DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

# Geology near a harardous waste landfill at the headwaters of Lake Marion, Sumter County, South Carolina

by

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ABSTRACT

A hazardous waste landfill near the headwaters of Lake Marion in Sumter County, S.C. is the site of a geohydrologic study by the U.S. Geological Survey. Cored drill holes in the vicinity of the landfill show four delta-dominated Cretaceous formations, one delta-dominated Paleocene formation, one marginal marine Paleocene formation, and one Plio-Pleistocene(?) fluvial formation. The Cretaceous formations are correlative with the Tar Heel, Bladen, and Donoho Creek Formations of the Black Creek Group and the Peedee Formation of the eastern Carolinas. The Paleocene strata are equivalents of the Rhems Formation and the Williamsburg Formation of the Black Mingo Group. Local variation in the thickness of these units is common but lithologies are relatively consistent across the study area. The geologic history of the area suggests that deltaic processes were prevalent from the Cretaceous through the lower Paleocene leaving behind thick sequences of sand and clay. In the late Paleocene, barrier-dominated marine conditions were established resulting in widespread well-sorted clay and silt deposits across the study area. Post-Paleocene erosion has removed all subsequent deposits except for channels filled with Plio-Pleistocene sand and gravel.

# GEOLOGY NEAR A HAZARDOUS WASTE LANDFILL AT THE HEADWATERS OF LAKE MARION, SUMTER COUNTY, SOUTH CAROLINA

## INTRODUCTION

### BACKGROUND

A hazardous-waste landfill near Pinewood, S.C. is one of two landfills in the southeastern United States permitted to accept hazardous waste. Since 1977, approximately one billion pounds of ignitable, corrosive, acutely hazardous, reactive, and toxic wastes have been buried at the 279-acre site. The landfill is located within 1,200 ft of South Carolina's largest reservoir, Lake Marion, which is managed by the South Carolina Public Service Authority. Although considerable geohydrologic information regarding the immediate site had been accumulated by the site operator, little is known about how the landfill area fits into the regional geohydrological setting. Concerns have been raised about the potential for contamination of ground water and surface water by leakage from the site. Therefore, the regional extent of geologic formations acting as aquifers is critical in the assessment of the impact of potential contaminants in the vicinity of the landfill.

### PURPOSE

The U.S. Geological Survey in cooperation with the South Carolina Public Service Authority is conducting a 3-year study designed to characterize the geology, hydrology, streamflow, lake-flow patterns, water quality, and sediment quality of the area within a 2-mile radius of the landfill site. A series of planned reports will describe the results of the investigation. This report is one in the series, and describes the geologic framework of the study area. An understanding of the site geology is instrumental to the development of a geohydrologic model that describes the directions and velocities of ground water flow. A description of the ground water hydrology at the site, including a discussion of the hydrologic implications of the geology, is to be the subject of a subsequent report. Additional reports will address rainfall quantity and frequency records, chemical and biological (macroinvertebrate population and diversity) quality characteristics of selected stream and lake sites, and numerical simulations of ground-water flow and contaminant transport in the study area.


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## STUDY AREA

The study area discussed in this report is a 10 square mile area on the eastern shore of Lake Marion about 4 miles downstream of the junction of the Congaree and Wateree Rivers. (Fig. 1). A hazardous waste landfill is located near the center of the study area (Fig. 2). Five, continuously-cored wells (Fig. 2, MAN-1A, LM-1A, LM-2A, RIM-1A, and RAILWAY 1A) were drilled outside of this facility to provide local, detailed geologic information about the characteristics and extent of lithologic units at the edge of Lake Marion. These cores, in conjunction with cores from three existing wells on the landfill site (Fig. 2, CBC-2, MW-32, and UBC-9), were used to describe the geologic formations in this report and construct the two geologic sections. In addition, well-known outcrops along the Congaree River to the north of the study area were visited to establish the relationship between those units and the shallow subsurface units in the study area.

## PREVIOUS WORK

The first geologic reconnaissance of the region around the study area was by Sloan (1907, 1908). His observations were confined to outcrops along major drainages and railroad cuts, and he recognized several lithofacies assigned to the Black Mingo Group discussed later in this report. The first regional mapping in this area was done by Cooke (1936), who reported both the Black Mingo Formation (Black Mingo Group of this report) and the underlying Cretaceous "Tuscaloosa Formation" in the vicinity of the study area. Later work has shown, however, that Cooke's Tuscaloosa Formation around the study area is actually a deltaic deposit in the lower part of the Paleocene Black Mingo Group. Cooke and MacNeil (1952) discussed the same general exposures as Sloan (1908) and Cooke (1936), but they also discussed regional age correlations from fossils. In particular, they presented evidence that the age of the Black Mingo strata might range from the Paleocene into the lower Eocene. Pooser (1965) examined outcrops east and northeast of the study area and reported the occurrence of the Black Mingo and Tuscaloosa Formations as did Cooke (1936). Pooser's ostracod data, however, suggested that the Black Mingo strata in the study area were lower Eocene. Additional mineralogic information about the Black Mingo strata was reported by Heron and others (1965) and Heron (1969). Padgett (1980) made a detailed analysis of the outcrops immediately adjacent to the study area and incorporated this information into his analysis of seven exploratory core holes in the area now covered by the hazardous waste landfill. Padgett (1980) recognized more of the interrelationships within the Black Mingo strata than previous workers and applied the Williamsburg nomenclature of Van Nieuwenhuise (1978) to the deposits in the study area. In addition, he concluded that the underlying Cretaceous strata were of latest Cretaceous age (that is to say, not the Tuscaloosa Formation) on the basis of data from Woollen (1978). Colquhoun and others (1983) published a geohydrologic study of South Carolina and one of their geologic sections passed near the study area. They were the first to apply the "Black Mingo Group" terminology of Van Nieuwenhuise and Colquhoun (1982) to the strata in the vicinity of Lake Marion. They recognized that the deltaic Paleocene deposits reported by Padgett (1980) should be assigned to the Black Mingo Group, and informally named them the Sawdust Landing Member of the Rhems Formation. This nomenclature has since been formalized by Muthig and Colquhoun (1988), who also proposed the name Lang Syne Member for the Tavern Creek Bed of Padgett (1980), which overlies the Sawdust Landing Member.

Local geohydrologic investigations of the landfill site have resulted in several unpublished engineering reports. Environmental Technology Engineering (1987) not only describes the results of previous investigations but also gives the currently accepted lithologic framework for the study area. The information in the following text does not significantly alter this existing framework except in terms of nomenclature, age, and regional correlations of geologic units.

## GEOLOGY

The development of a hydrogeologic model of the Coastal Plain strata in the study area requires not only a subdivision of subsurface lithologic units, but also an understanding of the depositional environments and regional distribution of these units. A deep core hole (MAN-1A) was drilled at a topographic high within the Manchester State Forest immediately north of the hazardous waste landfill (Fig. 2, site MAN-1A) to obtain the necessary information. This core hole penetrated the entire Tertiary geologic section and well into the Cretaceous strata of this part of Sumter County, and is by far the best stratigraphic reference section in this region. Therefore, data from this core will serve as a reference section to define the lithology, age, and nomenclature of geologic units hereafter used in this report.

Figure 3 is a graphic representation of the lithology of the MAN-1A core, and also includes information about the geophysical properties of the strata and layers sampled for paleontological analysis. The lithologies of all of the cores examined in this investigation are relatively consistent across the study area, but paleontological information had to be obtained from other cored wells to complete the local geologic picture. References made to other core samples in the stratigraphy section of this report will be explained in greater detail in later discussion sections. A regional correlation chart (Fig. 4) provides a cross reference of units described in this report with geologic units elsewhere in the Southeastern United States.

## STRATIGRAPHY

### Black Creek Group

#### Nomenclature

The name Black Creek Formation (Phase) was first proposed by Sloan (1908) for outcrops of black laminated clay and fine sand along Black Creek near its junction with the Pee Dee River in eastern South Carolina. Stephenson (1907, 1912) further developed the stratigraphic and faunal Black Creek terminology into the framework that has been used by almost all subsequent investigators. Since this time, numerous workers, such as Cooke (1936), Brett and Wheeler (1961), Swift (1969), Woollen and Colquhoun (1977a, 1977b), and Colquhoun and others (1983), have tried to characterize subdivisions of the Black Creek strata, but the "Black Creek Formation" of Stephenson (1912) remained largely unchanged.

