Geological investigations related to the stratigraphy in the kaolin mining district, Aiken County, South Carolina

edited by

Paul G. Nystrom, Jr. and Ralph H. Willoughby

CAROLINA GEOLOGICAL SOCIETY
Field Trip Guidebook 1982

October 9-10, 1982

Aiken, South Carolina

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GEOLOGICAL INVESTIGATIONS RELATED TO THE STRATIGRAPHY IN THE KAOLIN MINING DISTRICT, AIKEN COUNTY, SOUTH CAROLINA

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South Carolina Geological Society

Front cover: View looking southeast in Dixie Clay Company's McNamee No. 2 kaolin pit, Langley, South Carolina

Copies of this guidebook can be obtained from:

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Harbison Forest Road
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FOREWORD

FROM THE FLATS

by Sidney Lanier

What heartache—ne'er a hill!
Inexorable, vapid, vague, and chill
The drear sand-levels drain my spirit low.
With one poor word they tell me all they know;
Whereat their stupid tongues, to tease my pain,
Do drawl it o'er again and o'er again.
They hurt my heart with griefs I cannot name:
Always the same, the same.

Nature hath no surprise,
No ambuscade of beauty 'gainst mine eyes
From brake or lurking dell or deep defile;
No humors, frolic forms—this mile, that mile;
No rich reserves or happy-valley hopes
Beyond the bends of roads, the distant slopes.
Her fancy fails, her wild is all run tame:
Ever the same, the same.

Oh, might I through these tears
But glimpse some hill my Georgia high uprears,
Where white the quartz and pink the pebble shine,
The hickory heavenward strives, the muscadine
Swings o'er the slope, the oak's far-falling shade
Darkens the dogwood in the bottom glade,
And down the hollow from a ferny nook
Bright leaps a living brook!

DEDICATION

This volume is dedicated to the memory of Earle Sloan (1858-1926), State Geologist of South Carolina from 1901 to 1911. His 1904 work "A preliminary report on the clays of South Carolina" demonstrated an understanding of the physical stratigraphy in the western Aiken County kaolin belt that was far ahead of his time.

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SOUTH CAROLINA KAOLIN

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The major purpose of this short paper is three-fold: 1) To present some views concerning the stratigraphic, structural, and mineralogical setting for the kaolin deposits of South Carolina; 2) To make clear the differences and distinctions between the several types of kaolin; and 3) To correlate the various applications and uses of the several types of kaolin with physical properties such as particle size, brightness, and viscosity. This does not purport to be a comprehensive treatment of the subject in any of its many and varied aspects.

GEOLOGICAL FEATURES

Stratigraphy

Systematic stratigraphy for the area under consideration is to be covered elsewhere in this guidebook. Nevertheless, to provide proper perspective for the present discussion a few points need to be mentioned, as follow:

Cretaceous

The Cretaceous strata, of great importance in the production of kaolin in central Georgia, are of much less significance in South Carolina. In the Langley area only a few mines, namely the McNamee mine of Dixie Clay Co. and the Ideal and Paragon mines of J.M. Huber Corporation, produce from the Cretaceous. In the eastern part of Aiken County, and in Lexington and Richland Counties, several mines have produced kaolin from these strata. However, in recent years the clay produced from these localities has been used mainly if not entirely for manufacture of light colored brick. Except for the Langley-Bath area, Huber's Edisto mine, about 4 miles northeast of Aiken, is the only mine in South Carolina now producing Cretaceous kaolin for other than the manufacture of structural clay products.

By far the greater part of the kaolin now produced in South Carolina is from Tertiary strata.

Table 1: Outcropping formations in the field trip area near Aiken, S.C.

CENOZOIC	UPPER EOCENE	JACKSONIAN	Barnwell Group	Tobacco Road Sand Dry Branch Formation
				UNCONFORMITY
	LOWER AND MIDDLE EOCENE	CLAIBORNIAN AND OLDER TERTIARY		Huber Formation Medium to coarse-grained light-brown to gray to white sand and clayey sand; some cross-bedding and channeling. Streaks of dark minerals. Locally abundant balls of white clay in sand. Beds of nearly pure grayish to cream-colored to white kaolin, some with greenish tint. Lignitic clay in Town Creek Valley.
				UNCONFORMITY
MESOZOIC	UPPER CRETACEOUS			Upper Cretaceous Un-named Formation Bed of very pure kaolin, grading into or interbedded with micaceous sandy clay; locally very micaceous.
				UNCONFORMITY
				Crystalline rocks of the Piedmont region.

Cretaceous-Tertiary Boundary

Little if any disagreement exists geologists as to what constitutes the boundary between the Cretacious and Tertiary in eastern Georgia and the westernmost part of South Carolina, although scarcity of good exposures and ubiquity of sand makes the contact difficult to recognize in many places. For many years it was customary to regard as Cretaceous all of the outcropping sedimentary strata of the Coastal Plain that occur below the top of the uppermost white kaolin beds. This apparently was the view held by Cooke (1936; 1943), and it was generally accepted. The map by Siple (1967, plate 1) recognizes the presence of the McBean Formation (Claiborne) in the vicinity of Aiken, but includes all of the kaolin producing area in the “Tuscaloosa Formation”.

After Tertiary fossils were found in a stratum beneath commercial kaolin in Twiggs County, Ga., in 1964, it became obvious that the concept of all the kaolin being Cretaceous was incorrect. Subsequent work has shown that two distinct unconformities, rather than one, exist between the base of the Jackson strata and the top of the Cretaceous. (Buie and Fountain, 1968; Tschudy and Patterson, 1975; Buie, 1978, 1980).

Other stratigraphic breaks occur in the pre-Jackson portion of the stratigraphic section in central and eastern Georgia, and in South Carolina. However, it is reasonable to believe that the more conspicuous break, and the one that appears to represent the greater angularity between the subjacent and superjacent strata, marks the top of the Cretaceous. In the Langley area this is believed to be at the top of the main commercial clay body in the Ideal Mine.

Tuscaloosa Formation

It is extremely doubtful that the Tuscaloosa Formation, as occurs in its type locality, is present in South Carolina. How much, and what part of the Cretaceous is represented in eastern Georgia and South Carolina is still open to question. Recently, seven samples from the kaolin-bearing sequence in eastern Georgia that was formerly referred to by Cooke as “Tuscaloosa Formation” of Late Cretaceous age were submitted for palynological study. Four of the samples were determined to be Late Cretaceous (Maastrichtian), one Middle Eocene (Claiborne) and one Middle to Late Eocene (Claiborne-Jackson); one was indeterminate. Some of the samples were collected at the surface; none were taken from more than 250 feet below the surface, although the sedimentary—presumably Cretaceous—beds continue to much greater depth. These determinations were all consistent with present views concerning the age of the kaolin-bearing strata, but do not preclude the presence of older Cretaceous strata. Difficulty exists at numerous places in recognizing precisely where the Cretaceous-Tertiary boundary occurs. Even in the example of the Ideal mine there is no present proof that the kaolin is Cretaceous; nor is there any proof that the kaolin in the Chicora mine—about 60 feet higher—is Tertiary. (Palynological determinations by W.W. Fairchild, 1982.)

One obvious conclusion is that the term “Tuscaloosa Formation” should not be applied to the complete sequence of kaolin-bearing strata in eastern Georgia or South Carolina. This is especially true, now that it is doubtful that deposits of Cenomanian age, which the Tuscaloosa Formation in its type locality is believed to be, crop out in eastern Georgia and South Carolina (Gohn et al., 1979; Hurst, ed., 1979). It is probable that these upper Cretaceous strata, in part, correlate with the clay beds at the plant-fossil locality near Middendorf, a former station on the Seaboard Air Line Railway (now Seaboard Coast Line) in Chesterfield County, South Carolina (Berry, 1914). However, use of “Middendorf” as a formation name would require a fuller description of the section exposed at the Middendorf locality, and a better basis for correlation than now exists.

Structure

The southeastward slope of the buried surface of the crystalline rocks is locally variable. Results of several holes drilled to the crystallines near the boundary of Aiken and Lexington Counties, combined with surface elevations of exposed crystallines, indicate a slope of 25 to 30 feet per mile. This is somewhat less than observed in the Wrens area of eastern Georgia.

Siple (1967) in discussion of the geology in the vicinity of the Savannah River Plant, south of Aiken, states:

> The upper surface of the basement (pre-Cretaceous) rock has been eroded, tilted to the southeast, and buried… The general plane of the surface strikes north 62° east and dips to the southeast at approximately 36 feet per miles, …… The relief of the basement surface is perhaps as much as 150 feet… This relief is taken as evidence that peneplanation was incomplete prior to the deposition of the overlying sediments.

Distinction between the dip of bedding planes within the Cretaceous strata and the dip of the top of the Cretaceous as a unit, offers some difficulty. The slope of the top of the commercial kaolin in the McNamee mine during mining operations was measured at three feet per thousand, or 15.8 feet per mile. The top of the kaolin in the McNamee mine probably was an unconformity, as subsequently observed in the Ideal mine. Hence the top of the Cretaceous here probably is at an erosion surface developed sometime between latest Cretaceous and Jackson time. It is interesting to note that Siple (1967) gives the dip of the Cretaceous—presumably referring to the top of the Cretaceous—as 15 feet per mile from the 500-foot contour on the surface down to the 250-foot contour, and approximately 30 feet per mile between the 250 and the minus 200-foot contours. It seems reasonable to interpret the lesser of these two values as representing the inclination of the erosional surface developed between the initial tilting of the Cretaceous strata and the deposition of the Huber Formation; and the greater of the two as being the inclination of bedding within the Cretaceous.

If the dip of the unconformity at the top of the Cretaceous continues at three feet per thousand under the valley of Hollow Creek it should pass only a few feet below an exposure of dark colored lignitic clay in the road cut 100 yards south of B.M. 189 near the town of Hollow Creek. This is consistent with the opinion that this lignitic clay is in the Black Mingo Formation.

Mineralogy of the Kaolin Deposits

Kaolin and kaolinite

The term "kaolin" is used both as a rock name and as the name of a group of minerals. As a rock or commodity name in the kaolin districts of South Carolina and Georgia it refers to a concentration of minerals of the kaolin group having a composition and purity suitable for commercial use after beneficiation. The kaolin group of minerals includes the species kaolinite, nacrite, dickite, halloysite, hydrohalloysite, anauxite, and allophane. All of these are hydrous aluminum silicates, with composition varying only slightly from that of kaolinite, $(OH)_8Si_4Al_4O_{10}$, or $Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$. The theoretical percentage composition of kaolinite is SiO_2 46.54, Al_2O_3 39.5, H_2O 13.96. Kaolinite has relatively little ionic substitution in the crystal lattice, although evidence suggests minor substitution of iron for aluminum in some instances. This group of minerals is somewhat referred to as "kandite", or "the kandites", from *ka*, *n*, and *d*, of kaolinite, nacrite, and dickite.

The mineral kaolinite is the principal constituent of the sedimentary kaolin deposits of South Carolina; also of those in Georgia, although some deposits there contain an appreciable amount of montmorillonite, a member of the smectite group. It has been reported recently (Hurst, et al., 1979) that another of the kandites, tentatively referred to as nacrite, is almost always present in the kaolin deposits of Georgia; and in some deposits is the preeminent constituent.

Gibbsite

Pisolitic gibbsite, $Al(OH)_3$, is present in some of the kaolin bodies where leaching of kaolinite has occurred to such an extent that silica has been largely removed. This situation is found most commonly where the kaolin body occurs directly beneath an unconformity, such as at the top of the Cretaceous strata or the top of the Huber Formation. In Georgia, numerous small bodies of bauxite have been mined from such occurrences. In South Carolina no mineable bodies of bauxite are known, but a content of alumina higher than that appropriate for kaolinite is not uncommon in pisolitized zones.

Quartz and Other Impurities

In the form of sand particles quartz is generally the most abundant impurity in the commercial kaolin deposits of South Carolina and Georgia. There is no established limit for the percentage of quartz sand that can be present and the bed still be referred to as kaolin. Twenty years ago it was customary to reject as uneconomical, material that contained more than about five percent of sand. Now, 10 percent sand is not prohibitive under favorable conditions. Some companies now consider as reserves for future use clayey beds containing as little as 80 percent kaolinite.

In at least some of the Cretaceous kaolin deposits of South Carolina quartz is not important as an impurity. A suite of samples collected some years ago from the northern part of the Ideal mine contained almost no quartz. Apparently a consequence of intense leaching before the overlying strata were deposited, little other than muscovite, with a small amount of zircon, tourmaline, rutile and opaques, remains with the kaolinite. In the Georgia deposits anatase is a significant, impurity; it probably is in the South Carolina kaolin also, but is not so important here because of the different methods used in beneficiating the kaolin.

Types and Textures

Two principal types of kaolin are produced in South Carolina, in addition to the less-pure clays used for manufacture of fire-brick, light colored face brick, and other struc-

Table 2. Major Types of Kaolin Mined in Georgia-South Carolina "Clay Belt."

Type	General Distinguishing Characteristics
1) Coarse Particle Sized Kaolins, "Middle Georgia Type"	"Soft Clay"; - 2m < 70%; $Ti0_2$ 1%; $Fe_2\ 0_3 \leq 1.3\%$; Brookfield viscosity $\leq$ 1000 cps; Cretaceous age; conchoidal fracture; vermicular stacks of twinned crystals common;
2) Fine Particle Sized Kaolin, "Common, Huber Formation Kaolin"	"Hard Clay"; - 2m 78% to 88%; $Ti0_2 \geq 2\%$; $Fe_2\ 0_3 \geq 1.5\%$; Brookfield viscosity 300 cps to 3000 cps (highly variable); Claiborne or older; irregular to hackly fracture; randomly oriented single crystals common'
3) Fine Particle Sized Kaolin, "Wrens Type"	"Hard Clay"; - 2m 90% to 94%; $Ti0_2 \geq 2\%$; $Fe_2\ 0_3 \geq 1.5\%$; Brookfield viscosity 200 cps to 1500 cps (generally low); Claiborne or older; irregular to hackly fracture; sub-parallel arrangements of crystal flakes dominant;
4) Bauxitized Kaolin; "Bauxite"	"Bauxite"; - 2m < 58%; $Ti0_2$ and $Fe_2\ 0_3$ highly variable (may be leached); Brookfield viscosity $\geq$ 1500 cps; Cretaceous or Tertiary age; conchoidal fracture (may be somewhat irregular in Tertiary kaolins); free gibbsite common.

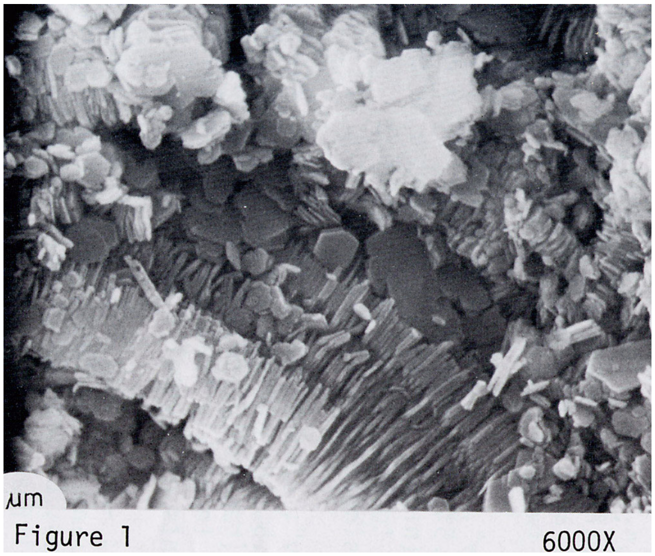


Figure 1. Typical Cretaceous kaolin showing large books and clusters of flakes in varied arrangement. From mine near Deepstep, Washington, County, Georgia.

tural clay products. The difference in the two types is that one appears to be Cretaceous in age, the other Tertiary.

The Tertiary kaolin is sometimes referred to by the miners as "hard clay," and the Cretaceous as "soft clay." Physical properties of both types are variable from one deposit to another, and in some it is difficult to decide which term to apply. Hinckley (1961) found that although the samples submitted by the producers as examples of "hard" or "soft" clay could be readily distinguished, there was much variability in

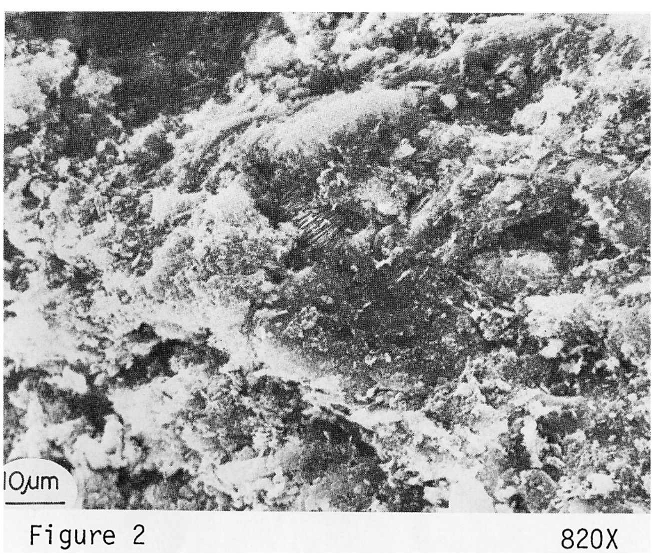


Figure 2 & 3. Co-centered views of kaolin from J.M. Huber Corp., Ideal Mine, Langley, S.C., show a book of kaolin about 10 mm across. Cretaceous.

the properties of each. Table 2 represents an attempt to categorize some of the kaolin types in Georgia, for comparison with those in South Carolina. Bauxitized kaolin, and—more rarely—rekaolinized bauxite occurs in some of the Georgia deposits, but have not been recognized in South Carolina.

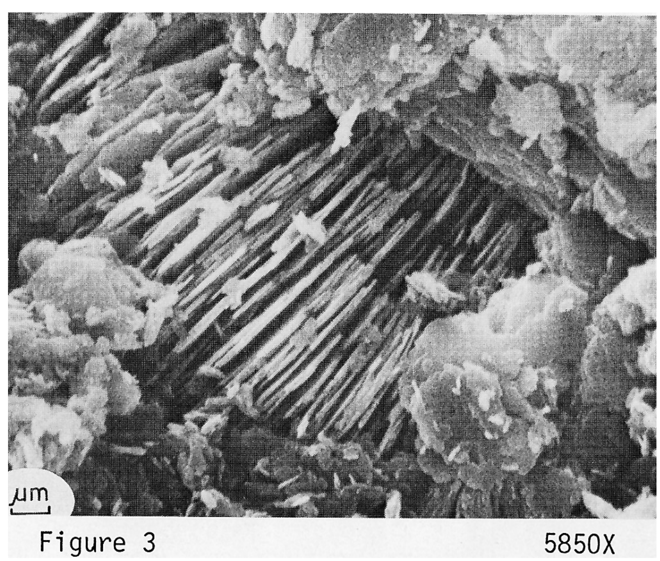
Cretaceous ("soft") Kaolin

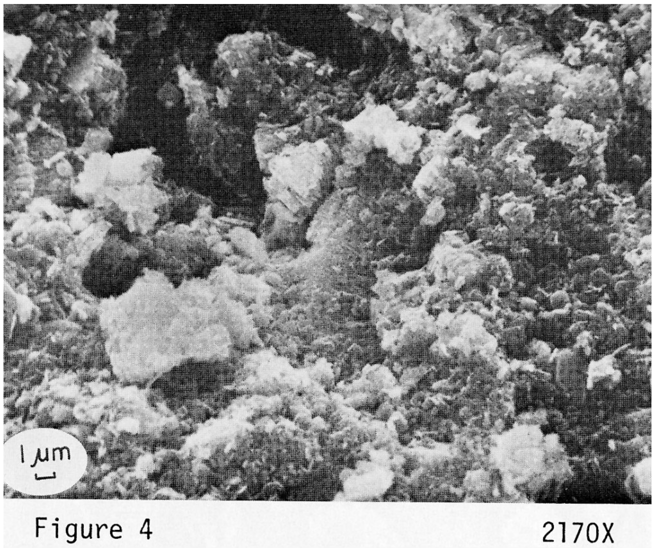
The "soft clay" is, according to understanding of the stratigraphy, of Cretaceous age, although some of it may possible be of Tertiary (Wilcox?) age. In physical properties and potential uses it is much like the "Middle Georgia type" clay mined in Twiggs, Wilkinson, and Washington counties, Georgia. The particle size is comparatively coarse, having generally less than 70 percent finer than two micrometers (equivalent spherical diameter). Viscosity is characteristically low. Vermicular stacks are common (Figures 1, 2 and 3). Generally this clay breaks with a smooth, gently curving, conchoidal fracture. As seen in a mine, individual fractures may extend for several feet. TiO_2 content is about 1 percent, or less; Fe_2O_3 content maximum is about 1.3 percent or less. Other South Carolina localities where the clay produced is believed to be Cretaceous are:

1. An old kaolin mine more recently operated as a source of brick clay, 1.3 miles south 70 degrees east of Edmund, in Lexington County. (Figures 4 and 5.)
1. A mine formerly operated successively by Monetta Clay Company, and Bell Kaolin Company, situated one-half mile southwest of S.C. 39, 10 miles southeast of Monetta, in the eastern part of Aiken County. (Figure 6.)
1. Edisto mine of J. M. Huber Corporation on the northeast side of South Fork Edisto River, 1.3 miles north of Cooks Bridge. An SEM photograph of this clay is shown in Figure 7.

