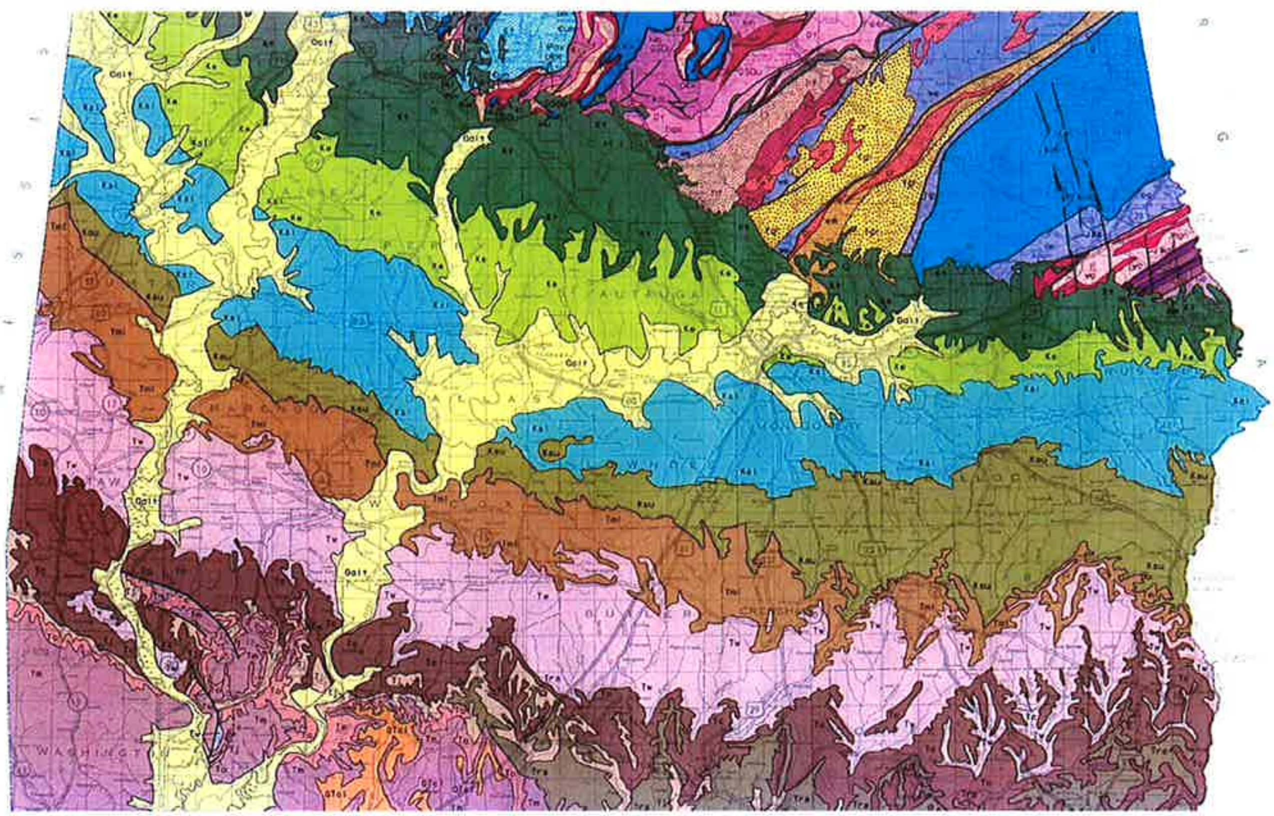
I. Introduction

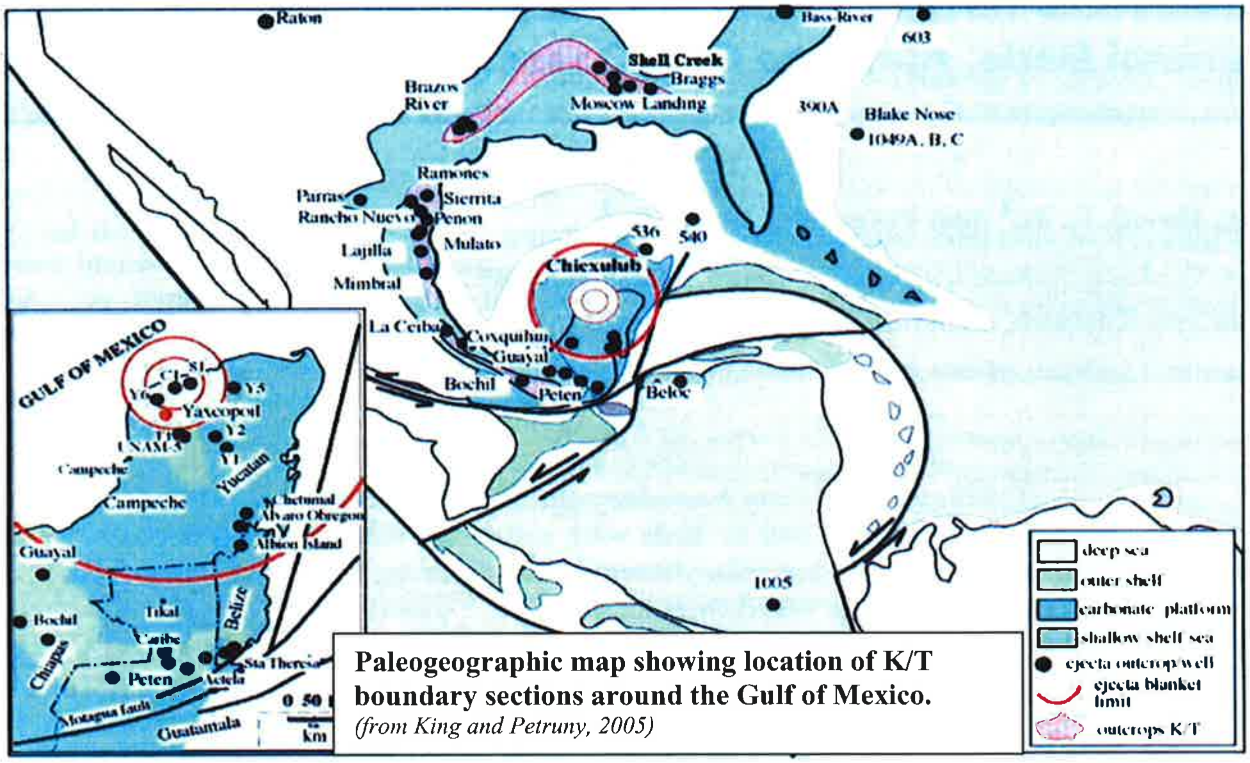
The Eastern Gulf Coastal Plain Physiographic Province comprises the Coastal Plain region that lies east of the Mississippi River to the Atlantic Coastal Plain. The Gulf and Atlantic Coastal Plains are separated by the northwest-southeast trending Ocala (or Peninsular) Arch that transects the states of Georgia and Florida, and formed a major positive structural feature during much of the Cretaceous and Tertiary. The northern limit of the area is defined by the northernmost extent of outcropping Upper Cretaceous or Paleocene strata which uncomformably overlie faulted and folded Paleozoic and Precambrian rock. The southern limit is defined by the southernmost extent of the continental rise of the Gulf of Mexico. Triassic, Jurassic and Lower Cretaceous strata only occur in the subsurface. In general the outcropping Mesozoic and Cenozoic strata of the eastern Gulf Coastal Plain comprise a seaward-dipping homoclinal wedge of sediments that reflect the infilling of a differentially subsiding, tectonically stable depositional basin on the passive margin of the southern North American continent. Paleogene strata consist about 2,500-feet of nonmarine, marginal marine and marine terrigenous clastic and carbonate sediments. Paleogene sediments are a clastic-sediment dominated sequence in Mississippi and a carbonate-dominated sequence in Georgia and the Florida panhandle. These lithofacies intertongue across southeastern Mississippi and southwestern Alabama making this area an ideal spot to study changes in Paleogene stratigraphy, sedimentology, and paleontology.



Geology Map- southern Alabama *(from state survey website)*

Tm – Miocene, To- Oligocene, Tj – Jackson, Tc-Claiborne, Tw-Wilcox, Tmi-Midway, Ksu – upper Selma Group, Ksl – lower Selma Group, Ke-Eutaw, Kt-Tuscaloosa

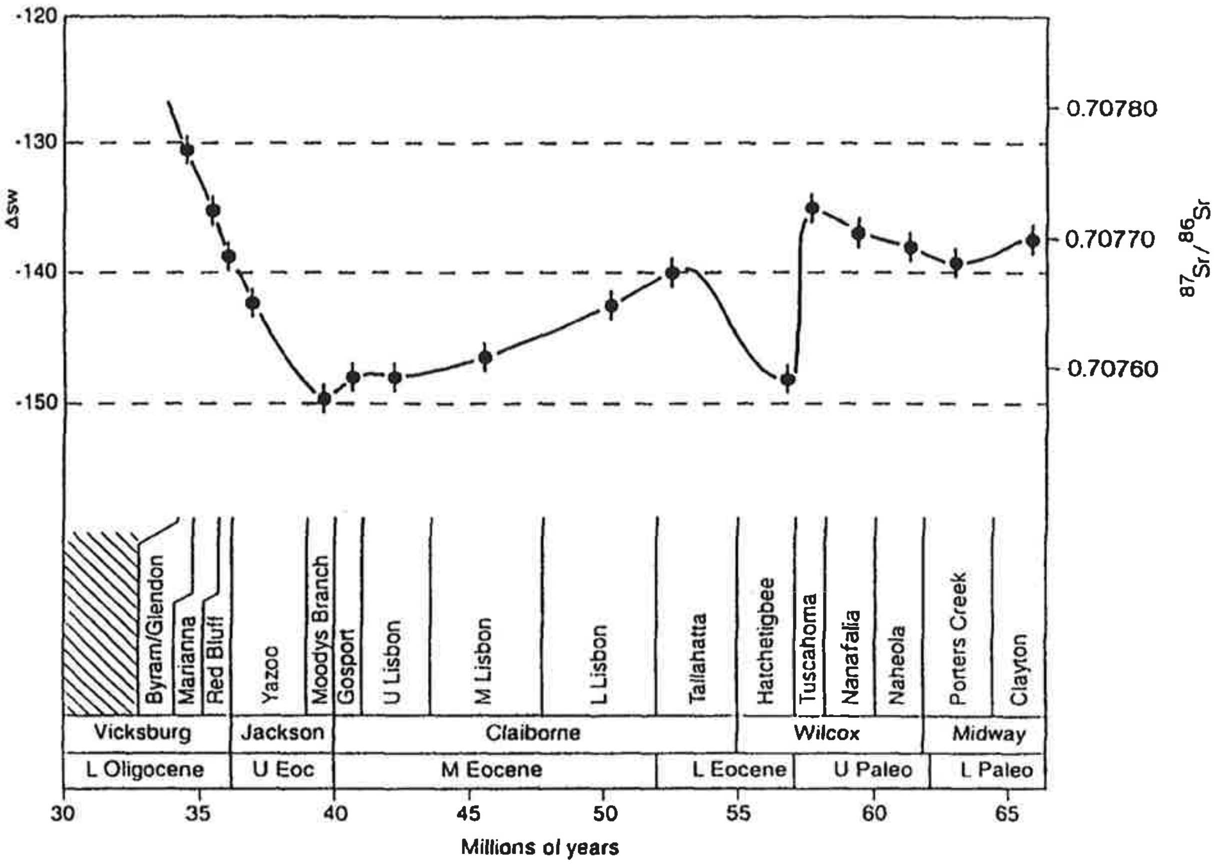
Worldwide, the Early Tertiary was a period of significant climatic and tectonic changes. The major extinction event at end of the Maastrichtian is generally attributed to effects of large bolide impact that has been associated with the circular basement structure at Chicxulub, offshore, Mexico. We will visit several K/T boundary sites on this trip.



Paleogeographic map showing location of K/T boundary sections around the Gulf of Mexico.
(from King and Petruny, 2005)

During the Paleocene, the suturing of India to the Asian continent was completed, and rifting initiated in the northern hemisphere between Greenland and Iceland. This rifting was accompanied by the extrusion of large volumes of flood basalts in eastern Greenland. One of the climatic effects attributed to this tectonic activity was the development of a late Paleocene thermal maximum. Isotope analysis suggests the late Paleocene was one of the warmest periods on time during the earth's history. The PETM (Paleocene-Eocene thermal maximum) has been attributed to the rapid release of 2000 X 10^9 metric tons of carbon in the form of methane (Zachos, et. al., 2005). This event would have lowered deep-sea pH and triggered a rapid rise of the CCD (calcite compensation depth). During the PETM the sea surface temperature at high latitudes rose as much as 9°C. Harrington (2001) suggests the transient greenhouse warming at the Paleocene/Eocene boundary (~55.2 ma) had a critical impact upon North American mammals, but apparently limited impact on subtropical plants. Pollen data from two marginal marine sections either side of the boundary in Alabama demonstrate subdued changes in composition that are manifest primarily as a restructuring of the vegetation type. Dockery (1998) also documents a corresponding significant seawater $^{87}Sr/^{86}Sr$ ratio down-spike at the Paleocene Eocene boundary, based on the analysis of fossil mollusk shells that likely represents a significant change in oceanic circulation at the Paleocene/Eocene boundary.

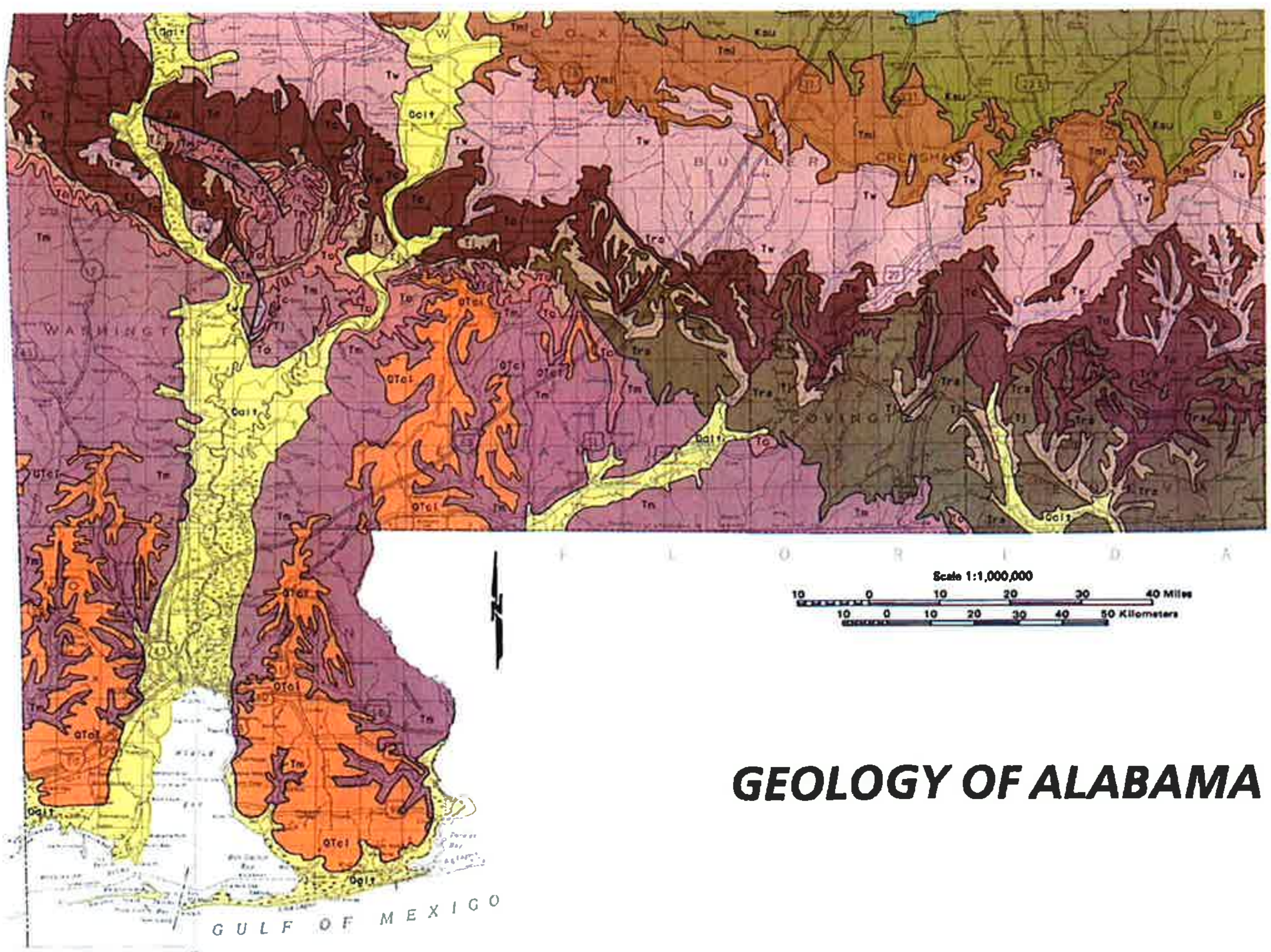
In western North America the final pulses of the Laramide orogeny continued into the



earliest Eocene. McGowran (1989) shows the Eocene was a time of greatly increased silica accumulation, with the peak occurring in the early middle Eocene, ~50 Ma. He concluded this was the cumulated effects of intensive volcanism and deep lateritic weathering on continental areas. The result was the deposition of silica-rich sediments throughout the world at this time. The 'buhrstone' beds in the Tallahatta Formation are a consequence of this sedimentation. Kobashi, et.al. (2004) demonstrated temperature and density profiles of the early Eocene oceans indicate an unstable and less stratified ocean, suggesting highly homogenous seawater induced by warm deep water. At the transition of the middle to late Eocene water stability increased and temperature at the bottom of the seasonal thermocline decreased by ~5° C. This significant change in water column structure disrupted planktonic foraminifer habits resulting in a major extinction of warm water taxa. Subsequent increase in stratification as shown in Late Eocene and Oligocene temperature density profiles might have restricted foraminifers' depth habitat to shallower depths. The late Eocene profile shows a close correspondence with present ocean temperature profile implying that the water mass temperature on the northern Gulf continental shelf was very similar to the present at the end of the Eocene. Deep-sea cooling from the Early Eocene to the Oligocene as compared with relatively constant low-mid latitude ocean temperatures suggest the density structure of the world ocean changed significantly during this time. These changes likely affected ocean water circulation and biogeochemical cycles, creating a large contrast between greenhouse world of the Paleocene and the icehouse world of the Oligocene. Analysis of tektite strewn fields in the southeastern U.S. has correlated tektite occurrences with a bolide impact in the vicinity of the modern Chesapeake Bay, dating around

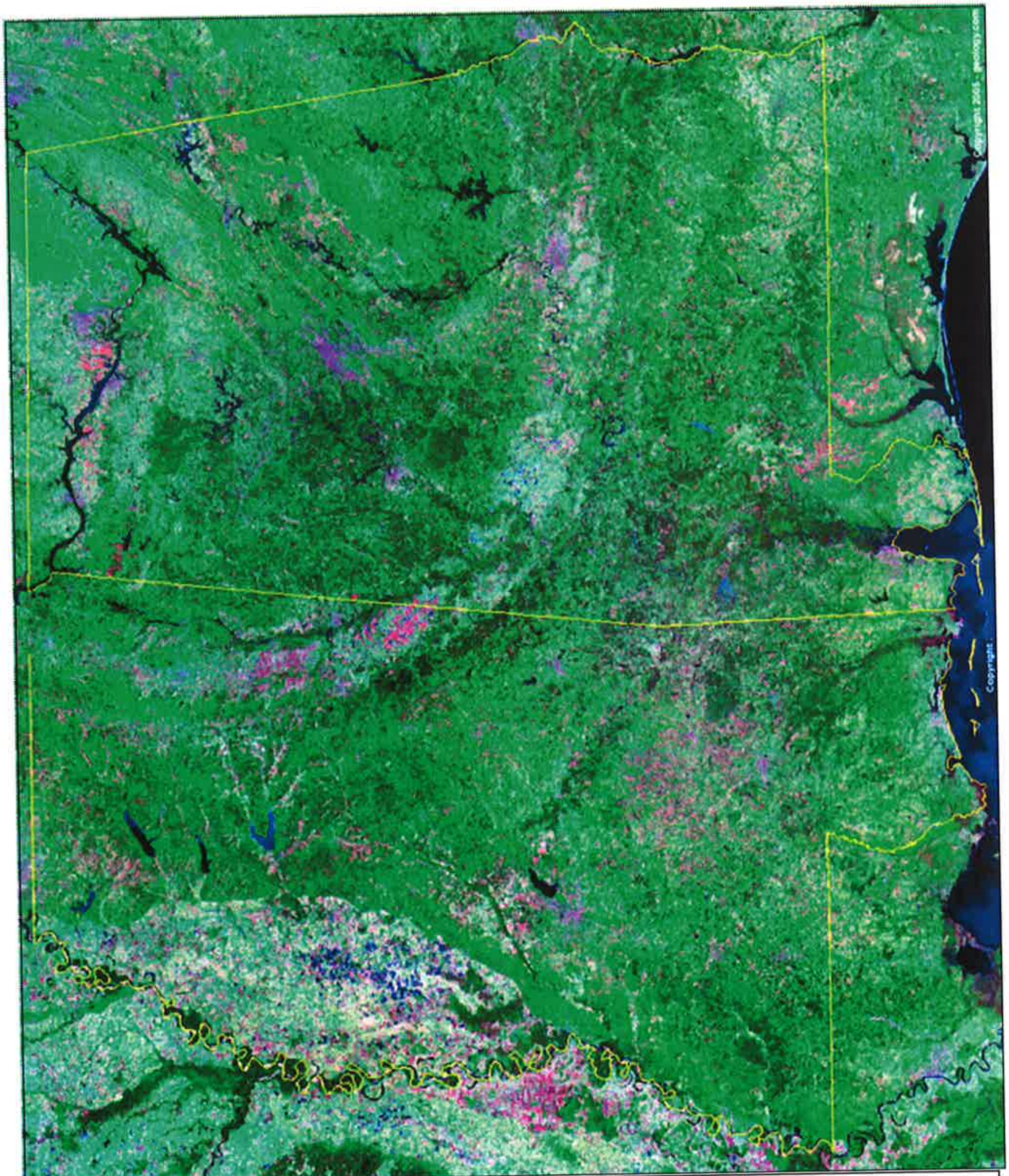
35 Ma, near the end of the Eocene. This was one of three impact craters that are dated around this time worldwide, suggesting a Shoemaker-Levy type event could have possibly occurred near the Eocene/Oligocene boundary. The Eocene/Oligocene boundary marks a transition from a generally warm climate (throughout the Eocene) to a significantly colder climate (during the Oligocene). This climatic change is indicated by the changes in diversity of various taxa from the Eocene to the Oligocene.

Various effects of these tectonic and climatic changes are recorded in the Paleogene strata in Southwest Alabama. On this trip we will 1) visit several K/T boundary sites which, arguably marks one of the most significant events that has occurred during the Phanerozoic, 2) visit and Eocene/Oligocene boundary site – which marks the change from the 'greenhouse world of the later Cretaceous/early Tertiary to the 'icehouse' world of the later Cenozoic and may have implications for present climatic change, and 3) see strata associated with increased biogenic silica output during the middle Eocene.



Geology Map- southwestern Alabama *(from state survey website)*

Tm – Miocene, To- Oligocene, Tj – Jackson, Tc-Claiborne, Tw-Wilcox, Tmi-Midway, Ksu – upper Selma Group, Ksl – lower Selma Group, Ke-Eutaw, Kt-Tuscaloosa

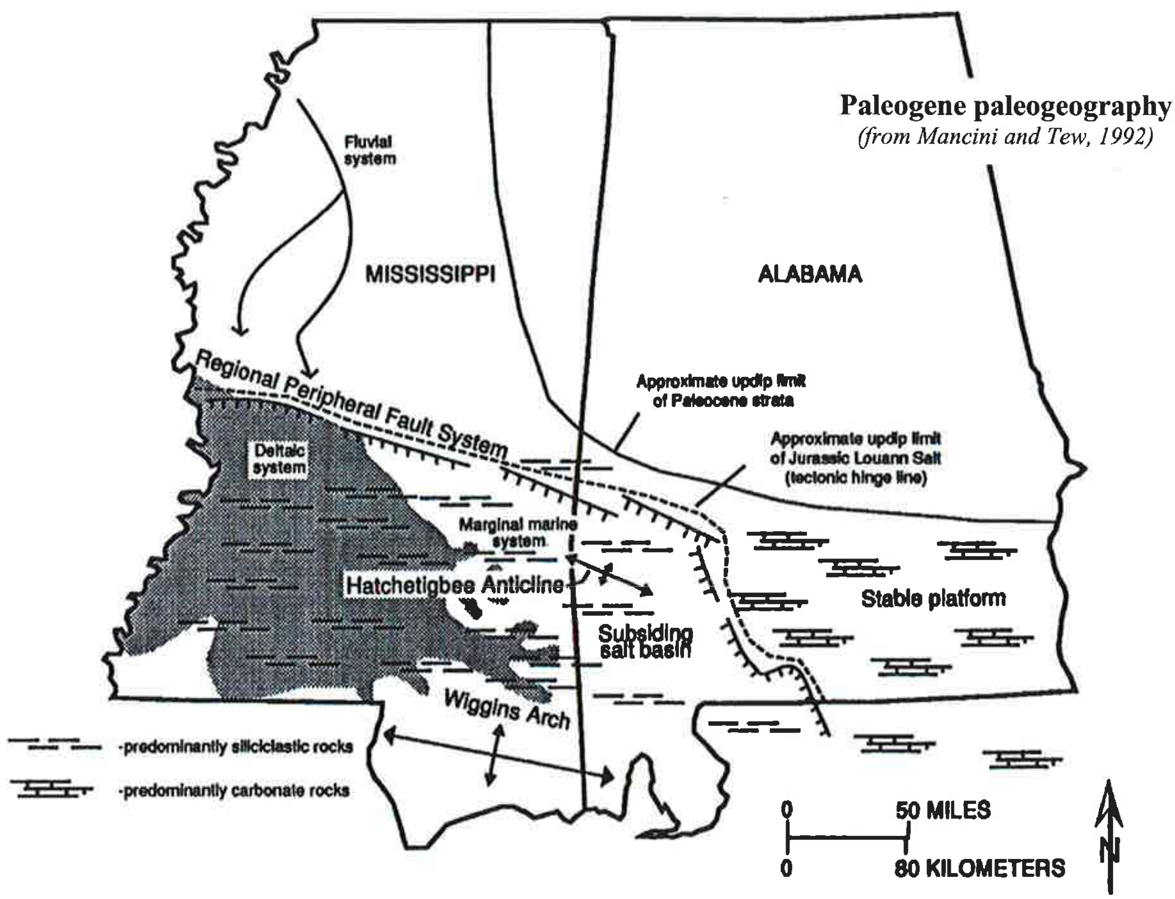


Composite Landsat Satellite Image Of Mississippi and Alabama

Note distinctive signatures of the northern edge of the coastal plain as it wraps around the southern end of the Appalachian Mountains and the modern Mississippi River meander plain within the Mississippi Embayment.
(from geology.com)

II.A.a. - Lithostratigraphy

The Paleogene succession of the eastern Gulf Coastal Plain consists of about 2500-feet of nonmarine, marginal marine, and marine siliciclastic and carbonate sediments. The stratigraphic sequence includes the Midway, Wilcox, Claiborne, Jackson and Vicksburg groups and upper Oligocene strata. The oldest Tertiary unit (Clayton Formation) disconformably overlies Upper Cretaceous (middle Maastrichtian) strata. The Paleogene strata comprise a seaward-dipping wedge of sediments that reflect the infilling of a differentially subsiding deposition basin on the passive southern margin of the North America continent. Lateral lithofacies changes in Paleogene strata from west to east suggest that deposition conditions in Mississippi were associated with clastic (deltaic and marginal marine sedimentation), while sedimentation is south-central and southeastern Alabama, Georgia and the Florida panhandle was dominated by carbonate sedimentation on a persistent stable platform that developed over Paleozoic basement rocks. This regional setting resulted in a siliciclastic-dominated succession in Mississippi and a carbonate dominated sequence in south-central and southeastern Alabama, Georgia, and the Florida panhandle. These lithofacies intertongue across southwestern Alabama.



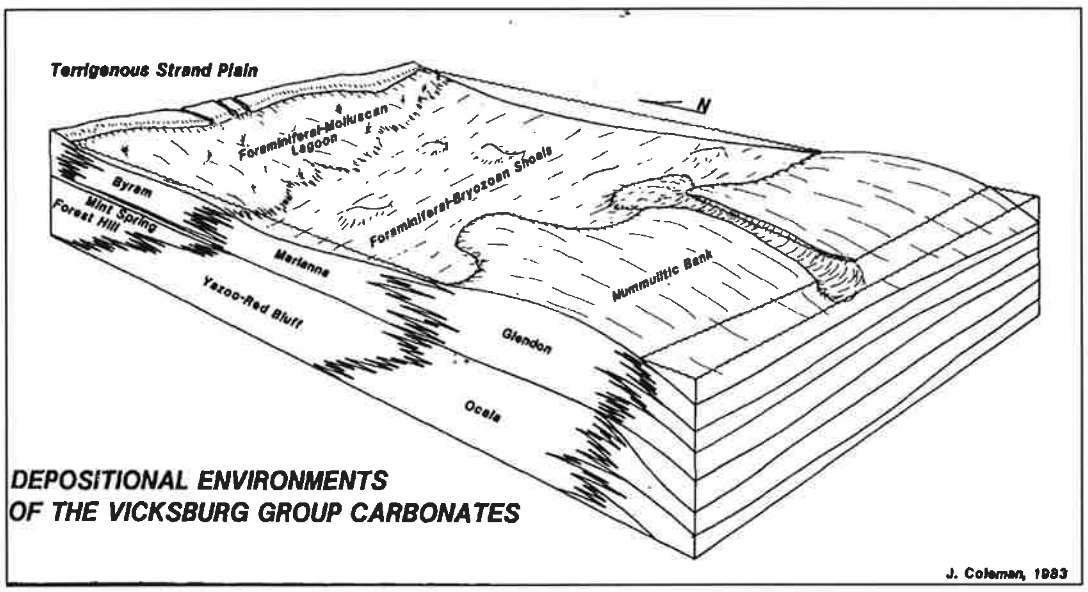
Paynes Hammock Sand

The Paynes Hammock consists of 13-feet of greenish, calcareous sand at its type locality along the Tombigbee River, Clarke County, Alabama. The Paynes Hammock Sand is up to 23-feet thick westward in Mississippi, and is comprised of fossilferous, arenaceous, glauconitic marl interbedded with fossilferous sands and silty limestones. The key macrofossil is the oyster *Ostrea blanpiedi*.

Chickasawhay Limestone

The Chickasawhay Limestone includes 14-42 feet of olive-gray, argillaceous to arenaceous, fossilferous limestone and bluish-green, fossilferous marl and clay. The Chickasawhay Limestone thins eastward into southwestern Alabama where it consists of 3-19 feet of interbedded greenish-gray, argillaceous, silty, sandy, glauconitic, fossilferous marl and yellowish-orange, argillaceous, silty, sandy, glauconitic fossilferous limestone. Key macrofossils in the Chickasawhay Limestone include the echinoid *Echinolampus aldrichi* and a calcareous tube of a boring mollusk *Kuphus incrassatus*.

Vicksburg Group



The Vicksburg Group consists of the Byram Formation (Bucatunna Clay, unnamed marl mbr., Glendon Limestone), Marianna Limestone (Mint Spring marl mbr. = Mint Spring Formation in Mississippi), Forest Hill Sand, and Red Bluff Clay/Bumpnose Limestone. The Eocene-Oligocene boundary is placed at or near the base of the Red Bluff/Bumpnose based on diagnostic planktonic foraminifera. This contact can be seen at the exposures in the quarry at old St. Stephens. Vicksburg Group strata are not recognized in southeastern Alabama where residuum overlies Eocene strata

Byram Formation

In southwestern Alabama the Byram Formation is about 40-feet thick, and includes the Glendon Limestone Member, an unnamed marl member, and the Bucatunna Clay Member. The Glendon consists of about 20-feet of gray, fossilferous limestone at its type locality (Glendon Station, Washington County, Alabama). In Mississippi the three members thicken, are elevated to formation status, where the unnamed middle member becomes the Byram Formation. The Byram consists of 29-feet of greenish-gray, argillaceous, arenaceous, glauconite, fossilferous marl at its type locality (Pearl River, near Byram, Hinds County, Mississippi). The type locality for the Bucatunna is along Bucatunna Creek, Wayne County, Mississippi, and includes 29-102 feet of dark gray, silty to arenaceous, micaceous, carbonaceous, fossilferous clay. Key macrofossils include the large foraminifer *Lepidocyclina supera*, the echinoid *Clypeaster rogersi*, and the bivalves *Pecten poulsoni* and *Pecten byramensis.*

Marianna Limestone

The Marianna Limestone consists of white, chalky, fossilferous limestone at its type area, west of the Chipola River, at Marianna, Jackson County, Florida. In southwestern Alabama, the Marianna does not exceed 60-feet in thickness and includes a basal marl unit, the Mint Spring Marl Member. The Mint Spring is considered a formation in Mississippi, where it consists of up to 17-feet of greenish-gray, argillaceous to arenaceous, fossilferous, glauconitic marl at its type locality (Mint Spring Bayou, Wayne County, Mississippi). Key fossils found in the Marianna Limestone include the echinoid *Clypeaster rogersi*, the bivalve *Pecten poulsoni*, and the large foraminifer *Lepidocyclina mantelli*.

Red Bluff Clay/Bumpnose Limestone

The Red Bluff includes 32-feet of greenish-gray clay and marl interbedded with hard limestone ledges and chalky limestone at its type area (Chickasawhay River, Wayne County, Mississippi). In southwestern Alabama, the Red Bluff consists of 60-feet of yellow, glauconitic limestone, greenish-gray, glauconitic, calcareous clay, and silty clay with thin beds of sand. The Red Bluff Clay grades eastward into the Bumpnose Limestone in south-central Alabama. The Bumpnose Limestone in south-central Alabama includes about 14-feet of white, glauconitic, fossilferous argillaceous limestone. Key macrofossils include the bivalves *Spondylus dumosus* and *Pecten perplanus*.

Jackson Group

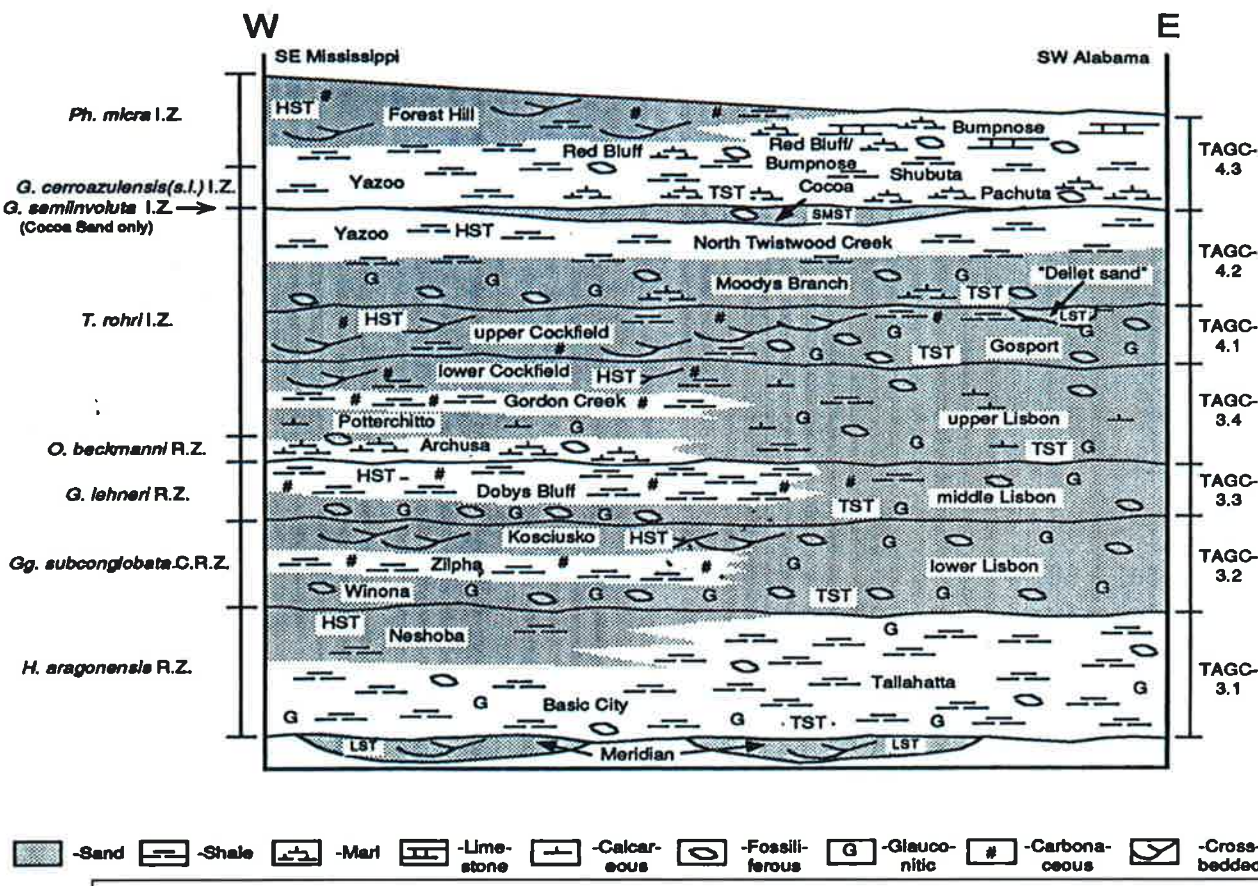
The Jackson Group includes the Crystal River, Yazoo, and Moody's Branch Formations. In Alabama the Yazoo Formation is divided into four members, 1) North Twistwood Creek Clay, 2) Cocoa Sand, 3) Pachuta Marl, and 4) Shubuta member. The Moody's Branch Formation disconformably overlies the Cockfield Formation in Mississippi, the Gosport Sand in southwestern Alabama, and the Lisbon Formation in southeastern Alabama (top of the Claiborne Group).

Crystal River Formation

The Crystal River Formation includes 108-feet of white, chalky, fossilferous limestone at its type locality in the Crystal River Rock Company Quarry, Citrus County, Florida. In south-central Alabama, the Crystal River consists of about 60-feet of white, fossilferous, argillaceous, silty limestone. In southeastern Alabama and into the Florida panhandle, the North Twistwood Creek, Cocoa Sand, and Pachuta Marl grade into the Crystal River Formation.

Yazoo Formation

The Yazoo formation is about 200-feet thick at its type locality (Yazoo River, Yazoo County, Mississippi), where it is a pale olive, calcareous, blocky clay. The formation thins to about 72-feet thick in southwestern Alabama, where it is divided into four members; 1) North Twistwood Creek Clay, 2) Cocoa Sand, 3) Pachuta Marl, and 4) Shubuta member. The North Twistwood Creek Clay is 40-60 feet of bluish-gray, glauconitic, calcareous, micaceous, sandy clay. The Cocoa Sand includes about 60-feet of gray, fossilferous, calcareous, massive, fine to medium grained sand at its type locality near Melvin, Choctaw County, Alabama. The Pachuta Marl is about 10-feet of greenish-gray, indurated, glauconitic, fossilferous, argillaceous marl in the area of its type locality (Pachuta Creek, Clarke County, Mississippi). The Shubuta Member includes about 90-feet of grayish-olive-green, blocky to massive, fossilferous, calcareous clay at its type locality (Chickasawhay River, near Hiwannee, Mississippi). The Shubuta thins eastward into southwestern Alabama, then increases in thickness into south-central Alabama, where it grades into the Crystal River Formation. Key macrofossils in the Yazoo Formation include the echinoid *Periarchus lyelli pileussinensis*, the brachiopod *Terebratulina lachryma*, the coral *Flabellum rhomboideum*, and the bivalves *Amusium ocalanum, and Chlamys spillmani.*



Schematic cross section showing lithofacies, foraminiferal zones, and depositional sequences for the Claiborne and Jackson Groups and related strata.
(from Mancini and Tew, 1994)

Moody's Branch Formation

In southwestern Alabama the Moody's Branch includes 10-20 feet of greenish-gray, glauconitic, fossilferous, calcareous sand, sandy marl. In southeastern Alabama, it is a glauconitic, sandy limestone. The lower 1.5-feet of fossilferous sand are informally termed the 'Dellet sand'. Is disconformably overlain by the '*Scutella* bed', the lowermost limestone bed, which is characterized by an abundance of fragments of the echinoid *Periarchus lyelli*. Key macrofossils occurring in the Moody's Branch include the echinoid *Periarchus lyelli* and the large foraminifer *Nummulites moodybranchensis*.

