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PRELIMINARY GEOLOGIC MAP OF THE SAVANNAH RIVER SITE, AIKEN, ALLENDALE, AND BARNWELL COUNTIES, SOUTH CAROLINA

by

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

The preliminary geologic map of the Savannah River Site (1:48,000)(Plate 1) and its supporting text constitute a derivative product of a mapping investigation of the Barnwell 30' x 60' (1:100,000) topographic quadrangle. The Barnwell geologic map was compiled to examine the characteristics of sedimentary and structural features at the transition from the Gulf Coastal Plain to the Atlantic Coastal Plain in Georgia and South Carolina (Prowell, in press).

The Savannah River Site (SRS), which comprises about 20 percent of the Barnwell quadrangle, is a nuclear fuels processing plant operated by the U.S. Department of Energy in the Coastal Plain of western South Carolina. The preliminary geologic map of the SRS is a pre-publication release of information about the outcropping geologic units within the boundaries of that facility. Subsurface information, including cross sections and descriptions of non-outcropping formations, have not been included in this U.S. Geological Survey open-file report, to facilitate its release and reproduction. Subsurface information will, however, be incorporated in the formal publication of the geologic map of the SRS as a U.S. Geological Survey miscellaneous field studies map.

Although the Barnwell 1:100,000 scale geologic map contains information about Paleozoic, Mesozoic, and Cenozoic geologic formations, only formations of Cenozoic age crop out at the SRS. Tertiary deposits are exposed in the majority of surface exposures and comprise most of the shallow subsurface sections at the SRS. Although these formations typically reflect marine-related paleoenvironments, several of the older Tertiary formations have characteristics that suggest delta-dominated sedimentation. These deltaic strata have been locally miscorrelated with underlying Cretaceous beds (for example, Cooke, 1936 and Siple, 1967) that have similar lithologies representing similar paleoenvironments of deposition. The large sediment source areas that supplied sediment to the early Tertiary deltas were largely depleted by the latter part of the middle Eocene, and subsequent sedimentation from the middle Eocene through the late Eocene is indicative of open-marine deposition during cyclic changes in sea level. This pattern was broken by a period of fluvial deposition during the upper Miocene(?) when a sheet of non-marine to marginal marine (?) strata was deposited across all of the Savannah River Site. Immature dune deposits, probably formed during a low stand of the sea prior to the late 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 River and its tributaries has dissected most of the thin sedimentary layers in the map area providing exposures of the various geologic units and the contacts between them. In addition, this erosion has produced a variety of alluvial and colluvial deposits, some of which are important Quaternary map units. Alluvial deposits derived from erosion of the local landmass are readily mappable in most larger stream valleys. Holocene alluvial deposits can be mapped in the present river valley and up most of the larger tributaries. The position of extensive older alluvial plains along the east side of the modern Savannah River flood plain suggests a long-term southwestward migration of the Savannah River valley. These coalescing strata are mapped as a single unit, but their lithologies vary depending on source area and stream size. Colluvial deposits that vary in lithology depending on their sediment source are very discrete, localized accumulations of sediment (see Newell and others, 1980). The age, interrelationships, and distribution of these deposits are questionable; hence they are not included as a unit on the map although they are common in the southern half of the SRS. Colluvial deposits 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 association of colluvium with certain map units is discussed under specific map headings but it is most common in late Eocene and younger strata. 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. Information about weathering is included in the map explanation where necessary.

Structural modification of the Coastal Plain is widespread in the southeastern U.S. (see Prowell, 1988). In particular, faulting complicates the subsurface stratigraphic section near the center of the SRS and quite possibly in adjacent areas (see Snipes and others, 1990; Stephenson and Stieve, 1992). These faults are indicative of compressive stresses in the earth's crust during the Cretaceous and Cenozoic 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 and adjacent to the SRS 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), Prowell and others (1985a), Fallaw and others (1990a), Harris and Zullo (1990), Nystrom and others (1990), Price and others (1990), Snipes and others (1990), Fallaw and others (1990b), and Fallaw and Price (1992). Most of the detailed geologic data at the SRS, however, are from a number of engineering, hydrologic, and geologic reports (commonly unpublished) generated by contractors for the U.S. Department of Energy. 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), and Price and others (1991).

