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PRELIMINARY GEOLOGIC MAP OF THE BARNWELL 30'x 60' QUADRANGLE, SOUTH CAROLINA AND GEORGIA

by

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INTRODUCTION

This preliminary publication is the result of a mapping investigation of the characteristics of sedimentation and structural features at the transition from the Gulf Coastal Plain to the Atlantic Coastal Plain along the Fall Line in Georgia and South Carolina. At this inner margin of the Coastal Plain, Cretaceous and younger unconsolidated sedimentary rocks overlap Paleozoic crystalline rocks and lower Mesozoic sedimentary rocks and form a gently dipping (1.9 to 3.8 m/km)(10 to 20 ft/mi), southeastward-thickening wedge (Applin, 1951; Milton and Hurst, 1965; Chowns and Williams, 1983). Two outcropping deltaic formations of Late Cretaceous age, once thought to be only one formation, reflect uplift and rapid erosion of mountainous sources areas to the west. Similarly, several lower Tertiary formations have characteristics suggesting that deltaic processes continued beyond the Cretaceous, but to a lesser degree. Sedimentation from the middle Eocene through the Pliocene, with the exception of an upper Miocene(?) unit, is indicative of open-marine deposition. The large sediment sources that formed the Cretaceous deltas were largely gone by this period and the sedimentary record reflects cyclic changes in sea level. The only exception to this pattern is a period of fluvial deposition during the upper Miocene(?) that affected much of Georgia and South Carolina. Dune deposits, probably formed during a low stand of the sea prior to the upper Pliocene, dot the landscape and become larger and better defined to the northeast. They are probably the poorly-developed fringe of massive eolian deposits forming the sandhills of North Carolina.

Erosion by the Savannah and Edisto Rivers and their tributaries has truncated most of the thin sedimentary layers in the map area and provides many exposures of the various geologic units and the contacts between them. In addition, this erosion has resulted in a variety of alluvial and colluvial deposits, some of which are important Quaternary map units. For example, high level terrace deposits near Augusta, Ga. provide evidence of an ancient Savannah River, as does a wide "older" alluvial plain immediately east of the present flood plain. The position of the older alluvial plain and the present location of the river suggests a long-term westward migration of the drainage basin. More youthful alluvium can be mapped in the present river valleys and up most of the larger tributaries. Whereas these strata are mapped as a singular unit, their lithologies vary depending on source area and stream size. Colluvial deposits vary in lithology depending on the sediment source, and they are very discrete, localized accumulations of sediment. They are typically characterized by: (1) Lack of well defined bedding, (2) lack of clay layers and clay clasts, and (3) the presence of iron-cemented sand pebbles known as plinthites (see Newell and others, 1980). The age, interrelationships, and distribution of these deposits is questionable so they are not included as a map unit. Their association with other map units, however, is discussed under specific map headings. Thick soil profiles have been developed over much of the land surface and the soil-forming processes can have a dramatic effect on the appearance of some geologic units. Significant information about weathering is included in the map explanation.

Structural modification of the Coastal Plain is a widespread process in the southeastern U.S. (see Prowell, 1988). In particular, faulting complicates the stratigraphic section within the Barnwell map area (Snipes and others, 1990; Stephenson and Stieve, 1992) and just west of the map boundary at Augusta, Ga. (Prowell and O'Connor, 1978). These faults are indicative of compressive stresses in the earth's crust from the Cretaceous through the lower Tertiary and are important features in the analysis of the development of the Atlantic continental margin (Prowell, 1988).

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PREVIOUS WORK

The geology of the strata within the Barnwell sheet has been discussed in regional geologic investigations by Sloan (1908), Cooke (1936), Cooke and MacNeil (1952), Colquhoun and others (1983), Huddlestun and Hetrick (1978, 1979, 1986), Nystrom and Willoughby (1982), Colquhoun and Steele (1985), and Prowell and others (1985a), Harris and Zullo (1990), Nystrom and others (1990), and Fallaw and Price (1992). Most of the detailed geologic data in the Barnwell study area are from investigations associated with the nuclear fuels industry along the Savannah River halfway between Augusta, Ga. and Allendale, S.C. The largest of these facilities is the Savannah River Site (SRS), operated by the U.S. Department of Energy, which has generated a number of (commonly unpublished) engineering, hydrologic, and geologic reports. Site-specific reports summarizing the local geology include Christl (1964), Siple (1967), Bechtel Corp. (1972, 1973, 1982), Daniels (1974), Marine and Siple (1974), Marine (1979), Prowell and others (1985b), Steele (1985a, 1985b), McClelland (1987), Dennehy and others (1988), Fallaw and others (1990a, 1990b), Snipes and others (1990), and Price and others (1990, 1991).

A variety of publications in addition to those mentioned above contributed to understanding the geology of the Barnwell sheet. These include Colquhoun (1965), Pooser (1965), Prowell (1978), Prowell and O'connor (1978), Wollen (1978), Oldham (1981), Kite (1982), McCartan and others (1984), and Nystrom and others (1986). Of particular importance are 1:24,000 scale open-file geologic maps by Kite (1983a, 1983b, 1984), Willoughby (1983, 1986), Maher (1979), Mittwede (1982), and Nystrom, P.G., Jr. (written commun. of unpublished data, 1989). The areas of the Barnwell 1:100,000 sheet covered by existing geologic mapping and the sources of that mapping are shown diagrammatically in Figure 1.