In recent years, parallel lithostratigraphic and biostratigraphic investigations of the Black Creek outcrop areas by the U.S. Geological Survey has shown that the section can be divided into several chronolithostratigraphic units (Christopher and Sohl, 1983). Owens (1988) incorporated this information into a reconnaissance mapping study and found that three separate formations could be delineated regionally in North Carolina. He proposed that the Black Creek be raised to Group status, preserving this well-known term, and that three new formation names, Tar Heel, Bladen, and Donoho Creek, be given to the new lithostratigraphic units. Sohl and Owens (in press) describes the lithologic characteristics, the distribution, and the paleontology of these new formations in both North and South Carolina, as well as inconsistencies of units such as the Snow Hill Member of Stephenson (1923). Since the geology of the Black Creek strata in the study area is very similar to that of the type areas described by Sohl and Owens (in press), the nomenclature that they have proposed will be incorporated into the discussion that follows.

#### Lithology

The strata of the Black Creek Group in the MAN-1A core extend from a depth of 258 ft to the bottom of the core at 725 ft. This section of core can be divided into at least three depositional sequences (see fig. 3; upper unit, 258 to 389 ft; middle unit, 389 to 542 ft; lower unit, 542 to 725 ft), which are differentiated by abrupt changes in depositional environment and probable erosional unconformities. These units will be described separately for later comparison to the formations of the Black Creek Group of Owens (1988).

The lower unit of the Black Creek Group in the MAN-1A core is comprised of thick beds of loose sand separated by beds of carbonaceous clay. In the basal part of this unit, the sand is typically fine to very coarse, angular, poorly-sorted quartz. Matrix clays are generally absent, but where present they are white kaolin. Accessory minerals include mica, rutilated quartz, monazite, garnet, granular pyrite, and opaque heavy minerals (probably magnetite and hematite). Some sand layers contain small, well rounded smoky quartz gravel, whereas others contain lignite fragments ranging from sand size to very large chunks. Much of the lignitic material shows signs of pyritization. The sand in the upper part of the unit is fine, sub-angular to sub-rounded, moderate to well-sorted quartz. Accessory minerals are like those of the lower sands with the exception of a small amount of glauconite in localized beds. Crossbedding and small scale slump faults (probably from compaction) were observed in the cored interval from 565 to 627 ft. The clay beds that separate these sand bodies are massive to laminated and contain small amounts of silt, fine sand, and mica. All of the clay layers appear to have been rich in carbonacous material (dark gray) during deposition, but the uppermost layers are now pale to dark brown/gray. These layers also show signs of post-depositional dessication fracturing generally associated with subareal weathering and oxidation. This episode of exposure could also account for the brown oxidation stains in the uppermost clay layers. The upper surface of the unit is highly fractured and contains faint impressions of leached lignitic material.

The middle unit of the Black Creek Group in the MAN-1A core is characterized by laminated carbonaceous clays and fine sand. The sand is largely very fine to fine, sub-rounded, well-sorted quartz, and accessory minerals include mica, granular phosphate, pyrite, opaque heavy minerals, and locally abundant glauconite. The clay laminae are gray to black, very carbonaceous, and commonly contain fine mica and silt. The majority of this unit is particularly well-laminated and thinly-bedded with molds of megafossils, mostly bivalves, common from 428 to 435 ft. The lower part of the unit, however, has sandier beds, evidence of small scale crossbedding, pyritized lignite, leaf fragments. and no marine megafossils. The uppermost 35 ft of the unit is well-sorted, very fine to fine sand with a mineralogy identical to that of the lower laminated sands. Crossbedded sands and a thin layer of well-rounded gravel are present in these uppermost beds as are a few thin (12 in.) carbonaceous clay beds.

The upper unit of the Black Creek Group in the MAN-1A core is a sequence of shallowing-upward strata from calcareous fossiliferous clay and limestone at the base to clayey sand at the top. The lower 31 ft of strata in the upper unit (358 to 389 ft) is dark green silty to slightly sandy clay to marl containing quartz sand, granular phosphate, and mica. Thin (6-12 in.) beds of limestone are common from 358-375 ft and aragonitic shells of bivalves and gastropods are abundant from 378-389 ft. These calcareous deposits grade upwards into beds of laminated carbonaceous clay and fine sand interbedded with more massive sand beds. In all cases, the sand is very fine to fine, well-sorted, sub-angular quartz. Accessory minerals include fine to coarse mica, abundant glauconite, fine granular phosphate, and opaque heavy minerals. The clays are dark gray to black, very carbonaceous, and typically contain some silt and mica. X-ray analysis of these clays indicates that they are largely illite/smectite with small amounts of kaolinite. Shell molds are present in the beds with more clay, and crossbedding and bioturbation is present in the sandier intervals. The uppermost part of the upper unit (258-314 ft) is composed of very fine to fine, well-sorted, sub-angular to sub-rounded, clayey quartz sand. Accessory minerals include abundant mica and glauconite, granular phosphate, ilmenite, garnet, zircon, monazite, potassium feldspar, staurolite, epidote, hornblende, rutile, leucoxene, pyrite, and opaque heavy minerals. The matrix is light gray-green clay. Large lignite chunks are common and typically show signs of pyritization. The sand in the lower part of this unit (295-314 ft) contains small crossbeds, shell molds, and shark teeth. A thin layer of quartz and phosphate pebbles is present at 314 ft and marks the transition from mostly laminated clay and sand to mostly sand.

Origin

All of the three units of the Black Creek Group described above were deposited in delta-dominated environments. This is suggested not only by the abundance of carbonaceous debris in these units, but also by studies in regional deposition to the west by Prowell and others (1985a), to the east by Sohl and Owens (in press), and to the south by Owens and Gohn (1985) and Gohn (1987).

The lower unit in the Black Creek Group of this report is characteristic of a lower delta plain depositional environment. In particular, the fine to very coarse, poorly-sorted sand and gravel with the abundant pyritized lignite is characteristic of distributary channels in this environment. Carbonaceous clay samples collected for pollen analysis also contain small numbers of dinoflagellates and acritarchs indicating a restricted marine influence on deposition. The massive clays and crossbedded fine sand layers in the upper part of this unit probably represent infilling of interdistributary bays and cutoff channels during the waining stages of deposition. Similarly, the fracturing and oxidation of the uppermost clay surfaces suggests subareal dessication and weathering.

The strata of the middle unit of the Black Creek Group are indicative of delta front deposition. The fine, well-sorted sand laminated with thin layers of carbonaceous clay suggest shallow shelf marine conditions which is also indicated by an abundance of dinoflagellates and acritarchs in carbonaceous clay samples. The open marine nature of this deposit is further substantiated by the abundant glauconite, phosphate, and shell molds.

The strata of the upper unit of the Black Creek Group are indicative of a deltaic system prograding from prodelta to shallow delta front. The fossiliferous clay, marl, and limestone beds at the base of the unit reflect open marine shelf conditions similar to those on a prodelta. Conformably overlying these beds are well-laminated carbonaceous clays and fine sands similar to the delta front deposits in the middle unit. Comformably overlying the laminated sand and clay are thicker sand layers containing crossbeds, small amounts of gravel, and large lignitic fragments suggestive of shallow delta front conditions.

Age

Samples of carbonaceous clay were collected from the MAN-1A core at the depths indicated on figure 3. Palynomorph assemblages from the lower and middle units of the Black Creek Group in the MAN-1A core are generally assignable to pollen zones CA-3 through CA-5A of Wolfe (1976). Unpublished palynomorph zonations from the Peedee River area (Christopher, written communication, 1983) indicate that these strata are correlative to the Exogyra Ponderosa Zone of Sohl and Christopher (1983) and Sohl and Owens (in press) and are therefore middle to late Campanian in age.

Palynomorph assemblages from the upper unit of the Black Creek Group indicate that it is generally equivalent to pollen zone CA-5B of Wolfe (1967). Unpublished palynomorph zonations from the Peedee River area (Christopher, written communication, 1983) indicate that these strata are correlative to the Exogyra Cancellata Zone of Sohl and Christopher (1983) and Sohl and Owens (in press) and are therefore early Maestrichtian in age. Ostracode samples from the RIM-1A core (Figs 2 and 5) at depths of 300 ft and 305 ft and the MAN-1A core (Figs. 3 and 5) at depths of 367 ft and 382 ft substantiate that the uppermost unit of the Black Creek Group is early Maestrichtian due to the presence of Antibythocypris phaseolites and Haplocytheridea wilmingtonensis (G.S. Gohn, written communication, 1988).

### Correlations

The strata described above as the Black Creek Group are largely correlative with the traditional "Black Creek Formation" of Stephenson (1912, 1923) outcropping along the Pee Dee River in South Carolina from Burch's Ferry to north of Mars Bluff. This would include Stephenson's type areas along Black Creek. The lower and middle units of the Black Creek Group described in this report are equivalent in age to the Tar Heel and Bladen Formations of Sohl and Owens (in press), although an exact one-to-one stratigraphic correlation is not possible at this time. The upper unit of the Black Creek Group in this report is directly equivalent to the Donoho Creek Formation of Sohl and Owens (in press) and the Black Creek strata immediately beneath the Peedee Formation as discussed in Sohl and Christopher (1983).

