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DIFFERENTIATION OF UNFOSSILIFEROUS CLASTIC SEDIMENTS: SOLUTIONS FROM THE SOUTHERN PORTION OF THE ALABAMA-MISSISSIPPI COASTAL PLAIN

WAYNE C. ISPHORDING
DEPARTMENT OF GEOLOGY/GEOGRAPHY
UNIVERSITY OF SOUTH ALABAMA
and
GEORGE C. FLOWERS
DEPARTMENT OF GEOLOGY
TULANE UNIVERSITY

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I. ABSTRACT

The scarcity of fossils in most non-marine Coastal Plain sediments of Tertiary age has surrounded these strata with a multitude of controversies. Not only is it difficult to correlate units believed on the basis of stratigraphic position to be of the same age, but it often poses a similar challenge to differentiate deeply weathered sands and gravels of markedly different ages when they are present in the same general area. As a consequence of this, some units simply have been "lumped" together and terms such as "upper Tertiary coarse clastics" and "undifferentiated Miocene" appear too often on state geologic maps. Further, this same lack of fossils also has led to major disagreements with respect to deposits laid down in more recent times: specifically, the age and number of identifiable terraces that developed by still-stands of the Pleistocene seas and the origin of these terraces (marine *vs.* non-marine?, erosional, depositional, or tectonic?).

Multivariate statistical analysis has proved useful in dealing with the identity of deeply weathered "red sands" in the Alabama Coastal Plain and strongly indicates that some units previously assigned to the Eocene Lisbon Formation are more likely recent terrace deposits. Similarly, detailed examination of sedimentary structures, mineral suites, and gravels has shown that the Miocene sediments in Alabama can be assigned to two mappable units (the Mobile Clay and the Ecor Rouge Sand). Criteria also exist that allow the differentiation of these units from the overlying Citronelle Formation. Recent work on a major vertebrate site, disconformably underlying the Citronelle Formation in Mobile County, Alabama, has also provided new information on the Citronelle age problem but, for several reasons, mis-use of the term "Citronelle" will undoubtedly continue. Similarly, though the controversy involving the number of Pleistocene terraces (and their origin) is far from solved, evidence is present in southern Mobile County, Alabama that clearly shows the deposition of marine features did take place during the Pleistocene and that this deposition took place at elevations in excess of 10 meters above present mean sea level.

II. INTRODUCTION

Though great strides have been made in the past 40 years in unraveling the stratigraphy of the thick sequence of sediments laid down during regression of the Cenozoic seas, controversies still exist regarding the age, origin, and field identification of a number of prominent units. This has resulted, for the most part, because of the extensive series of non-marine coarse clastics that accompanied withdrawal of the sea and emergence of the Gulf Coastal Plain. Deeply-weathered sands and gravels are found throughout the Coastal Plain and have been assigned ages ranging from Cretaceous to late Pleistocene. Identification of these units, however, is frequently predicated solely on factors such as elevation and location within the study area or on some peculiar idiosyncrasy of the unit, such as the composition of the gravel, the presence or absence of certain primary depositional features (massive *vs.* thin bedded), or specific textural characteristics. The unfossiliferous nature of these units, combined with their restricted mineral suites and similarity to other strata in the study area, thus makes it difficult to identify them positively when they occur in "floating sections" or in questionable contact relationships with other similar appearing sediments.

The following, for example, are major problems in the Alabama-Mississippi Coastal Plain that are still the subject of extended debate:

(1) The number of identifiable Pleistocene terraces that are present in the central Gulf Coast and whether these terraces represent erosional or depositional features or are "tectonic" in origin.

(2) The identity and criteria for differentiating units carried on existing maps as "undifferentiated Miocene" and criteria for differentiation upper Miocene "coarse clastics" from similar appearing sediments assigned to the younger Citronelle Formation.

(3) The Citronelle age problem. Specifically, are the units mapped as Citronelle in Mississippi, Alabama and Florida the same age.

(4) The "Lisbon Problem." Coarse clastic sediments assigned to the Eocene Lisbon Formation may actually consist, wholly or in part, of late Pleistocene fluvial deposits.

III. PROBLEMS WITH THE PLEISTOCENE

The Pleistocene history of the Gulf Coast is undoubtedly subject to less agreement among geologists than any other stratigraphic interval. As a case in point, there is yet no unanimity of opinion regarding:

(1) The number and age of alleged terraces that can be identified in the central Gulf Coast.

(2) Whether any "true" remnant Pleistocene depositional features can be identified at elevations greater than 7-10 m above present sea level.

(3) Whether specific deposits assigned to the Pleistocene represent marine or non-marine units.

(4) Whether terrace escarpments of Pleistocene age are littoral or tectonic features.

Terrace Nomenclature

The extensive debate over the number of identifiable terraces that formed as a result of major "still stands" of sea level can probably be traced to the early work of Cooke (1930, 1931). According to Cooke, repeated fluctuations of sea level during the Quaternary Epoch caused the development of seven major terraces, each of which was assigned a name from the area where it was initially described (see Table 1). Fisk (1944) continued this practice in his study of the terraces of the lower Mississippi Valley, but recognized only four such surfaces. Somewhat later, Carlston (1950) mapped escarpments in western Florida and Alabama and, using Cooke's original nomenclature, was able to identify a total of five terraces in Mobile County, Alabama. Doehring (1956), using a somewhat novel approach, argued that because the central Gulf Coastal Plain has undergone a continuous seaward tilting during the Pleistocene, that the terraces should be defined on the basis of their seaward gradient, rather than their elevation. Using this method, the oldest depositional surface would have the steepest slope, followed successively by younger surfaces with lower gradients. Because of the diffi-

Table 1. — Nomenclature for Gulf Coast Pleistocene terrace deposits.

FISK (1944)	COOKE (1966)		CARLSTON (1950)		HARVEY & NICHOLS (1960)
	Morley	(110 m)			
Williana (Aftonian)	Hazelhurst	(84 m)			Citronelle (58-92 m)
Bentley (Yarmouth)	Coharie	(66 m)	Coharie	(58-64 m)	
Montgomery	Sunderland	(52 m)	Sunderland Sunderland	(46-49 m)	Fourth Terrace (40-52 m)
	Okefenokee	(44 m)			
Prairie (Peorian)	Wicomico	(30 m)	Wicomico	(27-34 m)	Third Terrace (24-34 m)
	Penholoway	(21 m)	Penholoway	(18-21 m)	Second Terrace (9-15 m)
	Talbot	(13 m)			
	Pamlico	(8 m)	Pamlico	(6-9 m)	First Terrace (3-6 m)
	Silver Bluff	(2 m)			

culty in establishing true gradients of some of the terraces, Doehring's method has not yet been fully "tested" and thus lacks the widespread support that it may deserve. In more recent years, Cooke (1966) again addressed the Gulf Coast terrace problem and, disagreeing with Fisk, claimed that a total of ten terraces in the Mississippi Embayment could be identified. These ranged in elevation from 1.8 m above sea level (the Silver Bluff terrace) to one identified as far north as Cape Girardeau, Missouri, at an elevation of 107 m (the Morley terrace). Though Carlston recognized only five terraces in Mobile County, Cooke stated that the Silver Bluff and Talbot were well developed on the Coden Quadrangle and, similarly, the 81-m Hazelhurst terrace was also represented in Mobile County. Hence, in Cooke's view, all ten terraces can be identified in Alabama and can be correlated with those occurring at similar elevations on the Atlantic seaboard.

Though the authors do not care to add to the present controversy regarding the number of terraces identifiable in the central Gulf Coast, a "reasonable" number that can be identified on quadrangles in southern Alabama and Mississippi might be the five that were proposed by Harvey and Nichols (1960). Adopting a moderate approach, they identified four actual terraces and a Citronelle "surface" present at the elevations shown on Table 1. The escarpments and "flats" recognized by Harvey and Nichols can be identified on quadrangles of this area and, for convenience, their terminology is used in the road log.