NOMENCLATURE

The small portion of Piedmont crystalline rocks in the northwest corner of the map area was named the Belair Belt by Crickmay (1952) and this nomenclature has essentially remained unchanged although some lithologic units have been informally named by Maher (1979). The Coastal Plain geologic nomenclature in the study area was largely established by Sloan (1908) and Cooke (1936), but various modifications to their stratigraphy have been made in light of new fossil evidence (for example, Tschudy and Patterson, 1975; Prowell and others, 1985a) and new core

hole information. The Coastal Plain nomenclature used in the construction of this map and the regional correlation of geologic units is shown in Figure 2. In general, the Tuscaloosa Formation of Cooke (1936) has been split into four Cretaceous and two Tertiary units, all of which are considerably younger than the type Tuscaloosa Formation of western Alabama (see Christopher, 1978). Two of the Cretaceous units, the Middendorf Formation and the Black Creek Group, crop out along tributaries to the Savannah River and are shown on the geologic map. The other two Cretaceous units, the Cape Fear Formation and an unnamed Maastrichtian formation, were previously reported in Prowell and others (1985a) and are confined to the subsurface. Owens and Gohn (1985) and Gohn (1988) discuss the regional distribution of Cretaceous strata in greater detail.

The two Tertiary units, included in Cooke's (1936) Tuscaloosa Formation, the Ellenton Formation and the Huber and Congaree Formations (Undivided), also crop out in the Barnwell map area. The Ellenton Formation was defined from cuttings in well 52C on the SRS by Siple (1967), and its age and lithologic character have since been refined by Prowell and others (1985b) from core samples. The Huber and Congaree Formations (Undivided), however, posed a difficult problem to the Barnwell map nomenclature. The Huber Formation (Buie, 1978, 1980) was defined from commercial clay pits in central Georgia and is now known to include beds of both early Paleocene (Ellenton Formation) and middle Eocene age. These strata are delta-plain sediments deposited during two separate depositional events. Nystrom and Willoughby (1982) extended the Huber nomenclature to South Carolina but only applied it to the beds of middle Eocene age (Tschudy and Patterson, 1975). Therefore, in the Barnwell map area the name Huber Formation is reserved for the middle Eocene delta plain strata, whereas Ellenton Formation is applied to the Paleocene deltaic deposits. The Congaree Formation was first mentioned by Sloan (1907, 1908) and was later formalized by Cooke and MacNeil (1952) to describe delta-front deposits now believed to be a facies of the (Eocene) Huber Formation delta plain. The mineralogy of these two formations is identical, but sorting and bed forms change with respect to the position on the delta. Both names are in common usage in South Carolina and it is beyond the scope of this map explanation to restructure the nomenclature; therefore, this deposit is being designated as the Huber and Congaree Formations (Undivided).

The McBean Formation, as defined by Veatch and Stephenson (1911, p. 238), describes impure limestone, marl, clay, and glauconitic sand unconformably deposited on Cretaceous (presently Huber Formation) strata along McBean Creek (in Georgia). Whereas later authors (for example, Huddlestun, 1982) have tried to restrict the name to the calcareous lithofacies, the designation by Veatch and Stephenson (1911) was found to be most appropriate. Names such as Lisbon Formation, applied to the downdip marl facies, and Santee Limestone, applied to the downdip impure limestones, have been suggested by other investigators, but the name McBean has been retained for this map because it accurately represents the outcropping beds of the late middle Eocene marine transgression and regression.

The Barnwell Formation of Cooke (1936) was raised to the rank of Barnwell Group by Huddlestun and Hetrick (1986) with the Tobacco Road Sand (Huddlestun and Hetrick, 1978) included as the youngest formation. A review of the nomenclature preceding these changes was published by Huddlestun (1982). The Hawthorne Formation of Siple (1967) has been informally renamed the "Upland unit" after Nystrom and Willoughby (1982), and some previously unreported river-terrace and sand-dune deposits have herein been informally called Quaternary terrace deposits and Quaternary dune deposits, respectively.

METHODS

The geologic units shown on the Barnwell map are separated by physical unconformities representing intervals of missing geologic time. These contacts were mapped in natural and man-made surface exposures and in subsurface drill cores where available. The elevations of the contacts were then used to make a structure contour map of the base of each geologic unit, which were in turn overlain on the Barnwell topographic base to define regional outcrop patterns at points of equal elevation. This technique (see Lahee, 1961) provided the most accurate means for drawing the outcrop patterns shown on the final map, but it tends to overgeneralize extremely irregular contacts. For example, the base of the upland unit is very channelized and its elevation varies many meters (tens of feet) over short horizontal distances. Consequently, this contact could not be accurately portrayed at the scale of the final map. Similar variability occurs at the base of deltaic units and at the base of the McBean Formation. Therefore, the reader is cautioned to avoid strict application of contact information except where drill hole information is indicated or where good outcrops were present at the time of this mapping. If newly exposed strata do not match the description of the indicated map unit, the reader is advised to check the description for the overlying unit to see if channel cut and fill may be present.