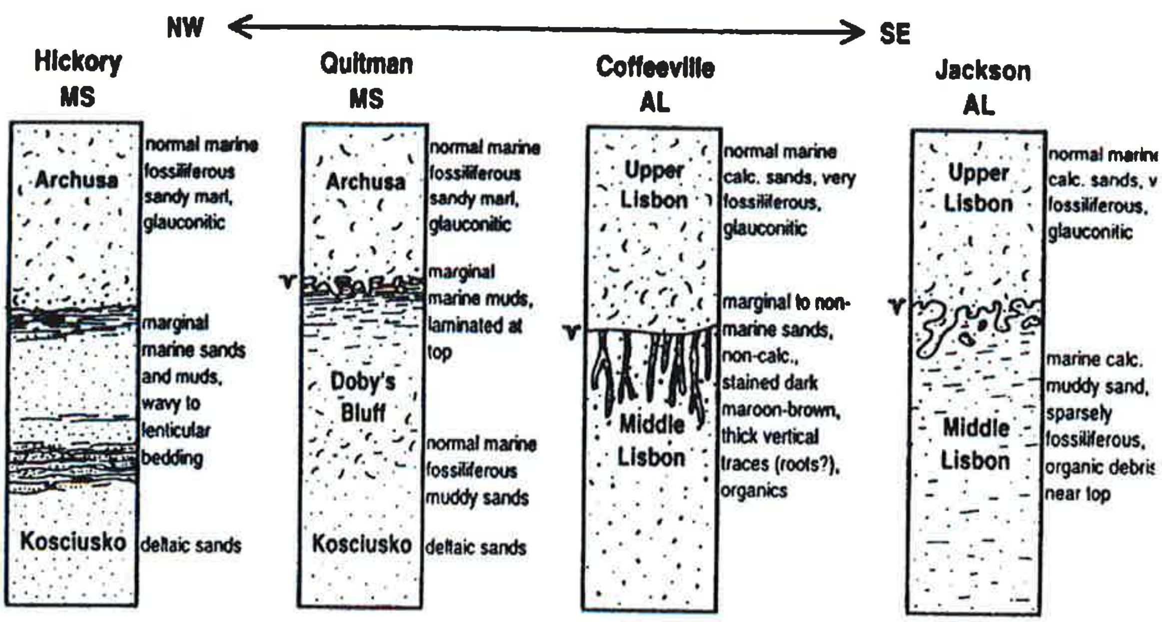
Claiborne Group

The Claiborne Group in Alabama consists of the Gosport Sand, Lisbon Formation, and the Tallahatta Formation. In Mississippi the Tallahatta is divided into the Meridian Sand, Basic City Shale, and the Neshoba Sand, and the Lisbon Formation is divided into the Winona Sand, Zilpha Clay, Kosciusko Formation, and Cook Mountain Formation. The Tallahatta Formation contains subeconomic amounts of clinoptilolite (a zeolite mineral).

Gosport Sand

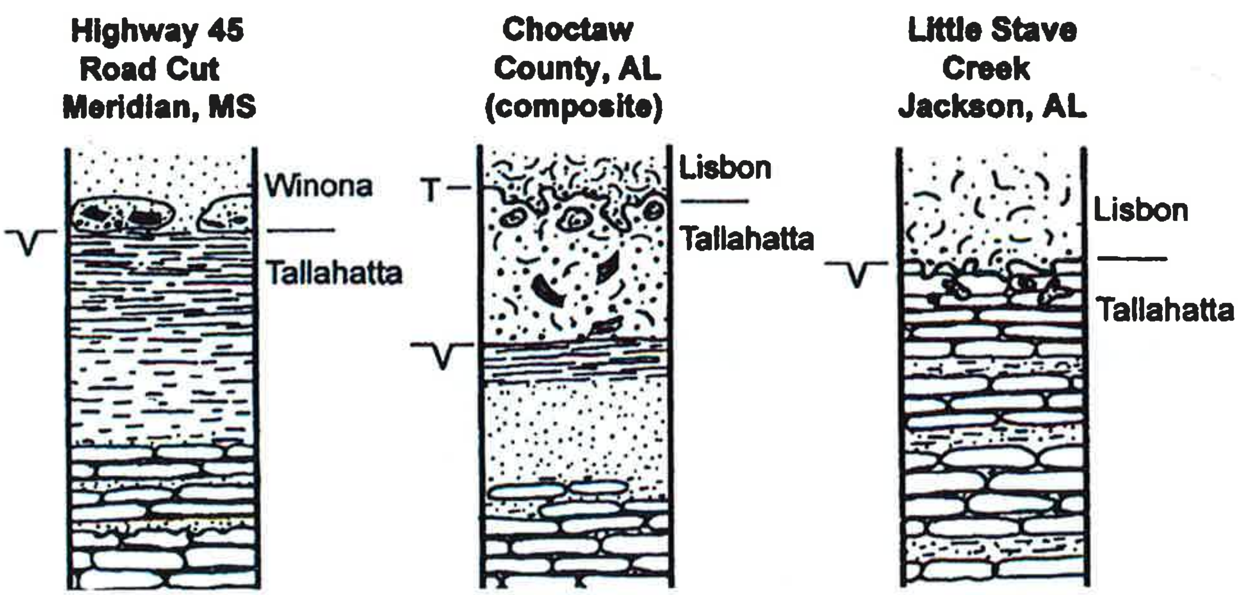
The Gosport Sand, at its type locality (Gosport Landing, Alabama River, Clarke County, Alabama) is 40-feet of glauconitic, fossilferous, calcareous sand. The Gosport pinches out to the west near the Mississippi state line, and is not present in southeastern Alabama. Equivalent beds in Mississippi are assigned to the Cockfield Formation. The Cockfield is 50-450 feet of cross-bedded sand and carbonaceous clay. A key macrofossils occurring in the Gosport Sand is the bivalve *Venericardia alticostata*.

Lisbon Formation



Schematic representation of lithologies at and below the sequence boundary between the middle and upper Lisbon. V's – sequence boundaries.
(From Ivany, 1998)

At it type locality, Lisbon Bluff along the Alabama River, Monroe County, south-central Alabama, the Lisbon Formation consists of 150-feet of glauconitic, calcareous, fossilferous, coarse-grained sand, sandy marl, and clay. In southwestern Alabama, the Lisbon is about 150-200 feet thick and includes 1) an upper glauconitic, calcareous, clayey sand unit, 2) a middle carbonaceous sand and silty clay unit, and 3) a lower fossilferous, glauconitic, a coarse-grained sand unit. The Cook Mountain Formation (Wautubbee) is equivalent to the upper Lisbon in Mississippi. The Cook Mountain in Mississippi is about 100-feet of fossilferous, glauconitic marl, sand, and sandy clay, and is divided into three members, 1) the Archusa Marl, 2) the Potterchitto Member, and 3) the Gordon Creek Shale. The Archusa Marl is 48-feet of glauconitic, calcareous sand and clay, at its type locality, Archusa Springs, Clarke County, Mississippi. The Potterchitto Member consists of 36-feet of glauconitic, calcareous sand and clay, at its type locality along Potterchitto Creek, Newton County, Mississippi. The Gordon Creek Shale is 15-25 feet of carbonaceous clay at its type locality along Gordon Creek at Wautubbee Station, Clarke County, Mississippi. In Mississippi, the upper part of the Kosciusko, called the Dobys Bluff Tongue of the Kosciusko Formation, is the equivalent of the middle Lisbon. At its type locality (Dobys Bluff, Chickasawhay River, Clarke County, Mississippi) it is about 20-feet of fossilferous, carbonaceous clay and fossilferous sand. In Mississippi, the Winona Sand, the Zilpha Clay, and the lower portion of the Kosciusko Formation are equivalent to the lower Lisbon Formation. The Winona Sand consists of 25-50 feet of glauconitic, fossilferous, medium to coarse grained sand at its type locality near Winona, Montgomery County, Mississippi. The Zilpha Clay includes about 40-feet of carbonaceous clays at its type locality, Bucksnort Hill, near Zilpha Creek, Attala County, Mississippi. The Kosciusko Formation, at its type locality near Kosciusko, Attala County, Mississippi, is up to 400-feet of cross-bedded, fine-grained sand. Key macrofossils in the Lisbon Formation include the echinoid *Protoscutella mississippensis*, the oysters *Cubitostrea smithvillensis, Cubitostrea sallaeformis, Cubitostrea lisbonensis*, and the larger foraminifer *Nummulites barkeri*.



Schematic showing the variation in lithology at the top of the Tallahatta Formation. The Tallahatta-Lisbon contact falls at the sequence boundary at the Hwy-45 road cut and at Little Stave Creek. This contact is placed at the level of the Transgressive surface (Copeland) in the Choctaw County section. The lowermost lithology symbol (ovoid blocks) is buhrstone. V – Sequence boundary. T-transgressive surface.
(from Ivany, 1998)

Tallahatta Formation

In the type area (Tallahatta Hills, Choctaw County, Alabama) the Tallahatta is 100-130 feet of greenish-gray, siliceous, sandy claystone, historically referred to as 'buhrstone'. In Mississippi, the Tallahatta is about 200 feet thick and is divided into three members, the lower Meridian Sand, the middle Basic City Shale, and the upper Neshoba Sand member. The Meridian Sand consists of about 100-feet of clayey, lignitic, cross-bedded, fine to coarse-grained sand at its Type locality near Meridian, Mississippi. The Basic City Shale is 80 feet of siliceous claystone and siltstone at its type locality near Basic City, Clarke County, Mississippi. The Neshoba Sand includes about 50-feet of micaceous, fine-grained sand, at its type locality at Neshoba, Neshoba County, Mississippi. Relatively large amounts of clinoptilolite (zeolite mineral) are identified in some parts of the Tallahatta Formation in Alabama. The clinoptilolite tends to be concentrated in 2-3 foot thick claystone beds just above the Meridian Sand, and again in claystone beds just below the Lisbon Formation. Key macrofossils occurring in the Tallahatta are the bivalves *Anodontia augustana* and *Cubitostrea perplicata*.

Wilcox Group

The Wilcox Group consists of the Hatchetigbee, Tuscahoma, and Nanafalia Formations. The base of the Eocene Epoch is placed at the base of the Bashi Marl, in the lower part of the Hatchetigbee Formation. A downdip equivalent of the middle part of the Nanafalia Formation, the Salt Mountain Limestone, is exposed south of Jackson, (Clarke County, Alabama) along the surface expression of the Jackson Fault. Sub-economic amounts of lignite occur in the Gravel Creek member of the Nanafalia Formation and in the Tuscahoma. Nine percent of the amount of estimated recoverable lignite in Alabama resides in the Gravel Creek member of the Nanafalia Formation.

Hatchetigbee Formation

The Hatchetigbee is named after Hatchetigbee Bluff on the Tombigbee River, Washington County, Alabama. This is a downdip exposure near the crest of the Hatchetigbee anticline on the right bank of the Tombigbee River. The Hatchetigbee is ~250-feet thick in southwestern Alabama and southeastern Mississippi. It is divided into an upper, unnamed member and a lower Bashi Marl member. The upper, unnamed member consists of 200-250 feet of gray, carbonaceous, micaceous, laminated clay and silt and cross-bedded, fine-grained sands. There are several fossilferous beds near the lower part of the exposure at its type locality. The lowest bed, at low water level contains a large oyster and double valves of *Venericardia hatcheplata*. The immediately overlying fossilferous beds contains abundant specimens of *V. hatcheplata* many of which are in living position and still retain the ligament and periostracum. The Bashi Marl is named after the exposures along Bashi Creek, Clarke County, Alabama. The Bashi Marl is 6 to 35 feet of greenish-gray, fossilferous, glauconitic, calcareous and marl. Key macrofossils found in the Bashi Marl are the gastropod *Turritella gilberti*, the bivalve *Venericardia bashiplata*, and the oyster *Ostrea brevifonta*. The Paleocene-Eocene boundary is placed at or near the base of the Bashi Marl, based on diagnostic microfossils. The Hatchetigbee Formation conformably overlies the Tuscahoma Formation.

Tuscahoma Formation

The formation was named for exposures at Tuscahoma Landing on the Tombigbee River. The Tuscahoma consists of ~350 feet of interlaminated silty clays, silts, and fine-grained sands in Mississippi and Southwestern Alabama. In southwestern Alabama glauconitic, fossilferous, fine-grained sands and marls occur in the lower part of the formation below cross-bedded, fine to medium sands containing angular blocks of clay. The upper Tuscahoma beds overlying the Bells Landing Marl consist of cross-bedded sands, laminated clays and silts, and several thin lignite beds. The upper fossilferous marl, The Bells Landing Marl member is 9-feet of highly fossilferous, calcareous, glauconitic, fine-grained sand and marl. At its type locality, there is 25-feet of gray, sandy clay and gray, very fine-grained sand between the Bells Landing and Greggs Landing Marls. The Greggs Landing Marl Member is the lower of two formally defined fossilferous marine units that occurs near the middle of the formation. The type section is at Greggs Landing on the Alabama River, Monroe County, Alabama. The Greggs Landing Marl is ~6-feet thick fossilferous, calcareous, glauconitic, quartzose, fine-grained sand and marl. A third marl, near the base of the Tuscahoma has been recently identified. It is informally called the Bear Creek Marl, and it lies ~30-feet below the Greggs Landing Marl. The fauna in the Bear Creek is identical to the fauna identified in the Greggs Landing marl. Key macrofossils found in the Tuscahoma include the oyster *Ostrea sinuosa*, the bivalves *Venericardia aposmithii* and *Chlamys greggi*, and the gastropod *Turritella postmortoni*. The Tuscahoma Sand conformably overlies the Nanafalia Formation.

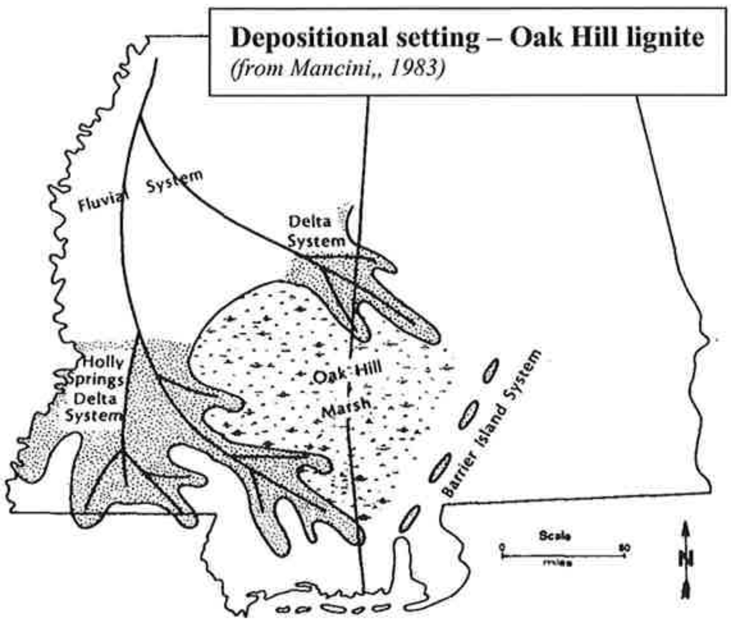
Nanafalia Formation

The Nanafalia is comprised of three members, 1) the Grampian Hills member, 2) "*Ostrea thirsae* beds", and 3) Gravel Creek Sand member. The type locality is at Nanafalia Landing on the Tombigbee River, Marengo County, Alabama. The upper Grampian Hills member is 80-110 feet of green to gray, indurated clay interbedded with glauconitic sand and marl at its type locality in road cuts south of Camden, Wilcox County, Alabama. The middle member, the "*Ostrea thirsae* beds", consists of 35 to 45 feet of calcareous, glauconitic, fossilferous sand and silty marl. The lower Gravel Creek Sand member is 50-feet of white to yellow, micaceous, cross-bedded, medium-to coarse grained sand at its type locality along Gravel Creek, Wilcox County, Alabama. The Salt Mountain Limestone, which only outcrops in a small area south of Jackson, Clarke County, Alabama, is a down dip carbonate equivalent of part of the Nanafalia Formation. The Salt Mountain Limestone is ~90-thick at its type locality (south of Jackson, Clarke Co., Alabama), and consists of hard, white crystalline limestone that forms irregular ledges 2-8 feet thick and beds and/or lenses of soft, white limestone. The Salt Mountain Limestone contains a fauna that includes reef-building corals, echinoderm plates and spines, and a poorly preserved microfauna. The key macrofossil in the Nanafalia Formation, particularly the "*Ostrea thirsae* beds" is the oyster *Odontogryphaea thirsae*. The Nanafalia Formation disconformably overlies the Naheola Formation.

Midway Group

The Midway Group consists of the Naheola, Porters Creek, and Clayton Formations, all assigned to the Paleocene Epoch. Substantial reserves of mineable lignite occur in the Oak Hill member of the Naheola Formation. The lignite in the Oak Hill accounts for 91% of the demonstrated lignite resource in Alabama. The Cretaceous-Tertiary boundary occurs at the base of the Clayton Formation. On this field trip, the K/T contact can be seen at 1) Moscow Landing, 2) Shell Creek, and 3) in road cuts southwest of Braggs. Both the Moscow Landing and Shell Creek localities have distinctive petrologic and sedimentological features that have been attributed to a bolide impact at the end of the Cretaceous.

Naheola Formation

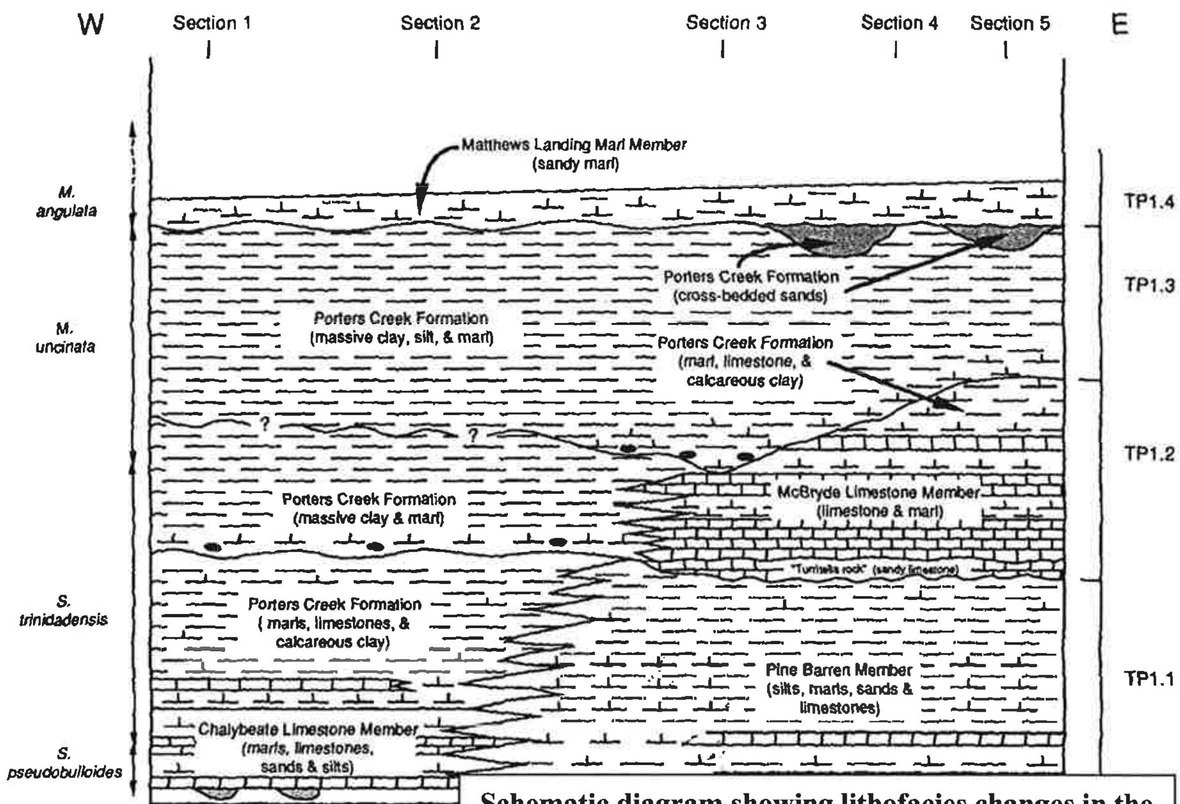


Uppermost formation of the Midway Group, its type locality is at Naheola Bluff on the Tombigbee River, where it consists of unfossilferous, thin-bedded sand and silty clay overlying the fossilferous marl of the Matthews Landing marl. In central Alabama (Wilcox County) the formation is comprised of two members, the lower Oak Hill member and the upper Coal Bluff member. These beds are absent in southeastern Alabama. The type locality of the Coal Bluff member is at Coal Bluff on the Alabama River, where it consists of 22-feet of fossilferous glauconitic sand resting on a four-foot thick bed of lignite. The Coal Bluff member is 10-20 feet fossilferous, glauconitic, micaceous, fine-to medium-grained sand and laminated lignitic clay and silt in its type area in Wilcox County, Alabama. In southwestern Alabama the Coal Bluff includes 40-60 feet of gray, micaceous, cross-bedded, medium-grained sand and gray, silty, lignitic clay. Fossils in the Coal Bluff are similar to those in the Matthews Landing Marl. The key macrofossils in the Coal Bluff member are the bivalves *Venericardia wilcoxensis* and *Cucullacea macrodonta*. The type location of the Oak Hill member is the Oak Hill Post Office, Wilcox County, Alabama. Generally the Oak Hill is comprised of 100-125 feet of gray, carbonaceous, micaceous, laminated silt and clay interbedded with cross-bedded sand. One or two beds of lignite generally occur near the top of this member. At Coal Bluff on the Alabama River there is a four-foot thick lignite bed at the top of the member. The Oak Hill thins greatly east of Wilcox County, and is generally absent east of Butler County. The member is generally unfossilferous, but at Coal Bluff on the Alabama River, a bed of *Ostrea crenulimarginata* is present about 20-feet below the top of the member. The Naheola Formation conformably overlies the Porter's Creek.

Porters Creek Formation

The type locality is along Porters Creek, in Hardeman County, Tennessee. In northern Mississippi it is about 200-feet of dark-yellowish-brown to dusky-brown massive marine clay.

The upper 3-6 feet of the formation in Alabama is a green to gray, fossilferous, glauconitic sand and marl, identified as the Matthews Landing Marl member. The thickness of the Matthews Landing Marl member increases to about 20-feet at its type locality on the Alabama River in Wilcox County, Alabama. At the type locality, 38 types of mollusks have been collected. The key macrofossil found in the Porters Creek is the bivalve *Venericardia wilcoxensis*. In southwestern Alabama, the Porters Creek consists primarily of 350-450 feet of black, massive clay. Along the Tombigbee River in Sumter and Choctaw Counties, Alabama, it is about 400 feet thick and consists almost entirely of massive marine clay containing a few thin glauconitic sand beds and ferruginous concretions, especially in the upper part. These beds thin eastward in south-central Alabama and in southeastern Alabama they are included in the Clayton Formation. The Porter's Creek conformably overlies the Clayton Formation in southwestern Alabama.



Schematic diagram showing lithofacies changes in the Porter's Creek Formation in southern Alabama.
(from Mancini and Tew, 1989)

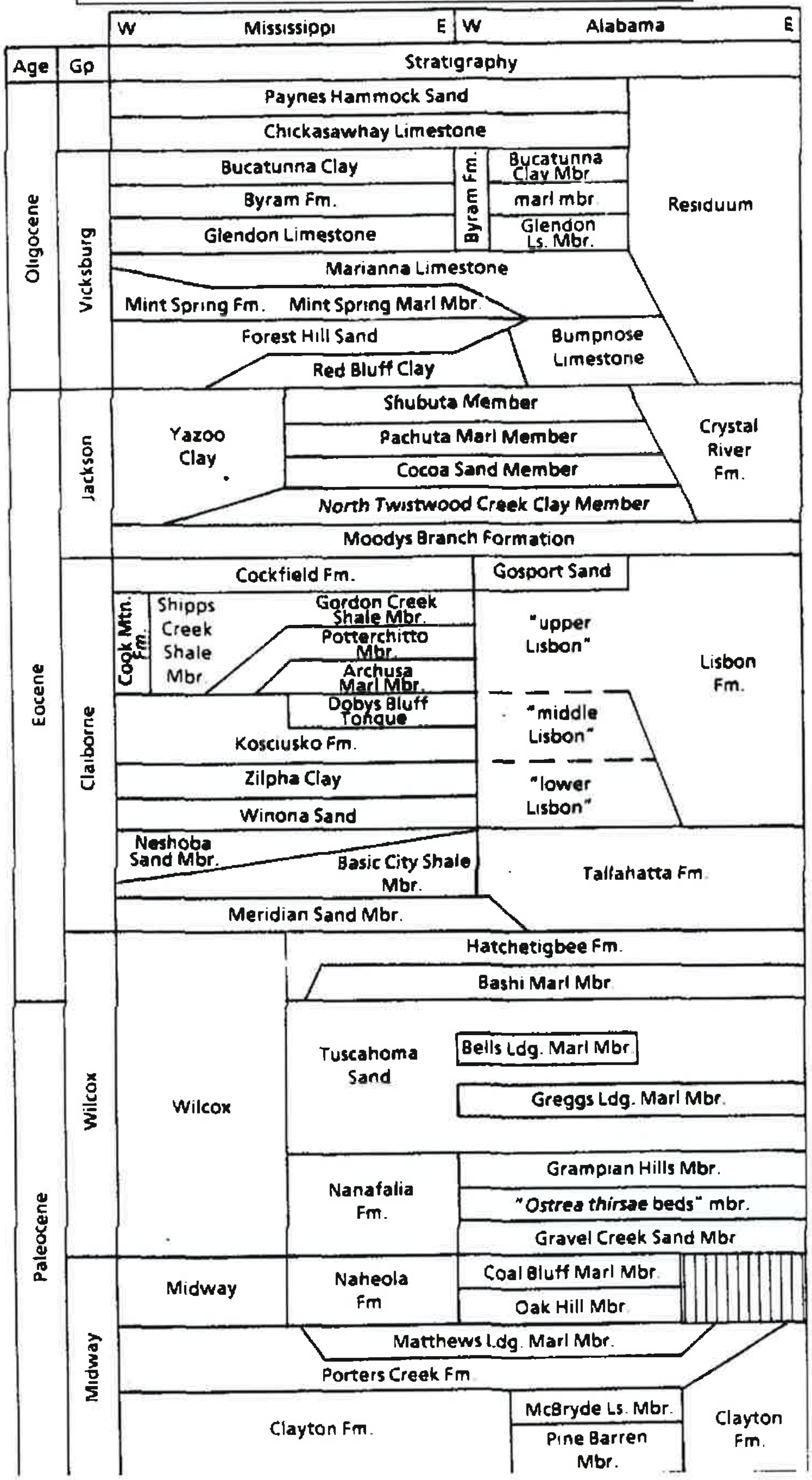
Clayton Formation

At the type locality of the Clayton Formation in eastern Alabama the formation consists of coarse-grained yellow sand resting on the eroded surface of the upper Cretaceous. Throughout most of the area of outcrop in eastern Alabama is Clayton is deeply weathered and leached. The best and most complete section is now under water along the Chattahooche River, behind the George Dam. The Clayton Formation is less than 20-feet of marl and limestone in southwestern Alabama (Choctaw County), but thickens to almost 200-feet in south-central Alabama, where it is divided into an upper McBryde Limestone mbr (~50-feet) and a lower Pine Barren mbr. (~150-feet). The McBryde is a sandy, argillaceous limestone and marl at its type locality at McBryde Station, Wilcox County. The most conspicuous fossil is the nautiloid

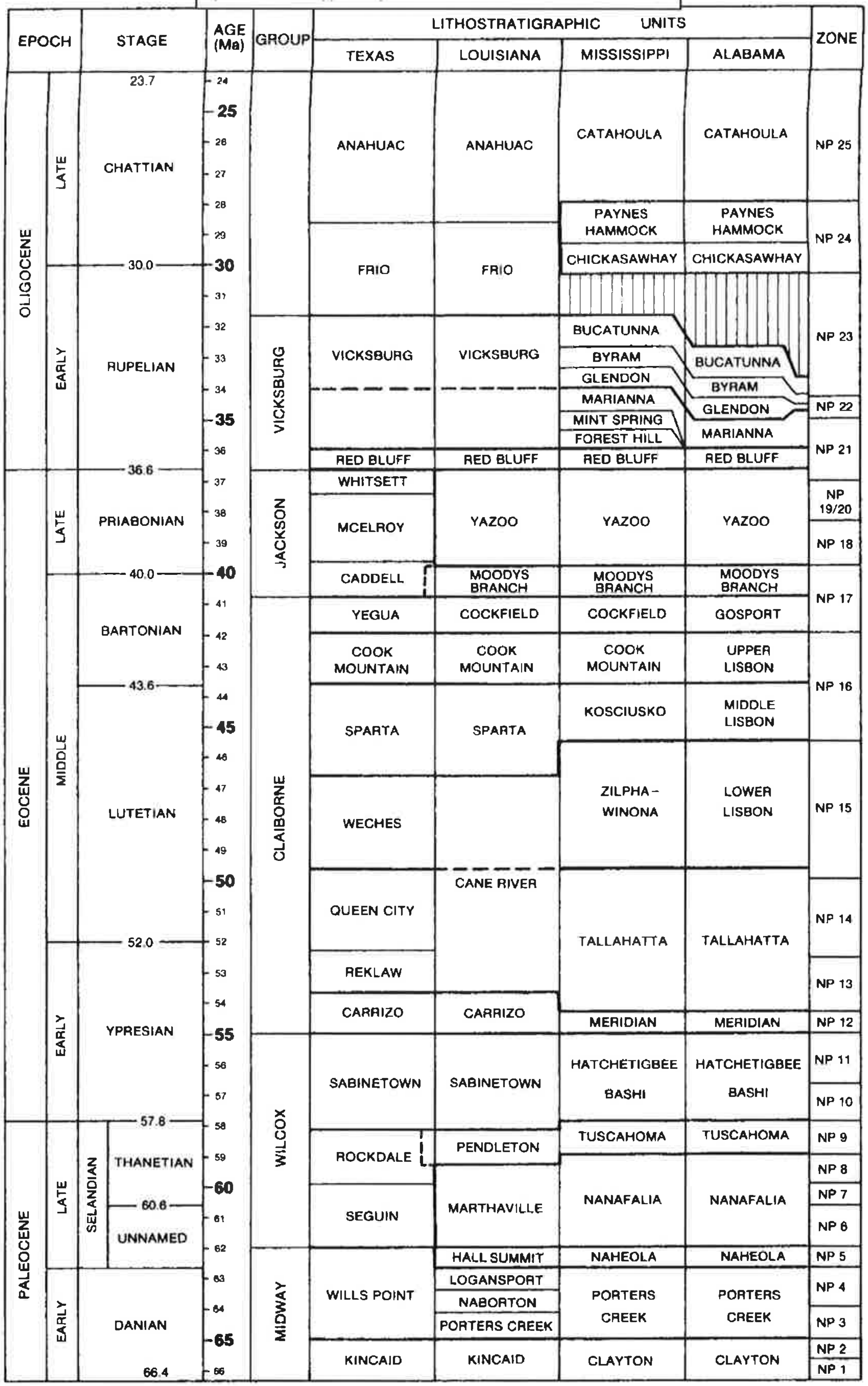
Hercoglossa ulrichi, leading to the informal designation of this bed as the "*Nautilus* rock". The Pine Barren (type locality, Pine Barren Creek, Wilcox County) is comprised of alternating indurated and soft beds of light gray calcareous silt containing abundant foraminifera and in places *Ostrea crenulimarginata* and molds of *Venericardia* species, overlain by sand and sandy limestone (at the top). A distinctive, very fossilferous, sandy limestone, called the '*Turritella* rock' occurs at the top of the Pine Barren member in south-central Alabama. The Pine Barren member thins to ~55-feet in western Wilcox County, and is not present in western Alabama. West of Wilcox County the entire Clayton thins to less than 30-feet and it is comprised of light-gray to white clayey chalk or marl containing abundant foraminifers and the bivalve *Ostrea pulaskensis*. Coarse grained sandstone occurs at the base of the Clayton in several localities (Moscow Landing, Shell Creek, Millers Ferry). The composition of this sand includes reworked Cretaceous fossils, coarse-medium sand, limestone clasts, and calcite filled spherules. This bed has been interpreted as including part of the fallout from the Chicxulub bolide impact (spherules) and being deposited/reworked by tsunamis generated by that impact. Key macrofossils occurring in the Clayton Formation include 1) the oysters *Ostrea pulaskensis* and *Ostrea crenulimarginata*, 2) other bivalves V*enericardia smithii, Pitar ripleyanus,* and *Jupiteria smirnia*, 3) the nautiloid *Hercoglossa ulrichi,* and 4) the gastropod *Turritella mortoni*. The Cretaceous-Tertiary boundary is placed at the base of the Clayton Formation based on diagnostic microfossils and macrofossils. The Clayton Formation disconformably overlies the Maastrichtian Prairie Bluff Chalk.

K/T boundary (red arrow), Moscow Landing

Paleogene Correlation Chart – Mississippi & Alabama
(from Mancini & Tew, 1990)

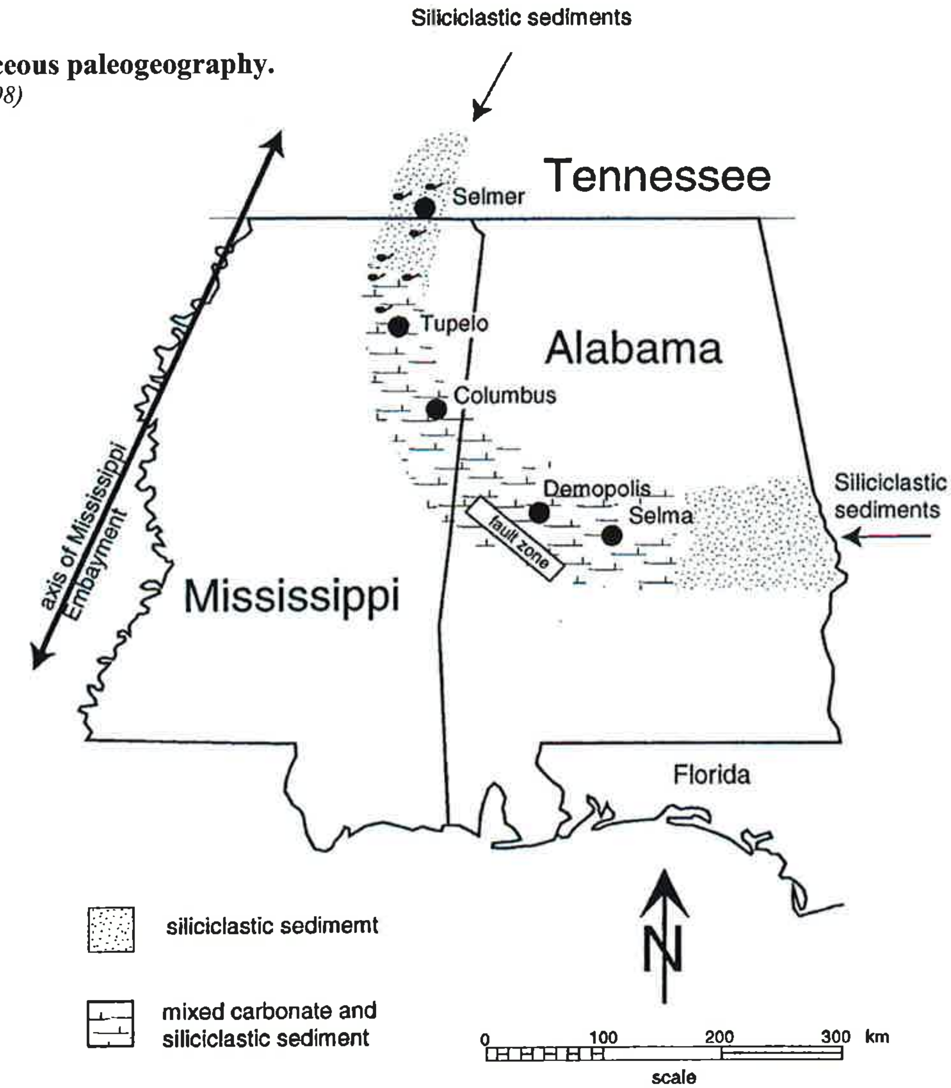


Paleogene Correlation Chart
Texas, Louisiana, Mississippi, and Alabama
(from Dockery, 1998)



Cretaceous-Maastrichtian

Generalized Late Cretaceous paleogeography.
(from Mancini and Puckett, 1998)



The Upper Cretaceous section includes marginal marine and marine siliciclastic and carbonate sediments. The only strata of the Upper Cretaceous seen on this trip are the Ripley and Prairie Bluff Chalk Formations. Both of these units are considered to be deposited in tidal and coastal shoreline to shelf environments.