## Peedee Formation

### Nomenclature

The term Peedee Formation (Phase) was initially used by Sloan (1907) and Stephenson (1912, 1923) to describe marls and dark colored massive sands that outcrop along the Pee Dee River in eastern South Carolina. Stephenson (1912, 1923) stated that the Peedee Formation overlay the laminated dark clays of his Black Creek Formation and is characterized in the Carolinas as a compact, dark green or dark gray, finely micaceous, glauconitic and argillaceous, fossiliferous, massive sand containing some impure limestones and beds of dark clay. One of the best known localities of the Peedee Formation is on the Pee Dee River at Burch's Ferry (Sloan, 1907; Stephenson, 1923, fig. 14). Apparently some confusion existed concerning the base of the Peedee Formation in North Carolina (Sohl and Christopher, 1983) due to eastward facies changes. Recent work by Sohl and Owens (in press) has established that the Peedee strata at Burch's Ferry (true Peedee Formation) is only the upper part (middle Maestrichtian) of the unit called Peedee in North Carolina by Sohl and Christopher (1983). This determination is based on fossil evidence from Stephenson (1923), Sohl and Christopher (1983), Lawrence and Hall (1987), Sohl and Owens (in press), and Christopher (written communication, 1983). The term "Peedee formation" is used in this report for beds that are biostratigraphically equivalent to the Peedee Formation of Sohl and Owens (in press), but are lithologically dissimilar due to a strong deltaic influence on middle Maestrichtian deposition in central South Carolina.

### Lithology

The Peedee formation in the study area is comprised of two lithologic units separated by a gradational contact about 10 ft thick. The lower part of the Peedee is composed largely of dark green to dark gray laminated fine sand/silt and carbonaceous clay. The sand/silt is fine, well-sorted, sub-angular quartz and accessory minerals include abundant white mica, glauconite, ilmenite, garnet, potassium feldspar, leucoxene, biotite, zircon, tourmaline, rutile, staurolite, monazite, pyrite, granular phosphate, and opaque heavy minerals. The clay is very carbonaceous and micaceous, and contains small to moderate amounts of silt. X-ray analysis of the clay fraction indicates the abundance of both illite/smectite and kaolinite. Localized beds of loose fine sand, marl, angular chert, and phosphatic pebbles are also present. Molds of bivalves and gastropods are common in beds containing more clay, and lignite fragments are abundant. The base of the formation (258 ft) is marked by a very thin bed of well-rounded phosphate and quartz pebbles.

The upper part of the Peedee formation in the study area is largely poorly-sorted quartz sand overlain by thick beds of sandy kaolinitic clay. The sand is fine to very coarse, sub-angular, moderately- to poorly-sorted quartz in a white kaolin matrix. Accessory minerals include abundant medium to large white mica, ilmenite, sillimanite, potassium feldspar (weathered), leucoxene, biotite, zircon, garnet, monazite, tourmaline, staurolite, pyrite, and rutilated quartz. Slightly pyritized lignite is also common. The clay beds in the top of the formation are typically sandy to silty and generally massive. Most of the clay in these beds is light gray to white kaolin although x-ray analysis indicates the presence of illite/smectite. The upper 10 ft of the formation typically contains red/orange oxidation staining presumably from subareal weathering at the end of the Cretaceous.

Origin

The Peedee formation in the study area represents a prograding deltaic sequence from open marine delta front strata at the base to restricted marine lower delta plain deposits at the top. The fossiliferous clays, marl, glauconite, and the abundance of dinoflagellates and acritarchs in the lower part of the Peedee strata indicate open marine conditions very similar to that of the true Peedee Formation described by Sohl and Owens (in press). The abundance of carbonaceous clays and lignite, however, indicates a closer proximity to the source of sediment supply. The poorly-sorted sand and massive clay beds in the upper part of the Peedee are lower delta plain deposits left as the delta prograded over the older delta front. This accounts for the rather rapid but gradational transition between the upper and lower units of the Peedee. The sands were probably deposited in large channels, whereas the uppermost massive clays were probably infillings of interdistributary bays and cut-off channels. Small to moderate numbers of dinoflagellates and acritarchs in carbonaceous clay samples suggests that sedimentation occurred under restricted marine conditions.

Age

Samples for microfossil analysis were not only collected from the MAN-1A core (Fig. 3), but also from the LM-1A core, the RIM-1A core, and the UBC-9 core (see Fig. 2 & Pl. 1). Pollen assemblages from carbonaceous clays from these cores indicate that the Peedee formation is within pollen zone CA-6/MA-1 of Wolfe (1967) and is the equivalent to the middle Maestrichtian part of the Exogyra costata Zone of Sohl and Christopher (1983). Ostracode assemblages from 219 ft in the RIM-1A core and 225 ft in the MAN-1A core verify that the lower Peedee strata are Maestrichtian (G.S. Gohn, written communication, 1988) based on the occurrence of Antibythocypris crassa of Hazel and Brouwers (1982).

Correlations

The biostratigraphic data definitely indicate that the Peedee strata in the study area are equivalent to the true South Carolina Peedee Formation of Stephenson (1923), Sohl and Christopher (1983), and Sohl and Owens (in press). Similarly, the lithology of the lower part of the Peedee in the study area is very close to the Peedee lithofacies described by Sohl and Owens (in press) in areas to the east.

Locally, the units described as upper and lower Peedee formation in this report have been called upper and lower Black Creek Formation by other workers (Environmental Technology Engineering, Inc., 1987). This unit does more closely resemble the lithologies of the "type" Black Creek strata than it does the "type" Peedee strata. For regional extrapolation, however, it is important to recognize that the Peedee strata of the study area are the lithofacies equivalents of the open marine Peedee Formation shelf deposits in the eastern Carolinas.

## Black Mingo Group

### Nomenclature

Sloan (1908) first coined the term Black Mingo (Phase) Formation for exposures of "light to dark gray laminated shales" near the confluence of the Black River and Black Mingo River in Williamsburg County, South Carolina. He included the Lang Syne beds of Calhoun County, the Rhems Shale, and the Williamsburg "Pseudo-Buhr" in what he called the Upper Black Mingo (Phase). Cooke (1936) made the first regional investigation of the Black Mingo and described it as representing all of the Eocene strata deposited prior to the middle Eocene McBean Formation. Subsequent biostratigraphic studies by Pooser (1965) and Hazel and others (1977) outside of the type Black Mingo area helped limit the age of the strata (largely to the Paleocene), but regional miscorrelations of various "Black Mingo" lithologies were still common. Van Nieuwenhuise (1978) made a detailed study of the type area of the Black Mingo (Formation) and on the basis of ostracode data determined that the strata were of three different ages. He proposed that the formation be split into a lower Paleocene Rhems Member and an upper Paleocene-lower Eocene Williamsburg Member. After additional study, Van Nieuwenhuise and Colquhoun (1982) proposed that the name Black Mingo be raised to Group status and that the Group be divided into the Rhems Formation, the Williamsburg Formation, and an unnamed Ypresian (lower Eocene) formation. The Black Mingo Group nomenclature of Van Nieuwenhuise and Colquhoun (1982) is used in this report because it is the most applicable terminology in the study area.

The Rhems Formation in the study area was informally divided by Colquhoun and others (1983) into the Sawdust Landing and Lang Syne Members based on the work of Padgett (1980). This nomenclature was later formally proposed and reference sections described in detail by Muthig and Colquhoun (1988). Padgett (1980), however, had originally placed the Lang Syne beds of Sloan (1908) in the Williamsburg Member of the Black Mingo Formation and he implied that the underlying deltaic strata (Sawdust Landing Member) also belonged in the Williamsburg. A lower Paleocene pollen age from black clays near the base of the Lang Syne beds at Old Sawdust Pile Landing (now Trezevant Landing) on the Congaree River about 6.5 mi upstream from the GSX landfill site (Fig. 1) apparently prompted Muthig and Colquhoun (1988) to formally assign these strata to the Rhems Formation. Other reports by Colquhoun and others (1983) and Environmental Technology Engineering, Inc. (1987) also included the Lang Syne and Sawdust Landing units as members of the Rhems Formation. Data included in the following discussion indicates that the Lang Syne is actually a member of the Williamsburg Formation, whereas the Sawdust Landing is probably the only member of the Rhems Formation in the study area. This scheme of nomenclature is used hereafter in this report, and the descriptions of these strata come both from cores in the study area and the beds exposed in the type section of the Sawdust Landing Member at Old Sawdust Pile Landing.

