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Abstract

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ROCK-STRATIGRAPHIC DISTRIBUTION OF SEDIMENTS LYING NORTHWEST OF THE SURRY SCARP IN CENTRAL SOUTH CAROLINA

by

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ABSTRACT

Sediments in central South Carolina underlying the Okefenokee Terrace (Cooke, 1954) are examined at the surface and in the subsurface. The Okefenokee Terrace is shown to be underlain by marine Middle Eocene and Late Miocene and fluvial post-Late Miocene rock-stratigraphic units. A significant hiatus between the development of the Okefenokee and the development of the Wicomico Terrace is illustrated by a contour map constructed on the Tertiary bedrock. The fluvial nature of the post-Late Miocene unit is illustrated by a lithofacies map.

INTRODUCTION

Many studies recognizing specific constructional and destructional features on the Atlantic Coastal Plain have been made through surface examination of topography, topographic maps, aerial photographs, and outcrops. Far fewer studies have been made using sediments at the surface and in the subsurface. This study has analyzed the geomorphology of an area using both methods. Observations and conclusions are based on data obtained through examination of topographic maps, aerial photographs, and samples obtained through surface mapping as well as by means of power auger holes and borings within and surrounding this area.

The Eutawville fifteen-minute Quadrangle (Figure 1) which lies athwart the Surry Scarp (Flint, 1940) and includes surficial sediments associated with the Sunderland, Okefenokee, Wicomico and Penholoway Terraces (Cooke, 1936, 1954) has been studied. Only sediments associated with the Okefenokee Terrace will be treated in detail in this paper.

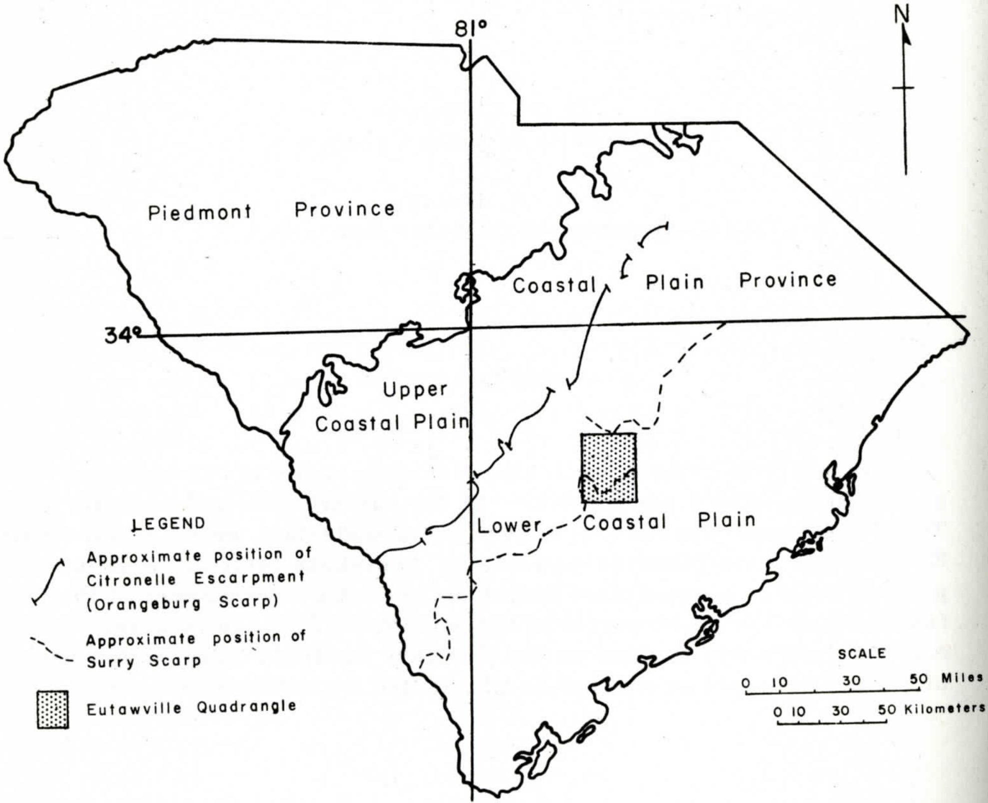

Figure 1. Location map of Eutawville Quadrangle.

ACKNOWLEDGMENTS

The writers acknowledge the aid of the Division of Geology, South Carolina State Development Board, for support and assistance during the acquisition of samples, and for numerous discussions with H. S. Johnson, Jr., State Geologist, during this period. The junior author is largely responsible for conclusions illustrated in the southeast quarter of the Eutawville Quadrangle, the senior author for surrounding area. The senior author acknowledges the aid of the South Carolina

Highway Department in making available route profiles and logs of borings made in connection with bridge construction, near the map area, and to the South Carolina Public Service Authority for information obtained during the construction of the Santee Dam. K. Pooser is responsible for the initial recognition of Miocene fauna and sediments within this area. The senior author gratefully acknowledges the aid of the National Science Foundation for grant support during the latter stages of this investigation (NSF-GP-1817).

METHOD

Sampling

Outcrops are confined to the south shore of Lake Marion and to a very few road cuts on the principal highways within the region. It was necessary to obtain subsurface stratigraphic data by use of a power auger drill which is capable of exploration to depths of approximately 100 feet. Smith (1961) has described the drilling equipment.

Drilled samples were obtained in two ways. Above the water table samples were obtained from the return spoil at the surface in five-foot increments. Two samples usually were taken for each five-foot increase in depth; one approximately in the middle of the spoil flow, and the other toward the end. After each sampling, the drill was rotated, raised and lowered to clear the hole. When the flow of spoil ceased, an additional five-foot auger rod was added to the string and the drill was advanced. Below the water table, or where excessive accumulation of spoil indicated the hole was caving, the drill was advanced continuously under high drilling pressure without sampling surface spoil. After bottoming at the desired depth the string was pulled from the hole in five-foot sections, and the samples were obtained directly from the auger flights.

The equipment yields samples defective in three respects: The samples are partially contaminated by caving and below the water table this can be a major problem if the second method described above is not followed. The samples are disturbed, particularly above the water table where they have been thoroughly mixed on arrival at the surface. Finally, the arrival of samples at the surface lags considerably behind the depth of penetration so that trained personnel must be present during the drilling in order to correlate surface spoil with depth. Variations in drilling pressure, rate of penetration, sudden drilling rate changes, and general behavior of the drill string while advancing, were noted at each drill site in order to make correlations and to coordinate spoil and auger-flight samples with their interpreted depth.

Drill Sites

Most of the holes were drilled along roads at spot elevations shown on the topographic map of the fifteen-minute quadrangle (Figure 3). Elevations of a few locations had to be run in by altimeter survey from nearby bench marks. A single altimeter was used. Aerial photographs were examined to avoid areas within "Carolina Bays" and within solution depressions to avoid erratic elevations of formational contacts. Holes were generally drilled about two miles apart but some were closer together.

Laboratory Procedure

The nature of the samples justifies only a rough quantitative laboratory analysis because of similarity in gross lithology and contamination. While procedural errors in the laboratory were generally held to within one percent, by weight comparison, it is thought that the contamination of the samples indicates a variation in reliability which can be well in excess of this. For this reason, grades mapped in Figure 7 have been chosen over broad ranges of size in order to eliminate insignificant variations.

The collecting of numerous samples at each drilling site allows lithologic contacts to be precisely picked when size analyses are compared with drilling characteristics (Figure 2, 3). As in rotary drilling, the first appearance of a characteristic size grade, even though of minor percentage, marks the upper contact. The lower contact is chosen either by a pronounced drilling change, or a readily apparent change in lithology. The method does not allow one to distinguish between minor lithologic variations with certainty.

A portion of each sample was selected, dried, weighed, and gently washed through a 230-mesh sieve. Sediment on the sieve was dried, shaken for ten minutes through a nest of 13 sieves and cumulatively weighed. A check on procedural error was periodically run by weighing the sample before shaking and comparing this weight with the cumulative weights. A portion of the material passing the 230-mesh sieve was caught, dried and retained. From these selected samples silt and clay percentages were analyzed by soil hydrometer. A deflocculating agent was used. During the early part of the program the weightings were plotted on graph paper to determine the 10, 25, 50, 75 and 90 percentile sizes where these were obtained and to calculate quartile sorting and skewness (Pettijohn, 1954). During the latter part of the

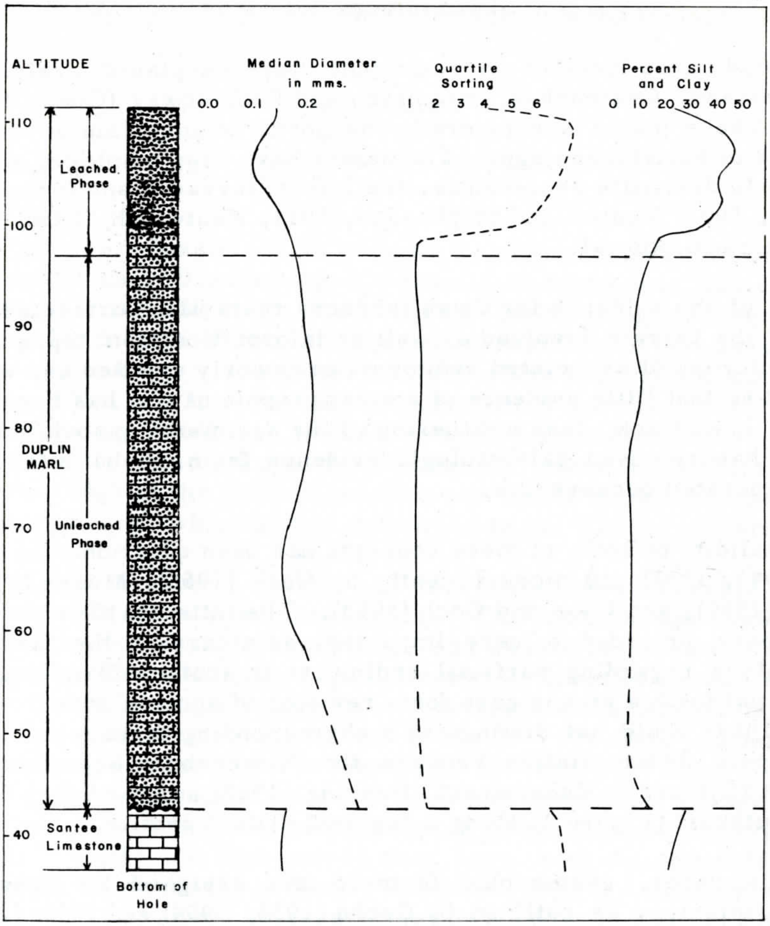

Figure 2. Sedimentary parameters in Drill Hole Orangeburg Number 57.

program an IBM 1620 computer was employed to do the same calculations for each sample. Microfossils were floated from the samples and some of the associated microfaunas identified.

PREVIOUS WORK

Summaries of previous work in South Carolina have been published by Richards (1962) and by Colquhoun (1962).

Terminology

The study area includes physiographic "terrace-plains" assigned to the Sunderland, Okefenokee, Wicomico and Penholoway (Cooke,1936, 1954). These plains are generally thought to be underlain by marine sediments of Pleistocene age. The names have been employed simultaneously to designate shore-lines, sea levels, terraces and formations (Shattuck, 1901; Veatch and Stephenson, 1911; Wentworth, 1930; MacNeil, 1949; and others).

Much of the evidence for these terraces rests with surface examination of the terrain involved as well as information from topographic maps. Outcrops of associated sediments are poorly exposed and widely scattered so that little evidence of a stratigraphic nature has been presented. In addition, deep weathering of the sediments associated with terraces has removed paleontologic evidence from all but a few very widely separated occurrences.

The validity of some of these concepts has been questioned by Flint (1940, 1941, 1957) and more recently by Hack (1955), Moore (1956), Doering (1960), and Oaks and Coch (1963). The latter in their detailed studies have provided a very important summary of the theory of nomenclature regarding surficial sediments in southeastern Virginia, and have put forth a strong case for a revision of nomenclature. Colquhoun (1962) could not distinguish a corresponding terrace and rock-stratigraphic differentiation between the "Orangeburg Scarp" on the northwest (Citronelle Escarpment, Doering, 1960) and the Surry Scarp on the southeast (Figure 1) along a regional drilled profile.

In this paper, geomorphic features are assigned the generally known terminology as outlined by Cooke (1936, 1954) and Flint (1940, 1957), while rock-stratigraphic names are applied to formational units where possible, specifically employing those names that have precedence in the literature.

A surficial rock-stratigraphic unit recognized in this paper is termed "Okefenokee" after C. W. Cooke's geomorphic correlations (1954, 1963, personal communication). The same unit is regarded as part of the Sunderland Formation by Doering (1960).

Surficial sediments adjacent to the Citronelle Escarpment are alluvial fans in their regional expression (Doering, 1960), and probably alluvial in their measured textures, structures and shape (Colquhoun, 1962). Within the Eutawville Quadrangle, however, it will be shown that the surficial unit is alluvial, but not an alluvial fan. The detailed rock-stratigraphic relationships between these two areas are unknown, therefore, the term "Okefenokee" is tentatively retained and used in a rock-stratigraphic sense for the first time in this area.

TOPOGRAPHY

The lower Coastal Plain of South Carolina southeast of the prominent scarp near Orangeburg (Citronelle Escarpment, Doering, 1960) contrasts markedly with the coastal plain lying to the northwest (Figure 1). In general the land slopes eastward from that scarp with decreasing gradient. The Coharie, Sunderland and Okefenokee terraces (Cooke, 1954, 1963, personal communication) and the Sunderland Terrace (Doering, 1960) are generally much less dissected by stream erosion than the land lying to the northwest. Near Holly Hill (Figure 6) the outer edge of the Okefenokee Terrace forms the steeper gradient of the Surry Scarp, which slopes downward to the Wicomico Terrace.