Age of Terraces

Leighton and Williams (1949), historically, first called attention to the age problem of

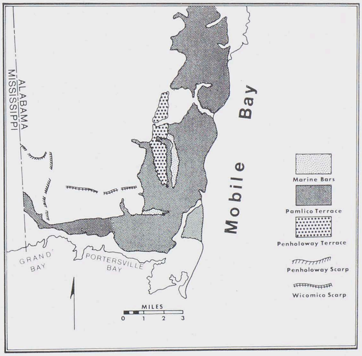

Figure 1. Pleistocene depositional surface features and escarpments (modified after Carlston, 1950).

the "Pleistocene" surfaces in the central Gulf Coast and suggested that at least some of the older terraces might be pre-Pleistocene. Similarly, Alt and Brooks (1965) agreed that the higher terraces were not Pleistocene features and stated that all terraces at greater than 25 meters in elevation were late Miocene to Pliocene in age and only those at elevations of less than 8 m could be assigned a Pleistocene age. Tanner (1965, 1968), and later Osmond *et al.* (1970), concurred that no Pleistocene shorelines had existed at elevations of greater than 10 meters. More recently, Otvos (1972, 1981) has stated that the maximum Pleistocene sea level was only 7 m in elevation above present sea level and that no relict shorelines or barriers of any age occur at elevations higher than this in Mississippi, Alabama, or Florida. Relict barriers of Miocene to Pliocene age, however, have been described by Gremillion *et al.* (1964) and Tanner (1966) at elevations of up to 80 m and, more recently, Winker and Howard (1977) identified extensive beach ridge plains and relict shoreline features, traceable throughout the western Florida panhandle on an upland surface reaching a maximum elevation of 100 m. The authors, likewise, would call attention to two prominent linear features in southern Mobile County that, we believe, are marine Pleistocene features (see Figure 1). The first consists of a north-south trending, curvilinear marine bar that is approximately 8.7 km long and 1.6 km wide. Near the town of Theodore, the elevation of the bar is 18 m whereas at its southern end the elevation is about 13 m above sea level. The sediments comprising this unit consist of clean, cross-bedded, well-sorted sands (see Figure 2) and differ markedly from those of nearby Citronelle and Miocene Formations. There is little doubt that they are Pleistocene in age (Penholoway, according to Carlston, 1950) and were deposited in the form of a southward-developing, prograding, marine bar. Approximately 4.75 km north of the present shoreline (see Figure 1), a second spit-like feature extends eastward for approximately 6.2 km, and is "attached" on the west to an east-west trending wave-cut

Figure 2. Cross-bedded "bar" sands exposed in pit in southern Mobile County.

cliff that parallels Mississippi Sound. The spit varies in width from nearly 355 m on the west, where it merges with sands of the Citronelle Formation, to approximately 1.6 km at its eastern extreme where it is dissected by parallel, easterly flowing streams that empty into Fowl River. The crest of the spit is at an elevation of 11 m and the sediments that form the spit are typical marine, estuarine, and stream deposits that have been assigned an upper Pleistocene (Pamlico) age.

The existence of both of these features, thus, provides evidence that remnant Pleistocene littoral structures do exist at greater than 7-10 m above sea level and that Pleistocene sea levels must, therefore, have exceeded 10 m in order to account for their formation.

Origin of the Pleistocene Escarpments

Extending westward from the Pleistocene spit described in the previous paragraph is an easily followed escarpment that can be traced from southern Mobile County, Alabama, to beyond Biloxi, Mississippi. This escarpment may be viewed at two sites of the field trip, one north of Biloxi, where it is called Big Ridge Scarp, and again in Alabama, just north of the town of Bayou La Batre. While usually interpreted as a shoreline feature (the "Pamlico" shoreline), Otvos (1981) has suggested a tectonic origin for the scarp and attributes its origin to faulting. He offers as evidence (in the area of Big Ridge Scarp) the following features:

(1) The lateral continuity of the feature with lineaments on adjacent, younger land surfaces.
(2) Sag pond-like marshy lows along the toe of the scarp.
(3) Its essential straightness.
(4) The basic flatness of its upper surface, both in constancy of elevation and lack of cross-sectional symmetry considered characteristic of beach ridges.
(5) Its parallelism with other lineations occurring to the north.

Otvos' tectonic origin is certainly deserving of consideration, especially in light of recently acquired geophysical evidence that does indicate the presence of a major east-west trending fault at depth in the general vicinity of the escarpment in southern Mobile County, Alabama. Whether or not this fault does produce surface expression, however, is another matter, especially in view of the fact that the escarpment has been traced into peninsular Florida, and northward, along the Atlantic Coast and, as such, closely resembles a shoreline feature.

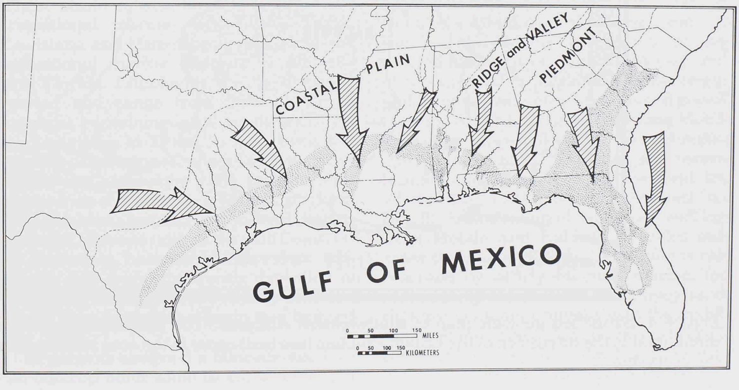

Figure 3. Outcrop of Miocene sediments in Gulf Coast showing source areas.

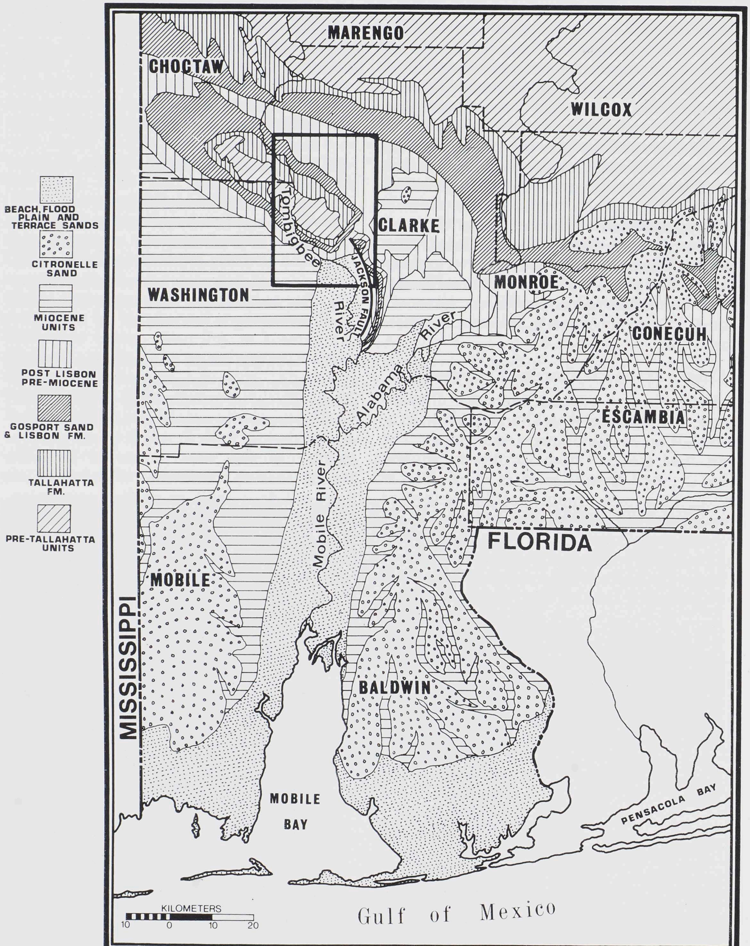

Figure 4. Simplified geologic map of southwestern Alabama. The misclassified clastics mentioned in the discussion of the Lisbon Problem (see text) occur in the area indicated by the rectangle.