Prairie Bluff Chalk

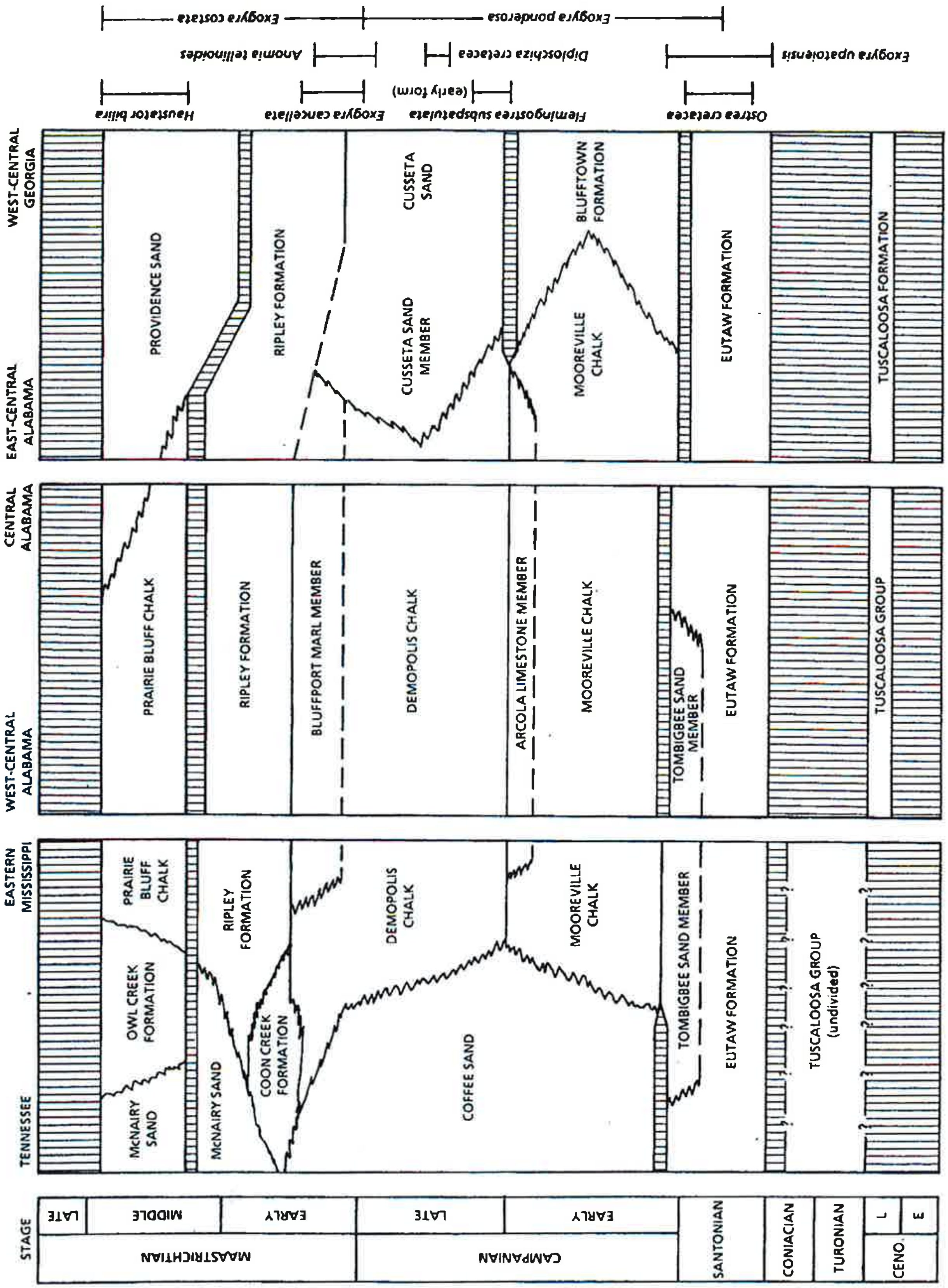
The Prairie Bluff Chalk is the uppermost formation of the Selma Group. It unconformably underlies the lowest Tertiary strata (Clayton Formation). At its type locality in northwestern Wilcox County, the formation is ~11-feet thick, but in other parts of Marengo and Wilcox Counties, it is missing. This variability in preserved thickness along outcrop is due to post-Cretaceous erosion, which in some places has completely cut out the Prairie Bluff and the lower Tertiary rests on the Ripley Formation. In western Alabama and northeastern Mississippi the

Prairie Bluff Chalks consists of 70-90 feet of massive, compact, white chalk with varying amounts of quartz sand. The Prairie Bluff thins and becomes increasingly sandy and micaceous in the eastern part of Alabama. Key fossils identified in this formation include the oyster *Exogyra costata*, the burrowing sponge *Cliona* sp., and the bivalve *Diploschiza melleni*. Abundant external casts and molds of numerous types of gastropods and bivalves are common on Prairie Bluff outcrops.

Ripley Formation

The Ripley consists of highly calcareous, micaceous, quartz sand and sandstone which rest unconformably on the underlying Demopolis Formation. The thickness of the Ripley is highly variable in southwestern Alabama, ranging from ~70-feet in the town well at Livingstone to a thickness of 220-feet, eight miles to the east of Livingston, along the Tombigbee River. The large variation in thickness is due to structural complications in the area. Faunal changes also occur from west to east along the Ripley outcrop. In western Alabama the *Exogyra cancellata* zone occurs about 5-feet below the base of the Ripley, but in the central part of the state and eastward, the base of the formation lies near the middle of this faunal zone. The sandstone of the Ripley Formation exhibits considerable topographic relief. The High Ridge cuesta is developed on the resistant strata of the Ripley across Alabama.

References for this section include:
Tolson (1985), Jones (1967), Mancini and Tew (1988), Mancini and Tew (1990), Beg (1992), Toulmin (1940), Toulmin (1977), Mancini (1984); Mancini and Puckett (1998).



Generalized correlation chart – Upper Cretaceous sediments.
(from Mancini and Puckett, 1998)

II.A.b. Sequence Stratigraphy

The Paleogene strata of southern Alabama accumulated as depositional sequences of terrestrial, marginal marine, or marine continental shelf deposits that reflect cycles of marine transgression and regression with accompanying retrogradation and progradation of the shoreline. Continental slope and basin deposits are not present in this relatively updip stratigraphic section. The sequences are bounded by stratigraphic discontinuities (sequence boundaries) which are typically developed as erosional or transgressive disconformities. Depositional sequences are based on the lower sequence-bounding surface. In southern Alabama the characteristic components of depositional sequences can be recognized in the Paleogene strata. The Type 1 depositional sequence generally consists of the following; 1) basal Type 1 unconformity, 2) lowstand systems tract shelf deposits, 3) transgressive, upward-deepening transgressive systems tract deposits, which may grade up into a condensed sections with associated surface of maximum sediment starvation/maximum transgression, 4) upward-shallowing highstand systems tract deposits, and 5) an upper Type 1 or Type 2 sequence boundary. Type 2 sequences differ in that the basal surface is a Type 2 boundary and the lowstand component is replaced by shelf margin systems tract deposits.

Lowstand systems tract shelf deposits of Type 1 depositional sequences are typically discontinuous, but regionally extensive, intervals of marine sandstone that fill topographically low areas on an eroded Type 1 boundary. These strata have been referred to as 'incised valley fill'. Off-shelf lowstand sequence components, such as deep-sea fans and slope-front fill are not represented in the Paleogene of southern Alabama. Typically these deposits consist of cross-bedded, bioturbated, quartz sandstone in southern Alabama. This sandstone generally contain reworked microfossils, detrital glauconite grains, and sediment clasts and are commonly texturally immature, comprised of poorly sorted and subangular quartz grains. Where these deposits are absent the sequence boundary is usually highly burrowed.

Lowstand shelf sediments are typically overlain by a disconformity that is typically marked by sediment clasts, quartz pebbles, phosphate grains, shell hash, and shark teeth. The transgressive deposits overlying this surface contain reworked fossils, detrital glauconite, and angular quartz grains.

Shelf margin system tract deposits are generally the lowermost depositional component of the Type 2 sequence in the field trip area. These deposits are typically of limited aerial distribution. Marine-shelf, glauconitic, fossilferous sandstone and sandy fossilferous limestone characterize the shelf-margin systems tract, and generally these strata are typically less than 50-feet in thickness in southern Alabama. The shelf-margin limestones represent a high-energy environment and contain angular quartz grains and broken fossil fragments.

Transgressive system tract deposits overlie either lowstand shelf deposits (Type 1 sequence) or shelf margin deposits (Type 2 sequence). In areas where the lower sequence components are not present, the transgressive deposits directly overly the basal sequence boundary. Transgressive deposits are rich in detrital glauconite and fossils, and represent lithofacies deposited in moderately high energy inner to middle shelf environments. Commonly, thin beds of glauconitic sandstone and marlstone comprise this systems tract, but calcareous claystone, siltstone, and limestone are also recognized.

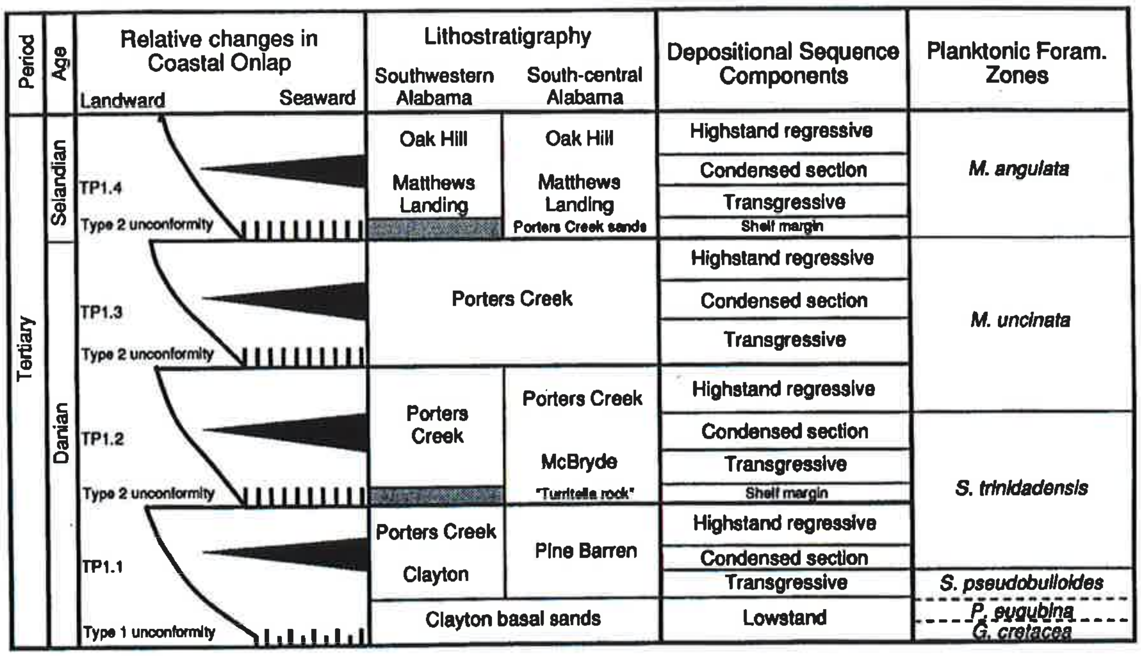
The transition from transgression to regression is commonly within a condensed section, which reflects sediment starvation on the shelf associated with maximum water depths. Condensed section deposits consist of marine-shelf calcareous claystone, marlstone, and/or limestone, are generally less than 10-feet thick, and typically are rich in authigenic glauconite and phosphate. The surface of maximum sediment starvation (minimum sedimentation) within the condensed section represents the inflection point between overall transgression and overall regression in the depositional sequence, and is usually marked by extensive burrowing or boring, and/or a concentration of glauconite, phosphate, quartz grains and/or fossils that have been bored or encrusted with sponges, serpulids, etc.

The highstand systems tract deposits either overlie the upper part of the condensed section or the transgressive deposits, depending on the position of the paleoshelf. Highstand deposits include terrestrial and marginal marine sandstone, siltstone, claystone, and/or lignite beds and represent progressive shallowing of water depths. Organic content in these deposits is well preserved and consists primarily of structured terrestrial mater. (Whereas, the organic content in the transgressive and condensed section is amorphous, nonstructured, and degraded). Sandstones associated with these deposits is typically fluvial or deltaic in origin and is texturally immature to submature, having poor to moderate sorting and containing angular to subangular quartz grains. These deposits are typically micaceous and carbonaceous and generally exceed 100-feet thickness in southern Alabama.

Five global supercycles have been reported for the Paleogene. Lowstand shelf deposits of the lower Clayton overlie progradational, highstand regressive deposits of the Upper Cretaceous Prairie Bluff Chalk. The Ta supercycle includes the Clayton Formation, Porters Creek Formation and the Naheola Formation (Midway Group). The Wilcox Group coincides with the Tb supercycle and consists of Nanafalia, Tuscahoma, and Hatchetigbee Formations. The Type 1 unconformity at the base of the Gravel Creek Sand Member of the Nanafalia Formation coincides with the contact between the Midway and Wilcox Groups. The Tc supercycle includes the Tallahatta and Lisbon Formations in Alabama, and the Tallahatta, Lisbon equivalents (Winona Sand, Zilpha Clay, Kosciusko Formation, Cook Mountain Formation), and the Cockfield Formations in Mississippi. The Type 1 unconformity at the base of the Meridian Sand Member of the Tallahatta Formation corresponds to the contact between the Wilcox and Claiborne Groups. The Type 1 boundary at the base of the Moody's Branch Formation in Mississippi and at the base of the Gosport Formation in Alabama separates the Tc supercycle from the overlying Td supercycle. The Claiborne-Jackson group boundary is coincident with the Type 1 boundary at the base of the Moody's Branch Formation. The Td supercycle consists of the Eocene, Moody's Branch Formation, Yazoo Clay, and Oligocene, Red Bluff/Bumpnose, Forest Hill Sand, Marianna Limestone, and the Byram

Formation. The Jackson-Vicksburg contact coincides with a surface of maximum sediment starvation in the Td supercycle. The Type 1 unconformity at the base of the Oligocene Chickasawhay Limestone is the boundary between the Td and Te supercycles. The Te supercycle consists of the Chickasawhay Limestone and the Paynes Hammock Formation.

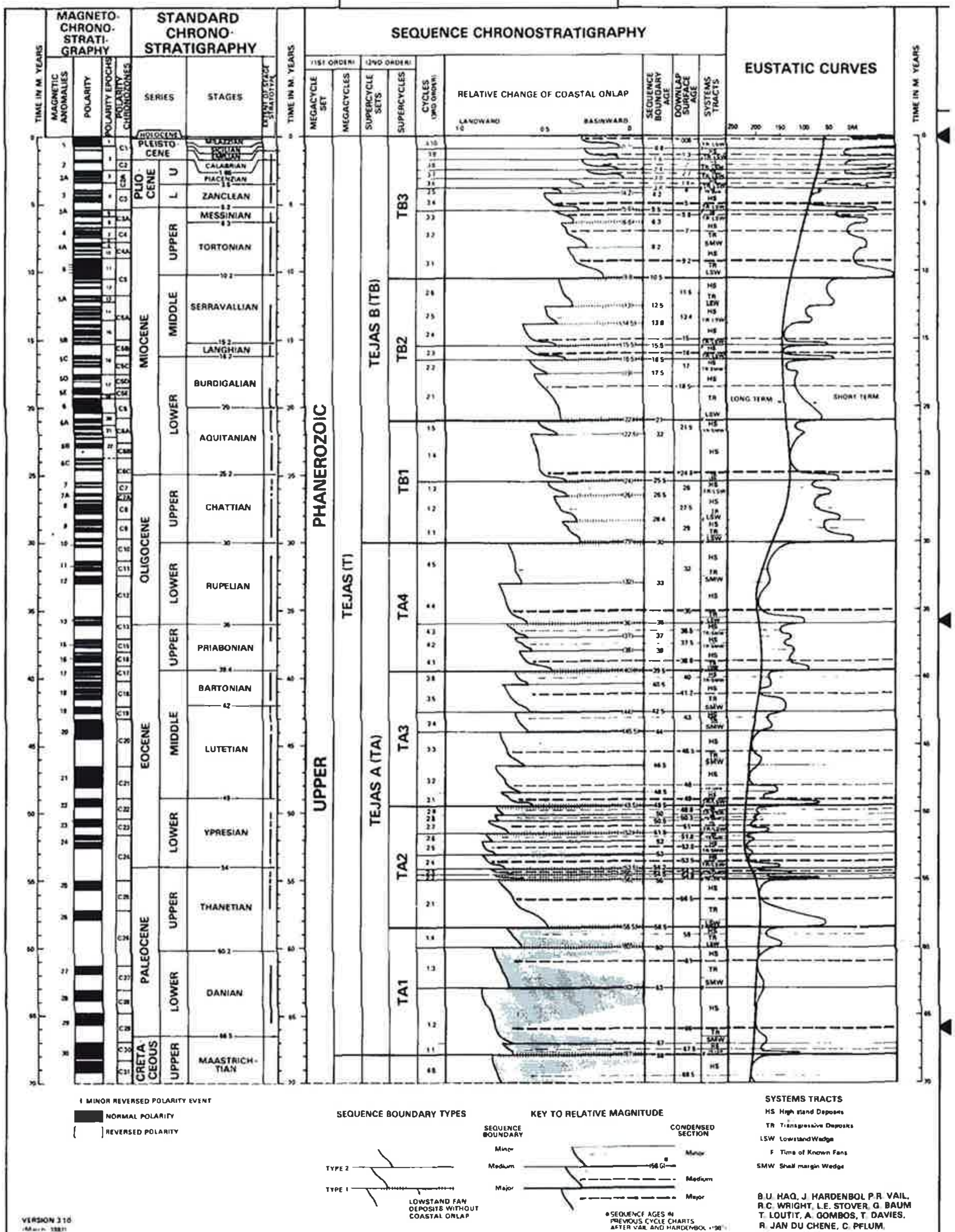
Third order depositional sequences are closely associated with eustatic sea level cycles. Based on regional stratigraphic, sedimentologic, and placontological data, Mancini and Tew (1992) recognize 21 unconformity bounded depositional sequences in southwestern Alabama and southeastern Mississippi. These sequences and their component strata are shown on the following tables.

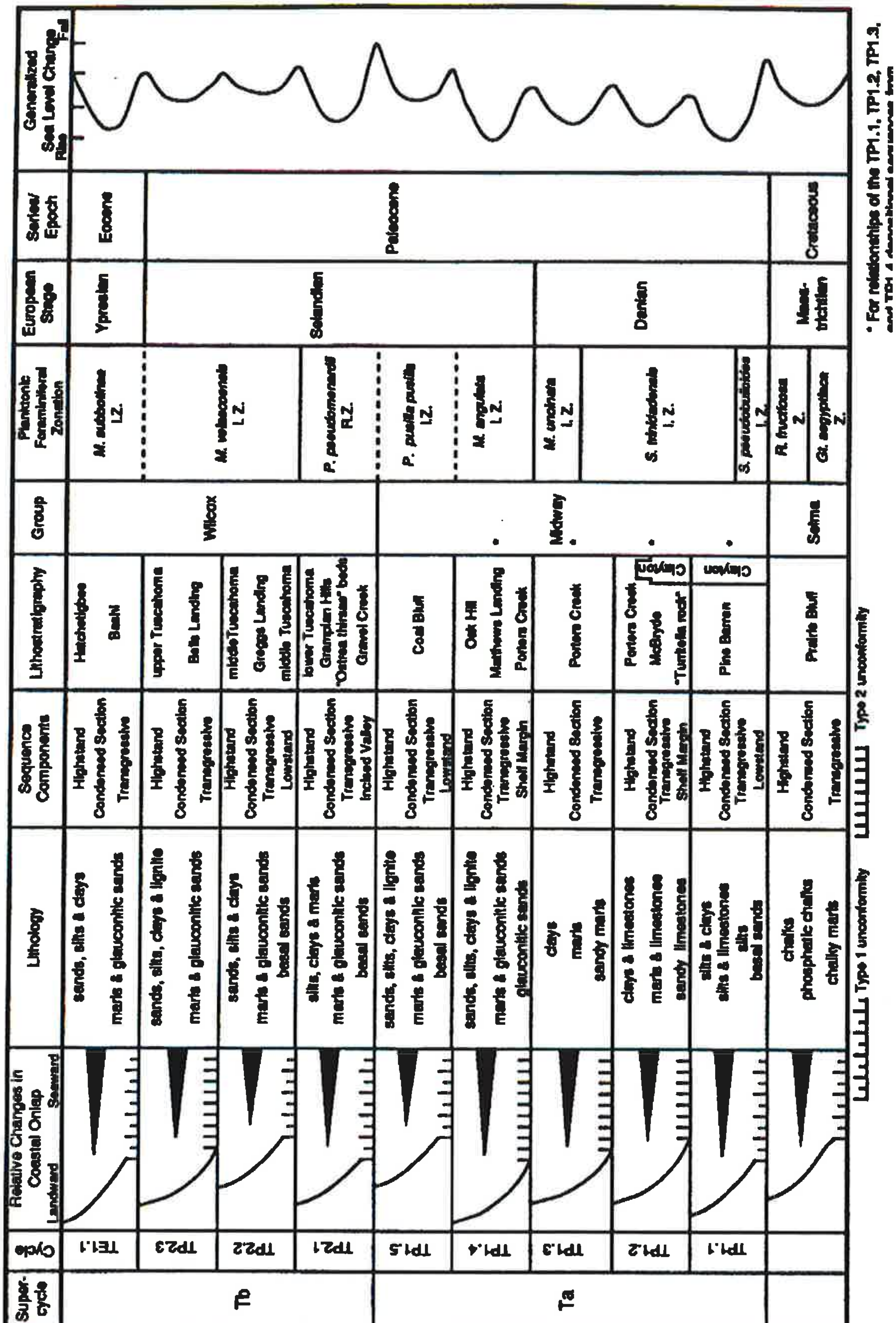


Detailed relationship of the sequences in the Midway Group from southwest to south-central Alabama
(from Mancini and Tew, 1992)

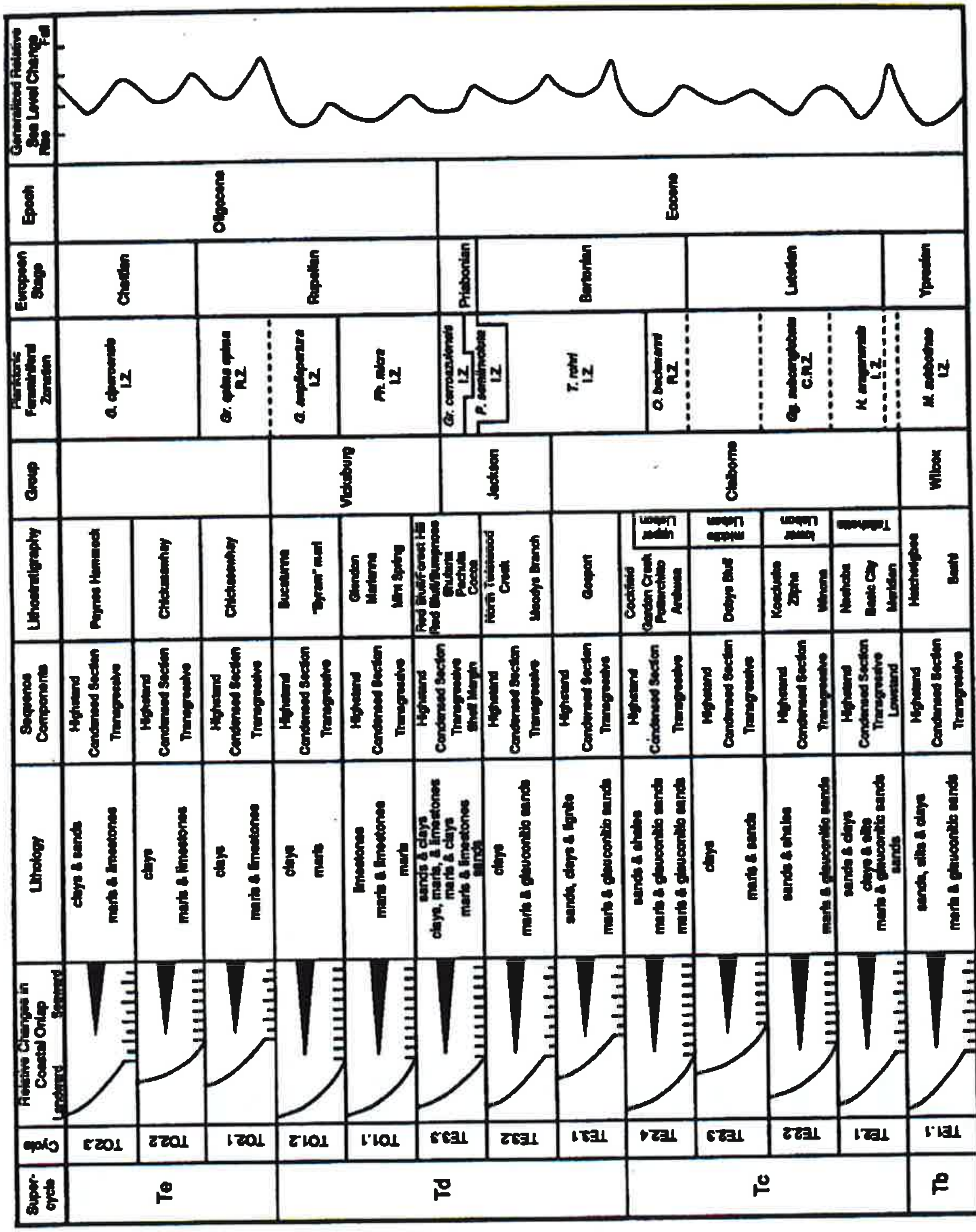
Cenozoic cycle chart.

(from Loutit, et.al., 1988)





Sequence Stratigraphy of Paleocene and Eocene strata
(from Mancini and Tew, 1992)

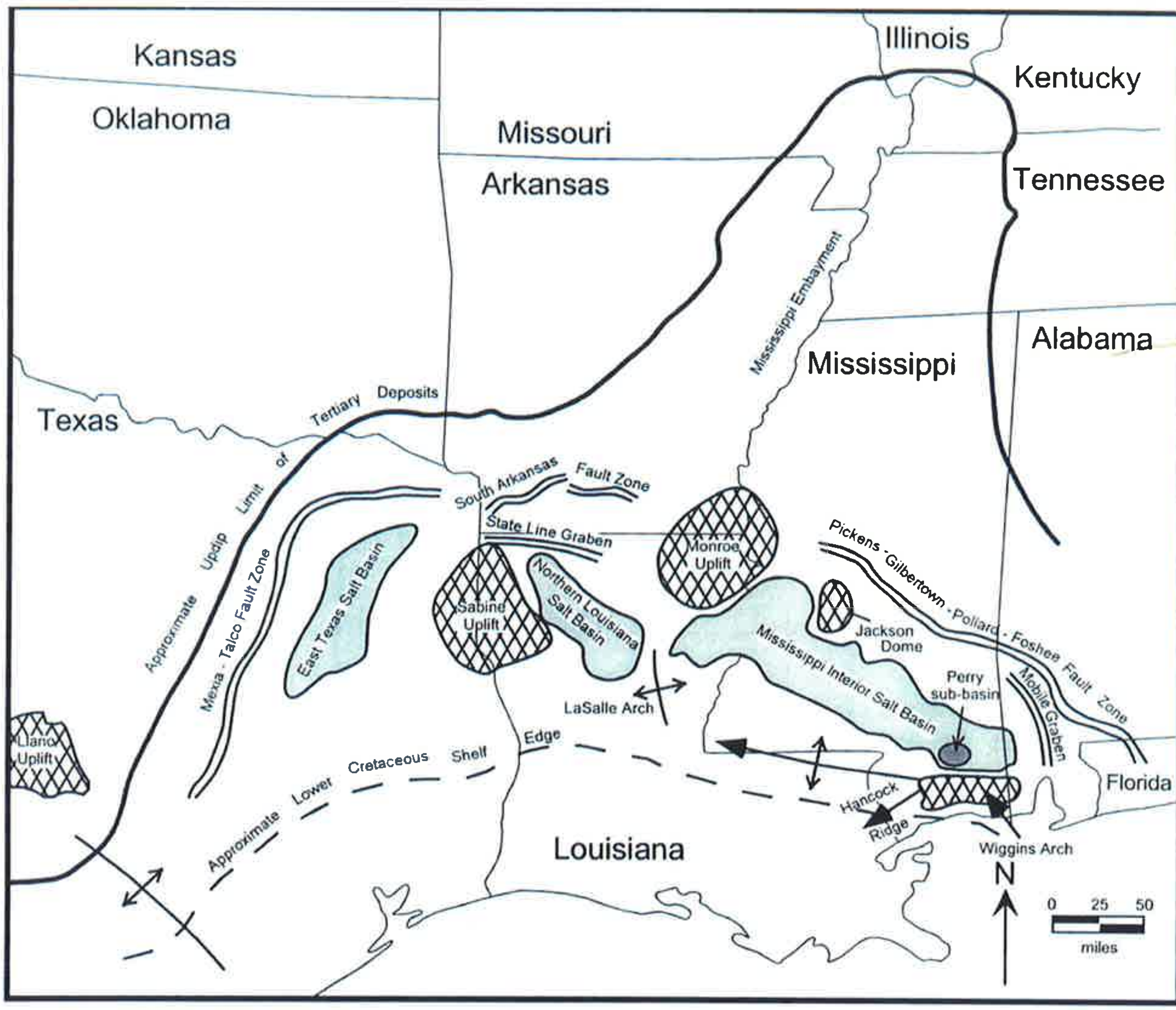


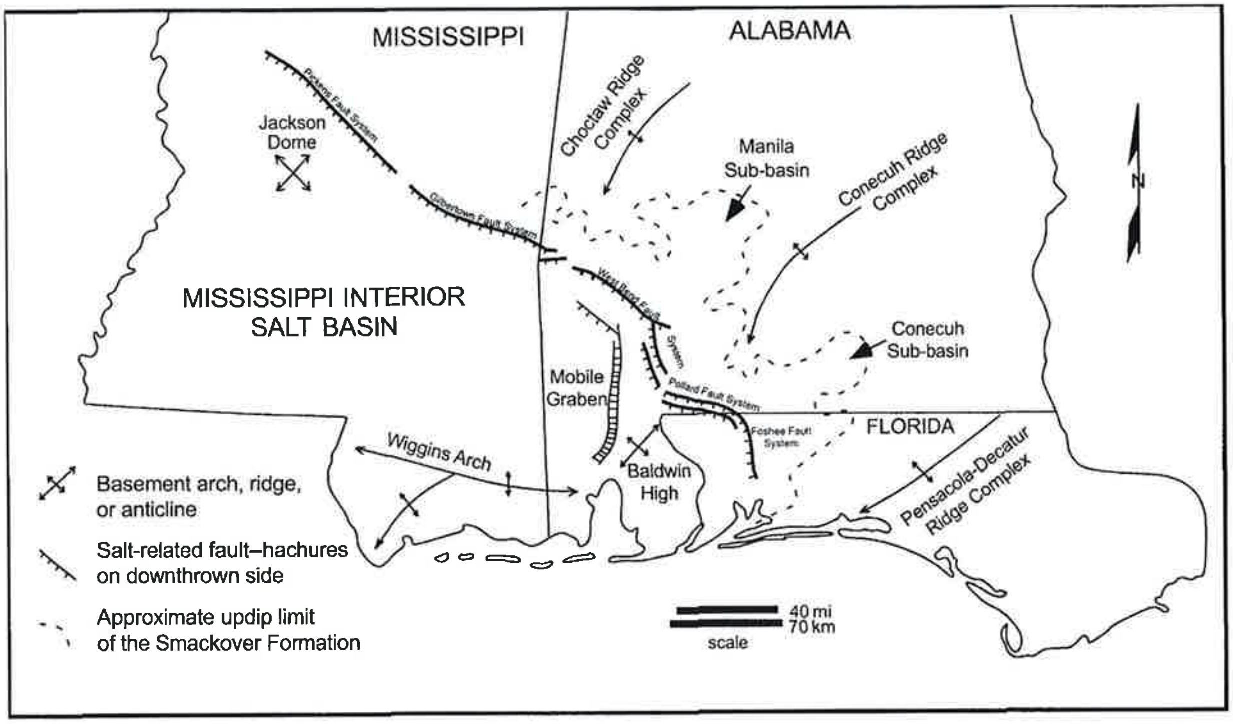
Sequence Stratigraphy of Eocene and Oligocene strata
(from Mancini and Tew, 1992)

II.B. Structure

Major structural features in the eastern Gulf Coastal Plain can be divided in three categories, 1) preexisting positive and negative basement features, 2) features associated with movement of Jurassic salt, and 3) features related to igneous activity. Movement of the widespread Louann Salt (Jurassic) has resulted in a complex network of salt-related structures in the southern and eastern Gulf Coastal Plain. Some have gone so far as to suggest that the structural fabric of most of the northern Gulf margin is the result of salt flowage. Salt related structures include salt diapirs, salt massifs, and related salt-cored anticlines and extensional fault and graben systems. This is a brief outline of the structural features of the Gulf Coastal Plain, with some discussion of features in the area of the field trip.

Structural features of the northern Gulf Coastal Plain
(from Mancini, et. al, 1999)





Structural features of southern Alabama and Mississippi
(from Mancini, et. al, 1999)

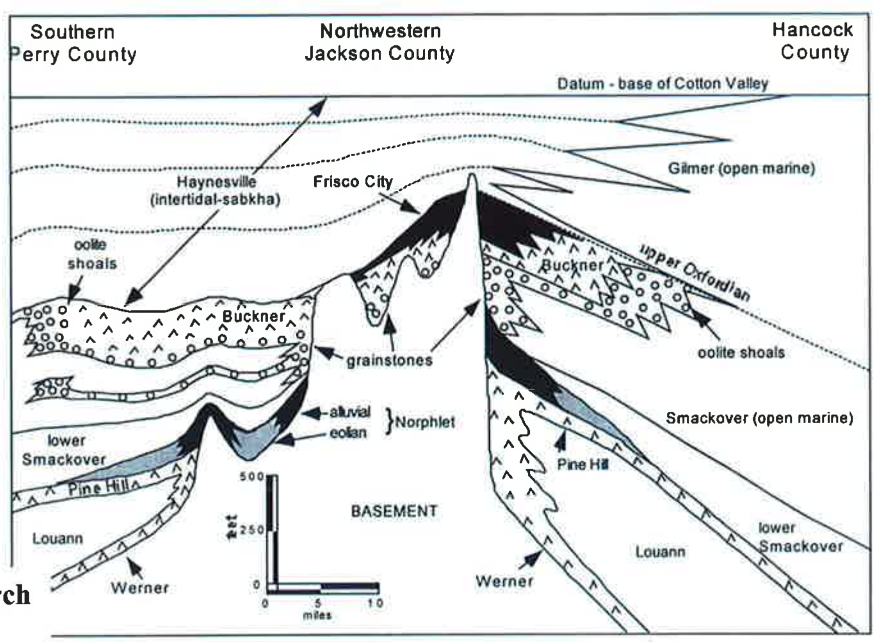
1. Basement features

A. Positive features

There are five major structural elements that have affected Mesozoic and Cenozoic sedimentation in the eastern Gulf Coastal Plain (Wiggins Arch, Conecuh Ridge, Choctaw Ridge, Pensacola-Decatur Ridge, Ocala/Peninsular Arch). These features are possibly related to the Late Paleozoic Appalachian fold and thrust structural trend structural that was generated in the by collisional tectonics. The Wiggins arch has also been interpreted as a remnant of the rifted continental margin of North America.

a. Wiggins Arch.

The Wiggins Arch is defined by on the basis of subsurface data and is typically mapped by the absence of salt and some Jurassic strata over the crest of the structure in extreme southeastern Louisiana and adjacent southwestern Mississippi. It is bounded on the north by the Mississippi Salt Basin and on the south



Cross Section – Wiggins Arch
(from Mancini, et. al, 1999)

by the deep basin of the coastal zone. The Wiggins Arch does not have any conspicuous geomorphic expression, but some workers have used tenuous geomorphic evidence to infer Quaternary movement.

B. Negative features

a. Mississippi Interior Salt Basin

Most of the Mississippi Interior Salt Basin lies within the state of Mississippi, with its southeastern extension in southwestern Alabama. Over sixty piercement salt domes have been identified within the basin, having tops ranging from relatively shallow depths (few hundred feet) to those that are only slightly higher than the top of the Louann Salt (several thousand feet).

b. Mississippi embayment

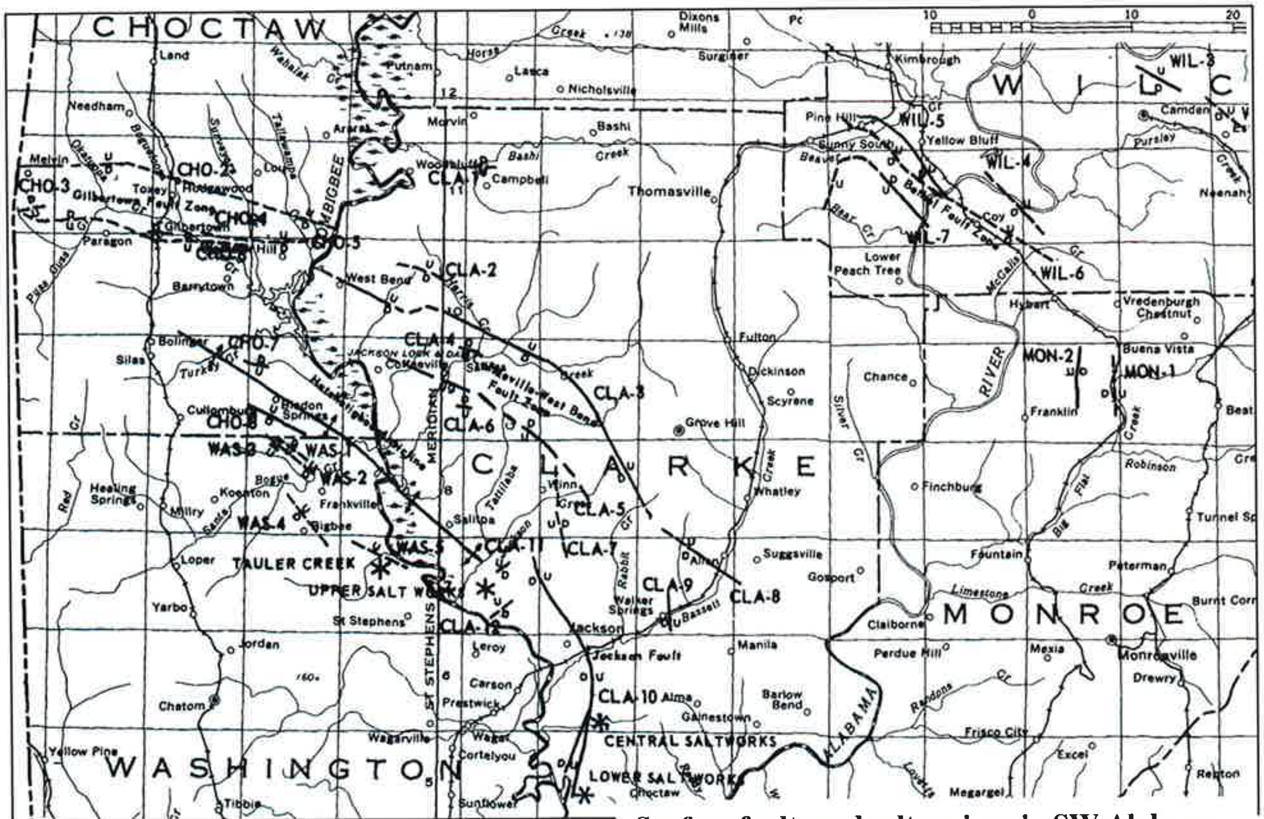
The Mississippi Embayment was a major structural through throughout the Mesozoic and Cenozoic. It has been described as a broad asymmetric synclinal structure that plunges rather steeply toward the Gulf of Mexico. Basement surface elevation in the embayment varies from slightly above sea level in southern Illinois to more than 30,000' below seal level near the present coast of the Gulf of Mexico. The embayment is interpreted to have originated as a Paleozoic megashear system associated with continental collision during the formation of Pangea. The structure subsequently became a zone of incipient crustal weakness, leading to the establishment of a subsiding depositional basin.

2. Features associated with salt movement.

A. Regional peripheral fault system.

In early to middle Mesozoic time, the opening of the Gulf of Mexico formed a south-facing, rifted, passive margin at the southern edge of North America. Subsequently, the rifted margin was buried beneath the thick, Middle Jurassic Louann Salt and an overlying, carbonate and clastic, marine and paralic sequence that continues to accumulate today. Rapid Mesozoic and Cenozoic deposition by large rivers and the resulting enormous thickness of the post-rift sediment pile caused it to collapse and spread seaward. Salt flowed southward and pierced upward and the overlying pile extended on listric, normal, growth faults that flatten downward into detachments in the salt and overpressured shale. These listric normal faults, their splays, and the antithetic and transfer faults make up the belt of gulf-margin faults, known at the regional peripheral fault system.

This is a group of related, largely en echelon extensional faults and grabens associated with salt movement. This system rims the northern Gulf basin from Texas through southern Arkansas, through the south-central part of Mississippi and into southwestern Alabama and is the most pronounced structural system in the area. The eastern Gulf portion of the system is knows as the Gilbertown-West Bend-Pollard-Foshee segment. The faults, which are parallel or subparallel to regional strike, correspond to the updip limit of thick Jurassic salt and generally offset Jurassic through Eocene strata. There have been literally hundreds of individual faults identified in this fault zone. Faults are normal up- or down-to-the-basin faults which form grabens that are generally 5 to 8 miles across. Fault planes tend to flatten with depth and exhibit dips from ~35° to 70°. Displacements on the major faults range from ~200-feet to over 2000-feet. The major displace is concentrated in Cretaceous age strata. There is also some minor movement recorded into the Miocene.