STRATIGRAPHY

The geologic units shown on the Barnwell map are much more than singular layers with uniform lithologies. They actually represent depositional episodes (for example, the transgression and regression of the sea) in the geologic past, and each (allostratigraphic) unit may contain of a variety of strata representing the differing depositional environments during that event. Where disconformities are suspected from paleontological data (but not mapped), the geologic units are combined into a group (for example, the Black Creek Group). The descriptions of the geologic units on the Barnwell map are therefore more complex than those on a traditional lithostratigraphic map. The following explanation includes information not contained in the map descriptions and was written to help the reader understand both the vertical and horizontal variability of each unit. In addition, the location of reference sections are given for most map units for the purpose of field comparison.

Paleozoic

Metavolcanics (Undivided) -- Metamorphosed volcaniclastic rocks of the Belair Belt of Crickmay (1952) are only exposed in the river bottom (rapids), low river banks, and tributaries to the Savannah River at Augusta, Georgia. The age of these rocks is best determined by a trilobite that was found along a tributary to the Savannah River immediately north of the map area. Maher and others (1981) used this fossil to establish the age of the rock belt as early Paleozoic (probably Cambrian).

Cretaceous

The Cretaceous strata in the study area are products of delta-dominated deposition in generally non-marine to shallow marine environments. Although stratigraphy in downdip areas suggests that there are at least five depositional units in the subsurface of the map area, the similarity of lithologies, the distribution of lithofacies, the variability of deltaic accurately

differentiate these units in outcrop. This is particularly evident in the Black Creek Group and younger stratigraphic sections where differentiation is very dependent on gross sediment characteristics and palynological age determinations.

Middendorf Formation -- The Middendorf strata are only exposed along the uppermost reaches of the Savannah River and adjacent tributaries. Bed thickness and grain size are highly variable, and large-scale crossbedding and massive beds of sediment are common. Fining-upward cycles consisting of coarse sands that grade upward into clay-and-silt layers are common, and a zone of iron oxidation and red staining typically exists at the tops of many of the clay and silt beds. The top of the formation is generally marked by several thin (1 to 1.5 m; 3 to 5 ft) beds of sandy kaolin which are locally stained by oxidation of iron minerals.

Core samples of carbonaceous clay were collected from the Middendorf Formation in wells P7R (-160.6 m)(-527 ft) (Christopher, 1982a) and P21TA (-221 m)(-725 ft) on the SRS. These samples yielded a pollen assemblage diagnostic of pollen zone V (subzone C) of Doyle and Robbins (1977) and Christopher (1982a, 1982b) which indicates a Santonian age. A small number of dinoflagellates and acritarchs were also present in the sample suggesting very restricted marine influence.

Black Creek Group -- The Black Creek Group strata in the Barnwell map area can be divided into two formations in the deep subsurface but the lack of diagnostic exposures in the outcrop area, however, required that they be portrayed as one map unit. The Black Creek strata reach a maximum combined thickness of about 91 m (300 ft) in downdip areas and form most of the outcropping Cretaceous strata shown on the geologic map. Microfossil samples taken from the carbonaceous clays in this formation contain a diverse assemblage of pollen, dinoflagellates, and acritarchs.

In the subsurface, the Black Creek Group is characterized by thick (tens of meters) accumulations of clay that are fairly distinct on borehole electric logs. In outcrop, these strata are characterized by beds of soft, coarsely crystalline white kaolin forming the top of the sedimentary unit. The kaolin beds are of commercial purity and are strip mined in updip areas. These beds also generally form the top of outcropping Cretaceous deposits shown on the Barnwell map.

Samples of carbonaceous clay collected from the Black Creek Group strata in wells P5R (-161.5 and -179.8 m)(-530 and -590 ft) (Prowell and others, 1985a), MSB-34 (-36.9 and -43.9 m)(-121 and -144 ft), and VSC-4 (-148.4 and -185 m)(-487 and -607 ft) yielded pollen assemblages assignable to pollen zones CA-4 and CA-5 of Wolfe (1976), Christopher (1978), and Sohl and Christopher (1983), and are correlative with late Campanian and early Maastrichtian strata elsewhere in Georgia and South Carolina. Moderate to high numbers of dinoflagellates and acritarchs were found in the pollen samples suggesting a restricted to open marine depositional environment.

The paleontological correlation suggests that the Black Creek Group in the study area contains a facies of the upper Campanian Bladen Formation and a facies of the lower Maastrichtian Donoho Creek Formation in eastern South Carolina (see Owens, 1988; Owens and Sohl, 1989; Sohl and Owens, 1991).