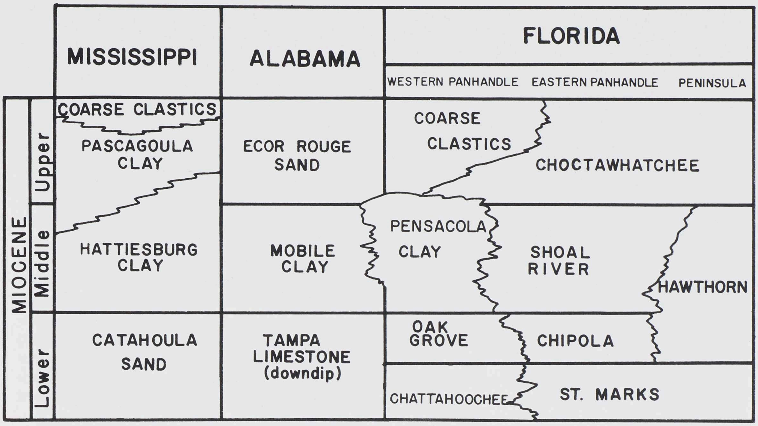

Figure 5. Generalized Miocene correlation chart for Mississippi, Alabama and Florida.

IV. THE "UNDIFFERENTIATED" MIOCENE OF ALABAMA

Miocene sediments crop out almost continuously from Texas eastward to the Florida peninsula (Fig. 3) and reflect deposition that took place in the Gulf Coast Geosyncline at a rate second only to the present. These strata consist, largely, of fluvial and transitional marine deposits, in Texas, Louisiana and Mississippi, and marine and transitional marine deposits in Alabama and Florida. Lithologies, locally, are quite varied and range from thick clastic sequences containing large quantities of volcanic detritus in Texas, to a relatively thin section of limestones, phosphatic sands and clays, and attapulgite clays that were deposited on the emerging Florida platform. The Alabama section is the least investigated of Miocene units in the Gulf Coast, but is important because it represents sediments that were apparently deposited on the eastern margin of the rapidly subsiding Gulf Coast depositional basin (see Isphording, 1977).

Sediments assigned a Miocene age form an outcrop band some 80 km wide (Fig. 4) and dip southward at a rate of 2 to 9 m/km (Reed, 1971). Most Miocene outcrops consist of either white, red, orange, or light brown, very fine- to coarse-grained sands with locally abundant ironstone lenses or consist of massive to laminated, green, grey, lavender or "brassy-colored" clay beds. Lenses of gravel are common in the sand units and range up to 3 m in thickness. Detailed examination of outcrops and well logs has allowed this sequence to be subdivided into a lower, dominantly clay unit, of marine and transitional marine origin, and an upper sequence of sands and gravelly sands of fluvial origin. The name Mobile Clay was suggested earlier by Isphording (1977) for the lower sequence and several locations may be seen on the field trip where clays of this unit are exposed (see Fig. 6). Examination of numerous well logs from Mobile and Baldwin Counties indicates that, downdip, this formation is represented by nearly 445 m of marine, fossiliferous, greenish clays and clayey sands that are contemporaneous with the middle Miocene Pensacola Clay, found eastward in the west Florida panhandle (Fig. 5). Overlying this middle Miocene clay sequence, conformably, is a 150- to 230-m section of coarse clastics, consisting of sands, gravelly sands, sandy gravel, with occasional thin lenses of kaolinitic clay, that are probably correlative with the late Miocene coarse clastics that overlie the Pensacola Clay in the western Florida panhandle. Excellent exposures of these sediments can be seen in Mobile, Washington, and Baldwin Counties where they are often capped, on the higher hills, by a thin veneer of sands and gravels of the Citronelle Formation. Perhaps the finest exposure of these upper Miocene sediments is found at Ecor Rouge (near Sea Cliff) on the eastern shore of Mobile Bay (see Fig. 7). This location, which is reported to be the highest point of land in the United States on the combined Atlantic and Gulf Coasts, reveals nearly 12 m of thin laminated clays, ironstones, cross-bedded sands and gravelly sands that are overlain by some 3 m of reddish-brown, fine to medium sands of the Citronelle Formation. As such, this site serves as the "type section" for the unit, which was named the Ecor Rouge Sand by Isphording (1977). Another excellent exposure of these upper sands is found on Wolf Ridge Road, near the northern Mobile city limits where approximately 10.5 m of sediments of the Ecor Rouge Sand are exposed. This exposure (STOP 4) also contains a prominent cut-and-fill structure of deeply weathered, reddish-brown sands of the Citronelle Formation and demonstrates well the fact that Citronelle sediments occur, chiefly, as a relatively thin, "drape" over the Miocene strata in the south Alabama area. Though some older reports claim difficulty in differentiating the upper Miocene sands from Citronelle deposits, the disconformably relationship is readily apparent in most exposures (see Fig. 8) and criteria are present that generally allow their immediate identi-

Figure 6. Bedded Miocene clays ("Mobile Clay") exposed in road cut on Highway 45, Mobile County, Alabama.

Figure 7. Upper Miocene sands ("Ecor Rouge Sand") exposed at type locality near Fairhope, Alabama.

	Citronelle Formation	Ecor Rouge Sand
1.	Sands consist of massive, deeply weathered, iron-stained quartz.	Sands are white, brown or reddish brown and usually display bedding or crossbedding. Liesegang banding is locally common.
2.	Gravels present are also highly iron-stained and consist of a mixture of quartzite and chert pebbles.	Gravels are typically white or tan and are largely quartzitic in composition.
3.	Many outcrops characterized by presence of highly polished, ironstone granules and small pebbles of polished ironstone.	Ironstone pebbles and granules, when present, are angular to sub-angular and lack the high polish found on those in the Citronelle formation.
4.	Heavy mineral suite: Ilmenite 30-40% average Tourmaline 5-8% average Rutile 5-7% average Zircon 5-15% average	Heavy mineral suite: Ilmenite 15-20% average Tourmaline 10-20% average Rutile 2-3% average Zircon 1-4% average

Table 2. — Criteria for differentiation of upper Miocene Ecor Rouge Sand from Citronelle Formation.

fication (see Isphording, 1976, 1981). These properties are summarized in Table 2 and may be observed at several stops on the field trip.

V. THE CITRONELLE AGE PROBLEM

Sediments assigned to the Citronelle Formation have been described in such diverse locations as Texas, Alabama, Louisiana and as far north as South Carolina. Stratigraphically, these units are found resting, unconformably, on formations that range in age from late Oligocene to early Pliocene. They are, in turn, overlain by Pleistocene-age fluvial, estuarine, terrace and high terrace deposits. This thickness of the formation cannot be determined with certainty, in many locations, because reworking has resulted in the incorporation of the materials into overlying Pleistocene deposits or into younger colluvial deposits that are too similar in physical and mineralogical properties to allow differentiation. Best estimates place the maximum thickness at approximately 85 m near the Alabama-Mississippi border, with most other locations having sections ranging from a few tens of feet to less than 45 m.

The sediments of the Citronelle Formation were originally described and given formational status by Matson (1916). The original type section of the formation, at Citronelle, Alabama, may be visited on the field trip (STOP 5).

In the same year that the formation was named and the type section described, Berry (1916) discovered plant fossils in a clay bed at an exposure on the Gulf, Mobile and Ohio Railway right-of-way, six miles south of Citronelle and, on the basis of the flora, confirmed the Pliocene age originally suggested by Matson. Since that time, the clay bed has been the subject of extended discussion, with Roy (1939) claiming that the bed is separated from the overlying Citronelle by a low-angle fault, whereas Carlston (1950) believes that a disconformity is present. Stringfield and LaMoreaux (1957) argued that an unconformity, even if present, was minor in extent and that this would not preclude the plants from belonging to the Citronelle Formation. They also noted that a similar leaf-bearing clay horizon was present at Red Bluff on Perdido Bay west of Pensacola, Florida, and was underlain by sediments of typical Citronelle lithology. Isphording has examined the plant locality and was unable to find any definite evidence of either a fault or unconformity. The sands overlying the clay horizon did appear to have been subjected to some penecontemporaneous deformation, however, but this died out laterally after a distance of a few tens of meters.