Surface faults and salt springs in SW Alabama

(from Copeland, et. al, 1976) * = salt spring

a. Pickens-Gilbertown-West Bend-Pollard-Foshee Fault Zone

These faults represent the Alabama portion of the peripheral fault complex that rings the northern part of the gulf coastal basin from Texas to Florida. These faults occur near the up dip limit of the Louann Salt. In extreme south Alabama and in the Florida panhandle, faults zones are only detected in the subsurface. In Clarke and Washington counties, and counties to the north, faults can be observed on the surface. Displacement on these faults generally ranges from less than 100' to a maximum of about 200'. At Gilbertown the faults have a maximum surface displacement of about 150', but in the subsurface, displacement of the Eutaw Formation ranges from 350-900' at depths between 3500-4000'. Contemporaneous deposition results in increased thickness of sediments in the downthrown faults.

b. Mobile Graben – Jackson Fault.

The Mobile graben is a complex, north-south oriented fault system extending from Jackson, Alabama to Mobile Bay. The Jackson Fault is the northernmost fault on the east flank of the graben system. Movement along faults within this system possible resulted in the confluence of the Alabama and Tombigbee Rivers and the formation of Mobile Bay. The major fault representing the western flank of the graben opposite the Jackson fault has not been penetrated (1968), suggesting the northern part of the structure is only an 'half-graben', where the Jackson fault comprises the eastern flank of a structural low. Mobile Bay doesn't exactly fit the fault trend of the system. The graben, as defined by well control, turns westward, north of Mobile Bay, however topographic escarpments along the east coast of the bay are indicative of faulting and it is possible that the escarpment represent minor en echelon faults in the Mobile Bay graben system. The system has been a highly mobile zone since late Mesozoic.

The Jackson fault is about 18 miles long, with a general northerly trend from it known southern extent to a point northeast of Jackson, Alabama. At the northern end it merges with the southeastern end of the Hatchetigbee Anticline and the Klepac Dome. It is downthrown to the west, and in the vicinity of Salt Mountain has a minimum displacement of 1350-feet. In the subsurface, the fault exhibits approximately 5,000-feet of displacement at a depth of 2450' where it was penetrated by the Champion-Klepac #1 well (drilled in 1955). This large amount of displacement could have resulted from subsidence related to salt removal. The salt being removed to supple the domal growth of the Klepac Dome. The Klepac dome is a high-relief domal structure with deep, nonpiercing salt dome at it core. The salt core was penetrated at 11,180' by the Champion-Klepac #1 well. From top of salt, the well penetrated another 4170 of salt to a total depth of 15350'

B. Salt-related structures.

a. Hatchetigbee anticline

The Hatchetigbee anticline is a broad, elongate, asymmetric structure which extends some 30 miles southeast from the Mississippi state line across the southern 1/3 of Choctaw County and the northeast corner of Washington County into west-central Clark County. The Hatchetigbee Formation is the oldest formation exposed at the surface in the breached crest of the anticline. Sediments as young as the Oligocene discontinuously surround the structure. Dips are steep on the SW flank of the anticline, reflecting the combined effect of normal down-to-the basin faulting and basinward downwarping. On the northeast flank dips are relatively gentle, accentuated somewhat by the down-to-the-northeast faults of the Coffeeville-West Bend Fault Zone. A gravity minimum occurs over the anticline suggesting it is has a salt core. A well drilled on the anticline bottomed in an evaportie/red bed sequence of the Haynesville Formation at ~13,500'. The surface expression of the Hatchetigbee Anticline is responsible for the excellent exposure of the marine Paleogene section in southwestern Alabama.

b. Piercement domes

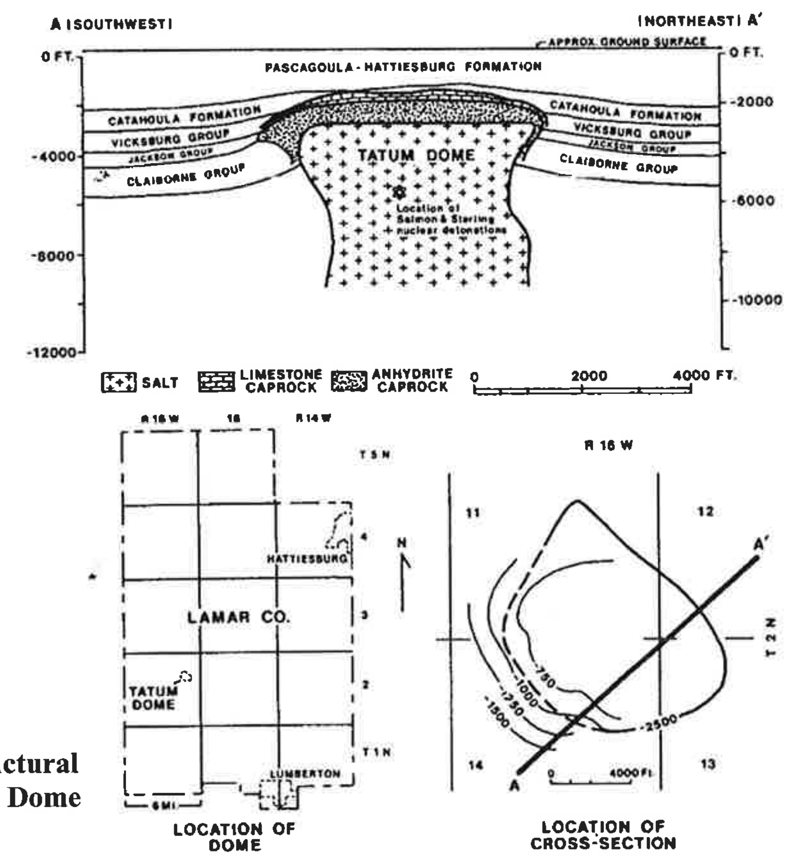
Over sixty piercement domes have been identified within the Mississippi Interior Salt Basin, with tops ranging from relatively shallow depths (722-feet, Richton Dome, Perry County, Mississippi; 410-foot, McIntosh Dome, Washington Co., Alabama) to those that are only slightly higher than the top of the Louann Salt (~20,000-feet subsurface). Piercement domes have been utilized in numerous ways over the years. This has included conventional mining for salt, solution mining for brine feedstock for chemical industries, storage of oil (government) and natural gas (commercial), and for nuclear research. In the area of the field trip we travel close to several domes in the southeastern part of the Mississippi Interior Salt Basin. In the late 1950's the Federal Government chose Tatum Dome, near Hattiesburg, as the site for a series of experiments involving the explosion of nuclear devices. Later in the early 1980's the DOE recommended three salt domes (Lampton, Cypress Creek, Richton) in the Mississippi Interior Salt Basin as potential sites for a national nuclear waste repository. By the late 1980, federal efforts to establish a nuclear waste repository was focused on the Yucca Mountain site, in Nevada, and interest in nuclear waste disposal in Gulf Coast salt dome waned. Recently, the Richton Dome has been chosen as a site for expansion of the National Strategic Oil Reserve, and a commercial company has announced creation of additional caverns in the McIntosh Dome for natural gas storage.

1. McIntosh Dome - Alabama

The McIntosh Salt Dome is the shallowest piercement salt dome in the Mississippi Interior Salt Province. The dome pierces Miocene sediments within 410 feet of the surface, and is approximately 1-mile in diameter. Discovered in 1945 by Gulf Refining Company, the dome was developed for chemical production by Olin Mathieson. The McIntosh salt dome is the most prominent shallow salt structure in southwest Alabama. Bay Gas Storage Company is planning to carve out a pair of new natural gas storage caverns in the salt dome. The two caverns will have a total capacity of 10 billion cubic feet of natural gas. Bay Gas currently operates two caverns in the McIntosh salt dome and is nearing completion of a third. The two existing caverns are operating at their full capacity of more than 6 billion cubic feet. The third cavern now under construction will add another 5 billion cubic feet when it is completed next summer (2007), according to the company.

2. Tatum Dome – Mississippi

Tatum Dome in Lamar County Mississippi, about 22 miles southeast of Hattiesburg. Top of salt is about 1970 feet below the surface. Limestone/anhydrite caprock overlie the almost horizontal top of the salt stock. Almost 1000-feet of caprock was identified in the first well (#1 Tatum Lumber Company, drilled in 1940) to penetrate the top of the dome. In 1958 the Federal Government began a series of experiments involving the detection of nuclear detonation (code named Vela). Initial site selection work was done during 1951 by the US

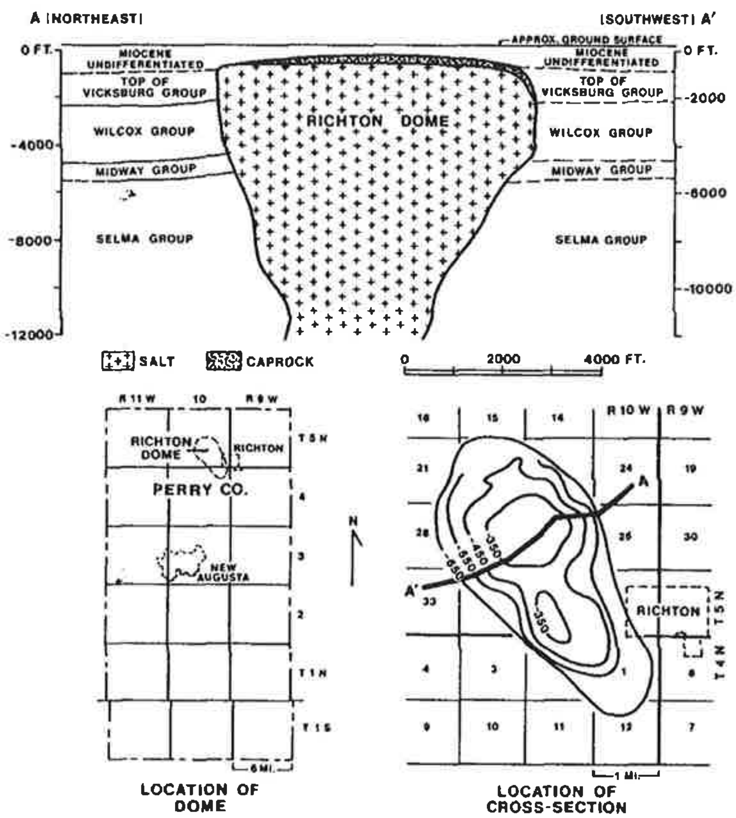


Cross section and structural contour map – Tatum Dome
(from Swann, 1989)

Bureau of Mines, and resulted in several salt domes in Mississippi, with Tatum dome, near Hattiesburg, eventually being chosen as a site for Project Dribble. Project Dribble involved the explosion of two nuclear devices within the dome, and subsequent measurement of the seismic signature of the blasts. The first blast was called the Salmon Event, and it involved the detonation of a 5.3 kiloton nuclear device in a borehole, 2700 feet below the surface. The explosion formed a roughly spherical cavity with a radius of about 57-feet. The second detonation was called the Sterling Event, and it had a yield of 0.4 kiloton. Re-entry after the second event retrieved radioactive salt from the bottom of the cavity, and several feet into the floor of the cavity. Rubble samples were described as yellow to white (minor radiation effects) to yellow to red-brown (increased radiation effects). As of 1968 the description of the core from the floor of the cavity was classified.

3. Richton Dome – Mississippi

During the early1980's the US DOE recommended three salt domes (Richton, Lampton, and Cypress Creek) in the MISB as potential sites for a national nuclear waste depository. Eventually, two domes Richton and Cypress, were identified as two potentially acceptable sites for nuclear waste. After further assessment, Richton Dome was considered along with other sites in Nevada, Texas, Louisiana, Utah, and Washington, as a possible site for a national nuclear was depository. But, by 1988, congress had determined the nuclear waste disposal site efforts were to be focused on the Yucca Mountain site in Nevada, and interest in Gulf Coast salt domes waned. Recently Federal interest in Richton Dome has renewed, with the dome being chosen as a new addition to the Strategic Petroleum Reserve. One of the primary reasons this site was chosen over alternatives in Texas and Louisiana was the stated need to diversify the locations of the SPR storage facilities.



Cross section and structural contour map – Richton Dome
(from Swann, 1989)

C. Features related to igneous activity.

1. Jackson dome

The Jackson Dome is a Late Cretaceous volcanic structure which is centered near the city of Jackson, Mississippi. The dome is ~25 miles in diameter and is a high relief, asymmetrical structure which is slightly elongated along the northwest and northeast axes. At the surface the Dome uplifts and alters the outcrop pattern of middle Eocene through Miocene strata, which are exposed around the flanks of the structure.

References for this section include;
Guido (1968); Swann (1989); Crone and Wheeler (2000); Copeland (1968), Mancini and Puckett, (1998), Mancini, et. al., (1999). Copeland, et.al., (1976).

II. C. Paleontology

The eastern gulf coastal plain is noteworthy for the abundance of fossilferous strata and for the excellent state of preservation of fossils in most of the formations.

Foraminifera are the most important protozoan group. They are present in large numbers in glauconitic, sandy shell beds; glauconitic sand marl; calcareous clay, clayey shale, and limestones. The tests are well preserved and easily obtained from the non-indurated sands, marls, and other clayey beds. Foraminifera are good guide fossils in the Coastal Plain and have been extensively used for identification and correlation of strata. Species of the large foraminifera *Discocyclina*, *Lepidocyclina*, and *Nummulites* are especially useful in zonation of both surface and subsurface sections. Genera of the larger foraminifera have separate and distinct geographic-ecologic distributions. *Lepidocyclina, Discocyclina, Pseudophragmina, and Nummulites* are found in glauconitic marl and limestone of the shelf environment in Mississippi, Alabama, western Florida and Georgia. *Lituonella, Coskinolina, Dictyoconus, Gunteria,* and others are found in the limestone beds of the limestone bank environment of peninsular Florida. Throughout most of Cretaceous and Tertiary time peninsular Florida marine faunas have been more closely related to those of the Caribbean than those of the northern Gulf Coast region.

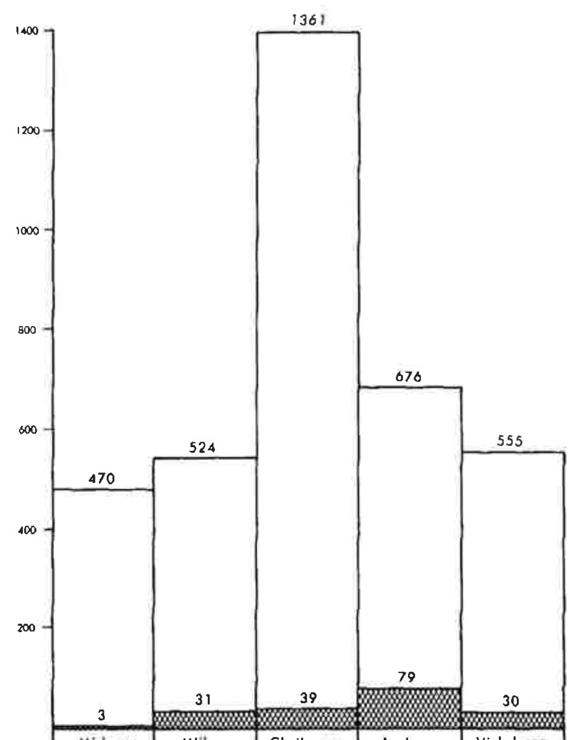
Fossils of early Tertiary sponges are rare in the Eastern Gulf Coastal Plain, and generally unimportant as stratigraphic markers. Fossil evidence of the boring sponge *Cliona* is very common in the Prairie Bluff Chalk (upper Cretaceous), and along with other common and distinctive fossils with it, can be used to distinguish upper Cretaceous strata from superjacent and lithologically similar Paleocene strata. Sponge spicules are present in some beds but have not been used as stratigraphic markers. Siliceous sterraster microscleres of the choristid demosponge, *Geodia* occur in outcrops of the lower Porter's Creek Formation, near Moscow Landing. The occurrence at Moscow Landing is the only reported occurrence in Mesozoic or Cenozoic strata either in the Gulf or Atlantic Coastal Plain.

Corals are the only group of coelenterates (cdinarians) that have been used for stratigraphic correlation in the eastern Gulf Coast. Few colonial corals have been described, but they have limited usefulness for stratigraphic correlation. Solitary corals are much more common and have been widely used. Some strata are characterized by abundant specimens of one, or sometimes more, species of a solitary coral, generating what is called a 'peak occurrence'. These peak occurrences can be used locally in correlations, but the range of the species typically extends through a considerable stratigraphic section and over a large geographic area. Sclerites of alcyonarian corals occur with other microfossils in some beds, but they have not been used for stratigraphic correlation.

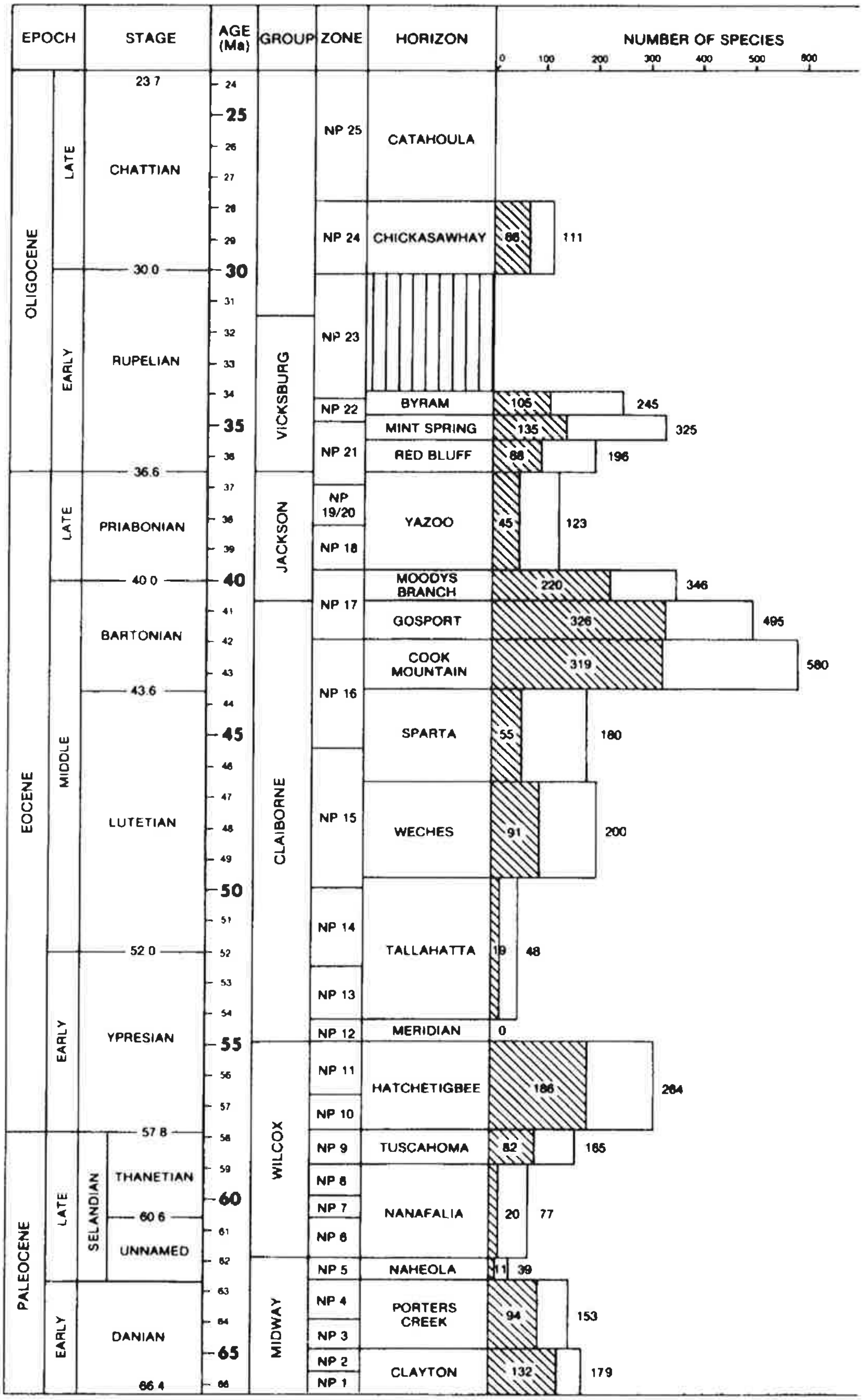
Brachiopods are rare in most Tertiary formations of the Coastal Plain, however some limestone beds, particularly in the Clayton and Salt Mountain Limestone, contain several species. The upper member of the Yazoo Clay and equivalent beds in the Crystal River Formation contains a characteristic species, *Terebratulina lachryma*. Environment seems to have exerted the chief control on brachiopod distribution, and the range of some species may be much greater than the local stratigraphic range (e.g. *Thecidellina cooperi* described from the Salt Mountain Limestone may be a synonym of *T. groenwalli* that ranges throughout the Paleocene in other parts of the world).

Bryozoans are abundant in some formations, especially in the limestone beds. Bryozoans are generally studied and identified microscopically, this along with complex descriptive terminology and general morphology has been factors that have limited their study. Some species found in the marl and calcareous sandy shell beds contribute to the uniqueness of the faunal suites that characterize each assemblage

Mollusks are by far the most abundant and useful megafossils in the Coastal Plain. The primary fossil zones in the surface sections are based on the occurrence and distribution of mollusks. Several groups of pelecypods (bivalves) are especially useful as guide fossils in the eastern Gulf Coastal Plains. Oysters are the most widely used fossils used for zonation, as well as for regional and local correlation. They are nearly the ideal guide fossil for several reasons, 1) they have restricted ranges (most species are restricted to one formation, or to part of one formation), 2) there is a repetition of favorable ecological conditions for oysters occurred frequently throughout the Tertiary, 3) many of the species have a wide geographical distribution, 4) individual specimens tend to be abundant (individuals are so common in some beds as to form oyster-shell coquina), and 5) most of the are distinctive enough to be readily identified by the field geologist. Because the oyster shell is composed of calcite, shells of oysters are commonly preserved even in beds where most of the other mollusks are represented only by molds. Shells of nautiloids, gastropods, and most bivalves are composed chiefly of aragonite and tend to leach faster than calcite shelled organisms. Scallops, (e.g. *Pecten* sp., and related genera) also have calcite shells and are preserved in beds where aragonite shells have been destroyed. Details of their morphological structure such as character and number of ribs have been the basis of establishing numerous species. Various *Pecten* species have been extensively used for stratigraphic correlations. One of the more useful bivalves are species of *Venericardia*, which have been called "guideposts to the Eocene', although it has an extensive post-Cretaceous range and is not limited to Eocene strata. Numerous species have been distinguished on the basis of character and number of ribs and other features. Species of *Venericardia*



Number of molluscan taxa reported from Paleogene groups of the southeastern US. *(from Dockery, 1998)*



Composite section for the Paleogene record of the northern Gulf of Mexico Basin showing the number of molluscan taxa recorded for each horizon.
(from Dockery, 1998)

Are common in Coastal Plain strata, and serve as useful guide fossils. Other stratigraphically useful bivalves include *Corbula, Crassatella, Cucullaea, Glycymeris, Lucina, Nucula, Nuculana,* and *Pitar.* Various species of *Turritella* is the gastropod fossil that is most widely used for stratigraphic correlation. There is considerable variation among species and some are distinctive and easily identified. Several other gastropod genera range through the geologic section and are represented by stratigraphically distinct species or subspecies. These include *Athleta, Bullia, Calyptraphorus, Caricella, Lapparia, Levifusus, Mesalia, Natica,* and *Pseudolivia*. Other mollusks found in coastal plain sediments include two scaphopod genera, *Dentalium* and *Cadulus*. Nautiloids are found in some limestone and calcareous clay beds, but are unknown in most of the strata. Nautiloids are so abundant in the McBryde Limestone member of the Clayton Formation that is has been informally called "*Nautilus* rock'.

Few annelid remain are identified in Tertiary Gulf Coast strata. Calcareous tubes of *Rotularia* are present in some Tertiary rocks, and *Hamulus* is common in some Cretaceous formations. Presumably annelids were as common as seen in similar modern environments, but few built structures that are preserved as fossils.

Crustaceous fossils are the only group of Arthropods generally identified in Gulf Coast Tertiary. Ostracods are the most abundant and stratigraphically significant of this group. They are relatively less important (less studied?) than foraminifera, but the occurrence of ostracods have been determined to have some specific environmental implications. Some of these include salinity, water depth, substrate, and associated plant growth. The most common crustacean macrofossils are relatively common crab claws, legs, and occasional carapaces and barnacles and barnacle plates. *Ophiomorphia* borings are also very common, and are especially conspicuous in soft sediment beneath a diastem representing marine transgression or cessation of deposition. These borings are typically filled with sand and broken shells that accumulate on the sea bottom under new sedimentation conditions.

Several kinds of echinoderm fossils occur in the Gulf Coast Tertiary. Few crinoid stems, arm plates of starfish, fragments of brittle stars, and holothurian sclerites have all been identified, but the echinoids are the most useful for stratigraphic correlations. Echinoids are abundant in most of the limestone beds, and are usually the most important stratigraphic markers in this facies. Entire tests of echinoids are commonly preserved even in beds where fauna with aragonite shells are only represented as molds. Echinoids are common in limestone, chalks, and marls. The sand dollar *Periarchus* was also abundant in a sandy environment. The more advanced, irregular echinoids are more diverse, highly specialized, stratigraphically restricted and common than the regular echinoids, and therefore more useful as guide fossils.

The most abundant vertebrate fossils are teeth of sharks, rays, and swimming reptiles. They are common in many basal sands at the bottom of glauconitic, fossilferous beds. Several genera of shark and ray teeth have been identified, but they tend to be long-ranging, and of little use for stratigraphic correlation. The only early Tertiary marine vertebrate that is common, widely distributed, and stratigraphically restricted so it can be used as a guide fossil is the upper Eocene whale *Basilosaurus cetoides*. Bones of this vertebrate are common in the Pachuta member of the Yazoo Formation and equivalent age strata from Mississippi to Georgia. A jaw fragment of an omomyid primate (vertebrate, mammal) was recovered from the Bashi Marl, in Lauderdale, Mississippi, during the late 1980's. This was the first early Eocene mammal fossil discovered in eastern North America.

References for this section include;
Rigby and Smith, 1992; Toulmin, 1977; Dockery, 1998; Beard and Tabrum, 1990.

III. Road Log

First Day: Lafayette to Jackson, Alabama

0.0	0.0	Mississippi Visitors Center - rest stop

Stennis Space Center (north of here) is the primary rocket-engine testing facility for NASA. Since 1966 the NASA Stennis facility has test-fired rockets from the Apollo engines that took Americans to the moon to the main engines of the Space Shuttle. Scientists at the center are also involved in testing rocket-engines for the next generation of space travel. Exhibits at the museum include a Space Shuttle main engine, a walk-though model of the International Space Station, a mock-up of a Space Shuttle cockpit, and a real moon rock.

12.5	12.5	Jourdan River – flowing south, then east into Bay St. Louis.
3.5	16.0	Harrison County Line, upper reaches of Bay St. Louis just to south.
15.5	31.5	Hwy 49 – Gulfport.
5.0	36.5	Biloxi River, both the Biloxi and the Tchoutacabouffa rivers flow into the upper reaches of the Back Bay section of Biloxi Bay, just south of here.
4.4	40.9	Tchoutacabouffa River.
3.1	44.0	I-110, Biloxi.

Photos from: Fraser, J. (2006)

Beauvoir, built in 1852, the beachfront retirement home of Confederate President Jefferson Davis has survived the Civil War, attempted arson, and 21 previous hurricanes in its 157 years of existence. Where all previous attempts at destruction had failed, Hurricane Katrina was almost successful. Pieces of the home have been identified blocks and even miles from the point of origin. Items from inside the museum were found scattered in all directions among assorted flotsam and jetsam. A confederate soldier's jacket was found hanging from a bush. Many items are gone completely, although an intensive search is underway for anything that might still be recovered. Much of the original furniture, including pieces by Anthony Quervelle, Prudent Mallard, and John Henry, some of the foremost names in 19th century furniture making, were rescued shortly after the storm and is now being restored.

(from Mississippi 2006 Official Tour Guide)

0.8	44.8	Jackson County Line.
13.9	58.7	Mississippi Sand Hill Crane Wildlife Refuge

The Mississippi Sandhill Crane National Wildlife Refuge is one of more than 500 national wildlife refuges administered by the U.S. Fish and Wildlife Service. It was established in 1975 to safeguard the critically endangered Mississippi sandhill crane and its unique disappearing habitat. The refuge consists of more than 19,000 acres in four units and is now part of the Gulf Coast National Wildlife Refuge Complex. Mississippi sandhill cranes (*Grus canadensis pulla*) are a critically endangered subspecies found nowhere else on earth in the wild but on and adjacent to the Mississippi Sandhill Crane National Wildlife Refuge. There are only about 100 individuals remaining, including about 20 breeding pairs. There are 15 species of cranes in the world, found on all continents except South America and Antarctica. Cranes are among the most endangered of the bird species. Eleven of the 15 crane species are considered at risk of extinction. Two crane species are found in North America, the whooping crane and the wide-ranging sandhill cranes. Several species of carnivorous plants also live in the Wildlife Refuge. The carnivorous plants grow in wet pine savannas. These habitats are seasonally flooded and wet for most of the year. Wet pine savannas get moisture from rainfall that collects on the clay soil surface, creating very muddy, soft soils that often pond. These soils are acidic in nature and have very low nutrient capacity. As such, the plants that grow in wet pine savannas are adapted for moist, high acid, low nutrient conditions. Some plants of the savannas make up the lack of nutrients in the soil by capturing, killing, and digesting animals -- mostly insects. The refuge is the home of 10 species of carnivorous plants that fall into four main groups: sundews, butterworts, pitcher plants, and bladderworts. The sundews and butterworts capture prey on small sticky, glue-like pads on their leaves. Insects are attracted to the sticky substance. Once they land on a leaf they are trapped by the glue. The leaf will roll up around the insect to encase it. The plant will then release chemicals to digest the insect. Pitcher plants have another unique method of capturing insects. The pitcher is actually a modified leaf and can hold water! Insects are attracted to nectar produced at the rim and on the inside of the pitcher. As the insect crawls into the pitcher to get more nectar, it is trapped by downward pointing hairs that do not allow the insect to crawl back out. The insect falls down into the base of the pitcher which is filled with digestive enzymes. One of the most elaborate and specialized methods for capturing prey is seen in the bladderworts. This plant has small bladders that have a trap door on one end. When the bladder is empty, the door is closed. If an insect brushes against the small hairs on the door, it swings open. Water and insect rush into the bladder. The door closes, trapping the insect inside. *(excerpted from website - http://www.fws.gov/mississippisandhillcrane/)*

2.7 61.4 Pascagoula River.

"The Singing River" The Pascagoula River is famously known for it mysterious music. The singing sound, like a swarm of bees in flight, is best heard in late summer and early autumn months in the stillness of the late evening. Barely caught at first, the music seems to grow nearer and louder until it sounds as though it comes from directly underfoot. An old legend connects the sound with the mysterious extinction of the Pascagoula tribe of Indians. The Pascagoulas were a gentle tribe of contented, indolent, innocent, and inoffensive people, whereas the Biloxis were a tribe calling themselves the 'first people' and were extremely jealous of their position. Anola, a princess of the Biloxi tribe, though betrothed to a chieftain of her people, loved Altama, a young chieftain of the Pascagoulas, and fled with him to his tribe. The spurned and enraged Biloxi chief led his Biloxi braves to war against Altama and the neighboring Pascagoulas, whereupon Altama begged his tribe to give him up for atonement. The Pascagoulas swore they would either save the young chief and his bride, or perish with them. However, when thrown into battle against terrible odds, they soon lost hope of victory. Out-numbered, they were faced with either subjection to the Biloxis, or death. They chose death. With their women and children leading the way into the river, the braves followed with joined hands, each chanting his song of death until the last voice was hushed by the dark engulfing waters.

(Mississippi Geological Society, 15th Field Trip, 1960)

5.0 66.4 Highway 63, Pascagoula.

In December 2005, the Depart of Energy (DOE) released a Proposed Action Information bulletin, announcing the proposed expansion of the Strategic Petroleum Reserve (SPR). The SPR was established in 1975, and it consists of underground oil storage facilities in salt domes, that can be used to protect the US from oil supply interruptions. Currently the storage capacity is 727 million barrels of oil. In 2005 President Bush signed the Energy Policy Act of 2005 which directs the DOE to select sites necessary to reach the full authorized capacity of one billion barrels of oil. Presently the SPR consists of four underground storage facilities, two in Louisiana (Bayou Choctaw, West Hackberry) and two in Texas (Big Hill, Bryan Mound). Proposed new sites include one in Texas (Stratton Ridge), two in Louisiana (Chacahoula, Clovelly) and two in Mississippi (Bruinsburg, Richton). In late 2006 the Richton Dome in Mississippi was announced as the official site for expansion of the SPR. According to the DOE, preparation of the Richton Dome site would require two co-located pipelines to Pascagoula: a 96-mile brine disposal pipeline to the Gulf of Mexico and an 83-mile oil distribution pipeline. It would also require a 118-mile oil distribution pipeline to the Capline Interstate Pipeline injection station at Liberty, Mississippi; a 10-mile raw water pipeline from the Leaf River; and new marine oil distribution facilities such as docks and storage tanks at the port of Pascagoula. In the later part of 2006, it was announced that the Richton Dome was chosen to develop as the next storage site for the SPR.

4.9	71.3	Escatawpa River.
3.2	74.5	Alabama State Line.
0.6	75.1	Alabama Visitors Center.
12.9	88.0	Bellingrath Gardens

Throughout the year, this 65-acre Garden Estate is in full bloom with camellias in the winter, azaleas in the spring, roses in the summer, chrysanthemums in autumn and Magic Christmas in Lights during the holiday season. Bellingrath Gardens was named the 2004 Top Public Rose Garden in the U.S., as awarded by the All-America Rose Selections. Also included on the grounds is the Bellingrath Home, complete with its original furnishings and Mrs. Bellingrath's extensive collection of decorative arts. Built in 1935, the 10,500 square foot home was designed by prominent architect, George B. Rogers. The style of the Home was dubbed "English Renaissance" by Rogers. The Gardens were the creation of Mr. and Mrs. Walter Bellingrath. The Gardens first opened to the public in 1932. The Bellingrath's ventured on a European excursion in the summer of 1927, and toured several English estates and gardens. Upon their return, they hired prominent Mobile architect, George B. Rogers to design a garden. Rogers took meandering paths and added a back drop of tall camellias and azaleas, which he and Mrs. Bellingrath collected from across the Deep South. Water features of fountains and waterfalls were installed and framed with English flagstone walkways. The stone had been obtained from old city sidewalks in Mobile where they had been in place since arriving as ballast in English sailing vessels collecting loads of cotton. During the spring of 1932, a national garden club meeting was being held in Mobile. On Sunday, April 7, 1932, the Bellingraths issued a general invitation to the public to view the Gardens between one and five that afternoon. Over 5,000 Mobilians jammed the roads to see what the Bellingrath's called "Belle Camp," at the height of its azalea season. The couple was stunned. Overwhelmed by the response, the Bellingrath's soon opened the Gardens to the public for spring appreciation and named the former fishing camp Bellingrath Gardens. Two years later in 1934, the couple decided to open the Gardens year-round. *(excepted from website - http://www.bellingrath.org/)*

6.8	94.8	I-65 (north) – Mobile.
9.6	104.4	I-165, south to downtown Mobile business district.
2.9	107.3	Citronelle Exit.

SYSTEM	SERIES	GROUP OR FORMATION		LITHOLOGY	THICKNESS (FT)
Quaternary	Pleistocene	Citronelle			1,600
Tertiary	Pliocene				
	Miocene	Undifferentiated		Sandstone and shale	
	Oligocene	Undifferentiated			
	Eocene	Jackson Claiborne Wilcox		Sandstone and shale	1,500
	Paleocene	Midway			1,300
Cretaceous	Upper	Navarro Taylor Selma		Chalk	1,300
		Eutaw		Sandstone	50
		Tuscaloosa	Upper Marine Lower	Sandstone and shale	900
	Lower	Dantzler Fredericksburg Paluxy		Massive sandstone section	3,800
		Mooringsport		Shale	
		Ferry Lake		Anhydrite	100
		Rodessa Pine Island Sligo	"Donovan"	Sandstone and shale	850
		Hosston		Sandstone and shale	2,100
Jurassic		Cotton Valley		Sandstone and shale	2,200
		Haynesville		Sandstone, shale, and ls.	2,100
		Buckner		Shale and anhydrite	300
		Smackover		Limestone	200
		Norphlet		Sandstone and shale	1,000

The Citronelle Field was discovered in 1955 by the Zack Brooks Drilling Company No. 1 Donovan, SW 1/4, NW 1/4, Sec. 25, T2N, R3W, Mobile County, Alabama. The well produced from the lower Glen Rose Formation at a depth of 10,879 ft. (3,315.9 m). During the next 10 years, 434 productive wells were drilled. Major production was from the Donovan Sand, considered to be equivalent to the Lower Cretaceous Rodessa Formation. The paraffin based crude oil ranges from 43° to 46° API gravity. The productive limits completely envelope the town of Citronelle, 32 mi (51.5 km) north of Mobile, Alabama. Forty-acre spacing, low gas-oil ratio and rapid bottom hole pressure drop, necessitating pumping of all wells, resulted in slow and spasmodic development. Unitization of 139 wells for waterflood was initiated in 1961, and a saltwater-injection program proved successful. Later, fresh water from the Wilcox Formation was used for injection fluids. By May 1966 all wells were unitized, and on December 31, 1973, the field had produced over 107 million bbl of oil. The structure, which lies in the Alabama portion of the Mississippi Interior Salt Basin, is residual in origin. The field, as well as the townsite, is topographically high. The field occurs on a slightly elongated, northwestward trending domal anticline which has about 450-feet of vertical closure on the Ferry Lake Anhydrite. The structure at the producing-depth datum is that of a simple, moderately flat-topped, ovate dome, but the field presents a complex meander belt pattern with 52 productive sandstone zones in 330 separate reservoirs. The entire field was eventually unitized under three agreements as thought there were three separate reservoirs. All the productive wells produce through electrically driven down hole pumps. Production for the field reached its peak in the spring of 1972. Thirty-three percent of the oil in place had been produced by the end of 1973. Profitable production is expected to continue for another 8 years. At present, the Citronelle Operators Unit is studying the economics of a tertiary flood using carbon dioxide as a miscible agent.

(Excerpted from PTTC website - http://egrpttc.geo.ua.edu/reports/citronelle/eaves.html, and Copeland, 1968)

Recognizing the dual energy and environmental benefits of CO_2 EOR/sequestration, the U.S. Congress mandated in the Energy Policy Act of 2005 that DOE pursue demonstration projects to promote the capture, transportation and injection of produced CO_2 for sequestration into oil and gas fields while boosting oil and natural gas production. The project selected under this funding opportunity was proposed by the University of Alabama-Birmingham (UAB), of Birmingham, Alabama. It calls for implementing a CO_2 flood in Citronelle oilfield in Mobile County. Citronelle field, Alabama's largest producer, is an ideal site for a CO_2 flood because of its reservoir's relatively uniform structure. A mature field that has already undergone primary and secondary recovery (water flooding) efforts, Citronelle is now a candidate for tertiary recovery, or EOR. Typically 20% more of the original-oil-in-place in a reservoir can be recovered using CO_2 EOR. In Citronelle's case, it is estimated that 64 million barrels of oil could be recovered using this technique. A successful demonstration of the technology in this project could open the door to commercial CO_2 EOR/sequestration efforts across the United States, offering a potential "two-for-one" solution to the country's crucial energy security and environmental concerns.
Excerpted from an article from New Technology Magazine online at:

http://www.nickles.com/ntm/extra.asp?article=NTM2006_S60000.html

6.5	113.8	Creola Exit – Head north on US-43 (rest stop 2).
5.2	119.0	chemical plants – Amvac, Axis, DuPont.
3.3	122.3	Bucks, Alabama Power – Barry Plant.