Tertiary ("hard") Kaolin

All of the "hard clay" is Tertiary in age, Claiborne (Middle Eocene) or older. In Georgia operations, where particle





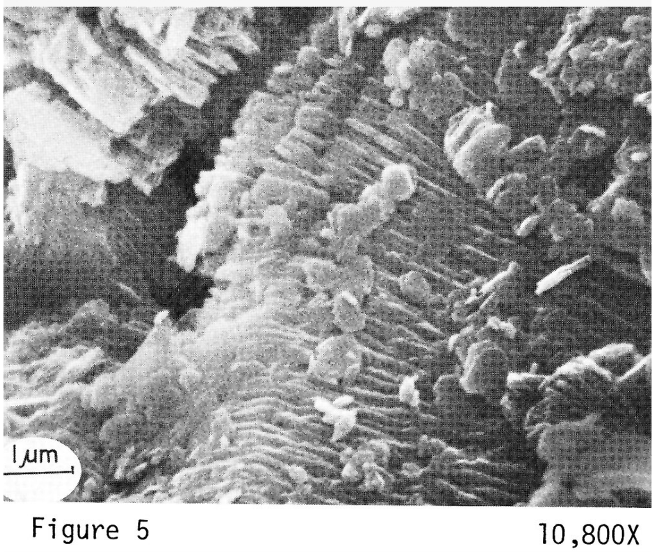


Figure 4 & 5. Co-centered views of kaolin from mine near Edmund, Lexington County, S.C. The large books strongly suggest this to be Cretaceous.

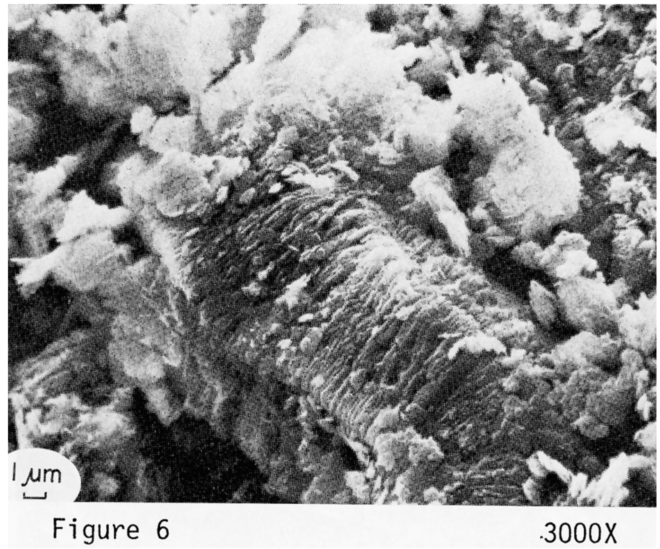


Figure 6. Kaolin from lower clay unit at Bell Kaolin Co. Mine near New Holland, Aiken County, S.C. Specimen was collected from most southeasterly exposure in the mine workings (1973), beneath an unconformity. Cretaceous.

size is routinely determined, it ranges from more than 90 percent finer than 2 micrometers to 78 percent less than 2 micrometers. A sub-type referred to as "Wrens type" has the finer particle size, from 90 to 94 percent finer than 2 micrometers, and having the flakes in parallel ("face-to-face") arrangement. Kaolin from the Graniteville operations of J. M. Huber Corporation and from a mine formerly worked by National Kaolin Company northeast of Aiken, appear to be like the Wrens type clay (Figures 8 and 9). Vermicular stacks are uncommon in the hard clay and absent from the Wrens type. Fracture is irregular to hackly. Content of TiO_2 is usually equal to or greater than two percent; Fe_2O_3 is equal to or greater than 1.5 percent. The texture of the Wrens type clay suggests that it may have been redeposited, but some of the Tertiary clay contains long vermicular forms that could hardly have survived reworking and redeposition (see Figure 10). A more typical view of South Carolina

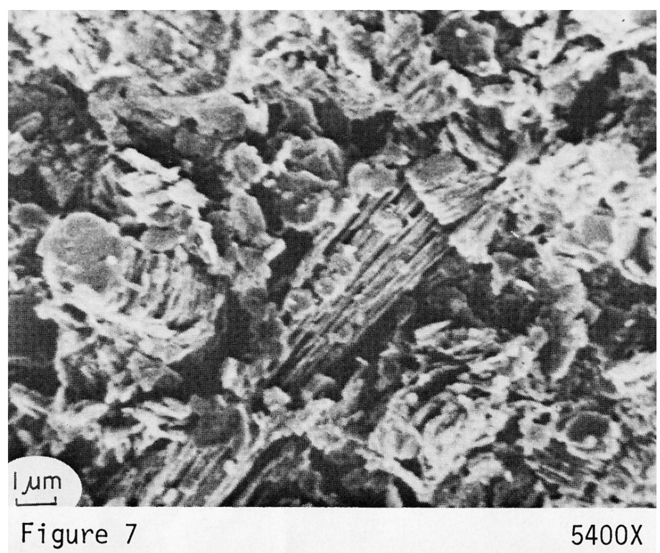


Figure 7. Kaolin from a prospect pit near Huber's Edisto Mine Aiken County, S.C. The large books and flakes strongly suggest Cretaceous correlation.

Tertiary clay is shown in Figure 11, an SEM photograph of a sample from a deposit near Summit, in Lexington County. This deposit is being worked for brick clay. At high magnification (30,000X) one can see the sharply defined crystals, a feature not evident at magnifications lower than about 15,000X. This indicates that the low "crystallinity index" of

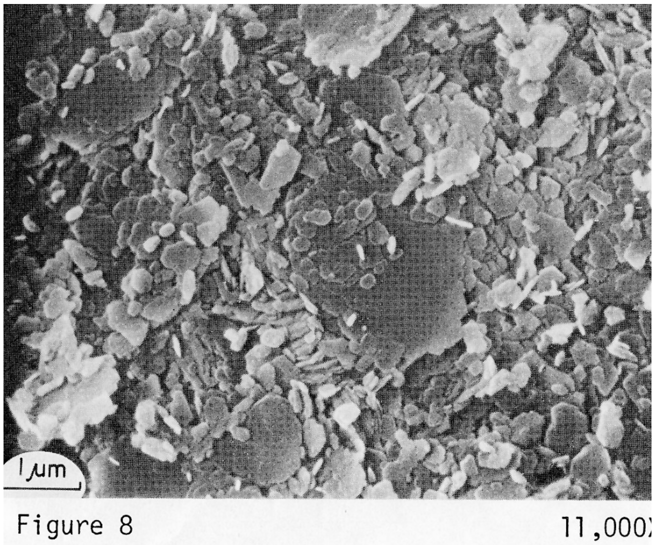


Figure 8. Typical Tertiary kaolin of the "Wren's type," showing small particle size and parallel arrangement of flakes. Huber's Permenter Mine, Graniteville, Aiken County, S.C.

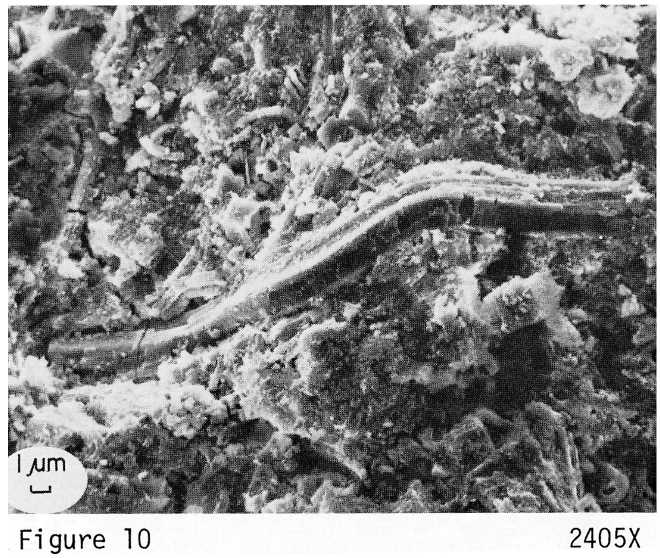


Figure 10. An unusually long vermicular kaolinite crystal in older Tertiary kaolin; M & M Company Mine, Wilkinson County, Ga.

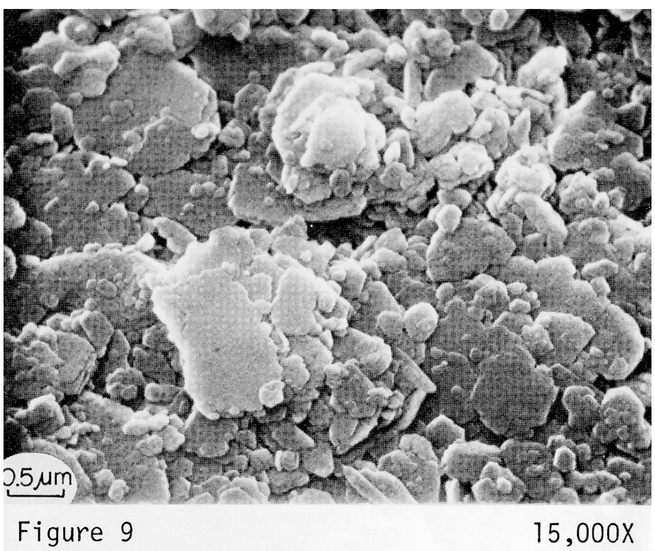


Figure 9. Kaolin from a mine in eastern Aiken County formerly worked by National Kaolin Co. Small kaolinite flakes in parallel arrangement. Tertiary.

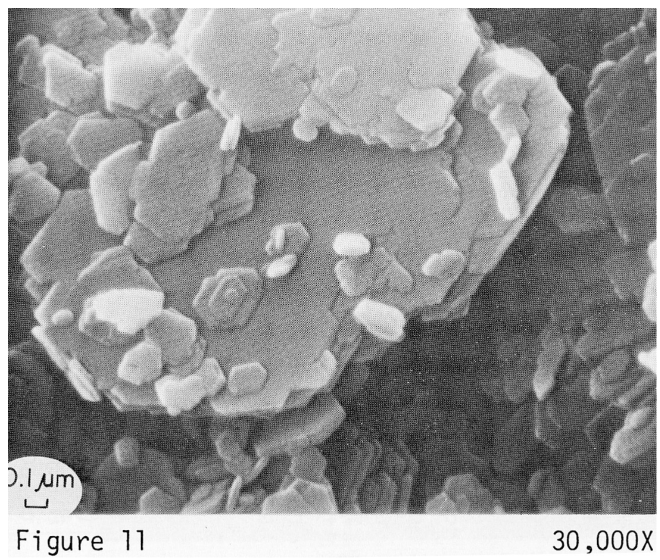


Figure 11. Tertiary kaolin mined for brick, near Summit, Lexington County, S.C. Only at high magnification do the very small flakes show crystal outlines.

the hard clay as determined by Hinckley (1961) is attributable to fine particle size rather than crystal imperfection. (See also Hurst, 1979, p. 11-12.)

Intermediate Type Kaolin of Questionable Age

Most if not all deposits of this type occur above the unconformity taken as the top of the Cretaceous portion of the section. Some of these clays are more like the "hard clay" in particle size, arrangement of particles, and lack of vermicular stacks (Figure 12). Others more closely resemble the Cretaceous clay. In the Aiken area this type is represented by Huber's Chicora deposit, which is topographically and stratigraphically about 60 feet higher than the clay the Ideal mine. Its properties are also intermediate between the "soft" and "hard" kaolin. It possibly is pre-Claiborne Tertiary in age.

Other types, namely bauxitized and re-kaolinized bauxitized kaolin, occur in the middle Georgia district, but these are absent or relatively unimportant in South Carolina.

(Historical Note: During World War II, when an experi-

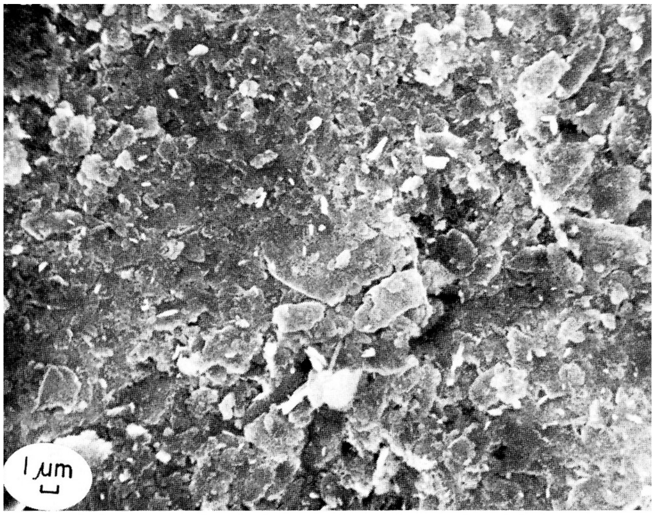


Figure 12 2400X

Figure 12. Kaolin from Chicora Mine of J.M. Huber Corp., Langley, S.C. The larger indistinctly outline flakes appear to be breaking up into smaller flakes.

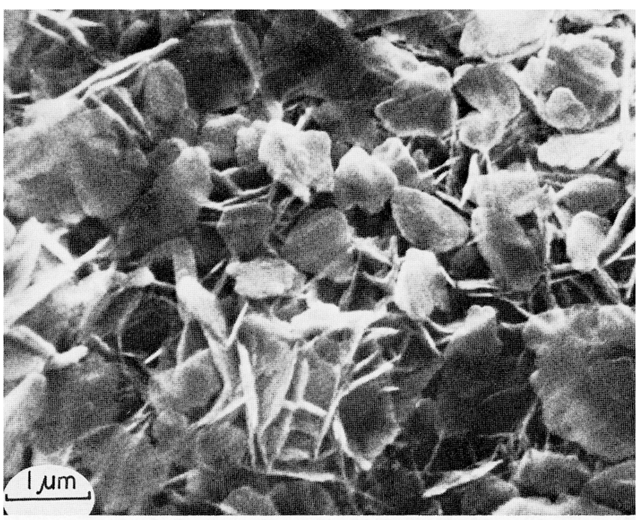


Figure 13 11,800X

Figure 13. Flint clay or chimney rock, from abandoned mi near Gibson, Glascock County, Ga. Thin crystals of cristobal on an between flakes of kaolinite and grains of sand.

mental plant for production of alumina from kaolin was being established at Harleyville, S.C., Dr. Stephen Taber, then Ex-officio State Geologist, chose as a more favorable source material a sample of kaolin from an Aiken County deposit that showed incipient pisolitization. As he suspected, this sample contained a higher content of Al_2O_3 than any of the others.)

Flint Clay

Flint clay and related material called "chimney rock"

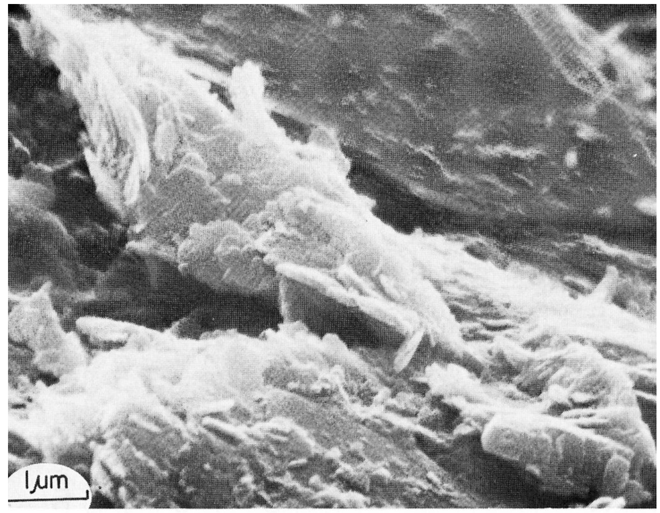


Figure 14 11,700X

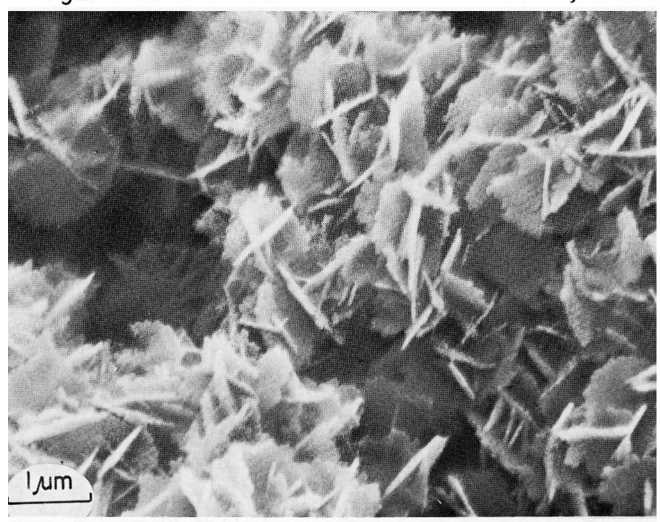


Figure 15 11.700X

Figure 14 & 15. Two views of slightly different portions of the same specimen from exposure of siliceous clay in roadcut on S.C. Route 39, 9.7 miles north of Wagener, Aiken County, S.C. (Near former operation of Bell Kaolin Co.) Figure 14 illustrates the kaolin, and Figure 15 the cristobalite aggregates in the kaolin.

(Figure 13), that occur extensively in Georgia, are not common in South Carolina. One occurrence in Aiken County is in a road-cut exposure of S.C. route 39 about two miles north of New Holland. This exposure is a short distance up-slope from the former mine of Bell Kaolin Company (Figures 14 and 15). As in most occurrences, the flint clay appears to be at the contact of Claiborne and Jackson strata, having resulted from the leaching and redeposition of silica.

EXPLORATION, DEVELOPMENT, MINING AND BENEFICATION

Historical Background

Mining of kaolin in what is now the United States appears to have been first conducted in South Carolina. Josiah Wedgewood, who is well known as an early manufacturer of fine China-ware in England, in his diary describes at some length his importation of kaolin from the Colonies, especially South Carolina. Toumey (1848) describes the occurrence of "porcelain clay or kaolin" in the vicinity of Hamburg, Graniteville and Aiken. Lang (1940, p. 23) states:

The kaolins of South Carolina were recognized before the now famous English china clays were known. An old pottery works stood upon a ridge 1½ miles south of Bath, in Horse Creek Valley, Aiken County. Here were molded and fired all manner of crockery and plates, bricks, pipes, and telegraph insulators. This plant was destroyed during Sherman's march to the sea, and material interest in ceramics in South Carolina apparently passed out with it.

However, interest in the kaolin in South Carolina was not lost. One of the few publications issued by the South Carolina Geological Survey (Earle Sloan, State Geologist) before the Survey and the position of State Geologists were abolished by the State Legislature about 1913—not to be reestablished until over 40 years later (1957)—was a "Preliminary Report on the Clays of South Carolina." In this report Sloan gives what was at that time an excellent description of the occurrence of mining and the physical properties of the kaolin.

Modern development of kaolin deposits in Georgia began in 1876 (Smith, 1929, pp. 1-2). The deposits in Georgia are more numerous and of greater extent and thickness. This has resulted in larger scale mining and more diverse methods having been developed there, and a greater annual production, than in South Carolina.

Exploration

For many years exploration for kaolin in South Carolina and Georgia has been conducted mainly by drilling; first by hand augers and later by use of power augers and core drills capable of drilling to depths of several hundred feet. It was only about 25 years ago that geological study became extensively used in the search for deposits. Drilling is still the method used to test an area that appears to be geologically favorable, and to prove, or develop, areas that preliminary drilling indicates to be worth while. In development work a rectangular grid is surveyed on 200 foot spacing, and elevation of each grid point determined. Initial drilling is customarily at spacing of between 800 and 200 feet. Depth of drilling depends upon the geological situation, but is usually less than 200 feet. A fishtail or similar bit is used until clay is reached, then replaced by a special core bit and barrel to sample the clay bed. Cores are cut into sections, carefully labeled, bagged or boxed, and taken to the laboratory for testing. Each section is dried, pulverized, and evaluated for several or all of these properties: 1) crude brightness, 2) residue on a 325-mesh screen, 3) degritted brightness, 4) loss of ignition, 5) particle size distribution, 6) high-shear viscosity, and 7) low-shear viscosity. Percentage of TiO_2, and iron, calculated as Fe_2O_3, is also determined. Response may be determined to various beneficiation methods, including leaching and ozone treatment, and high-intensity magnetic separation.

Mining

All mining is by open pit methods. Kaolin bodies of good quality and thickness can be economically mined from beneath 100 feet or more of overburden. The overburden is removed by wheeled earth-moving equipment ("pans") or by large draglines. After the kaolin bed is uncovered it may be drilled and resampled at more closely spaced intervals to obtain detailed information for guidance in mining. Mining is by small dragline, power shovel, front-end loader, or hydraulic backhoe. The clay may be hauled to the beneficiation plant by truck, or stockpiled on an upper level of the mine to be blunged into a slurry and pumped to the plant through pipelines. Most South Carolina clay is hauled by truck.

Before commencing mining operations it is necessary to obtain from state authorities a mining permit, which involves commitments concerning environmental controls and land reclamation. Costs of these recently added requirements commonly exceed the value of the reclaimed land.