Regardless of the stratigraphic position and relationship of the clay bed, additional controversy arose when Doehring (1958) questioned the age of the flora described by Berry and concluded that there was no valid reason to assign a Pliocene age and that an early Pleistocene age was more logical. Marsh (1964) reported that this conclusion was supported by pollen studies that were carried out by Estella Leopold, who stated that the flora present (p. 83) ". . . provides clear fossil evidence of a Quaternary age for the middle and upper parts of the Citronelle Formation in westernmost Florida." Alt and Brooks (1965), however, after studying the soil associations and distribution of major terrace deposits in the east Gulf Coast, concluded that the Citronelle Formation, at least in peninsular Florida, probably deserved a late Miocene age and that they could (p. 408) ". . . find no evidence to favor the Pleistocene age proposed by numerous authors." Their conclusions supported earlier studies carried out by Ketner and McGreevy (1959), who also believed that the Citronelle sediments of the Lake Wales Ridge area of Florida should be assigned a late Miocene age. The Citronelle Formation, hence, may be variously designated as late Miocene, as Pliocene, as Plio-Pleistocene, or as Pleistocene, depending upon where in the Gulf Coast its sediments are described (and to whom in the Gulf Coast you are talking!). Obviously, the age problem of the Citronelle Formation reduces to a simple lack of vertebrate or invertebrate fossils on which a reliable date may be placed.

The search for fossils that would finally allow the formation to be dated was accidently rewarded about ten years ago when a student in an introductory geology course at the University of South Alabama casually mentioned that a clay bed containing some "old bones" was exposed in a creek on his uncle's land, in northern Mobile County. A visit to the site revealed the presence of some 2+ m of bedded, dark gray, carbonaceous, silty clay and clayey sand overlain, disconformably, by typical coarse clastic

Figure 8. Citronelle sands containing abundant highly-polished ironstone pebbles lying disconformably on Miocene clays (Mobile County, Alabama).

Figure 9. Vertebrate fossil locality on Chickasabogue Creek, northern Mobile County (NW ¼ Sec. 27, T2S, R2W).

sediments of the Citronelle Sand (Fig. 9). The unit contained an abundance of wood fragments and, most important, an interval of about 0.6 m that contained abundant vertebrate remains. A number of the fossils were gathered by Dr. George Lamb and shipped to the U. S. National Museum and, shortly thereafter, Dr. Frank Whitmore (U. S. Geological Survey/U. S. National Museum) visited the site. Additional fauna were removed and were identified by Dr. Whitmore and his colleagues. A list of the fauna described at that time may be found in an article by Isphording and Lamb (1971). Unfortunately, before the site could be excavated to Dr. Whitmore's satisfaction, the landowner became suspicious that something "valuable" was being removed and refused permission for further excavation unless suitable "compensation" was forthcoming. Thus, for nearly ten years, no further work was carried out. Late in 1981, however, the former landowner's son took possession and again allowed entrance to

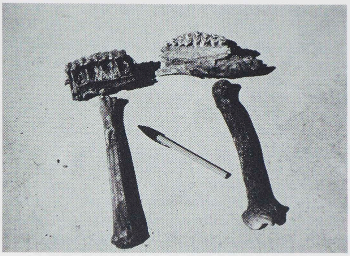

Figure 11. Protoceratid and horse fossils collected at vertebrate fossil site, northern Mobile County, Alabama.

the site. Dr. Whitmore returned and carried out an extensive excavation, which may be viewed on the field trip at STOP 4. The fauna collected during this recent field visit are presently being analyzed by Dr. Whitmore and his colleagues at the U. S. National Museum and he has kindly consented to supply the following description of the site for inclusion here.

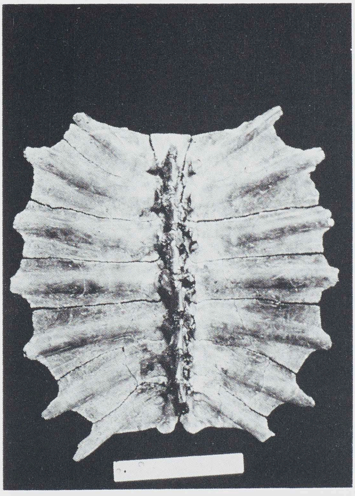

Figure 10. *Trionyx* species of soft-shelled turtle (either *spinifer* or *farox* species) from fossiliferous unit at vertebrate fossil site, northern Mobile County, Alabama.

Hemphillian Vertebrate Fauna From Mobile County, Alabama

Frank C. Whitmore, Jr.
U. S. Geological Survey

A vertebrate fauna of Hemphillian age (Late Miocene to early Pliocene, or about 10 to 3.5 mya according to Berggren and Van Couvering, 1974, Fig. 1), occurs on the right bank of Chickasabogue Creek, in northern Mobile County, 1.5 km northeast of the town of Mauvilla.

The bones are found in a gray clay with thin intercalated sand beds, mapped by the Alabama Geological Survey as Miocene Undifferentiated and underlying the Citronelle Formation. The bones, occupying a stratigraphic thickness of about 60 cm and lying about 2 m below the top of the clay were associated with large logs, ranging from 0.5 m to almost 1 m in diameter and oriented subparallel, between N30°E and N50°E. The largest concentration of bones, all of which were disarticulated, lay close against the west sides of the logs in association with large amounts of woody trash.

Soft-shelled turtles *(Trionyx)* were the most numerous components of the fauna (see Fig. 10). Land tortoises were also present, and gar scales were very numerous. The lower jaw of a long-beaked porpoise *(Pomatodelphis inaequalis)* was collected by the author and George Lamb at the site in 1967, but further digging has produced no more porpoise bones.

Land mammals of the fauna included the rhinoceros *Teloceras*, the horses *Hipparion* and *Nannippus* (see Fig. 11), the protoceratid (horned ruminant) *Synthetoceras* (Fig. 11), a large camel, peccary, and a large beaver, near *Castoroides*. The bones are fresh and unabraided, so they do not appear to have been transported far; some of them show signs of having rotted, probably subaqueously. A jawbone of an infant protoceratid bears tooth marks on both sides, from the canine teeth of a carnivore. No carnivore bones have yet been found in the collection (preparation of which has just begun).

The clay in which the bones are found shows cyclic sedimentation, with repeated alternation of clay beds (about 10 cm thick) and gray sand stringers (2 to 3 cm thick). Most of the bones are in sand stringers, embedded in the top of a clay bed.

From the freshness of the bones, it is probable that they represent a fauna inhabiting a single small drainage basin. They were probably deposited during floods in a backwater where there was little current, except during flood stage. The puzzling presence of a long-beaked porpoise may be explained by the hypothesis that *Pomatodelphis* was a fresh water porpoise. *Inia*, the long-beaked Amazon porpoise, has been reported as observed swimming through the woods during Amazon floods.

One additional major conclusion that may be drawn from Dr. Whitmore's work is the fact that the obvious unconformable contact with the overlying Citronelle clastics places a minimum age on the formation. Deposition of the Ctironelle could not have begun before the middle Pliocene and appears to have continued into the pre-Nebraskan Pleistocene (based on pollen data from upper Citronelle sediments in the western panhandle of Florida).

The Citronelle age problem itself, however, will unfortunately continue to persist in the Gulf Coast because of the historical misuse of the term "Citronelle Formation." This is particularly true in the case of the sands that form Lake Wales Ridge and Trail Ridge, in peninsular Florida. Because it has been fairly well established that these sediments are late Miocene in age, they cannot thus belong to the "same" Citronelle For-

Figure 12. Terrace sands lying on dipping Miocene strata, near Jackson, Alabama.

mation that is described at the type locality in Alabama and should, therefore, be redefined. Further, even in south Alabama, problems with the Citronelle will continue because of the similarity in appearance of these sands to those of younger (or contemporaneous!) terrace deposits. The Citronelle Formation is largely the aggradation product of coalescing, braided streams and, as such, is identical in depositional environment to most other terrace sediments. It has also been subjected to the same weathering regimen as the terrace sands and, thus, is expectedly similar in general appearance. For this reason, sands overlying Miocene sediments on the south side of the Tombigbee River, at St. Stephens, Alabama, were designated on State maps as "Citronelle," whereas those on the north side were termed "terrace deposits" (see Fig. 12). The problem is even more acute in southeastern Mississippi where little in the way of agreement is found on what to map as Citronelle and what to call terrace deposits. The problem in establishing what truly "belongs" to the Citronelle may, therefore, be insurmountable because it might actually require developing a means of defining the depositional limits of individual "terrace" sands that were deposited during the late Pliocene and Pleistocene.