Tertiary

Ellenton Formation -- The Ellenton Formation consists of crossbedded clayey sand beds and clay beds that are indicative of delta-dominated deposition. An abundance of sillimanite and feldspar, and traces of cristobalite in the clay-size fraction distinguish the Ellenton from the underlying deltaic Cretaceous formations. The outcropping beds of the Ellenton shown on the Barnwell map are of marginal marine origin and are of early Paleocene age (Prowell and others, 1985b). Siple (1967) included well laminated clayey silt and clay beds and low density siltstone of restricted marine origin in the top of the Ellenton at its subsurface type section on the Savannah River Site and this convention was followed by later workers (see Cahill, 1982; Prowell and others, 1985b). New paleontological evidence (N.O. Frederiksen, U. S. Geological Survey, written communication, 1986) suggests that these upper beds may be of late Paleocene age and probably were deposited unconformably on top of the older Ellenton delta. These uppermost laminated beds do not crop out at the surface. This entire sequence is probably correlative with the Black Mingo Group of Van Nieuwenhuise and Colquhoun (1982).

Core samples of carbonaceous clay from the Ellenton Formation were collected from wells FC-4A (+16.1, +17, and +17.4 m)(+53, +56, and +57 ft), FC-3A (+10.4 and +11.3 m)(+34 and +37 ft), FC-5A (+11.6, +13.7, +18.6, and +22.9 m)(+38, +45, +61, and +75 ft), MSB-23 (+25.6 m)(+84 ft), CE-1 (-26.5, -40.8, -51.2, and -57.6 m)(-87, -134, -168, and -189 ft), CE-3 (-50.3 m)(-165 ft), VSC-2 (-58.5 m)(-192 ft), BW-240 (+14 and +19.5 m)(+46 and +64 ft), and A-8 (+ 44.5 and 45.7 m)(+146 and +150) in South Carolina, and wells VG-1 (-81.4 and -89.3 m)(-267 and -293 ft), Vogtle 246 (-26.5 and 43.6 m)(-87 and -143 ft) and BMPD-1 (+16.8 m)(+55 ft) in Georgia. Pollen and dinoflagellate assemblages from these samples yield Paleocene ages ranging from middle Midwayan through earliest Sabinian (N. O. Frederiksen and L. E. Edwards, U. S. Geological Survey, written communication, 1980, 1982, 1983, 1984, 1985, 1986; Prowell and others, 1985a; and Prowell and others, 1985b). In addition, a Paleocene (late Midwayan) age was determined from an outcrop sample at the community of Hollow Creek, S. C. (N. O. Frederiksen, U. S. Geological Survey, written communication, 1982; Prowell and others, 1985b), and several Paleocene ages were reported from shallow auger hole samples in Georgia by McClelland (1987).

Huber and Congaree Formations (Undivided) -- The Huber Formation and the Congaree Formation are both lithofacies of the same episode of deltaic deposition. The Huber represents the lower (restricted marine) delta plain whereas the Congaree represents the open marine delta front. The best exposures of the Huber Formation are in the commercial kaolin strip mines whereas exposures of the Congaree Formation are found in larger tributaries to the Savannah River such as Upper Three Runs Creek and in the upper Edisto River valley. Although the formations can interfinger into each other, the marine (Congaree) component is usually found below the prograding fluvial (Huber) component. The two formations, however, differ only in bedding characteristics and their contact is gradational and conformable. Because they represent only one depositional unit, they are mapped as one layer with combined names until a new nomenclature is established.

Core samples of carbonaceous clay beds in the Huber and Congaree Formations (Undivided) unit from wells FC-3A (+27.7 and +43 m)(+91 and +141 ft), VSC-2 (-21.6 m)(-71 ft), BW-240 (+26.8 m)(+88 ft), MSB-18A (+46.6 m)(+153 ft), and VSC-4 (-36 m)(-118 ft) in South Carolina and well VG-1 (-54.5 m)(-179 ft) in Georgia contained flora (pollen and dinoflagellates) indicative of lower middle Eocene strata in the southeastern U.S. (L.E. Edwards and N.O. Frederiksen, U. S. Geological Survey, written communication, 1982, 1983, 1984, 1985; Prowell and others, 1985a). In addition, two outcrop samples of the uppermost beds of the Huber Formation from the Dixie Clay Company mines near Langley, S. C. (see Nystrom and Willoughby, 1982) contain pollen indicative of the lower middle Eocene (N.O. Frederiksen, U. S. Geological Survey, written communication, 1982, 1986). Middle Eocene age determinations from shallow auger hole samples in Georgia have also been reported by McClelland (1987).

McBean Formation -- The McBean Formation consists of sandy limestone, marl, clay, and sand in a coarsening-upwards sequence indicative of transgression and regression of the sea. The calcareous beds that characterize the formation in downdip areas are generally absent in the majority of the formation that forms outcrops in the map area. Weathering of the calcareous phases that are present in near surface areas produces beds of white sandy clay and clayey fine sand. Locally (for example, bluffs on Upper Three Runs at SRS), these weathered calcareous beds are cemented by silica probably derived from the conversion of the illite/smectite clays to kaolinite near the bluff face.

The McBean Formation reaches a maximum thickness of about 42 m (140 ft) in the southwest corner of the map area and has been overlapped and truncated in updip areas by the upper Eocene (Barnwell Group) sea. The McBean sea was very erosive as evidenced by channels cutting deeply into underlying formations. The base of the McBean can be highly-irregular with as much as 10 m (33 ft) of relief over short distances.