The southeastern portion of the Okefenokee Terrace and the Wicomico Terrace are much alike. The land, though sloping gently toward the southeast, is very flat, and away from drainage areas dry and sandy. The maximum regional relief in interfluve areas within the Eutawville Quadrangle is only 60 - 70 feet, while the maximum regional relief including the drainage areas is but 90 - 100 feet. Over most of the quadrangle local relief is less than 20 feet per mile. Areas of higher local relief occur adjacent to major drainage systems. The south shore of Lake Marion (Figure 3) rises 55 feet above the lake in places. Cliffs as high as 30 feet have been cut since the lake was formed by the damming of Santee River in 1939. A number of short, steep, stream valleys intersect the south shore and interrupt the cliff exposures. The approach toward Four Hole Swamp, a major drainage channel in the southwestern quarter of the quadrangle, is of very low relief, but generally greater than normal local relief.

A gentle rise from the inner edge of the nearly level Wicomico Terrace is here regarded as the extension of the Surry Scarp of Flint (1940, 1957) and is so named in Figure 3. Its somewhat variable slope is only slightly steeper than that of the main part of the Okefenokee Terrace, of which it forms the outer edge. In the field, without an altimeter, its presence is more easily noted by change in local topography, drainage, and soil characteristics than by abrupt elevation change. In several areas it is readily apparent. Two and one half miles east of Eutawville, near Toney Bay, the 20 foot decrease in altitude from the Okefenokee Terrace to the Wicomico Terrace is abrupt, occurring in less than one-half mile. Near Holly Hill a 20 foot altitude decrease is much more gradual, occurring in a series of small

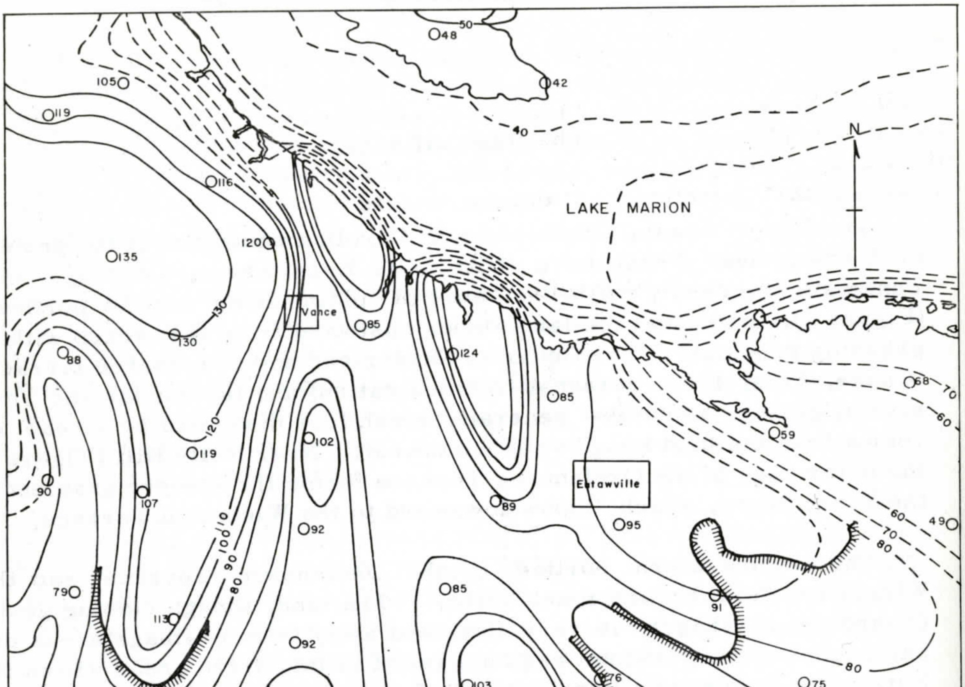

Figure 3. CONTOURS on TERTIARY FORMATIONS, EUTAWVILLE QUADRANGLE, SOUTH CAROLINA

LEGEND

Surry Scarp

Contours on formations, control data good.

Contours on formations, control data sparse.

O21 Drill hole and altitude of top of Tertiary.

steps over a distance of two to three miles.

Areas of extremely low relief occur within the major drainage system of the Santee River (now inundated by Lake Marion), Four Hole, and Dean Swamps. These areas, assigned by Cooke (1936) to terraces lower than the Wicomico, possess local relief of the order of two feet in a mile.

The Okefenokee Terrace exhibits several features that are not present to a marked degree on the Wicomico Terrace. Somewhat linear depressions radiate from the Vance area near Lake Marion. For the most part these are not readily apparent on the ground and, with the exception of two or three which are poorly depicted, they are not reflected on topographic maps. The linear depressions are easily seen on aerial photographs, however, where they exhibit a fan-like or possibly deltaic aspect between Lake Marion, Four Hole and Dean Swamps (Figure 3). Carolina Bays, generally smaller than those occurring on the Wicomico Terrace, are developed more extensively on the interdepression areas of the Okefenokee Terrace. Toward the east, in the vicinity of Eutawville and Eutaw Springs, a solution topography with solution pans and sinks is well developed and incompletely covered by thin sands. Similar features, developed southeast of this area, have been described in detail by Taber (1939, 1960-62 personal communication). All these features are generally poorly drained and swampy. In general the Okefenokee Terrace appears more dissected by stream erosion than the Wicomico Terrace.

The Wicomico Terrace also presents unique features in comparison with the Okefenokee Terrace. Adjacent to the Surry Scarp, in several areas, small hills of 5 to 10 feet relief are present. Southeastward from the scarp these features are succeeded by a northeast trending flat, featureless, poorly drained plain which lies between altitudes + 80 to + 90 feet.

Several major features within the Eutawville Quadrangle have been genetically interpreted by earlier workers on the basis of their surficial aspect. The boundary between the Okefenokee Terrace and the Wicomico Terrace was interpreted as a shoreline by Cooke (1936). Flint (1940, 1941), in correlating the Surry Scarp southward from Virginia to Georgia, was in agreement. In addition, Flint (1940) recognized features suggestive of a "fan-like alluvial plain" to the south of the Santee River and west of the Surry Scarp extension herein depicted.

UNCONFORMITY ON TERTIARY SEDIMENTS

Figure 3 shows contours on top of the Tertiary sediments. The distribution of the buried Tertiary formations is shown in Figure 4.

In Figure 3 the writers have tried to separate areas of good reliability from areas of poorer reliability by solid and broken contour lines respectively. The features illustrated by these broken lines undoubtedly exist, but their exact position may vary somewhat because of sparse control. Interpretation used in constructing Figure 4 is subject to the same limitations.

The Santee Limestone underlies the entire area and is commonly overlain by the Duplin Marl north of the Surry Scarp and by the Cooper Marl to the south. Along the subsurface extension of the Surry Scarp (Colquhoun, 1962, Figure 3), and in the several channels lying to the northwest, the Santee Limestone lies directly below the surficial deposits. It lies very close to the surface or at the surface in the vicinity of Eutawville. Away from the channels, the higher areas are underlain largely by the Duplin Marl.

The surface of the Tertiary formations under the Okefenokee Terrace is depicted in Figure 3. Two different types of topography are apparent; a channelled surface north of the Surry Scarp and a flattening surface to the south. The channels are weakly reflected at the surface on topographic maps and aerial photographs and strongly developed in the subsurface on the Tertiary formations. A good correspondence between the two is apparent. On aerial photographs, other valleys can be noted above the buried channels so that these channels are in a sense composites of several valley sequences. Most of the buried channels are floored by Santee Limestone, which is much more resistant to erosion than the Duplin Marl. The Duplin Marl is commonly present between the channels, and it outcrops in several large areas of the quadrangle.

An abrupt change in the degree of the relief developed on the buried Tertiary formations is noted immediately south of the Surry Scarp. The surface of the Santee Limestone and the Cooper Marl (Figure 4) slopes with decreasing gradient toward the south, and gradually flattens. Local buried relief, which may be as high as 50 feet per mile under the Okefenokee Terrace, is generally less than 10 feet per mile under the Wicomico Terrace.

The Surry Scarp divides these two topographically distinct areas. The Surry Scarp should be thought of in terms of both its surface and sub-surface continuity rather than in its surface expression alone. The

Surry Scarp constitutes an important stratigraphic boundary on the Coastal Plain. It separates two distinct stratigraphic sequences. In this broad sense the Surry Scarp is a major unconformity caused by the marine transgression responsible, in part, for the formation of the Wicomico Terrace. It is the land surface against which the Wicomico sea came to rest.

Even more germane to the study of the development of the surficial sediments is the relative altitudes of the Tertiary formations underlying Lake Marion and those in the vicinity of Four Hole Swamp. These areas were assigned by Cooke to the Wicomico and younger terraces. Within these areas (Figure 3), channels which developed in the Tertiary surface immediately prior to the formation of the Surry Scarp lie at an altitude some 20 to 30 feet below the base of the channels underlying the Okefenokee Terrace and contrast with the Okefenokee channels that cut across present drainage. Regional contours reflect the south-bank cutting tendency observed in present rivers along the central and southern Atlantic Coastal Plain.

Cooke (1936, Plate 1) has indicated that two distinct sedimentary sequences underly Lake Marion. What he has mapped as Penholoway can be shown by borings to have a minimum basal altitude of + 25 feet, while that which he has indicated as Wicomico possesses a minimum altitude of less than + 40 feet. Differentiation between these two sequences is not indicated on Figure 3 because the control data are sparse and lie outside, although close to, the map area.

ROCK-STRATIGRAPHIC UNITS

Santee Limestone

The Santee Limestone of Medial Eocene age is the oldest formation that crops out within the area studied (Figure 6). The unit contains faunas analogous to those carried by the Castle Hayne Limestone and the Santee Limestone proper. It has been subdivided into these units by Cooke and MacNeil (1952) on the basis of the contained fauna. Differentiation on the basis of lithology, however, has not proved possible within the study area. Accordingly, the older name "Santee" (Tuomey, 1848) will be used in this paper. This unit may be correlated with the Upper-Middle and Upper Claiborne Group (Cooke and MacNeil, 1952).

The Santee Limestone is a moderately well-sorted to very poorly-sorted (So 2.0 - + 5.0), finely-micrograined to cryptograined (Thomas and Glaister, 1960), arenaceous, skeletal limestone. It is surficially well-indurated, but only slightly consolidated at depth. The unit locally has a high clay content or a high content of fine-grained sand. An average obtained from five very slightly contaminated samples indicates 37.39% of the Santee Limestone was of silt and clay size and had a median diameter of 0.166 mm. In places fossiliferous lenses and beds contain a predominantly pelecypod fauna. The Ostrea selaeformis zone is exceptional in that it crops out consistently at an altitude of about +75 feet along the south shore of Lake Marion, between the Santee State Park boat landing near Elloree and Mill Creek near Vance.

A solution topography is developed on the Santee Limestone in the vicinity of Eutawville where it occupies a large portion of the Okefenokee Terrace. The topography is covered thinly by sand as mentioned above. This is readily apparent on aerial photographs of the area. Within the subsurface a solution topography occurs elsewhere, where it is covered by the Duplin Marl. It has been noted, rarely, underlying the Cooper Marl as well. The presence of this topography in the subsurface is indicated by erratic altitudes of the top of the Santee Limestone and by the presence of subsurface caverns as shown by a free fall of drill rods of as much as 14 feet.

Sink holes also have been observed, particularly along the south shore of Lake Marion between Mill Creek and the Santee State Park boat landing, in several areas where the Santee Limestone is overlain by the Duplin Marl and not eroded by post Duplin fluvial units. In prominent lake cliffs the sink holes occur as semi-circular depressions in the upper surface of the limestone, sometimes up to 20 feet in depth below the normal Duplin-Santee contact. The Duplin Marl, largely composed of unconsolidated medium and fine sand, has been eroded selectively by lake wave action, leaving the walls of the sink holes exposed clearly close to the level of Lake Marion (75 feet).

Within the Eutawville Quadrangle the highest altitude noted for the Santee Limestone was + 102 feet where it lies in contact with the Duplin Marl. The lowest altitude noted was approximately +35 feet where it also was in contact with the Duplin Marl.

The Santee Limestone requires a high hydraulic pressure for auger penetration (approximately 800 to 1200 pounds). The rate of penetration under this pressure is erratic. Generally, samples are difficult to obtain from the spoil and most of those studied were recovered from the auger rods after pulling the string.

Cooper Marl

In the southern part of the Eutawville Quadrangle, the Cooper Marl,

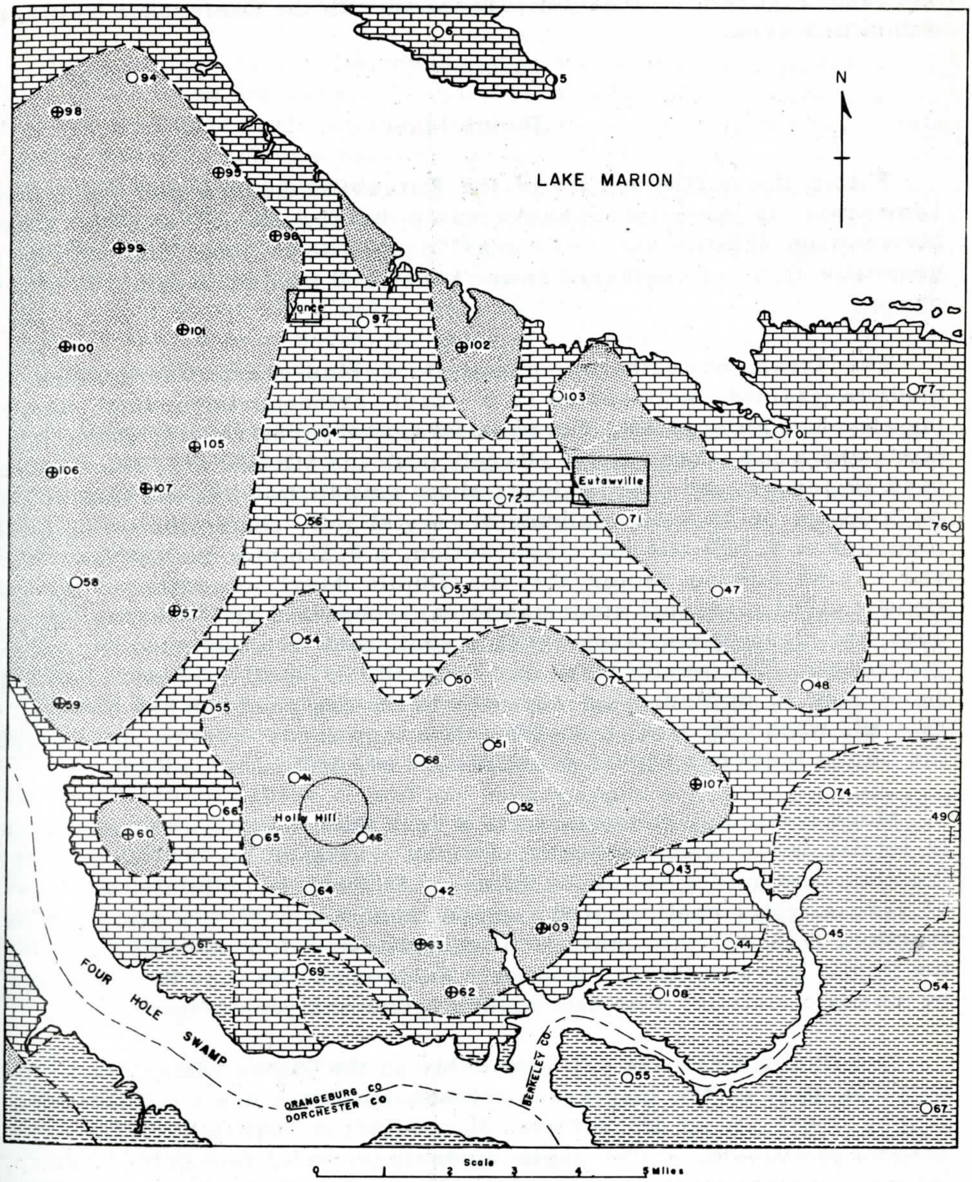

Figure 4. GEOLOGIC MAP of BURIED TERTIARY FORMATIONS, EUTAWVILLE QUADRANGLE, SOUTH CAROLINA

Geology by D. J. Colquhoun and D. A. Duncan

Drafted by W. D. Paradeses

LEGEND

Tertiary
- Miocene — DUPLIN MARL
- Oligocene — COOPER MARL
- Eocene — SANTEE LIMESTONE

○ 12 Drill Hole and Number Assigned by County.