A variety of publications concerning areas immediately adjacent to the study area also contributed to the mapping of the geology of the SRS sheet. These include Nystrom and Willoughby (1982), Kite (1982), and Nystrom and others (1986).

NOMENCLATURE

The 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 corehole information. The nomenclature used in construction of this map and the regional correlation of geologic units is shown in Figure 1 (modified from Prowell, in press).

The nomenclature for the Huber and Congaree Formations posed a difficult problem for the SRS map compilation. The Huber Formation (Buie, 1978, 1980) was defined from commercial clay pits in central Georgia and is now known to include beds of early Paleocene age (Ellenton Formation) and middle Eocene age in the type area. These strata are delta-plain sediments that have similar appearance but that were 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. Therefore, in the SRS map area the name Ellenton Formation (see Prowell and others, 1985b) is applied to the Paleocene deltaic deposits, whereas Huber Formation is reserved for the middle Eocene delta-plain strata. The Congaree Formation, first named by Sloan

(1907, 1908) and later formalized by Cooke and MacNeil (1952) to describe delta-front (fluvio-marine) deposits, is now known to be a facies of the (Eocene) Huber delta-plain section. 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 allostratigraphic unit is designated as "Huber and Congaree Formations Undifferentiated" although most of the exposures and core samples on the SRS encounter the Congaree lithofacies.

The McBean Formation, as defined by Veatch and Stephenson (1911, p. 238), included impure limestone, marl, clay, and glauconitic sand unconformably deposited on "Cretaceous" strata (presently assigned to the Eocene Huber Formation) along McBean Creek (in Georgia). Whereas later authors (for example, Huddlestun, 1982) tried to restrict the name to the calcareous lithofacies, the designation by Veatch and Stephenson (1911), which includes siliciclastic strata, 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 group rank by Huddlestun and Hetrick (1986) with the Tobacco Road Sand (Huddlestun and Hetrick, 1978) included as the youngest formation. Two other formations in this group, the Dry Branch Formation and the Clinchfield Formation (subsurface only), are also present in the map area. A review of the nomenclature preceding these changes was published by Huddlestun (1982).

The Hawthorne Formation as used by Siple (1967) is herein called the "Upland unit", consistent with the informal renaming by Nystrom and Willoughby (1982). In addition, some previously unmapped river and sand-dune deposits have been informally called Quaternary alluvium and Quaternary dune deposits, respectively.

METHODS

The geologic units shown on the SRS 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 construct a structure contour map of the base of each geologic unit, which were in turn overlain on the SRS 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 contacts that in reality may be extremely irregular. 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. Therefore, the reader is cautioned to avoid rigorous application of contact information at significant distances from outcrop or drill hole information. In addition, the reader is cautioned to avoid direct application of map patterns in construction areas on the SRS. Topographic contours on the SRS base map were derived from U.S. Geological Survey topographic maps (1:24,000) dating back to 1964, and in some areas discrepancies of tens of feet exist between the map contours and recently revised points of reference (for example, the water surface of L-Lake southwest of the South Carolina Electric and Gas Company service line). In these areas, the reader is advised to compare the elevation of geologic contacts shown on the map with recent elevation surveys to determine the present outcrop pattern.

STRATIGRAPHY

The geologic units shown on the SRS map are not homogeneous layers with uniform lithologies. They actually represent depositional episodes in the geologic past generally associated with the transgression and regression of the sea, and each unit may contain a variety of strata representing the differing depositional paleoenvironments during that event. Where disconformities are suspected from paleontological data (but not mapped), the geologic units are combined into a group (for example, the Barnwell Group). The descriptions of the geologic units on the SRS map are therefore more complex than those on most traditional geologic maps. The following explanation 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 map units for the purpose of field comparison.

Tertiary

Huber and Congaree Formations Undifferentiated -- 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 north of the SRS, whereas exposures of the Congaree Formation are found in larger tributaries to the Savannah River such as Upper Three Runs Creek. Although the formations locally interfinger, the delta-front (Congaree) component is usually found below the prograding delta-plain (Huber) component. The two formations differ, however, only in their 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. The maximum thickness of this unit is about 25 m (83 ft) on the southern end of the SRS.