The Barry Steam Plant, an Alabama Power Company electric generating plant, is located on the banks of the Mobile River, north of Mobile. The plant has five coal-fired units and one natural gas-fired combustion turbine unit. The Alabama Environmental Council has a rather dim view of operations at the Barry Plant. "This is one of Alabama Power's oldest plants and it violates their particulate matter permit limits on a regular basis". EPA data shows two years of uninterrupted violations of the Clean Water Act. While some violations involved unpolluted water from impaired treatment systems, most problems came from clogged pumps that bypassed contaminated sump or process water."
(from Alabama Environmental Council website
http://www.aeconline.ws/Dirty%20Dozen%20Info.htm#City%20of%20Prichard%20is%20in%20Mobile%20Count)

5.9	127.2	Boykin Wildlife Management Area (to west).
2.3	129.5	Mt. Vernon compression station – natural gas pipeline.

Just to the west, on Al-96 is the MOWA Choctaw Cultural Center and Museum. The museum is the focal point of the cultural center and is located in a Creole-style home built by Christian Becker, a German native. The home was built between 1855-60, and is the oldest home in Mt. Vernon. Between 1887-94 it became a holding ground for Geronimo and several hundred Apache prisoners. Geronimo was a frequent visitor in the Beckner home as was Dr. Walter Reed, who discovered mosquitos were the carriers of yellow fever. The MOWA Choctaw Indians of South Alabama are a segment of the Choctaw Indians who refused to migrate from their homeland during the infamous removal known as the "Trail of Tears".

Very little is known of the MOWA Choctaw Indians between the 1830's and 1890's; few records were kept. There were few non-Indians living in the Indian settlement until the late 19th century. After the enactment of the Trail of Tears, the President issued a degree declaring that the Indians, who in the past owned land, could homestead forty acres on the condition they no longer speak their own language, practice their religion, or call themselves a tribe. Afraid of being forced from their homes, the Indians settled in the most isolated places because many people believed that "the only good Indian is a dead Indian". In the early 19th century, the average Indian family was very large. There was little work to be found. It was a struggle to remain alive. The Indians were uneducated, therefore, they had to work with their hands; they logged and cut ties for railroads, but the major occupation for Indians was cutting pulpwood. In the last decades of the 19th century, the isolation of the MOWA Choctaw Indians began to come to an end. There were four main factors that brought about change to the Indian communities. After a century and a half of literal isolation, the MOWA Choctaw Indians came forth seeking, and getting, official recognition by the state of Alabama. They adopted the name "MOWA Choctaw Indians" to identify the Indians in Mobile and Washington Counties who are descended from several Indian Tribes: Choctaw, Creek, Cherokee, Mescalero, and Apache. Today, there are nearly 6,000 members of the MOWA Band of Choctaw Indians, over 2,500 of whom live in the vicinity of McIntosh, Alabama. All the members are descendants of the original Choctaw Nation who are bound together by a complex network of multigenerational kinship. The MOWA Band of Choctaw Indians was duly incorporated in 1979 with its tribal office located in McIntosh and purchased 160 acres of land in south Washington County in 1983. There are five officers and fourteen members of the tribe's commission who voluntarily assist the operations of tribal affairs. *(From website — http://www.aiac.state.al.us/MOWA%20tribal%20history.htm)*

2.6	132.1	Washington County Line.
6.8	138.9	Olin Chlor-Alkali Products McIntosh Plant

Olin Chlor Alkali Products' McIntosh plant is situated on 2200 acres of land, 250 acres of which are developed. The facility is located on Industrial Road, less than a mile off of U.S. 43. The plant's population includes more than 305 full-time employees. Olin's McIntosh Plant produces chlorine, caustic soda, sodium hypochlorite, dilute sulfuric acid, hydrogen (sold to the local Praxair plant for use as rocket fuel) and salt. Olin Chlor Alkali Products was first attracted to McIntosh by an unusual geographic feature—a giant underground salt dome which was discovered in 1945. (Salt is one of the essential raw materials needed for our manufacturing process.) We began our McIntosh plant operations—and a valued relationship with the McIntosh community—in 1952. Our contribution to the greater McIntosh community is substantial. Our payroll is approximately $17.7 million annually. We purchase around $70 million of goods and services locally and regionally each year.

(from www.olinchloralkali.com/loc_mcintosh.asp)

McIntosh Salt Dome

The McIntosh Salt Dome is the shallowest piercement salt dome in the Mississippi Interior Salt Province. The dome pierces Miocene sediments within 410 feet of the surface, and is approximately 1-mile in diameter. Discovered in 1945 by Gulf Refining Company, the dome was developed for chemical production by Olin Mathieson. The McIntosh salt dome is the most prominent shallow salt structure in southwest Alabama. *(Copeland, 1968)*

Press release – Mobile Press-Register, Oct, 2006 - Bay Gas Storage Co., a fast-growing subsidiary of Mobile-based EnergySouth Inc., said Wednesday it will carve out a pair of new natural gas storage caverns near McIntosh to help meet rising demand from across the Southeast. The two caverns will have a total capacity of 10 billion cubic feet of natural gas and will be constructed inside an underground salt dome about 40 miles north of Mobile in southeast Washington County. Each will connect to nearby interstate pipelines operated by the Houston-based Transcontinental Gas Pipe Line Co. and the

Birmingham-based SONAT Inc. The cost of the project was not disclosed. Bay Gas said it expected to have the caverns completed and in service by fall 2009. "We believe additional market opportunities for salt-dome storage services exist in the Mid-South region and along the East Coast," said Greg Welch, president and chief executive officer of Bay Gas. Bay Gas currently operates two caverns in the McIntosh salt dome and is nearing completion of a third. The two existing caverns are operating at their full capacity of more than 6 billion cubic feet. Each have direct connections to interstate pipelines operated by Florida Gas Transmission Co. and Gulf South Pipeline Co., both based in Houston. The third cavern now under construction will add another 5 billion cubic feet when it is completed next summer, according to the company. That project will cost Bay Gas about $60 million.

(Website www.al.com/business/mobileregister/news.ssf?/base/business/)

1.1 140.0 McIntosh.

McIntosh Bluff Historical Marker - 1967

"Near here in 1807 ex-vice president Aaron Burr was arrested and sent on horseback via Ft. Stoddart to Richmond where he was tried for treason and acquitted. Weekly mail service to Natchez was established in 1802. The first civil court in Alabama was held here in 1803. McIntosh Bluff was the ancient seat of the Tohome Indians. Included in the first Choctaw Cession to the British in 1765, and thereafter granted to John McIntosh, a Scottish trader. The earliest American settlement north of 31° in present state of Alabama. First county seat of both Washington and Baldwin counties."

1.2 141.2 McIntosh, Ciba Specialty Chemicals plant.

Ciba Specialty Chemicals occupies ~1500 acres and contains 9 different production units and an on-site waste management facility. Currently the site produces additives for plastics, paints, and oils; optical brighteners used in detergent, paper, and textile industries; and chemicals used in household and farm products, such as herbicides, pesticides, and insecticides.

13.8 155.0 Shortcut to St. Stephens Historic Park.
3.3 158.3 Washington CR-34: turn left, (north) to old St. Stephens.
6.2 164.5 St. Stephens – historical marker & museum.

Photo – R. Cormier

The museum is located upstairs in the old Washington County courthouse. Displays reflect the heritage of the Native Americans, Spanish settlers, and American pioneers during the territorial period of St. Stephens. One of their exhibits is a wooden canoe ~2000(?) years old (photo). When the Corps of Engineers made a cutoff across the neck of a meander loop on the nearby Tombigbee River, the altered current flow began to remove mud from different parts of the river. Eventually this (and other) Native American canoes floated to the surface and were recovered.

Old St. Stephens Masonic Lodge #9 (1821-1834) – Historical Marker - 1973

"Charter and early members were: Gov. Israel Pickens, CO. Silas Dinsmore, Thomas Eastin, R. Chamberlain, Thomas Malone, J.F. Ross, Daniel Coleman, John Womack, W.D.Gaines, James Roberts, James K. Blunt, Ptolemy Harris, F.S.Lyon, Micajah Brewer, and John F. McGrew. This was one of nine lodges that organized in the Grand Lodge of Alabama at Cahaba in 1821, but Masonry existed here as early as 1811. After the decline of old St. Stephens, members moved and the lodge #9 was disbanded. Another lodge was organized her in 1854, and it has been the site of continuous meeting since that time."

0.1	164.6	Turn right to Saint Stephens park.
0.2	164.8	Bear right on Cement Plant Road.
0.7	165.5	Park entrance – follow road to river landing (bear left at archaeological site/marker; also bear left at the fork in the road in the lower quarry.

St. Stephens Historical Marker - 1922

"Spanish Fort 1789, evacuated to the United States, 1799; Designated Alabama territorial capital, 1817. Here was located US Court and land offices and for some years the seat of justice of Washington County."

1.9	167.4	St. Stephens landing, Tombigbee River.

St. Stephens Landing – Historic Marker

"This site first served as a landing in 1789 when Spanish governor Estevan Miro established Ft. San Estevan to protect Spain's interest n this area. During the early days of American settlement the landing served as a port for the Choctaw Trading house and as a ferry crossing for settlers traveling west. St. Stephens Landing also became a port of entry for passengers, goods, and supplies during the early 19th century. In 1819 the steamboat 'Alabama' was constructed here and upon completion sailed to New Orleans."

Stop 1. St. Stephens Quarry

Upper Eocene – Lower Oligocene; Yazoo Fm. (Pachuta Marl, Shubuta Marl), Red Bluff/Bumpnose Fm., Forest Hill Fm., Marianna Limestone

Return to the Intersection of CR-34 and US-43, turn left on US-43 toward Jackson.

0.0	0.0	Intersection of CR-34 and US-43, reset mileage.
1.1	1.1	Historical marker – Taylor House.

Taylor House – Historical marker, 1986

"Built ca. 1841 by Walter Taylor on Commerce Street in Jackson. In 1985 it was removed from its original site to make way for a new City Hall Complex and was brought to this site and restored as the Leroy Branch of the Washington County State Bank."

1.5	2.6	Tombigbee River – middle of bridge.

Downstream (right) can be seen the Boise-Cascade Jackson Paper Mill and the Charles B. Lowman Power Plant.

Located on the Tombigbee River near Leroy, Ala., the Charles R. Lowman Power Plant is Alabama Electrical Cooperative's primary generating source. With its three coal-fired generating units, Plant Lowman's generating capacity equals 556 megawatts. Coal is the primary source of fuel used at Lowman, with number 2 fuel oil used for start-up and flame stabilization. Each year, Plant Lowman burns around 1.5 million tons of coal to produce the steam needed to make electricity. Coal is transported to the plant by barge on the Tombigbee River and by rail. The plant's three operating units are equipped with electrostatic precipitators (ESPs), which preserve air quality by preventing particulate matter from entering the atmosphere. Units 2 and 3 are equipped with "scrubbers," a high-technology system designed to remove sulfur dioxide from smokestack emissions. Plant Lowman's unit 1 was built between 1965 and 1969, and commercial operation started in 1969. Construction on units 2 and 3 commenced in 1976, with commercial operation beginning in 1979 for unit 2 and in 1980 for unit 3.

(from the Alabama Electrical Cooperative website, forhttp://www.powersouth.com/about_power.aspx unit)

0.7	3.3	Intersection with Al-177, turn right.
2.6	5.9	Intersection with CR-15, turn right.
0.8	6.7	Boise Cascade Jackson Mill.

This mill is a paper manufacturer with facilities for woodcutting, wood chipping, pulping, pulp refining, papermaking, and paper preparation for distribution. In 1995, the on-site landfill was redesigned to extend its life span, however, improvements only extended the projected life of the land fill until approximately 2004. Because of the significant capital costs of permitting and constructing a new landfill, extensive pollution prevention and recycling methods were investigated and implemented. An example of this is the companies use of boiler ash (bottom and fly ash from a combination boiler and ash generated by the sawmill operation). In 2000 the mill diverted over 17,000 cubic yards of ash to 1) a cement plant for incorporation as an aggregate, 2) bagging operation for ultimate use as a potting soil, and 3) a local road-building project as a load-bearing aggregate mix. This represents 100% of the ash generated at the mill since the beginning of the project. This, and other projects in the combined Beneficial Use Program is estimated to have save the Jackson Mill ~$1.7 million and eliminated the need for 182 thousand cubic yards of landfill.

(Alabama Department of Environment Management:
http://www.adem.state.al.us/Education%20Div/P2%20Program/P@ Wimmers.htm)

0.9	7.3	Bear right at fork.
0.4	7.7	Boise Cascade industrial landfill. High terrace (red mudstone / gravel) on north side of road.
2.9	10.6	Richmond Branch.
0.1	10.7	Outcrops of Marianna and Byram Limestones on left side of road.

Stop 2. Richmond Branch
Oligocene - Marianna Limestone, Byram Limestone

0.1	10.8	Salt Creek.
0.1	10.9	Historical marker, Central Salt Works.

Central Salt Works – Historical Marker, 1985

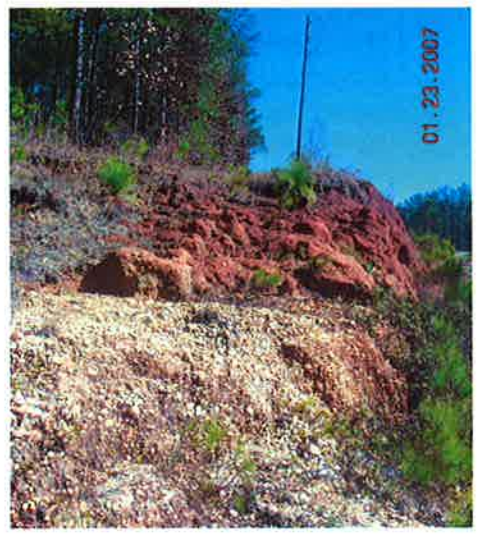
"Here was located the large and important central salt works. Official government reports indicate that salt was being mined at this works as early as 1816, but the Indians had obtained salt here for centuries prior to this. During the blockade of 1861-1865 thousands came here from all over the state to obtain salt for their families. Remains of rock furnaces and wooden pipes can still be seen. Overshadowing this site is Salt Mountain."

The central salt works was the site of an extensive salt processing operation during the War Between the States. Brine was obtained from wooden-cased springs and wells, and then evaporated to obtain the salt. Three separate occurrences of salt springs are known in Clarke County, and each was the site of salt processing operations. These sites are referred to as the upper, central, and lower salt works. The central salt works are reported to have produced 88,000 tons of salt, per year, during the War. The brines range from about 25,000 to 45,000 ppm sodium chloride. The springs and wells at the central salt works are in the outcrop of formations of the Wilcox Group, but the brine is believed to be derived from lower formations, possibly of Cretaceous age. The brines possibly reach the surface through openings formed as a result of displacements which produced the Hatchetigbee Anticline and Jackson fault zone.

(Copeland, et al, 1976)

0.2	11.1	Outcrop – Salt Mountain Limestone.

Stop 3. Salt Mountain
Paleocene - Salt Mountain Limestone, Jackson Fault



Return to intersection of Al-177 & US-43, head north on US-43

0.0	0.0	AL-177 & US-43 intersection, reset mileage.
0.4	0.4	Terrace outcrops– left side of highway.
0.2	0.6	Terrace outcrops – left side of highway.
0.2	0.8	Terrace deposits – left side of highway.
0.6	1.4	Intersection w/ Al-69, to Old Lock 1 park.

Located off Highway 69 between Coffeeville and Jackson. The original park development in the mid-50s resulted from a modernization program of the locks and dams on the Black Warrior-Tombigbee Waterway begun in 1937. Lock #1, which was completed in 1902, was one of 17 low-lift locks and dams constructed on the Black Warrior and Tombigbee rivers between 1895 and 1915. In 1956, Coffeeville Lock and Dam replaced three of the old structures, Locks 1, 2 & 3. With construction of the replacement locks and dams, the old structures were removed and in many cases the sites converted into recreation areas, providing access to the river. The modernization program also included removing sharp and sometimes lengthy bends in the river by construction of bypass canals, which resulted in formation of "oxbow lakes" in the old river channel. Lock #1 was bypassed by a canal and remains intact in one of the oxbow lakes. The lock and dam has been determined as eligible for listing on the National Register of Historic Places.
(http://www.clarkecountyal.com/old_lock.htm)

1.4	2.8	Intersection with Al-177 (to the south), Jackson
0.4	3.2	High terrace outcrops, behind Best Western Inn
0.2	3.4	Breakfast - Exxon at top of hill

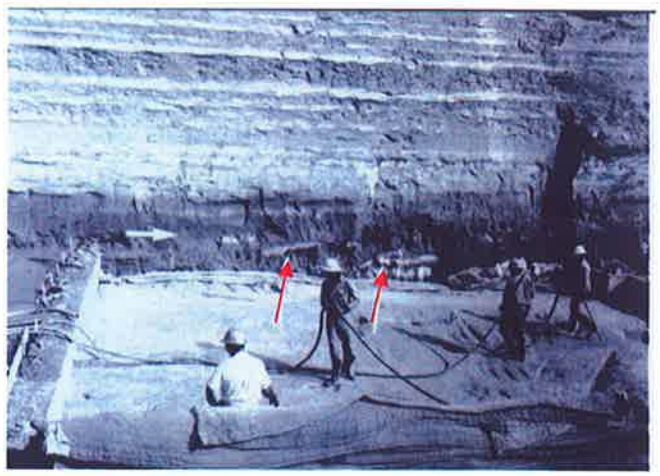
<u>End day one.</u>

Day 2 – Miller's Ferry, Alabama River; Camden; Braggs; Claiborne Bluff

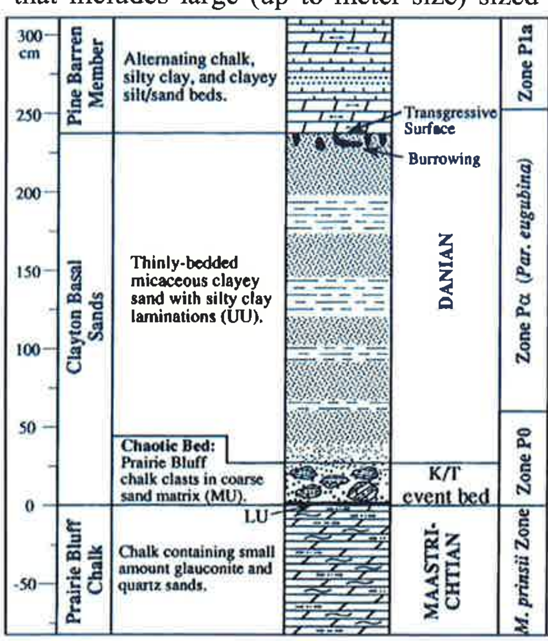
We will drive north on US-43, Al-5, Al-162, and Al-28 to the Millers Ferry Lock and Dam on the Alabama River.

Stop 4. J. Lee Long Bridge, Alabama River
Paleocene - Clayton Formation (Pine Barren Mbr., McBryde Limestone Mbr.)

- ***a. low road cut along south side of Al-28, 0.8 mile from (east) of the J. Lee Long bridge over the Alabama River.***
- ***b. 'rock pile', in flat area north of side road to Shell Creek boat launch.***



Excavations for the Millers Ferry dam powerhouse (just downstream from here) in 1967 exposed a large area of the top of the Prairie Bluff Chalk and cross sections of the lowermost Pine Barren member and the basal coarse-grained sandstone of the Clayton Formation. Archival photos of excavations illustrated numerous intriguing features that have been correlated with tsunami-deposition of the basal coarse-grained sand of the Clayton Formation and tsunami-related erosion of the top of the Prairie Bluff Chalk. The surface of the Prairie Bluff is severely scoured with groove marking, striations, and flute marks that suggest significant erosion on a large scale. Numerous normal faults that offset the Prairie Bluff Chalk and that are in turn buried by the overlying Clayton basal sands indicate impact-related earthquakes. The basal sands in the Clayton consist of a coarse-grained sand at its contact with the Prairie Bluff, a chaotic layer that includes large (up to meter-size) sized blocks (red arrows, photo) of the Prairie Bluff Chalk, and overlying Danian inner-shelf micaceous clayey sand. The chaotic layer is interpreted as a tsunami generated deposit. Analysis of benthic foraminifera in the Prairie Bluff Chalk and in the Danian shelf sands indicates there was no significant change in sea level at the K/T boundary, and that sea level was at a low stand. The sudden cessation of the Prairie Bluff Chalk deposition is coincident with a sudden extinction of marine biota. The K/T contact at Millers Ferry separates chaotic beds above the contact and a severely scoured, faulted surface below the contact. The erosion and deposition of these features can be related to the bolide impact at Chicxulub, which is across the Gulf of Mexico directly south of Millers Ferry area. Earthquakes caused normal faulting and liquefaction of the Prairie Bluff Chalk. A tsunami followed and severely eroded the surface of the Prairie Bluff Chalk, tearing up large blocks of the chalk. Subsequent backwash from the Providence Sands, which lay to the north, deposited coarse sands that mixed with the chalk clasts, producing a



chaotic bed that was deposited in broad channels across the surface of the Prairie Bluff. A return to normal inner-shelf sedimentation resulted in the deposition of the upper micaceous sand part of the basal Clayton sands. Primitive Danian planktonic foraminifers lived in this environment and these foraminifers led to the radiation that repopulated early Paleocene seas.
(Olsson, Liu, van Fossen, 1996)

From the entrance road to the Shell Creek boat launch, travel north on US-28 for about 2.1 miles, then right on dirt road in front of broken down board fence. Travel 0.8 mile down dirt road, cross low water bridge, and park in open space at intersection just beyond bridge. Outcrops occur in creek downstream from bridge.

Stop 5. Shell Creek
K/T boundary – Cretaceous, Prairie Bluff Fm., and Paleocene, Clayton Fm.

Return to the J. Lee Long bridge over the Alabama, River – Road log mileage will start at this point (mid-bridge).

0.0 0.0 J. Lee Long bridge over Alabama River - downstream is the Miller's Ferry Lock and Dam

Bill Danneley Lake on the Alabama River encompasses 105 miles of the Alabama River, with a surface area of about 27 square miles and a shoreline of over 500 miles. It is a popular lake, boasting of nearly 3 million visitors a year. The reservoir was created by the construction of the Millers Ferry Lock and Dam (photo), which was completed in 1970. The power plant produces enough electricity to power 50,000 homes. The reservoir is named for the late Judge William Danneley of Camden, who was an active supporter of river development.
(http://al-lakes.sam.usace.army.mil/bill/)

Midway Landing, Alabama River

This locality is about 2- miles south of the J. Lee Long Bridge, in a bluff on the west side of the Alabama River. The upper beds of the Paleocene McBryde Limestone and the lower beds of the lower member of the Porter's Creek Formation are exposed. The basal beds of the Porter's Creek are 2-feet of greenish-gray, glauconitic, fossilferous, calcareous marl. This bed includes reworked fossils, marl clasts, quartz grains and phosphate pebbles. This marl grades upward into 6-feet of blocky-weathering gay to black, calcareous, massive clay. This is the typical lithology of the lower part of the Porter's Creek Formation. The basal marl bed disconformably overlies the underlying limestone beds of the McBryde member of the Clayton Formation. The glauconitic marls are interpreted to be transgressive and condensed section deposits and the massive clays to be highstand regressive deposits of a Type 2 depositional sequence. The McBryde includes 7 feet of interbedded, gray, fossilferous, calcareous marl and nodular limestone. The flora and fauna of the McBryde limestone and marl are characteristic of open marine shelf deposits.

These beds probably represent condensed section and highstand regressive deposits of a Type 2 depositional sequence at this locality. *(Mancini and Tew 1988, Stop 4)*

9.8	9.8	Intersection with Al-41.
1.3	11.1	Intersection with Al-164.
0.2	11.3	Intersection with Al-41/Al-10 north, Camden, turn left.
0.1	11.4	Intersection with Al-265, Camden, turn right (south).
6.3	17.7	Shoal Creek.
0.1	17.8	Outcrops of *O. thirsae* beds.
0.4	18.2	Grampian Hills outcrop, at abandoned(?) St. John's church.

Photos – R. Cormier

0.2	18.4	Grampian Hills outcrop, at milepost 15.

Stop 6. Shoal Creek, along Al-265, south of Camden, Wilcox Co.
Paleocene - *Ostrea thirsae* beds & Grampian Hills member, Nanafalia Formation

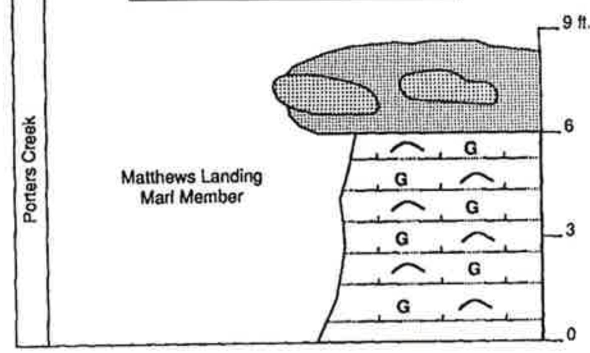
a. low outcrops of Grampian Hills mbr., around milepost 15 and/or at the old church.
b. prominent outcrops of Ostrea thirsae beds just above Shoal Creek.

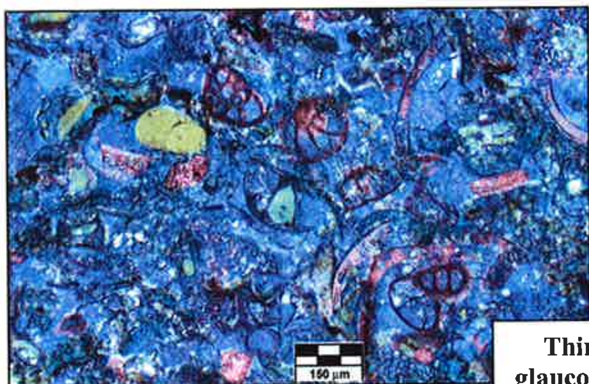
Return to intersection of Al-265 with Al-41/Al-10, in Camden. Turn right (east) on Al-41/Al-10.

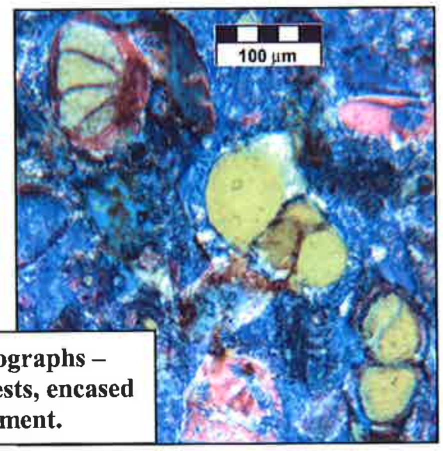
7.0	25.4	Intersection of Al-265 and Al-41, Camden, turn right on Al-41.
0.7	26.1	Intersection with Al-10, continue straight on Al-10. (Hardee's- rest stop)
3.2	30.0	Intersection with CR-49.
0.4	30.4	Intersection with Al-28.
4.9	35.3	Intersection with CR-65.
0.7	36.0	Outcrops of Matthew's Landing Marl on left (drive by).

About 8-feet of the Matthews Landing Marl are exposed at this stop (A on map). The Matthews Landing Marl consists of greenish-gray, glauconitic, fossilferous, calcareous marl and very fine-grained sand with nodular concretions. It overlies micaceous, fine-grained sands of the lower un-named member of the Porter's Creek Formation. The fauna and flora contained in the Matthew's Landing marl are characteristic of open marine shelf deposition. The Matthews Landing Marl is interpreted as the transgressive and condensed section deposits of an unconformity-bounded Type 2 depositional sequence.

From Mancini and Tew. 1988

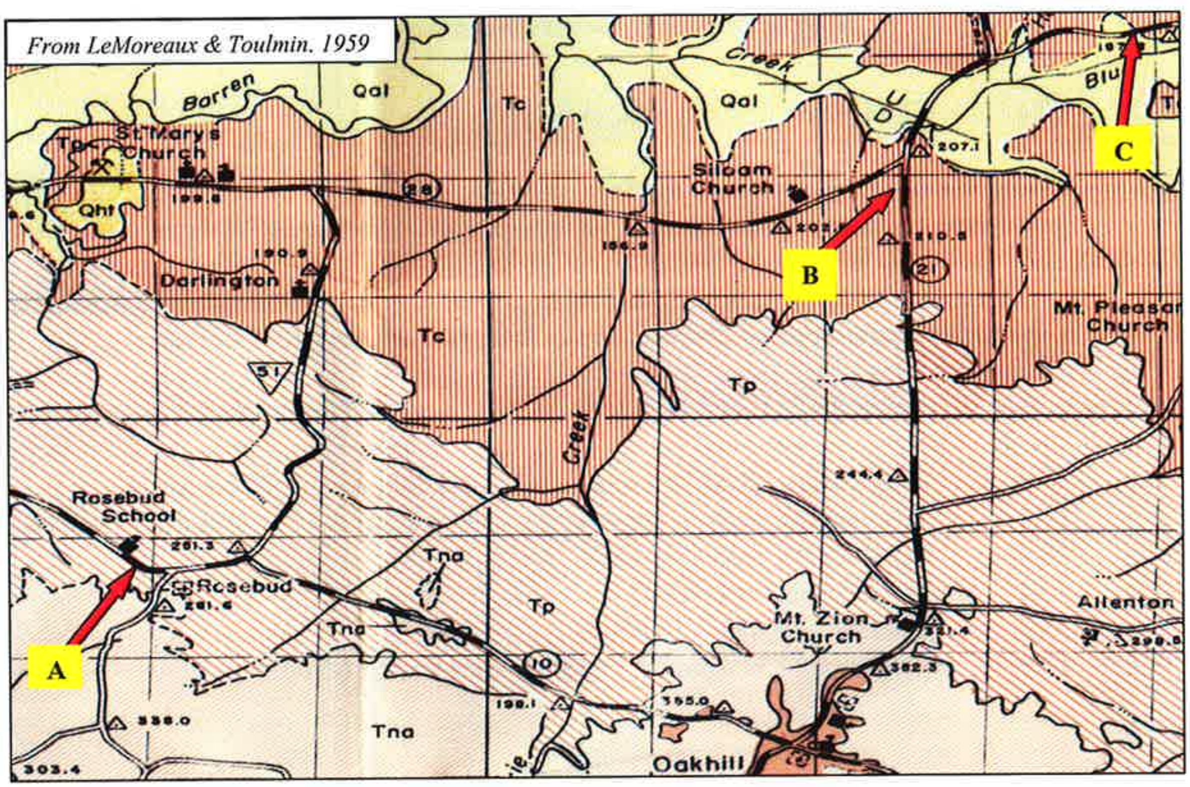






Thin section photomicrographs – glauconite, foraminifera tests, encased in ferroan calcite cement.

From LeMoreaux & Toulmin. 1959



4.9	44.9	Power substation on left – outcrops of Pine Barren and McBryde. Limestone members of Clayton Fm (drive by).

About 6 feet of the lower McBryde Limestone and 2 feet of the '*Turritella* rock' beds of the Pine Barren Member are exposed at this stop (B on map). The McBryde Limestone consists of gray, glauconitic and pale orange limestone. The McBryde disconformably overly the top of the Pine Barren Member. The '*Turritella* rock' occurs at the top of the Pine Barren Member, is a yellow-gray, very fossilferous, sandy limestone, characterized by an abundance of species of Turritellid gastropods. The type section of the Pine Barren Member is 0.3 mile north of the intersection of Alabama Highways 21 and 28. The exposure is weathered, but foraminifera are abundant in the weathered silts. The flora and fauna in both the Pine Barren and the McBryde marls and limestone are characteristic of open marine shelf deposits. The '*Turritella* rock' and McBryde Limestone are interpreted as shelf margin, transgressive and condensed section deposits of an unconformity-bounded, Type 2 depositional sequence. The marine marls and marginal marine clays of the lower member of the Porter's Creek Formation represent the highstand regressive deposits of this Type 2 sequence. *(Mancini and Tew, 1988, Stop 8)*

0.1	45.0	Intersection with Al-28 (to left) continue right on Al-21.
1.1	46.1	Intersection with Al-89.
0.6	46.7	K/T boundary(?) along Hwy 21 (C on map).

Cursory inspection of this outcrop indicates it appears very similar to Braggs K/T outcrop that occurs along AL-263, with dark-gray Prairie Bluff underlying light colored, lower Clayton Formation containing distinctive limestone ledges. At the Braggs location, the Prairie Bluff consists of gray, micaceous, clayey silt containing *Exogyra costata*. The Prairie Bluff contact is disconformable and is marked by quartz grains and phosphate pebbles at the base of the lowermost Pine Barren limestone. The Pine Barren member includes olive gray, micaceous, glauconitic, calcareous, fine-grained sand; olive-gray, argillaceous, glauconitic limestone; greenish gray, micaceous calcareous, glauconitic, silty clay and silt; and gray silt and clay.

8.1	54.8	Outcrops - ?Clayton.
2.5	57.3	Wolf Creek.
2.3	59.6	Lowndes County line.
1.0	60.6	Intersection with CR-11.

3.7	64.3	Intersection with Al-263 (formerly CR-7) – turn right onto Al-263, beginning of Braggs K/T section.

Stop 7. Series of four outcrops along Al-263, southwest of Braggs.
K/T boundary; Cretaceous (Ripley Fm., Prairie Bluff Fm.), Paleocene (Clayton Fm., Pine Barren mbr., McBryde Limestone mbr.)

0.8	65.1	**Stop - 7A : Cretaceous - Ripley Formation.**
1.2	66.3	Ripley Fm – both sides of road.
1.0	67.3	Prairie Bluff Chalk.
1.2	68.5	Dirt road to left.
1.1	69.6	Prairie Bluff Chalk.
0.4	70.0	**Stop - 7B: Cretaceous - Prairie Bluff Chalk.**
1.4	71.4	**Stop - 7C: K/T contact, Clayton/Prairie Bluff.**
1.6	73.0	Creek.
1.6	74.6	McBryde Limestone.
0.3	74.9	**Stop - 7D: Paleocene (Midway) McBryde Limestone, Clayton Fm.**

Optional Stop A. Mussell Creek, K/T boundary.

Continue south on Al-263 to I-65, at Greenville. Travel south on I-65 to intersection with US-84, and then east on US-84 to Claiborne Bluff, Alabama River.

Claiborne, Historical Marker, 1939

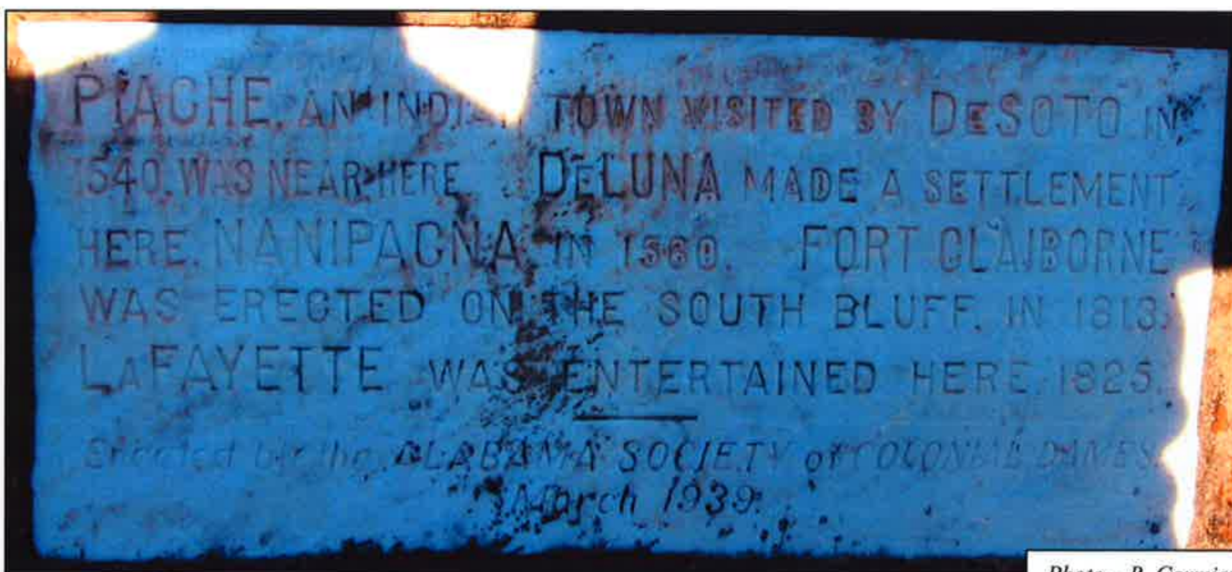


Photo – R. Cormier

Historical Marker – Claiborne, 1999

"During the westward expansion of the United States in the early 1800's, those whose destination was the new Mississippi Territory took a right fork off the Federal Road which led to the Alabama River ferry at Claiborne. After the land cessions of the Creek Indians in 1814, Claiborne became one of the fastest growing settlements in the old Southwest, attracting a number of Alabama's early prominent men. Among there were future state governors John Gayle, John

Claiborne became one of the fastest growing settlements in the old Southwest, attracting a number of Alabama's early prominent men. Among there were future state governors John Gayle, John Murphy, and Arthur Bagby. Claiborne was also the home of William Barrett Travis, who traveled to Texas and became the hero of the Alamo in 1836."

Road log segment, along US-84, between Claiborne Bluff on the Alabama River and Grove Hill.

0.0 0.0 **Claiborne Bluff (Optional Stop B).** US-84 bridge over the Alabama River.

Claiborne Bluff is beneath the bridge over the Alabama River. This is the type section for the Claiborne Group. The upper part of the Gosport Sand (Claiborne Group), and the Moody's Branch Formation and North Twistwood Creek and Cocoa Sand members of the Yazoo Formation (Jackson Group) are also well exposed. Just upstream from the bridge is the Claiborne Lock and Dam, which backs up Claiborne Lake on the Alabama River. Claiborne Lake encompasses over 60 miles of the Alabama River, from the Claiborne Lock and Dam to the Millers Ferry Lock and Dam. There is no power plant associated with the Lock and dam. The Alabama River Heritage Museum is also located at the Claiborne Lock and Dam. Exhibits in the museum include fossils collected at Claiborne Bluff, Native American artifacts found in Monroe County, and on the steamboat era, that includes a miniature replica of a steamboat that traveled the Alabama River. Water behind the dam also covers only known exposure (former) of the Gregg's Landing Marl member of the Tuscahoma Formation. (Bollman, 1968; http://al-lakes.sam.usace.army.mil/claib/)

CLAIBORNE FOSSILS (from River Heritage Museum website)
The fossils on display are from the Gosport Sand, a layer of Southeast rocks noted for its concentration of fossils. Sir Charles Lyell, of England, father of modern Geology and friend of Charles Darwin, visited Alabama in 1846, in part to see this 60 million year old shallow-water sea floor of Eocene age. The Gosport Sand, uppermost formation of the Claiborne fossils are known and studied by geologists world-wide. Examples are found in Natural History Museums around the world, according to Dr. Doug Jones, retired Geology Professor of the University of Alabama. Judge Charles Tait of Claiborne, Alabama was something of an amateur geologist in the early 1800s. He recognized the significance of the exposed layer of fossils, halfway up the Claiborne Bluff, visible from the cotton slide and landing steps, which traversed the 150-foot bluff. The samples he shipped to the Philadelphia Academy of Sciences were sent all over the world when word got out that this Eocene-age layer was sloughing off whole shells in perfect condition. Dr. Timothy Conrad, from Philadelphia, spent almost 2 years studying and collecting at Claiborne as a house guest of the Taits. He found many unknown species. The Gosport Sand is renowned for the great number and variety of fossils - over 150 species can be identified in it. The most rare and significant are the smallest specimens, some being microscopic. He also found important examples of these Eocene fossils in the Bell's Landing Bluff, North of Claiborne, also in Monroe County, known especially for its large turritella shells. *http://www.frontiernet.net/~mchm/page6.html*

3.8 3.8 Monroe County line.
1.7 5.5 Historical marker.