Core samples of the dark green clays in the McBean Formation from wells FC-3A (+44.5 m)(+146 ft), MSB-19A (+58.5 m)(+192 ft), and VSC-4 (-21.3 m)(-70 ft) in South Carolina, and from well VG-1 (-2.1 m)(-7 ft) in Georgia yielded diagnostic dinoflagellate assemblages indicative of a late middle Eocene age (L. E. Edwards, U. S. Geological Survey, written communication, 1982, 1983, 1984).

Cooper Group -- Weems and Lemon (1984) raised the Cooper Marl to group status because lithologic and paleontologic evidence indicated a major unconformity in the middle of the sedimentary sequence (see Ward and others, 1979). They divided their Cooper Group into one upper Oligocene (Ashley Formation) unit and two upper Eocene (Parkers Ferry and Harleyville Formations) units largely from subsurface stratigraphy. The Eocene part of the Cooper Group in its type sections in eastern South Carolina is composed of calcareous clay, calcareous sand, calcarenite, and impure limestone. These strata are confined to the subsurface of the eastern part of the Barnwell sheet except for one exposure in a small strip mine (Kirkland pit, see upper Pliocene section) near Clear Pond, S.C. A power auger hole at the edge of the pit indicates that the unit is 11.5 m (38 ft) thick and overlies a fossiliferous sandy limestone. Samples of the Cooper Group from the strip mine pit were examined for dinoflagellates, and the moderate to good flora indicates a

late Eocene age (L.E. Edwards, U.S. Geological Survey, written commun., 1985). Comparison of this information with the paleontological data by Hazel and others (1977) from eastern South Carolina, and comparison of the lithologic characteristics with the descriptions of Weems and Lemon (1984), suggests a probable correlation with the Parkers Ferry Formation. The limited exposure of these strata in the Barnwell map area does not, however, provide evidence of a positive correlation with a either of the two Eocene components of the Cooper Group, so the strata are shown only as Cooper Group (Eocene).

Barnwell Group -- The Barnwell Group of Huddlestun and Hetrick (1979, 1986) is a coarsening-upwards sequence of sandy limestone, marl, clay, and sand deposited during one transgression and regression of the sea. The base of the Barnwell Group is marked by a 0.6 m (2 ft) thick unconformable lag bed consisting of very coarse, angular quartz sand, quartz gravel, perforated shell fragments, lignite fragments, clay balls, and other debris remaining after the transgression and erosion of the underlying geologic formations. The group is composed of three formations, the Clinchfield Formation, the Dry Branch Formation, and the Tobacco Road Sand, and each formation has members present in the study area. The Clinchfield Formation has such limited exposure that it could not be shown at the scale of the map. In its reference locality on the steep bluffs on the Savannah River south of Hancock Landing, the thickness of the formation is only 3 to 4 m (10 to 14 ft) and it disappears quickly in outcrop both updip and downdip.

The lithofacies of the Clinchfield Formation present in the Barnwell map area was named the Utley Limestone member by Huddlestun and Hetrick (1986). They report that the formation locally contains an abundance of the echinoid *Periarchus lyelli*, a guide fossil that is useful in regional correlation. Although the age of the Utley Limestone cannot be directly determined from exposures in the study area, Huddlestun and Hetrick (1986) correlate the beds with lowermost upper Eocene strata in central and western Georgia. Some of the lowermost beds might be latest middle Eocene but paleontological problems defining the middle Eocene/upper Eocene boundary make this correlation tenuous.

Huddlestun and Hetrick (1986) divided the Dry Branch Formation into members using both new and previously existing nomenclature. The calcareous (fossiliferous) clayey sand and marl at the base of the formation is called the Griffins Landing member for outcrops on the west side of the Savannah River at Griffins Landing. The laminated (carbonaceous) clays are called the Twiggs Clay member and the massive, well-sorted sand layers are called the Irwinton Sand member, after frameworks suggested by Cooke and Shearer (1918), Cooke (1943), and LaMoreaux (1946a, 1946b).

The different members of the Dry Branch Formation have not been differentiated on the geologic map because the lateral and vertical gradation of the lithofacies makes field determinations and mapping difficult. In general, the coarsening-upwards sedimentation from the Griffins Landing lithofacies grades into the Twiggs clay lithofacies which grades into the Irwinton sand lithofacies, reflecting regressive marine conditions in shallow shelf to tidal flat environments.

Samples of dark green carbonaceous clay and marl were collected from the Griffins Landing lithofacies of the Dry Branch Formation at Griffins Landing

(+20 m)(+66 ft) in South Carolina. These samples yielded dinoflagellate assemblages indicative of late Eocene (early Jacksonian) strata elsewhere in the southeastern U.S. (L. E. Edwards, U. S. Geological Survey, written communication, 1986; Prowell and others, 1985a).

Unlike the sands and clays of the Dry Branch Formation, the Tobacco Road Sand (see Huddlestun and Hetrick, 1978) is slightly to moderately burrowed in the coarser-grained beds, and heavily bioturbated in finer, better-sorted beds. Ovoid-shaped gravel and extensive crossbedding suggest deposition in a high-energy, shallow marine, probably shoreface, environment.