Core samples of carbonaceous clay beds in the Huber and Congaree Formation from the SRS wells FC-3A (+27.7 and +43 m) (+91 and +141 ft), VSC-2 (-21.6 m)(-71 ft), and MSB-18A (+46.6 m)(+153 ft) contained flora (pollen and dinoflagellates) indicative of middle middle Eocene and lower middle Eocene strata in the southeastern U.S. (Lucy E. Edwards and Norman O. Frederiksen, U. S. Geological Survey, written communication, 1982, 1983, 1984, 1985; Prowell and others, 1985a).

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 crops out 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 the SRS), these weathered calcareous beds are cemented by silica that was probably derived from the conversion of the dark-green illite/smectite clay and marl to kaolinite near bluff faces. The clay and marl are equivalent to beds called the "green clay" by Root (1980, 1981) on the SRS in F and H Areas.

The McBean Formation reaches a maximum thickness of about 26 m (86 ft) in the southwest corner of the map area and forms extensive outcrops along Upper Three Runs and Tinker Creek. Drill hole data suggest that the base of the McBean can be highly-irregular with as much as 10 m (33 ft) of relief over short distances. Apparently, the McBean sea was very erosive as evidenced by channels cutting deeply into underlying formations.

Core samples of the dark-green clays in the McBean Formation from wells FC-3A (+44.5 m)(+146 ft), and MSB-19A (+58.5 m)(+192 ft) yielded diagnostic dinoflagellate assemblages indicative of a late middle Eocene age (Lucy E. Edwards, U. S. Geological Survey, written communication, 1982, 1983, 1984).

Barnwell Group -- The Barnwell Group of Huddlestun and Hetrick (1979, 1986) is a coarsening-upwards sequence of sandy limestone, marl, clay, and quartz sand deposited during 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 does not crop out on the SRS and therefore will not be further discussed in this open-file report.

Huddlestun and Hetrick (1986) divided the Dry Branch Formation into members using both new and previously existing nomenclature. Calcareous (fossiliferous) clayey sand and marl at the base of the formation are called the Griffins Landing Member for outcrops on the west side of the Savannah River at Griffins Landing. Laminated (carbonaceous) clays are called the Twiggs Clay Member and the massive, well-sorted sand unit is called the Irwinton Sand Member, after stratigraphic frameworks suggested by Cooke and Shearer (1918), Cooke (1943), and LaMoreaux (1946a, 1946b). In addition, oxidized laminated clay beds in this formation near the SRS F and H Areas have also been designated the "tan clay" by Root (1980, 1981).

The 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 observation and mapping difficult. In general, the gradational coarsening-upwards sequence from the Griffins Landing lithofacies to the Twiggs clay lithofacies to the Irwinton sand lithofacies reflects 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 (+26 m)(+85 ft) on the Savannah River and in a core sample from well VSC-2 (+20 m)(+66 ft) on the SRS. These samples yielded dinoflagellate assemblages indicative of upper Eocene (lower Jacksonian) strata elsewhere in the southeastern U.S. (Lucy 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 where it represents shallow marine deposition. The ovoid pebble layer at the base of the formation, however, might represent a significant basal 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 Lucy 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 thickness of the formation can exceed 30 m (100 ft) 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 the 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. Prowell (in press) shows the unit partly truncated and overlain by the upper Pliocene marine strata near the Orangeburg Scarp (see Colquhoun and Johnson, 1968). The upland unit also unconformably overlies the upper Eocene Barnwell Group, which suggests its age is either Oligocene, Miocene or perhaps early Pliocene. Downdip projections of the upland unit strata by Nystrom and others (1986), in conjunction with geologic correlations in Georgia by Huddlestun (1988), suggest that this unit is the updip equivalent of Miocene shallow-marine strata of the Hawthorn Formation or the Altamaha Formation of Huddlestun (1988).