⊕23 Drill Hole with Miocene Fauna.

---- Approximate Geologic Contact.

assigned to the Oligocene by Malde (1959), underlies the Wicomico Terrace (Figure 6). It is not associated with the Okefenokee Terrace within this area.

Duplin Marl

Within the northern part of the Eutawville Quadrangle, the Santee Limestone is overlain unconformably by the Duplin Marl of Late Miocene age (Figure 6). The marl occurs in two dominant phases; a generally thin, unweathered lower phase and a thick, weathered upper phase.

The fresh unweathered phase is a blue-gray, fine-grained or medium-grained, well-sorted (1.5 - 2.0), orthoquartzitic sand, carrying abundant Pelecypoda, Foraminifera, and more rarely, Ostracoda, Gastropoda and other shells. Rarely does the silt and clay fraction exceed 10 percent and size analyses show very little variation with depth. An average of 22 size analyses of very slightly contaminated samples indicates a 9.58% silt and clay fraction, a 0.226 mm median diameter and a 1.63 sorting factor for the Duplin Marl unweathered phase. Pooser (1962, personal communication) recognized late Miocene Ostracoda and Gastropoda taken from a spoil bank of a dug pond within the quadrangle. The fossiliferous unit from which these were obtained was penetrated in drilled holes adjacent to the dug pond and has been correlated, where present, over the entire map area. Holes from which the Duplin Marl has proved fossiliferous are indicated on Figure 4.

More commonly encountered is a very thick weathered phase which is totally leached of carbonate fossils, enriched in the silt and clay fraction, and golden yellow in color. An average of 26 size analyses of very slightly contiminated samples indicates a 25.43% silt and clay fraction, a 0.290 mm median diameter and a 1.66 sorting factor for the Duplin Marl weathered phase. The two phases may be correlated by means of detailed size and mineralogical analyses (Figure 2).

The Duplin Marl lies unconformably on the Santee Limestone in the northern part of the map area. Since the latter has a solution topography developed at its surface, the contact is regionally erratic with respect to altitude. The upper contact, in part, lies at the surface, forming a significant portion of the Okefenokee Terrace and, in part, lies at the contact with the overlying Okefenokee formation.

The Duplin Marl responds as a loose "runny" sand to the auger and usually can be pumped to the surface. It drills easily (200 pounds pressure). The best samples were obtained by penetration of the unit, direct pulling of the string and sampling from the auger flights.

Okefenokee Formation

Introduction. The term "Okefenokee Formation" was introduced in 1911 (Veatch and Stephenson). The term Okefenokee Terrace was suppressed by Cooke (1930) in favor of the term Sunderland Terrace. The Okefenokee Terrace was revived by MacNeil (1949) on recognition of a shoreline at 145 feet altitude. The terrace and its shoreline has been traced through Georgia (MacNeil 1949) and South Carolina (Cooke 1954, 1963 personal communication). The term Okefenokee Formation is applied for the first time in this area to stratigraphic units lying unconformably above the Duplin Marl and Santee Limestone. It is exposed at the surface north and west of the Surry Scarp within the Eutawville Quadrangle and adjacent quadrangles.

Sediments of the Okefenokee Formation occur in radiating, slightly sinuous channel-like bodies trending at a high angle to the Surry Scarp and approximately parallelling the regional slope. They are apparently older than other post Late-Miocene units that are found southeast of the Surry Scarp.

The base of the Okefenokee Formation is highly variable in this area, but interpolation from regional drilling indicates an minimum altitude between + 60 to + 70 feet. In the vicinity of the Surry Scarp the formation has been eroded by recent subaerial processes as well as by post Okefenokee marine processes. The upper part of the formation lies at the surface within the channelled areas of the Okefenokee Terrace indicated on Figure 3, and has been mapped within this quadrangle as shown on Figures 6 and 7. It also occurs within adjacent quadrangles. Stratigraphically it is a mappable unit which is separate and distinct from other established formations within the area. It is composed of two dominant members, which are intergradational both laterally and vertically which is shown by many of the drilled holes and surface exposures. These lithofacies are herein designated informally the Holly Hill and Eutawville members (Figure 5).

The Holly Hill member, named after the town of Holly Hill in the west central portion of the quadrangle, generally occurs near the base of Okefenokee Formation, although lenses may be present at varying altitudes throughout the channel-like bodies. This member may be as much as 30 feet thick in the central channel areas but is laterally much thinner away from this area. Two dominant lithofacies frequently are present. Conglomerates consisting of subangular to well-rounded, subspherical quartz pebbles with some sand often are found immediately adjacent to the Tertiary bedrock, but may occur as lenses and discontinuous beds anywhere within the Holly Hill member. Along the south shore of Lake Marion this lithofacies may be as much as 4 feet in

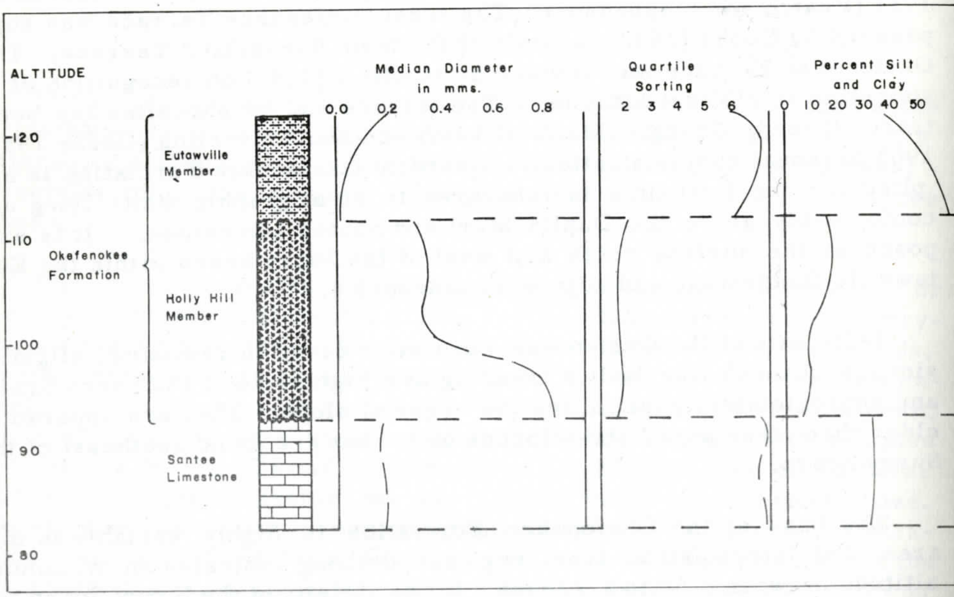

Figure 5. Sedimentary parameters in Drill Hole Orangeburg Number 56.

thickness. The major portion of the Holly Hill member is composed of a second lithic type which consists of moderately well-sorted to well-sorted (1.5 - 2.5) orthoquartzitic, or occasionally subarkosic (Pettijohn, 1956) sand. The sand grains are angular and not appreciably abraded. Occasionally pebbles occur within this unit in very thin discontinuous lenses. The pebbles are subrounded to well-rounded and rarely exceed one inch in diameter. Clay balls can be quite common within the unit. Moderately fresh feldspar pebbles have been obtained from drill holes, and weathering of feldspar is represented in the lake cliffs where the pebbles have been altered to clay. The sand lithofacies of the Holly Hill member frequently exhibits cross bedding and only rarely beds can be traced over short distances. However, toward the upper portion of the formation, rather thin discontinuous sand beds can be traced for distances up to 8 or 10 feet. Small angular local unconformities are common within the Holly Hill member. An average of 9 size analyses of very slightly contaminated sediments indicates a silt and clay percentage of 17.14 percent, a median diameter of 0.363 mm, and a sorting factor of 2.17 for the Holly Hill member.

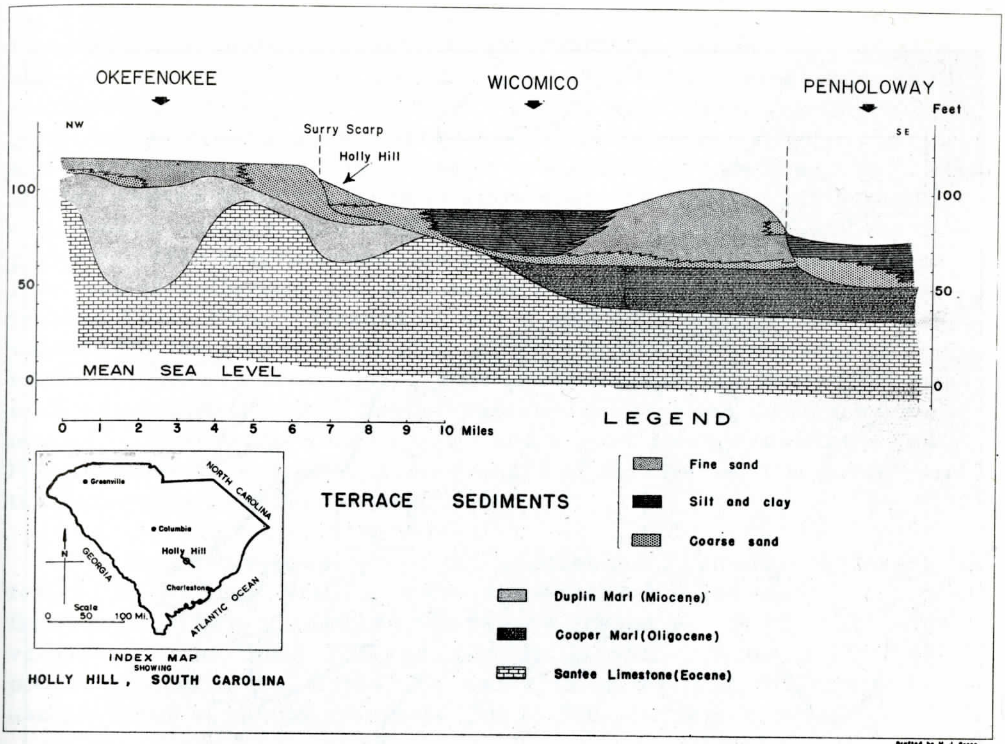

Figure 6. Cross section drawn northwest-southeast through Holly Hill, South Carolina, along U. S. 178.

The Eutawville member, named after Eutawville in the central portion of the Eutawville Quadrangle, generally occurs near the top of the Okefenokee Formation and may be up to 20 feet thick. It is developed most widely away from the center of the channelled areas. It is a fine-grained, silty, clayey, very poorly-sorted (over 5.0) sand. It frequently appears massive to blocky in fresh cuts but has been observed to be thinly laminated. Soil developed from it is red, while the fresh material is light to medium gray. An average of 16 size analyses of very slightly contaminated sediments indicates a silt and clay percentage of 42.82 percent and a median diameter of 0.207 for the Eutawville member. Differentiation of the Eutawville member and the Duplin Marl, within their respective soil profiles, has proved exceedingly difficult without recourse to size analyses. Size analyses of samples taken at each drill location usually show sufficient change in median diameter and size grade distribution to allow a significant contact to be drawn between many of the drilled holes.