Beneficiation

Airfloat

Basically, two beneficiation methods are employed to generate merchantable kaolin: airfloat and water-wash. Airfloat, or dry-processed, kaolin is dried in a rotary kiln, and pulverized in a Raymond mill or similar type grinder. Simultaneously, with the grinding, a current of air lifts the finely pulverized material through a "cyclone" and into a collector. In going through the cyclone the coarser particles fall back, to be further ground or rejected. The process is simple and comparatively inexpensive, but does not permit great control over the quality of the product. Quality control is accomplished mainly by selectively mining the material to be milled. All of the kaolin produced in South Carolina at present is airfloat. The airfloat (or aeroflote) procedure is illustrated in Figure 16, lower left portion.

Waterwash

A simple plant for producing washed clay was operated in eastern Aiken County, near Seivern, many years ago. From old photographs (Sloan, 1904) it appears that washing

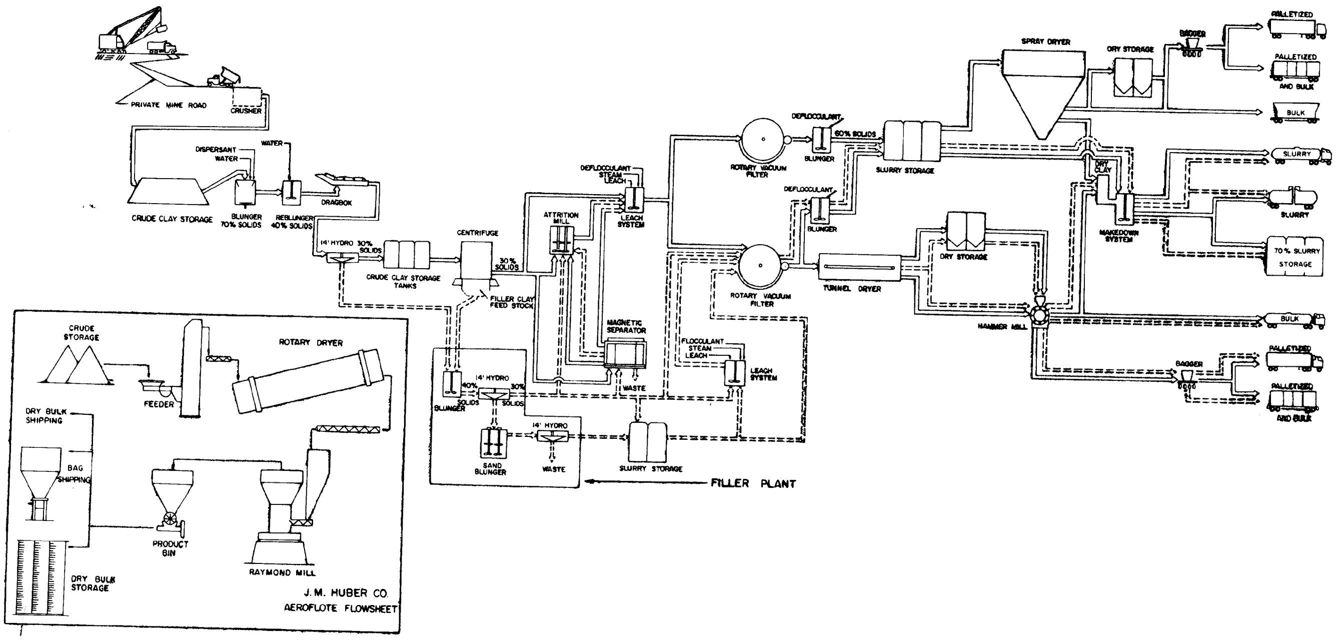


Figure 16. Flowsheets for Aeroflote and waterwashed clay. Courtesy of J.M. Huber Corporation.

consisted of a sedimentation process only.

In a water-wash circuit the crude kaolin is first slurried in a high-shear blunger. If the clay is pumped from the mine, coarse sand may be in large part removed by drag classifiers or sand traps before the slurry reaches the main beneficiation plant. Further removal of coarse impurities and classification of the kaolin into different size fractions is effected by sedimentation, centrifugation, and in hydroseparators. The procedure for removal of impurities is somewhat complicated, and varies in different plants. The main diagram in Figure 16 illustrates a typical operation. Other impurities such as iron and titanium oxides and carbonaceous stain, which are detrimental to brightness of the kaolin, are removed by one or more of these methods: 1) chemical leaching with a strong reducing agent, such as hydrosulfite, after acidifying to a pH of about 3 with sulfuric acid; 2) froth flotation, for removal of anatase (TiO_2) by conditioning the water suspension so that the extremely fine particles of anatase will cling to coarser particles of calcite and be removed; 3) flocculation of anatase by so conditioning the charge on the particles of anatase as to cause them to coagulate and be removed by sedimentation; 4) high intensity magnetic separation; 5) oxidation by ozone, hydrogen peroxide, or other strong oxidizing agent; 6) delamination of coarse crystals ("books") of kaolinite to improve brightness and produce thinner flakes, which are more efficient as a coating clay for paper.

Specific beneficiation procedures vary with the product and the technological preference to the production engineer and company. The kaolin is dried by rotary vacuum filters which remove most of the water, and then by heat in either a tunnel drier or spray drier. The lumps of clay that go into the tunnel drier from the vacuum filter become hard when thoroughly dried, and must be re-pulverized. Clay that goes to the spray drier as a slurry (60% solids) forms minute droplets that dry into microscopic size hollow spheres of kaolin as the droplets fall through the drier.

Shipping

Kaolin is shipped as a slurry (70% solids), or dry in bulk and in 50 pound bags. Much of that shipped overseas is "containerized"—50 lb. bags packed in containers holding approximately 20 tons each. These can be conveniently lifted directly onto ships. No shipments in slurry form are made from South Carolina, as no kaolin is prepared here by wet-method beneficiation.

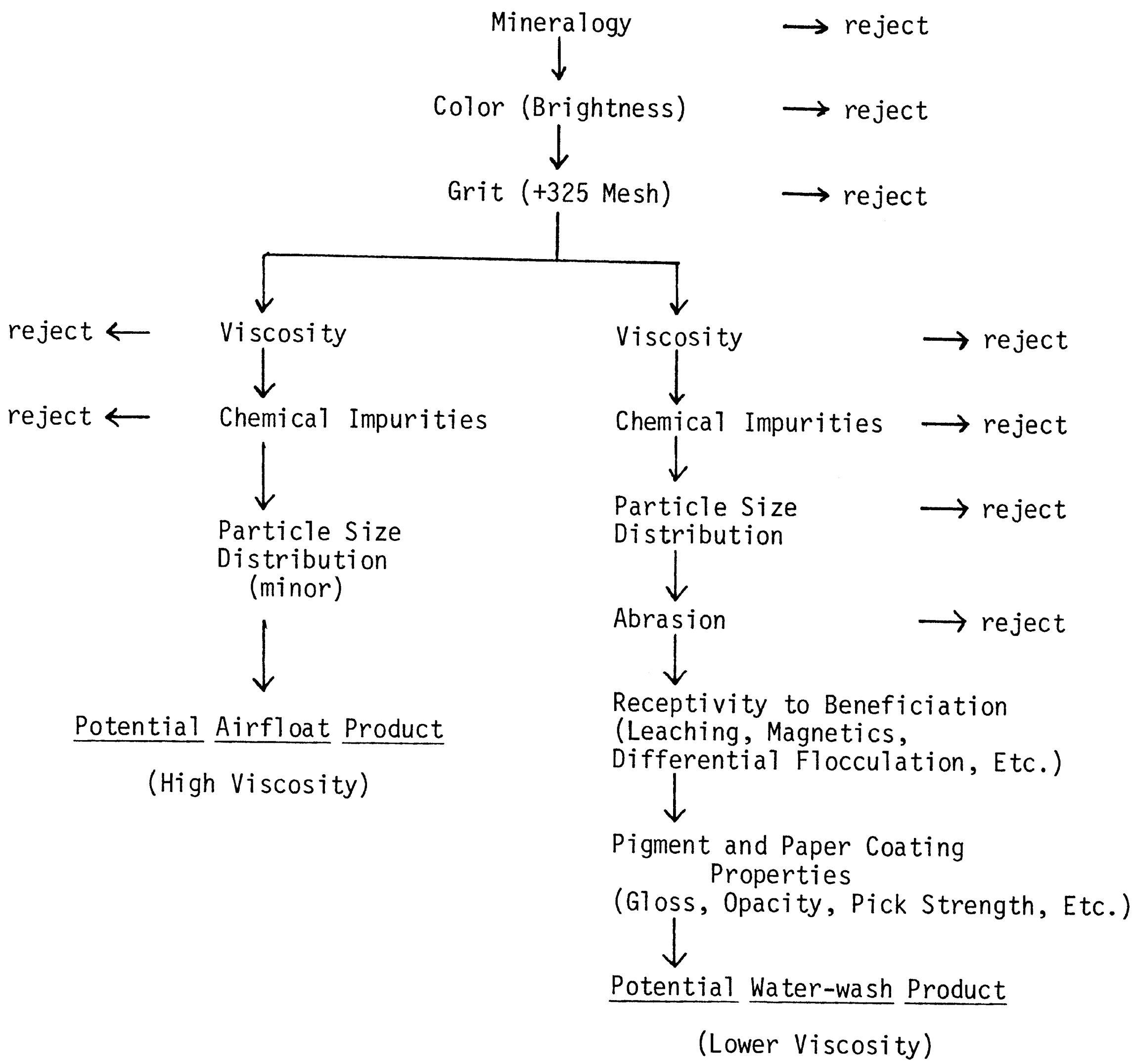
PROPERTIES, USES, AND PRODUCTION

Characterization of Kaolins

The potential merchantability of crude kaolin is determined by a variety of physical and chemical analytical procedures. Probable commercial quality of a given kaolin is indicated by these tests. Results of the tests depend largely upon differences among the types of kaolin being mined. The major types being mined and the more important analyzed characteristics determining these types are schematicized in Tables 2 and 3.

Table 3 presents a general scheme for characterizing and evaluating crude kaolins. Of paramount importance is the mineralogy of the sample. Only minerals of the kaolinite group are acceptable for production of merchantable kaolin. Only kaolinite, nacrite, and dickite are acceptable as a source for the principal types of clay produced in South Carolina

Table 3. General Scheme for Characterizing Kaolin Crudes.



and Georgia. Halloysite is satisfactory for ceramic uses, but because of the cylindrical shape of the individual particles is not suitable for paper coating clay. Silica polymorphs, smectites, and hydrated aluminum hydroxides may be similar to kaolin in gross, megascopic appearance, but all have physical properties, not amenable to current beneficiation technology, that make them unsuitable as replacements for kaolinite.

After mineral composition the next most important measured parameters are brightness (color) and grit. If either of these quantities is unacceptable, an otherwise promising crude may be characterized as non-commercial. Generally, crude brightness less than 70 percent and grit more than 30 percent are cut off values for potentially economic kaolin deposits.

Viscosity may be defined as "resistance to flow" and is measured in centipoises (c.p.s.). The viscosity of a crude sample is measured, using the Brookfield method, on a clay-water suspension comprising 70 percent solids. Viscosity measurements may be performed at lower solids levels, but generally a crude that will not "make up" to 70 percent solids is classified as high viscosity.

Depending upon the viscosity, a kaolin may be considered for either water-wash or airfloat beneficiation, or may be rejected. Viscosity of clay-water suspensions may be influenced by particle size distribution, impurities in the finer size fractions, soluble calcium salts, and other factors (Prince, 1977).

High levels of chemical impurities, usually TiO_2, Fe_2O_3, and sometimes cristobalite or other SiO_2 polymorphs, may exclude the use of a specific crude in some applications, or cause it to be rejected altogether. However, these impurities might be removable with application of patented technology such as differential flocculation, magnetic separation, leaching, and mineral phase floatation.

The particle size distribution of the less than 325 mesh clay fraction generally dictates the use of kaolins for specific applications. Kaolins used for various paper coatings are often classified as to the general "coarseness" of particle size (see Prince, 1977). Additionally, generally coarse particle sized kaolins are primarily seen to be from Cretaceous aged strata. Finer particle sized kaolins are mostly Tertiary (Huber Formation) in age (Buie, 1980, 1978). The role of particle size distribution is of less importance in evaluating crudes for use in airfloat beneficiation.

Abrasion, receptivity to various water-wash beneficiation techniques, and pigment/paper coating qualities of finished clays are more or less specialty tests for water-wash kaolins. The reader is referred to Hurst, et al. (1979) and Prince (1977) for discussions of beneficiation and pigment/paper coating properties respectively.

Uses of Kaolin

The numerous and varied uses of kaolin depend upon a combination of qualities which few if any other natural substances can provide. These include chemical inertness, insolubility in water, low viscosity in slurry form, low abrasion, good absorptive properties, softness, brightness, electrical non-conductivity, and large surface area of particles. In clay for ceramic uses, plasticity, high dry strength, and high fired strength are important. The low cost of only a few cents per pound for the highest quality washed kaolin is also an important factor in promoting the wide use of kaolin.

Uses include such diverse applications as compounding in rubber and insulation for electrical wiring, addition to finely ground materials to prevent caking, as a carrier of insecticides, pigment in paint, in medicines, and in glass and dinner-ware production. In paper manufacture fine-grained filler clay fills the open pores between fibers, and larger thin flat flakes form a smooth, high-finish surface. In adhesives the addition of kaolin facilitates drying, and makes “clean-up” easier.

An increasing amount of kaolin is being sold in modified forms. Calcining to drive off water of constitution produces high quality super-duty refractories, and pigments of higher brightness and excellent durability. Chemical treatment can result in other products of many uses.

For kaolin produced in Georgia the five major uses are for: 1) paper coating; 2) paper filling; 3) refractories; 4) alum and other chemicals; 5) china ware, porcelain, and other ceramic products. South Carolina kaolin has two dominant uses: 1) rubber and 2) fiberglass.

Production

Georgia and South Carolina together supply almost 90 percent of U.S. production, 1980 (Ampian; U.S. Bureau of Mines, 1981).

	Short Tons	Value
Total U.S. production	7,878,993	$527,098,609
Georgia	6,311,407	$463,700,320
South Carolina	657,752	$ 20,835,482

These figures clearly demonstrate the dominant position of the Georgia-South Carolina clay belt in production of kaolin in the United States.

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Appreciation is expressed to Lee Barrs of J. M. Huber Corporation for providing the flowsheets shown in Figure 16; and to Dr. Stephen Vaos for taking most of the SEM photographs used in this paper.

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THE DEVELOPMENT OF THE STRATIGRAPHIC TERMINOLOGY OF THE CLAIBORNIAN AND JACKSONIAN MARINE DEPOSITS OF WESTERN SOUTH CAROLINA AND EASTERN GEORGIA

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INTRODUCTION

The marine, clastic, middle and upper Eocene deposits of Georgia and western South Carolina have been treated so differently by various investigators in the past (Sloan, 1907, 1908; Veatch and Stephenson, 1911; Shearer, 1917; Cooke and Shearer, 1918, Cooke, 1936, 1943; LaMoreaux, 1946; Cooke and MacNeil, 1952; Siple, 1967; Herrick and Counts, 1968; Colquhoun et al., 1969), and differently by the same investigator at different times (Cooke and Shearer, 1918; Cooke, 1936, 1943; Cooke and MacNeil, 1952) that duplication of results in the field and understanding the lithostratigraphy and biostratigraphy of these deposits based on the literature has been fraught with difficulty and uncertainty. There are a number of reasons for the differing viewpoints of the various past investigators of these deposits:

(1) No type locality has been designated by the original author or subsequent knowledgeable investigators (Barnwell sand), the type locality has been only approximately delineated and is accessible only with difficulty (McBean formation), or the type locality is so distant from the eastern Georgia-western South Carolina area that few investigators of these deposits examine the type of locality and trace the deposits in the field to the particular area of investigation (Lisbon Formation).

(2) There are relatively few good exposures in the area.

(3) The deposits have been deeply weathered, commonly resulting in the obliteration of original sedimentary features.

(4) Concepts of formations of earlier authors, especially C. W. Cooke, were different from our present lithostratigraphic concepts. Formations as understood and applied by Cooke were quasi-chronostratigraphic/biostratigraphic units whose recognition was based on fossil content or assumed biostratigraphic equivalency. If there were significant changes in faunal elements vertically between deposits in a section, this justified change in formation name with little regard to lithologic criteria. Similarly if two deposits had entirely different lithologies but similar or identical faunas, only one formation name was applied (e.g., the use of the name Hawthorne in Georgia and Florida [Cooke, 1943, 1945] or the use of the name "Byram" from Mississippi to Florida [Cooke, 1945]).

(5) Much of the volume of middle and upper Eocene sediments in western South Carolina and eastern Georgia is noncalcareous and nonfossiliferous even before weathering, resulting in intrinsic difficulty in treating these deposits biostratigraphically and chronostratigraphically. Since Cooke did not recognize formations lithostratigraphically, his recognition of nonfossiliferous formations in nonfossiliferous sequences of deposits is basically uncertain.

The object of this paper is to describe the origin and development of the stratigraphic terminology and concepts of the middle and upper Eocene stratigraphic framework of the eastern Georgia-western South Carolina area. It is hoped that this contribution will be of value to future students of the geology of this area in determining the relative merits of the earlier literature. The quasi-chronostratigraphic/biostratigraphic terminology that was developed in the first half of this century will be described in terms of the strictly lithostratigraphic terminology and chronostratigraphic framework as developed by the author over the past ten years (Huddlestun and Hetrick, 1978; Huddlestun and Hetrick, in press; Huddlestun, in review; also Huddlestun and Hetrick, 1979).

This lithostratigraphic framework is as follows: It has been proposed that the Barnwell be raised in rank to group status to accommodate three distinctive formations: a lower Clinchfield Formation, middle Dry Branch Formation, and upper Tobacco Road Sand. In eastern Georgia the Clinchfield Formation is represented by the Utley Limestone Member in Burke and Screven Counties, and possibly by the Albion Member (Carver, 1972) in Richmond County. The Dry Branch Formation is composed of three members, a lower Twiggs Clay Member and upper Irwinton Sand Member in central and east-central Georgia, and by the Irwinton Sand Member and Griffins Landing Member in eastern Georgia. The Twiggs Clay, in eastern Georgia and western South Carolina, is represented by discontinuous lenses of Twiggs clay lithofacies. The Tobacco Road Sand is undivided in this area but an important, discontinuous bed of flat pebbles occurs at the base of the formation in updip areas.

The lithology of the Dry Branch Formation can be characterized as well-stratified, fine to medium, well sorted sand commonly with thin layers or laminae of clay (Irwinton Sand Member) to massive-bedded, structureless, calcareous, argillaceous, well sorted sand with local concentrations of fossils (especially *Crassostrea gigantissima*) in the lower part (Griffins Landing Member). Lenses, layers, or beds of Twiggs-type clay occur scattered throughout the Irwinton and Griffins Landing members and consist of thinly bedded, gray clay with interlayers ranging from silt partings to thin layers of fine sand. The Tobacco Road Sand generally consists of fine to coarse, well to poorly sorted sand that is generally bioturbated in the downdip areas. *Ophiomorpha nodosa* occurs locally in abundance in the Tobacco Road Sand, which is the only formation in the Savannah River area of Georgia and South Carolina that contains an abundance of this trace fossil. Similarly the only relatively persistent bed or zone of flat pebbles in this area is the one at the base of the Tobacco Road Sand in Richmond County, Georgia, and Aiken County, South Carolina. It does not, however, extend down the dip beyond northern-most Burke County in Georgia and it has not been reported from southern Aiken or Barnwell counties in South Carolina. In Georgia, a discontinuous bed of fossiliferous chert with local occurrences of *Pariarchus quinquefarius* occurs at the base of the Tobacco Road Sand in downdip areas of Burke County.

Where deeply weathered the Tobacco Road residuum can be differentiated from Dry Branch residuum in that the Tobacco Road residuum typically is a moderate reddish-brown (10R 4/6), massive-bedded, structureless, tough and resistant, generally poorly sorted sand (typical Barnwell lithology of past usage). Dry Branch residuum commonly is paler in color with yellows and oranges predominating, softer and more poorly consolidated, well sorted, and the sand is typically fine- to medium-grained. Only after severe weathering does the Dry Branch residuum begin to take the appearance of Tobacco Road residuum.

The Lisbon Formation (Huddlestun, in review) is equivalent to the concept or meaning of the McBean Formation of previous authors. It is not, however, entirely equivalent lithostratigraphically to the McBean Formation of previous authors. In the Savannah River area the Lisbon Formation is typically a fine to coarse, well sorted, massive-based, microfossiliferous and sporadically macrofossiliferous, argillaceous, calcareous sand with scattered lenses of impure limestone and rarely impure clay. The McBean is considered by this author to be a member of the Lisbon Formation and is characteristically an impure limestone (see Brantley, 1916, p. 44-55) that is restricted only to the McBean-Shell Bluff area in Georgia. The McBean Member grades laterally into the Blue Bluff Member of the Lisbon Formation (Huddlestun, in review; also see Huddlestun, 1981; and Brantley, 1916, p. 54). The Blue Bluff Member is a very thinly layered to laminated, microfossiliferous, argillaceous, very calcareous, silty fine sand.