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. They are mapped as dune sands because they have features suggestive of immature, wind-blown, sedimentation. Although bedding is generally absent, Prowell (in press) reports that a few exposures west of the SRS show well-defined crossbedding and graded bedding indicative of eolian conditions. He also reports that many of the sand mounds are reminiscent of common dune shapes that have been modified by post-depositional erosion. These deposits average about 1 to 1.5 m (3 to 5 ft) in thickness, but some are as thick as 3 m (10 ft). Although the deposits are all mapped as sand dunes, the sand on stream valley slopes may actually be colluvium derived from sand dunes or sandy formations 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. Prowell (in press) reports that the dunes are found inland of, but not on, upper Pliocene marine deposits southeast of the SRS. Therefore, they probably pre-date this late Pliocene high stand of the sea. These observations suggest that the age of the dune sand is probably early Pliocene or perhaps latest Miocene.

Quaternary

Alluvium -- On the eastern side of the Savannah River valley, a large mass of alluvium (Qal2) forms a series of plains (or terraces) at slightly higher elevations (6 to 15 m; 20 to 50 ft) than the deposits of the modern flood plain. These higher and older deposits are very similar lithologically to the younger alluvium but are slightly more compact and lithified. Sparse drill hole information suggests that they average about 9 m (30 ft) in thickness. They also show signs of secondary iron mineralization, oxidation due to weathering, and primitive soil profile development. These secondary features, in conjunction with their elevation above the modern flood plain, allowed mapping of the older alluvium (Qal2) as a separate geologic unit.

The alluvial deposits (Qal1) of the modern river and stream valleys in the study area are largely composed of fine to very coarse quartz sand in a sparse clay matrix. Most outcrops expose 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 in the study area is believed to be in the modern Savannah River floodplain and data on the SRS suggests that it exceeds 9 m (30 ft). Data outside of SRS suggests that the maximum thickness does not exceed 18 m (60 ft).

The age of the alluvium in the SRS map is considered Holocene although conclusive age information is not available. The general absence of weathering and soil profile development suggests that all of these deposits are relatively young.

STRUCTURE

The regional distribution of Cretaceous and younger faults in the region around the SRS has been cataloged by Prowell (1983), and the characteristics and implications of these structures were discussed in Prowell (1988). Small scale deformations in Eocene strata were cataloged by McDowell and Houser (1983) for several localities on the SRS, and a more detailed explanation of their observations is available in Prowell and Obermeier (1991). Post-Cretaceous faults have been described at the SRS by Snipes and others (1989), Price and others (1991), Stieve and others (1991), and Stephenson and Stieve (1992).

No faults are evident at the surface in the SRS map area, although surface exposures (not scarps) of a northeast-trending reverse fault having Cretaceous and early Tertiary displacement were mapped by Prowell and O'Connor (1978) at Augusta, Georgia, northwest of the SRS. Similar northeast-trending reverse faults have been recognized in the Cretaceous and lower Tertiary strata in the subsurface of the SRS through 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). None of these faults were encountered during surface mapping of the SRS.

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 on the SRS is given below. Better exposures of these units can generally be seen offsite and directions to these are available in Prowell (in press).

Huber and Congaree Formations Undifferentiated (Thc): Small stream exposures (below + 160 ft MSL) northwest of F-area in an unnamed tributary to Upper Three Runs Creek located immediately west of SRS well FC-4A.

McBean Formation (Tm): The lower half of the large roadcut on northeast side of SRS road "C" just southeast of the Upper Three Runs bridge.

Dry Branch Formation (Tdb): Large erosion ditch in a construction materials area about 0.5 mile east of the junction of Upper Three Runs Creek and SRS Road C near F-Area.

Tobacco Road Sand (Ttr): Large erosion ditch in a construction materials area about 0.5 mile east of the junction of Upper Three Runs Creek and SRS Road C near F-Area.

Upland unit (Tu): Artificial cuts on CSX railroad about one mile southwest of Snapp (Gate 21) located on Patterson Mill Road (SRS Road B-6).

Dunes (Td): Hill crest roadcuts on SRS Road 8-1 between Upper Three Runs Creek and Reedy Branch on the northeast side of the SRS.