## Rhems Formation
## Sawdust Landing Member

### Lithology

The Sawdust Landing Member of the Rhems Formation in the MAN-1A core is characterized by thick massive to weakly crossbedded beds of very clayey sand which are in unconformable contact with the underlying Peedee formation. The beds are generally very well packed, and the cores are extremely dense and heavy. The sand in the Sawdust Landing strata is fine to very coarse, poorly sorted, angular quartz. Some beds of quartz grit and rounded smokey quartz and potassium feldspar gravel are also present especially in the few feet of strata above the basal unconformity. Accessory minerals include large white mica, small to very large potassium (white and pink) feldspars, ilmenite, siderite, garnet, leucoxene, zircon, pyrite, rutile, sillimanite, biotite, tourmaline, monazite, rutilated quartz, and opaque heavy minerals. Small amounts of lignite and pyritized lignite are also present, and in the RAILWAY 1A core (Fig. 2) pyrite is filling fractures in the uppermost few inches of the unit. Evidence in the form of clay molds and staining also suggests that undetermined amounts of primary carbonaceous material has been leached out of the Sawdust Landing strata.

X-ray analysis indicates that the matrix clays are pale green illite/smectite or gray to off white kaolinite. The illite/smectite clays are mostly confined to the upper part of the Sawdust Landing Member and the cores containing illite/smectite typically become a much darker green when exposed to the air. X-ray analysis also indicates small amounts of cristobalite in the matrix. Cristobalite is characteristic of similar lithologies in the Paleocene Ellenton Formation (Prowell and others, 1985a & 1985b) and the Cretaceous Cape Fear Formation (Heron and Wheeler, 1964). Like these formations, the Sawdust Landing Member commonly has a pale red/orange/purple staining locally overprinting the characteristic pale green/gray color. As this characteristic is found in deep cores, the staining is thought to be from subareal weathering and mineral oxidation shortly after deposition. This coloration, the massive, dense nature of the beds, and the large unweathered feldspars are unique to the Sawdust Landing Member in this region.

Origin

The strata of the Sawdust Landing Member of the Rhems Formation represent deposition in an upper delta plain environment. The thick, massive beds, evidence of crossbedding (in outcrop and cores), poor sediment sorting, large unweathered feldspars, presence of carbonaceous debris (both present lignite and altered remains), and evidence of cristobalite implies that these strata were deposited in a high energy, fluvial environment of mass erosion and rapid deposition. The removal of carbonaceous debris from most of the beds, the pale red/orange/purple staining in many places, and pyrite-filled fractures in the upper few inches of the unit also suggests periods of subareal exposure, weathering, oxidation, and(or) erosion typical of an upper delta plain. Padgett (Oral communication, 1989) says that sharks teeth can be found in the Sawdust Landing strata at Old Sawdust Pile Landing, but these are probably remnants of eroded and redeposited Black Creek Group strata, because other evidence of marine influence (megafossils or marine flora in carbonaceous clays) is absent. In addition, the large channel-form beds and variable crossbedding at the type section (Old Sawdust Pile Landing) are indicative of fluvial, not marine, conditions.

Age

No fossils have been recovered from the Sawdust Landing strata in the study area or the type sections along the Congaree River. Only weakly carbonaceous clays were recovered from cores in the study area, and none yielded any pollen, dinoflagellates, or acritarchs. Therefore, the age of the Sawdust Landing strata must be inferred by stratigraphic bracketing and extrapolation from other areas. Since (1) the Peedee Formation is the youngest Cretaceous formation known in South Carolina, and (2) the Sawdust Landing strata were deposited unconformably on the Peedee, then the age of the Sawdust Landing strata is most likely Tertiary and not Cretaceous. In a later section of this report describing the strata that unconformably overlie the Sawdust Landing strata, microfossil data indicates that the overlying beds are equivalent to the basal beds of the Williamsburg Formation (upper Paleocene, middle Selandian/Thanetian). Therefore, the age of the Sawdust Landing strata is most likely early Paleocene (upper Danian). This assumption is substantiated by the palynomorph analysis of carbonaceous clay cuttings (depth 175-185 ft; +100 ft MSL) from the town well at St.

Matthews, Calhoun Co., S.C. (see Colquhoun and others, 1983), about 15 miles east of the study area, in which early Paleocene dinoflagellates were reported by L.E. Edwards, U.S. Geological Survey, Reston, Virginia (written communication, 1980).

Correlations

Regional stratigraphic correlations are generally made by either lithologic extrapolation or paleontological comparisons. The only regional lithologic comparison of the Sawdust Landing strata in the study area was reported by Colquhoun and others (1983). They found that downdip extrapolation of these beds suggested equivalence with the Rhems Formation of the Black Mingo Group of Van Nieuwenhuise and Colquhoun (1982). The most recent information concerning the age of the Rhems Formation in its type area indicates that its age is lower Paleocene (middle to upper Danian) (N.L. Frederiksen, U.S. Geological Survey, written communication, 1988). The paleontological equivalents to the Rhems Formation, and presumably the Sawdust Landing strata, would therefore be the lower part of the Ellenton Formation of eastern South Carolina (Prowell and others, 1985b) and the lower part of the Huber Formation of central and eastern Georgia (Prowell and others, 1985a).

## Williamsburg Formation
## Lang Syne Member

Lithology

The Lang Syne Member of the Williamsburg Formation in the study area is largely a medium to dark gray, low density, carbonaceous claystone to siltstone with thin beds of sand and clay at its unconformable contact with the underlying Sawdust Landing strata. In the MAN-1A (Fig. 3) core, the base of the unit is marked by several feet of fine to coarse, moderately-sorted, subrounded quartz sand in a dark green clay matrix. Well-rounded quartz gravel, sharks teeth, pieces of lignite, and fossil shell fragments are also present. Accessory minerals include mica, glauconite, garnet, granular phosphate, pyrite, and opaque heavy minerals. In other cored holes, these basal beds are as much as 6 ft thick (Pl. 2, RAILWAY 1A site), contain silicified layers of coarse sand and shells (Pl. 1, LM-1A site), and have beds of sticky black clay interlaminated with quartz sand (Fig. 2, Pls. 1 & 2, LM-2A, UBC-9, MW-32, & RAILWAY 1A sites). These basal beds are interpreted as lag deposits generated by initial marine invasion and erosion of the old Sawdust Landing deposits. Hence, they are immature sediments relative to the rest of the unit and contain eroded elements (for example, quartz gravel and carbonaceous matter) from older formations.

The bulk of the Lang Syne is dark green to gray, moderately consolidated, silty clay (claystone) to clayey silt (siltstone) containing small amounts of fine, rounded, well-sorted quartz sand. X-ray analysis of the clays suggests that they are high in illite/smectite with some kaolinite, and they are rich in disseminated carbon. Accessory minerals include mica, pyrite, granular phosphate, glauconite, secondary opal, and opaque heavy minerals. Bedding in the Lang Syne is very regular with bed thicknesses ranging from 0.25 to 12 inches. Beds in the MAN-1A core are generally well laminated and vary from about 0.25 to 1.0 inches thick. More clayey parts of the unit generally contain shell molds and shell fragments of bivalves, gastropods, and bryozoans, and remnants of leaves. Sandier beds typically contain sand-filled, clay-lined burrows of marine organisms and lignitic material. Beds of silicified fine to very coarse angular quartz sand (with no clay) and shells are also present generally in the upper part of the formation.

Most of the formation has apparently experienced a weak secondary silicification resulting in precipitation of secondary opal described by Heron (1969) and Wise and Weaver (1978). This lithofacies is commonly called "opaline claystone" and is referred to as the Tavern Creek bed by Padgett (1980). The more opal-rich strata exhibit concoidal fractures and where replacement is extensive (in outcrop at the top of the unit), the beds have been termed "Buhrstone" (Sloan, 1908; Heron, 1969). The low bulk density of the opaline beds is the most unique characteristic of this unit in the study area and is possibly associated with the opaline replacement. Both in outcrop and cores, steeply-inclined, commonly slickensided, planar joints and(or) fractures characterize the Lang Syne claystone/siltstone as well.

Origin

The evenness of bedding, the sediment sorting, the abundant fossil evidence, and the presence of glauconite and phosphate indicates that the Lang Syne strata were deposited under marine conditions. The basal poorly-sorted beds of lag deposits are interpreted as erosional remnants of the transgressing sea. However, the considerable thickness (over 120 ft) and uniformity of the unit above the basal beds in the study area, the abundance of lignite and leaves, and the lack of coarse sediment suggests a very unique depositional environment that was restricted largely to clay and silt size sediment but was open to the influx of terrestrial organic matter. In addition, samples of carbonaceous clay for palynological analysis contain an abundance of dinoflagellates, but relatively few species (L.E. Edwards, U.S. Geological Survey, Oral Communication, 1988). This suggests not only restricted marine conditions, but also either hypo- or hypersaline water conditions. Therefore, the Lang Syne beds in the study area are interpreted as being deposited in back-barrier bays and restricted lagoons in a marginal marine environment.