HISTORICAL DEVELOPMENT

Sloan (1907, 1908) named the “Barnwell phase”, a quasi-chronostratigraphic term, for those sediments deposited during middle Eocene time subsequent to the “Santee phase”, concurrent with the “Mount Hope phase”, and preceding the “Ashley-Cooper phase”. The clastic sediments deposited during the “Barnwell phase” he called both Barnwell buhr sands and Barnwell sands. Sloan (1908, p. 461) referred to the lithology of the Barnwell sands as “irregular beds of glauconites and shells…”, “extensive beds of extremely fine grained sands of yellow and reddish color with delicate whorls of very fine white sand”, and “fine grained sands, ferruginous sands, and glauconites” with common development of silica-cemented sandstone and limonite-cemented sandstone and claystone. He did not assign a type locality for the Barnwell sands and the type area is indicated only in his choice of names. Sloan did indicate a stratigraphic position for the Barnwell sands in central South Carolina but one is not indicated for western South Carolina. His brief account of the lithologies of the Barnwell sands are not at all consistent wit the lithologies of the Barnwell as presently exposed in the Savannah River area of Georgia and South Carolina.

Sloan (1908, p. 269-273) recognized the calcareous deposits at McBean Creek and Shell Bluff in Georgia as being middle Eocene in age and related to the Warley Hill and Santee “phases”. He did not, however, refer to the deposits at McBean Creek and Shell Bluff as Warley Hill or Santee, or in a lithostratigraphic sense.

The main concept of the Barnwell Sand that Veatch and Stephenson (1911, p. 285-296) adopted from Sloan (1907, 1908) consisted of deeply weathered red sand that commonly contained beds of chert, fossiliferous chert, and chert-cemented sandstone (buhrsands) of middle Eocene age. These cherty Barnwell sands were recognized mainly on the basis of their stratigraphic position and deep weathering. According to the concept and usage of Veatch and Stephenson (1911) the Barnwell sand always overlies the McBean Formation and lies close to the ground surface or at high elevations.

Veatch and Stephenson (1911, p. 235-284) named the McBean Formation for middle Eocene, Claiborne-age deposits exposed along McBean Creek between the community of McBean, Richmond County, Georgia, and the confluence of the creek with the Savannah River. They were of the opinion, in contrast to modern stratigraphic practices, that “Although in a general way the correlatives of” the Gosport greensand, Lisbon formation, and Tallahatta buhrstone “may be recognized in Georgia, the extension of the use of these terms to this State is inappropriate, since the Claiborne group is not naturally divisible into the same units as in Alabama; therefore, in Georgia the group is divided into two formations;” the Barnwell sand and the McBean formation, with the Congaree clay member (p. 236). Evidently they felt that if the same sequence of formations in a group is not present in an area, then use of any of the formations is inappropriate. Therefore they chose to apply new names, i.e., McBean Formation, rather than to extend the use of older, established names (Lisbon Formation) to new areas.

Veatch and Stephenson (1911, p. 242) presented five measured sections exposed in ravines on the south side of

McBean Creek in Burke County. The parts of the five sections that are still exposed is the Barnwell (Tobacco Road?) residuum in the upper parts of the sections. Only at the mouth of the northern-most ravine is the McBean Limestone Member still exposed. However, it would appear that the only McBean Member in the sections of Veatch and Stephenson are beds 1 of their sections 3, 4, and 5. The rest of the overlying McBean (p. 242) is evidently Twiggs clay lithofacies of the Dry Branch Formation, based on this authors' knowledge of the particular area discussed by Veatch and Stephenson (1911, p. 242). In retrospect it would appear that this initial definition and application of the name McBean was rendered ambiguous by the probable inclusion of what later would be recognized as being the lower part of the Barnwell (Cooke and Shearer, 1918; LaMoreaux, 1946).

Veatch and Stephenson (1911, p. 267-284) also extended the Congaree of Sloan (1908) into Georgia as a member of the McBean Formation. Although the Congaree Clay of Veatch and Stephenson was subsequently renamed the Twiggs Clay by Shearer (1917) and shown to be of late Eocene age and therefore younger than the McBean Formation, Veatch and Stephenson (1911) were consistent in their assignment of the "Twiggs Clay" and other lower Barnwell deposits to the Congaree and McBean respectively.

The conclusion is inescapable that the Barnwell sand of Veatch and Stephenson (1911) is approximately equivalent to the Tobacco Road Sand of current usage and the Dry Branch and Clinchfield Formations of current usage were clearly and unambiguously included in the McBean Formation and assumed to be of middle Eocene age.

Brantley (1916, p. 44-55) presented seven chemical analyses of the McBean Member from exposures adjacent to McBean Creek and two chemical analyses from the McBean Member from Shell Bluff on the Savannah River. The percent limestone in these nine samples ranged from approximately 70% to 87%, definitely indicating that the typical McBean lithology is a limestone.

Shearer (1917, p. 14) recognized that the Congaree Clay Member of the McBean Formation of Veatch and Stephenson (1911), and the greater part of the McBean Formation in Georgia (in the sense of Veatch and Stephenson), consistently overlies the "typical Jackson bryozoan limestone throughout central Georgia." Consequently he changed the name of the clay to Twiggs Clay Member of the Barnwell Sand and relegated the associated sands (Irwinton Sand of current usage) simply to the Barnwell Sand.

Cooke and Shearer (1918, p. 42-51) submitted the paleontological basis for transferring much of the eastern Georgia McBean Formation of Veatch and Stephenson (1911) to the Barnwell Formation. They showed this transferal to be consistent with the biostratigraphy and chronostratigraphy then being developed for the upper Eocene deposits of the southeastern United States. Essentially, they were the first to lay out the upper Eocene stratigraphic framework in a format consistent with the results of later investigations in the Georgia Coastal Plain. Cooke and Shearer (p. 51, 59-61) restricted their recognition of the McBean Formation to the vicinity of McBean Creek and Shell Bluff in Georgia. The rest of the Claibornian deposits in western Georgia were referred to as "undifferentiated Claibornian deposits (p. 51, 61, 62). However, they still included some noncalcareous, nonfossiliferous sands and clays in the McBean Formation (p. 60).

The concept of the Barnwell Sand as employed by Cooke (1936, p. 89-95) is vague and lithostratigraphically inadequate and suggests that Cooke did not understand the Barnwell unit. No type locality for the formation had been assigned because "it is difficult to specify any particular locality in South Carolina that can be considered the original type." This is because "subsequent study of the fossils has shown that many of the localities definitely referred by Sloan to the Barnwell really belong to the McBean Formation" (Cooke, 1936, p. 89). However, Cooke continued to use the name Barnwell in the sense of the original concept, i.e., "as indicating an Eocene formation composed chiefly of sand that overlies unconformably the McBean Formation."Cooke (1936, p. 41, 42, 55, 57-60) formally extended the McBean Formation into South Carolina. He revised the concept of the formation by proposing the abandonment of the Congaree and Warley Hill "formations" of Sloan (1907, 1908) and included the deposits that had formerly been assigned to those "formations" into the revised McBean Formation. In addition to incorporating the Warley Hill and Congaree concepts and lithologies into the McBean Formation, Cooke (1936) retained the overlying sands and clays (Irwinton and Twiggs lithologies of the Dry Branch Formation of current usage) in his concept of the McBean Formation. As a result, the McBean Formation, which previously included mainly calcareous deposits in eastern Georgia, henceforth included mainly noncalcareous and nonfossiliferous sands and clays of undemonstrated age in western South Carolina. Very little of the McBean Formation of Cooke (1936) can be definitely related to the McBean limestone lithology at the type locality. Although no reasons were given for this change in the concept of the McBean Formation, Cooke and MacNeil (1952, p. 21) later indicated that the intent of Cooke (1936) was merely to follow the original (Veatch and Stephenson, 1911) usage in Georgia.

What those localities are that were "definitely referred by Sloan to the Barnwell" that "really belong to the McBean Formation" is not clear because Cooke does not enumerate them. Furthermore, it is impossible to apply Cooke's concept of the Barnwell Sand in the field because not only was the Barnwell inadequately defined physically, but the underlying McBean was also inadequately defined physically. It appears, however, from Cooke's discussion that his concept of the Barnwell in 1936 largely approximated that of Veatch and Stephenson (1911). Similarly the McBean Formation of western South Carolina included both the strict McBean limestone lithology and the overlying Barnwell (Dry Branch Formation) of current usage, in conformity with Veatch and Stephenson (1911).

The reasons for Cooke's (1936) reevaluation of the McBean/Barnwell can perhaps be more clearly inferred from his account of the McBean and Barnwell Formations in Cooke (1943). In the first reference to the flat pebble bed, Cooke (1943, p. 62) observed that the base of the Barnwell "nearly everywhere contains flat polished beach pebbles, which aid in distinguishing it from the coarser facies of the McBean Formation." The flat pebble bed (LaMoreaux, 1946; Huddlestun and Hetrick, 1978) is not known to occur in and has not been reported from Barnwell County, South Carolina, and it does not occur downdip of northern-most Burke County, Georgia. It is evident from earlier reports (Veatch and Stephenson, 1911; Cooke and Shearer, 1918; Cooke, 1936) that the basic concept of the Barnwell Sand was the massive, brownish-red, residual sands that occur at the top of the Eocene section in Georgia and South Carolina. It is this same deposit (Tobacco Road Sand of current usage) that in updip areas contains the flat pebble bed at its base, and there is no other extensive zone of flat pebble concentration in the Barnwell. Therefore the conclusion is inescapable that what Cooke (1943) considered to be the Barnwell Formation is the Tobacco Road Sand and only the upper part of the Barnwell Group of current usage. Simlarly, where Cooke (1943) defined the base of the Barnwell Formation on the basis of the flat pebble bed, all of the underlying Jacksonian, i.e., the Dry Branch and Clinchfield Formations, were included in the McBean Formation.

Cooke (1943) was not consistent in terms of internal correlation of these deposits in Georgia, and therefore, in application of stratigraphic terminology. He still held to the earlier correlation and identity of the post-Ocala deposits in the vicinity of Dry Branch in Twiggs County, Georgia. There the Twiggs Clay and associated sands were understood to be late Eocene in age and, by definition, Barnwell Formation because they overlie the Ocala Limstone of unquestioned late Eocene age (p. 66, 67). Where upper Eocene sands and clays overlie the Ocala Limestone, they were correlated with the Barnwell Formation. Where the flat pebble bed occurs, the underlying deposits were correlated with the McBean Formation. Unfortunately the flat pebble bed does not occur (as a result of finer grained facies) in northern and western Twiggs County where the Ocala is commonly exposed during mining operations. Therefore Cooke missed the critical relationship between the stratigraphic occurrence of the flat pebble bed and the Ocala Limestone. There is no alternative to the conclusion that at some sites, Cooke (1943) correlated Twiggs Clay and associated sands (Irwinton and Griffins Landing Sands) with the established concept of the Barnwell Formation (p. 66, 67) whereas at other sites he correlated them with the underlying McBean Formation (p. 58, 59).

LaMoreaux (1946b, p. 54) concluded, in contrast to Cooke (1943), that "no part of the so-called Congaree clay or Twiggs clay in east-central Georgia was of Claiborne age, and that the base of the Barnwell in this area is the base of the Twiggs clay member, which rests unconformably on the Tuscaloosa formation except where the channel sands are present." LaMoreaux (1946) proposed the name Irwinton Sand for the Barnwell sands that conformably overlie the Twiggs Clay in the vicinity of Irwinton, Wilkinson County, Georgia. Also in contrast to Cooke (1943) he recognized that the unit that contained the flat pebble bed at its base was an upper subdivision of the Barnwell sand and he referred to it informally as the upper sand member of the Barnwell Formation.

LaMoreaux (1946a, p. 19) suggested that the Irwinton Sand east of the Ocmulgee River in Georgia may correlate at least in part with the "Cooper Marl" (Ocmulgee Formation of Huddlestun and Hetrick, in press) west of the Ocmulgee River because both units in their respective areas overlie the Twiggs Clay.

Cooke and MacNeil (1952, p. 21-23) again redefine the McBean Formation in South Carolina. They subdivided the middle Eocene deposits along similar lines previous to Cooke (1936). This included in ascending order of age the Congaree Formation, the Warley Hill Formation, and the McBean Formation. The Congaree Formation was "deemed of formational rank because it is equivalent to the Tallahatta formation of Mississippi and Alabama, which presumably is separated from younger deposits by an erosional interval." The name McBean was "retained, in a restricted sense, for the zone represented by the type locality of that formation. This zone, the *Ostrea sellaeformis*, is equivalent to the Cook Mountain formation of Texas and Mississippi, the upper part of the middle Claiborne."

The reason for this redefinition is contained in the following quote (Cooke and MacNeil, 1952, p. 21): "The Claiborne group throughout the States from Alabama to Texas has been divided into well-defined formations, each characterized by its distinctive fossils, and it now seems desirable to divide the McBean of Cooke (1936) along similar lines into three formations." It must be concluded that there was no new internal evidence for resubdividing the middle Eocene of South Carolina. The impetus came from progress in stratigraphic definition and resolution elsewhere. Furthermore, the new definition of the McBean is impossible to apply in the field: "The McBean is here restricted to include only the Cooke Mountain equivalent, the *Ostrea sellaeformis* zone, of the Lisbon formation. This is represented at McBean, Georgia, and in South Carolina by white sandy marl and massive yellow or red sand, which appears to be at least partly residual from sandy marl." (Cooke and MacNeil, 1952, p. 24). Most of the deposits that they (Cooke and MacNeil, 1952) believed to be McBean are noncalcareous and nonfossiliferous, and therefore do not contain *Ostrea sellae-*

formis, and the zone, the Cook Mountain equivalent, is inherently unidentifiable.

Cooke and MacNeil (1952, p. 21,22) expressed doubt as to the stratigraphic position and age of the Twiggs Clay in the type area in Georgia. Referring to Veatch and Stephenson (1911) they note, "How much of their Congaree is really Claiborne, however, is still uncertain; some deposits referred to it, notably the thick bed of fuller's earth at Pike's Peak, in Twiggs County, Georgia (the type locality of the Twiggs Clay), are now believed to be of Jackson age because of their supposed equivalence to similar clay in Houston County, Ga., that lies above fossiliferous Jackson limestone. Cooke and Shearer (1918) supposed that all their Congaree clay member was of Jackson age and transferred it to the Barnwell formation under the name Twiggs clay member. Later Cooke (1943, p. 61) restored that facies consisting of thin-bedded or laminated sand and clay to the McBean formation". It is to be noted that the "thin-bedded or laminated sand and clay" is the Irwinton Sand of LaMoreaux (1946a, 1946b) and both C. W. Cooke and F. S. MacNeil field checked and approved the stratigraphic interpretation of LaMoreaux (LaMoreaux, pers. com., 1980).

Essentially then, Cooke and MacNeil (1952) changed the concept of the McBean Formation from theoretically including all Claibornian deposits in western South Carolina and eastern Georgia (Cooke, 1936), to including, in principal, only those deposits of Cook Mountain age. However, it is clear that Cooke and MacNeil (1952) still retained those deposits now called the Dry Branch Formation (of late Eocene age) in the McBean Formation. Their stratigraphic interpretation still approximated that of Veatch and Stephenson (1911) and their concept of a formation was still a quasi-chronostratigraphic/biostratigraphic unit.

Siple (1967, p. 43-57) evidently derived his concept of the McBean and Barnwell directly from Veatch and Stephenson (1911), Cooke (1936), and Cooke and MacNeil (1952). However, Siple (p. 45) also considered the water-bearing properties of the deposits in determining stratigraphic terminology, "and because the rocks of Claiborne age within the report area appear to function principally as one or two water-bearing zones, the deposits of Claiborne age are grouped together for convenience as the McBean Formation generally and more specifically as the McBean Formation for the upper part and the Congaree (?) Formation for the lower part."

Siple (p. 45) listed five types of deposits as lithologies that are included in his concept of the McBean Formation. However, only lithology (4), "impure beds of soft fossiliferous limestone or marl" is consistent with McBean lithology. The other four lithology types (sand, clay, and silicified claystone) are not McBean lithostratigraphic unit. This is particularly true of the claystone that crops out north of New Holland Crossroads (Siple, Fig. 15, p. 46), which is the type locality of Turritella mcbeanensis Bowles, a misnomer based on the assumption that the fossil came from the McBean Formation.

The Congaree (?) Clay of Siple (1967) is evidently Twiggs Clay because no Congaree Formation in the strict sense is known to occur in the Savannah River area and because the Dry Branch Formation does overlie the "Tuscaloosa Formation" directly in much of Aiken County. Furthermore the "fuller's earth appearance" of hackly gray clay, and "greenish-gray clay" (p. 47) is all characteristic of Twiggs Clay and not of McBean Formation. However, as stressed above, Veatch and Stephenson (1911), Cooke (1936, 1943), and Cooke and MacNeil (1952) included Twiggs Clay and Irwinton Sand of current usage in their concepts of the McBean Formation and Siple derived his stratigraphic model from these authors. Finally, it is to be noted that Siple believed that the Twiggs Clay of Georgia is the Congaree Clay, "the Twiggs Clay Member as designated in Georgia is equivalent to the Congaree Formation of middle Claiborne age in South Carolina." (Siple, p. 55). As with the earlier above authors, Siple's concept of the McBean Formation and the overlying Dry Branch Formation of the Barnwell Group of current usage.

Siple also derived his concept of the Barnwell Formation from Veatch and Stephenson (1911), Cooke (1936, 1943), and Cooke and MacNeil (1952). Siple, however, was not consistent in his usage of the name Barnwell. For example, "the red sand clay of the Tertiary Barnwell Formation" (Siple, Fig. 7, p. 27) is not Barnwell but rather deeply weathered, brownish-red "Tuscaloosa Formation" that stratigrpahically overlies various kaolin lenses. The color difference between the beds within the "Tuscaloosa Formation" at this site is probably a result of the perched water tables above the lenses of impermeable clay. Similarly Siple (p. 60) believed that Ophiomorpha nodosa (= Halymenites major of Siple) occurs only in the "Hawthrone Formation". It is this author's experience in the Savannah River area that Ophiomorpha nodosa occurs locally in abundance only in the Tobacco Road Sand. Ophiomorpha nodosa does not occur in the McBean Formation, it is very rare in the Dry Branch Formation, and is not known in the fluvial "Hawthorne Formation" (Altamaha Formation). Similarly, the purple clay of Siple (p. 57) is characteristic of the Tobacco Road Sand in southern Burke County, Georgia, and is not present in the overlying "Hawthorne".

In terms of the Barnwell of Siple (1967), then, it is to be noted that at some sites Siple included "Tuscaloosa Formation" in the Barnwell (p. 27), at other sites the upper Barnwell (Tobacco Road Sand) is included in the "Hawthorne Formation" (p. 60), and the lower part of the Barnwell (Dry Branch Formation) is consistently included in the McBean Formation.

Both the concepts of the McBean Formation and the Barnwell Formation of Colquhoun, Heron, Johnson, Pooser, and Siple (1969) are derived directly from Cooke and MacNeil (1952) and Siple (1967) and need no further discussion here.

Finally, because of the change in the recognized age of the Cooper Marl in South Carolina to Oligocene (Cooke and MacNeil, 1952), and because of the suggested correlation of the Irwinton Sand with the "Cooper Marl" by LaMoreaux (1946b, p. 19), Herrick and Counts (1968, p. 37) correlated the Irwinton Sand in part with the "Cooper Marl", the Flint River Formation, and the Suwannee Limestone. In addition they (p. 54-63) correlated the beds containing *Crassostrea gigantissima* at Shell Bluff and Griffins Landing (Griffins Landing Member of the Dry Branch Formation of current usage) with the "Cooper Marl" and in general with the Oligocene series.

SUMMARY

There has been controversy in both the age assignments and the stratigraphic terminology of the marine middle and upper Eocene deposits in eastern Georgia and western South Carolina. The differing opinions on age assignments for these deposits are a result of the very poorly fossiliferous deposits above the McBean Limestone Member of the Lisbon Formation. Because in the past, stratigraphic terminology has been very intimately associated with age assignments, the stratigraphic terminology has naturally been unstable. This has resulted in two different stratigraphic models for the middle and upper Eocene deposits in the Savannah River area. The first model includes the McBean (in the strict sense) and the overlying Dry Branch Formation of current usage in one formation, the "McBean Formation" of assumed middle Eocene age (Veatch and Stephenson, 1911; Cooke, 1936, 1943; Cooke and MacNeil, 1952; Siple, 1967, and Colquhoun et al., 1969). The assumed age spread of this "McBean Formation" ranges from the entire Claibornian (Veatch and Stephenson, 1911; Cooke, 1936) to the "Cook Mountain equivalent" (Cooke and MacNeil, 1952; Siple, 1967; Colquhoun et al., 1969). The Barnwell Formation of this stratigraphic model is stratigraphically vague but conforms generally to the Tobacco Road Sand of current usage.

The second stratigraphic model recognizes the late Eocene age of the Dry Branch Formation, i.e., those sands and clays that underlie a flat pebble bed. This model is characteristically used in Georgia because it is in central Georgia, and not in South Carolina, that the stratigraphic relationships of the deposits in question (Dry Branch Formation) can be seen in the field in their full context. The Twiggs Clay and Irwinton Sand members of the Dry Branch Formation can be seen in kaolin pits to overlie the Ocala Limestone. This model was first conceived by Shearer (1917) and developed on by Cooke and Shearer (1918), LaMoreaux (1946a, 1946b), Huddlestun and Hetrick (1978, 1979, in press), and Huddlestun (in review). In this model the McBean Formation is restricted to only those calcareous deposits exposed at and lithologically correlatable with the type McBean, and the upper part of the Barnwell (Tobacco Road Sand) is recognized as a separate formation.