Alluvium (older) (Qal2): 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) (Qal1): Low exposures at the southwest end of the inlet channel leading from the Savannah River to Pump House 1 near Point Comfort.

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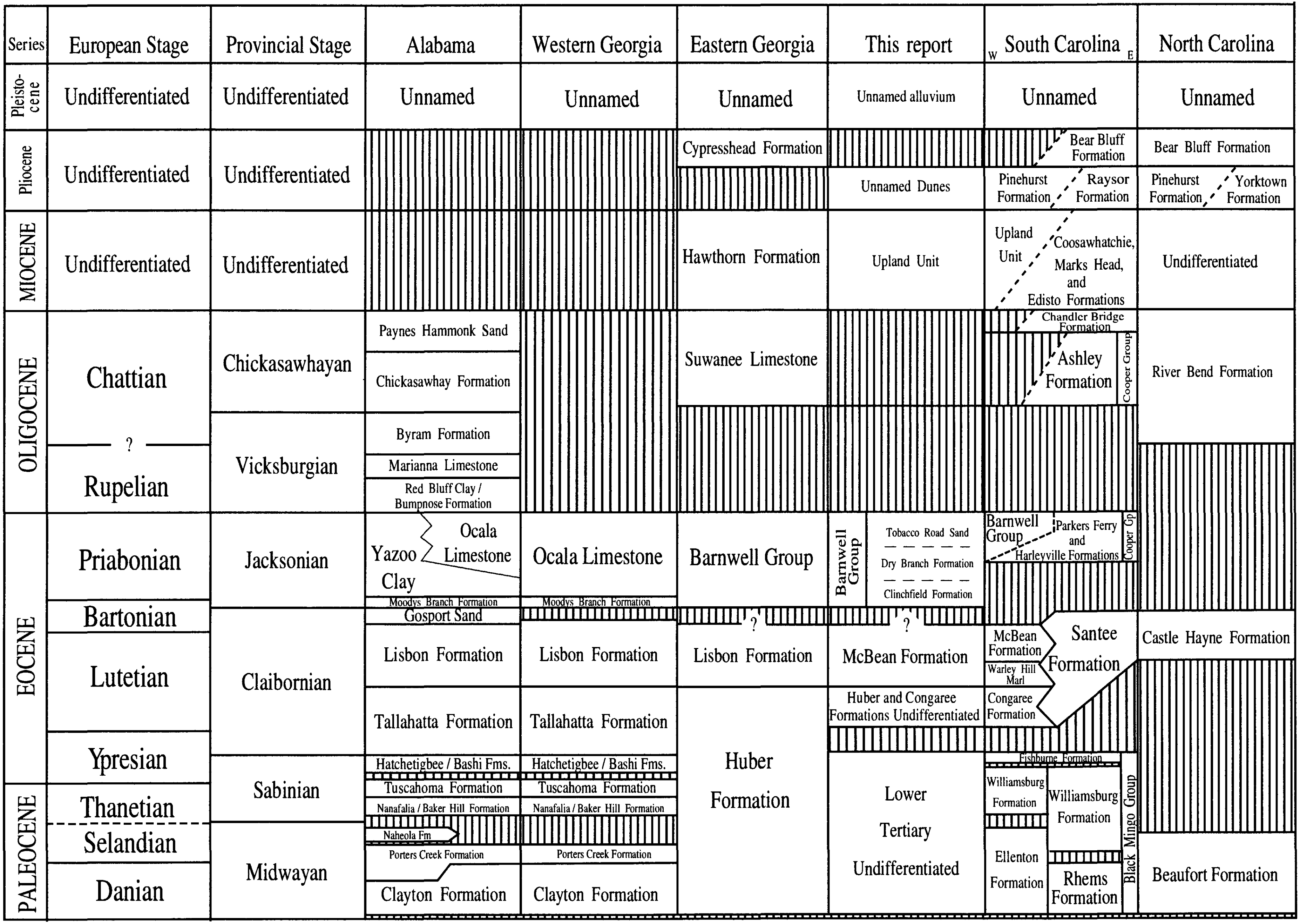

Figure 1: Correlation chart of geologic units