Outside of the study area (for example, Old Sawdust Pile Landing), the Lang Syne contains thick beds (3-5 ft) of well-sorted, quartz sand containing small-scale crossbedding. These Lang Syne beds are herein considered to reflect interbay areas where tidal creeks are transporting sand into open marine areas. These sand beds are interbedded with clay and silt beds similar to those in the study area and are therefore taken to be coevel. The comparison of Lang Syne strata in the study area (this report) with sections outside of the study area (see Padgett, 1980) suggests that lateral changes in depositional environment are common. The Lang Syne strata in this region therefore probably represent a moasic of restricted shallow water fluvio-marine environments.

Post-depositional processes are probably responsible for the silicification of the various strata of the Lang Syne. Various explanations for the replacement have been discussed by Heron (1969) and Wise and Weaver (1978). In the study area, the replacement appears closely associated with the well-bedded clay and silt facies of the unit (where bulk density has decreased) and the thin beds of coarse fossiliferous sand (where bulk density has increased). This would imply that formation fluids have carried silica away from the clay/silt beds and deposited that silica in the originally-porous, coarse sand beds. One explanation for this process is that illite/smectite clays in the matrix of the clay/silt layers may have been altered to kaolinite by post-depositional processes that simultaneously released free silica. This free silica would tend to migrate to local high porosity beds and precipitate the secondary cement seen today.

Age

Samples of carbonaceous clay were collected from cores in the MAN-1A well, the UBC-9 well, and the MW-32 well in the study area (Fig. 2) and from the outcrop of the Lang Syne Member on the bluff at Old Sawdust Pile Landing (Fig. 1) and on the bluff at Devil's Elbow on the west bank of the Congaree River just upriver from Old Sawdust Pile Landing (see Padgett, 1980). The samples were examined for both dinoflagellates and pollen. The samples commonly contain abundant numbers of dinoflagellates but only a few dominant species are present. Unfortunately, these species are long-ranging and offer no useful age information

(L.E. Edwards, U.S. Geological Survey, oral communication, 1988). However, as mentioned previously this does indicate unusual water conditions and very restricted depositional environment.

The samples from the MAN-1A core were barren of pollen, but the remaining 4 Lang Syne samples yielded diagnostic assemblages. The sample from the MW-32 core at 79 ft (Fig. 2) is from the lowermost Lang Syne strata in the study area ("basal clay" of Environmental Technology Engineering, 1987), whereas the sample from the UBC-9 core at 27 ft is from the middle of the Lang Syne section ("claystone" of Environmental Technology Engineering, 1987). The samples from the bluffs at Devil's Elbow and Old Sawdust Pile Landing are also just above the basal unconformity of the Lang Syne. These samples contain palynomorph assemblages from the Caryapollenites prodromus interval zone which are indicative of the very latest Midwayan (middle Selandian/Thanetian) part of the upper Paleocene (N.L. Frederiksen, U.S. Geological Survey, written communication, 1988). This contrasts with the interpretation reported by Muthig and Colquhoun (1988) that these beds are lower Paleocene (Danian) based on analysis of dinoflagellates by Clark (1988) from one sample taken from old Sawdust Pile Landing. Clark's palynomorph assemblage clearly indicates that the sample could be as as old as Danian, but the youngest possible age is based only on one dinoflagellate species whose uppermost age range can be questioned. In contrast, the pollen data not only shows a biologic continuity between the Lang Syne beds and the Williamsburg Formation, but it questions the uppermost limit of the Danian/Selandian stage boundary.

### Correlations

Comparative analysis of pollen assemblages from the Lang Syne strata of the study area (and the outcrops along the Congaree River area) with samples from the type sections of the Black Mingo Group of Van Nieuwenhuise and Colquhoun (1982) show that they are biostratigraphically equivalent to the Williamsburg Formation (N.L. Frederiksen, U.S. Geological Survey, written communication, 1988). More specifically, the Caryapollenites prodromus interval zone is equivalent to the upper part of the Lower Bridge Member and the basal part of the Chicora Member of the Williamsburg Formation (Van Nieuwenhuise and Colquhoun, 1982). The age designation of the Lang Syne beds also suggests correlation with the uppermost beds in the Ellenton Formation at the Savannah River Plant described by Siple (1964) and Prowell and others (1985b). Lithologically, the Lang Syne Member of the Williamsburg Formation is similar in appearance to the lithofacies of the Lower Bridge Member as described by Van Nieuwenhuise and Colquhoun (1982) and is directly equivalent to other deposits in the upper Coastal Plain of South Carolina mapped as the Black Mingo Formation (Phase) by Sloan (1907, 1908), Cooke (1936), Padgett (1980), Cooke and MacNeil (1952), Heron and others (1965), Heron (1969), and Colquhoun and others (1983).

## Upland Fluvial Deposits

### Nomenclature

The term "Upland fluvial deposits" is an informal designation used in this report for crossbedded clayey sand and gravel beds that cap the hilltops in the study area. Although Sloan (1908) did not report the localities of these deposits in the study area, he certainly would have included them in his Plio-Pleistocene Lafayette Phase (Formation). Cooke (1936) mapped these strata as part of his Quaternary Coharie Formation, which was apparently based on elevation more so than lithostratigraphy. Environmental Technology Engineering, Inc. (1987) informally referred to the upland deposits in the study area as "Plio-Pleistocene sediments" to avoid confusion that has arisen over the Quaternary stratigraphic nomenclature of Sloan (1908) and Cooke (1936). This terminology is somewhat unacceptable in that the age of the upland deposits has not been established except in very generalized terms. Therefore, the informal term "upland fluvial deposits", a rock-descriptive term, will be applied to these beds in the remainder of this report.

Lithology

The upland fluvial deposits have only been cored in the MAN-1A and RAILWAY 1A drill holes (Fig. 2), but the unit is well exposed in a large roadcut on the road to Sparkleberry Landing about 0.25 mi south of the MAN-drill site. In the cored holes, the upland deposits are largely clayey sand with a thick (1-2 ft) bed of very coarse, rounded quartz gravel marking the basal unconformable contact with the Williamsburg Formation. The sand is fine to very coarse, poorly-sorted, angular quartz locally containing quartz grit and fine gravel. Accessory minerals include mica, garnet, potassium feldspar, and fine opaque heavy minerals. The matrix clay is brown, tan, or white kaolin, and the upper part of the unit tends to be more clayey than the lower part. The upper part of the unit is also characterized by heavy red/orange oxidation stains suggesting subareal weathering and alteration of iron-bearing minerals.

The outcrop of the upland fluvial deposit along the Sparkleberry Landing road shows large scale crossbedding within the different sand layers. In addition, the beds occupy a large channel form and crossbedding is multi-directional. Two layers of quartz gravel are present in the basal beds of this exposure and their geometries suggest crosscutting channel relationships.

Origin

The poor sorting, angularity, and feldspar content of the sand in the upland deposits in conjunction with the evidence of crossbedding and channel forms suggests that the strata were deposited in a large fluvial system. These beds probably formed in a system of meandering river channels flowing on top of the Lang Syne claystone deposits. Evidence collected in this study cannot define the regional extent of these deposits, but from descriptions of Sloan (1908), they appear to be best developed along the eastern side of the Congaree/Santee River drainage basin. Therefore it would appear that they are deposits left by an ancestrial river system that has since migrated westward. Although Environmental Technology Engineering, Inc. (1987) referred to these deposits as an upper delta plain system, the association with delta-type sedimentation downdip has not been established.

Age

No fossils have ever been found in the upland fluvial deposits so no direct age assignment can be applied to the strata in the study area. The similarity to the modern drainage system, considered to have been established after the late Miocene, would suggest that the upland deposits are Pliocene or younger in age. Sloan (1908) called these deposits Plio-Pleistocene, and similarly Cooke (1936) referred to them as Quaternary. No better age designation is presently available.

Correlations

The upland fluvial deposits encountered in this study are direct equivalents with the "Plio-Pleistocene sediments" of Environmental Technology Engineering, Inc. (1987) and the LaFayette Formation (Phase) at Wedgefield, S.C. noted by Sloan (1908). They are also similar in character to the "upland unit" mapped along the east side of the Savannah River by Nystrom and Willoughy (1982) and Dennehy and others (1988), which has now been extended as far east as Orangeburg County (Nystrom and others, 1986), but these deposits are thought to be much older. The direct association of these various units, however, is still unresolved.

# Alluvium

## Nomenclature

Cored holes along the edge of the Santee River valley (Fig. 2, Rimimi 1A & 1E, LM-1A, and LM-2A) encountered as much as 38 feet of fluvial strata considered to be flood plain deposits of the ancestrial Santee River. They are hereafter referred to as "Santee alluvium".

## Lithology

The Santee alluvium is largely thick beds of clayey sand overlain by sandy clay at the top. The base of the unit is marked by a thick bed (1-3 ft) of very coarse quartz gravels and cobbles surrounded by coarse quartz sand and very little clay. The sand in the remainder of the unit is fine to very coarse, poorly-sorted, angular to sub-angular quartz. Accessory minerals include mica, feldspar, monazite, garnet, and opaque heavy minerals. The clay is brown to gray and typically carbonaceous. The beds in the Santee alluvium appear rather massive in core samples and lithologic changes are gradational to abrupt. In general, the lower half of the unit contains more sand and has very little matrix clay near the base. The upper part of the unit is typically less sandy with dense, sticky, plastic clays.