The Tobacco Road Sand could not be dated in the study area but it has been included in the upper Eocene Barnwell Group as part of the regressive marine deposition. The ovoid pebble layer at the base of the formation, however, might represent a significant depositional unconformity with the Tobacco Road Sand being a shallow water lithofacies of a later marine transgression. Prowell and O'Connor (1978), Zullo and others (1982), and L. E. Edwards (U. S. Geological Survey, written communication, 1983) reported inconclusive evidence that all or part of the Tobacco Road Sand may be Oligocene as opposed to Eocene, but nothing found in the map area substantiates their information.

Upland Unit -- The upland unit is characterized by lithofacies that reflect a high-energy, highly variable, fluvial depositional environment. The deposits conform to the shapes of large stream channels with extensive cross-cutting and refilling relationships. Local relief on the basal unconformity can be as much as 10 m (33 ft), and the formation can exceed 30 m (100 ft) in thickness in downdip areas. The lithologic variability of these fluvial deposits and the scour-and-fill process creates a complex internal vertical stratigraphy. These lithofacies are described separately in the rock unit explanation, but they can occur in any vertical or horizontal sequence in individual outcrops and drill holes. Generally, the coarser (gravel) lithofacies is more prominent in the northwest part of the study area along the eastern side of the Savannah River drainage basin whereas the crossbedded sand and clay lithofacies are more characteristic of downdip areas. Large clay-lined, noded burrows are found on the southeast end of SRS and immediately outside of the southeastern border of the SRS near Patterson's Mill, suggesting an estuarine influence to the southeast.

The age of the upland unit cannot be directly determined due to the absence of fossils. The unit is clearly truncated by the upper Pliocene marine strata at the Orangeburg Scarp and is also overlain by the lower (?) Pliocene dune sand. The upland unit also unconformably overlies the upper Eocene Barnwell Group, which suggests its age is either Oligocene or Miocene. Downdip projections of these strata by Nystrom and others (1986) in conjunction with geologic correlations in Georgia by Huddlestun (1988) suggest that this unit is the updip facies of upper Miocene shallow marine strata of the Hawthorn Formation or Altamaha Formation of Huddlestun (1988).

Upper Pliocene (Undivided) -- This is a shallow marine deposit that thins to a few feet thick near the base of the Orangeburg Scarp (see Colquhoun, 1965, and Colquhoun and Johnson, 1968). The original updip limit of the formation was probably the Orangeburg Scarp, which extends from Allendale, S.C. to Bamberg, S.C., but erosion has caused the inner margin to retreat seaward several miles. The

formation is about 16.8 m (55 ft) thick in the BAM-68 core hole near Ehrhardt, S.C. and its base is locally marked by a 0.3 to 0.6 m (1 to 2 ft) bed of megafossils with well-preserved large pectin shells. Exposures of the formation are very limited, and the updip limit of these strata is approximated from sparse data.

The age of the unconformity at the base of the formation was determined from a mollusk assemblage collected in Kirkland's strip mine (81° 06' 36" E x 33° 11' 41" N) located just north of the junction of S.C. Rt. S-5-41 and the Little Salkehatchie River west of Clear Pond, S.C. L.W. Ward (written comm., 1986) found "Pecten" eboreus Conrad, 1843, Anomia simplex d'Orbigny, 1842, and Ostrea sculpturata Conrad, 1840 to establish the age as upper Pliocene; however, the fossil assemblage was insufficient to provide biostratigraphic correlation with other specific late Pliocene formations such as the Bear Bluff Formation, the Raysor Formation, or the Goose Creek Formation (see Sloan, 1908; Dunbar, 1971; McCartan and others, 1984).

Dune Sand -- These deposits occur as widespread to very localized features that cap hilltops and some hillsides in the eastern part of the study area and were mapped as dune sands because they have features suggestive of immature, wind-blown, sedimentation. Although bedding is generally absent, a few exposures, such as those at the Barnwell County landfill, show well-defined crossbedding and graded bedding indicative of eolian conditions. Similarly, many of the sand mounds are reminiscent of common dune shapes that have been modified by post-depositional erosion. On 1:24,000 topographic maps, the areas of dune sand are easily recognizable as hummocky terrain dotted with shallow, dry depressions (for example, immediately west of Windsor, S.C.). These deposits average about 1 to 1.5 m (3 to 5 ft) in thickness but some are as thick as 4.5 m (15 ft). Although the deposits are all mapped as sand dunes, the sand on stream valley slopes may actually be colluvium derived from sand dunes at higher elevations. The nondescript nature of the sand bodies and the absence of sedimentary structures in most deposits has made this differentiation difficult.

The age of the dune deposits can only be estimated by relative position to other units. The dunes are clearly deposited unconformably on the Upland unit (Tu) and therefore are considered post-Miocene. The dunes are found inland of but not found on the Late Pliocene (Undivided)(Tp) marine deposits and therefore probably pre-date this high stand of the sea. These circumstances suggest that the age of the dune sand is probably lower Pliocene.