VI. ALABAMA LISBON PROBLEM

In Washington, Clark, and Choctaw Counties in southwestern Alabama, many hills are capped by a conspicuous, massive red sand (see Fig. 13). The appearance of this sand is very similar to sediments of the Citronelle Formation, the Miocene Ecor Rouge Sand, and high terrace deposits of the Tombigbee River. For the most part, these sands have been mapped as belonging to the Middle Eocene (Claibornian) Lisbon Formation. In the light of multivariate statistical analysis of heavy mineral populations and corrobrating field evidence, Isphording and Flowers (1980) sug-

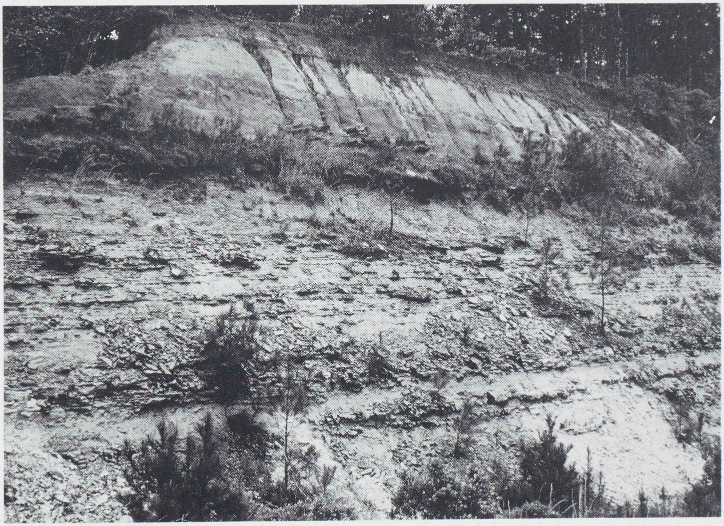

Figure 13. Red sands (Lisbon?) lying on Tallahatta clays and claystones, Clarke County, Alabama.

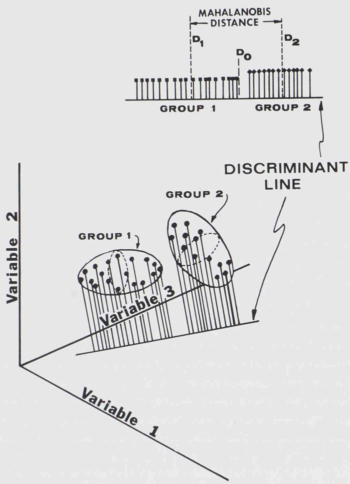

Figure 14. Schematic representation of the relationship between the discriminant function and distributions for groups 1 and 2.

gested that the "blanket" assignment of red sands to the Lisbon Formation may not be warranted. A summary of the evidence for this conclusion is presented below.

Statistical Analysis

It is reasonable to assume that sediments deposited at different times or in different areas will display variability in the relative abundance of different heavy mineral species. Further, even if no variability exists in the species found in two different formations, differences would be expected in the individual mineral ratios. Factors such as basin configuration, particle size, hydraulic selectivity, and the availability of a given mineral constituent would, thus, give rise to modal variation in the heavy mineral suites of any two formations. The problem encountered by geologists considering impoverished heavy mineral populations, however, is how to "distill" the differences among several groups, especially if such differences are subtle. Fortunately, the multivariate statistical technique of discriminant analysis provides an approach to this problem.

Discriminant analysis is a linear transformation of original variables, which maximizes the difference between groups while minimizing the scatter within each group. It can be seen in Figure 14 that the transformation, in addition, reduces the dimensionality of the problem and provides a simple discriminant function, which can be used to assign observations to one group or the other. The discriminant for the ith observation can be expressed as:

$$D_i = \sum_j d_j X_{ij}$$

where d_j denotes the discriminant coefficient for the jth variable, and X_{ij} refers to the value of the jth variable for the ith observation. The mean discriminant score for each group (designated by D_1 and D_2 in Figure 14) is calculated by substituting the mean value of each variable into the above equation. The difference between the mean discriminant score for the two groups is called the Mahalanobis Distance (D^2), which is a measure of the separation or distinctness of the two groups.

Isphording and Flowers (1980) used discriminant function analysis to test the hypothesis that modal variation in the heavy mineral suite alone was sufficient to determine whether or not sand samples were taken from the same population (group). Heavy mineral analyses for samples taken from the Cohansey Sand (New Jersey) and the Citronelle Formation (Alabama) were considered in the analysis. Both of these sands are characterized by an

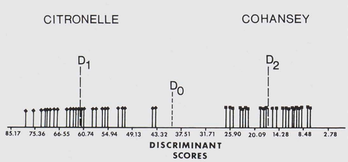

Figure 15. Plot of discriminant scores for Citronelle and Cohansey formation samples.

impoverished heavy mineral suite, consisting of the stable to ultrastable heavy minerals: kyanite, rutile, staurolite, tourmaline, zircon, ilmenite, and leucoxene. As can be seen in Figure 15, the discriminant function was extremely efficient in segregating the two groups, demonstrating that the procedure could be used as a classification tool.

Application to the Lisbon Problem

The Lisbon Formation in southwest Alabama consists of a sequence of greenish gray glauconitic clays, sandy clays and sands that are frequently weathered to a deep reddish-brown color. As such, exposures of these dominantly sandy sediments frequently resemble a number of other younger clastic units that occur in southwestern Alabama. Comparison of heavy mineral analyses for these clastic units and the red sands indicated that all had essentially the same heavy mineral suite. This fact, combined with the similarity in appearance and the frequent occurrence of erosional contacts, makes differentiation of these units difficult, particularly in the case of "floating" sections. Discriminant function analysis was used by Isphording and Flowers (1980) to see if a new variable, formed as a linear combination of the heavy mineral percentages, could aid in the classification of red sand exposures. The results of pair-wise analysis, which compared the mineralogy of each of the known groups (terrace, Miocene, Citronelle, and Lisbon sediments) with the red sands, are shown in Figure 16. Comparison of the Mahalanobis Distance for each analysis suggested that a number of the red sands mapped as belonging to the Lisbon are closer in character to high terrace deposits of the Tombigbee River. The results of multiple discriminant analysis, a procedure where all groups are considered simultaneously, were more definitive. The majority of the red sands were classified as high terrace deposits, with a smaller number classified as belonging to the Lisbon Formation. In many cases where the coarse red sands had been classified as Lisbon sediments, field evidence also suggested that an unconformable relationship between the massive red sand and the finer, laminated Lisbon clays and silts was present (see Figs. 17 and 18). The field evidence, further, indicated that a Lisbon "character" was frequently imparted to the terrace sands in some areas due to extensive reworking of older Lisbon sediments.

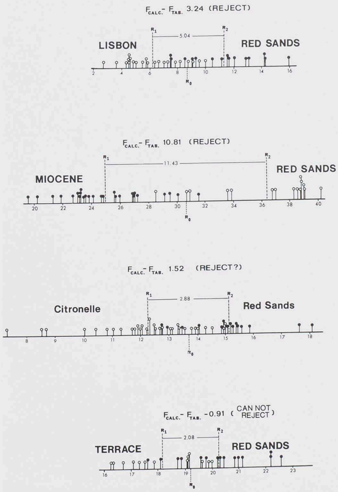

Figure 16. Pair-wise discriminant plots for "red sands" versus Lisbon, Miocene, Citronelle and Terrace sands.

Analysis of these "Lisbon" sediments thus demonstrated that multivariate statistical techniques could be used to examine the contact relationships of sediment units, as well as to provide a means of classifying "floating" sections. Specifically, the following conclusions were drawn from the analysis:

1. Discriminant function analysis is effective in differentiating sedimentary units of identical mineralogy and similar depositional environments, solely on the basis of modal variation.
2. Large Mahalanobis Distances indicate different provenance for sedimentation units of the presence of a diastem or unconformity.
3. Failure of the analysis to discriminate two units suggests that the units have the same provenance and/or that both were deposited at nearly the same time.