## Origin

The poor sorting, feldspars, and massive carbonaceous beds of clayey sand suggest that the Santee alluvium was deposited in a fluvial environment such as the present Santee River flood plain. The distance from the modern flood plain, however, precludes that the strata were deposited by modern floods. The lithology of the Santee alluvium is similar to that of the upland fluvial deposits largely due to similar provenence and environment of deposition. The erosional truncation of the upland fluvial deposits by the Santee River valley and the extreme difference in elevation between the upland fluvial deposits and the Santee alluvium indicates that they differ significantly in time of deposition.

## Age

No fossils were recovered from the Santee alluvium so an absolute age determination for the strata could not be obtained. The carbonaceous matter in the unit, however, has not entirely been altered to lignite, which would suggest a relatively recent age. Therefore the best estimate of age for this deposit is late Quaternary.

## Correlations

Previous investigators have largely ignored this geologic unit because it does not form outcrops and is confined to the Santee River valley. The strata in the study area are more-or-less equivalent to the other deposits in the ancient floodplain east of the present Santee River channel, most of which has been flooded by Lake Marion.

## DISTRIBUTION OF STRATA

Two geologic sections (Fig. 2, A-A' and B-B') were constructed across the study area to assess the lateral change in thickness and lithology of the stratigraphic units previously described. The A-A' geologic section (Pl. 1) was constructed parallel to the edge of Lake Marion as a generalized dip section to evaluate the coastward changes in depositional environment. The B-B' geologic section (Pl. 2) approximates the regional strike of Coastal Plain deposits and provides evidence of depositional irregularities. The following discussion of the geologic sections is organized in terms of the geologic units they portray.

### Black Creek Group

Strata of the Black Creek Group have only been encountered in the MAN-1A and RIM-1A core holes (Fig. 2 & Pl. 1). Only the uppermost unit of the Black Creek Group (Donoho Creek Formation of Sohl and Owens, in press) was reached in RIM-1A so therefore the Lower portion of the Black Creek Group cored in MAN-1A was omitted on section A-A'. Both cores show that the uppermost unit contains shallowing, coarsening-upward lithologies with calcareous, locally fossiliferous, carbonaceous clay laminated with fine sand overlain by beds of crossbedded glauconitic sand containing thin localized beds of clay. This unit shows little variation across the study area as would be expected under open marine conditions.

### Peedee Formation

The strata of the Peedee Formation were encountered in all of the cored holes, but the lower part (shelf) of the Peedee was only cored in MAN-1A, LM-1A, RIM-1A, and RAILWAY-1A (Fig. 2). The lower part of the Peedee is consistent across the study area being characterized by fossiliferous carbonaceous clay laminated with fine sand. Only in the RAILWAY-1A core on section B-B' (Pl. 2) is the transition from the upper to lower Peedee units not especially evident in the geophysical logs. This is because of an abundance of coarse sand in the carbonaceous clays at the top of the lower Peedee. The upper Peedee is generally consistant across the study area and is characterized by fine to coarse sands overlain by a few tens of feet of kaolin. Thin beds of sand indicated by geophyical logs (Pls. 1 & 2) occur within the uppermost beds of kaolin, but these are typical of delta plain bay and channel fills. The lateral extent of these sand beds is commonly very limited in this depositional environment, and therefore are not considered connected along geologic sections (Pls. 1 & 2). Similarly, thin clay beds within the distributary channel sand deposits of the upper Peedee are interpreted as layers of limited lateral extent.

### Rhems Formation
#### Sawdust Landing Member

The strata of the Sawdust Landing Member are probably the most variable throughout the study area. This is not surprising because upper delta plain sedimentation is generally erratic and highly variable. The Sawdust Landing beds in cores at the center of geologic section A-A' (Pl. 1, LM-1A & LM-2A) are well-packed clayey sands with an extremely high bulk density. Although the geophysical logs indicate variations in porosity, the most porous beds are still extremely compact. The Sawdust Landing sections at the ends of geologic section A-A' (Pl. 1, RIM-1A and MAN-1A) contain relatively more sand (less high density material) in the upper and lower parts of the formation. The absence of these sands in the intermediate wells, however, suggests that they are probably not interconnected. Along geologic section B-B' (Pl. 2), the Sawdust Landing strata become sandier away from Lake Marion. At the RAILWAY-1A drill site however, the Sawdust Landing beds have been thinned to only 7 ft by erosion prior to deposition of the overlying Lang Syne beds. Although not conclusive evidence, this thinning is suggestive of less clayey, easily eroded sandy strata in the Sawdust Landing. None of the layers within the unit could be extrapolated with confidence along either geologic section (Pls. 1 & 2). The Sawdust Landing strata are probably best portrayed as localized accumulations of sediment deposited in bays and cross-cutting channels without significant vertical or lateral extent.

## Williamsburg Formation
### Lang Syne Member

The strata of the Lang Syne Member are lithologically consistent along geologic sections A-A' and B-B', but the unit is highly variable in thickness. In core holes RIM-1A, LM-1A, and LM-2A (Pl. 1), development of the Santee River valley has removed the majority of the section. Only 2 ft of basal clayey sand remain in the core at LM-2A (Pl. 1). In contrast, post-depositional erosion of the Sawdust Landing beds at the RAILWAY-1A core site (Fig. 2 & Pl. 2) has resulted in at least 124 ft of Lang Syne deposition. Consequently, the base of the unit slopes eastward away from Lake Marion (Pl. 2). Considerable irregularity of the base of the Lang Syne is also seen between wells LM-2A, UBC-9, and MW-32 on geologic section B-B' (Pl. 2), even though the three wells are closely spaced. This suggests that the widely-spaced wells may not accurately portray the true configuration of the base of the Lang Syne.

Basal beds of sand discussed in the stratigraphy section of this report have been recognized in all of the cores examined in this study. These are generally lag deposits on the basal unconformity with the exception of the beds from the LM-2A, UBC-9, and MW-32 cores, which are laminated sand and black clay. These basal beds of sand and clayey sand are thought to characterize the Lang Syne across the study area. Similarly, silicified beds of coarse fossiliferous sand are almost exclusively restricted to the uppermost Lang Syne beds (Pls. 1 & 2, MAN-1A & RAILWAY-1A). The bulk of the Lang Syne is fractured, low density, claystone and siltstone and shows very little variability across the study area; however, facies changes seen at Old Sawdust Pile Landing (Fig. 1) suggest that this characteristic may change within a short distance from the study area.

## Upland Fluvial Deposits

The upland fluvial deposits shown in geologic sections A-A' and B-B' (Pls. 1 & 2) were only encountered in wells MAN-1A and RAILWAY-1A. These crossbedded sands and gravels are lithologically similar across the study area, but are probably rather localized deposits. The environment of deposition is similar to an upper delta plain, and therefore the upland fluvial deposits probably are infillings of meandering channels.

## Santee Alluvium

The alluvium shown on geologic section A-A' (Pl. 1) in wells LM-1A, LM-2A, and RIM-1A is directly associated with the ancient Santee River valley. Its abrupt termination against the bluffs bordering the river valley is representative of this interpretation. Lithologically the alluvium is moderately consistent between these holes, but the configuration of the basal contact is extremely irregular. At the RIM-1A well cluster site (Fig. 2), vertical changes exceeding 10 ft were found in wells only 50 ft apart. As in the case of the Upland fluvial deposits, variability of both elevation and lithofacies may actually be extreme.

## SUMMARY AND CONCLUSIONS

The investigation of the area east of Lake Marion has resulted in a number of new geologic insights. These are:

1.) No pre-Black Creek Group strata (for example, Middendorf, Cape Fear, or Tuscaloosa Formations) have been encountered in any wells in the area as evidenced by Black Creek strata and lower Campanian palynomorph assemblages at the bottom of the MAN-1A core hole.

2.) The Black Creek Group strata in the study area are generally representative of the Donoho Creek, Bladen, and Tarheel Formations of the Black Creek Group as defined by Owens (1988) and Sohl and Owens (in press).

3.) Uppermost Cretaceous strata in the landfill area previously considered part of the Black Creek (Formation) Group is actually equivalent to the Peedee Formation of the eastern Carolinas.

4.) The Sawdust Landing Member is probably the only part of the Rhems Formation in the study area.

5.) The Lang Syne Member strata are correlative with the upper Paleocene Williamsburg Formation of the Black Mingo Group of Van Nieuwenhuise and Colquhoun (1982) and not the lower Paleocene Rhems Formation.