John Murphy – Historical Marker, 1979
"John Murphy, fourth governor of Alabama. Born in Robeson Co., North Carolina, came to Monroe Co., Alabama in 1818. Represented Monroe County at the Alabama Constitutional Convention in 1819, and in the state legislature from 1819 – 1822. Served as governor of Alabama from 1825-1829. Elected to the US congress in 1833 for one term. Died in 1841 and is buried in Gosport, 2 miles from here, on his Clarke County Plantation."

3.5 9.0 Outcrop on left – Marianna Limestone.

1.8 10.8 Intersection with CR-35, historical marker.

Old Line Road – Historical Marker, 1978

"Commences at the Cut-Off, or the first high ground in that vicinity. Follows the watershed between the Alabama and Tombigbee Rivers, and ends at Choctaw Corner. Established in 1808 by the Creek and Choctaw Indians as the dividing line between their lands."

2.2 13.0 Intersection with CR-22.
1.0 14.0 Intersection with CR-14, historical marker.

Kimbell-James Massacre - Historical Marker, 1954

"½ mile from here. Sept 1, 1813. Creek Indian War, 1813-14. Part of War of 1812. British used Pensacola as base to arm, incite Indians against US. Prophet Francis led Indians in this raid on Kimbell home. They killed and scalped 12 of 14 (two survivors left for dead): pillaged house, killed livestock."

3.1 17.1 Intersection with CR-18.
1.7 18.1 Intersection with Al-295, in Grove Hill.

Turn left on US-43 to Jackson (~13 miles)

End Day 2

Abandoned loading chute (top), Tombigbee River (right), St. Stephens Quarry.

Day Three – Jackson, Alabama to Lafayette

Leave Jackson, and drive northwest on AL-69, along the east side of the Tombigbee River. Road log will start at the intersection of Al-69 and US-84 in Coffeeville.

0.2 mile west of intersection is dirt road to right (sign to Ed's Landing). For $3 you can park and look at the outcrops of the Lisbon Formation at the water's edge. This spot is best visited during periods of low water.

Coffeeville Landing, Tombigbee River
Eocene (Claiborne): Lisbon Formation

Early descriptions of this exposure described about 40-feet of the Lisbon Formations in 7 different beds. The following description is taken from Jones (1968, p.86), which in turn was a modification of the original description of the area by Smith and Johnson (1887). When I visited this outcrop in 1986, the water level was about the level of beds 3 and/or 4. Solitary corals (*Flabellum* sp.) and large mollusk shells were abundant on the shoreline. When visited earlier this year, only the top few inches of the described section could be seen because of high water.

Geologic Section Exposed at Coffeeville Landing, Tombigbee River, Clarke Co., Alabama

7. Sand, light yellow, partly indurated, with *Ostrea sellaeformis*.
6. Sand, yellowish, calcareous, with *O. sellaeformis*; upper part loose, lower part an indurated sandy ledge.
5. Sand, yellowish gray, calcareous, very fossilferous, loose; abundant *O. sellaeformis*; separated from next bed by sandy ledge.
4. Clay, sandy, or sand, clayey, bluish gray, with *O. sellaeformis* and *Flabellum;* in two parts separated by a hard ledge, the upper part is ~8 feet, the lower part is 3-4 feet.
3. Sand, glauconitic, filled with shell fragments and perfect shells; *Flabellum cuneiforme pachyphyllum, O. sellaeformis, Venericardia densata*, and many others.
2. Clay, dark bluish gray, nearly black, nonfosilferous, breaking into cuboidal blocks.
1. Sand, dark greenish gray, clayey, like that near the base of Claiborne Bluff, about 5-feet showing above water.

0.0	0.0	Intersection with US-84, in Coffeeville, continue north on Al-69.
0.5	0.5	Intersection with CR-31 (to right) in Coffeeville.
1.6	2.1	Intersection with Al-154.

West of here (across the Tombigbee River) is the village of Womack Hill, namesake of the Womack Hill Oil Field. The field was discovered in 1970, and extends into the western part of Clarke County (approximately here). The trap was initially interpreted to be a salt pillow anticline. The field has produced ~30 million barrels of oil, out of initial estimated reserves of 110 million barrels. The production is from the upper Smackover Formation (Jurassic). The Womack Hill oil field is one of 57 Smackover fields (in Alabama) associated with the regional peripheral fault trend. This trend has produced ~670 million barrels of oil up to 2005. *(PTTC)*

3.5	5.6	Intersection with CR-21, (to right).

0.1	5.7	Intersection with CR-21, (to left).
2.4	8.1	Intersection with CR-31.
2.4	10.5	Outcrops of terrace deposits on both sides of the road for the next 2.4 miles.
2.4	12.9	End section of road with abundant terrace deposits.
1.5	14.4	Stop – Tallahatta cuesta.

Stop 8. Hwy 69 road cut @ Tallahatta Creek, south of Campbell
Eocene (Claiborne) - Tallahatta Formation

1.0	15.4	Tallahatta Creek.
1.1	16.5	Intersection with CR-44, Campbell.
0.5	17.0	Crest of hill – top of Bashi Creek section.
0.2	17.2	Stop – Bashi Marl outcrop.

Stop 9. Hwy 69 road cut @ Bashi Creek, north of Campbell
Eocene (Wilcox) - Bashi Marl, Hatchitigbee Fm.

0.2	17.4	Bashi Creek.
3.1	20.5	Intersection with CR-10, to Bashi Creek Landing on Tombigbee River.
0.3	20.8	Clarke County line.
3.6	24.2	Intersection with CR-4, Putnam.
1.4	25.6	Horse Creek.
0.4	26.0	Terrace-dirt.
3.4	29.4	Gravel Creek Sand mbr – covered outcrops.
1.1	30.5	Intersection with CR-9.
1.1	31.6	Intersection with Al-10.
5.5	37.1	CR-90 (to right).
2.6	39.7	Transco Pipeline Compressor Station, Williams Company.

Williams' Transco pipeline delivers natural gas to its customers though a 10,560 mile pipeline network extending from south Texas to New York. The pipeline system and compressor stations move gas from the Gulf coast to twelve southeast and Atlantic seaboard states, including major metropolitan areas in New York, New Jersey, and Pennsylvania. The pipeline system is designed to move 8.1 billion cubic feet per day and has a seasonal storage capacity of 216 billion cubic feet. The pipeline contains 43 separate compression stations. Williams is one of the largest natural gas producers in the US, controlling a portfolio of 3.4 trillion cubic feet equivalent reserves and producing 612 million cubic feet of natural gas equivalent, per day, as of the end of 2005. The primary producing basins are the Piceance, San Juan, Powder River, Arkoma, and Fort Worth Basins. *(www.Williams.com)*

0.5	40.2	CR-17 (to left).
0.5	40.7	Beaver Creek.

1.7	42.4	Intersection of Al-69 and Al-114, continue north on Al-69.

Five miles west on Al-114, the road crosses the Tombigbee River at old Naheola Landing, just south of the bridge is Naheola Bluff. At one time this was a good exposure of the Porter Creek mudstone and Matthew's Landing Marl – but is presently badly slumped and overgrown, with good exposures only of the Porters Creek mudstone at water level.

4.1	46.5	Threemile Creek.
4.4	50.9	Intersection of US-43 with Al-69, turn left on US-43.
0.6	51.5	RR crossing.
0.2	51.3	RR crossing.
0.5	51.8	Intersection with Al-28 (from east) continue straight on US-43/Al-69/Al-28, in Linden.
0.5	52.3	Intersection of Al-28, with US-43 and Al-69, in Linden, turn left onto AL-28.
0.5	52.8	Terrace deposits.
1.5	54.3	First of 5 bridges across the Chickasaw Bouge drainage.
0.6	54.9	Bridge – Chickasaw Bogue.
0.5	55.4	Intersection with CR-44.
0.5	55.9	RR crossing.
0.1	56.0	Intersection with CR-19.
0.7	56.7	Ditch crop – Prairie Bluff.
0.5	57.2	Terrace – red.
3.3	60.5	Historical marker – Jefferson Methodist Church.

Jefferson Methodist Church, historical marker, 1976

"Built on two acres of land deeded by John D. Catlin, May 30, 1842, to Daniel Finch, E. Ellis, James Turner, David Compton, and John Besteder, trustees of Methodist Episcopal Church known as Asbury Meeting House. This early Greek Revival building was dedicated on the first Sunday in June, 1856, by the Reverend Phillip Phillips Neely, minister from Marion, Alabama. Services are held 2^{nd} and 4^{th} Sundays, 9:00 AM."

0.1	60.6	Historical marker – Jefferson Baptist Church

Jefferson Baptist Church, historical marker, 1965

"Jefferson Baptist Church established as Mt. Pleasant Baptist by Elder James Yarbrough in 1820 with 27 charter members. By 1834 it had 150 members. Church is among the oldest in Demopolis area. Buried in the church cemetery are John Gilmore, Reuben Hildreth and John Sample – Revolutionary War veterans who founded Jefferson and helped establish this church."

0.3	60.9	Intersection with CR-21.
0.5	61.4	Outcrop – terrace deposits.
0.5	61.9	Outcrop – Porter's Creek capped by high terrace deposits.
0.5	62.4	Outcrop - left side of road, Cretaceous – Prairie Bluff/Ripley undifferentiated.
0.2	62.6	Outcrop right side of road - Reworked fossils in basal Clayton – Ripley/Prairie Bluff undifferentiated.

Stop 10. Hwy 28 road cuts – NW. of Jefferson
K/T contact - Prairie Bluff/Ripley undifferentiated, Clayton (weathered)

3.5	66.1	Bridge over Double Creek.
1.7	67.8	Gas line – compressor station (left).
0.5	68.3	Intersection of US-80 & Al-28, RockTenn Demopolis Plant ahead and to right along Tombigbee River – (this plant is a pulp and paperboard mill, which has a capacity to produce 327,000 tons per year of solid bleached sulfate (SBS) board and 91,500 tons per year of southern bleached softwood kraft market pulp. *(from a recent company press release)*
0.9	69.2	Rooster Bridge over the Tombigbee River.
0.2	69.4	Marengo County line.
0.3	69.7	Historical marker (on left), Rooster Bridge.

The Rooster Bridge, historical marker (no date)

"In 1919 a rooster sale organized by Frank Derby raised money to begin construction of a bridge over the Tombigbee River at Moscow Ferry. This was the last link in the completion of the Dixie Overland highway between Savannah and San Diego. The idea was "to bridge the Bigbee with cocks": Roosters would be solicited from world-famous persons and an auction and barbeque held in the city of Demopolis for the benefit of the bridge. Congressman "Buck" Oliver, Admiral William S. Benson, and Secretary of Navy Josephus Daniels helped sell President Wilson on the idea. He and the others of the Big Four, Lloyd George, Clemenceau, and Orlando, who were meeting at the Versailles Conference, shipped rosters on the USS Northern Pacific. Governor Kilby sent 27 prominent Alabamians to the White House to receive the roosters from President Wilson. By August 14, 1919, 600 roosters (and one hen from Helen Keller) had arrived in Demopolis. President Wilson's rooster auctioned for $44,000. Over $200,000 was pledged, but most was not collected. The names of 88 donors appear on markers at the original site, one mile downstream. With the addition of state and federal funds the bridge was constructed and opened in 1925 as Memorial Bridge. Always known locally as Rooster Bridge, the name was officially changed in 1959 when a bill sponsored by Senator E.O. Eddins passed the State Legislature. In July, 1971, a bill sponsored by State Representatives I.D. Pruitt and R.S. Manley was approved, which decreed that all future bridges over the Tombigbee at Moscow would be named Rooster Bridge and bear plaques relating the unique plan devised by Frank Derby in building the first bridge."

3.1	72.8	Intersection with CR-25, turn left.
2.9	75.7	Boise Cascade Lumber / Chip Mill.
0.3	78.8	Road ends @ the Rooster Bridge historical marker, Moscow Landing, Tombigbee River.

Stop 11. Moscow Landing, Tombigbee River
K/T Boundary - Prairie Bluff Chalk, Clayton Formation, Porter's Creek Formation

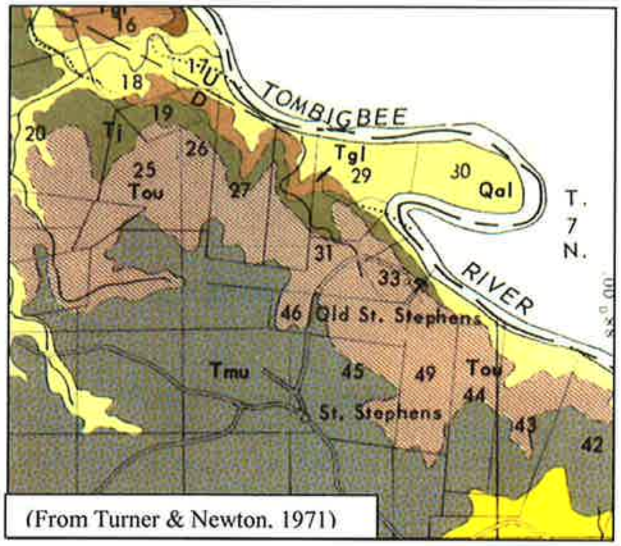
End Road Log

Return to Hwy 80, continue east to I-59, travel south on I-59 through Meridian, Laurel, and Hattiesburg to I-12 at Slidell, travel west on I-12 to I-10 (Baton Rouge), continue west on I-10 to Lafayette.

IV. Stop Descriptions

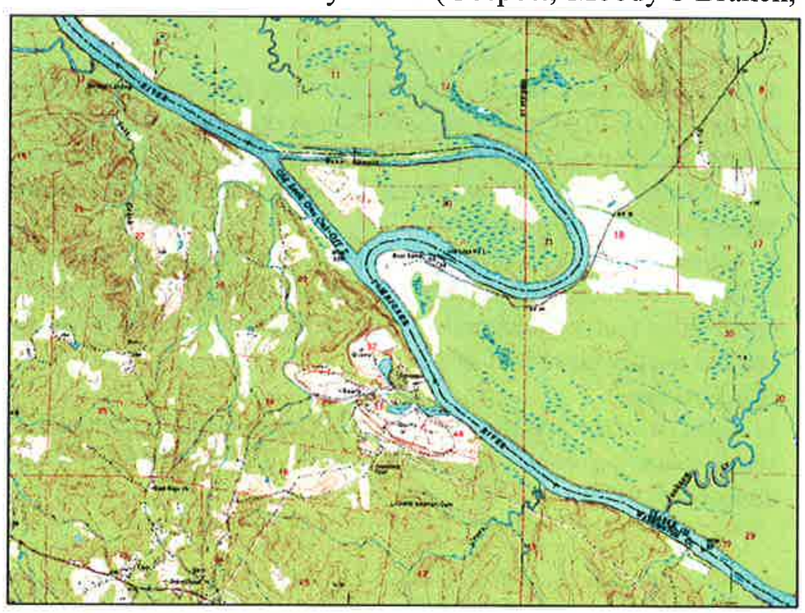
Stop 1, Day 1
Old St. Stephens Quarry, Washington Co., Alabama

References: Mancini & Copeland, 1986; Jones,1967, stop 16; Mancini & Tew, 1988a, Stop 1; Turner & Newton, 1971; Baum & Vail, 1988: Matte, Brown, Waddell, 1999:



(From Turner & Newton, 1971)

St. Stevens Bluff, once a prominent landmark and well-known exposure of the "White Limestone" located near the one-time State Capitol at 'old' St. Stephens, has now been mainly quarried away. The quarrying operation, however, has revealed one of the most complete and continuously exposed Oligocene sections in North America. The geologic section includes over 14-feet of upper Eocene strata (Pachuta Marl and Shubuta Clay members, Yazoo Formation), and about 160-feet of Oligocene strata (Red Bluff to Chickasawhay Limestone). The Eocene-Oligocene contact occurs at the base of the Red Bluff/Bumpnose Limestone. Also exposed at this location are the Gosport and Moody's Branch (on right bank of the Tombigbee River, 200 yards northeast of the Pelham Hill Quarry, probably part of the Gopher or Bakers Hill section of Smith (1894). The quarry is near the southeastern nose of the Hatchitigbee anticline. As a result the beds strike about N 70° W and dip 2-2.5° SSW. The entire Eocene and Oligocene section at St. Stephens is marine (marginal to open outer shelf) and is very fossilferous. Microfossils and megafossils are abundant in the sandy marl, clay marls, and limestone, but rare in the black clays and silts. Throughout most of the section, microfaunal assemblages are highly varied. In contrast, he megafaunal assemblages, with the exception of the rich molluscan faunas of the sandy marls (Gosport, Moody's Branch, and Chickasawhay) are mainly orbitoids and pectinids. The Lone Star Cement Company Quarry at St. Stephens was opened in 1928 and has operated continually, 7-days per week since that date (through the early 80's). Material was removed from the quarry at a rate of 750,000 tons per year. The Glendon and Marianna Limestones were mixed with Yazoo and Red Bluff Limestones. The materials are then crushed and loaded on barges and shipped to New Orleans through the intracoastal canal.



***Stratigraphic Column** (from Jones, 1967)*

Pliocene? - *Citronelle Formation*

13. Sand and silty clay, red to brown; unconformable lower contact (20+')

Oligocene - *Chickasawhay Limestone*

12. Marl, buff (weathered), sandy, glauconitic with limestone ledges; contains *Pecten howei howei, Chlamys glendonensis, C. mcquirti, C. gainstownensis, C. chickaria, Kuphus incrassatus, Anomia taylorensis, Echinolampus aldrichi, and Cassidulus gouldii*. In places burrows are present at lower contact (18.9')

Bucatunna Clay member, Byram Formation

11. Clay, green to black (weathers brown), bentonitic, gypsiferous; with occasional silt beds (one inch or less thick) which in the lower part are fossilferous (25.9')

Unnamed Marl member, Byram Formation

10. Marl, olive (weathers buff) glauconitic, contains *Pecten perplanus byramensis, P. howei mariannensis* (rare); gradational upper contact; burrowed lower contact. (1.1')

Glendon Limestone

9. Interbedded limestone ledges and marl, cream colored (weathers brown), skeletal; weathering of limestone produces a "horsebone" appearance. Marls become nodular; contains orbitoids, *Ostrea vicksburgensis, Chlamys duncanensis*

Marianna Limestone

8. Limestone, very soft; upper 9-feet cream colored, remainder gray; upper part nearly pure calcium carbonate; lower part argillaceous and slightly glauconitic; with some thin persistent limestone ledges; contains *Clypeaster rogersi, Lepidocyclina mantelli, Ostrea vicksburgensis, Pecten perplanus perplanus* (lower beds), *Pecten perplanus poulsoni* (middle and upper beds); basal 1.5 feet is brownish, very glauconitic bedded marl; irregular lower contact. (59')

Forest Hill Sand

7. Clay, dark-brown, carbonaceous, blocky, sparingly fossilferous; gradational lower contact. (8.8')

Red Bluff Clay/Bumpnose Limestone

6. Interbedded limestone ledges and marl: Limestone, greenish-gray to cream, sandy, and argillaceous, glauconitic, fossilferous; marl, olive- to brownish- gray, glauconitic, containing *Cyclaster drewryensis, Ostrea vicksburgensis, Spondylus dumosus, Flexopecten anatipes, Pecten perplanus perplanus*, basal bed is brownish-gray marl, 2-feet thick, lower contact is irregular. (13.5')

Eocene - *Yazoo Clay – Shubuta Member*

5. Clay, blue gray, very glauconitic, contains phosphatic nodules and few megafossils, transitional lower contact. (4')

Yazoo Clay – Pachuta Marl Member

4. Marl, blue-gray, sandy, glauconitic; with abundant phosphatic nodules; contains *Chlamys spillmani, Periarchus lyelli pileussinensis, Eburnopecten scintillates*, and *Actinocyclina bainbridgensis*. Floor of Pelham (north) quarry is generally near the Pachuta Marl – Cocoa Sand contact. Approximately 50-feet of Cocoa Sand and North Twistwood Creek members are not exposed. (11')

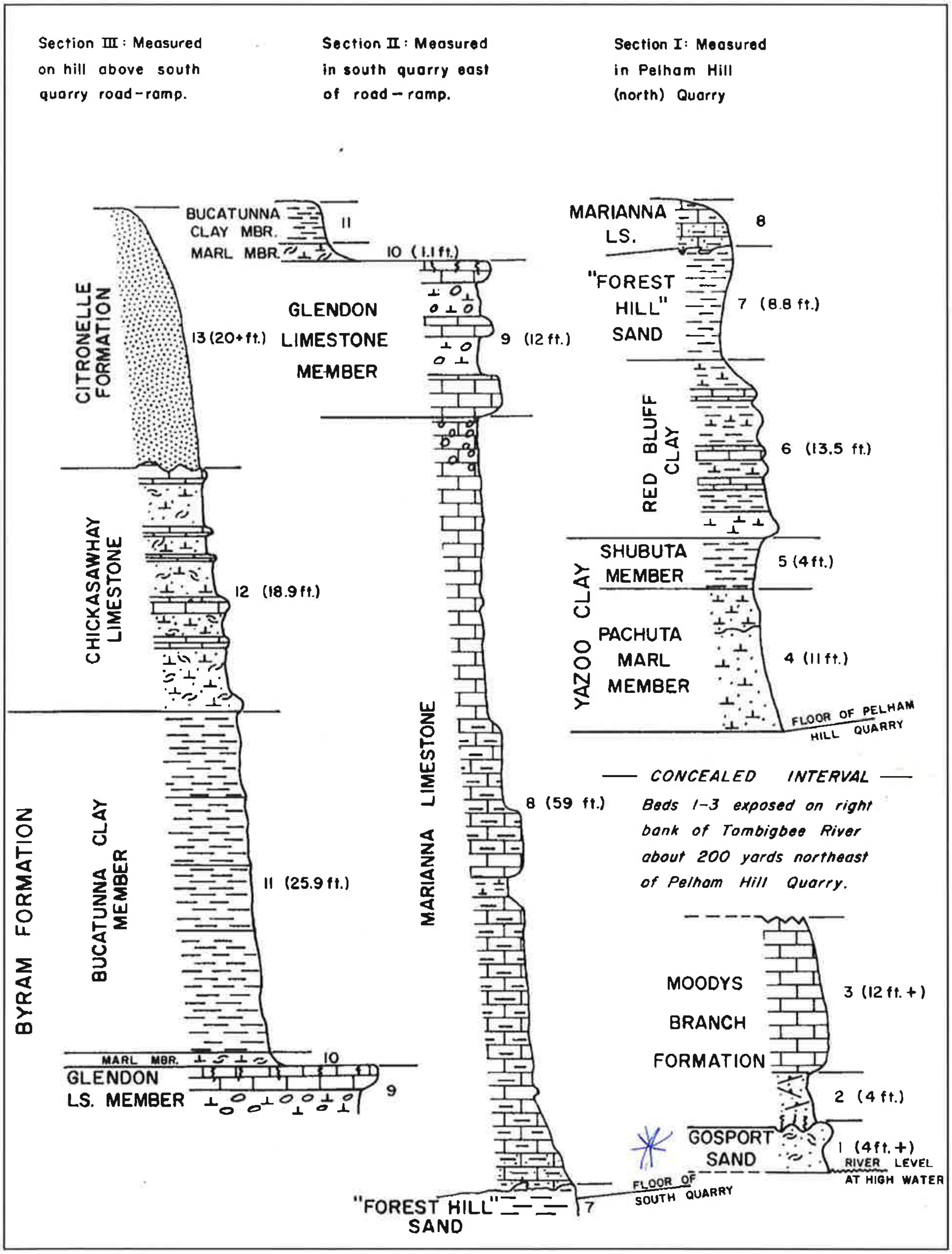
Moody's Branch Formation

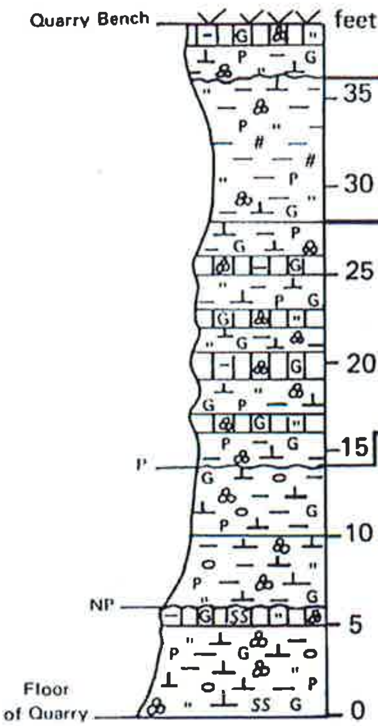
3. Limestone and silt, gray, glauconitic, contains molds and impressions of fossils. (12+')
2. Marl, weathers yellowish brown, sandy, glauconitic, contains *Periarchus lyelli* scattered throughout in upper three feet, concentrated as the 'Scutella bed" n the lower foot. Also contains *Chlamys nupera*; lower contact deeply burrowed. (4+')

Gosport Sand

1. Sand, weathers reddish brown, medium to coarse grained, glauconitic, contains many mollusks and corals including *Venericardia claiboplata, Calptraphorus velatus, Endopachys maclurii,* and *Chlamys deshayesii*. (4+')

(from Jones, 1967)





Oligocene

Marianna Limestone (3^+ feet)

Limestone; very pale orange (10YR8/2), argillaceous, silty, glauconitic, fossiliferous.

Marl; yellowish gray (5Y8/1), argillaceous, silty, glauconitic, pyritic, fossiliferous, irregular lower contact.

Forest Hill Formation/Red Bluff Clay (8 feet)

Clay; dark greenish gray (5GY4/1), carbonaceous, pyritic, calcareous, sparingly glauconitic and fossiliferous becoming more so at the base of the unit, gradational lower contact.

Red Bluff Clay/Bumpnose Limestone (14 feet)

Limestone and Marl interbedded:

Limestone; yellowish gray (5Y8/1), argillaceous, silty, glauconitic, fossiliferous.

Marl; greenish gray (5GY6/1 to 5G6/1) to dark greenish gray (5GY4/1), argillaceous, silty, very glauconitic, pyritic, fossiliferous.

Clay; light olive gray (5Y8/1), calcareous, glauconitic, pyritic, fossiliferous, irregular lower contact.

Eocene

Yazoo Clay, Shubuta Clay Member (4 feet)

Marl; greenish gray (5G6/1), argillaceous, glauconitic, phosphatic, pyritic, fossiliferous, transitional lower contact.

Yazoo Clay, Pachuta Marl Member (10^+ feet)

Marl and Limestone interbedded:

Marl; dusky yellow green (5GY5/2), argillaceous, silty, sandy, glauconitic, phosphatic, pyritic, fossiliferous, burrowed.

Limestone; dusky yellow green (5GY5/2), argillaceous, silty, glauconitic, fossiliferous, burrowed.

LEGEND

Sand · Limestone · Phosphatic · Silty/sandy · Burrowed

Clay · Fossiliferous · Glauconitic · Argillaceous · Micaceous

Marl · Calcareous · Pyritic · Carbonaceous

from Mancini and Copeland, 1986

P = Eocene-Oligocene boundary recognized on the basis of planktonic foraminifera

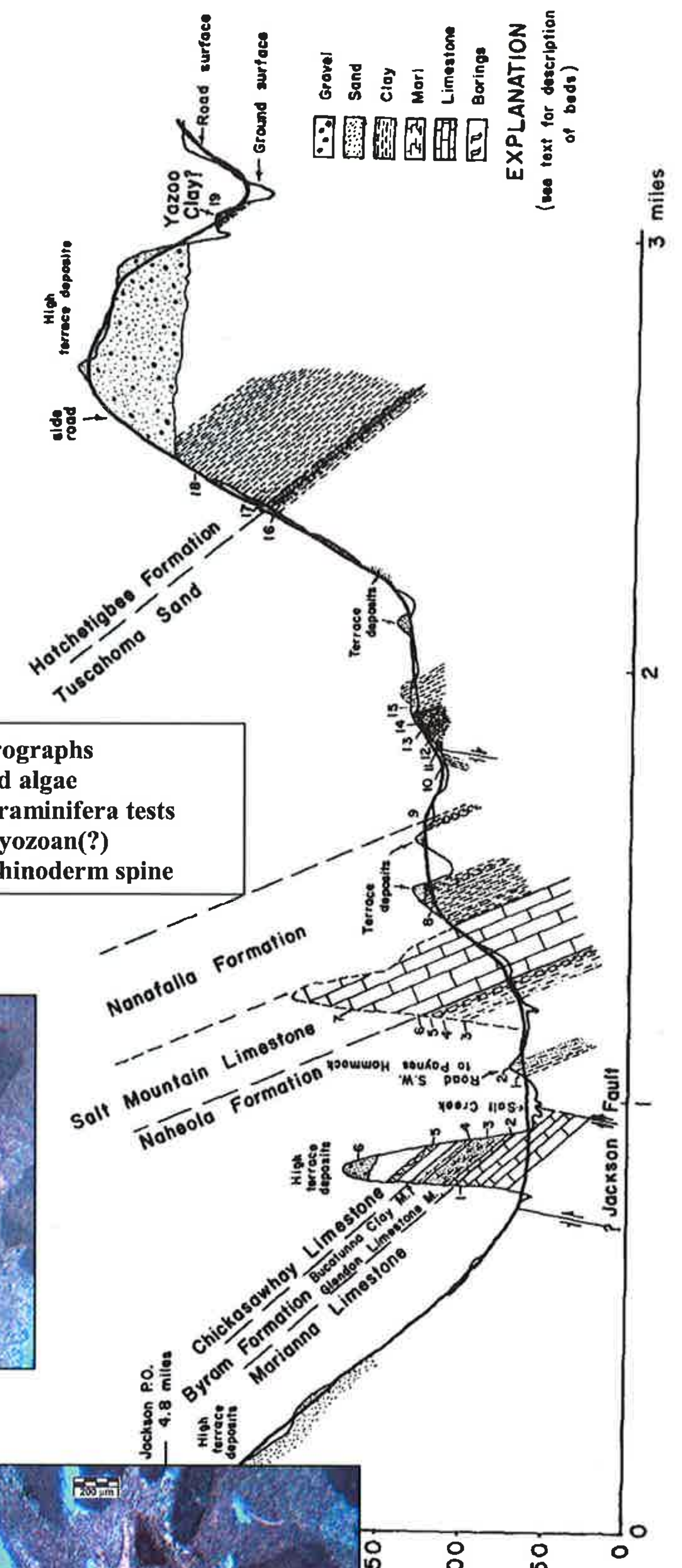
NP = Eocene-Oligocene boundary recognized on the basis of calcareous nannoplankton

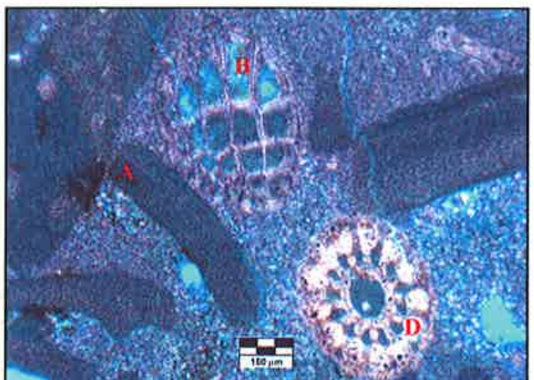
Glendon Limestone @ 'Indian Baths'

Stop 2, Day 1
Richmond Branch, along CR-15, south of Jackson

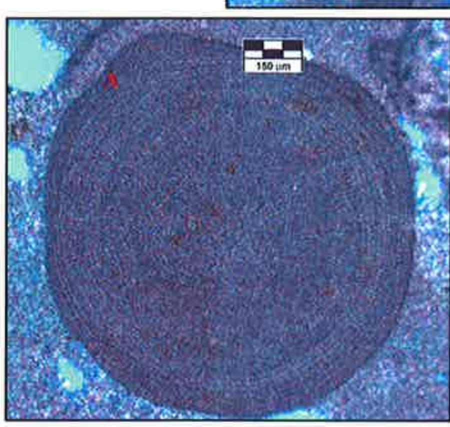
Reference:
Copeland, et. al., 1976, Stop 8A.

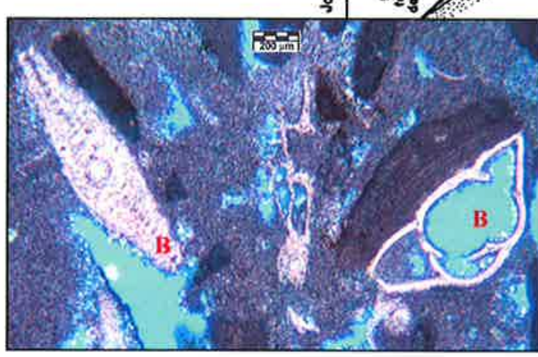
This exposure of highly inclined beds of the Marianna Limestone and Glendon Limestone is on the upthrown side of the Jackson Fault. The lithology and elevations of the Marianna and Byram and other geologic units cropping out along CR-15 in the vicinity of Richmond Branch and Salt Mountain are shown on the geological profile.





t/s photomicrographs
a. red algae
b. foraminifera tests
c. bryozoan(?)
d. echinoderm spine





Stop 3, Day 1
Salt Mountain, outcrops along CR-15, south of Jackson, Alabama
References: Copeland, et. al., 1976, Stop 8B; Jones, 1967, *from Jones, 1967* , 1940.

The Salt Mountain Limestone generally ranges in thickness from 60-90 feet and consists mainly of white, very fossilferous (micro) indurated limestone. The formation is only exposed at this locality on the upthrown side of the Jackson Fault in the vicinity of Salt Mountain. It is included in the Paleocene largely on the basis of its plankonic foraminifera assemblage. Toulmin, and other workers, based on stratigraphic relationships consider it a down-dip correlative to the *Ostrea thirsae* beds (member) of the Nanafalia Formation. The plane of the Jackson fault is not exposed and only the approximate trace is known. The displacement exceeds that of other faults in the Alabama Coastal Plain and at the surface at Salt Mountain it is about 1400-feet. Displacement decreased northward, and is about 50-feet near Jackson Creek, 7-miles northwest of Jackson, Alabama.

Bed Descriptions along Clarke County Hwy 15
in the vicinity of Salt Mountain and Salt Creek

Chickasawhay Limestone
Limestone, grayish-yellow, argillaceous, glauconitic, soft, fossilferous, poorly exposed (20')

Byram Formation
Limestone, white, weathers dark yellowish-orange, crystalline, cemented by calcite, fossilferous. Middle consists of yellowish-gray coquina that contains abundant *Lepidocyclina* sp., and *Ostrea vicksburgensis*. Contains irregular solution pits and cavities. Upper part is poorly exposed greenish-yellow clay. (20')

Marianna Limestone
Limestone, white to grayish-yellow, weathers grayish orange, soft, massive, *Lepidocyclina mantelli* abundant throughout, a few tubular solution cavities near top. (25' +)

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Nanafalia Formation
Clay, light-gray to medium light gray weathering various shades of gray and pale to dark yellowish orange, thin-bedded to massive, very finely sandy, glauconitic, and micaceous throughout, subconchoidal fracture; contains some thin layers of very fine-grained sand that weather limonite plates from partings. A layer of fine to coarse-grained, abundantly glauconitic sand 1-foot thick is present in the lower part (70')

Salt Mountain Limestone
Limestone, white, stained black on surface in places, massive, irregularly indurated, weathers and erodes to irregular surfaces, sparsely glauconitic, abundantly microfossilferous in places. Rests on basal sand 1-3 inches thick which is pale greenish-yellow, fine to very-coarse grained, glauconitic, and fossilferous, containing *Discocyclina blanpiedi, Pseudophragmina cookie,* and *Ostrea thirsae.* (60')

Naheola Formation
Sand, yellow-gray, weathers dusky yellow to pale yellowish-orange, thin-bedded to laminated with some crossbedding, fine-grained, sparsely glauconitic, micaceous. Lower part is olive-gray, very finely sandy, silty micaceous carbonaceous laminated clay. Data for lower part is obtained from auger hole.

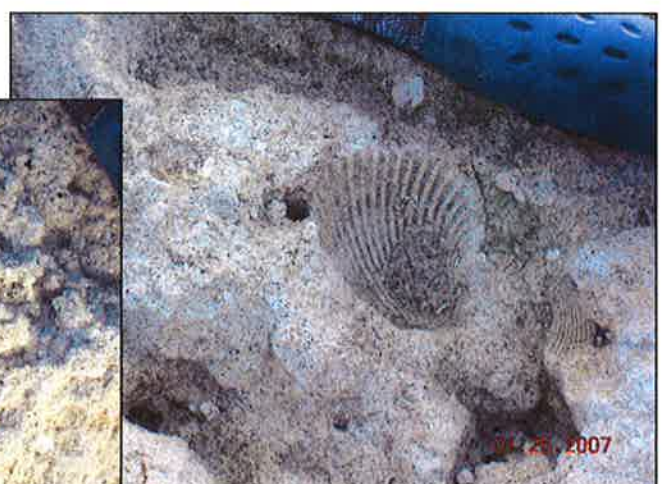
Stop 4, Day 2, Alabama River @ J. Lee Long Bridge, near Millers Ferry
Reference: Jones, 1967, stop 9.

a. **low road cut – McBryde member, Clayton Formation (4a on map).**
b. **rock pile – Pine Barren member, Clayton Formation.**

The Pine Barren member of the Clayton Formation is much thinner at this stop that it is just a few miles further east. At Old Canton Landing, about 7 miles to the east, it is approximately 145-feet thick. It continues to get thinner as it is traced westward from this stop, and pinches out or becomes indistinguishable near the Wilcox-Marengo County line. The McBryde Limestone member, also, is not distinguishable west of Wilcox County.

Geologic Section (after LaMoreaux & Toulmin, 1959)

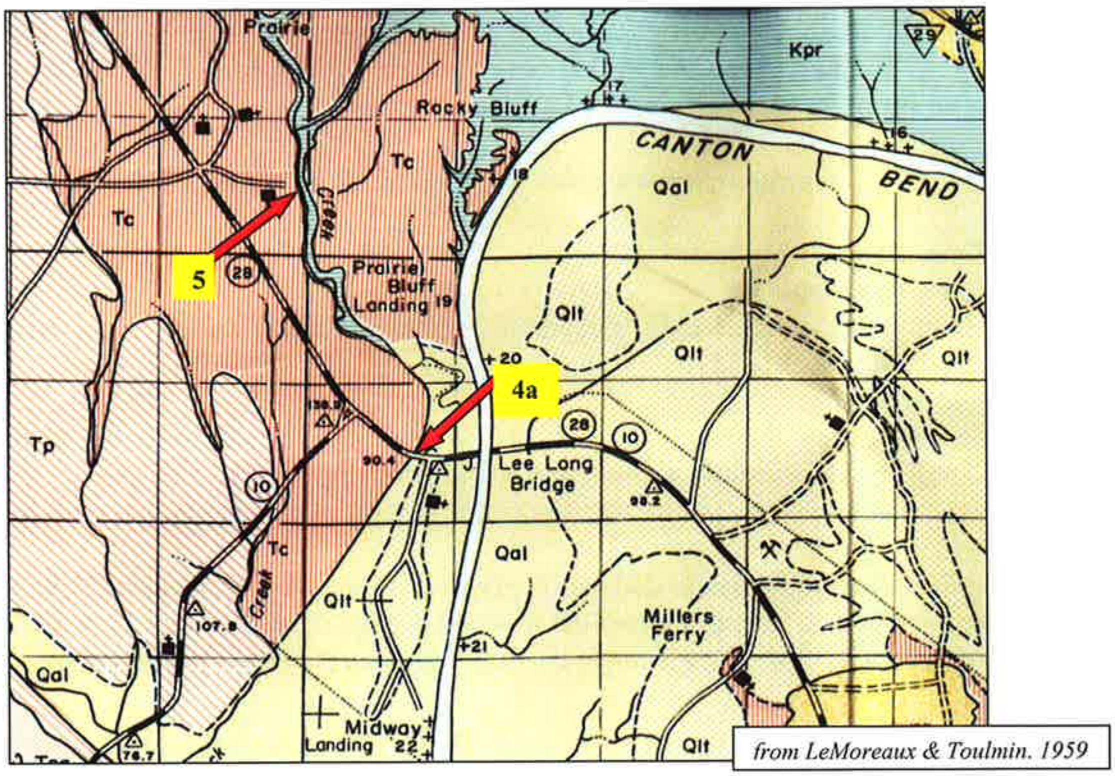
Clayton Formation
McBryde Limestone member
5. Chalk, light-gray to white, sandy, glauconitic, contains nautiloids and large zoaria of a bryozoan. "*Nautilus* rock" (7')
Pine Barren member
4. Sand, brownish-gray, medium to coarse-grained, glauconitic, calcareous; contains irregular masses of hard, sandy limestone, *Ostrea*, and a few other fossils (3')
3. Limestone, dusky-yellow, sandy, fossilferous; in irregular alternate ledges with brown sand. "*Turritella* rock". (10')
2. Silt and fine sand, yellowish to dark-gray, glauconitic, very argillaceous and micaceous, calcareous, fossilferous; includes indurated siltstone ledges about 6-inches thick. (22')
1. Covered to contact with Cretaceous rocks near water level in river below bridge. (20+')

'dog-bone' burrow & *Venericardia* sp. cast.
Pine Barren mbr., Clayton Formation

Stop 5, Day 2
Shell Creek
References: Jones, 1967, stop 10; King & Petruny, 2005, 2004, 2003; Smit, et.al., 1996; Bralower, et.al., 1998;

The K/T boundary is well exposed along Shell Creek. The type locality of the Prairie Bluff Chalk in on the Alabama River, about a mile east of here.