4. Failure of the analysis may also indicate the reworking of older material into a younger sedimentation unit.

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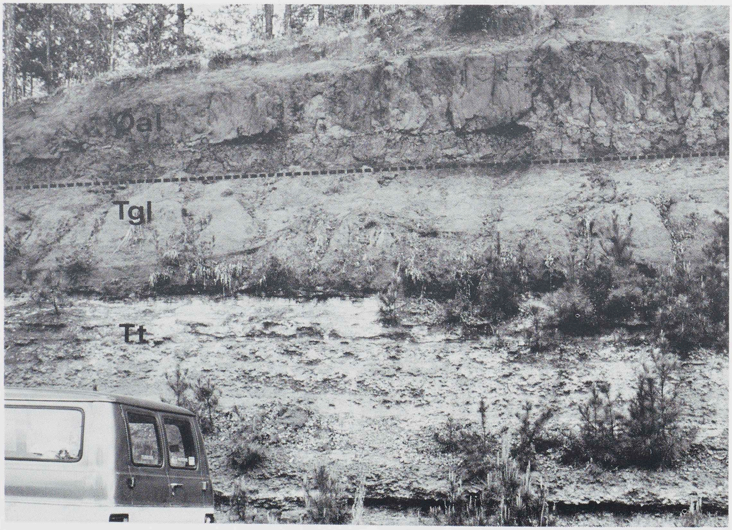

Figure 17. Massive red terrace sands in contact with upper sands and clays of Lisbon Formation (Tgl). Lisbon-Tallahatta (Tt) contact also visible.

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Figure 18. Red sands forming large cut-and-fill structure which extends through Lisbon sediments into the lower Claibornian Tallahatta Formation.

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VIII. APPENDIX: Field Trip — New Orleans to Jackson, Alabama

ROAD LOG FIRST DAY OF FIELD TRIP

Mileage

0.0 Marriott Hotel, New Orleans, La. Proceed northwest toward Lake Pontchartrain on Canal St.

0.7 Turn right on North Claiborne Avenue and proceed northeast toward the Interstate 10 on ramp.

1.4 Junction I-10. Proceed on Interstate 10 East. This portion of New Orleans is built upon sediments of the subsided St. Bernard Delta, which was active from about 4500 to 1000 years B.P.

4.5 High rise bridge over the Inner Harbor Navigation Canal.

5.3 Crest of the high rise. From this point a rare panoramic view of the New Orleans East area can be seen. Straight ahead (to the east) the subsided surface of the St. Bernard Delta Plain can be seen. Also visible from the bridge is a St. Bernard distributary levee, marked by the stand of hard wood trees adjacent to the railroad tracks on the right side of the bridge. This levee is associated with the Bayou Sauvage distributary channel (Kolb *et al.*, 1975). On the left side of the bridge can be seen Lake Pontchartrain, a large land locked coastal bay. The large canal on the southeastern side of the high rise is the Mississippi River-Gulf Outlet. Relatively undisturbed marshes can only be seen just before crossing the Lake Pontchartrain bridge. Most of the area between the high rise and the Lake Pontchartrain bridge is an old cypress swamp and brackish to fresh water marsh, which is being prepared for development by draining and filling.

10.8 Top of the overpass at the Bullard Ave. exit. To the northeast a borrow pit can be seen. In this pit was exposed the largest section of late Quaternary deposits in the New Orleans area. Unfortunately, this pit has been filled with water, so as to create lake front property for a subdivision. (See Miller, this volume.)

18.9 Hurricane levee. We are entering an area of less completely drained swamp, which will be used for expansion of New Orleans East. Already the interstate highway has interchanges which dead end in the mire. The area is protected from flooding by a series of levees that surround it.

20.7 Lake Pontchartrain bridge and junction U. S. 11. Proceed on Interstate 10 towards Slidell. The bridge for U. S. 11 can be seen on the left hand side of the vehicle.

23.5 Enter St. Tammany Parish.

24.9 Crest of the large craft passage (high rise). From this point the upland, which represents the Pleistocene Prairie Terrace, can be seen directly ahead. The well-drained nature of the Prairie sediments is indicated by the large stands of pine trees. The Prairie Terrace is correlative with the Pamlico surface in Mississippi and Alabama (see below). The fringing, brackish water marsh of the lake can also be seen from this vantage point.

26.2 End of the Lake Pontchartrain bridge. The marsh lands adjacent to the bridge landing have been drained and are now protected from flooding by levees.

28.4 Scarp of the Prairie Terrace. Interstate 10 rests on this terrace in this portion of Mississippi, except where present day rivers have deposited alluvium.

29.3 Junction 433 — Slidell exit. Proceed east on Interstate 10.

30.2 Borrow pit on the right side of the interstate. Exposed are mottled, buff-colored clays of soil horizon developed on the Prairie Terrace.

33.2 Junction I-12, and I-59. Proceed east on Interstate 10 towards Bay St. Louis.

35.6 Cross West Pearl River and entering Pearl River floodplain (cypress-tupelo swamp).

39.6 At the crest of the Pearl River draw bridge the Louisiana state line is crossed. Enter Hancock County, Mississippi.

40.3 Re-enter pine forest of the Prairie Terrace.

42.4 On the left side of the interstate in the distance can be seen the engine test towers of the Mississippi Test Facility (NASA).

54.8 Jourdan River. Note the undisturbed marsh.

58.6 Enter Harrison County, Mississippi.

67.4 Wolf River.

78.5 Enter floodplain of the Biloxi River.

79.4 Biloxi River.

83.5 Tchoutacabouffa River.

84.1 Leave I-10 at exit 44 (Cedar Lake Road) and proceed south towards Biloxi.

84.7 Traffic light. Turn left on Popps Ferry Road.
Now driving along Big Ridge. This feature has variously been designated as an old shoreline (Pamlico) or attributed a tectonic origin (fault). The authors favor the former hypothesis because of its continuity with other similar features at the same elevation in Alabama and Florida.

86.0 STOP 1 — Good view of Big Ridge escarpment looking down on Rolling Hills trailer park. A nearly identical feature, with similar relief, will be seen just north of Bayou La Batre, Alabama.

86.8 Continue east on Popps Ferry Road to intersection with Highway 67. Turn right on Highway 67.

87.4 Turn right on service road just before Interstate 110 overpass.

87.9 Turn left on Rodriguez Street and proceed to I-110 north entrance.

88.1 Turn left on I-110.

89.4 Continue north on I-110 to I-10 interchange (Exit 4A, east), and proceed east on I-10 toward Mobile, Alabama.

90.4 Jackson County Line.

106.7 Western edge of Pascagoula River tidal marsh.

120.3 Alabama State Line.

124.5 Leave I-10 at Dawes-Grand Bay exit. Turn right toward Grand Bay on County Highway 11.

125.8 Intersection with U. S. Highway 90. Turn right on U. S. 90. (Elevation = 120 feet.)

125.9 Intersection with State Highway 188 in Grand Bay. Turn left on Highway 188. Cross railroad tracks and turn right parallel to tracks for 0.2 miles. Turn left and continue 0.3 miles to intersection. (Elevation = 97 feet.) Turn left.

126.9 Three and one-half miles south on road entering on left is an excellent exposure of the Pamlico terrace escarpment—similar to that seen at the stop on Big Ridge. Citronelle Formation sediments are also in visible contact with the younger terrace sands at this location.

131.6 Siderite nodules in road cuts. Now driving on Wicomico Terrace (Third Terrace of Harvey and Nichols, 1960).

132.2 Edge of Third Terrace. (Elevation = 85 feet.) Drop down onto Second Terrace (Penholoway).

133.1 Intersection with State Highway 39. Intersection lies at the top of an escarpment that forms the southern margin of the Second Terrace. Erosional plain of the First Terrace (Pamlico) is visible at bottom of hill and continues southward toward the coast.
Turn left on Highway 39 and proceed north.

134.6 STOP 2 — "Dirt Incorporated." This stop provides an excellent exposure of both the Citronelle Sand and Ecor Rouge Sand. Most of the criteria that are discussed in the text that serve to distinguish the two units may be seen at this stop. Note especially the numerous ironstone pebbles that are characteristic for Citronelle formation throughout Mobile and Baldwin counties.
Leave pit and turn left on Highway 39.

139.1 Intersection with U. S. Highway 90. (Elevation = 130 feet.) Turn right on Highway 90. Now driving on Third Terrace (Wicomico).