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A LATE OLIGOCENE OR EARLY MIOCENE AGE FOR THE DRY BRANCH FORMATION AND TOBACCO ROAD SAND IN AIKEN COUNTY, SOUTH CAROLINA?

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INTRODUCTION

A barnacle-bearing, clay-rich, partially silicified, partly leached, silica-cemented, quartz sandstone exposed in the vicinity of Graniteville, Aiken Municipal Airport, and Silver Bluff Road, in western Aiken County, South Carolina is mapped as the uppermost part of the Dry Branch Formation and perhaps the basal part of the Tobacco Road Sand (Figure 1). Huddlestun and Hetrick (1979) named the Dry Branch Formation to include three lithofacies: a basal (where present), rudely bedded to massively bedded, calcareous, fossiliferous sand lithofacies (Griffins Landing Member); a marine, montmorillonitic clay lithofacies (Twiggs Member); and an uppermost, distinctly bedded sand or sand and clay lithofacies (Irwinton Member). The Twiggs and Irwinton lithologies are present at the type section of the Dry Branch Formation in Twiggs County, Georgia. At places the named members are distinct and can be recognized separately, but in many places the different lithofacies, particularly of the Twiggs and Irwinton members, are intimately interbedded so that only the formational name is used. Huddlestun and Hetrick (1979, p. 21) point out that at different localities the Twiggs lithofacies is present at different stratigraphic levels within the Irwinton Sand sequence. The Twiggs lithofacies in much of eastern Georgia and in South Carolina probably is at a higher stratigraphic level than the type Twiggs Clay. For discussion of detail of Dry Branch stratigraphy, see Huddlestun and Hetrick (1979) and Nystrom and Willoughby (this volume).

The barnacle-bearing quartz sandstone appears locally at or near the top of the Dry Branch Formation and perhaps at the base of the Tobacco Road Sand in Graniteville, Hollow Creek, and Aiken Northwest 7 ½' quadrangles (Figure 1). In northern Graniteville Quadrangle the barnacle-bearing rock overlies kaolin beds of the Huber Formation. In northern Hollow Creek Quadrangle and in southern Aiken Northwest Quadrangle the barnacle-bearing rock occurs in the top of the Dry Branch Formation. Other silica-cemented sandstone blocks at the top of the Dry Branch Formation or base of the Tobacco Road Sand that occur with the barnacle-bearing sandstones may lack or contain few fossils. Specific locality information is given in the Appendix to this paper.The Tobacco Road Sand was named by Huddlestun and Hetrick (1978) for massive to thin-bedded, well-sorted and fine-grained to poorly-sorted and coarse-grained, granule- and pebble-bearing sand in Richmond County, Georgia that they traced from central Georgia into western South Carolina. Later, Huddlestun and Hetrick (1979) established the Barnwell Group in Georgia and defined it to include the basal Clinchfield Sand, the Dry Branch Formation, and the overlying Tobacco Road Sand (Figure 2). Huddlestun and Hetrick (1979, p. 8) correlated the Clinchfield and Dry Branch formations with the lower part of the Gulf Coast Jacksonian Stage (lower upper Eocene) and the Tobacco Road Sand with the upper part of the Jacksonian Stage (upper upper Eocene). Geologic mapping by Willoughby and Nystrom demonstrates that the Dry Branch Formation occurs in southern Graniteville Quadrangle and throughout Hollow Creek Quadrangle, and that the Tobacco Road Sand occurs throughout both quadrangles; the Clincfield Sand is not present in either quadrangle.

The Aiken County quartz sandstone includes abundant compartmental and opercular plates of a small archaeobalanid barnacle, together with a few echinoid spine and test fragments, benthonic foraminifera, worm tubes, and fragments and shells of small pectinid mollusks. Although the barnacles are preserved as silica and clay replacement of the original calcite, every morphological detail is faithfully reproduced. The Aiken County archaeobalanid barnacle is unrelated to any archaeobalanid group known from the Eocene of either the Gulf or Atlantic coastal plains, but is attributable to a group that appeared in the Oligocene of North Carolina and Mississippi and continued through the lower Miocene in North Carolina.

EOCENE-LOWER MIOCENE DISTRIBUTION OF BARNACLES

Detailed stratigraphic collections from Claibornian, Jacksonian, Vicksburgian, and Chickasawhayan strata (middle Eocene through lower Miocene) in the eastern Gulf Coastal Plain and from their equivalents in Georgia and the Carolinas have yielded several genera and species of scalpelloid ("goose") and archaebalanid ("primitive acorn") barnacles. Establishment of the stratigraphic ranges of individual species and of species assemblages in the eastern Gulf Coast has permitted recognition of two formal Eocene cirriped

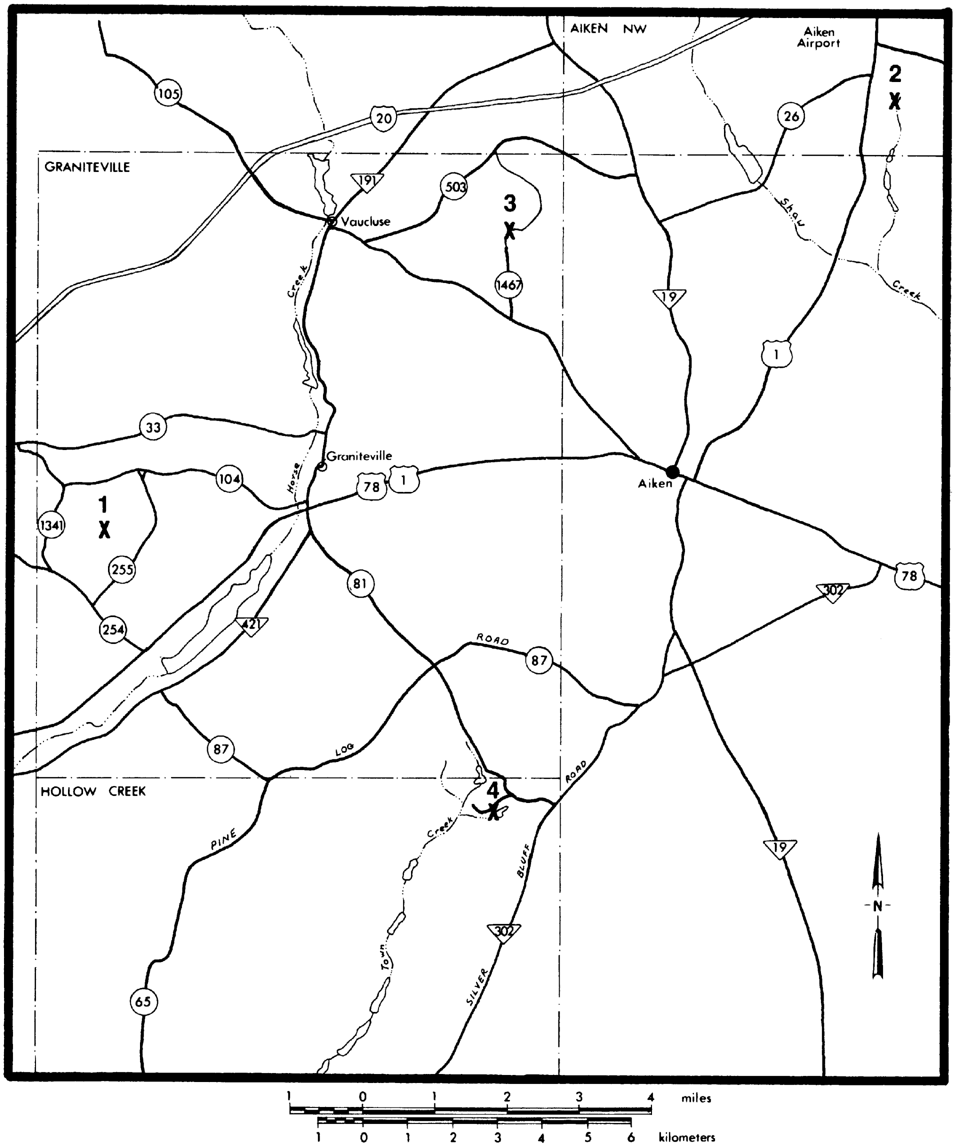


Figure 1. Map showing barnacle localities in Aiken County, South Carolina. See Appendix for detailed locations. See road log (this volume) for measured section at locality 2.

zones: the Arcoscalpellum subquadratum Assemblage Zone of late Claibornian age, and the A. jacksonense Assemblage Zone of Jacksonian age (Zullo, 1980, in press, Figure 3). Both of these zones are represented in the Eocene of Georgia and the Carolinas (Figures 2, 4). Species representative of the A. subquadratum Assemblage Zone are found in the McBean Formation of Gerogia and in the upper Santee Limestone of South Carolina. Representatives of the A. jacksonense Assemblage Zone occur in the Clinchfield Sand and the Griffins Landing Member of the Dry Branch Formation in Georgia, in the Cross Formation in South Carolina, and in the Castle Hayne Limestone in North Carolina. Two archaeobalanid groups (new genera) characterize these Eocene zones. One group, typified by *"Solidobalanus" antiquus* (Meyer, 1868) from the Gosport Sand of Alabama, occurs in both the Gulf Coastal Plain and in the southeastern Atlantic Coastal Plain (Pl. 1, figs. 1-5). The other group, typified by *"S." cornwalli* (Zullo, 1966) from the Cowlitz Formation of southern Washington is found in southeastern Atlantic Coast and in Pacific Coast stratigraphic units (Pl. 1, figs, 6-8). The only barnacle known from the Tobacco Road Sand in Georgia is an unusual archaeobalanid species with an extremely striated scutum and no definite affinity with any of the Paleogene archaeobalanids now known from the Gulf or Atlantic coastal plains.

Vicksburgian and Chickasawhayan (Oligocene through lower Miocene) strata in the eastern Gulf Coastal Plain and their equivalents in North Carolina contain barnacle assem-

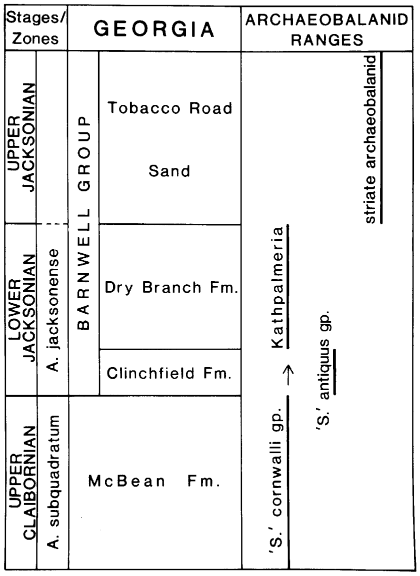


Figure 2. Distribution of archaeobalanids in exposed Paleogene units in central and eastern Georgia. *Kathpalmeria* Ross is a member of the *"S." cornwalli* group and occurs, together with another species of that group, in the Griffins Landing Member of the Dry Branch Formation. Correlation after Huddlestun and Hetrick (1979).

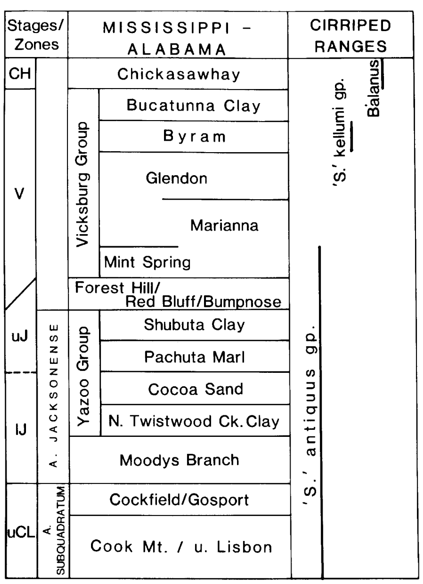


Figure 3. Distribution of archaeobalanids in exposed Eocene and Oligocene units in Mississippi and Alabama. The balanid genus *Balanus* Da Costa makes its first appearance in the eastern Gulf section in the upper Oligocene Chickasawhay Formation. Abbreviations used for Gulf Coast Stages are: uCL = upper Claibornian; lJ = lower Jacksonian; uJ = upper Jacksonian; V = Vicksburgian; CH = Chickasawhayan.

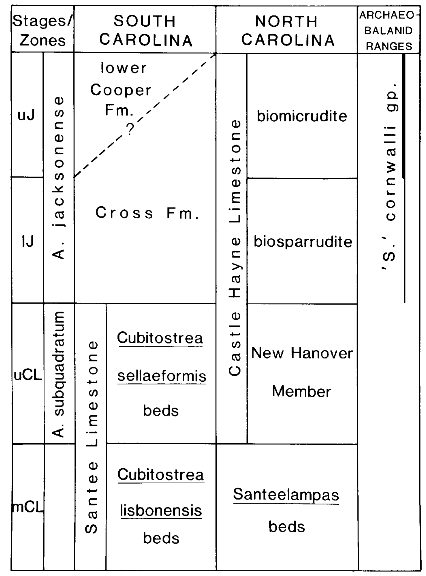


Figure 4. Distribution of archaeobalanids in exposed Eocene units in the Carolinas. Total range of the *"S." cornwalli* group is range based on its presence in the Cross Formation. Heavy solid line indicates distribution of the "S." cornwalli group in the biomicrudite member of the Castle Hayne Limestone. Stage abbreviations are; mCL = middle Claibornian; uCL = upper Claibornian; lJ = lower Jacksonian; uJ = upper Jacksonian.

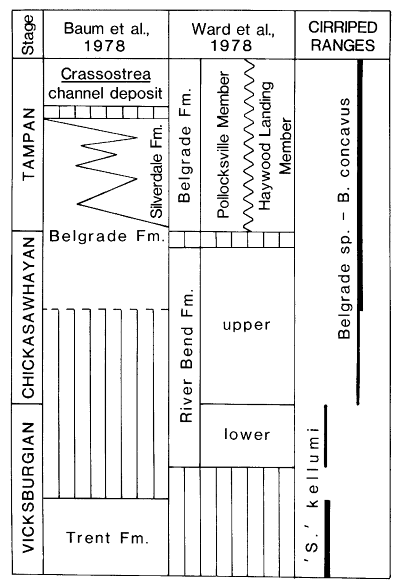


Figure 5. Distribution of the *"S." kellumi* group and *Balanus concavus* in Oligocene and lower Miocene units in North Carolina. Heavy solid lines indicate ranges based on correlations of Baum and others (1978) and Zullo (1979). Fine solid lines indicate alternative ("S." kellumi) or additional (Belgrade species + B. concavus) ranges based on correlations of Ward and others (1978). The Trent Formation is the lower River Bend, the Belgrade Formation is the upper Fiver Bend, the Silverdale Formation and *Crassostrea* channel deposit is the Belgrade.

blages substantially different from those of the *Arcoscalpellum subquadratum* and *A. jacksonense* zones. Scalpelloid barnacles are absent. Archaeobalanids are represented by a continuation of the "Solidobalanus" antiquus lineage in the Red Bluff Formation, Bumpnose Limestone, and the lower Vicksburgian Mint Spring Formation. The "S." antiquus lineage died out prior to the time of deposition of the upper Vicksburgian Byram Formation, which contains a species that is unrelated to the *"S." antiquus* group (Pl. 1, figs. 9-14), but is placed in a separate group (new genus) with "S." kellumi Zullo and Baum.

This younger archaeobalanid genus is best represented in the Oligocene and lower Miocene of North Carolina, where two species are known. The older species, *"S." kellumi*, is found in the Oligocene Trent Formation of Baum and others (1978; = lower River Bend Formation of Ward and others, 1978). Baum and others (1978) considered the Trent Formation to be early to mid-Oligocene in age, whereas Ward and others (1978) correlated these same deposits with the Byram Formation of late Oligocene age. In the eastern Gulf Coast, a species of the *"S." kellumi* genus-group first appears in the Byram Formation of Mississippi, as the preceding paragraph and Figure 3 indicate. The presence of a representative of the *"S." kellumi* genus-group might suggest a late Oligocene, rather than early Oligocene, age for the Trent Formation of North Carolina. However, of the two species in the *"S." kellumi* genus-group present in North Carolina, it is the younger species (see following paragraph), rather than the older species *"S." kellumi*, that is more similar to the Byram species. Thus the biostratigraphic relationships indicate an early Oligocene (pre-Byram) age for the Trent Formation of North Carolina.

Overlying the Trent Formation are the Belgrade Formation and Crassostrea channel deposits of Baum and others (1978; = upper River Bend and part of the overlying Belgrade formations of Ward and others, 1978) that contain a second, derivative, species of the *"S." kellumi* genus-group (the Solidobalanus n. sp. C of Zullo, 1979) (Pl. 1, figs. 15-22). This species is found in association with two new species of the Balanus concavus Bronn group, a group first recorded from lower Miocene (Aquitanian) rocks in other parts of the world (Zullo, 1979). On the basis of the first known occurrence of the B. concavus group in the Tertiary of the Atlantic and Gulf coastal plains, and on the assumed lateral equivalency of the Belgrade Formation with the lower Miocene (Tampan Stage) Silverdale Formation of North Carolina, Baum and others (1978, 1979) and Zullo (1979) considered their Belgrade Formation and overlying Crassostrea channel deposit to be lower Miocene. Ward and others (1978), however, regarded the Belgrade (their upper River Bend) as a lower Chickasawhayan equivalent (upper Oligocene), and only the Crassostea channel deposit (part of their Belgrade Formation) as lower Miocene. Thus, the Belgrade Formation of Baum and others (1978), which contains a derivative species of the *"S." kellumi* genus-group, has been considered either a lower Chickasawhayan (upper Oligocene) or a Tampan (lower Miocene) equivalent. Of possible relevance to this argument is the observation that Balanus is represented in the Chickasawhay Formation of Alabama (St. Stephens quarry, Washington County) not by a member of the B. concavus group, but by a primitive species with archaeobalanid affinities (Zullo, in press). The distribution of barnacles occurring in North Carolina Oligocene and lower Miocene stratigraphic units, together with a summary of the relationships between the stratigraphic interpretations of Baum and others (1978) and Ward and others (1978), in presented in Figure 5.

Plate Legend

Figures 1-3, 5. *"Solidobalanus" antiquus* (Meyer), Gosport Sand, Claiborne Bluff, Alabama. (1) exterior of rostrum showing broad radii; (2) interior of rugose tergum (spur broken); (3) interior of scutum – note lack of adductor ridge; (5) interior of rostrum showing broad radii with crenate sutural edges.

Figure 4. Interior of tergum of new species of *"S." antiquus* group from the Cocoa Sand, Isney, Alabama, showing rugosities.

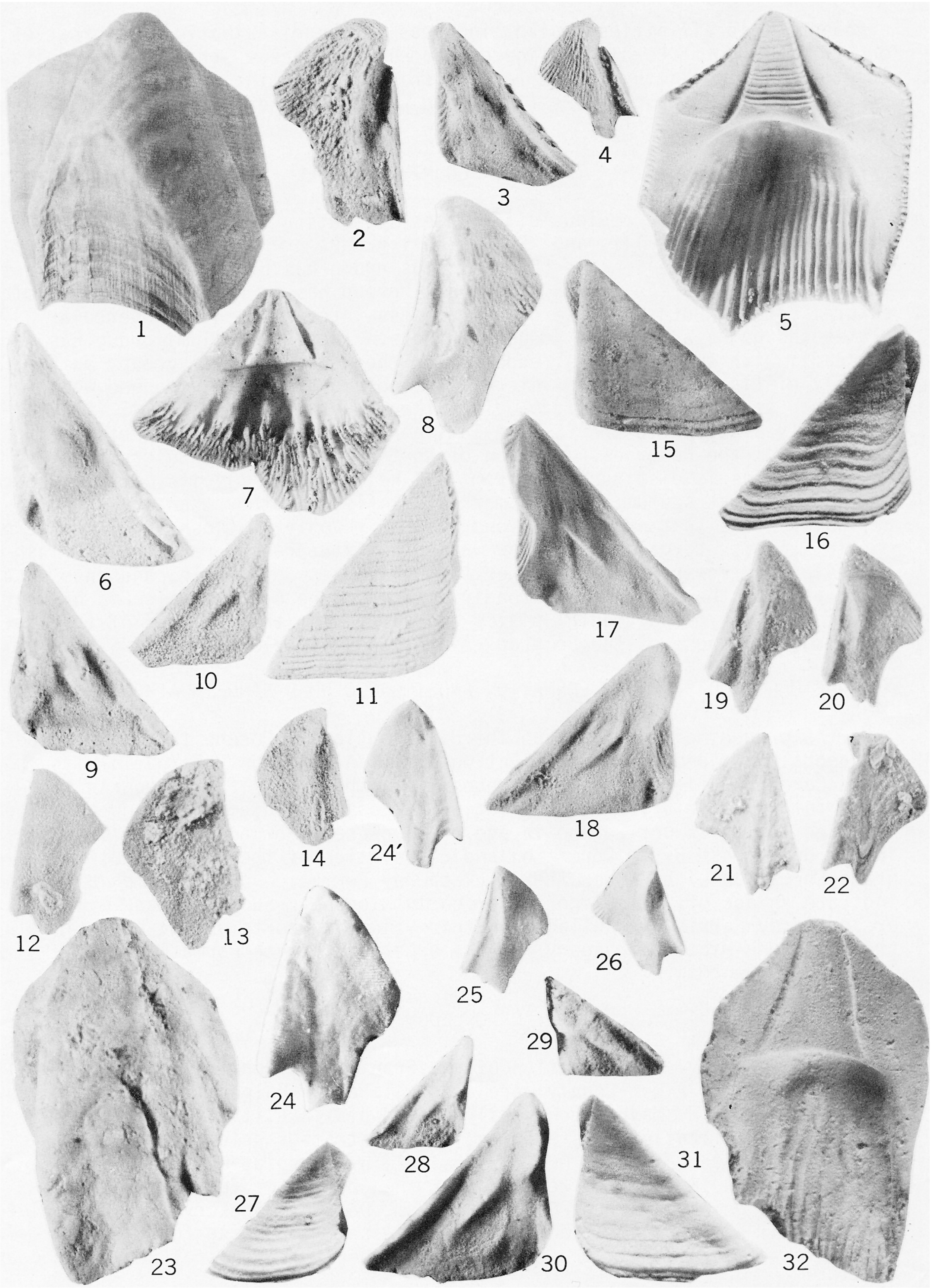
Figures 6-8. Kathpalmeria georgiana Ross, type locality of Griffins Landing Member, Dry Branch Formation, Griffins Landing, Burke County, Georgia. (6) interior of scutum – note lack of adductor ridge; (7) interior of rostrum with smooth radial suture edges and infolded ribbing; (8) interior of non-rugose tergum.