Grain-size characteristics of the Okefenokee Formation within the Eutawville Quadrangle are illustrated in Figure 7, a tripartite lithofacies map produced by averaging the size analysis for all samples taken from each drill hole and weighting the results equally at each

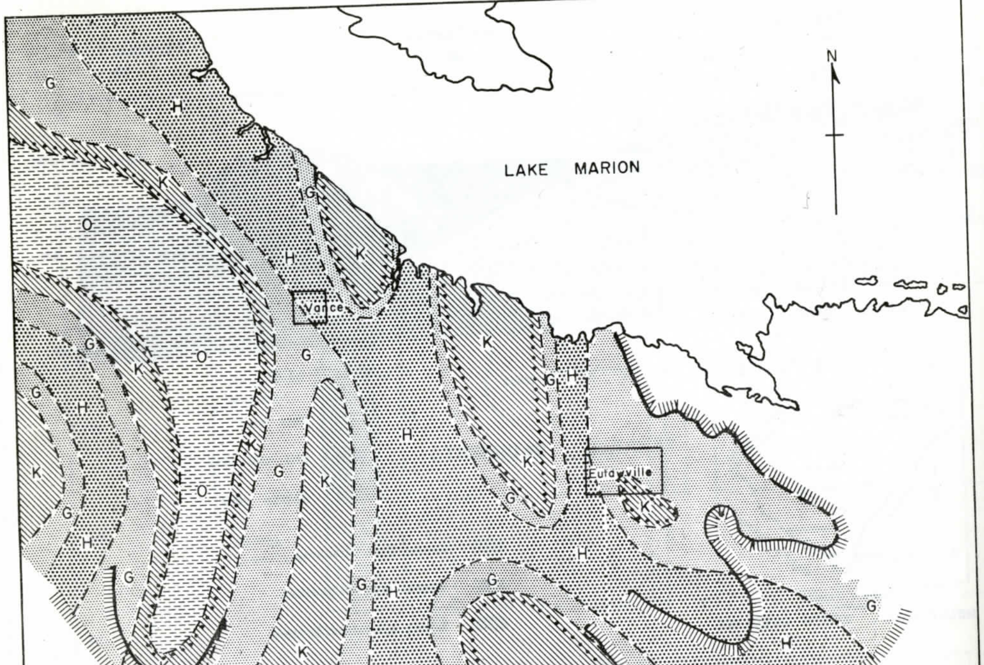

Figure 7. LITHOFACIES MAP of SURFICIAL SEDIMENTARY UNIT and COLLUVIUM EUTAWVILLE QUADRANGLE, SOUTH CAROLINA.

location. The analyses were: 1) subdivided into percent silt and clay, and percent coarse and medium sand of the total sand fraction; 2) plotted on a triangular diagram, and 3) subdivided into three-fold grades. The resulting map, therefore, illustrates variation in medium and coarse sand as well as variation in silt and clay. Of necessity the grades chosen were too large to allow sharp delineation of the Duplin-Okefenokee contact on a regional basis for reasons previously explained. The diagram contains parameters developed from the upper five feet of colluvium and soil on the Duplin Marl as well as the Okefenokee Formation. Grades O and K reflect colluvium and soil developed on the Duplin Marl while K, G, and H reflect the results from total Okefenokee Formation. Grade L, developed near Holly Hill, possibly represents a unit of limited extent older than the Okefenokee Formation. Comparison of Figure 7 and Figure 3 suggest that the Holly Hill member is dominant in the troughs of the channel-like areas, and the Eutawville member on the flanks.

The Eutawville member of the Okefenokee Formation is characterized by difficult drilling above the water table and moderately difficult drilling below it (600 to 800 pounds pressure). A soil profile developed on the Holly Hill member drills with difficulty (600 to 800 pounds pressure) but below the water table the Holly Hill member is usually much easier to penetrate (200 to 300 pounds pressure).

From the foregoing discussion it is apparent that a stratigraphic unit, hitherto unmapped in detail, is present within this area, and occupies a significant portion of the Okefenokee Terrace. This unit, herein identified tentatively as the Okefenokee Formation, has an uncomfortable relationship with surficial sediments underlying the Wicomico Terrace southeast of the Surry Scarp. This relationship can be demonstrated locally as illustrated in Figure 6, or regionally as indicated in Figure 7. Transitional rock-stratigraphic correlation between the Okefenokee and Wicomico Formations (as mapped by Cooke, 1936, 1954) cannot be demonstrated within the Eutawville Quadrangle. Moreover reference to Figure 3 indicates that the minimum altitude of the Wicomico Formation is approximately 40 to 50 feet, while that of the Okefenokee Formation is approximately 60 to 70 feet, even where they lie in close proximity.

<u>Interpretation</u>. From the preceding observations, it is apparent that the Okefenokee Formation is composed of two dominant lithofacies herein informally designated the Holly Hill and Eutawville members. The Okefenokee Formation is thought to have been deposited by alluvial processes in a valley-flat environment and the Holly Hill and Mill Creek members to represent channel sand, point bar, natural levee, and over bank deposits. The difficulty in distinguishing between

channel and overbank deposits has been noted by Wolman and Leopold (1957).

The Okefenokee Formation occupies broad channels, surficially resembling floodplains, floored by the Santee Limestone. The valley walls are composed of Santee Limestone and Duplin Marl. The channels are developed at a high angle to the Surry Scarp, roughly parallelling the regional slope. The abandoning of channel courses in favor of other channels within the complex can be envisioned since the Duplin Marl, through which the channels largely cut, is unconsolidated and is composed dominantly of those size grades which Hjulstrom (1955) has indicated to be most susceptible to erosion by running water.

The Holly Hill member was deposited in a high energy environment. The presence of torrential cross bedding, scour and fill structures, moderate to good quartile sorting (1.5 to 2.5) and large (when Coastal Plain sediments of this area are considered in toto)median diameter are noteworthy. Bimodal curves have been developed from grain size analyses. The lithofacies map indicates that this environment was developed along the channels and more commonly towards the center of the channels. The Holly Hill member is developed more commonly near the base of the channels where a basal gravel is present, but the facies has been observed at varying altitudes within the formation. The Holly Hill member is immature when compared mineralogically with other marine surficial sediments southeast of the Surry Scarp. Orthoclase feldspar pebbles are found commonly within the unit. The heavy mineral suite obtained from the Holly Hill member has not been studied thoroughly. Theseobservations indicate a channel origin in an alluvial environment could have formed much of the member.

The Eutawville member of the Okefenokee Formation was deposited in a low energy environment. Within the channel complexes this lithofacies occurs upward in the stratigraphic sequency more commonly, and really is more widespread than the Holly Hill member. The locally banded structure, very thin discontinuous laminations, local stringers of sand, clay or gravel, moderate to poor sorting factor, and generally much lower median diameter, are noteworthy. These observations indicate an overbank origin in an alluvial environment for part of the member.

A general correspondence between the Okefenokee Formation and floodplains of rivers currently active in this region is apparent. Cross sections of river floodplains in the Carolinas have been illustrated and discussed by Wolman and Leopold (1957, p. 104).

Immediately adjacent to the map area closely spaced borings across the Santee River indicate a lithofacies variation within the present

Santee River floodplain (now underlying Lake Marion) generally similar to the variation observed within the Okefenokee Formation. Comparison of size distribution curves obtained from samples taken from streams in the Coastal Plain Province of this region are generally similar to some of the curves obtained from Okefenokee sediments but detailed study is yet to be completed.

The Okefenokee Formation is considered to be older than surficial strata lying southeast of the Surry Scarp. An unconformity lying at the base of the Wicomico Formation intersects the surface adjacent to the Surry Scarp and precludes correlation across the Okefenokee and Wicomico Terraces. Moreover, as will be demonstrated in a subsequent paper by Colquhoun, the channel and overbank phase of the Wicomico Formation lies at a considerably lower altitude than the minimum altitude of the Okefenokee Formation even where these are in close proximity.

The Okefenokee Formation is considered to be post Late-Miocene in age because it unconformably truncates the Duplin Marl. It is in turn eroded and overlain by surficial sediments underlying the Wicomico and Penholoway Terraces and, therefore, must be younger than these. Fossils collected by the senior author from surficial sediments underlying the Penholoway and Wicomico Terraces have been tentatively correlated by Du Bar (personal communication 1961) with the Waccamaw fauna of the Carolinas (Du Bar 1959, 1962). The Okefenokee Formation in a time-rock sense is, therefore, post Duplin Marl and, tentatively, pre-Waccamaw Formation.

CONCLUSION

From the foregoing evidence and interpretation it is apparent that in central South Carolina the Okefenokee Terrace is underlain by at least three stratigraphic units exposed at or very close to the surface: the Santee Limestone, the Duplin Marl, and the Okefenokee Formation.

The Santee Limestone, considered as a rock-stratigraphic unit, cannot be subdivided. The solution topography developed on its surface and well expressed (though masked by thin sands) in the Eutawville area is in part of pre-late Miocene age but possibly largely post-Late Miocene.

The Duplin Marl at the surface and for depths up to 20 feet below the surface is generally unfossiliferous because of intensive weathering which has produced a very thick leached zone. Without recourse to drilling and size and mineralogical analysis, the Duplin Marl may be confused easily with the Okefenokee Formation over broad areas of the Okefenokee Terrace, since in their soil profiles they are very similar (Figures 2 and 5).

The Okefenokee Formation is an alluvial rock-stratigraphic unit which is younger than the Duplin Marl but older than terrace sediments toward the southeast.

The topography developed between the northwesterly lying Citronelle Escarpment near Orangeburg, South Carolina, and the Surry Scarp toward the southeast near Holly Hill, South Carolina, is of composite origin. Its relative flatness compared to terrain northwest of the Citronelle Escarpment is controlled initially by Miocene transgression and deposition and possibly by Oligocene transgression (Colquhoun, 1962), coupled with subsequent alluvial fan deposition (Doering, 1960). The Duplin Marl occurs southeast of the Citronelle Escarpment but not to the northwest (W. K. Pooser, 1961, personal communication). The overlying stratigraphic units are alluvial in nature and not marine (Colquhoun, 1962). In the Eutawville and adjacent quadrangles this surface has been modified by fluvial valley scour and valley fill as represented by the Okefenokee Formation. The Okefenokee Formation is a channel and floodplain deposit and may have been controlled by a rise in sea level prior to the marine transgression that cut the Surry Scarp and formed the Wicomico Terrace. The Surry Scarp constitutes, therefore, an important stratigraphic boundary on the Coastal Plain. It separates two distinct stratigraphic sequences, the alluvial Okefenokee Formation from the Wicomico.

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GRAVITY STUDIES IN THE CONCORD QUADRANGLE, NORTH CAROLINA

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ABSTRACT

215 gravity stations have been computed in the Concord quadrangle of North Carolina, and simple Bouguer and residual gravity anomaly maps have been constructed from the gravity data. The distribution of anomalies shows excellent correlation with a previous geologic reconnaissance map.

Gravity anomalies outline two sharply discordant plutons. The first is a circular, steep-walled, granite stock (-24 mgal.); the second is an irregular intrusion of gabbro (+35 mgal.) which is almost entirely within the Concord syenite ring-dike. The structure of the ring-dike is partly clarified by the gravity studies. There seems to be no central subsidence of the gabbro into a less-dense differentiate of syenite. The syenite probably was intruded into a shear zone around the margins of the earlier gabbro.

The other rocks within the quadrangle, granite, granodiorite, and diorite, have irregular and ill-defined anomalies ranging from + 14 to -7 mgal. These rocks are apparently part of an earlier rock series.

INTRODUCTION

The purpose of this paper is to present the results of a gravity study of the Concord quadrangle of North Carolina. A gravity survey of the quadrangle was made and the data were analyzed with respect to a geologic map of the area (Bell, 1960). The data from the survey were used to compute simple Bouguer and residual anomaly gravity maps.

The Concord quadrangle is a 15 minute quadrangle and is a part of Cabarrus and Mecklenburg counties. The area is immediately to the northeast of Charlotte, North Carolina (Figure 1).

ACKNOWLEDGEMENTS

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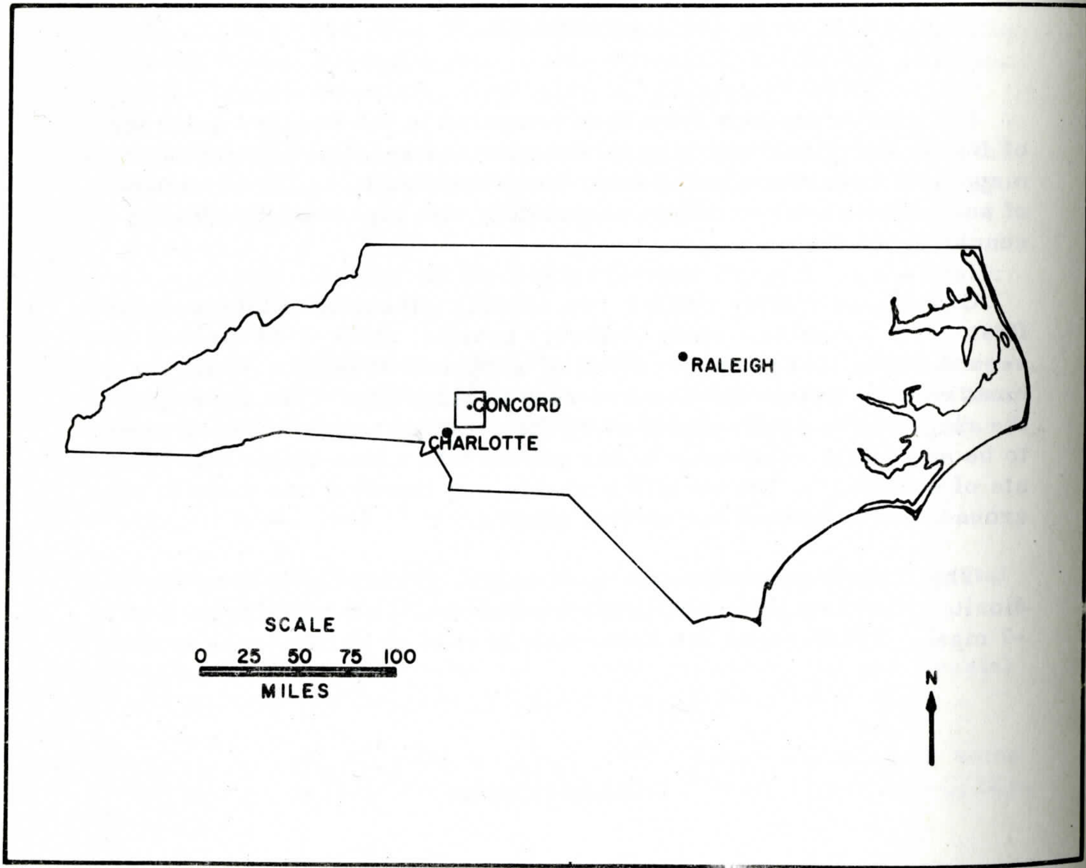

Figure 1. Index Map Showing the Location of the Concord Quadrangle, North Carolina

previously unpublished M. A. thesis (1963).

GEOLOGY

The crystalline rocks of the Southeastern Piedmont are divided into narrow belts which persist for long distances along their strikes. King (1955) designated five such crystalline belts within the Piedmont province: the Brevard belt, the Inner Piedmont belt, the Kings Mountain belt, the Charlotte belt, and the Carolina Slate belt. The Concord quadrangle lies near the Southeastern edge of the Charlotte belt.