142.4 Descend hill underlain by Miocene sands. (Elevation at bottom of hill approximately 100 feet.)

143.6 Cross Bellingrath Road.

144.2 Turn right on Hamilton Road (National Butane on right at intersection).

145.0 Pit owned by Counts Construction Company. (Elevation = 45 feet.)
The town of Theodore is located on terrace sands that are fluvial and estuarine in origin. Extending southward for approximately 10 miles (see diagram in text) is a sequence of clean, white, cross-bedded sands that evidence a Pleistocene-age, curvilinear marine bar. The bar has a maximum width of one mile and was considered by Carlston (1950) to be Penholoway in age.
STOP 3 — The upper part of this bar is exposed in the pit and the sediments are noticeably dissimilar to Citronelle, Ecor Rouge, and non-marine terrace deposits that will be seen the remainder of the trip. The existence of this marine feature argues against those claiming that no Pleistocene deposits of marine origin are present in the Gulf Coast at elevations greater than 10 meters.

147.8 Pass under Interstate Highway 10. Now driving on dissected surface of Second Terrace.

149.6 Large quarry behind Stacy Lumber Company (on right) has exposure of 40 feet of Miocene sands and clays of the Ecor Rouge Formation.

150.6 Turn left on Demetropolis Road (at traffic light). Now climbing onto Citronelle surface. Miocene sediments exposed in ditches as hill is ascended. (Intersection elevation = 45 feet.).

152.8 Turn left on Cottage Hill Road. (Elevation = 180 feet.)

153.0 Turn right onto University Boulevard. Citronelle sands exposed in cuts along road.

155.2 Cross Airport Blvd.

156.2 Cross Old Shell Road.

156.5 Campus of the University of South Alabama on left. (Elevation = 185 feet.)

157.7 Municipal Park on right. Note extensive tree damage from Hurricane Fredrick (1980) and flooding (1981).

158.2 Cross Ziegler Blvd. University Blvd. now becomes Forest Dale Drive.

158.8 Turn right on Overlook Drive.

159.2 Intersection with Moffat Road (U. S. Highway 98). (Elevation = 203 feet.) Continue east on Moffat Road.

159.3 Traffic light (Mobile Waterworks on left).

159.4 Traffic light

160.3 Turn left onto Wolf Ridge Road at next traffic light. (Elevation = 120 feet.)

161.4 Mobile-Prichard city limits.

162.2 STOP 4 — Sand and gravel pit located on east side of road. A section of approximately 35 feet is exposed on the east face of this pit. A large cut-and-fill structure is visible and consists of deeply weathered channel sands of the Citronelle Formation overlying the Miocene Ecor Rouge Sand. A number of sites are present where well developed Leisegang Banding may be seen in the Miocene sands.

Return to Wolf Ridge Road. Turn right and continue north to intersection of U. S. Highway 45.

163.2 Turn left (west) on Highway 45. (Elevation = 45 feet.)

164.4 Cross Shelton Beach Road (3rd traffic light).

167.0 Kushla.

167.7 Cross Highway 185.

168.2 Reddish-brown sands of the Citronelle Formation exposed in ditch on right side of road.

170.2 Enter town of Mauvilla.

171.2 Citronelle sands exposed in large quarry on left side of road.

171.4 Turn right on Kali Oka Road and proceed 0.2 miles. Turn right on dirt road and proceed to house at end of road. Drive past house and turn left across small dam. Continued driving from here depends on condition of road. Follow road down to railroad tracks and cross tracks. Exposure is located in bend of Chickasabogue Creek. (Elevation of creek = 30 feet.)

STOP 5 — Approximately 7 feet of dark gray, bedded sandy clays are exposed above creek level. These sediments form a slight angular unconformity with the horizontal Citronelle sands that overlie them. The vertebrate fossils are found in a bed located about three feet above present water level.

Return to paved road and turn left (back to Highway 45).

171.8 Turn right on Highway 45. (Elevation = 175 feet.)

172.3 Dirt road on left side of Highway 45. Citronelle sands exposed along dirt road.

173.3 Miocene clays on left side of road.

173.6 Mottled Miocene clays exposed in ditch on left side of road.

173.9 Lavender and green Miocene clays exposed in ditch on left side of road.

174.1 Miocene clays exposed intermittently for next 1/4th mile.

174.9 Citronelle sands exposed on right side of road. At top of hill on left side of road is another cut-and-fill structure of Citronelle sands cut down into the Miocene clays.

175.7 Miocene clays exposed on left side of road.

176.1 Citronelle sands exposed at top of hill.

177.0 Entering Chunchula. (B.M. = 112 feet.)

177.4 Crossing Georgetown Road.

177.3 Miocene clays exposed on left side of road.

181.5 Road to left leads to Chunchula landfill; Citronelle sands exposed on left at top of hill.

181.8 Bridge.

183.2 Miocene sands and clays exposed on left side of road.

184.1 Climb onto old Citronelle erosional surface.

184.7 Citronelle sands exposed on road on left.

186.5 Drive along old Citronelle erosional surface (elevation 300 feet). Citronelle sands exposed along road and in ditches.

187.7 City limits of Citronelle, Alabama. (Elevation = 310 feet.)
188.7 Turn right on paved road that angles off to the center of Citronelle.
190.3 Traffic light in downtown Citronelle. Continue straight ahead on Coy Smith Highway.
190.6 Immediately past railroad overpass, turn left on paved road.
190.9 Paved road ends and becomes a dirt road. Continue on dirt road 0.1 mile to type section of Citronelle Formation.
STOP 6 — Two to three feet of deeply weathered reddish-brown sands are present at the top of this exposure, underlain, successively, by five feet of massive gray clay and four feet of reddish-brown, structureless, sand. The actual type section described by Matson (1916) was probably located about 100 yards to the east along the old railroad cut.
Return to Coy Smith Highway.
191.3 Turn left on Coy Smith Highway (State Highway 96). Citronelle sands are exposed in a number of cuts along this road.
192.7 Storage tank farm on left side of road. Oil here is pumpted from Cretaceous Tuscaloosa Formation at depth of approximately 10,000 feet.
192.9 Fifteen feet of Citronelle sands exposed in quarry on right side of road. The deeply weathered, reddish-brown sands at this site occur as a channel deposit incised into bedded Miocene sands and clays.
193.7 Exposure of bedded Miocene clays approximately 100 yards off highway on left side of road.
194.8 Miocene clays, sand, and intra-formational ironstones on left side of road. Note characteristic "brassy" yellow color of the Miocene sands at this site.
196.4 Miocene sediments exposed on left side of road.
196.9 Citronelle channel sands on right side of road.
199.2 Cemetery on left.
200.9 Citronelle sands exposed in small ravine on right side of road.
201.5 Citronelle sands on both sides of road.
202.5 Possible Citronelle-Miocene contact on left side of road.
202.8 Miocene sands on left side of road.
203.9 Miocene sands on both sides of road.
205.1 Searcy Hospital on right.
205.5 Dropping down onto western side of Mobile River flood plain.
205.7 Railroad tracks. (B.M. = 48 feet.)
205.8 Intersection with U. S. Highway 43. Turn left on Highway 43. Intermittent exposures of Miocene clays, Citronelle colluvium and recent allumvium are present along highway, which lies about 3 miles west of the present river channel.
206.8 Railroad crossing. (Elevation = 50 feet.)
208.6 Large exposure of Miocene clays on right side of road.
210.1 Calvert.
210.7 Washington County Line.
211.1 Bridge.
211.2 Bridge.
212.9 Malcolm city limits. Terrace sands(?) on right side of road. (Elevation = 50 feet.)
214.3 Bridge (Bates Creek).
216.4 Bridge (Bilbo Creek).
217.4 MacIntosh city limits. (B.M. = 48 feet.)
218.4 County Highway 35 on left.
218.7 MacIntosh Bluff historical marker: "Here in 1807 ex-Vice-President Aaron Burr was arrested and sent on horseback via Fort Stoddart to Richmond where he was tried for treason and acquitted".
223.5 Bridge.
226.1 Sunflower. (B.M. = 67 feet.)
227.0 Orange brown terrace sand(?) exposed intermittently for the next mile.
229.1 Rest-area turn-off.
230.0 Miocene clays on both side of road. Terrace sands occurs as channels in the clays at several sites at this exposure.
230.8 Wagarville.
231.2 State Highway 56 on left to Chatom, Alabama. (Elevation = 66 feet.)
231.5 Mottled terrace(?) sands on right side of road.
232.1 Miocene sands on left side of road.
232.7 Bridge (Bassetts Creek).
233.0 Miocene sands and gravels on left side of road.
233.2 Miocene sands on left side of road.
234.2 Large exposure of Miocene sands and gravels exposed in quarry on left side of road.
STOP 7 — The sands and gravels exposed in this pit represent a coarse, fluvial phase of the Miocene that is only locally developed. These coarse clastics will be seen again at Jackson, Alabama, where they are disconformably overlain by younger terrace deposits.
236.3 Turn-off to St. Stephens (former State Capitol of Alabama). A large quarry is located on the Tombigbee River at St. Stephens where an excellent section of Eocene and Oligocene limestones and clays are exposed.