Quaternary

Terrace Deposits -- These high level terrace deposits are present in the higher bluffs along the eastern side of the Savannah River valley near Augusta, Ga. and the uppermost strata are as much as 21 m (70 ft) above present river level. They are flood plain deposits of the ancestral Savannah River and are comprised of quartz cobbles, sand, and clay in fining upward beds. Most of the strata are probably overbank deposits or point bar sequences because they are characteristically graded from very coarse sand and gravel at the base to sandy clay at the top. Man-made outcrops on the east bank of the Savannah River exposure more than 10 m (33 ft) of this strata.

The Quaternary terrace deposits are easily distinguished from the Quaternary alluvium by their elevation and sediment maturity. The terrace deposits are very

compact, show signs of extensive oxidation and alteration from weathering, and have well-developed soil profiles in the uppermost sandy clays. The age of the terrace deposits cannot be established except in terms of relative position to other units. Their elevation above the Holocene alluvium and present Savannah River flood plain suggests that they are probably Pleistocene.

Alluvium -- On the eastern side of the Savannah River valley, a large mass of alluvium (Qal 2) forms a plain at a slightly higher elevation than the deposits of the modern flood plain (Qal 1). These higher (and older) deposits are very similar lithologically to the younger alluvium but are slightly more compact and lithified. They also show signs of secondary iron mineralization, oxidation due to weathering, and primitive soil profile development. These secondary features in conjunction with the difference in elevation of the modern flood plain, allowed mapping of the older alluvium (Qal 2) as a separate geologic unit.

The alluvial deposits (Qal 1) of the major river valleys in the study area are largely composed of fine to very coarse quartz sand in a sparse clay matrix. Most outcrops show evidence of crossbedding, and large exposures typically expose small to large, cross-cutting channels. In smaller tributaries, the alluvium is typically derived from the geologic formations exposed upstream, and therefore can vary considerably depending on the local sediment sources. The thickest alluvium is believed to be in the Savannah River valley and has been measured at 21 m (70 ft) in a drill hole (Georgia Geological Survey #3156) just south of Augusta.

The age of the alluvium in the Barnwell sheet is considered Holocene although it has not been firmly established. The general absence of weathering and soil profile development suggests that all of these deposits are relatively young.

STRUCTURE

Structural features in the Coastal Plain of the southeastern U.S. can generally be categorized as either faults or folds. The regional distribution of Cretaceous and younger faults in this region has been cataloged by Prowell (1983), and the characteristics and implications of these structures were discussed in Prowell (1988). Folds in Cretaceous and younger strata were cataloged by McDowell and Houser (1983) for much of the Barnwell map area, and a more detailed explanation of their observations is available in Prowell and Obermeier (1991). Pre-Cretaceous faults have been described by Marine and Siple (1974), Hatcher and others (1977), Prowell (1978), Price and others (1991), Stieve and others (1991), and Stephenson and Stieve (1992).

No faults are evident at the surface in the Barnwell map area, although surface exposures of a northeast-trending reverse fault having Cretaceous and early Tertiary displacement was mapped by Prowell and O'Connor (1978) immediately northwest of the Barnwell map area. Similar northeast-trending faults have been recognized in the Cretaceous and early Tertiary strata in the subsurface of the SRS though seismic reflection profiling and confirmatory core drilling (Stephenson and Chapman, 1988; Snipes and others, 1989; Price and others, 1991; Stieve and others, 1991; and Stephenson and Stieve, 1992).

The only possible folding recognized at the surface in the Barnwell map area is exposed in low bluffs along the west bank of the Savannah River just north of Hancock Landing. At this locality, beds of the McBean Formation dip upstream in contrast to its characteristic coastward dip. This feature could not be studied in more detail to determine its origin, but its proximity to the subsurface trace of the Pen Branch fault could make it a drag fold or monoclinal warping over the fault.

REFERENCE LOCALITIES

For the benefit of those readers that wish to make a field study of the geologic units portrayed on this map, a reference locality of the best exposure of each unit is given below. Visitors should obtain permission to trespass from landowners or site managers prior to entering many of these areas.

Metavolcanics (Undivided) (Cmv): Outcrops at the spillway canal along Seaboard Coast Line railroad just east of Lake Olmstead in Augusta, Ga.

Middendorf Formation (Km): Augusta Sand and Gravel Company mine located on the east side of U.S. Rt. 278 just south of Horse Creek near Clearwater, S.C.

Black Creek Group (Kbc): Large pit on the south side of Dixon Airline Road (southwest of Augusta Airport along Butler Creek) about 0.5 mile east of Old Savannah Road.

Ellenton Formation (Te): Lower beds exposed in a building site excavation on the south side of U.S. Rt. 278 just east of the Hollow Creek bridge.

Huber and Congaree Formations (Undivided) (Thc): Dixie Clay Company McNamee #2 strip mine about 1.5 miles southeast of Bath, S.C.

McBean Formation (Tm): Large roadcut on northeast side of Savannah River Site road "C" just southeast of the Upper Three Runs bridge.

Cooper Group (Tco): Strip mine (81° 06' 36" E x 33° 11' 41" N) located just north of the junction of S.C. Rt. S-5-41 and the Little Salkehatchie River west of Clear Pond, S.C.

Barnwell Group:

Dry Branch Formation (Tdb): Large roadcut on Windsor Spring Road just south of Butler Creek near Augusta, Ga. shows Twiggs and Irwinton member lithologies. Griffins Landing member exposed in outcrops on the west side of the Savannah River at Griffins Landing.