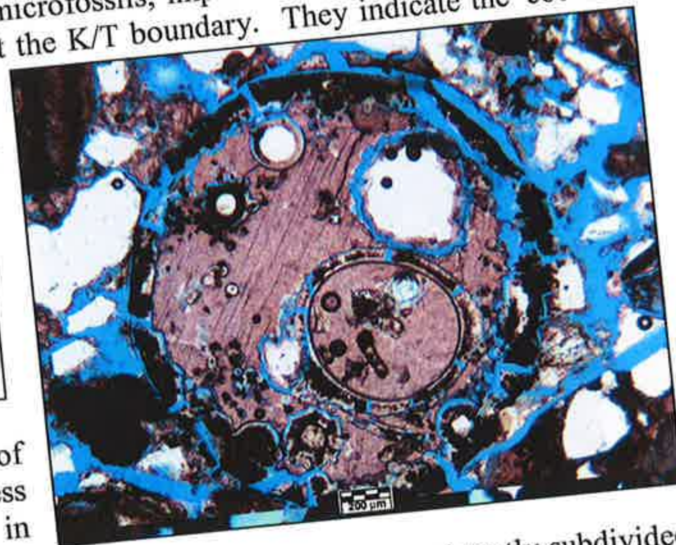
from LeMoreaux & Toulmin. 1959

Section at Shell Creek (from Toulmin, 1955b)

Paleocene
Clayton Formation – Pine Barren mbr.
4. Hard ledges of calcareous sandstone
3. Sand, yellowish, massive, slightly argillaceous, coherent, with *Ostrea pulaskensis* and with reworked Cretaceous fossils in the bottom part; lies with sharp erosional contact on the chalk below.

Cretaceous
Prairie Bluff Chalk
2. Chalk, bluish-gray, argillaceous, massive, similar to bed 1, but with no observed fossils.
1. Chalk, bluish-gray, argillaceous, massive, with numerous Cretaceous fossils including *Exogyra costata, Nautilus dekayi, Paranomia scabra, Gryphaea sp., Discoscaphites conradi*, and an echnoid.

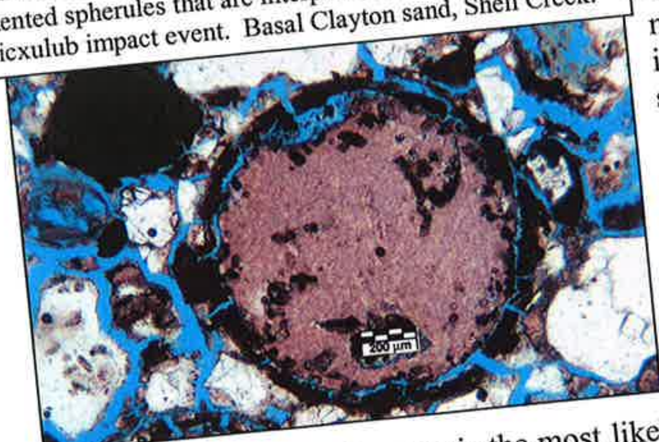
Bralower, Paull, and Leckie (1998) describe a K/T boundary 'cocktail' they suggest is characteristic of sediments at the K/T boundary throughout the Gulf of Mexico Basin. This 'cocktail' is a distinctive mixture of reworked microfossils, impact derived materials, and lithic fragments that occur in sediments that occur at the K/T boundary. They indicate the 'cocktail' was deposited by giant sediment gravity flows, apparently triggered by the collapse of continental margins around the Gulf of Mexico as a result of the Chicxulub impact.

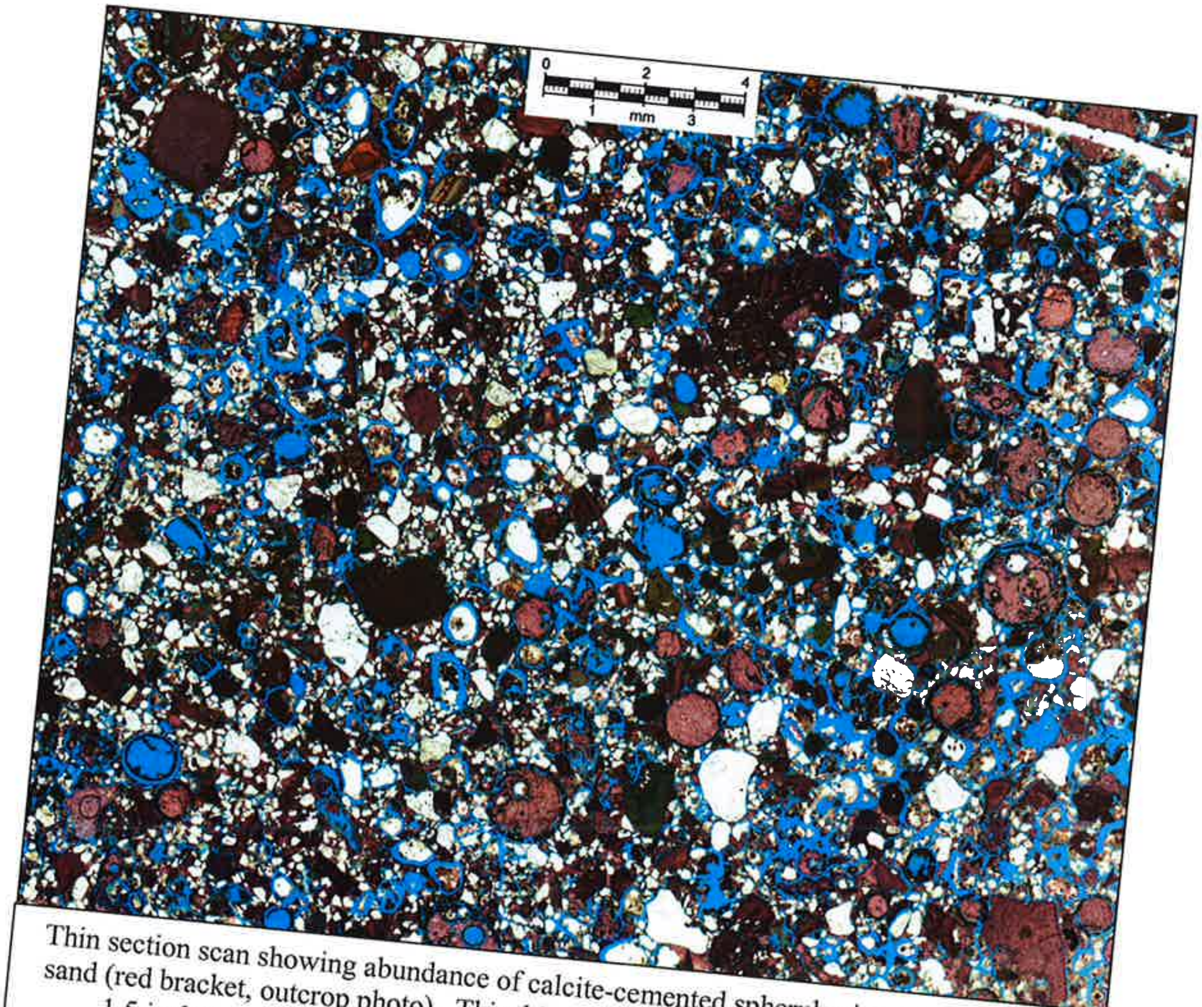


Thin section photomicrograph (50X) showing calcite-cemented spherules that are interpreted to be ejecta from the Chicxulub impact event. Basal Clayton sand, Shell Creek.

Smit, et. al. (1996) describes a series of unusual sandstone beds (ranging in thickness from 2-inches to 27-feet thick) that occur in almost any outcrop exposure of the K/T boundary. The sandstone beds have a complex architecture, but can be consistently subdivided into three (sometimes four) successive lithological units. From bottom to top the units decrease in grain size and change in composition and texture. The lowest unit is characterized by millimeter-size particles, spherules, and other splash-form particles with interfiled vesicles, and limestone clasts. Both are interpreted as altered impact ejecta. This ejecta, mixed with rip-up clasts from underlying formations, washed-out foraminifers, and other material scavenged from the seafloor, fill shallow channel-like depressions. The overlying unit consists of a sequence of several lenticular sandstone layers made up of a mixture of foraminifers, bioclasts, plant remains and terrigenous material. This sandstone may be massive, graded, or parallel or current ripple laminated. Spherules and limestone clasts are rare in this unit. These sandstones are deposited in very shallow, stacked channels or erosional-depression infillings and display a variety of sedimentary features contains evidence for repeated up-section changes in current direction and strength. The upper unit consists of strngers of fine sand ripples alternating with thin silt layers. Only this unit and the overlying graded, silty mudstone (if present) contains anomalous iridium and Ni-rich spinels, concentrated in the silt layers. The coarser basal units in particular show internal unconformable stratigraphic relationships, but all of the units and beds are amalgamated on top of each other, without interruption by layers of normal background sediments. There is no unequivocal evidence (such as intercalated burrow layers) that the deposition of the entire sandstone complex took more than a few days. Deposition by a series of large, waning tsunami waves is the most likely explanation for the texture of the K/T sandstone beds, although locally, gravity flows may have assisted in the transport of sands from the near

Thin section photomicrographs (50X) showing calcite-cemented spherules that are interpreted to be ejecta from the Chicxulub impact event. Basal Clayton sand, Shell Creek.





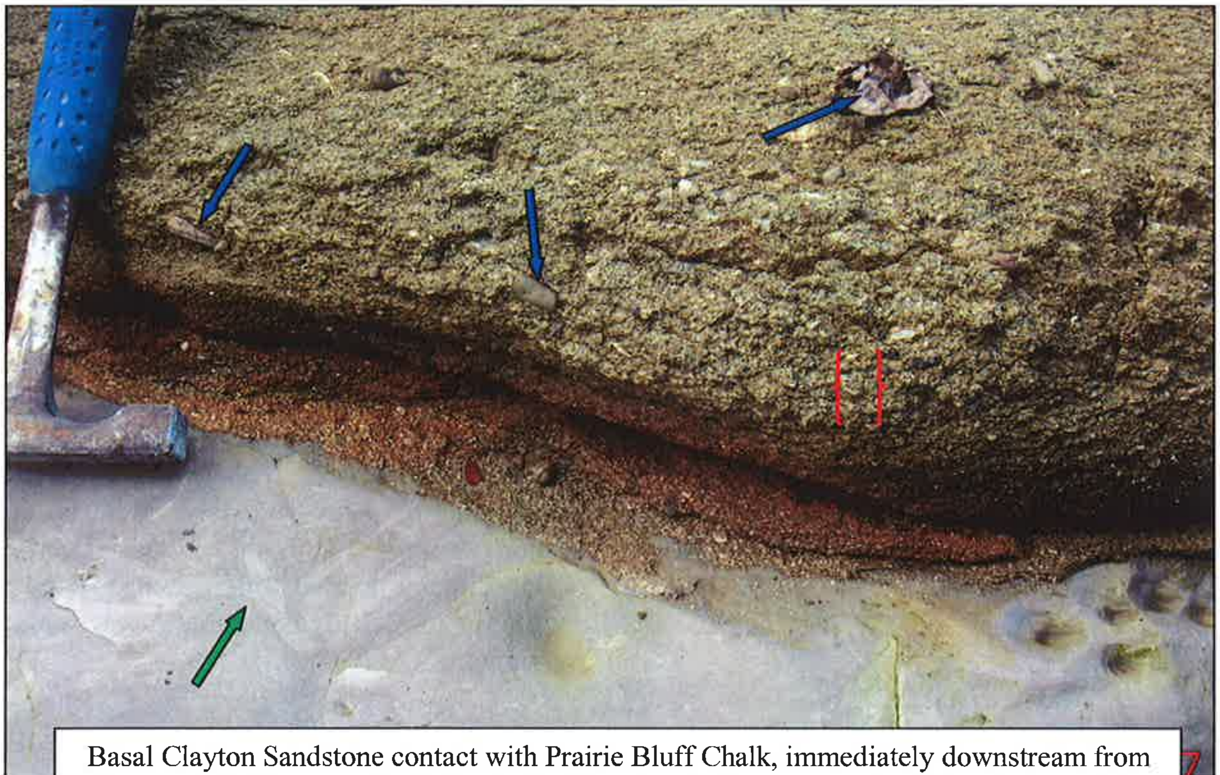
Thin section scan showing abundance of calcite-cemented spherules in part of the basal sand (red bracket, outcrop photo). This thin section is from part of the formation about 1.5 inches above the basal contact with the Prairie Bluff Chalk. Shell Creek.

shore areas. In shallow shelf-seas (e.g. Alabama) earliest Danian sea-level fluctuations have modifies or (partially) removed the K/T sandstone complex.

The lowermost 'pockets' of basal Clayton-age sands found at Moscow Landing are described as a poorly-sorted conglomerate containing Cretaceous macrofossils, Prairie Bluff chalk clasts, in a matrix of coarse sand. Characteristic components of the sand matrix are green, sparry calcite-filled spheroids and droplets, 2-3 millimeters in diameter, with an external lining of clay minerals. The spheroids contain internal cavities, also filled with sparry calcite. Identical spheroids are found in the nearby outcrops of Shell Creek and Lynn Creek, and these are interpreted as altered splashform tektites, by analogy with spheroids from Beloc (Haiti) and Mimbral (Mexico) which are filled with bubble-cavity-rich glass.

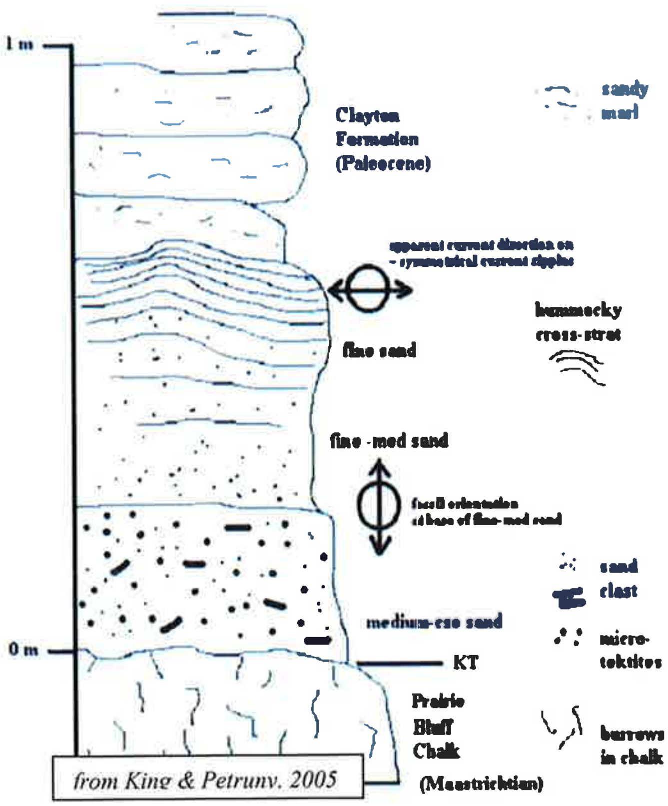
King and Petruny (2005) indicate the microtektites at Shell Creek represent the most easterly occurrence of Chicxulub impact ejecta (termed the Chicxulub microtektites strewn field), within the US Gulf Coastal Plain. Coeval microtektites are known from sections in Texas, at Moscow Landing, Tombigbee River, Alabama, in Mexico and in Haiti, but only a few locations in Mexico and Haiti have the density of tektites seen in the Shell Creek section. This is even more remarkable because tektites are not identified in any K/T sections in Alabama, east of Shell

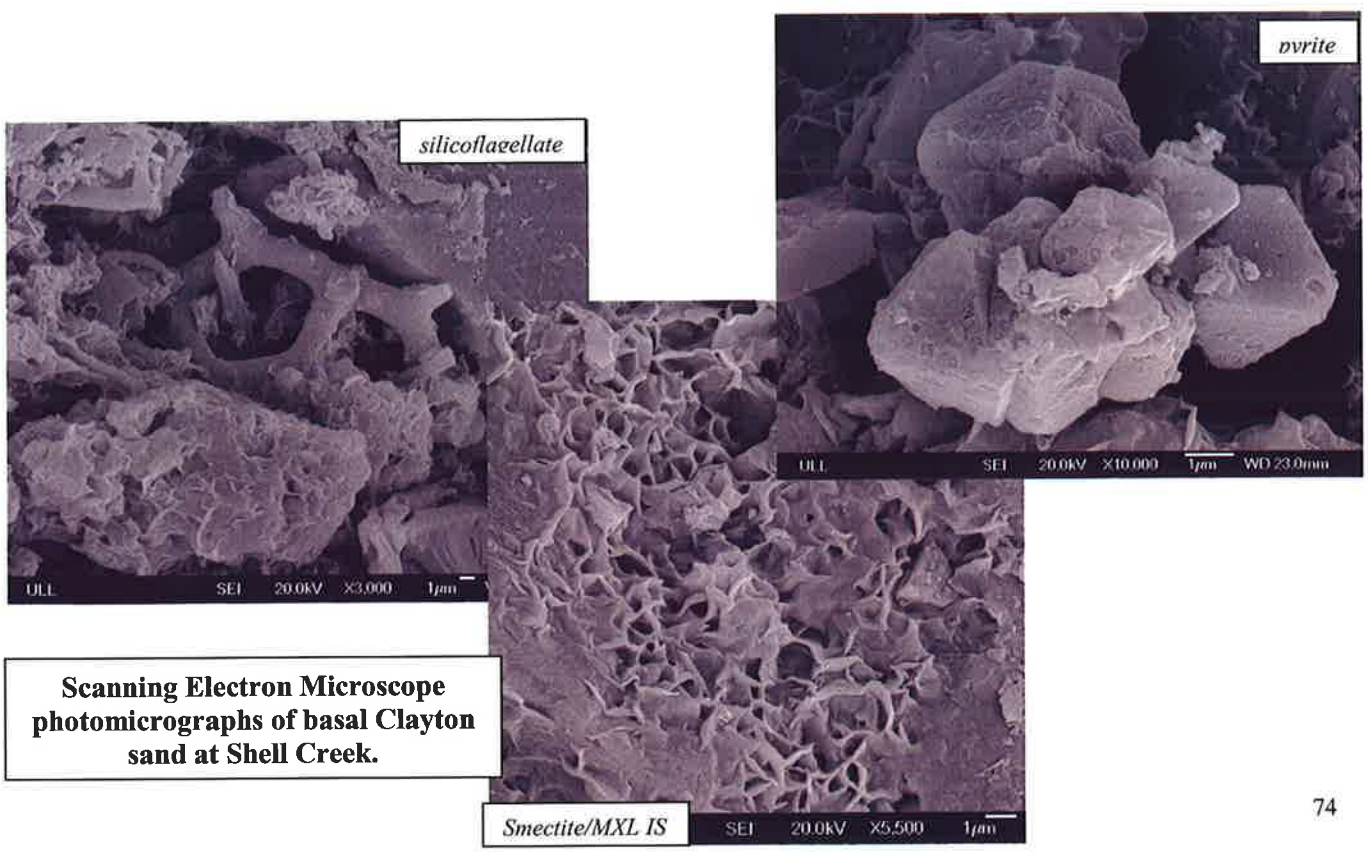
Creek (Braggs, Mussell Creek). At Shell Creek the upper surface of the Prairie Bluff Chalk is truncated and an impact-related basal sand couplet consisting of microtektite-rich sand and an overlying cross-laminated 'tsunamite' unit, ranging from 14-30 inch thick – rests directly on top of the Prairie Bluff chalk. This basal sand comprised the lower two beds of the Paleocene Clayton Formation in this vicinity.



Basal Clayton Sandstone contact with Prairie Bluff Chalk, immediately downstream from low water bridge over Shell Creek. Red brackets indicate approximate level where thin section was made (previous photos). Blue arrows indicate reworked Cretaceous macrofossils (oyster, cephalopod – nautiloids). Green arrow indicates burrow on top surface of Prairie Bluff. Brown layer contains medium to coarse grained sand, reworked Cretaceous fossils (including shark teeth), but very few spherules, especially compared to about 1-2 inches above the Prairie Bluff/Clayton contact.

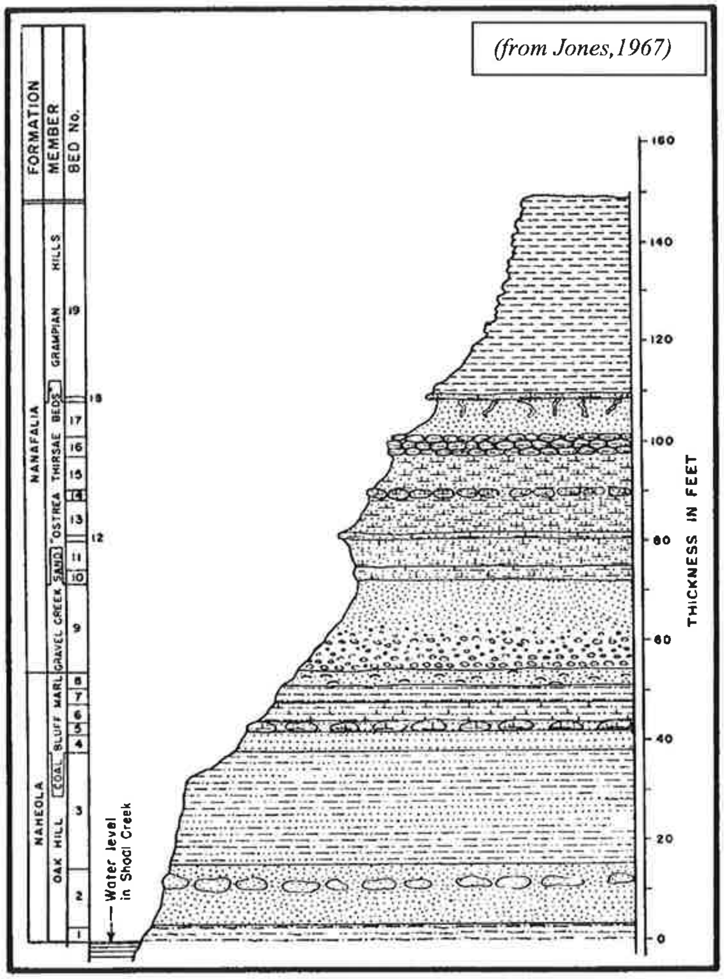
At Shell Creek there is a sharp contact between the gray, bioturbated shelfal chalk and the overlying gray, microtektite-rich coarse to medium sand bed (which is 6-15 inches thick). The basal inch or two contains significant amounts of hematite, in the matrix, giving a rusty appearance to the lowest part of the sand, but the upper part of the sand is mainly cemented by clay and calcite. The microtektite layer does not appear to be graded, but is very densely packed with microtektites which make us as much as 25% of the grains in some parts of the rock. The sand grains are medium to coarse sand size and are associated with fossil fragments and glauconite. They are not remarkable, except they are 'texturally' out of place" within the shelf-depositional realm of the adjacent strata. Characteristics (size, density, and layer-thickness) of the Shell Creek microtektite bed is more similar to the coeval layers seen in some of the Western Interior and Atlantic Coastal Plain sites, than sites in the Mexican sections. The overlying 12 to 20 inch thick layers of tan, medium to fine quartzose sand contains no microtektites, and there is a sharp, flat contact between the overlying sand and the underlying, gray, microtektite-bearing layer. The main features of these upper sands are thin laminations which are more nearly horizontal near the base, and grade upward into hummocky-type cross-laminations near the top. There are not burrows within this unit or penetrating the unit from above. Above this upper sand bed, rippled, sandy marls of the Clayton Formation are found, signaling a return to normal shelf sedimentation. King and Petruny (2005) interpret the basal sand unit here at Shell Creek to consist of two parts. The micro-tektite rich unit represents condensed particles of the vapor clouds from the deep Yucatan bedrock created by the Chicxulub bolide impact. They arrive at Shell Creek not long after impact. They determine, based on the average size of the particles they could settle on the bottom on the Prairie Bluff sea in about 7-minutes (assuming about 100' water depth). The occurrence of medium to coarse sand, glauconite, and shell fragments (non-ejecta material) indicates some mixing of coastal and near shore sand and microtektites. This could be tsunami-related, or gravity-deposit related, or a combination of both. The overlying, hummocky-bedded, finer-grained, sand was likely produced by subsequent, episodic tsunami waves.





Scanning Electron Microscope photomicrographs of basal Clayton sand at Shell Creek.

Stop 6, Day 2
Shoal Creek, along Al-265, south of Camden, Wilcox Co.
References; Jones, Stop 8, 1967.



This series of outcrops show parts of the Oak Hill and Coal Bluff members of the Naheola Formation, and the Gravel Creek Sand., *'Ostrea thirsae* beds', and Grampian Hills members of the Nanafalia Formation.

The Grampian Hills member, Nanafalia Formation, includes over 40-feet of 1) gray, glauconitic, sandy marl, 2) calcareous, fossilferous clay, 3) glauconitic, medium-grained sand, and 4) sandstone concretions. These are interpreted to be marine to marginal marine deposits.

The *'Ostrea thirsae* beds' (Nanafalia Formation) disconformably overly the Gravel Creek member. The *'Ostrea thirsae* beds' include more than 30-feet of greenish-gray, fossilferous, glauconitic, sandy marl, with sandstone concretions. These beds are rich in macrofossils, particularly *Odontogryphaea thirsae*. The contact between the *Ostrea thirsae* beds and the underlying Gravel Creek Sand is characterized by 1-2 feet of gray, highly bioturbated, clayey sand. The contact with the underlying Gravel Creek Sand member is disconformable. This unit is interpreted to be open marine shelf sediments.

The Gravel Creek Sand member (Nanafalia Formation) includes 44-feet of white, micaceous, unconsolidated cross-bedded, medium to coarse grained sand. The Gravel Creek-Coal Bluff contact is marked by the occurrence of large quartz grains, pebbles, and lignite clasts. The Gravel Creek Sand is interpreted to have accumulated as a barrier island to marginal marine sands.

The Coal Bluff member, Naheola Formation, consists of 39-feet of 1) greenish-gray, fossilferous, glauconitic marl and medium to coarse grained sand with sandstone concretions, 2) gray, silty, lignitic clay, and 3) thin lignite beds. The Coal Bluff disconformable overlies the Oak Hill member. The Oak Hill-Coal Bluff contact is marked by the occurrence of glauconite, quartz grains, lignite clasts, and abraded and broken shells, including a subspecies of *Venericardia* *wilcoxensis*. The clay and lignite beds likely represent marginal marine to deltaic deposits. The sands and marls were likely deposited as open marine shelf deposits.

The Oak Hill member of the Naheola Formation includes about 9-feet of blue-gray, silty clay, overlain by about 1-foot of lignite. These likely represent marginal marine to deltaic deposits.

Sequence stratigraphy. The Nanafalia is interpreted to represent an unconformity-bounded, Type 1 depositional sequence. This sequence is comprised of lowstand incised valley fill (Gravel Creek Sand), transgressive and condensed sections deposits (*'Ostrea thirsae* beds'), and highstand regressive deposits (Grampian Hills and lower Tuscahoma Formation). The Coal Bluff is also interpreted to represent an unconformity-bounded, Type 1 depositional sequence. The marls and glauconitic sands represent the transgressive and condensed section deposits of the sequence, and the silty, lignitic clays and lignite beds represent the highstand regressive deposits.

Ostrea thirsae beds, Nanafalia Formation, Shoal Creek

Stop 7, Day 2
Hwy 263 outcrops South of Braggs

Stop 7A. Ripley Fm. (Cretaceous), Al-263 road cut, ~0.8 miles from intersection with Al-21.
References: Bollman, 1968; Mancini & Puckett, Stop 2, 1998.

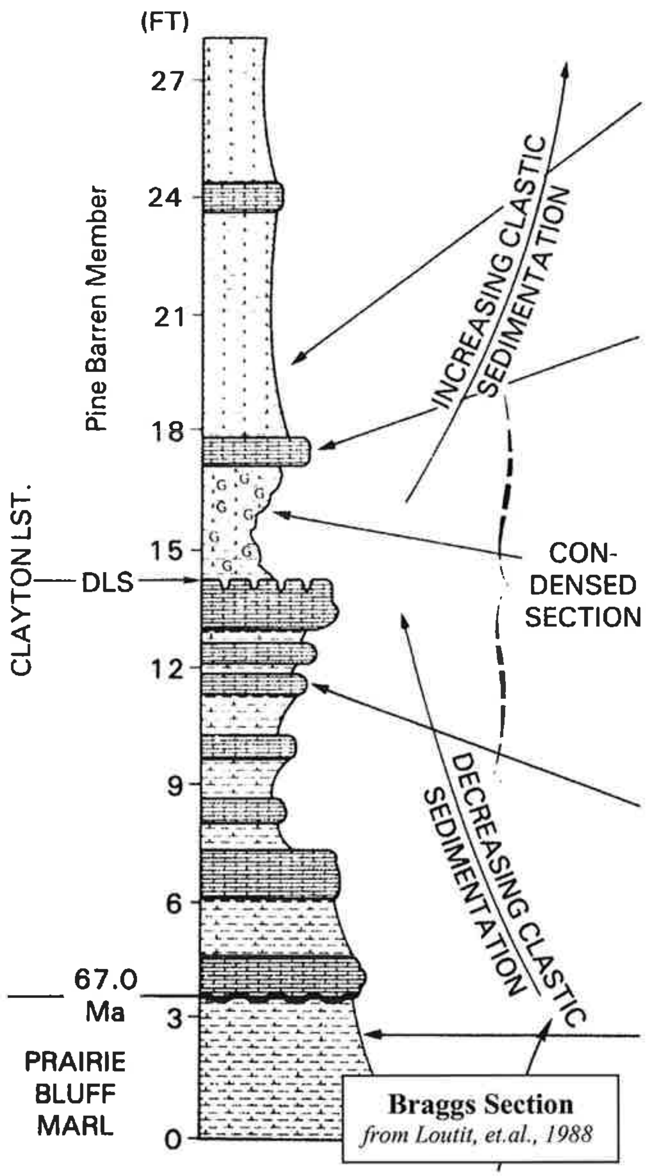
The Ripley Formation in this area includes ~10-feet of interbedded marl and fossilferous limestone and sandstone. The uppermost beds in the Ripley are very distinctive because of the abundant occurrence of *Flemingostrea (Ostrea) subspatulata* (photo). The beds are described as light-gray, weathering to yellowish-gray, sandstone and sandy limestone, irregularly bedded with medium-grained loose sand.

Stop 7B. Prairie Bluff Fm. (Cretaceous), Al- 263 road cut, ~5.7 miles from Al-21.
References: Bollman, 1968.

In this area the Prairie Bluff Chalk consists of 40+ feet of micaceous, clayey silt. The silt is dark gray, but weathers yellowish-gray, is massive, clayey, and is abundantly fossilferous. Macrofossils include *Exogyra costata and Anomia* sp. The basal 2-3 feet is a medium-gray chalk, indurated limestone, fine to coarsely sandy, glauconitic, fossilferous, packed with phosphatic pebbles and cobbles that are much as four-inches in diameter.

Stop 7C. K/T boundary, Al-263 road cut, ~7.1 miles from Al-21.
References: Bollman, 1968, Stop 10; Donovan, et. al., 1988; Copeland & Mancini, 1986; Zachos, J.C., et.al., 1989; Greenlee & Moore, 1988; Mancini & Puckett, Stop 2, 1998, Loutit, et.al, 1988.

The K/T contact is disconformable and occurs in the lowest indurated beds of the Pine Barren Member of the Clayton Formation. This unit is characterized by the occurrence of coarse to very coarse sand-size quartz grains and phosphate pebbles at the base of the bed. This is the lowest of the indurated beds in this exposure. The uppermost unconsolidated beds of the Prairie Bluff are gray-black, calcareous, silty and sandy, micaceous claystone. The large quartz grains seen in the basal Clayton are not seen in the underlying Prairie Bluff. Characteristic Cretaceous bivalves (*Exogyra costata, Anomia argentaria*) were relatively common at the contact, when the highway was first constructed. The Pine Barren includes approximately 110-feet of 1) olive gray, micaceous, glauconitic, calcareous, fine-grained sand, 2) olive-gray, argillaceous, glauconitic sandstone, 3) greenish-gray, micaceous, calcareous, glauconitic, silty clay and silt, and 4) gray silt and clay. *Ostrea pulaskensis* (bivalve, guide fossil for the lower Paleocene) is relatively abundant in the Pine Barren.

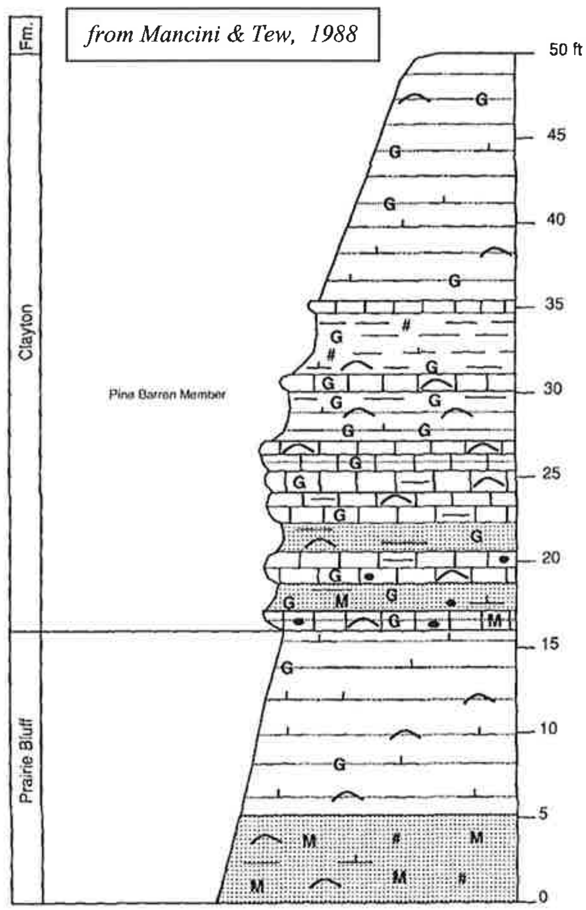


Braggs Section
from Loutit, et.al., 1988

Donovan, et. al. (1988) using sequence stratigraphic principles interpret the K/T boundary at the Braggs location to be located within the lower portion of the Clayton Formation. The K/T microfauna and microflora transition occurs within an 8-foot section of interbedded sandstones and limestones that directly overlies a sequence boundary, marked by regional truncation of the underlying Prairie Bluff Formation. This sequence boundary is related to a major eustatic fall in the late Maastrichtian (67 Ma). The interbedded sandstones and limestones in the Clayton Formation are interpreted as two backstepping parasequences deposited on the inner shelf during the subsequent rise in sea level. These two backstepping parasequences are overlain, in turn, by about 5-feet of glauconite rich strata representing a condensed section produced during a period do slowed terrigenous deposition, continued parasequences backstepping, and shoreline retreat. Three small iridium anomalies have been identified at the Bragg locality. These anomalies occur at marine-flooding surfaces, interpreted to be parasequence boundary, in the uppermost Prairie Bluff and basal Clayton Formations. The uppermost of these anomalies coincide with the base of the well-developed condensed section in the basal Clayton formation. The occurrence of iridium concentrations with marine-flooding surfaces at Braggs suggests that iridium was present in the open ocean during the latest Maastrichtian through earliest Danian, but concentrated only during periods of terrigenous-sediment starvation.

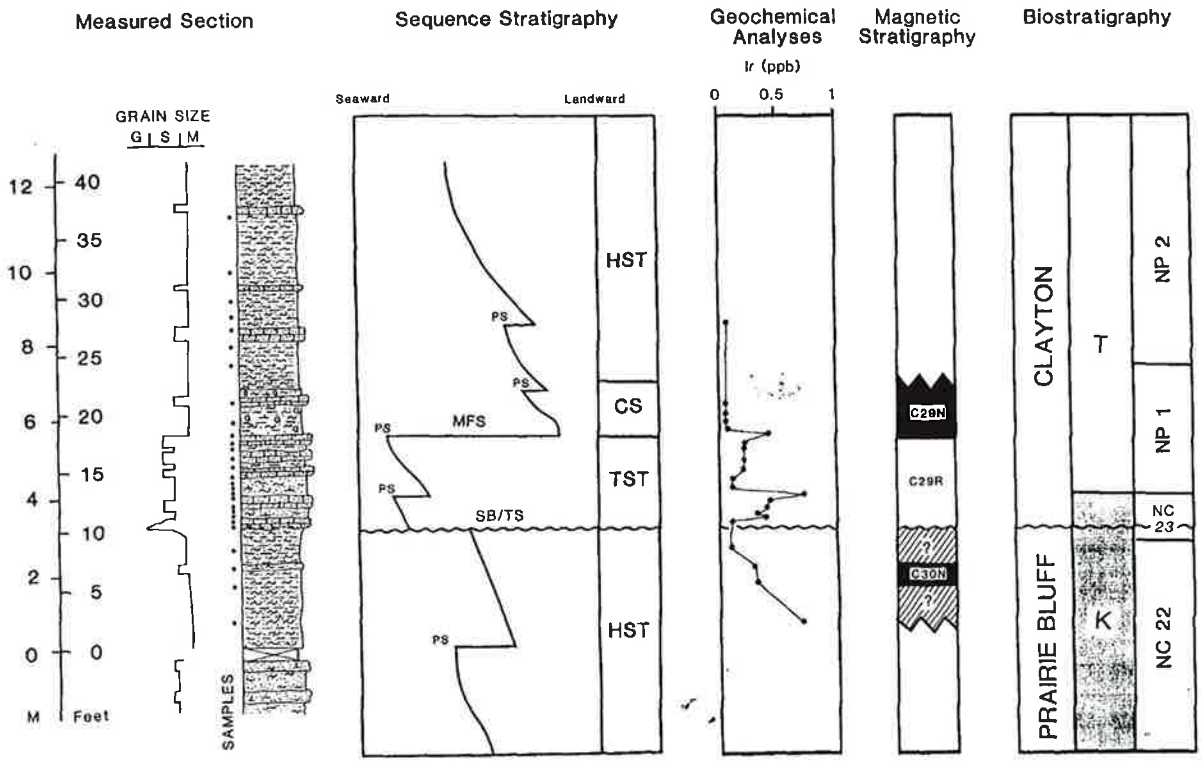
The top of the Prairie Bluff (and coeval Providence Sands to north and east) is marked by a regional unconformity, interpreted to be a sequence boundary. This sequence boundary is typically overlain by a quartz and phosphate pebble lag (0.5 to 2.0 feet thick) at the base of the

Clayton Formation, which is interpreted as a transgressive surface. Locally the sequence boundary at the top of the Prairie Bluff Formation and the transgressive surface at the base of the Clayton Formation diverge and bound laterally discontinuous sandstone bodies with sharp erosional bases. These sandstone bodies are interpreted as incised-valley fill deposits. They have been observed at Mussel Creek in Lowndes County, along the Alabama River at Millers Ferry dam site, and at Moscow Landing, on the Tombigbee River. Cretaceous macrofauna, microfauna, and microflora are present in the incised-valley fills. A lack of Danian fossils in these deposits suggests that the Cretaceous fossils are not just reworked. (editors note – subsequent work has found *Ostrea pulaskiensis* in some of these beds).