The rocks of the Charlotte belt are predominately plutonic and were emplaced during the Paleozoic Era (King, 1955, p. 335). These rocks are inter-related in a complex manner. Granite and closely allied rocks were thought to be the major rock type; however, outcrops of granitic rocks are discontinuous and are scattered widely throughout the belt. Extensive areas are occupied by dark diorites and gabbros. Boundaries between the granitic and gabbroic intrusions are obscure and these rocks collectively have been described by LeGrand and Mundorff (1952, p. 8) as a "granite-diorite injection complex." Such a complex contains thin stringers or pods of granite and diorite-gabbro intermingled in varying proportions. The regional geology map shown in Figure 2 shows the relationship of the Concord quadrangle to the Charlotte belt in North Carolina.

Henry Bell published a reconnaissance map of the Concord quadrangle and has since continued extensive studies of the area. His preliminary report discusses briefly the geology of the quadrangle (Bell, 1960, p. 189-191):

> "In the Concord area the rocks of the Charlotte belt consist of granitic and granodioritic gneisses, massive and foliated dioritic and mafic rocks, and small bodies of granite. Some of the granite bodies are coarse-grained and one pluton of circular outline which extends into the northern part of the area consists of porphyritic andesite, pyroxenite, granite, pegmatite, syenite, and lamprophyres. The largest dikes, which consist of light colored coarse-grained augite syenite, form a partial ring structure near the center of the area. The ring structure is not so complete as it was thought to be by LeGrand and Mundorff.

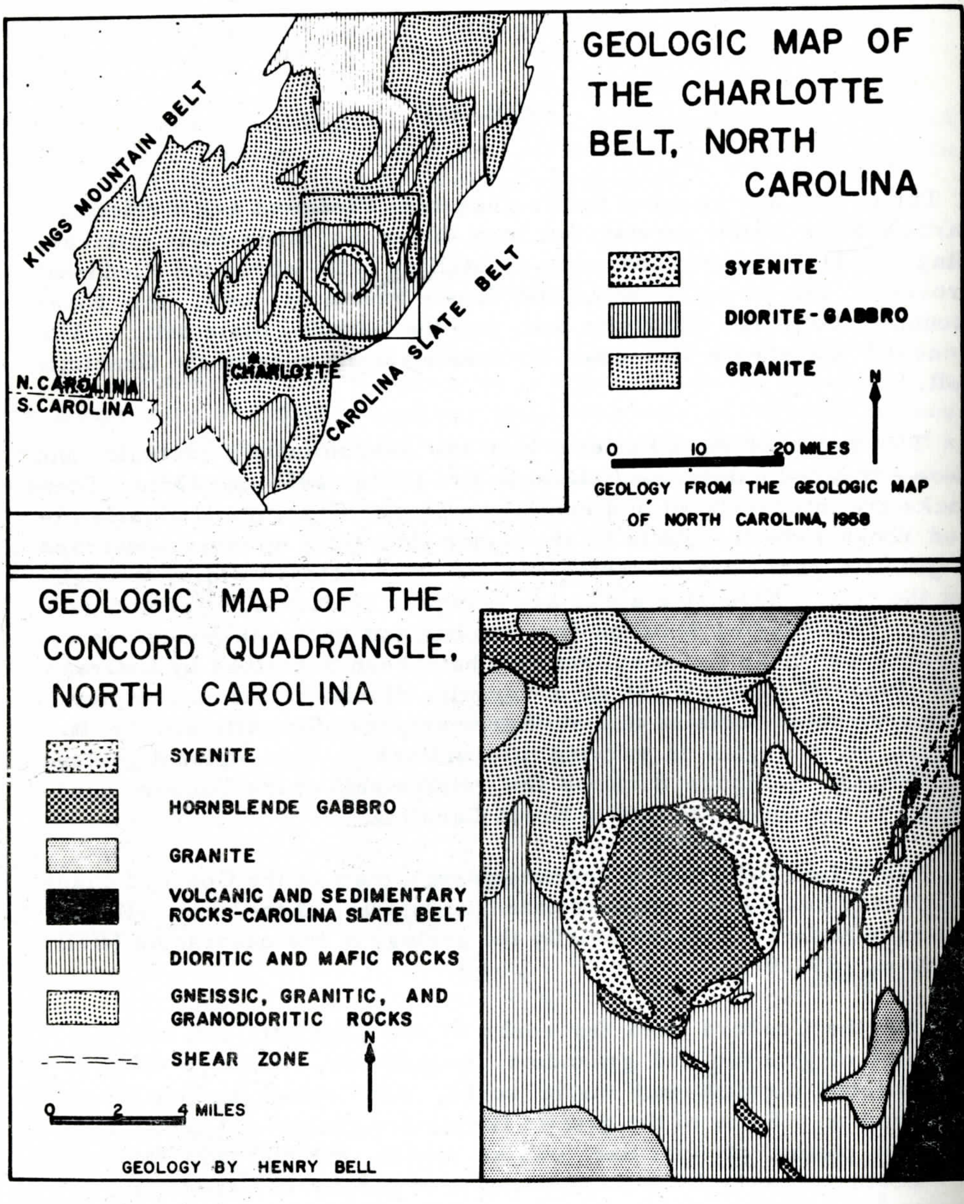

Figure 2. Geologic Maps of the Concord Area, North Carolina

Closely associated with the syenite is a large mass of coarse-grained hornblende gabbro."

The geologic map of the Concord quadrangle shown in Figure 2 is a copy of the map published by Bell (1960, p. 190).

GRAVITY

General Statement

A gravity survey of the Concord quadrangle has given data which may be applied to two problems. First, the boundaries of post-orogenic intrusions can be more precisely located. This is especially important in an area of widely scattered outcrops such as this portion of the Southeastern Piedmont. Second, the gravity data can add a third dimension to the geologic map. An accurate interpretation of the distribution of certain rock masses at depth can be determined from the anomaly patterns.

During the spring of 1961, 215 gravity stations were established in the Concord quadrangle. These stations were placed at approximately one mile intervals along all roads within the quadrangle. An evenly spaced grid of gravity stations was possible because of the widespread distribution of both highway and rural access roads. The gravity readings were made with Worden gravimeter no. 121 which has a sensitivity of 0.3187 milligals per scale division. Regional stations had previously been determined by Woollard, Mann, and Guidroz.

A Paulin altimeter was used to determine the elevations of the stations. The drift of the altimeter was corrected at least once each hour by tying into benchmarks. The elevations that were determined had an accuracy of at least plus or minus five feet.

All gravity stations were tied into the station at Chapel Hill, North Carolina which was established by Woollard and Mann in 1956. This station is part of the international network of gravity stations.

The simple Bouguer anomaly was obtained by the formula: observed gravity - theoretical gravity + elevation correction = Bouguer anomaly. The elevation correction is a combination of the free air correction and the Bouguer correction. The free air correction adjusts all gravity readings to a common base level (sea level) and is a

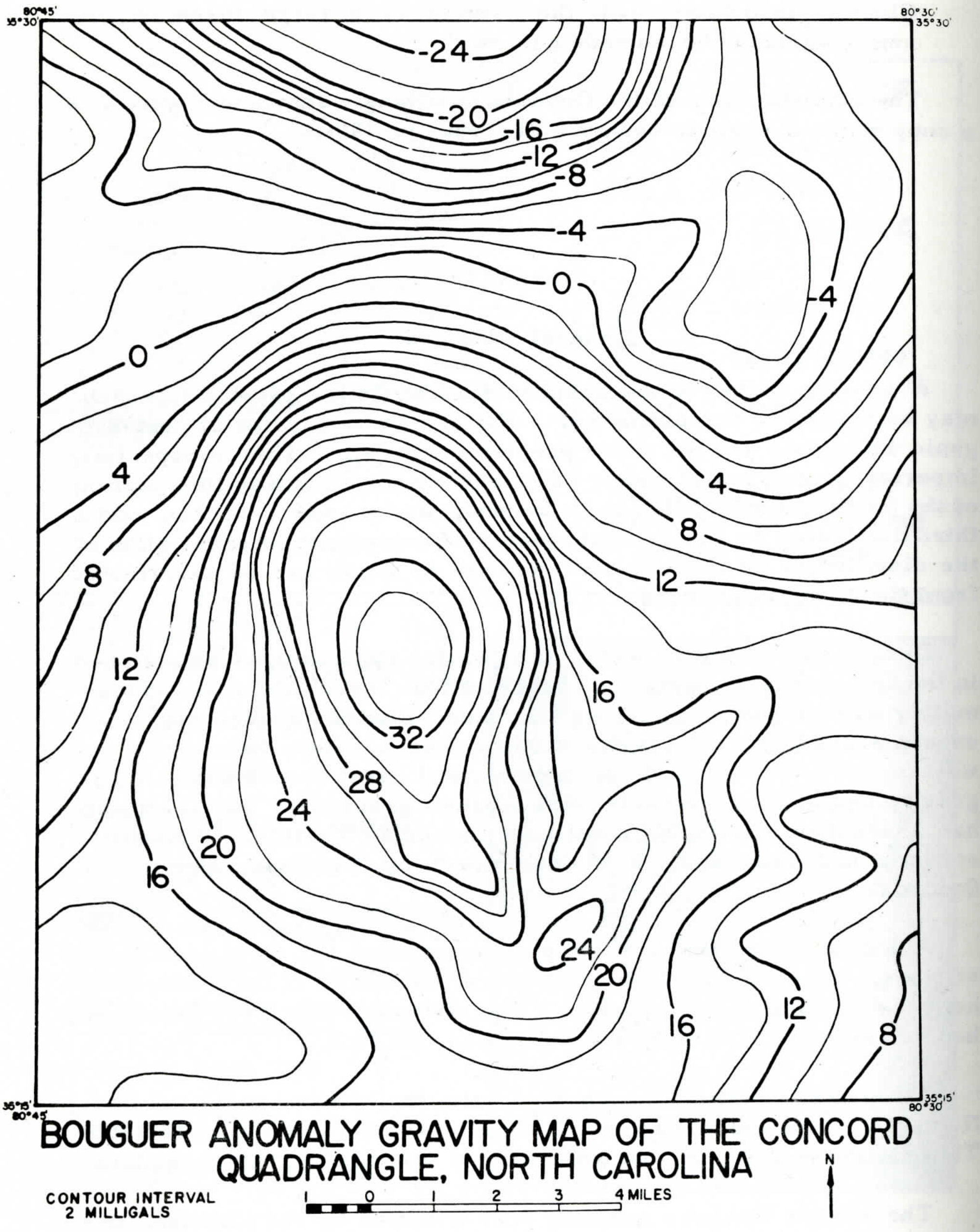

Figure 3. Bouguer Anomaly Gravity Map of the Concord Quadrangle, North Carolina

correction only for the height above the base level. It is added to the observed gravity. The Bouguer correction accounts for the attraction of rock material between the base level and the station level. Assuming a density of 2.67, this material is subtracted from the observed gravity value by subtracting the Bouguer correction. The resulting elevation is the free air correction minus the Bouguer correction which is 0.094 - 0.034 = 0.06 milligals per foot. The computations for the simple Bouguer anomaly were checked by duplicate computations on IBM cards by the Geophysics Department of the University of Wisconsin. Bouguer values of rocks with a specific gravity of 2.67 were used for making all corrections in order to develop a uniform pattern. No terrain corrections were made.

The Bouguer anomaly values have been depicted in two ways: as a simple Bouguer anomaly gravity map (Figure 3), and as a residual anomaly gravity map (Figure 4). The values were plotted on a base map taken from the Cabarrus County road map which is printed by the Highway Commission of North Carolina.

Simple Bouguer Anomaly Gravity Map

The simple Bouguer anomaly gravity map was constructed by plotting the simple Bouguer anomaly values on the base map. These values served as the guide points for an isogal contour map having a contour interval of 2 milligals.

The Bouguer anomaly gravity map shows a very close correlation with the geologic map of the quadrangle (compare Figures 2 and 3). Two geologic units dominate the gravitational configuration. The first is a relatively unaltered porphyritic granite stock in the north central portion of the quadrangle. The second is the hornblende gabbro stock in the center of the quadrangle.

The granite stock, only one half of which is within the quadrangle, has a considerable mass deficiency in comparison to the surrounding gneissic, granitic and granodioritic rocks. The Bouguer values decrease sharply away from the contact and reach a minimum of -24.8 milligals near the northern boundary of the quadrangle. The configuration of the anomaly is almost perfectly concentric with the contacts of the granite stock; the -18 isogal falls almost exactly on the contact. The pattern is maintained to about the -4 isogal indicating that the granite stock dips steeply outward away from the center as it extends into the crust.

The intrusion of hornblende gabbro is closely delineated by a pronounced anomaly which dominates the central portion of the quadrangle.

The anomaly reaches a maximum of 35.5 milligals near the center of the intrusion and about one mile southwest of Roberta Mills. The anomaly associated with the gabbro does not parallel the outcrop pattern as closely as does the gravity pattern over the granite stock north of the gabbro. The gabbro anomaly is elliptical having a steep gradient only on the northern sides where it is modified by the more felsic country rock. The more southerly portion of the anomaly widens over the geologic unit labeled dioritic and mafic rock. A persistently high gravity ridge is associated with the discontinuous bodies of hornblende gabbro south of the main intrusion. In the extreme northwest portion of the map, a small body of hornblende gabbro gives rise to a slight positive adjustment in the otherwise negative-trending anomaly. If the gabbros are all related, only the southern group appears to be continuous at depth. Reconnaissance investigation of the small northwestern outcrop of gabbro revealed that it is more mafic than the other gabbros and that it is highly serpentinized. Extensive serpentinization of this gabbro would result in a loss in mass; hence the resulting gravity anomaly would be considerably reduced.

The syenite ring-dike, closely associated with the central mass of gabbro, does not appear to modify the simple Bouguer gravity anomaly significantly.

In the northeast portion of the geology map, a wide expanse of gneissic, granitic, and granodioritic rocks is accompanied by a broad gentle negative anomaly having a minimum of only -7.3 milligals. Inasmuch as these rocks do not seem to have downward extending projections or roots that would extensively affect the anomaly configurations, the writers conclude that these rocks belong to an earlier series and are syntectonic and/or are non-magmatic.

A somewhat similar anomaly is associated with the granite body in the southwestern portion of the quadrangle. The anomaly is broad and featureless, having a minimum of +12.4 milligals. This granite body is a small portion of a much larger granitic intrusion of batholithic extent which has been called the Mecklenburg granite. This granite group is everywhere associated with a moderately low positive anomaly and may, like the rocks in the northeast portion of the Concord quadrangle, be a syntectonic or metamorphic granite.