6.) The Lang Syne strata exceed a thickness of 120 ft two miles east of Lake Marion, whereas nearer the lake these beds have almost entirely been removed by erosion from the Upland fluvial channels and the ancestrial Santee River.

7.) Due to the erosion of the Sawdust Landing strata by the Lang Syne sea, the basal contact of the Lang Syne Member slopes eastward away from Lake Marion in the study area.

In summary, the stratigraphy of the strata studied in the MAN-1A core (Fig. 3) indicates a geologic history dominated by deltaic deposition. At least four periods of Cretaceous deltic sedimentation are represented by the three units in the Black Creek Group and by the deposition of the Peedee Formation. These deposits are all marginal to open marine sediments representing the transition from updip restricted and non-marine sedimentation and open marine sedimentation in downdip areas. After a hiatus of deposition and erosion spanning the end of the Cretaceous and the earliest Paleocene, another delta system deposited the Sawdust Landing Member of the Rhems Formation. This must have marked a low-stand of the sea as deposition was largely without marine influence. After a depositional and erosional hiatus near the end of the lower Paleocene, a rising sea established a marine barrier island system in the area which resulted in the deposition of the Lang Syne Member of the Williamsburg Formation in back barrier bays and lagoons. Observations by Sloan (1908) suggest that Eocene sediments probably were present in the study area at one time, but subsequent episodes of erosion have removed any trace of them. Continential erosion and deposition related to a low-stand of the sea during the Plio-Pleistocene was probably responsible for the upland fluvial deposits that have been channeled into the top of the Lang Syne strata. After this deposition, the present Santee River drainage was established, and development of the present drainage basin and flood plain has carved the bluffs along the eastern side of Lake Marion and left the succession of alluvial deposits at the base of the bluffs. As the Santee River has apparently migrated westward, these deposits have been protected from erosion and subjected to subareal weathering and oxidation.

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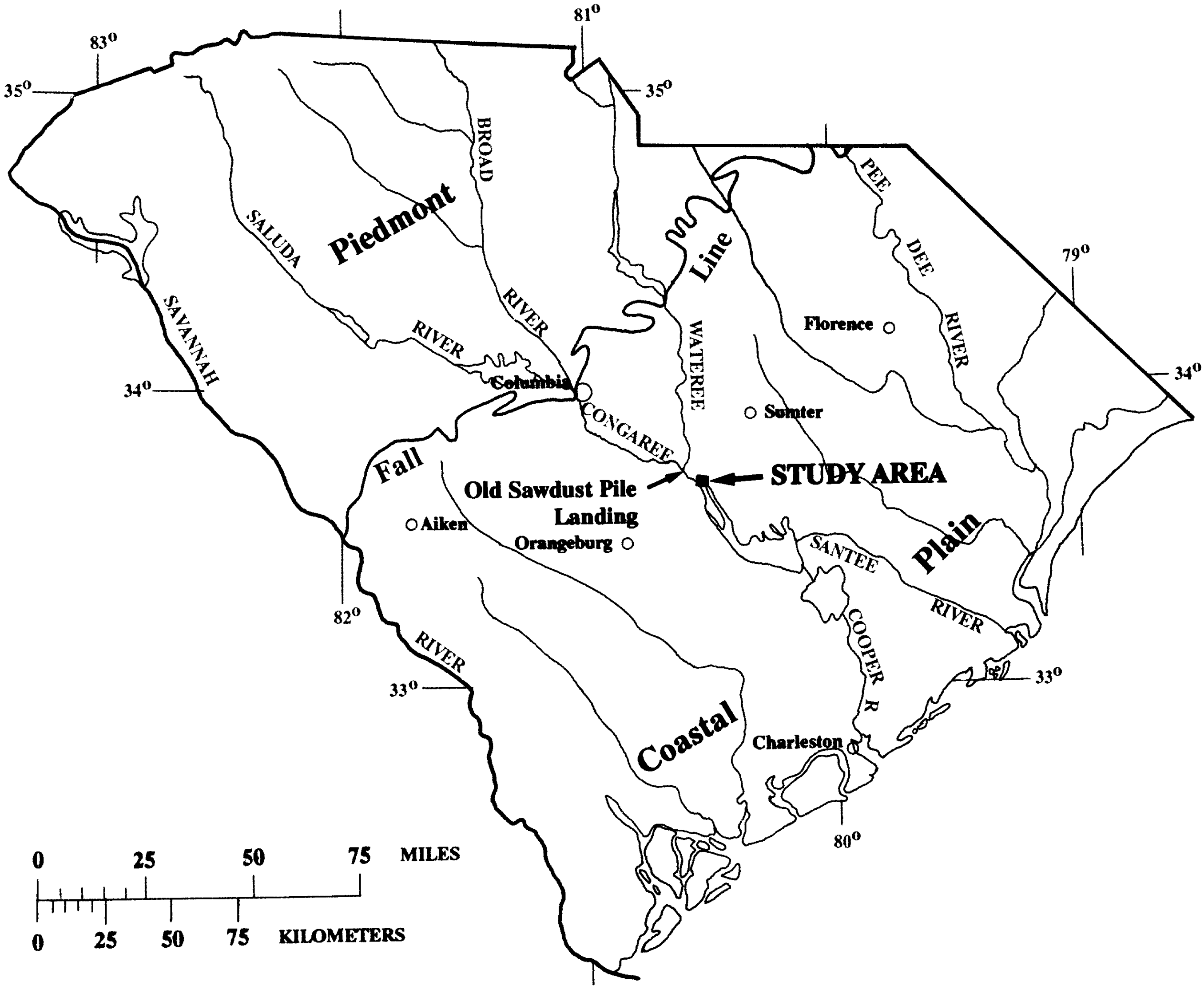
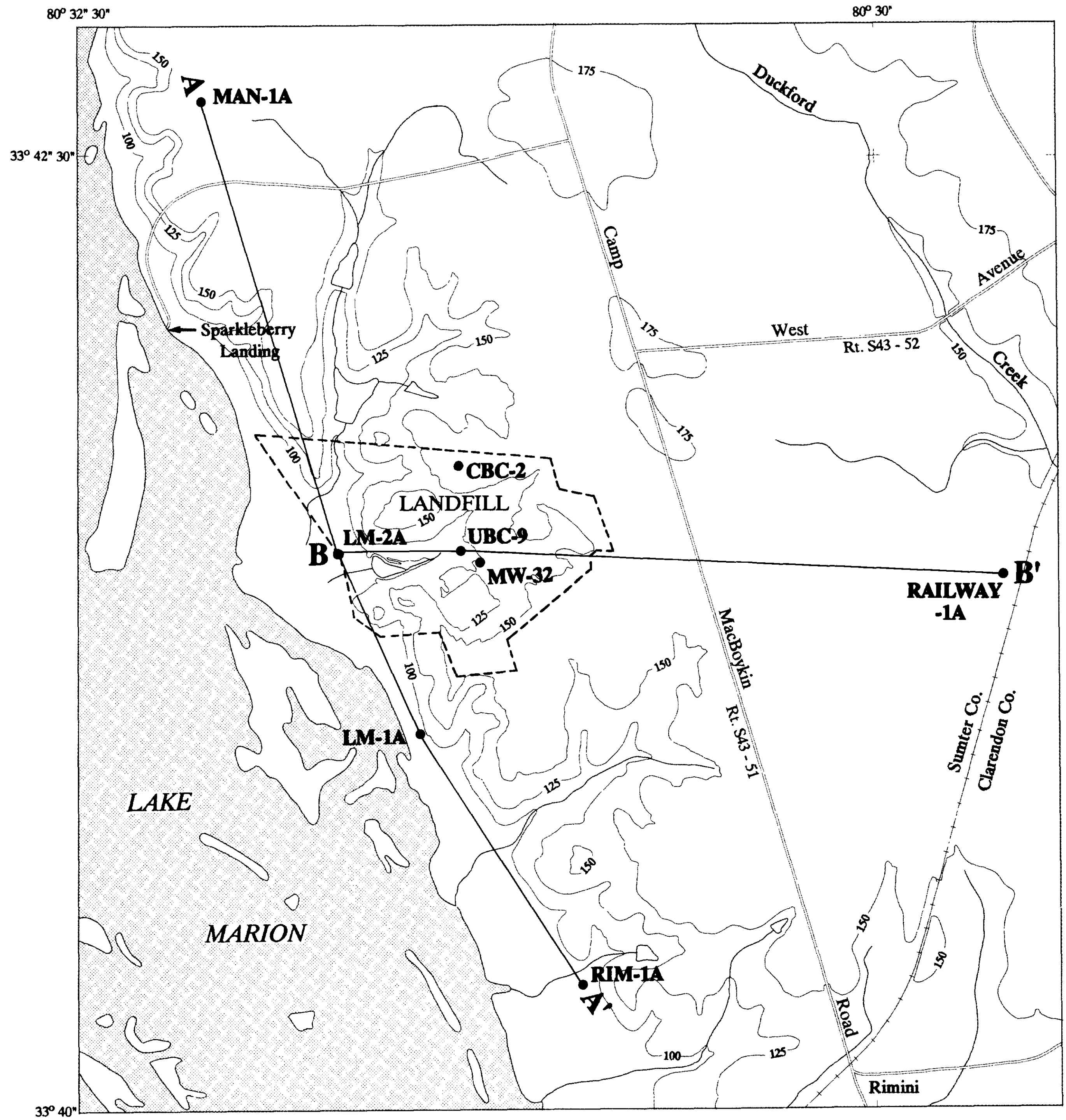