238.7 Begin descent to Tombigbee River flood plain. Miocene sands and gravels are exposed intermittently along the road.
239.7 Southern edge of Tombigbee River flood plain.
239.7 Bridge. A large quarry can be seen off to the right at the top of the hill which contains an excellent exposure of upper Miocene coarse clastics.
240.7 Highway 177 turns off to right. Miocene sands and gravels are exposed, continuously, along both sides of the road as the hill is climbed.
241.4 Contact of Miocene coarse clastics with terrace sands.
241.1 State Highway 69 turns off to left.
242.4 Miocene sediments exposed on right side of road.
242.8 Thirty feet of Miocene sands are exposed in a cut on the left side of the road. The upthrown side of the Jackson Fault has just been crossed.
243.3 Terrace sands exposed on top of hill.
243.8 Contact of terrace and Miocene sediments exposed on right side of road.
244.7 Beverly Lane turn-off to Little Stave Creek on left.
245.2 West Point Drive turn-off to Little Stave Creek on left.
245.6 Terrace sands exposed at top of hill.
246.8 Contact of terrace and Miocene deposits.
247.3 STOP 8 — Miocene sands at this location form an angular unconformity with overlying terrace sands. Faulting is a consequence movement along the nearby Jackson Fault.
Turn around and return to Jackson, Alabama.
250.8 Downtown Inn Motel.

END OF ROAD LOG FOR FIRST DAY.

ROAD LOG SECOND DAY OF FIELD TRIP

250.8 Downtown Inn Motel. Proceed south on Highway 43 and turn right at intersection of Highway 69. Miocene sands exposed on right side of road. (Elevation = 190 feet.)
251.1 Terrace sands crop out on both sides of road.
Jackson Academy. Terrace sands exposed in cut behind football field. (Elevation = 240 feet.)
252.2 Terrace sands exposed on both sides of road.
252.7 Miocene sands present on both sides of road. Dropping down into valley of Stave Creek.
253.1 Marianna Limestone (Oligocene) exposed on right side of road.
253.3 Stave Creek Bridge.
253.6 Miocene sands on right side of road.
255.6 Terrace sands on right side of road.
256.0 Lisbon Formation (Eocene) exposed in cut behind house.
256.7 Tallahatta Formation (Eocene) exposed on right side of road.
256.8 Historical marker: "Upper saltworks. The area from Stave Creek to Jackson Creek was one of the sites for the making of salt during the years 1862-64. Furnaces of native stone were built and saltwater from dug wells evaporated by boiling in large kettles. Amount of salt 600 bushels per day. Price, $10-$40 per bushel. Workers were exempt from military service."
The source of these waters is reported as derived from saline waters rising from the Cretaceous Tuscaloosa Formation(?) along the Jackson Fault and is, therefore, not believed associated with salt dome activity in the area.
256.9 Tallahatta Formation exposed on right side of road.
257.2 Weathered Hatchetigbee sediments exposed on both sides of road.
257.5 Cross Jackson Creek.
257.7 Bridge. (Elevation = 40 feet.)
258.4 Clays of the Hachetigbee Formation exposed in ditches on both sides of road.
258.5 Terrace sands on both sides of road. Driving along crest of Hatchetigbee Anticline for next 3 miles.
258.8 Terrace sands on left side of road in road cut and ditch.
259.6 Road to left leads to old lock #1 on Tombigbee River.
260.2 Cuts on right side of road expose terrace sands.
261.0 Salitpa. (Elevation = 184 feet.)
262.4 Weathered Hatchetigbee clays exposed on side of road.
263.1 Terrace sands on both sides of road. Descending through the Hatchetigbee Formation, which is largely covered.
263.7 Bridge (Kanetuche Creek).
264.0 Terrace sands at top of hill on right side of road.
264.8 Terrace sands in cut on right side of road.
265.2 Tallahatta Formation exposed on right side of road.
265.8 Terrace sands with lenses of fine to medium gravel.

266.6 STOP 9 — The road cut on the right reveals a sequence of approximately 6 feet of green to bluish-green clays from the Tallahatta Formation overlain by 12 feet of brown sands, clays and sandstones, belonging to the Lisbon Formation. These are, in turn, overlain by 4 to 5 feet of reddish-brown, terrace sands.

267.0 Exposure of Tallahatta, Lisbon, and terrace sands on right side of road.

267.6 Bridge (Satilpa Creek).

267.8 Bridge.

268.2 Tallahatta exposed on right side of road.

268.7 Terrace sands on both sides of road.

269.5 Terrace sands exposed in cut on right side of road. Begin descent into Valley of Eberline Mill Creek.

269.8 Bridge.

270.2 Terrace sands in cut on left side of road.

270.5 Terrace sands in cut on right side of road.

271.0 Large exposure of terrace sands.

272.0 Coffeeville city limits. (Elevation = 180 feet.)

272.9 Intersection with U. S. Highway 84. Turn left onto Highway 84 toward Silas.

273.2 Highway 69 turns off to right. Continue on Highway 84 (west).

273.6 Terrace sands exposed in cuts on both sides of road. Beginning descent into Tombigbee River valley.

273.8 Choctaw County Line.

274.0 Big Jim Folsom Bridge across Tombigbee River.

274.1 Tombigbee River floodplain. Sediments consist of recent alluvium.

275.9 Bridge.

276.3 Western edge of Tombigbee River floodplain. Tallahatta, Lisbon, and terrace sediments exposed in cuts on both sides of road.

276.6 Choctaw County Highway 6 on left. Turn left on County Highway 6. (Elevation = 120 feet.)
STOP 10 — A large cut-and-fill structure is apparent here with terrace sands filling a channel that has been cut down through the Lisbon Formation, into the Tallahatta Formation.
Turn around and return to Highway 84.

276.8 Turn left on Highway 84.

276.9 STOP 11 — Large cuts on right side of road shows excellent exposure of Tallahatta overlain by Lisbon sediments. The Lisbon is, in turn, overlain by terrace sands.
A number of exposures of the Tallahatta Formation will be seen in road cuts for the next few miles. The red sands that are seen disconformably overlying the Tallahatta clays, and claystones, have been mapped as belonging to the Lisbon Formation.

280.9 Tallahatta sediments on right side of road.

282.6 Bridge.

282.8 Turn right on Choctaw County Highway 21.

283.8 Reddish-brown sands of the Lisbon Formation on right side of road.

285.7 Fossiliferous, gray, clays and sandy clays (Lisbon) exposed in cut on left side of road. Upper sands appear to disconformably overlie these clays.

286.9 Turn left at intersection (west) toward Gilbertown.

289.4 Lisbon clays on right side of road.

290.5 Oil well on right side of road. This well is located in the Gilbertown Field which was originally discovered in 1944. As such, it represents the oldest field in Alabama. Production is currently derived from the Selma and Eutaw Formations at depths of approximately 3,500 feet.

292.6 Enter Gilbertown. Highway 17 junction. Turn left on Highway 17 and proceed south.

295.3 STOP 12 — Quarry on right side of road reveals an excellent exposure of 30 to 40 feet of Lisbon sediments. The variability in lithology found in the upper part of the Lisbon may be well seen at this site.

296.6 Tallahatta clays and claystones on left side of road.

299.7 Cross U. S. Highway 84 in Silas, Alabama.

305.8 Washington County Line.

308.8 Millry city limit.
A number of exposures of Miocene sands and clays will be seen on the highway between Millry and Chatom.

321.0 Chatom city limit.

338.3 Junction with U. S. Highway 45. Continue south on Highway 45.

347.0 Mobile County Line. (Citronelle city limits).

350.6 Traffic light in Citronelle. Continue south on Highway 45 to Interstate Highway 10, in Mobile. Return to New Orleans via Interstate 10.

END OF ROAD LOG.