A small granite body in the southeast portion of the quadrangle is marked by an extremely irregular but not intense anomaly. Such irregularity could be the result of interfingering of dioritic and granitic units.

The contact between the Charlotte belt and the Carolina Slate belt is in the extreme southeast corner of the quadrangle. The isogals are parallel to this contact, but are otherwise essentially featureless.

The southern portion of the main anomaly associated with the hornblende gabbro is offset to the northeast. At first glance, it appears to be associated with the shear zone on the geologic map of the quadrangle. Further inspection shows, however, that the offset of the anomalies is southeast of the shear zone which Bell mapped. Examination of the regional and residual maps which follows would seem to indicate that the offset is more likely the result of superposition of deep-seated regional northeast-southwest trends upon local, shallow northwest-southeast trends. However, the possibility of a shear surface dipping steeply to the southeast cannot be entirely discounted.

Regional Anomaly Gravity Map

A regional anomaly gravity map was derived from the simple Bouguer anomaly gravity map of the state of North Carolina (Mann, 1962). Extrapolation of regional gravity trends across the quadrangle produced a series of smooth isogals. As a result, the gravitational patterns for the regional gravity map of the Concord quadrangle represent a portion of broad sweeping gravitational trends which embrace an area more than ten times that of the Concord quadrangle itself.

These gravitational trends are northeast-southwest to east-west and roughly parallel the regional structure of the Southeastern Piedmont. Values become increasingly negative toward the northwest corner of the map. An east-west series of isogals form a band across the center of the quadrangle.

Residual Anomaly Gravity Map

The residual anomaly gravity map (Figure 4) was computed from the Bouguer and regional anomaly gravity maps. The regional map was superimposed on the Bouguer map. Intersection points of the two sets of isogals were ploted on a third map. At every intersection, the value of the regional isogal was subtracted from the value of the Bouguer anomaly isogal. The resulting number was suffixed to the plotted intersection points on the third map, and these values were contoured to form the residual anomaly gravity map. The residual anomaly map supposedly represents the gravitational distribution only of shallow, near surface, and entirely local phenomenon. The residual anomalies are interpreted as being related only to near surface mass-distributions within the Concord quadrangle because the effect of deep

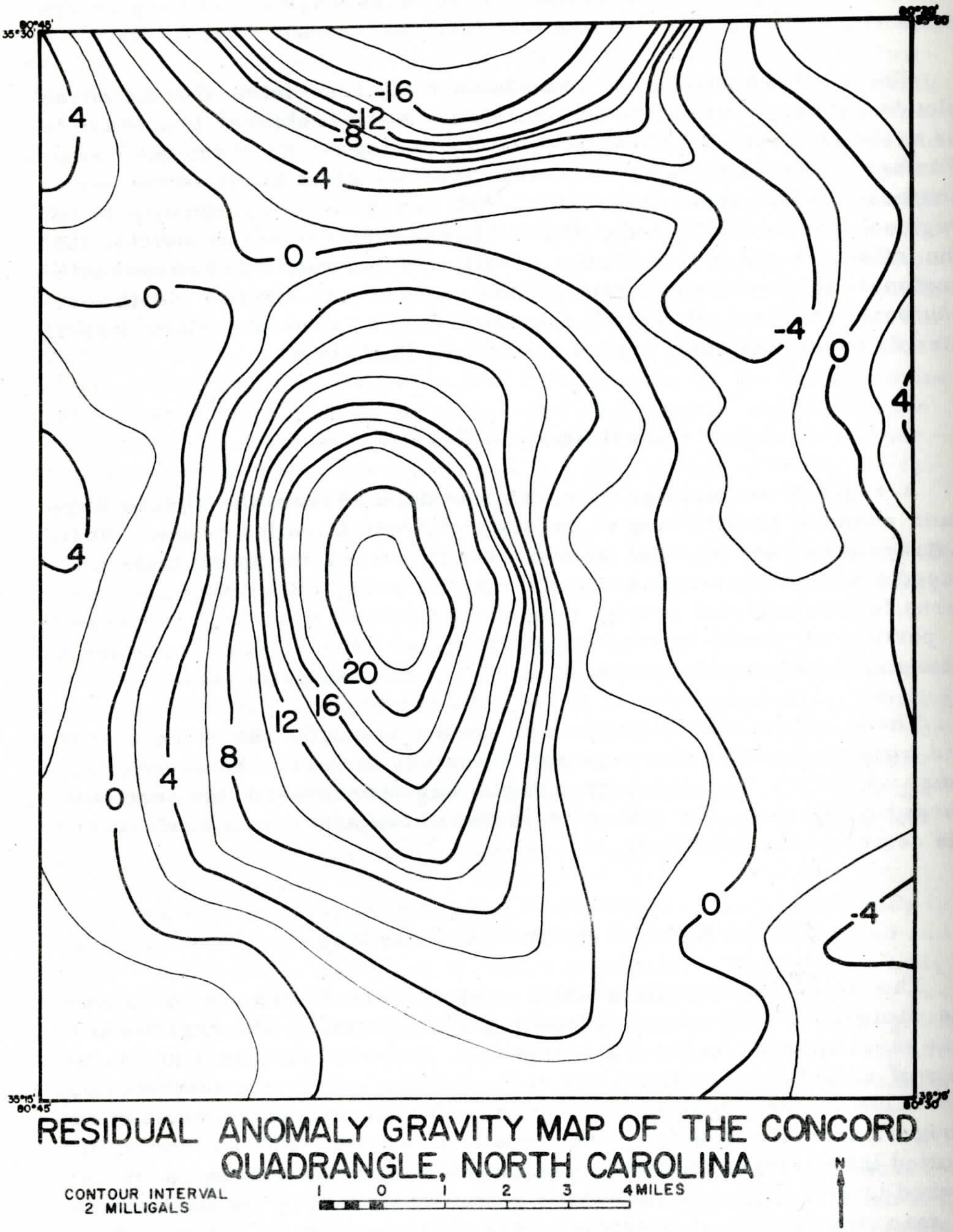

Figure 4. Residual Anomaly Gravity Map of the Concord Quadrangle, North Carolina

seated and regional trends has been subtracted.

Examination of the residual anomaly gravity map enables one to refine observations that were previously made from an inspection of the simple Bouguer map. The residual map is still dominated by two distinct anomalies: (1) a negative residual anomaly of - 18 milligals associated with a small granite stock in the north central portion of the quadrangle; and (2) a positive residual anomaly of + 22 milligals associated with the gabbro intrusion in the center of the quadrangle. This anomaly has been shifted slightly to the north and to the west as a result of the removal of the northeast-negative trends of the residual map.

When the residual gravity map is related to known geology, certain interpretations may be made about the geology of the Concord quadrangle.

The gravity gradients suggest that the granite stock has much steeper contacts than could have been inferred from the simple Bouguer map. Further, the stock seems to be quite distinct from any other granitic body within the quadrangle.

The gabbroic pluton is strikingly discordant to general structural trends in the Piedmont. The pluton forms an almost completely isolated mass within the Charlotte belt. The small gabbro intrusion in the northwest corner of the quadrangle is not connected to the main body of gabbro. However, the isolated intrusions to the south are a part of the larger subsurface body of gabbro. The gabbro intrusion does not dip outward as steeply as does the granite stock immediately to the north.

The other granitic bodies within the quadrangle, the portion of the Mecklenburg granite, and granites in the northeast and southeast portions of the quadrangle, have very similar residual anomalies. The isogals sweep around the boundaries of these bodies but do not delineate these plutons very sharply. The residual values range from 0 to -4 milligals. These granites seem to be related to one another from the standpoint of mass distributions. If these granites are magmatic, the "roots" of these plutons cannot extend to great depths. This is also what one might expect if the granites were magmatic, but were emplaced during tectonic activity rather than after the disturbance.

Structural relations are not interpretable from the residual anomaly gravity map. Zones of shearing are not reflected by any distortion of the isogals, and the boundary between the Charlotte belt and the Carolina Slate belt is not marked by any anomaly.

CONCLUSIONS

Several conclusions may be drawn from the gravity studies:

1. On the basis of gravity anomalies, the plutonic rocks of the Concord quadrangle may be divided into two series: the first series is marked by a poorly defined set of anomalies that do not outline accurately the outcrop patterns of those rocks; the second series is marked by a strongly defined set of anomalies that more accurately outline the outcrop patterns of that series.

2. The rocks which are strongly outlined by gravity anomalies, although quite different in composition, are coarse-grained, unmetamorphosed, and apparently strongly discordant to the regional structure. To the present authors these rocks appear to have an igneous origin, and because they must project downward some distance into the crust, their "roots" have not been destroyed by later orogeny; hence, they are post-orogenic.

3. The rocks which are poorly outlined by gravity anomalies, although quite different in composition also, are generally finer-grained, and are often sheared, metamorphosed and lineated. From the gravity patterns the present authors conclude that these rocks are either igneous or sedimentary in origin, and that they do not have "roots" that extend to any depth into the crust. Either they never extended downward to any depth, or their roots were destroyed by subsequent orogeny. Hence, they are either metamorphic or were emplaced during a period of tectonic activity.

4. The origin and structure of the Concord ring-dike is one of the central problems in the quadrangle. The gravity survey shows that the gabbro stock which is enclosed by the ring-dike is a relatively steep-walled pluton. Also, the gravity evidence points out that the syenite ring-dike does not appreciably influence the anomaly, probably because the syenite is confined to the sides of the much denser gabbro. Theories of ring-dike emplacement have usually considered the subsidence of a central block into a less dense magma which subsequently welled up around the subsiding block to form a circular intrusion. The syenite ring-dike in the Concord quadrangle is quite wide, about one mile along the western side. Several miles of subsidence of the steep-walled gabbro stock would be necessary to create room for the syenite. The high residual anomaly of the gabbro does not support the idea of a central core subsiding into a less dense differentiate of syenite. It is more probable that the syenite was emplaced around a fracture zone

created by the intrusion of an earlier, highly discordant gabbro stock.

5. Finally, the variation of rock units can be quickly determined by the use of similar gravity studies in igneous and metamorphic terrain. This is of special importance to workers in the Southeastern Piedmont where outcrops are widely scattered and the bedrock is normally overlain by a thick layer of residual and alluvial soils. In such studies, changes in lithology are apt to be far more striking than the revelation of structural features such as faults, fold belts, or major unconformities.

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NOTES ON MARINE GEOLOGY OFF THE MOUTH OF THE NORTH EDISTO RIVER, SOUTH CAROLINA

by

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"The sea never changes,
and its works, for all the talk of men,
are wrapped in mystery."

-Joseph Conrad-

ABSTRACT

Bottom samples were collected along a ten mile traverse eastward from the mouth of the North Edisto River, South Carolina, on a one day exploratory cruise. The character of the samples and the general configuration of the sea floor indicate the area is divisible into inlet, delta, and shallow shelf environments.

The North Edisto inlet is the mouth of a tidal river characterized by a deeply scoured channel, coarse sand, shell hash, fresh whole valves of *Crassostrea virginica*, and phosphate pebbles.

A delta has been built outward about 3.5 nautical miles from the river mouth. It is predominantly coarse sand, and its asymmetrical

shape attests to a southwestward longshore current in the area. The shallow shelf seaward of the delta is composed predominantly of fine grained sand, and the bottom is characterized by eastward trending troughs and ridges that strongly resemble ancient offshore bars and beach ridges on the adjacent exposed Coastal Plain. Coarse sand and shell hash, worn shells, and brackish water species from one submerged ridge indicate that at least some of these features were formed or re-worked under high energy, beach conditions. Shelf sediments off the ridges are notably finer grained and better sorted than those from the other environments studied.

The heavy mineral suite is chiefly a rutile-epidote-hornblende association. Distinct differences in the relative amounts of the heavy minerals occur between the inlet-deltaic and shallow shelf environments. The submarine ridge is more similar mineralogically to near shore features than to normal shelf sediments.

The ridges on the shallow shelf were probably formed as offshore bars and beach ridges as the sea retreated at the close of the Sangamon Interglacial Stage. Their preservation on the present sea floor is thought to be due to quick flooding in a rapid advance of the post-Wisconsin sea.

INTRODUCTION

On April 19, 1963, a one day exploratory bottom sampling expedition was made out of Bears Bluff Laboratories, Wadmalaw Island, South Carolina, aboard the station's 65 foot research vessel, T-19. Aboard were Captain C. B. Stevens, two crewmen (Henry W. Hodges and Henry L. Welch), J. R. Du Bar, C. J. Cazeau, Henry Bell III, D. J. Colquhoun, Donald Secor, T. L. Burnett, Charles M. Bearden, Reid Wiseman, and Henry S. Johnson, Jr.

Six bottom samples (BB-1 through BB-6) were taken with a 6" x 2' tubular dredge (Figure 1) at points along a 10 mile traverse extending southeastward from the mouth of the North Edisto River. Additional samples (BB-7 through BB-11), predominantly fauna, were collected with a 3 foot triangular wire dredge and a 20 foot trawl. Figure 2 shows the track of the boat, sample locations, soundings, and the general character and configuration of the bottom off the mouth of the North Edisto River.