**Figure 1: Location of study area.**




Base from U.S. Geological Survey
Lone Star, 1:24,000, (Prov. map, 1989)
Pinewood, 1:24,000, 1980

CONTOUR INTERVAL 25 FEET

0 1 2 MILES

0 1 2 KILOMETERS

**Figure 2: Location of drill holes and geologic sections.**

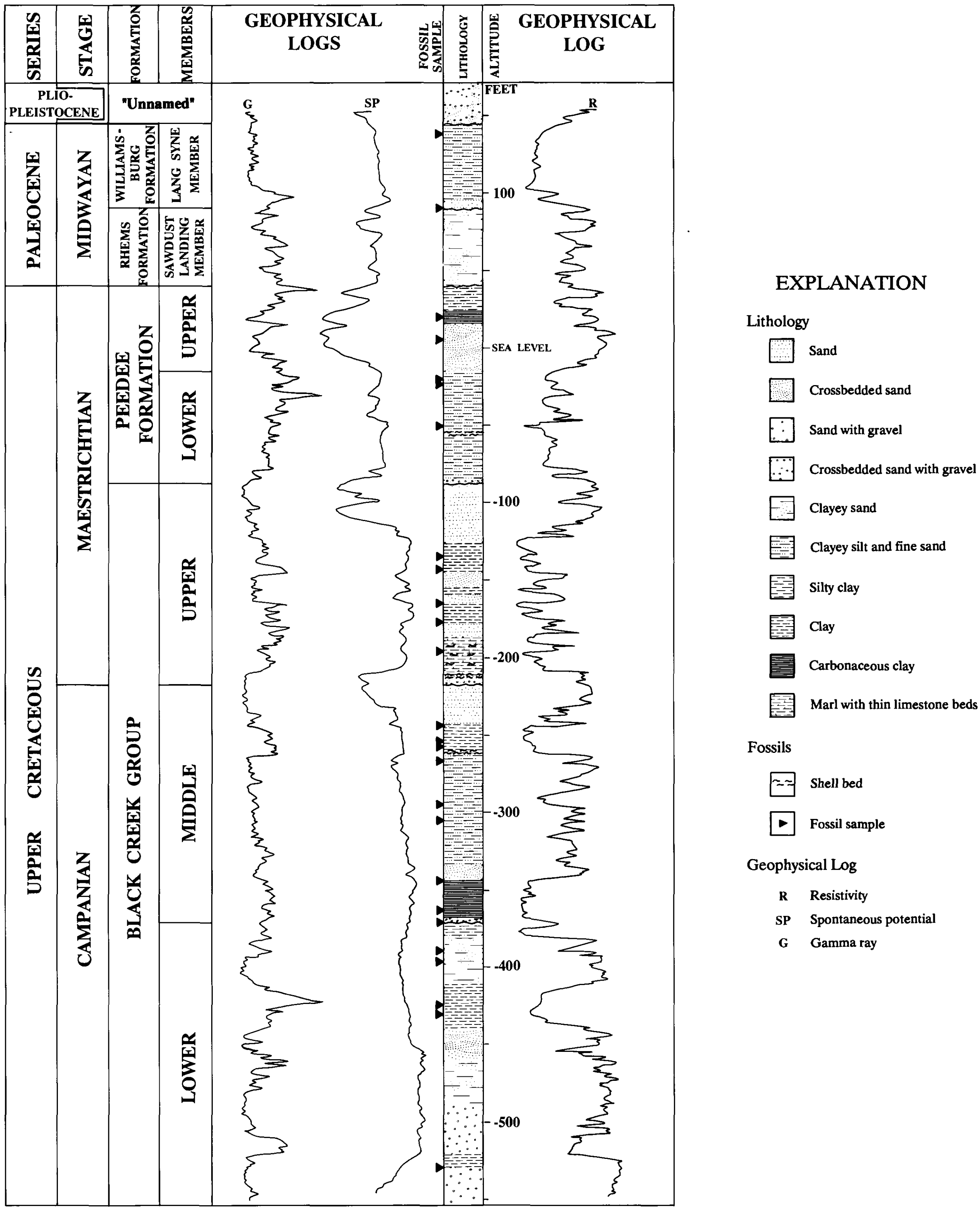



**Figure 3: Geology of the Manchester-1A core hole.**

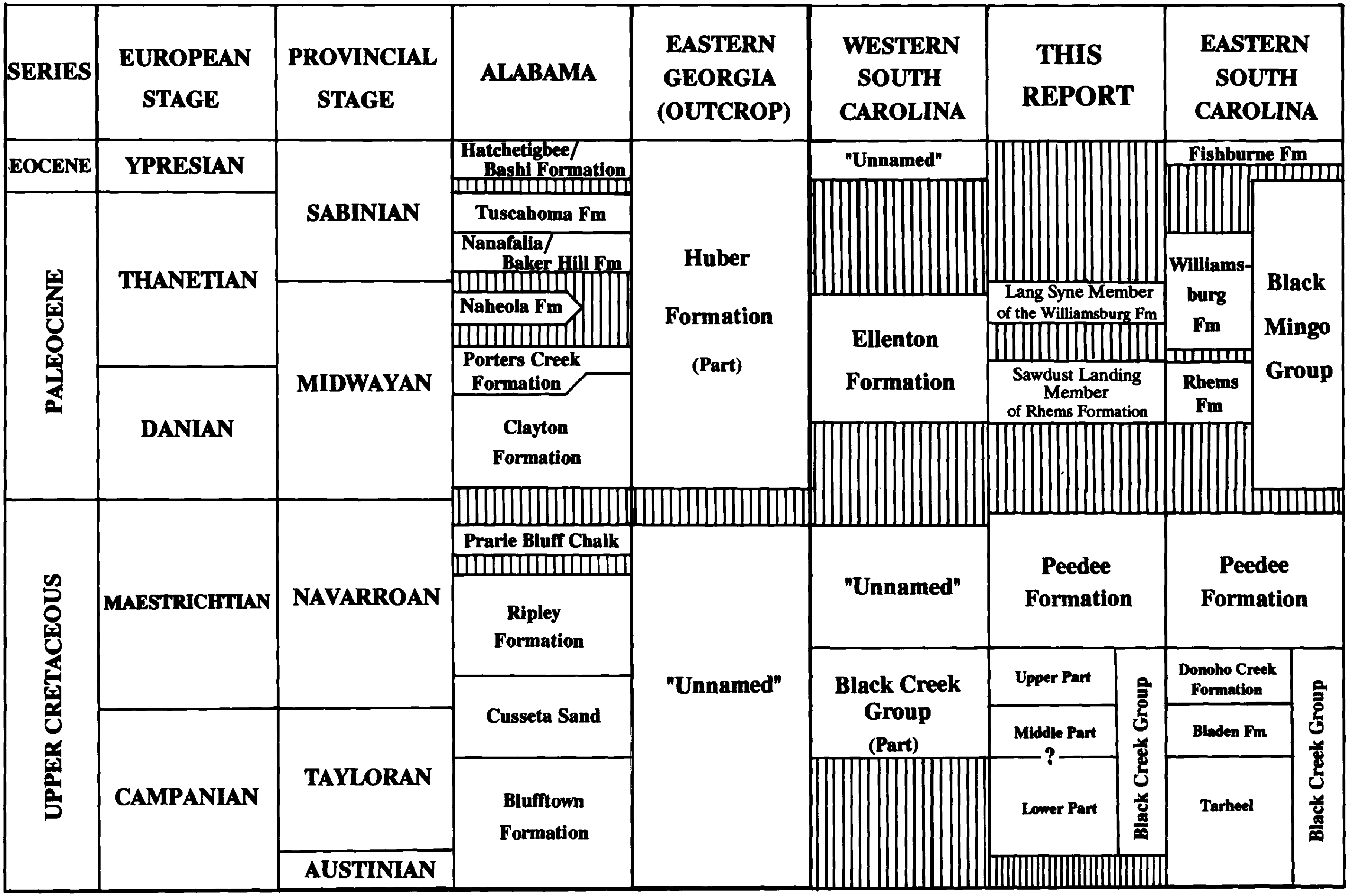



Figure 4: Correlation chart of regional geologic units.