Figures 9-14. *"Solidobalanus" kellumi* Zullo and Baum, Trent Formation, Onslow County, North Carolina. (9-10) interior of flat scuta with erect articular ridges and short, prominent adductor ridges; (11) exterior of flat scutum with non-protrudent articular ridge; (12-13) exteriors of terga with flush spur furrows and broad spurs; (14) interior of tergum with broad spur.

Figures 15-22. Belgrade Formation species of *"S." kellumi* group, Belgrade Formation of Baum and others (1978), Martin Marietta Belgrade quarry, Belgrade, Onslow County, North Carolina. (15-16) exteriors of bowed scuta showing protrudent articular ridges; (17-18) interiors of scuta with adductor ridges; (19-20) interior of smooth terga with narrow spurs; (21-22) exteriors of terga showing depressed spur furrows.

Figures 23-32. Aiken County species, localities 1 and 2, Aiken County, South Carolina. (23) exterior of rostrum (loc. 2); (24-24') exteriors of terga with narrow spurs and depressed spur furrows (loc. 2); 25-26) interiors of terga (loc. 2); 27, 31) exteriors of bowed scuta with protrudent articular ridges (loc. 2); (28-29) interiors of scuta with adductor ridges (loc. 1); (30) interior of scuta with adductor ridge (loc. 2); (32) interior of rostrum showing smooth sutural edges of radii.

All illustrations except figures 1, 5, 7, 23, 32 are x7; figures 1, 5, 23, 32 are x4; figure 7 is x3.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THE AIKEN COUNTY BARNACLE

Some of the most obvious differences separating the "*Solidobalanus" antiquus*, "*S." cornwalli*, and *"S." kellumi* groups are readily observed from the figures in Plate 1. The *"S." antiquus* group has broad radii with crenate sutural edges, whereas the "S." cornwalli group has narrow radii with smooth sutural edges. Both of these groups possess internally rugose opercular plates and both lack scutal adductor ridges. The *"S." kellumi* group has narrow radii with smooth sutural edges as in the *"S." cornwalli* group, but is readily distinguished by its internally smooth opercular plates and well-developed scutal adductor ridge. The Aiken County Species (Pl. 1, figs. 23-32) is readily assigned to the *"S." kellumi* genus-group and is conspecific with the species from the Belgrade Formation of North Carolina. The Belgrade-Aiken County Species is distinguished from *"S." kellumi* by; (1) its markedly bowed rather than flat scutum; (2) its markedly reflexed rather than erect scutal articular ridge that projects beyond, rather than being flush with, the tergal margin; and its tergal spur furrow which (3) is depressed rather than flush and (4) is narrower, placed farther from the basiscutal angle, and ends in a blunt point rather than being broadly rounded. The Byram species is presently known only from compartmental plates and scuta, but the features of the scutum are more like those of the Belgrade-Aiken County species than of *"S." kellumi.*

AGE OF THE DRY BRANCH FORMATION AND TOBACCO ROAD SAND IN AIKEN COUNTY

The preceding discussion of the distribution of Eocene through Miocene archaeobalanids and the identification of the Aiken County barnacle with the North Carolina Belgrade species suggest that the fossiliferous quartz sandstone in the upper Dry Branch Formation and basal Tobacco Road Sand as mapped in Aiken County is not Eocene in age. The presence of a Belgrade-like species in the Gulf Coast Byram Formation and correlation of the North Carolina Belgrade Formation with either the Chickasawhay Formation or the Tampa Limestone indicate an age of late Oligocene or early Miocene. Supplementary evidence presented by Harris and Fullagar in this volume supports an age approximating the Oligocene-Miocene boundary for the upper Dry Branch Formation at one locality in Georgia.

ACKNOWLEDGMENTS

The discovery and collection of the Graniteville barnacles, together with the field work in Aiken County were accomplished by Ralph Willoughby and Paul Nystrom. Arthur H. Maybin generously shared his locality information. Collection, identification, systematics, and biostratigraphic interpretation of barnacle assemblages in the Gulf Coastal Plain, Georgia, North Carolina, and northeastern South Carolina were accomplished by Victor Zullo with the invaluable and generous aid of Gerald R. Baum, David T. Dockery III, W. Burleigh Harris, Paul F. Huddlestun, and Ernest T. Russell. Funding for field work in Georgia was provided by a grant from the Southeastern Regional Education Board.

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APPENDIX

Barnacle localities in western Aiken County

Locality 1. SCGS A-001. J.M. Huber Corporation's Barden kaolin pit in west-central Graniteville, S.C. 7 ½' Quadrangle (1964 map; photo-revised 1980), at 33º33' 00" N latitude, 81º51' 4" W. longitude. Barnacle plates were collected from an isolated, silica-cemented sandstone block that appears to be in place at the bottom of a mining pit. Only sand (no kaolin) and two silicified blocks are present at the bottom of the pit, but other silicified blocks have been moved to the surrounding land surface. The block that supplied the fossils is apparently from the base of the Tobacco Road Sand or from in the Dry Branch Formation. Elsewhere in the pit, the Tobacco Road Sand lies directly on kaolin of the upper Huber Formation in one exposure (see road log, this volume, Stop 12), and the Dry Branch Formation occurs above kaolin of the upper Huber Formation and below the Tobacco Road Sand at the “high wall” in the Barden pit.

SCGS A-001a. In the Barden pit at 33º32’ 55” N latitude, 81º51’ 26” W. longitude. Barnacle plates occur abundantly in large silicified sandstone blocks that were moved and piled together during kaolin mining operations. The blocks lie 2-4 meters above water’s edge and above kaolin of the upper Huber Formation, and are 161 m N 13 W. of the tombstone of Esther Emmons LeCoultrie (1914-1980) in Carter Cemetery; or 53 m due north and then 110 m N 20 W. of the cited tombstone. Mr. W.H. Kirkland of J.M. Huber Corporation in Langley, S.C. has stated to RHW that the blocks originally came from immediately overlying the kaolin beds in this pit. The blocks are from the base of the Tobacco Road Sand or from in the Dry Branch Formation.

Locality 2. SCGS A-002. In the south-central part of the Aiken Northwest, S.C. 7 ½’ Quadrangle (1964 map), at 33º 38’ 8” N latitude, 81º 40’ 15” W. longitude. The fossiliferous rock is a silica-cemented sandstone exposed in a low wall at the north end of an abandoned fullers earth pit along the upper reaches of Bradley Mill Branch. The entire exposure at this locality lies within the Dry Branch Formation, and Twiggs Clay lithology is present at the base of the pit and in the streambed to the east.

Locality 3. SCGS A-003. In the northeastern part of Graniteville, S.C. 7 ½’ Quadrangle (1964 map; photorevised 1980), at a sharp bend in a dirt road (S-2-1467) located at 33º 36’ 41” N latitude, 81º 45’ 44” W. longitude. Fossils are from silica-cemented boulders displaced during road-grading, are on both sides of the road, and are from above the top of the kaolin (upper Huber Formation) exposed in the road. The boulders and the pebble bed in the sand overlying the kaolin may represent the base of the Tobacco Road Sand or part of the Dry Branch Formation.

Locality 4. SCGS A-004. In a recently opened housing subdivision in northeastern Hollow Creek, S.C. 7 ½’ Quadrangle (1964 map; photorevised 1971), just to the south off of a paved road not shown on the map, in a gully leading downhill towards the dam shown on the map; at 33º29’ 37” N latitude, 81º49’ 5” W. longitude. Barnacle plates are abundant in loose, weathered, clayey sand at the top of the gully. The locality is within the Dry Branch Formation, in sand overlying Twiggs Clay lithology that is exposed just west of the dam. Silicified sandstone blocks with barnacles, shark teeth, and ray teeth occur across the road and to the southwest.

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RB-SR GLAUCONITE ISOCHRON, TWIGGS CLAY MEMBER OF DRY BRANCH FORMATION, HOUSTON COUNTY, GEORGIA

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ABSTRACT

Five hand-picked, authigenic glauconite concentrations that were analyzed for Rb, Sr, and Sr, isotopic compositions yielded an isochron age of 23.0 ± 0.2 m.y. (87 Rb=1.42 x 10 $^{-11}$ yr $^{-1}$) for the uppermost part (bed #19) of the Twiggs Clay Member of the Dry Branch Formation, Houston County, Georgia. The initial $(87Sr/86Sr)_0$ ratio of 0.7087 ± 0.0006 calculated from the isochron is in good agreement with previous estimates of the strontium isotopic composition during the Oligocene/Miocene. Although the Twiggs Clay is generally considered to have a late Eocene age (Jacksonian), the isochron age suggests a position near the Oligocene/Miocene boundary for the uppermost part (bed #19) of the unit.

INTRODUCTION

Recently reported glauconite radiometric ages from Europe (Odin et al., 1978) and the Atlantic Coastal Plain (Owens and Sohl, 1973; Harris, 1976; Harris and Zullo, 1980; Fullagar et al., 1980; Harris, in press; and Harris et al., in press) demonstrate that glauconite ages can be used to accurately determine the time of sediment deposition in post-Jurassic marine strata. Although Owens and Sohl (1973) and Odin et al. (1978) utilized the K-Ar method, Harris (1976), Harris and Zullo (1980), Fullagar et al. (1980), Harris (in press), and Harris et al. (in press) employed the Rb-Sr method. Harris (1976) suggested that as daughter 87Sr is usually far less susceptible to system loss than daughter 40Ar, the Rb-Sr method may yield more accurate glauconite ages. To alleviate the problems that are inherent in the use of the model age method, i.e., where the original quantity of 87Sr (expressed as the $(87Sr/86Sr)_0$) present at the time of glauconite formation is estimated, Harris (1976), Harris and Zullo (1980), Fullagar et al. (1980), and Harris et al. (in press) utilized the isochron method. Because a minimum of five co-existent samples from the same lithostratigraphic zone or horizon are utilized in isochron age determinations, erroneous samples are easily identifiable by their deviation from the isochron. To date, our work in the southeastern Atlantic Coastal Plain of Virginia and North and South Carolina has not yielded glauconite isochron ages that conflict with the biostratigraphic data.

As a result of this success, we have initiated glauconite studies on Georgia, Alabama, Mississippi, and Louisiana Paleogene units. This report briefly outlines the results of application of the Rb-Sr isochron method to glauconite from the uppermost Twiggs Clay Member of the Dry Branch Formation, Barnwell Group, Houston County, Georgia (Figure 1).

GEOLOGIC SETTING

The Jacksonian stage (upper Eocene) in the Georgia Coastal Plain consists of two distinct lithofacies, a dominantly calcareous facies lying to the south and southeast and a dominantly clastic facies lying to the north and east. The calcareous facies or Ocala Group (Murray, 1961) consists of several differentiated limestones in Georgia (Huddlestun and Hetrick, 1979) and the Inglis, Williston, and Crystal River formations in Florida. The clastic facies or Barnwell Group (Huddlestun and Hetrick, 1979) consists, in ascending order, of the Clinchfield Formation, the Dry Branch Formation, and the Tobacco Road Sand. In the central and east-central Jackson outcrop belt, the Ocala and Barnwell groups and a clay lithosome that is recognized in Alabama and Mississippi as the Yazoo Group, interfinger. This area of interfingering presents a complex of lithosomes whose stratigraphy is difficult to interpret. The Clinchfield and Dry Branch formations are assigned to the lower Jacksonian Stage, whereas the Tobacco Road Sand is assigned to the upper Jacksonian Stage. The boundary between the lower and upper Jacksonian grades from disconformable updip to conformable downdip. The Clinchfield Formation is a persistent unit which is recognized throughout the entire Jackson outcrop belt; however, the Dry Branch Formation consists of several different members which are developed in different areas. To the north and east, the Dry Branch Formation consists principally of the Irwinton Sand Member and the Griffins Landing Member whereas in the central Georgia Coastal Plain, the entire Dry Branch stratigraphic interval consists mainly of the Twiggs Clay Member (Huddlestun and Hetrick, 1979).

The Twiggs Clay was named by Shearer (1917) and formally designated a member of the Barnwell Formation by Cooke and Shearer (1918); exposures near Pikes Peak station on the Macon, Dublin, and Savannah Railroad, Twiggs

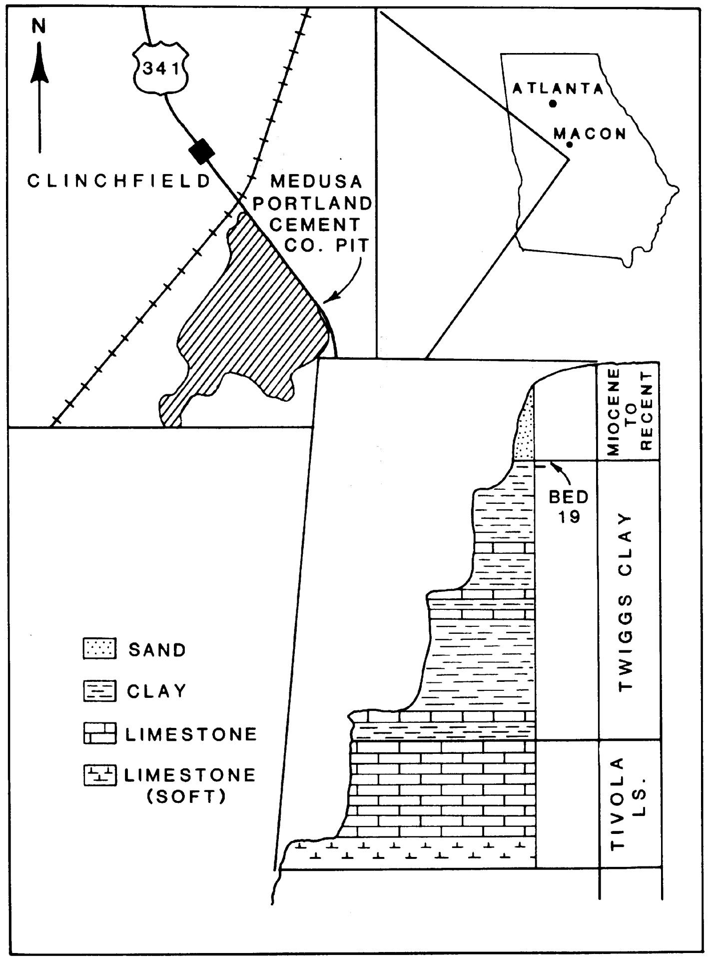

Figure 1. Location of the Medusa Portland Cement Company pit, Houston County, Georgia.

County, were identified as the type locality. As the type locality is now covered by a second generation forest, Huddlestun and Hetrick (1979) designated the railroad cut called "map locality E" by Shearer (1917) as the neostratotype, and also proposed the exposure at the pit of the Medusa Portland Cement Company, Houston County, as a hypostratotype.

The Twiggs Clay Member of the Dry Branch Formation is a pale greenish, olive green to dark gray silty clay with occasional concentrations of silt to fine sand along bedding planes. Previous workers have recognized an eastern and western lithofacies. The eastern, east of the Ocmulgee River, is characterized by a paucity of calcite and glauconite and the almost universal presence of disordered cristobalite resulting from the abundance of diatoms, radiolarians, and sponges. The western lithofacies, west of the Ocmulgee River, is generally calcareous with admixtures of sand, glauconite, mica and pyrite. Glauconite-rich beds are generally present near the top of the unit (Huddlestun and Hetrick, 1979) and occur either as burrow fillings or as cross-laminations in the clay. The glauconite collected for radiometric analyses came from the cross-laminated zone. Although most of the morphological types described by Triplehorn (1966) are present, mammillated to lobate varieties are the most common.

ANALYTICA PROCEDURES AND RADIOMETRIC RESULTS

A composite sample of glauconitic bed #19 of Huddlestun et al. (1974) was collected at the hypostratotype of the Twiggs Clay Member of the Dry Branch Formation along the south face of the Medusa Portland Cement Company pit, Houston County. Five glauconite concentrates were separated on the basis of grain-size and external morphology into samples designated GA9-260D, GA9-260L, GA9-280, GA9-2120D, and GA9-2120L. The samples were further prepared for analysis according to the procedure described by Harris and Bottino (1974). The concentrated samples contained less than 1% pyrite. X-ray diffraction analysis of the glauconite confirmed that the samples consisted of the disordered mineral glauconite as defined by Bentor and Kastner (1965).

Table 1. Rb-Sr Analytical Data for the Twiggs Clay Member of the Dry Branch Formation, Houston County, Georgia

Sample	Rb (ppm)	Sr (ppm)	Rb^{87}/Sr^{86}	$(Sr^{87}/Sr^{86})_N$
GA9-260D	280.0	2.43	337.7	0.8189
GA9-260L	276.0	7.38	108.6	0.7445
GA9-280	269.9	1.32	601.4	0.9054
GA9-2120D	277.1	5.27	152.8	0.7584
GA9-2120L	275.9	5.61	143.1	0.7550

The five glauconite samples were analyzed for Rb, Sr, and Sr isotopic composition using standard chemical and isotopic dilution procedures. Rb and Sr were separated by using concentrated acids and small ion-exchange columns according to the technique developed by Russell (1978). The results are shown in Table 1.

Rb and Sr blanks were collected in order to monitor contamination encountered in handling and preparing the samples for analysis. Analysis of the blanks has shown that procedural contamination for Rb and Sr was negligible. On the basis of replicate analyses of rock samples and the National Bureau of Standards standard sample 70a, K-feldspar, one-standard deviation experimental errors are estimated to be no greater than $\pm$ 0.0005 for the 87Sr/86Sr and 1.0% for the 87Rb/86Sr ratios.

The 87Sr/86Sr values in Table 1 have been normalized to 86Sr/88Sr = 0.1194, and are given relative to a 87Sr/86Sr ratio of 0.7080 for the Eimer and Amend $SrC0_3$ Standard. The isochron age was calculated using the decay constant of 87Rb = 1.42 x $10^{-11}yr^{-1}$ (Steiger and Jager, 1978).

The Rb-Sr mass spectrometry was performed at The University of North Carolina at Chapel Hill with a single-focusing, 12-in., triple-filament mass spectrometer. Data were collected and analyzed with a Nuclide DA/CS-III automation and data-reduction computer system.

The results of the five glauconite samples have been calculated as an isochron age using the least-squares regression method of York (1969). The isochron plot for the five samples indicates an age of 23.0 $\pm$ 0.2 m.y. for the uppermost bed (#19) of the Twiggs Clay Member of the Dry Branch Formation at the Medusa Portland Cement Company pit in Houston County, with an initial $(87Sr/86Sr)_0$ = 0.7087 + 0.0006 (Figure 2).