The mechanical analyses and heavy mineral investigations reported

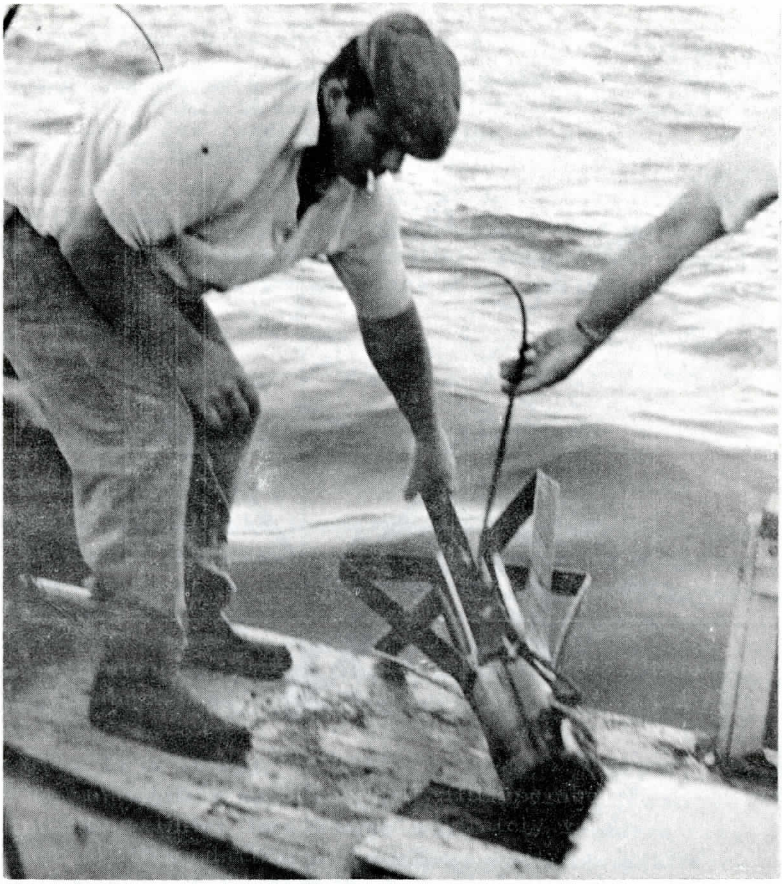

Figure 1. Tubular dredge being hauled aboard T-19.

herein were carried out by Cazeau, and the faunal studies were made by Du Bar.

ACKNOWLEDGMENTS

Dr. G. Robert Lunz, Director, Bears Bluff Laboratories, made the trip possible by providing boat and crew and overnight housing. T. L. Burnett assisted in keeping the plot; and crew members and all biologists and geologists aboard helped in dredging, sorting, bagging, and labeling samples.

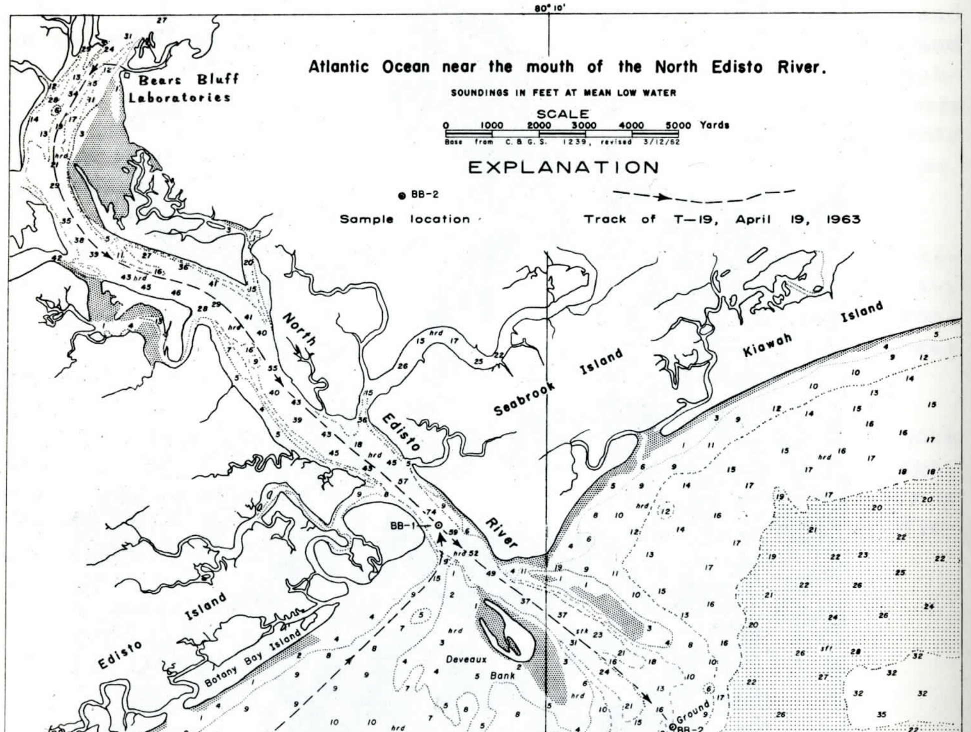
Atlantic Ocean near the mouth of the North Edisto River.
SOUNDINGS IN FEET AT MEAN LOW WATER
SCALE
0 1000 2000 3000 4000 5000 Yards
Base from C. & G. S. 1239, revised 3/12/62
EXPLANATION
BB-2
Sample location
Track of T—19, April 19, 1963
Bears Bluff Laboratories
North Edisto River
Seabrook Island
Kiawah Island
Edisto Island
Botany Bay Island
Frampton Inlet
Deveaux Bank
Middle Ground
BB-1
BB-2
BB-3
BB-4
BB-5
BB-6
BB-7
BB-8 to 11
80° 10'
32° 30'
Drafted by M. J. Green

Figure 2

SAMPLES

Table 1 gives numbers and field descriptions of samples taken. Figure 2 shows sample positions as plotted at sea on U. S. Coast and Geodetic Survey Chart 1239 by dead reckoning and comparison of continuous depth recorder readings with depths as shown on the chart. Sample points were chosen so as to obtain material from the North Edisto Inlet, the sub-sea delta, and the shallow ocean floor beyond the influence of the delta. Samples BB-5 and BB-6 were intended to allow comparison of eastward-trending parallel troughs and ridges on the sea floor (Figure 2) beyond the influence of the North Edisto delta.

TEMPERATURE AND SALINITY

The authors did not make temperature and salinity observations on the April 19 Bears Bluff cruise. General conditions in the sea a few miles off the mouth of the North Edisto are indicated, however, by Table 2, showing data collected on the nine Gill cruises conducted by the U. S. Bureau of Commercial Fisheries during the years 1953-54 (Anderson, Gehringer, and Cohen, 1956a, 1956b; Anderson and Gehringer, 1957a, 1957b, 1958, 1959a, 1959b, 1959c).

Gill Station 44 is at Lat. 32° 25' N., Long. 79° 50' W., approximately 14 nautical miles east-southeast of Bears Bluff sample BB-6. In general it can be seen that winter water temperatures range from about 13 to 16° C (55 to 60° F), and summer water temperatures range from about 27 to 28° C (81 to 82° F). Summer temperatures appear much more stable than winter temperatures. Salinities seem to follow no set pattern, though they may tend to be slightly higher during the fall and winter, possibly because of less stream discharge along the coast during these seasons.

Salinity data provided by G. R. Lunz, Bears Bluff Laboratories, for Station BB-3 (North Edisto Sea Buoy) show the effect of flow of the North Edisto River in this area. A total of 237 observations made over the period January 1953-July 1962 have a salinity range of 23.8 to 37.0, with the following monthly averages.

	Surface	Bottom	Difference
January	33.4	32.7	- 0.7
February	32.0	31.9	- .1

	Surface	Bottom	Difference
March	31.6	31.3	- .3
April	31.3	30.4	- .9
May	30.7	29.1	- 1.6
June	32.1	29.1	- 3.0
July	33.3	30.1	- 3.2
August	34.0	31.5	- 2.5
September	33.9	32.8	- 1.1
October	33.6	32.7	- .9
November	33.3	33.4	.1
December	33.4	33.8	.4

Table 1. Identification numbers and field descriptions of bottom samples, Bears Bluff Cruise, April 1963.

Sample	Field Description
BB-1	Bottom sample. Coarse sand with abundant *Ostrea* sp. and sparse phosphate pebbles. Everything dead. Taken from deep scour in main channel of North Edisto River. Water depth 70'.
BB-2	Bottom sample. Coarse sand with sparse to moderate shell. Contained one live specimen of *Mellita quinquesperforata*. Everything else dead. Water depth 15'.
BB-3	Bottom sample. Fine grained sand. Everything dead. Water depth 20 to 25'.
BB-4	Bottom sample. Fine grained shelly sand. Water depth 26'.
BB-5	Bottom sample. In trough. Fine grained sand. Water depth 40'.
BB-6	Bottom sample. On ridge. Coarse sand and shell. Water depth about 30'.
BB-7	Triangular dredge sample. Water depth about 20 to 25'.
BB-8 to BB-11	Triangular dredge samples. Abundant *Mulinia lateralis*. Water depth 12 to 15'.

Of the 237 observations, 73 were surface salinities and the remainder were bottom readings (depth approximately 21 feet). The

Table 2. Temperature and salinity data, Gill Cruises, Station 44

Cruise	Month	Depth(m)	Temperature (^oC)	Salinity[1]
1	February	1	13.39	34.92
		10	13.40	34.99
2	May	1	22.01	33.58
		10	19.59	34.36
3	August	1	28.26	34.97
		10	28.32	34.96
4	October	1	22.20	36.06
		10	22.23	36.04
5	February	1	12.46	35.55
		10	12.52	35.71
7	July	1	27.69	35.64
		10	27.21	35.39
8	September	1	27.30	36.08
		10	27.32	36.07
9	December	1	16.53	36.36
		10	16.56	36.35

[1]Parts per 1000.

monthly averages and differences between surface and bottom salinities reflect the effects of temperature and salinity stratification, the volume of flow of the North Edisto River, and possibly increased surface evaporation during the summer months.

It is noted that bottom salinities appear lowest during May and June. This is interpreted as due to increased flow of the river during the spring and early summer.

The difference between surface and bottom salinity is greatest during the summer months. This is thought to be due primarily to a temperature stratification between cooler river waters and warmer ocean waters. This temperature difference is apparently great enough to overcome any density differences between the more saline ocean waters and the fresher river waters except during the coldest winter months, when river and ocean temperatures are probably closest.

It is not known what part the long days and hot sun of the summer months may play in the increased surface salinities of summer.

BOTTOM CONFIGURATION AND SEDIMENTARY ENVIRONMENTS

The configuration of the inlet and sea bottom in the vicinity of the mouth of the North Edisto River, as indicated by depths shown on Figure 2, shows the area to be readily divisible into inlet, delta, and shallow shelf environments.

Inlet

The inlet and lower portion of the tidal river is characterized by a nearly straight, deeply scoured channel through which great volumes of water rush with each tide. The bottom sediment consists predominantly of coarse sand, coarse shell hash, dead whole shells, and phosphate pebbles. Living mollusks are sparse or absent in this high energy environment.

Delta

The strong river current apparently decreases rapidly once it enters the sea, and a delta has been built up on the sea floor for a distance of about 3.5 nautical miles out from the mouth of the North Edisto. From a 70 foot deep scour in the river mouth, the water shoals abruptly to 0 to 10 feet (mlw) over most of the delta. The delta is characterized by coarse sand similar to that in the tidal inlet and river channel and entirely different from the fine grained sand of the surrounding shallow shelf. The delta is well outlined by the configuration of the sea floor, the 20 foot depth line being essentially its outer margin. The southward curve of spitlike banks extending seaward across the delta and the relatively abrupt northeast margin as compared to the gently sloping southwest margin attest to the southwestward-flowing longshore current in this area.

Shallow Shelf

Seaward of the 20 foot depth line (mlw) the sea floor within the area of study (Figure 2) is characterized by eastward-trending troughs and ridges similar in outline and orientation to ancient offshore bars, beach ridges, and related constructional features on the exposed South Carolina Coastal Plain below the Surry Scarp (100' elevation). The sediment over most of the shallow shelf in the study area appears to be fine grained sand (e.g., BB-3, BB-4, BB-5) but coarse sand and abundant shell hash of sample BB-6 indicate at least some of these ridges were formed or re-worked under high energy, beach conditions. Relationships on the emerged Coastal Plain indicate that similar bars and ridges there were formed under conditions of static or slowly falling sea level. Though it is conceivable that the ridge and trough topography on the shallow shelf may have been formed during minor fluctuations of a somewhat lower post-Wisconsin sea level, it seems more likely that these features formed during the retreat of the sea at the close of the Sangamon Stage and that their present state of preservation testifies to the rapid advance of post-Wisconsin seas to the present level. Quick flooding would seem necessary to prevent the ridges from being destroyed in the surf zone of a transgressing sea.

MECHANICAL ANALYSES

The size distributions of bottom samples BB-1 through BB-6 were examined to determine the relationship of sedimentary parameters and environment. Calcium carbonate was removed by treatment with dilute (1:10) HCl. The samples were dried, split to 50 grams, and sieved in a Ro-tap for 15 minutes. The screens were spaced at 1/2 ∅ intervals. The size fraction weights were transformed to percentages and plotted on probability paper. The following percentiles were obtained: 5 ∅, 16 ∅, 25 ∅, 50 ∅, 75 ∅, 84 ∅, and 95 ∅. These values were used to calculate mean diameter, sorting, kurtosis, and skewness based upon formulas suggested by Folk and Ward (1957).

Results

Table 3 shows the values for each parameter. The mean diameter and sorting values appear to be the most useful in differentiating the shelf environment sediments, which are notably finer and better sorted, from sediments in the other environments. The coarsest sediments were found on the submarine ridge (BB-6).

Kurtosis values indicate that the shelf sediments tend to be more leptokurtic, or peaked, than sediments found in the inlet and sub-sea deltaic environments. Relationships based on skewness seem to be less determinable, although sediments on the ridge (BB-6) are very positively skewed compared to the other sediments.

Table 3. Selected sedimentary parameters for each of six bottom samples. Values of mean diameter are expressed in ∅ units.

Sample #	Mean diam.	Sorting	Kurtosis	Skewness	Environment
BB-1	1.43	.960	0.91	.102	Inlet
BB-2	1.29	.435	1.01	-.017	Delta
BB-3	3.04	.182	1.69	.112	Shelf
BB-4	2.71	.289	1.33	-.250	Shelf
BB-5	2.70	.255	1.55	-.110	Shelf
BB-6	.80	.665	1.32	.460	Ridge

HEAVY MINERALS

Further comparison of the bottom sediments, which consisted essentially of quartz and subordinate mica, was made by study of the heavy mineral fraction contained in samples BB-1 through BB-6.

Procedure

Bromoform was used to separate the heavy minerals from a 50-gram split of each sample. The heavy mineral crop was weighed and subsequently reduced in a Jones-type microsplitter. The grains were mounted in balsam, identified, and counted, using a binocular petrographic microscope equipped with a mechanical stage. An average of 217 grains was counted per slide.

Results

The data were treated quantitatively by conversion of relative percentages to actual weight in grams, knowing the total weight of each heavy mineral separate. Table 4 lists the heavy minerals found in each sample, with the values transformed into whole numbers to facilitate comparison. The associated environments are also indicated.