The Braggs K/T boundary section is located in an interfluve area where the sequence boundary and the transgressive surface at the base of the Clayton Formation are coincident. An abrupt change in lithology occurs about 10-feet from the base of the exposure, where a pebbly lag separates fossilferous mudstones of the Prairie Bluff Formation (below) from interbedded muddy sandstone and limestones (sandy packstones) of the Clayton Formation (above). These sandstone and limestone beds contain a diverse suite of benthic and planktonic organisms, indicative of a shelf environment with normal salinity. The sandy, limestone beds, which contain broken macrofauna debris and medium to coarse-grained quartz sand, are more closely related to higher energy sedimentary processes than the interbedded muddy sandstone. The microfloral and microfaunal K/T boundary occurs within the limestone and sandstone interbeds from 10-18' on the measured section. The boundary, based on foraminifer and calcareous nannoplankton is placed 2-3 feet above the base of the Clayton. About 18' from the base of the section there is an abrupt lithologic change from interbedded limestones and sandstones (below) to glauconitic mudstones (above). The top of the uppermost limestone is highly burrowed and bored. The burrows are fabric selective and do not truncate framework components. The borings, however, appear nonfabric selective, suggesting at least partial early lithification on this surface.

The Braggs section is an unusual K/T boundary site in that there have been three iridium spikes identified in the succession. The lowest anomaly occurs in the Maastrichtian, the middle anomaly near the K/T boundary, and the upper anomaly at the burrowed/bored limestone surface (limestone/glauconite mudstone). Donovan, et.al. infer that the three iridium anomalies at Braggs correlate with marine-flooding surfaces that are interpreted as sequence boundaries. The presence of iridium at these flooding surfaces suggests iridium is present in the open ocean from the latest Maastrichtian through the earliest Danian and was concentrated on the Alabama paleoshelf during periods of terrigenous-sediment starvation caused by rapid sea-level rises. Whatever the cause for the increase in iridium concentrations in the water column during this period, the decrease in terrigenous sedimentation associated with a global rise in sea level was fundamentals part of the process than concentrated the iridium and other possible cosmogenic debris in the sediments.



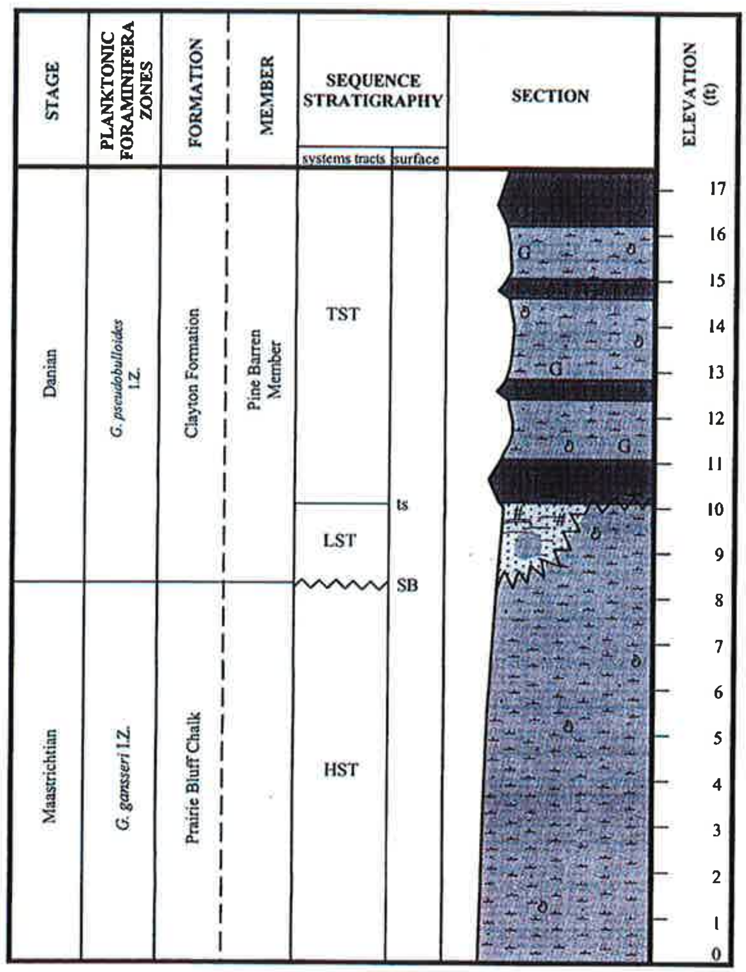
Sequence stratigraphic interpretation of the Braggs K/T boundary locality.
(from Donovan, et.al., 1988)

Stop 7D. McBryde Limestone

At this stop over 25-feet of the McBryde Limestone member of the Clayton Formation is exposed. Beds are chiefly white to gray crystalline limestone are fossilferous including *Ostrea crenulimarginata, Hercoglossus ulrichi (photo)*, and some echnoids.

Optional Stop A, Day 1
Mussell Creek
References: Mancini and Puckett, 1998, Stop 1.

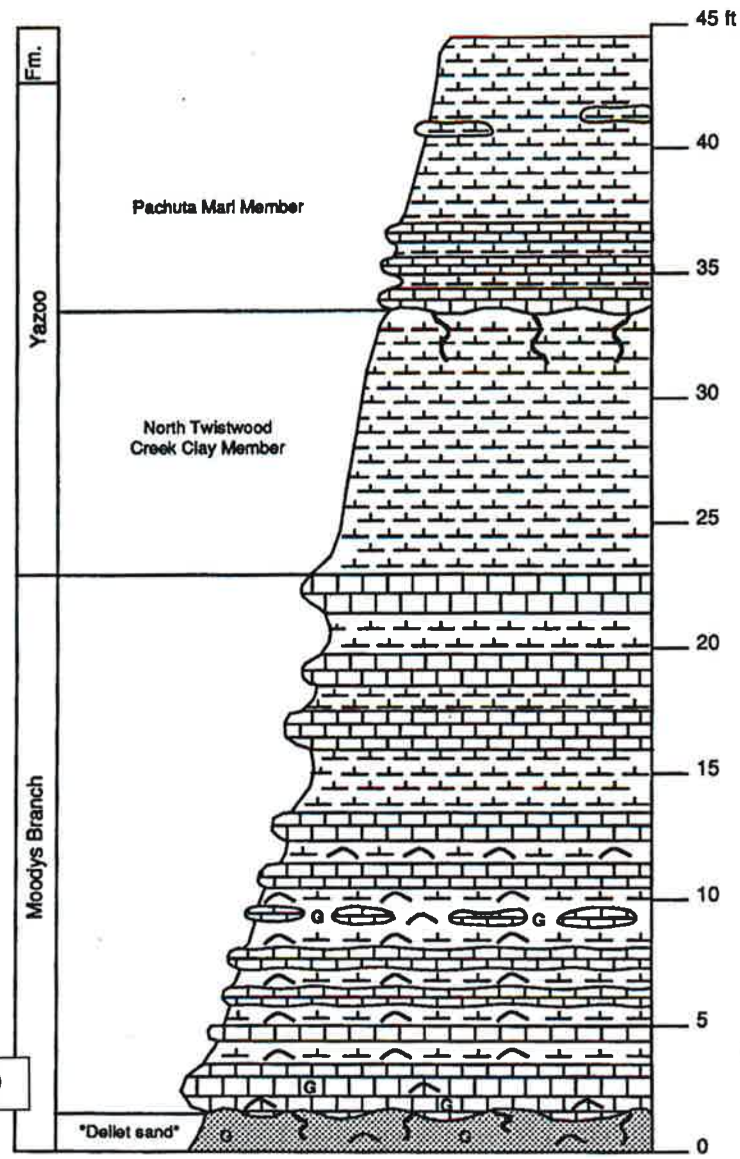
This section is located along Mussell Creek, off Highway 263, on a dirt road originating at the Lowndes-Butler county line. The section includes 8-10 feet of the Maastrichtian Prairie Bluff Chalk and 7 ½-feet of the Paleocene Pine Barren Member of the Clayton Formation. The Prairie Bluff is a gray, micaceous, fossilferous silt and sandy marl. The Pine Barren consists of a lower sand and an interbedded marl and limestone unit. The basal estuarine sand (lower Pine Barren) is cross-laminated, carbonaceous, lignitic, micaceous, and fine- to medium-grained. This sand disconformably overlies the Prairie Bluff. The base of the sand is marked by phosphate and other gravel-size pebbles. The limestones are brown, glauconitic and fossilferous. The marls are argillaceous, sandy, glauconitic, fossilferous, and micaceous. The Prairie Bluff beds are highstand system tract deposits. The basal Clayton sands are interpreted as lowstand systems tract deposits of the overlying Paleocene depositional sequence. The disconformity as the base of these sands represents a Type 1 sequence boundary. The surface at the base of the interbedded marls and limestones is the initial transgressive surface. This surface is merged with the sequence boundary at the Braggs stop.



(from Mancini and Puckett, 1998)

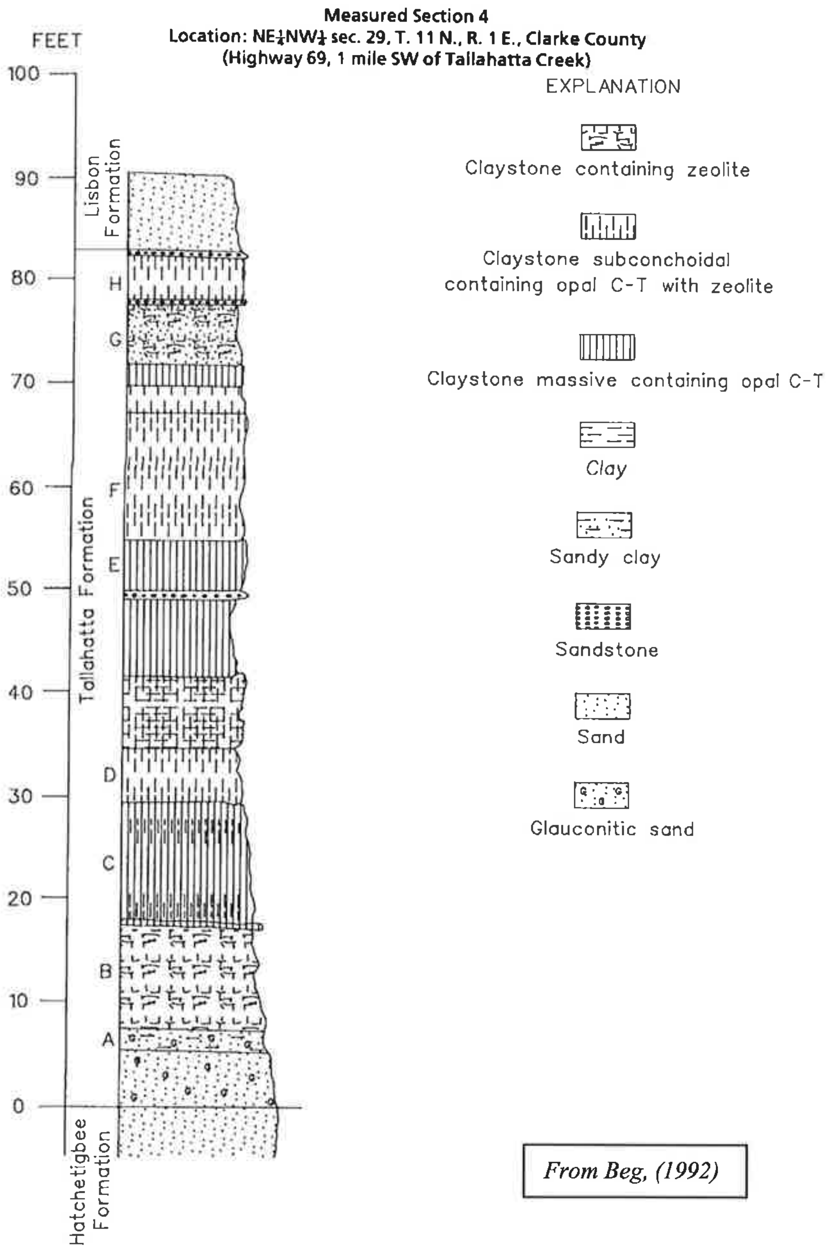
Optional Stop B, Day 2
Claiborne Bluff, US-84 bridge over the Alabama River.
References: Mancini and Tew, 1992

Strata exposed beneath the highway bridge, along the road to the boat landing include the Moody's Branch Formation and the North Twistwood Creek and Pachuta Marl members of the Yazoo Formation. The Moody's Branch includes ~23-feet of interbedded fossilferous, glauconitic, sandy marl and limestone. The lower 1.5-feet of fossilferous sand is informally referred as the 'Dellet Sand' and is disconformably overlain by the lowermost limestone bed, which is characterized by an abundance of fragments of the sand dollar *Periarchus lyelli*. This limestone is sometimes called the "*Scutella* bed'. Common fossils found in the Moody's Branch include *Periarchus lyelli* and *Nummulites moodybranchensis*. The Moody's Branch is conformably overlain by the North Twistwood Creek member of the Yazoo Formation, which is ~11-feet thick. This unit is clayey marl. The Pachuta Marl member is also about 11-feet thick and disconformably overlies the North Twistwood Creek member. The Pachuta is composed of sandy, fossiliferous, glauconitic marl and limestone. The Moody's Branch Formation and the North Twistwood Creek member of the Yazoo Formation constitute a Type 1, unconformity - bounded depositional sequence. The Dellet sand, which disconformably overlies the Gosport Formation, is the lowstand systems tract of the sequence. Like most of the lowstand systems tract strata recognized in the Paleogene succession, the Dellet sand has a discontinuous distribution and varies markedly in thickness of relatively short distances, indicating that the unit is confined to topographic depression on the underlying Type 1 surface. The transgressive systems tract is represented by the cyclically interbedded marl and limestone couplets of the Moody's Branch Formation. Strata of the North Twistwood Creek member of the Yazoo Formation are the highstand regressive systems tract deposits.



(from Mancini and Tew, 1992)

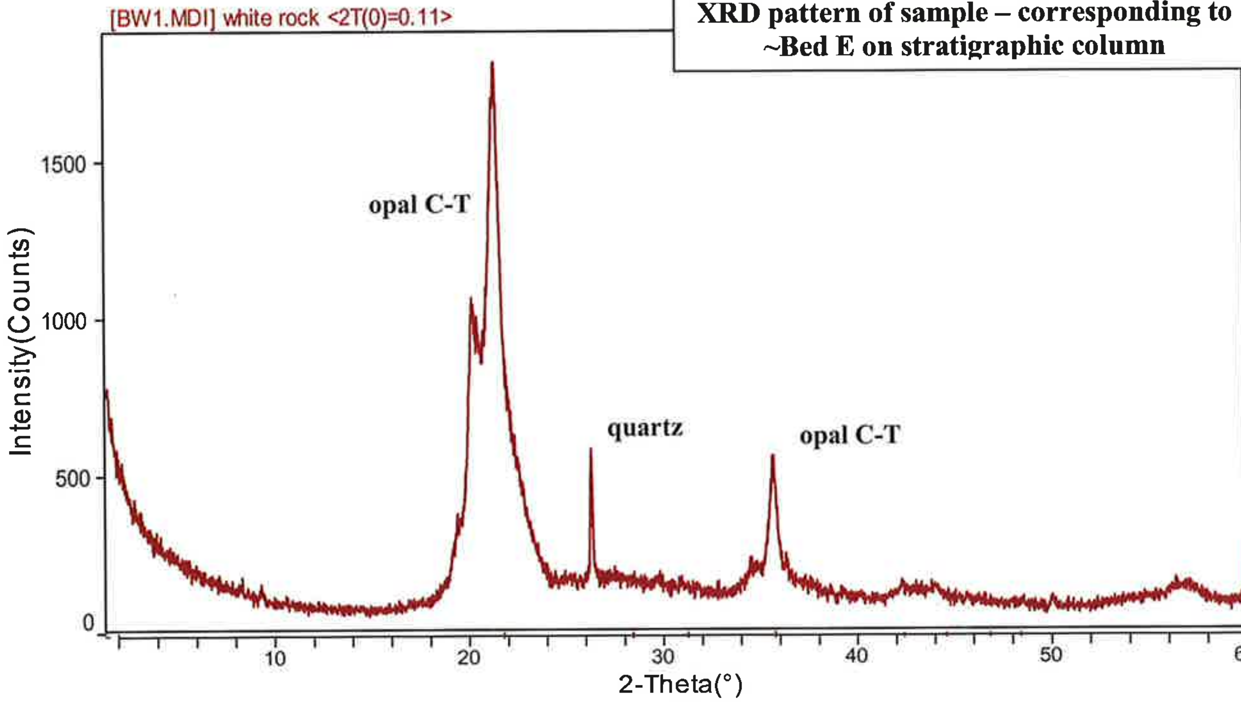
Stop 8, Day 3
Tallahatta Creek, Hwy 69 road cut, south of Campbell
References: *Mancini and Tew, 1990, Stop 3b; Jones, 1967, Stop 12; Beg, 1992.*



From Beg, (1992)

The Tallahatta Formation includes a lower 3-foot thick unit of yellowish-green, micaceous, glauconitic, clayey, fine to medium grained sand. Overlying this unit is about 77-feet of gray, silty, micaceous clay and siliceous claystone ('buhrstone'). The siliceous claystone beds are composed primarily of opal CT and/or opal CT with zeolite (predominantly clinoptilolite). Beg (1992) indicates some of the beds contain as much as 25% clinoptilolite. The Meridian Sand (lower member of the Tallahatta Formation) overlies the Hatchetigbee Formation. The Meridian Sand consists of about 6-feet of white, micaceous, bioturbated, fine-grained sand. The Hatchetigbee Meridian contact is disconformable. The Hatchetigbee is comprised of about 132 feet of gray, micaceous, carbonaceous, sandy, laminated clay and silt and gray, micaceous, glauconitic, cross-bedded, fine grained sand. The Bashi marl occurs at the base of the formation.

The Tallahatta is also believed to represent an unconformity-bounded Type 1 depositional sequence comprised of lowstand deposits (Meridian Sand), transgressive and condensed section deposits (marine glauconitic shelf sands of the lower Tallahatta) and highstand regressive deposits (marine to marginal marine clays and siliceous claystones of the upper Tallahatta)

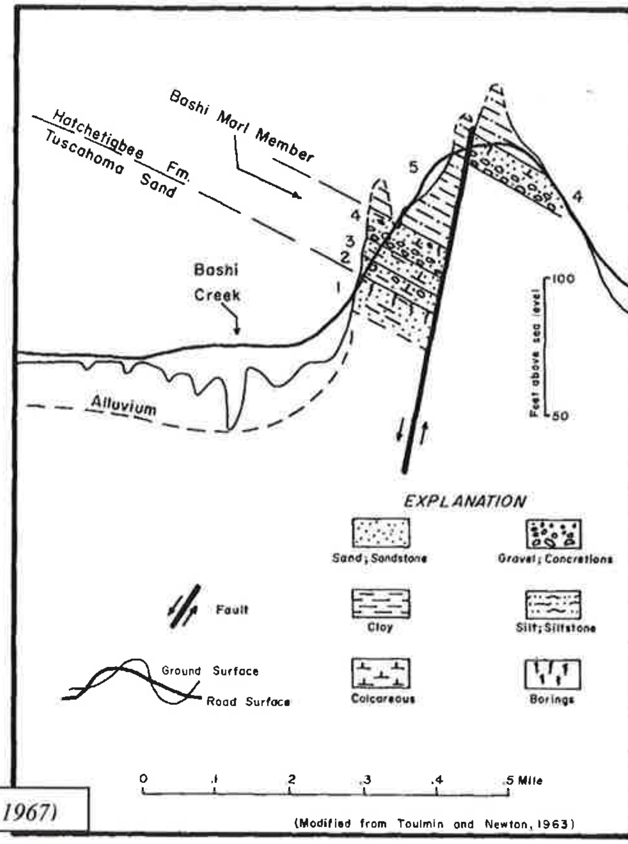


XRD pattern of sample – corresponding to ~Bed E on stratigraphic column

Scanning Electron Microscope photomicrographs of opal-CT bed.

Stop 9, Day 3
Bashi Creek, Hwy 69 road cut north of Campbell
References: *Mancini and Tew, 1990, Stop 3a; Jones, 1967, Stop 11.*

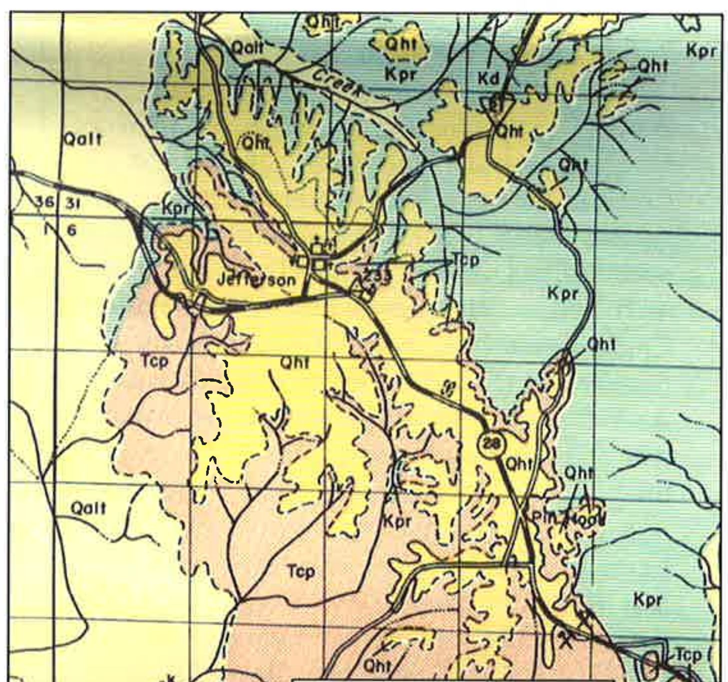
The Bashi Marl includes about 25-feet of greenish-gray, fossilferous, glauconitic marl and fine grained sand with sandstone concretions. The contact with the underlying Tuscahoma is not exposed. The Hatchetigbee is interpreted as an unconformity-bounded, Type 1 depositional sequence, with the Bashi marine shelf marls and sands representing the transgressive and condensed sections and the Laminated marine and marginal marine clays, silts, and sands in the upper part of the Hatchetigbee represent the highstand regressive deposits.



(from Jones, 1967)

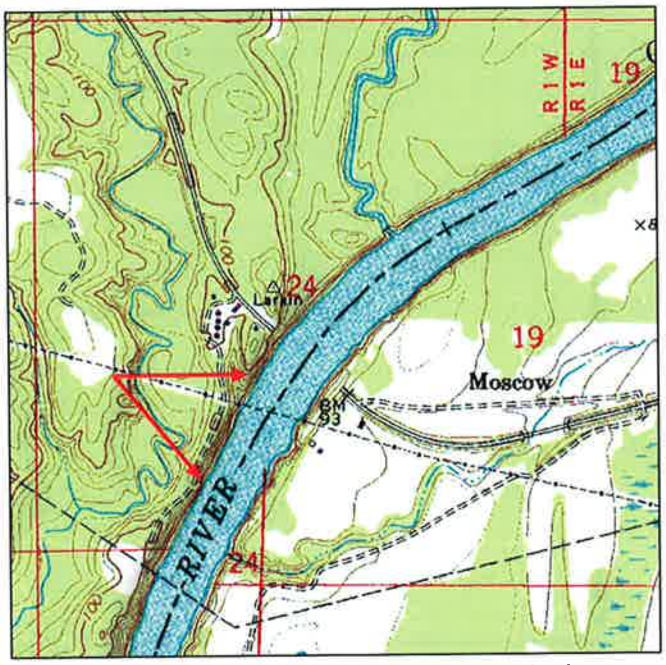
Stop 10, Day 3
Hwy 28 road cuts, NW. of Jefferson.
Reference: Jones, 1967, Stop 7; Bollman, 1968, alt. stop, p.7.

Road cuts at this location expose the upper part of the Ripley, the entire Prairie Bluff, and the lower few feet of the Clayton Fm. The Ripley and Prairie Bluff are hard to differentiate at this location, and are mapped as 'undifferentiated' (right, Kpr). The lower part of the larger road cut is considered to be Ripley due to the smallness of grain size and abundance of mica. The Prairie Bluff is particularly fossilferous. The overlying Clayton Formation is a represented by a few feet of hard, massive to cross-bedded sandstone, which forms irregular channel-type fills in this area. There appears to be no calcareous lithology in the Clayton here in contrast to the exposure at Moscow Landing where *Ostrea pulaskensis* is abundant in the limy facies.



(from Newton, et. al., 1961)

Stop 11, Day 3
West bank of Tombigbee River, @ Moscow Landing, Sumter Co., Alabama
References: Mancini & Tew, 1990, stop 1; Smith, 1997; Jones, 1967, Stop 6; Copeland, et.al., 1976; Mancini and Puckett, 1998, Stop 7; Smit, et. al, 1996;



This outcrop includes the lower part of the Paleocene Porter's Creek Formation and all of the Clayton Formation (which included 1) discontinuous, crescent-shaped wedges of coarse-grained sand - as much as 8-feet thick, and/or 2) interbedded marl and sandy limestone - as much as 6-feet thick), and the upper part of the Prairie Bluff Chalk (~ 23-feet of bioturbated chalky limestone). Both the Cretaceous and Paleocene strata are faulted at this locality. The normal faults complicate the interpretation of the stratigraphic units. The oldest faults displace only the Prairie Bluff chalk and may have had an effect on Paleocene sediment deposition and distribution. Younger faults displace all of the units exposed at this locality. The Cretaceous-Tertiary contact is disconformable and the strata at this boundary as exposed in the field trip area do not represent a continuous record of geologic time.

Porters Creek Formation

Blocky weathering, black, sparsely fossilferous clay is typical of the Porters Creek in the upper part of the exposure. This typical black, sparsely fossilferous, clay occurs about 21-feet above the lower sandy, marl bed. The lower part of the Porter's Creek becomes increasingly calcareous and fossilferous toward the base of the formation. A ~1-foot thick limestone bed occurs about 2-feet above a sandy, marl unit. This 18-inch thick sandy, glauconitic, marl, containing quartz and phosphate pebbles rests on the lower gray, calcareous, silty clay (about 15-feet from the base of the formation). The lower 15-feet of the formation are gray, calcareous, fossilferous, silty clay.

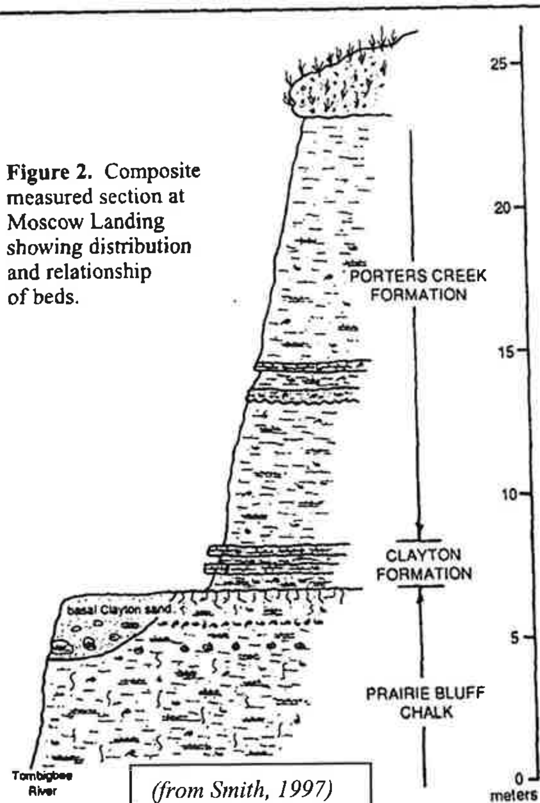


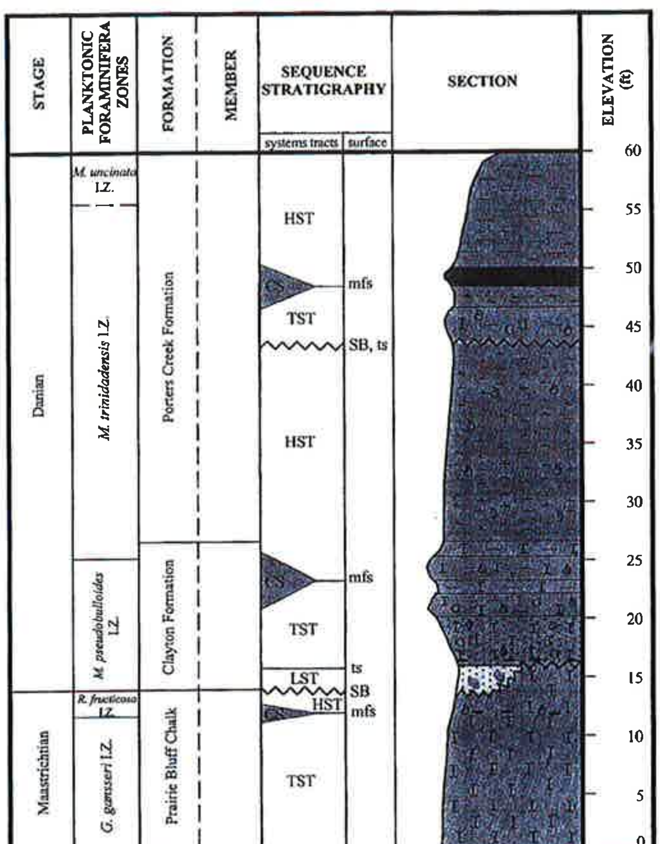
Figure 2. Composite measured section at Moscow Landing showing distribution and relationship of beds.

Clayton Formation

The upper part of the Clayton consists of olive-gray, calcareous, fossilferous, glauconitic, sandy marls are interbedded with 6 - 12-inch thick sandy limestone beds. Together the interbedded Clayton marls and limestones are about 4-feet thick. This unit overlies fossilferous marl. This marl contains quartz and phosphate pebbles, reworked Cretaceous fossils, and abundant *Ostrea pulaskensis*. This bed is considered to be a basal transgressive lag, and in the absence of the basal sands, it typically rests on dark-gray calcareous silt containing *Ostrea pulaskensis* or on the upper contact of the Prairie Bluff chalk which is generally highly burrowed, with the burrows being filled with overlying Clayton-age sediment. The silt beds attain a maximum thickness of about 5-feet and are more prominent at the south end of the bluff. At the north end of this exposure the lower Clayton consists of lenticular, discontinuous, irregularly bedded, calcareous, glauconitic, fossilferous, phosphatic, quartzose, fine to coarse grain sand. The sand attains a maximum thickness of 5-feet at this locality, weather yellow-orange, and contains chalk clasts up to 3-feet diameter, reworked Cretaceous (e.g. *Exogyra costata*) and Paleogene macrofossils (e.g. *Ostrea pulaskensis*). The sand rests on an eroded surface on the underlying chalk and it likely represents lowstand fill of incised valleys.

Prairie Bluff Chalk

The Prairie Bluff consists of over 32-feet of light gray, burrowed, silty chalk and marl. The upper surface of the Prairie Bluff is marked by abundant *Thalassinoides* burrows which extend downward as far as ~2.5 feet into the underlying chalky-marl. A 6 to 12 inch thick bed of quartz grains, phosphate pebbles, water –worn, abraded and fragmented fossils (shell material, molds, casts), and shark teeth, generally occurs 2-3 feet below the top of the formation. Over 45 taxa have been identified from this horizon including *Pycnodonte* sp., *Exogyra* sp., *Pterotrigonia* spp., *Protocardium* spp., *Turritella* spp., *Gyroides*, spp., *Baculites* spp., *Discoscaphites* spp., among many others. This fauna has been assigned to the *Haustator bilira* Assemblage Zone (Sohl), and has been traced in Upper Cretaceous sediments extending from New Jersey to Texas. At the north end of the bluff, this bed occurs about 10-11 feet below the top of the formation. A discontinuous bed containing *Cliona* sponge-bored *Exogyra costata* occurs about 5-feet foot below the phosphatic macrofossil bed.



(from Mancini and Puckett, 1998)

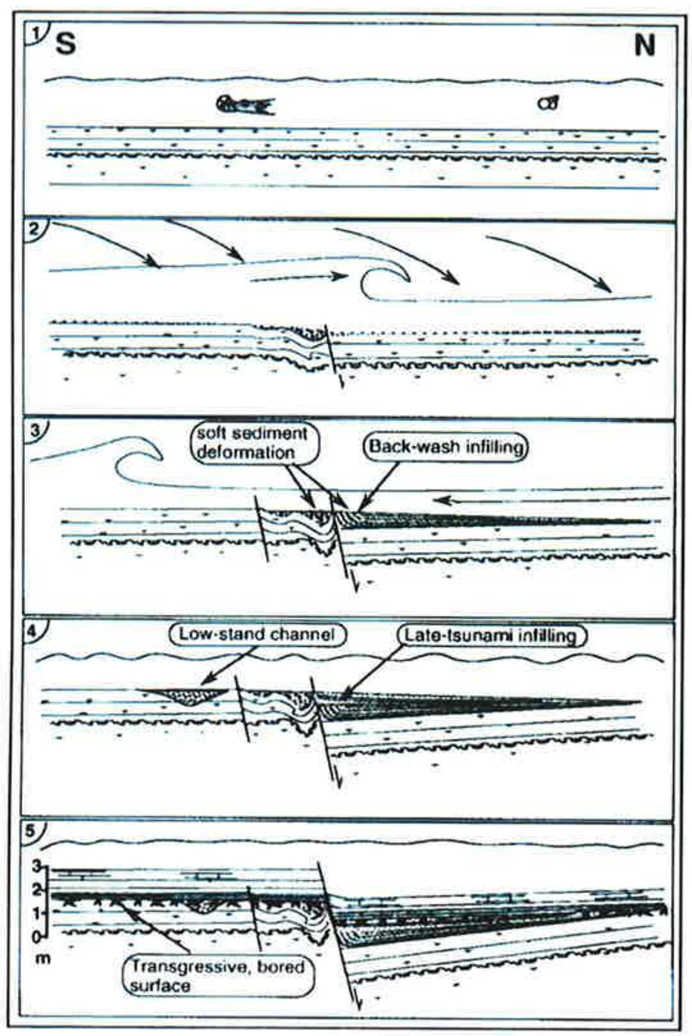
Traditional sequence stratigraphic interpretation of this outcrop (after Mancini and Puckett, 1998) indicates the marine –shelf chalks of the Prairie Bluff are part of an unconformity-bounded, type 1 depositional sequence. This depositional sequence consists of marine sand of the upper Ripley (lowstand deposits), sandy, fossilferous chalks of the upper Ripley and lower Prairie Bluff (transgressive deposits) burrowed, glauconitic chalks containing phosphate pebbles, shark teeth, and mollusk molds (condensed section), and dense chalks of the upper Prairie Bluff (highstand deposits) The burrowed surface in the middle chalk bed represents the surface of maximum starvation within this depositional cycle. The accumulation of phosphate pebbles and reworked clionid (sponge) bored mollusk shells that are encrusted with serpulid (worm) tubes and partially replaced with iron sulfides and in come cases, phosphatized, indicates long exposure on the sea floor, therefore a low sedimentation rate. The Clayton Formation and lower calcareous clays of the Porters Creek Formation represent the earliest Type 1 sequence of the Tertiary. The basal Clayton sands are interpreted as lowstand fill of low areas on the shelf in this sequence, and the Clayton calcareous silts represent lowstand 'interfluve deposits' that are chronostratigraphic equivalents of the sands. The interbedded Clayton marls and limestone are the transgressive and the Clayton/Porters Creek transitional marl and limestone are the condensed section deposits. The lowermost calcareous clays of the lower unnamed member of the Porters Creek are the high stand deposits of the sequence. The glauconitic marl bed in the lower unnamed member of the Porters Creed is interpreted to be the transgressive systems tract of an overlying type 2 depositional sequence. The calcareous clays and limestones overlying the marl are the condensed section deposits, and the black, massive, carbonaceous clays of the Porters Creek are the highstand regressive deposits.

Smit, et.al, (1996) indicates this outcrop is more complex than indicated by the traditional sequence stratigraphic interpretation. Over most of the outcrop, the Danian transgressive surface overlies paraconformably the Prairie Bluff Chalk, but the same surface also overlies the coarse-grained basal Clayton sand bodies. Within the tilted blocks that are bounded by the small normal faults, the bedding planes of the Prairie Bluff chalk are not disturbed and remain mostly parallel. However, near the faults, bedding is chaotic, displaying a mixture of soft and semisoft sediment deformation. In some of the fault blocks, the bedding planes are tilted vertically and truncated by the Danian transgressive surface. Some of the faults offset the basal Clayton sands, but do not offset the early Danian transgressive surface. The lowermost infillings of the basal Clayton sands consists of poorly sorted conglomerate containing Cretaceous macrofossils, Prairie Bluff chalk clasts, in a matrix of coarse sand. Characteristic components of the sand matrix are green, sparry-calcite filled spheroids and droplets, 2-3 millimeters in diameter, with an external lining of clay minerals. The spheroids contain internal cavities, also filled with sparry calcite. Identical spheroids are found in the nearby outcrops of Shell Creek and these are interpreted as altered splashform

tektites. The basal conglomerate has the appearance of a mass-flow and is found only where the Prairie Bluff Chalk is deformed and slumped. This conglomerate is overlain and truncated by lenticular layer of very-poorly sorted, poorly graded, parallel laminated coarse sandstone and pebbly sandstone, rich in Cretaceous macrofossils and chalk clasts. The laminated texture is typical for high current strength (upper flow-regime) and rapid sedimentation. The transgressive surface overlies the Prairie Bluff Chalk, the basal most sand wedges and the symmetrical channels. Thalassoinoides-type burrows extend down from the Danian transgressive surface penetrate a few feet into the top of the Prairie Bluff Chalk as well as into the top of both types of sand channels. Smit, et.al. (1996) interpret the basal Clayton sands as two different types of deposits; 1) a basal sequence consisting of several nonburrowed, rapidly deposited, partially mass-flow-type deposits, followed by 2) low-stand ravinement valleys filled with Danian lowstand deposits. During and immediately following an initial phase of faulting the mass-flow conglomerates with green, bubbly spheroids and the laminated pebbly sandstone layers were rapidly deposits. The faulting and slumping and deposition of mass-flow units may be explained by seismic shaking resulting form the Chicxulub impact event, followed by deposition of the spheroid-rich ejected. The ejecta are mixed with rip-up clasts and redeposited by strong currents, believed to be induced by passage of large tsunamis, resulting in the deposition of the coarse-grained sandstone. Any later fine-grained deposits that may have been associated with tsunami waves were removed during low-stand erosion preceding the Danian transgressive surface.

Sequence of events at the K/T boundary at Moscow Landing (after Smit, et. al, 1996).

1) Just before Chicxulub impact, The Prairie Bluff Chalk is undisturbed and parallel bedded, and contains a phosphatic lag bed. 2) Arrival of tsunami waves, possibly preceded by earthquakes, causing slumping and faulting. The ejecta from the impact arrives about the same time are reworked into conglomerate pockets loaded into slumped areas. 3) Continued faulting caused deformation of the edges of the sandstone channel infill. Some channels appear to originate as a result of faulting are infilled with coarse terrigenous (?backwash) sand. 4) Triangular wedges caused by continued faulted are further filled with pebbly sandstone and the early Danian sea-level-fall-caused lowstand channels are filled with basal Danian sediments. The low-stand phase and subsequent transgression erodes part of the lowstand channel, the tsunami deposits, and the top of the Cretaceous and leaves a bored hard ground.



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