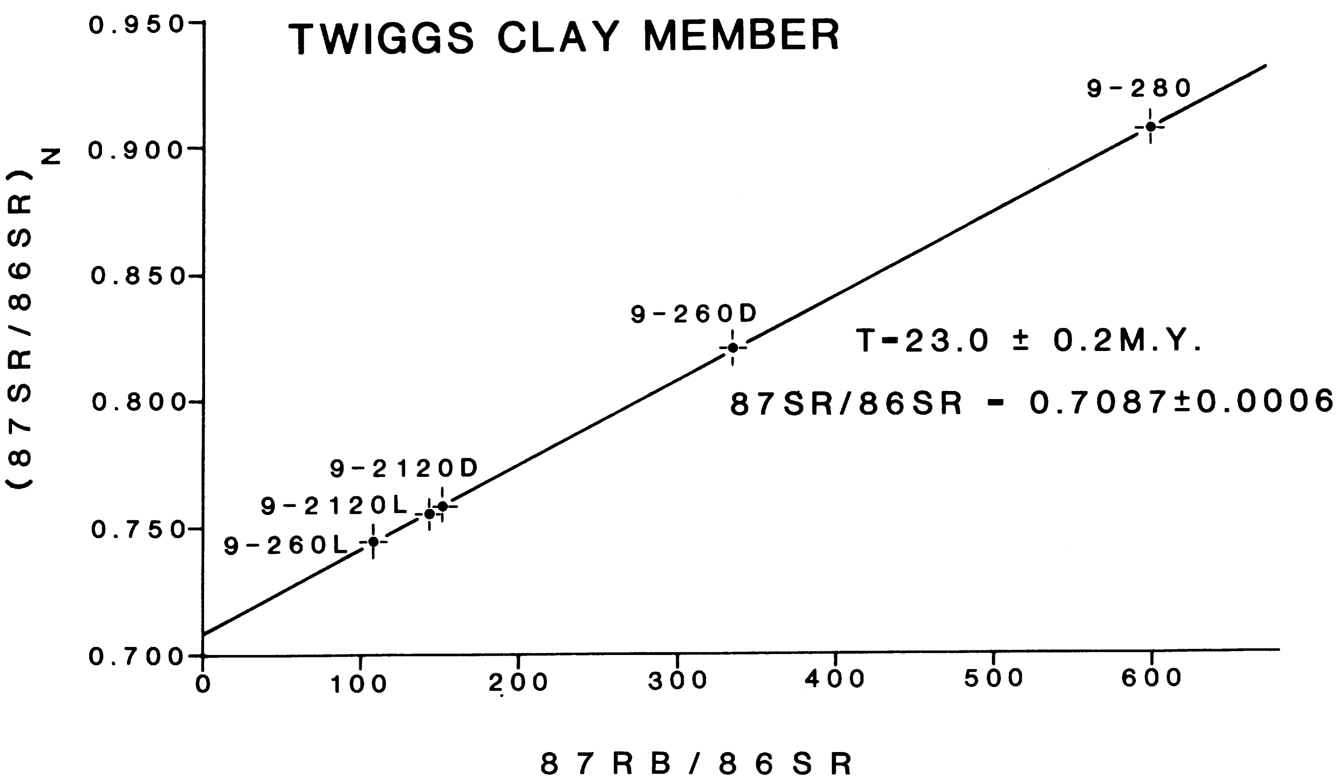

Figure 2. Plot of $(87Sr/86Sr)_N$ versus 87Rb/86Sr for bed #19, Twiggs Clay Member, Dry Branch Formation.

DISCUSSION AND CONCLUSIONS

The Rb-Sr glauconite isochron age of 23.0 ± 0.2 m.y. suggests a position near the Oligocene/Miocene boundary (in the lower Miocene?) for the upper bed of the Twiggs Clay at the Medusa Portland Cement Company pit. Although the dated zone does not contail a diagnostic flora or fauna, fossils of late Eocene age have been reported from several localities that are correlated with the Twiggs Clay Member of the Dry Branch Formation (Veatch and Stephenson, 1911; Shearer, 1971; Cooke and Shearer, 1918; Cooke, 1943; Cushman, 1945; Pickering, 1970; Schmidt, 1970; Darrell, 1974; Huddlestun et al., 1974; Huddlestun and Hetrick, 1979). Hence, it is difficult to dispute the reported Eocene age for the Twiggs Clay. However, several lines of evidence other than the isochron suggest that the upper part of the Twiggs Clay at the Medusa Portland Cement Company pit may be as young as earliest Miocene. The Tivola Limestone, which conformably underlies the Twiggs Clay at the pit, contains Periarchus pileussinensis and Pecten spillmani (Huddlestun et al., 1974). P. pileussinensis and P. spillmani are restricted to the Yazoo Clay (Pachuta Marl) in Mississippi and Alabama and the middle Crystal River Formation of the Ocala Group in Georgia and Florida (Toulmin, 1977). These units have a well-documented upper Jacksonian age and are assigned to calcareous nannofossil zone NP19. Thus, as the Tivola Limestone should be assigned to calcareous nannofossil zone NP19, the Twiggs Clay is younger.

P. pileussinensis occurs in the Cross Formation in South Carolina (Zullo, 1982, personal communication), a unit that is considered late Eocene (Jacksonian, NP19-20) in age (Baum et al., 1980). Fullagar et al. (1980) and Harris et al. (in press) dated the Cross Formation and its partial equivalent in North Carolina, the Castle Hayne Limestone, by the Rb-Sr isochron method and obtained ages of 34.1 ± 1.5 m.y. and 34.9 ± 1.1 m.y., respectively. As the sample of the Twiggs Clay that yielded an age of 23.0 ± 0.2 m.y. was collected about 30 m stratigraphically above calcareous nannofossil zone NP19, it is probably younger than this zone. An apparent youngness of the Twiggs Clay appears to have been alluded to by Cushman (1945) when he stated that "The fauna of this Twiggs Clay, while evidently Jackson age, … has some species (that) have not previously been recorded earlier than the Miocene." It seems reasonable that a clay unit greater than 30 m in thickness could span several nannoplankton zones. Our extremely consistent radiometric data for the Twiggs Clay indicate that the top of the unit at the Medusa Portland Cement Company pit may be in nannoplankton zone NN1, just above the Oliogocent-Miocene boundary based on the numerical limit for the boundary suggested by Hardenbol and Berggren (1978). The Twiggs Clay at the Medusa Portland Cement pit occurs above beds which are considered to be late Eocene in age and below beds which are considered Miocene to Holocene (Huddlestun et al., 1974); therefore, it is suggested that as there are no diagnostic flora or fauna in the dated zone, there is no biostratigraphic evidence present to dispute the radiometric age. A detailed investigation of the floral and faunal assemblages of the entire Twiggs Clay at the Medusa Portland Cement Company pit should be made in order to document correlation of the unit with Eocene, Oligocene, or Miocene stratotypes in the Gulf Coastal Plain.

ACKNOWLEDGMENTS

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TERTIARY STRATIGRAPHY OF THE OAKWOOD QUADRANGLE, AIKEN COUNTY, SOUTH CAROLINA

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INTRODUCTION

The Oakwood 7.5-minute quadrangle is located in the Upper Coastal Plain of South Carolina in Aiken County, east of the town of Aiken. The Upper Coastal Plain in this region consists of a broad upland area (the Aiken Plateau) which has been greatly dissected by stream erosion, resulting in somewhat limited exposure of underlying Cretaceous and Tertiary sediments, with Quaternary alluvium present along flood plains of major rivers in the area.

The stratigraphic section of Upper Coastal Plain sands and clays exposed in the Oakwood quadrangle contains the same Tertiary lithologic units recognized in the Graniteville-Hollow Creek area to the west (Nystrom and Willoughby, this volume). The Tobacco Road Sand (Huddlestun and Hetrick, 1978), the Dry Branch Formation (Huddlestun and Hetrick, 1979) and the Huber Formation (Buie, 1978) are relatively recently named Tertiary units for which detailed descriptions have been confined mostly to their exposures in central and eastern Georgia. That these units extend eastward of the Savannah River into Aiken County, South Carolina was recognized (Smith, 1979) but the limit of their eastward extent is generally undetermined. Nystrom and Willoughby (1982a) first correlated sediments overlying the Huber Formation in Graniteville and Hollow Creek quadrangles with the Tobacco Road Sand and Dry Branch Formation of eastern Georgia, which have been assigned an Upper Eocene (Jacksonian) age by Huddlestun and Hetrick (1978; 1979). Smith (1979) had not made a distinction between these two units, but mapped them together as the Barnwell Group.

Recent detailed geologic mapping of the Oakwood quadrangle (Figure 1) has shown that this sequence of stratigraphic units is present and exposed in this area, and that these units can be distinguished and delineated. This work was part of an ongoing program of geologic mapping and compilation by the South Carolina Geological Survey aimed toward publishing an up-to-date state geologic map. The purpose of this report is to briefly describe the Tertiary stratigraphy of the Oakwood quadrangle.

STRATIGRAPHY

Huber Formation

The Huber Formation, defined by Buie (1978) as being the post-Cretaceous pre-Jackson strata occurring in the kaolin mining districts of Georgia, and assigned a Paleocene and Middle Eocene (Claibornian) age, is the most extensively outcropping unit within the Oakwood quadrangle. Its lithology is quite diverse, showing both vertical and lateral variation.

The lower portion of the formation consists of fine- to medium-grained sands, moderately to well sorted with thin discontinuous kaolin laminae, and some small rounded or discoidal kaolin balls. However, beds of quartz gravels or poorly sorted coarse sands are not uncommon in this part of the section. The fine sands commonly exhibit well developed small scale crossbedding and are frequently clean and loose. Clay-lined burrows are present and are noted to be of two varieties, small tubular burrows about 3 mm or smaller in diameter and larger (10-25 mm diameter) borings (*Callianassa* ? burrows), both types which branch and run in all directions.

The upper portion of the formation is comprised predominantly of beds of medium- to very coarse-grained quartz sand with fewer beds of finer grained sands. These sands show medium to large scale crossbedding. Kaolin is more abundant than in the lower portion, occurring as thin continuous layers, as conglomeratic layers of rounded kaolin balls, and as beds of pure to sandy massive kaolin. These massive kaolin beds are nearly always located within the uppermost portion of the unit and commonly mark the top of the formation. This is noted particularly in exposures in the northeastern corner of the quadrangle.

For the most part the contact between the upper Huber sands and overlying Dry Branch Formation is poorly exposed; however in at least one auger hole the top of the Huber was oxidized to a deep red color. Throughout its thickness, the Huber is typically orangish-red to yellowish-orange in weathered exposures.

Vertebrate marine fossils, including shark teeth and ray teeth and spines, have been found in the lower Huber at a location in the northeastern portion of the quadrangle (Figure 1). This is the first reported occurrence of vertebrate marine fossils within the Huber Formation. The fossils (Figure 2) are poorly preserved at best and are very fragile, having been almost completely altered to clay. The bed in which most of the fossils were found consists of poorly sorted, mostly very coarse quartz sands with some rounded quartz pebbles. A few scattered phosphate grains were also found. The exposure contains little or no interstitial clay with only scattered small kaolin balls or stringers. A detailed description of the entire outcrop at this locality is presented in Table 1. The shark and ray fossils as well as the presence of burrows and some phosphate grains indicate a marine origin for at least this section of the Huber Formation. Burrows seen elsewhere in the lower Huber in Oakwood Quadrangle and in the Gran-

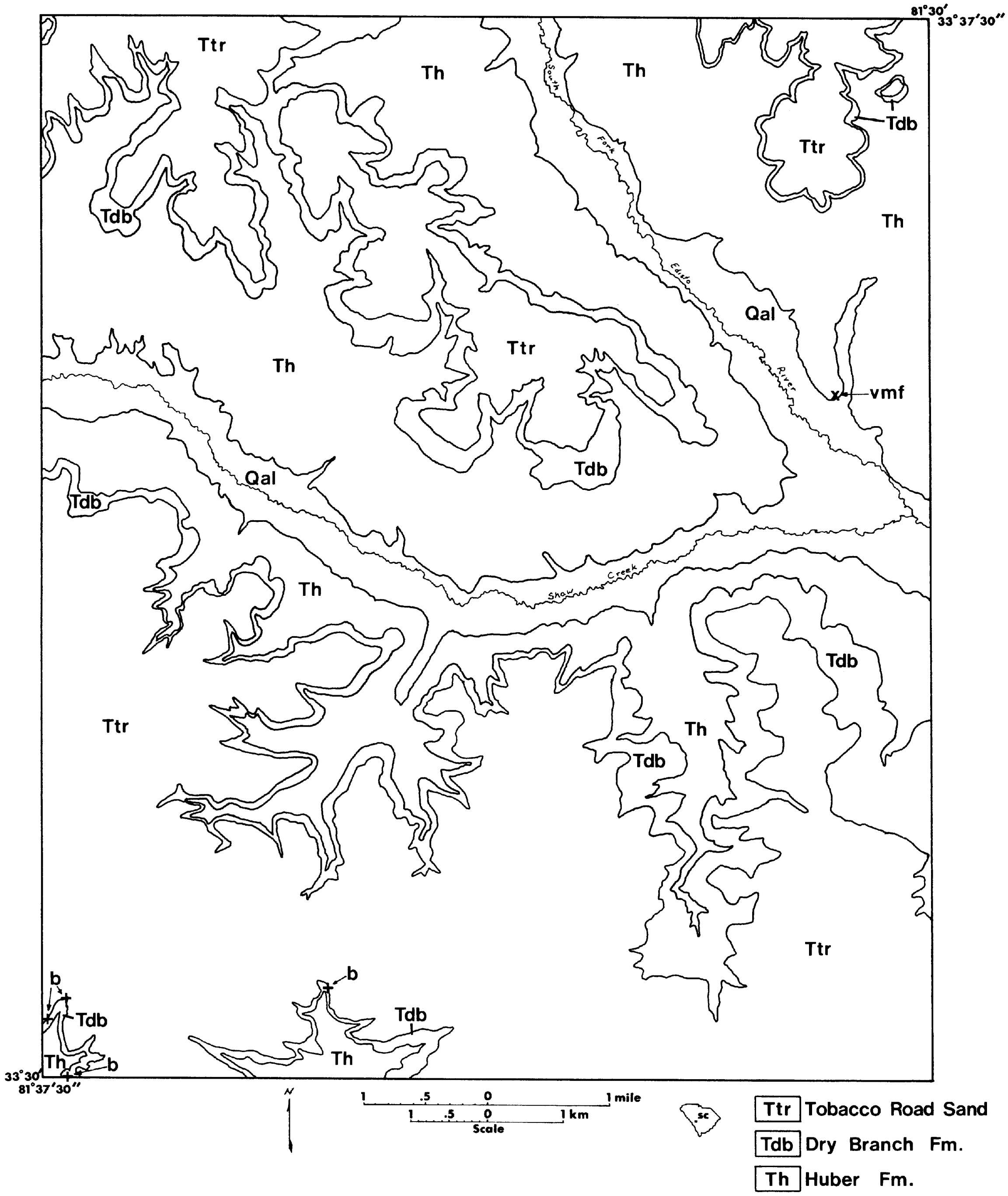

Figure 1. Geologic map of Oakwood Quadrangle, Aiken County, South Carolina; (x) marks locality at which vertebrate marine fossils (vmf) are found; (+) marks buhrstone (b) localities.

iteville-Hollow Creek area (Nystrom and Willoughby, this volume) indicate a marine origin for these sediments over a large area.

Exposures have not permitted positive identification of any Cretaceous sediments within the map area, and thus the thickness of the Huber Formation in this area has not been determined. Sediment retrieved from a power auger hole at the fossil locality included a .3 m thick black clay at a depth of 9.5 meters (31 feet), which is interpreted by the author to be not of the Huber Formation but of Cretaceous age. Thus the fossil bearing Huber sediments would be at most 10.5 meters (35 feet) above possible Cretaceous sediments and the total thickness of the Huber in this part of the map area would be a maximum of 36 meters (120 feet).

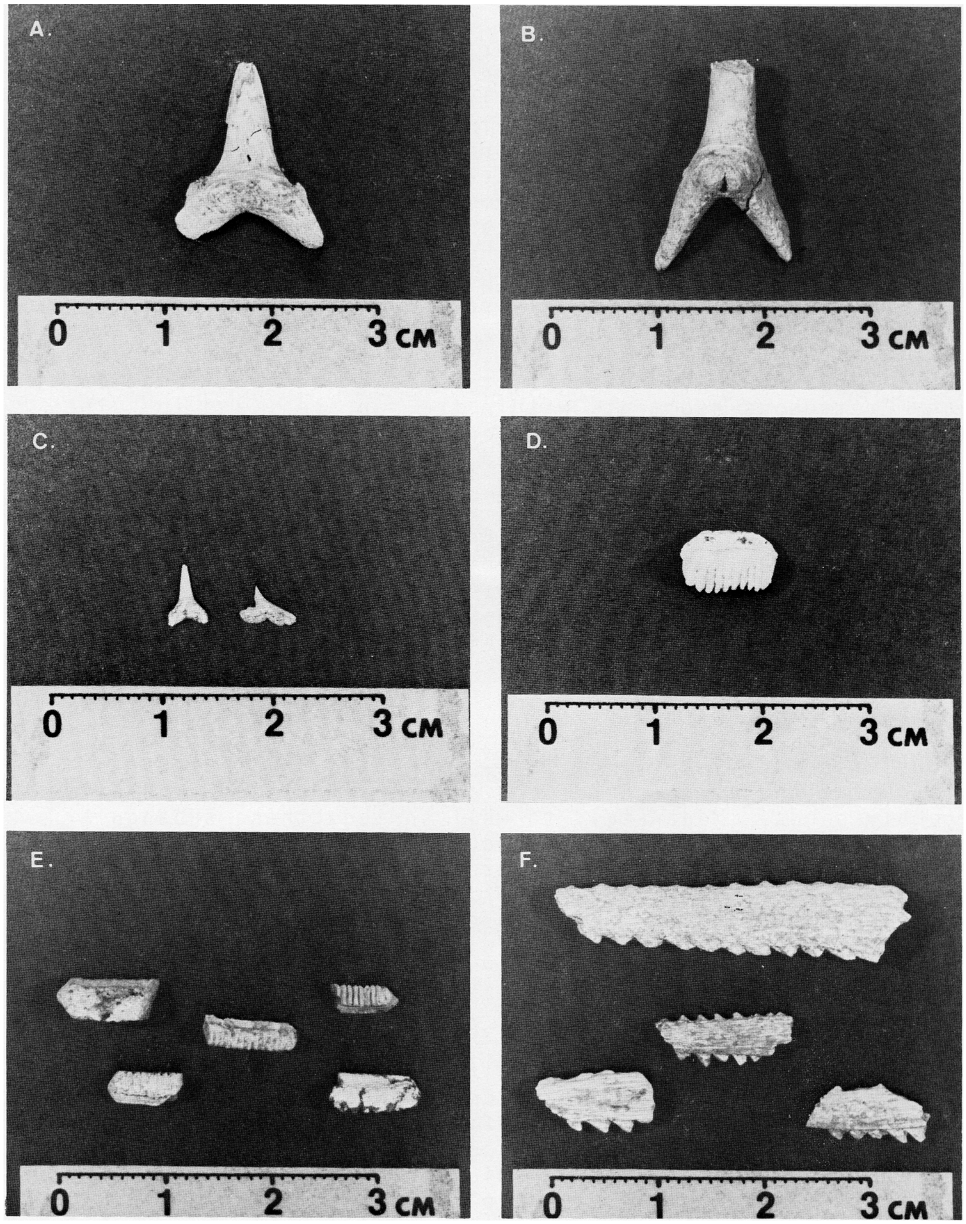

Figure 2. Marine vertebrate fossils collected from the Huber Formation in Aiken County, S.C., at roadcut on Rt. 264, three hundred feet northwest of intersection with Rt. 302; A., B., C. shark teeth; D., E. ray teeth; F. ray tail soines.

Dry Branch Formation

In the Oakwood quadrangle the Dry Branch Formation consists predominantly of fine- to medium-grained quartz sands, although there are beds of coarser grained, sometimes pebbly sands. Moderately to well sorted, these subangular to subrounded sands commonly occur in thin wavy beds, sometimes exhibiting small scale crossbedding. Fresh exposures are yellow-orange to yellow, while weathered exposures are usually more reddish-orange in color. Typically these sands are relatively soft and loose with little or no interstitial clay. Clay does commonly occur within these sands as wispy laminae or thin discontinuous layers which vary in color from white to tannish brown to deep purple.

Exposures of montmorillonitic clay (Twiggs Clay lithology, LaMoreaux, 1946) within the Dry Branch are confined to the extreme southwest corner of the Oakwood quadrangle, where these clays compose a single bedded unit which in places exceeds one meter in thickness. These clays are greenish-tan in color, have a plastic consistency when moist, and exhibit well developed parting along horizontal planes of silty quartz only one to two grains thick. Other exposures of the Dry Branch Formation to the north and east within the quadrangle do not contain these well developed sections of

Table 1. Detailed stratigraphic section of a portion of the Huber Formation in which vertebrate marine fossils are found, northeast side of roadcut on County Road 264, 300 feet northwest of intersection with State Road 302.

Thickness Feet	Thickness Meters	
3.0	.9	Quartz pebble conglomerate; pebbles include milky quartz, smoky quartz and rotten quartz gravels in a matrix of poorly sorted fine to coarse sand; also some badly weathered clay balls; limonite cemented sands and gravels found locally at base. Concentration at base of fine to coarse, dark heavy minerals. Slight fining upward in grain size, fewer pebbles. Lower contact abrupt, undulating.
6.6	2.0	Coarse to very coarse sand at base (.4 m) grades into fine to medium, mostly fine, well-sorted quartz sands with occasional coarse grains; quartz grains subangular to subrounded with a clay coating. Kaolin present as very thin (1-2 mm) stringers and as small stubby flakes and chips, these clay stringers become thicker, more continuous laminae in upper portion of unit. Small scale crossbeds present in finer sands and most apparent in middle of unit. Grain size of sands increases to medium to coarse with occasional pebbles in upper 1 meter of unit with limonite cemented material scattered in top .3 meters. Small (2-3 mm dia.) clay lined burrows present in fine sands of unit. Sparsely fossiliferous with shark teeth and ray spines. Lower contact gradational.
2.0	.6	Coarse to very coarse sands with quartz pebbles and some limonite cemented chips and flakes; pebbles are subrounded to rounded; coarse sand grains are angular to subrounded, a few showing crystal faces. Fossiliferous with shark teeth, ray teeth and spines, also occasional phosphate grains. Orangish-red in color. Little interstitial clay, some small discoidal kaolin balls and thin short laminae. Lower contact gradational.
1.6	.5	Medium to coarse, moderately well-sorted quartz sand; grains angular to subangular with a clay coating; no clay balls or laminae present; orange to orangish-red in color.