The opaque mineral suite is not itemized separately but consisted chiefly of rutile (83%-88%),* with subordinate magnetite-ilmenite (6%-11%) and leucoxene (3%-11%). The rutile is usually black, angular to rounded, and exhibits a characteristic resinous luster. Many of these grains are partially encased in leucoxene, the alteration product. It is probable that the grains counted as leucoxene enclose a core of either rutile or ilmenite. Magnetite and ilmenite were counted together; they occur as pitted, rounded, grains.

The transparent heavy mineral suite is dominantly an epidote-hornblende association which conforms to the "high epidote" province off the Carolinas found by Pilkey (1963). Both of these minerals occur as green and brown varieties.

Also present in significant amounts are sillimanite, zircon, tourmaline, garnet, and staurolite. The sillimanite is clear and non-fibrous. The prismatic zircons show little signs of wear and are usually colorless. There are several varieties of tourmaline; elongate or rounded grains may be brown, black, colorless, mauve, and rarely green. Pink to colorless garnet appeared to be present only as relatively large, highly angular grains. Staurolite also occurs as large grains containing numerous inclusions.

*/Recent electro-magnetic seperator test shows that this material is dominantly ilmenite.

Table 4. Quantitative distribution of heavy minerals in each sample. Values are in thousandths of grams multiplied by 1000 to obtain whole numbers. Tr = trace amounts.

	Inlet	Delta	Shelf			Ridge
Mineral	BB-1	BB-2	BB-3	BB-4	BB-5	BB-6
Opaques	60	44	351	252	181	81
Epidote	21	15	368	217	103	67
Hornblende	35	16	356	200	91	41
Sillimanite	34	14	80	52	27	6
Zircon	7	8	47	52	30	18
Tourmaline	10	6	29	32	6	6
Garnet	8	Tr	-	12	-	16
Staurolite	16	6	-	Tr	Tr	14
Trans. rutile	-	-	Tr	-	Tr	Tr
Chlorite	-	Tr	15	8	-	Tr
Titanite	Tr	-	Tr	-	-	-
Kyanite	2	-	-	-	-	-

Minor amounts of transparent rutile, chlorite, kyanite, and titanite were also present. These minerals were not found in all samples.

Interpretation

The limited number of samples studied precludes any far-reaching conclusions, but a few observations appear to be worthwhile.

(1). The heavy mineral suite represents a predominant metamorphic assemblage reflecting its origination from the rocks of the Piedmont.

(2). The shelf sediments are readily distinguished from inlet and deltaic sediments by the rather sharp increase in the amount of the heavy mineral suite as a whole as well as in most of the individual constituents. The shelf sediments are distinctly finer than those in the other environments, and hence this heavy mineral increase can be ascribed to the concentration of the heavies in the finer size grades. In this instance the enrichment of heavy minerals appears to be the result of selective sorting on the shelf due to the action of waves and littoral currents.

(3). The quantitative distribution of heavy minerals in BB-6, collected on the submarine ridge offshore, is more closely allied to the samples obtained in the inlet and delta. This seems to lend added credence to the assumption that the ridge is a former shoreline feature covered by a rapid rise in sea level, and thus has temporarily escaped the extensive reworking of the normal shelf sediments.

(4). The minerals garnet and staurolite apparently do not participate in the pronounced on-shelf increase of the rest of the heavy minerals. It might be possible to use these minerals as indicators of linear submarine features not otherwise detectable.

Trends related to mineral stability, if they exist, are not easily discernible, although sillimanite is lowest in the most seaward sample (BB-6).

Analysis of heavy minerals within specific size fractions and roundness studies may be fruitful.

FAUNA

Macrofauna

Mollusca. -- The molluscan fauna from the stations sampled are listed in Table 5. Totals of 54 species of pelecypods, 36 species of gastropods, and 2 species and one subspecies of scaphopods were identified. Most of the species are represented only by the shells of dead individuals; however, many of the shells are very fresh, indicating that the animals died very recently. Many shells are darkened or heavily worn and bored and appear to be very old. A radiocarbon age determination on a valve of *Mercenaria campechiensis* collected from Station BB-10 yielded a date of 33,750 years (±3,200 years). Thus, it is evident that some of the molluscan shells are reworked fossils. A date of 1,250 years (±105 years) was obtained from fairly fresh shells of *Mulinia lateralis* collected from Station BB-10. If the latter date is reliable it would seem to suggest that much of the shallow shelf area a few miles offshore is literally nondepositional at the present time.

Along the main traverse, Stations BB-1 to BB-6, the fauna was most sparse at the outer edge of the delta (Station BB-2) and most abundant on the submarine ridge at Station BB-6. The abundance of the fauna on the ridge, the worn and old appearance of many of the shells, the relative abundance of valves of *Crassostrea virginica*, and the presence of such species as *Olivella mutica* tend to support the hypothesis that this ridge is a submerged Pleistocene offshore bar.

Other macrofauna. -- In addition to mollusks, a wide variety of invertebrates were collected. For the most part these were not identified to species but were noted to include the following:

	Stations
Coelenterata:	
Gorgonid corals	BB-10; alive
Astrangia danae Agassiz	BB-5; dead BB-6; dead BB-11; dead
Bryozoa:	
Discoporella sp.	BB-2; dead BB-6; dead BB-7; dead BB-8-11; dead
Encrusting bryozoans	BB-8-11; alive
Arthropoda:	
Balanus sp.	BB-4-6; dead BB-8-11; dead
Decapoda	BB-4; dead BB-8-11; alive
Echinodermata:	
Mellita quinquesperforata (Leske)	BB-2; alive BB-4; dead BB-5; dead BB-7; alive BB-8-11; alive and dead
Regularia spines and plates	BB-6-7 BB-9-11

Microfauna

No detailed study of the microfauna was attempted, however a few generalized observations about the Foraminifera and Ostracoda seem worthy of note.

Table 5. Check list of molluscan species (R = rate, C = common, A = abundant, F = fresh shell, X = alive).

SPECIES	STATIONS							
	Inlet	Delta						
	BB-1	2	3	4	5	6	7	8-11
Pelecypoda:								
Abra aequalis Say					R			A
Anadara brasiliana (Lamarck)		R					R	R
Anadara ovalis (Bruguiere)	R	C		R	R		R	R
Anadara transversa (Say)	R	R		C	R	R	R	R
Anomia simplex d'Orbigny	R				R	R	C	R
Cardita sp. cf. c. granulata (Say)	R	RC				R	R	
Cardita perplana (Conrad)							R	
Cardita tridentata (Say)								R
Caryocorbula barrattiana (C. B. Adams)	R	RC				R	R	R
Caryocorbula swiftiana (C. B. Adams)	R	R				R		R
Caryocorbula contracta (Say)						R		
Chama congregata Conrad						R	R	R
Chione grus (Holmes)						R	R	
Chione intapurpurea Conrad						R	RC	
Chlamys gibbus (Linné)						R	R	
Crassinella lunulata Conrad		R		FR	C	FC	C	R
Crassostrea virginica (Gmelin)	FC	R	R			C	R	RC
Cyrtopleura costata (Linne)	R	R						R
Dinocardium robustum (Solander)						R		
Diplodonta sp. (young shells)							R	
Divaricella quadrisulcata d'Orbigny		R			R		R	R
Donax variabilis Say	R	FA						C
Dosinia discus Reeve					R			R

Table 5 cont'd.

SPECIES	STATIONS							
	Inlet BB-1	Delta 2	3	4	5	6	7	8-11
Dosinia elegans Conrad								R
Echinochama cornuta Conrad						R		
Ensis minor Dall			FC	FR	FR		R	RR
Ervilia concentrica Gould			C	FA	FA	FC	FA	R
Glycymeris americana (DeFrance)						R		
Glycymeris pectinata (Gmelin)					R	R	FR	R
Gouldia cerina C. B. Adams					R	RC	R	R
Hiatella arctica (Linné) ?							RC	
Labiosa plicatella (Lamarck)	R					R		R
Macoma sp.								R
Macrocallista nimbosa Solander						R		R
Mercenaria campechiensis (Gmelin)	FR					R	R	R
Mulinia lateralis Say	FA	FA	C	R	CA	R	A	A
Noetia ponderosa (Say)	R	R			R			R
Nucula proxima Say	R	R		R	R	R	RC	RX
Nuculana acuta Conrad						R		R
Ostrea equestris Say					R		R	
Pandora arenosa Conrad			R		R		R	
Petricola pholadiformis Lamarck	R							R
Phacoides amiantus Dall		R						
Phacoides multilineatus (Tuomey and Holmes)		R	R	FR	RC	R	R	RC
Phacoides radians (Conrad)						R	R	
Plicatula gibbosa Lamarck					R	FR		R
Semele proficua Pultney								R
Semele bellastriata (Conrad) ?						R	R	
Spisula solidissima Dillwyn		R					RC	R

Table 5 cont'd.

SPECIES	STATIONS							
	Inlet BB-1	Delta 2	3	4	5	6	7	8-11
Strigilla mirabilis Philippi				R	R		RC	
Tagelus plebeius (Solander)								R
Tellina alternata Say								R
Tellina texana Dall	R	C	R		R		R	RC
Trachycardium egmontianum Shuttleworth					R	R	R	
Gastropoda:								
Anachis avara Say								R
Anachis obesa (C. B. Adams)							R	R
Balcis intermedia (Cantraine)								RCX
Busycon carica (Gmelin)		R						RX
Busycon contrarium (Conrad)								FR
Caecum cooperi S. Smith ?					R	R		
Caecum pulchellum Stimpson					R			
Calyptraea centralis Conrad					R	R		
Conus sp. indet.						R		
Crepidula fornicata (Linné)								
Crepidula plana Say	FR				R	R	R	R
Cylichnelia sp. cf. C. bidentata (d'Orbigny)			R		R			
Epitonium humphreysi Kiener								RCX
Epitonium multistriatum (Say)								RCX
Epitonium sp.					R			R
Eupleura caudata (Say)								RCX
Fasciolaria apicina Dall ?						R		
Kurtziella limonitella Dall						R		R

Table 5 cont'd.

SPECIES	STATIONS							
	Inlet BB-1	Delta 2	3	4	5	6	7	8-11
Littorina irrorata Say								R
Mitrella lunata (Say)	R	R						R
Nassarius obsoletus (Say)	R	FC						R
Nassarius trivittatus (Say)		R					F	RC
Nassarius sp.					R	R		R
Odostomia impressa Say	R							
Oliva sayana Ravenel						R	R	R
Olivella mutica (Say)	R	R		FR	R	C	R	RC
Polinices duplicatus (Say)	R	R					R	R
Prunum sp.								R
Retusa canaliculata (Say)	R	C			R			RC
Seila adamsi (H. C. Adams)	R	R						FR
Sinum perspectivum (Say)							RX	RX
Terebra concava Say								R
Terebra dislocata Say		C			R		R	R
Terebra sp.						R		
Turbonilla interrupta Tuomey and Holmes						R		
Turbonilla sp.					R		R	R
Scaphopoda:								
Dentalium eboreum (Conrad)					R	R		
Dentalium texasianum Philippi					R			C
Dentalium texasianum cestum Henderson								R

The greatest abundance of foraminifers occurs on the shallow shelf, where species of Elphidium and Quinqueloculina predominate. Among the shelf areas sampled the foraminifers are least abundant on the submerged ridge at Station BB-6. This is as would be expected if the ridge represents a high energy Pleistocene environment.

Foraminifers are rarest in the sample from the delta (BB-2). In the inlet (BB-1) foraminifers are relatively abundant and are represented most commonly by species of the genera Streblus and Elphidium.

Ostracodes are rare at all stations but appear to be most common on the shallow shelf.

SUMMARY AND CONCLUSIONS

A one day exploratory bottom sampling cruise was made April 19, 1963, in the Atlantic Ocean within a few miles of the North Edisto River, South Carolina. The character of bottom samples and the general configuration of the sea floor indicate the area may be divided into inlet, delta, and shallow shelf environments. The following conclusions are reached:

(1). The North Edisto inlet and tidal river is a deeply scoured channel characterized by coarse sand and shell hash, dead whole shells, and phosphate pebbles. This is a high energy environment in which living mollusks are not common.

(2). A delta, consisting predominantly of coarse sand, has been built on the sea floor to a distance of about 3.5 nautical miles out from the mouth of the North Edisto River. Shape of the delta attests to a southwesterly longshore current in the area.

(3). The shallow shelf seaward of the delta is composed predominantly of fine grained sand and is characterized by eastward-trending troughs and ridges that strongly resemble ancient barrier bars and beach ridges on the adjacent emerged Coastal Plain. Coarse sand and shell hash in one bottom sample (BB-6) indicates at least some of these ridges were formed or re-worked under high energy, beach conditions.

(4). Monthly average surface and bottom salinities at the outer edge of the sub-sea delta (BB-3) are thought to reflect changes in volume of flow of the North Edisto River and temperature differences between river and ocean waters.

(5). Shallow shelf sediments are readily recognized on the basis of mean diameter and sorting values. Kurtosis and skewness appear to be of lesser importance in distinguishing environments, but this supposition is only tentative. Coarsest sediments were found on the submarine ridge (BB-6), in keeping with the hypothesis that this is an ancient high energy, beach environment.

(6). The heavy minerals are of metamorphic origin and consist mainly of opaque rutile, epidote, and hornblende. Distinct differences in the relative amounts of the heavy minerals occur between the inlet-deltaic and shallow shelf environments. These differences are probably a function of grain size. The submarine ridge sampled by BB-6 is more similar, mineralogically, to near shore features than to normal shelf sediments.

(7). Radiocarbon ages on shells indicate reworked fossils (33,750 years) are included in the sediments of the shallow shelf and that the fresher looking shells may be as old as 1,250 years. Much of the shallow shelf area may be an essentially nondepositional environment at the present time.

(8). The abundance,worn and old appearance, and types of the fauna on the submerged ridge (BB-6) support the hypothesis that this ridge is a submerged Pleistocene barrier bar.

(9). The ridges on the shallow shelf were probably formed as barrier bars and beach ridges as the sea retreated at the close of the Sangamon Interglacial Stage. Their preservation on the present sea floor is thought to be due to quick flooding in a rapid advance of the post-Wisconsin sea.

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