Tobacco Road Sand (Ttr): Type section located about one mile east of the junction of Tobacco Road and U.S. Rt. 1 near Augusta, Ga.

Upland unit (Tu): Seaboard Coast Line railroad cuts about one mile southwest of Patterson Mill Road (B-6) (Gate 21) on the Savannah River Site.

Dunes (Td): Savannah River Site County Landfill excavations located east of the County Vocational School on Reynolds Road (S-6-41) between the towns of Barnwell and Blackville, S.C.

Upper Pliocene (Tp): Strip mine (81° 06' 36" E x 33° 11' 41" N) located just north of the junction of S.C. Rt. S-5-41 and the Little Salkehatchie River west of Clear Pond, S.C.

Terrace Deposits (Qt): Embankment behind South Carolina power plant located just southeast of the State Rt. 28 bridge across the Savannah River.

Alluvium (older) (Qal 2): Outcrop at the junction of the CSX railroad and SRS Road A-17.1 about 0.7 km (0.5 mi) east of Robbins Station.

Alluvium (younger) (Qal 1): New Savannah Bluff on the west bank of the Savannah River immediately east of the Augusta Airport (Bush Field).

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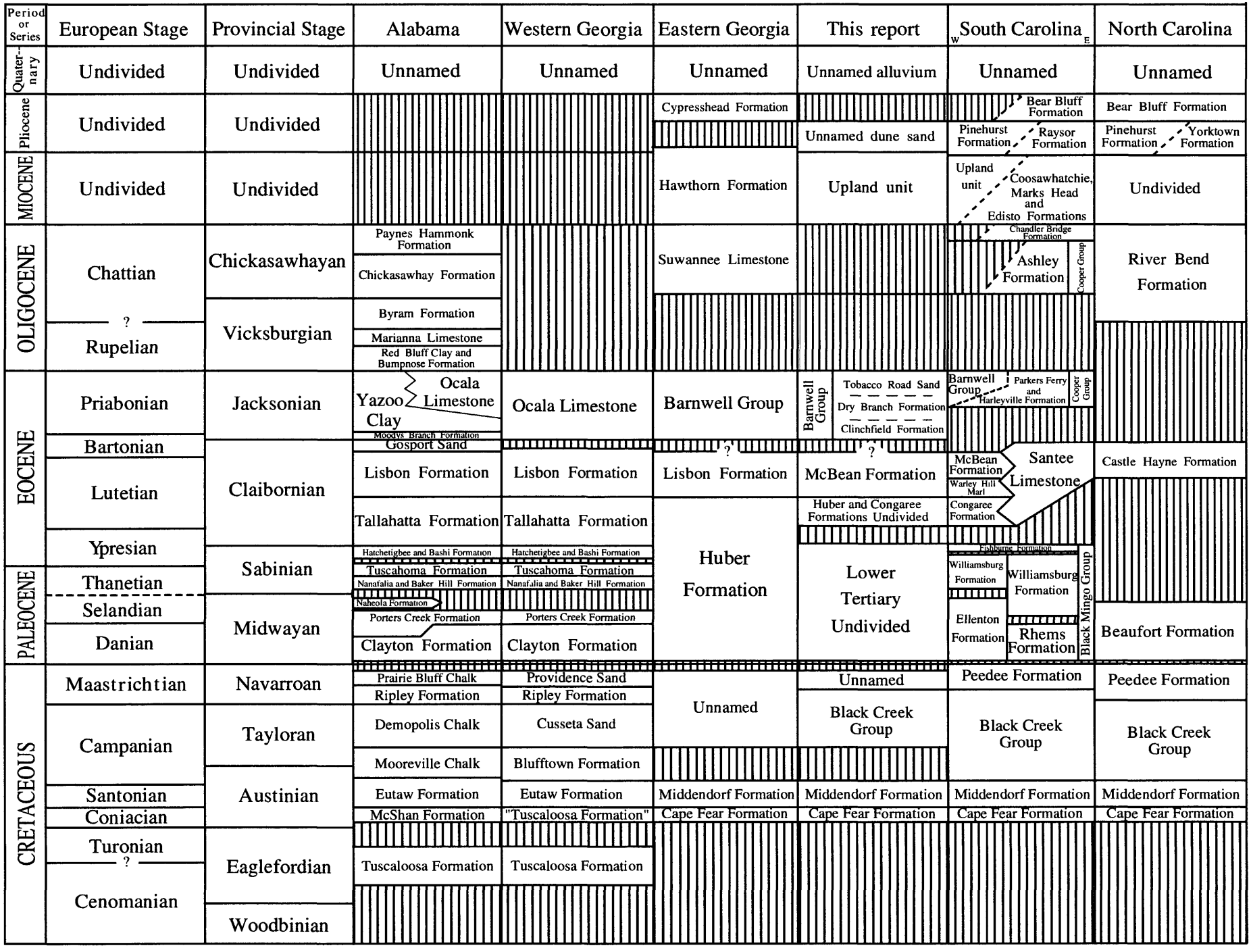

Figure 1: Correlation chart of geologic units