Twiggs lithology. In the northeast corner of the quadrangle, well-bedded sands with wispy clay laminae (Irwinton Sand lithology) are found directly upon massive kaolin beds of the underlying Huber Formation; and the Twiggs Clay lithology, which typically is found at the base or in the lower third of the Dry Branch Formation (LaMoreaux, 1946; Huddlestun and Hetrick, 1979; Nystrom and Willoughby, this volume), is absent.

Large outcrops of silicified fossil-bearing sandstone, Sloan's (1908) buhrstone, occur in the extreme southwestern corner of the Oakwood Quadrangle (Figure 1) at the horizon corresponding to the contact between the Dry Branch Formation and the overlying Tobacco Road Sand. This silicified sandstone correlates with the fossiliferous silica-cemented sand found in the Graniteville-Hollow Creek area discussed by Nystrom and Willoughby (this volume) and Zullo, Willoughby and Nystrom (this volume). Fossils occurring in this lithology include abundant barnacles, as well as a few pelycepods and small bryozoans.

Tobacco Road Sand

The Tobacco Road Sand is found capping the upland stream divides in Oakwood quadrangle. It is characterized by mostly medium to coarse, poorly sorted sands with common quartz gravels and subordinate amounts of clay and mica. The clay most commonly occurs as small balls or clasts or as thin discontinuous layers. Beds locally exhibit small to medium scale crossbedding, but other exposures are massive. Bioturbation is commonly observed, particularly in upper portion of the unit which are more clay-rich. Large clay-lined burrows up to 25 mm or more in diameter (Callianassa ? burrows) are present and locally abundant. Typically deep red in color where weathered, some exposures of these sands in the higher elevations of the upland areas show pinkish-purple color commonly accompanied by variable amounts of purple clay. The unit is typically indurated throughout; there are sporadic occurrences in outcrop of iron-cemented sands.

The base of the Tobacco Road is typically characterized by a well-rounded discoidal quartz pebble horizon. Though widespread, this pebble zone is not always observed, the base of the unit being marked locally by a distinct coarsening of the clayey red sands overlying the finer loose yellow sands of the Dry Branch Formation.

SUMMARY

Detailed geologic mapping of the Oakwood quadrangle has produced significant results. The Tertiary stratigraphy exposed there, as described in this report, includes lithologies which are physically correlatible with the Huber Formation, Dry Branch Formation and Tobacco Road Sand of the Graniteville-Hollow Creek area of western Aiken County, South Carolina (Nystrom and Willoughby, this volume) and eastern Georgia (Huddlestun and Hetrick, 1978; 1979). Though no age determinations have been made for the Oakwood lithologies, the physical correlation of these units with those of the west suggests they are of the same age (Paleocene and Middle Eocene; and Upper Eocene to Miocene).

The presence of vertebrate marine fossils within the lower Huber is significant in that it not only is the first reported occurrence of such fossils from this unit, but also indicates a definite marine origin for these sediments. Prior to this field study the Dry Branch Formation and Tobacco Road Sand had not been identified as separate units within the Oakwood area, having been mapped simply as the Barnwell Group (Smith, 1979). Also the fossiliferous silicified sand (buhrstone) which is locally found at the horizon marking the contact between the Dry Branch Formation and Tobacco Road Sand has been shown to be present at least as far east as southwestern Oakwood quadrangle.

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STRATIGRAPHY OF THE JACKSON AREA, AIKEN COUNTY, SOUTH CAROLINA

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ABSTRACT

The Jackson 7.5-minute quadrangle (excluding the Georgia and Savannah River Plant portions) was the subject of a detailed field investigation (Figure 1). Field mapping and power auger drilling were the chief means of acquiring data.

Four pre-Quaternary lithologic units have been identified in the Jackson, S.C. area. The oldest unit has been tentatively designated the Middendorf Formation and generally consists of micaceous, coarse, angular to subangular, poorly sorted sands with clay beds common. The Huber Formation (Buie, 1978) unconformably overlies the Middendorf Formation and is separated from the Middendorf Formation based on an abrupt change in grain size and sorting. The Huber Formation is characterized by medium-grained, subangular to subrounded, well-sorted clayey sands and sandy clays. Above the Huber Formation is the Irwinton Sand Member of the Dry Branch Formation (Huddlestun and Hetrick, 1979). This unit is a yellow, fine- to medium-grained, well-sorted sand. It is characteristically well-bedded and high-angle crossbeds are common. The Tobacco Road Sand (Huddlestun and Hetrick, 1978) overlies the Dry Branch Formation and together with it, should be considered a single depositional package. The Tobacco Road Sand is a clayey, generally coarse-grained, red sand.

A single Quaternary unit was mapped and is composed of the fluvial sands of Hollow Creek and a Pleistocene (?) river terrace deposit which overlies and truncates the Middendorf Formation. Local upland gravel deposits occur sporadically in the northeastern corner of the study area but were not delineated.

INTRODUCTION

The Jackson 7.5-minute quadrangle is located in southern Aiken County and is bounded by parallels 33º 15’ and 33º 22’ 30” and meridians 81º 45’ and 81º 52’ 30” (Figure 2). The area of study is located in the Upper Costal Plain physiographic region and lies in the Savannah River Valley and on the western slope of the Aiken Plateau (Cooke, 1936). Three topographic divisions are noticeable in the Jackson area and it should be noted that there is a direct relationship between lithology changes and these topographic divisions. The topography is dominated by the gently sloping flood plain of the Savannah River, which extends from about 140 feet to river level (approximately 95 feet). A gentle slope from 190 feet to 140 feet forms the second topographic division, while the third division is comprised of two upland lobes of the Aiken Plateau and is located in the northern one-third of the quadrangle. The lobes are separated by Hollow Creek and are dissected and drained by its tributaries. Hollow Creek empties into the Savannah River just northwest of Silver Bluff.

The quadrangle was the subject of a detailed mapping and power auger drilling project and is part of a continuing program of geological mapping by the South Carolina Geological Survey, aimed at the publication of a current state geologic map. Previous mapping work in the study area was performed by Cooke (1936), Siple (1967) and Smith (1979).

The author expresses thanks to Ralph H. Willoughby and Paul G. Nystrom of the South Carolina Survey for their discussions and cooperation. Thanks also to Gary L. Taylor (SCGS) and John Bishop (University of South Carolina) for their services in auger drilling and to Lou E. Kite (SCGS) for her drafting work.

STRATIGRAPHY

In the Jackson area, four pre-Quaternary lithologic units are recognizable. Although no pollen or fossil dates have come from the study area, the author believes that these lithologies are correlative with units mapped by other workers in Aiken County (Nystrom and Willoughby, 1982a; Nystrom and Willoughby, this volume; Kite, this volume). These four units have proved to be extensive, distinctive, and mappable.

The oldest unit in the area, tentatively designated the Middendorf Formation, is correlated to the lower lithology of the Hamburg cut in the Augusta East quadrangle (Nystrom, Willoughby, and Kite, this volume). These four units have proved to be extensive, distinctive, and mappable.

The oldest unit in the area, tentatively designated the Middendorf Formation, is correlated to the lower lithology of the Hamburg cut in the Augusta East quadrangle (Nystrom, Willoughby, and Kite, this volume). The Middendorf Formation is frequently pebbly, with smoky quartz pebbles common. Excellent exposure of interbedded, massive gray to off-white clays and red clayey sands can be seen in railroad cuts of the Seaboard Coast Line Company, which extend from the northwest corner to the southeast corner of the area. As in the overlying Huber Formation, the Middendorf Formation is comprised mainly of clayey sands and sandy clays. Kaolinitic phases are found in both units, but are more common in the Middendorf sequence. Abundant clay beds, abundant mica, poor sorting, and coarse grain sizes characterize the Middendorf Formation in the Jackson area. The strata of the Middendorf Formation are variegated,

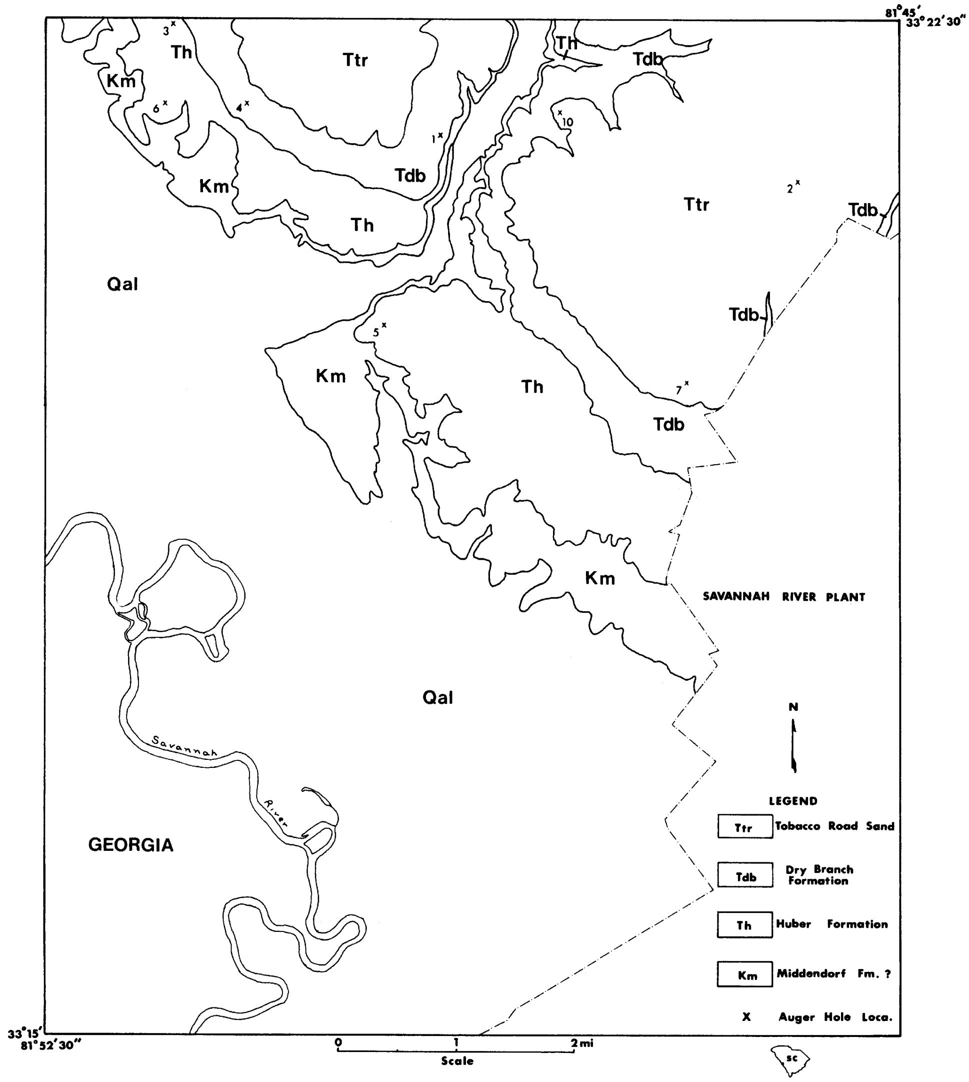

Figure 1. Geologic map of the Jackson Quadrangle, Aiken County, S.C.

with colors ranging from red and pink to white, off-white, and gray. In the Jackson quadrangle, Smith (1979) was not able to separate the Middendorf Formation from the Huber Formation.

The Huber Formation unconformably overlies the Middendorf Formation in the study area. It is a generally deeply weathered, yet distinct lithology and consists of fairly well-sorted, medium- to coarse-grained clayey sands and sandy clays. This lithology in the Jackson area is correlated to the Huber Formation of central Georgia, defined by Buie (1975). Very little exposure of this unit is available and its contacts were delineated almost entirely from drill hole information (Figure 3). The Huber Formation is separated from the underlying Middendorf Formation based on an abrupt change in sorting (from poor sorting in the Middendorf Formation to good sorting in the Huber Formation) and grain size (from coarse and very coarse grains in the Middendorf Formation to generally medium grains in the Huber Formation). The Huber lithology was recognized in the area by

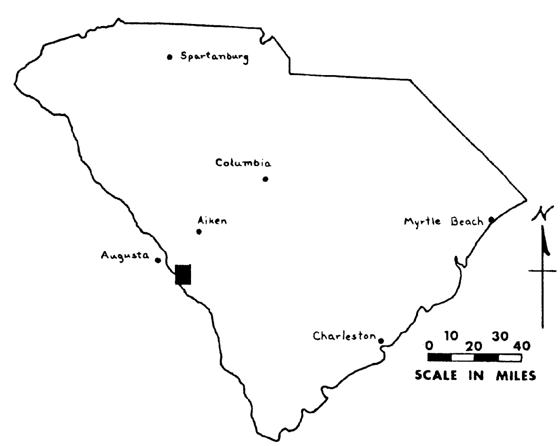

Figure 2. Location Map (adapted from Colquhoun and Johnson, 1968).

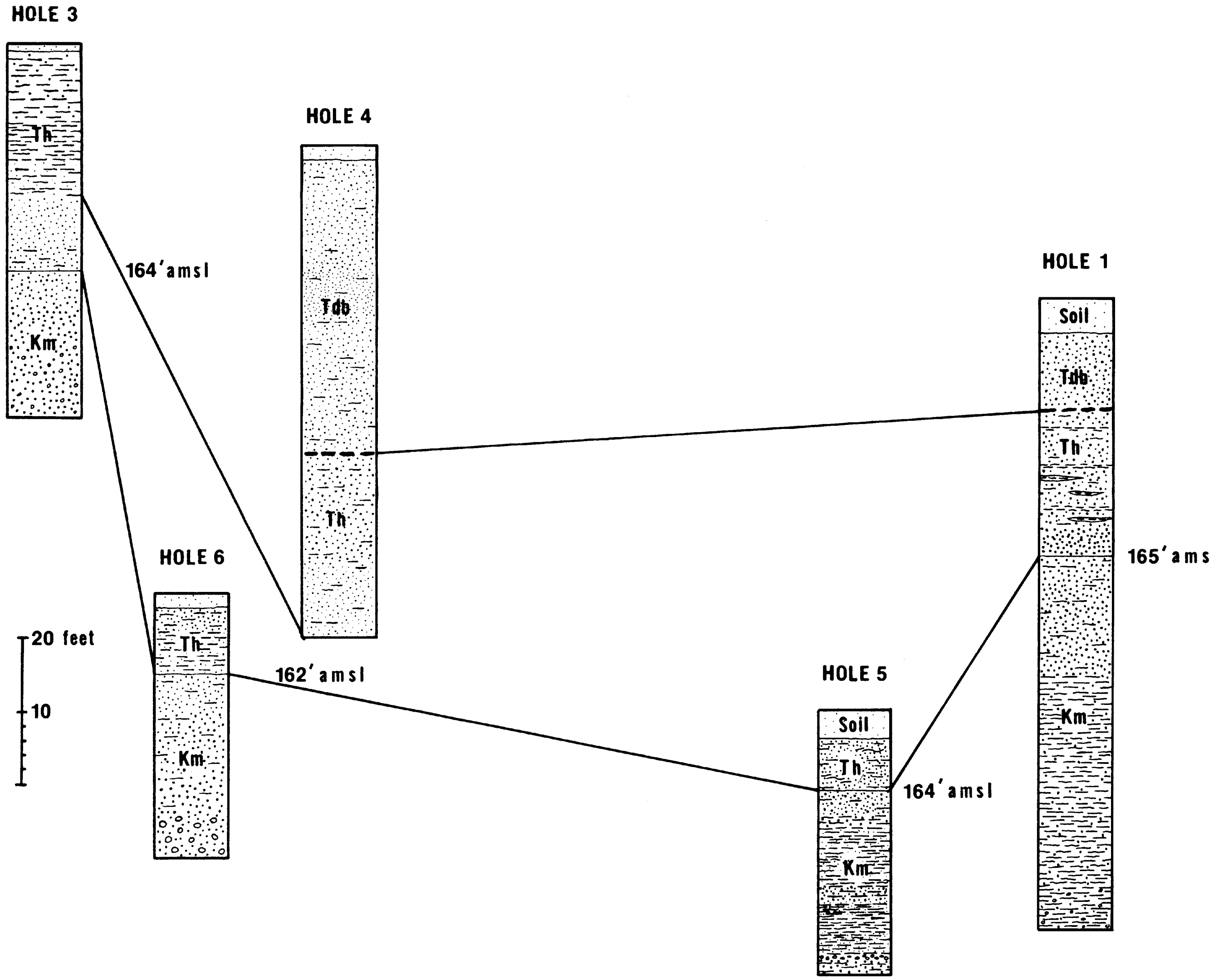

Figure 3. Auger hole columns.

Hole 1
Location: .8 miles N53ºW of the intersection of State Highway 125 and Aiken County Road 1409, Collar elevation: 200' amsl, Total depth: 86 ft.
Drill log – description

Residuum	0-5'	Soil
Dry Branch (Irwinton Sand) lithology	5-15'	Sand, medium- to coarse-grained, clayey, brown to red color
Huber lithology	15-35'	Sand, clayey, kaolinitic in upper 15 feet, with clay interbeds, white to pink and purple in color; lower 5 feet in coarse, mustard yellow sand
Middendorf lithology	35-86'	Sand, clayey, interbedded with gray to lavender clays and sandy clays, some white (kaolinitic) and yellow phases; in last 6 feet, encounter white to yellow kaolinitic sandy clays, pebbly

Hole 3
Location: 1.15 miles N34ºW of the intersection of Aiken County Road 5 and Aiken County Road 32, Color elevation: 195' amsl, Total depth: 51 ft.
Drill log – description

Residuum	0-1'	Loose sandy soil
Huber lithology	1-11' 11-16' 16-31'	Clay, gray to pink, cohesive, with some coarse sand Clay, cohesive, yellowish-gray color Sand, clayey, well-sorted, fine- to medium-grained, yellow to orange and off-white in color
Middendorf lithology	31-51'	Sand, medium- to coarse-grained, poorly sorted, very pebbly in last 10 feet, yellow to orange color except last 5 feet, which is kaolinitic with noticeable heavy mineral fraction

Hole 4
Location: .3 miles N2ºE of the intersection of Aiken County Road 5 and Aiken County Road 32, Collar elevation: 240' amsl, Total depth: 67 ft.
Drill log – description

Residuum	0-2'	Sandy soil, tan color
Dry Branch (Irwinton Sand) lithology	2-17' 17-42'	Sand, fine- to medium-grained, well-sorted, slightly clayey, red color Sand, fine- to medium-grained, clayey, lighter color (red to orange/tan) poorly sorted in lower 10 feet
Huber lithology	42-47' 47-67'	Sand, clayey, medium- to coarse-grained, poorly sorted, yellow to tan color; finer-grained and better sorting in last 10 feet, also some mica

Hole 5
Location: 1.2 miles N87ºW of the intersection of Aiken County Road 5 and Aiken County Road 63, Collar elevation: 175' amsl, Total depth: 36 ft.
Drill log – description

Residuum	0-4'	Sandy soil, tan to light brown color
Huber lithology	4-11'	Sand, medium-grained, well-sorted, very clayey. Subrounded grains, orange to yellow color with some grey grey clay laminae
Middendorf lithology	11-36'	Sand, clayey and sandy clay, poorly sorted, fine- to coarse-grained, very micaceous, sand is mostly angular, with larger grains and pebbles being subrounded red/pink to yellow and orange color

Hole 6
Location: 75 miles N66ºW of the intersection of Aiken County Road 5 and Aiken County Road 32, Collar elevation: 173' amsl, Total depth: 36 ft.
Drill log – description

Residuum	0-3.5'	Sandy soil, tan to light yellow color
Huber lithology	3.5-6' 6-9½ ' 9½-11'	Clay, with medium- grained quartz sand, stiff, micaceous, off-white/yellow to red color Clay, sandy, red color with white clay laminae, micaceous Sand, clayey with sandy clay, mustard yellow sand interbedded with pinkish-red fine- to medium-grained sandy clay, micaceous
Middendorf lithology	11-36'	Sand, generally poorly sorted, medium- to very coarse-grained, very micaceous, color ranges from pink to tan and yellow, kaolinitic at 11 feet and again at 33.5 feet, large pebbles up to 3 cm. in lower 6 to 8 feet

Smith (1979) and Faye and Prowell (1982).

The third lithologic unit recognized in the Jackson area is the Irwinton Sand Member, which LaMoreaux (1946a, 1946b) placed in the Barnwell Formation and which Huddlestun and Hetrick (1979) placed in the Dry Branch Formation. This unit is directly correlatable to Map Unit A of Nystrom and Willoughby (1982a). While other workers (Nystrom and Willoughby, this volume; Kite, this volume) have identified the Twiggs Clay lithology of the Dry Branch Formation in Aiken County, no Twiggs Clay lithology was encountered in outcrop or in drill holes in the Jackson quadrangle. Here, the Dry Branch Formation is generally a loose, fine- to medium-grained, micaceous quartz sand and is characteristically mustard yellow, orangish-yellow, or white in color. It is often well-bedded; high-angle cross bedding is common. White to tan clay drapes and laminae and thin, discontinuous clay beds are common features of the Dry Branch Formation. This unit thickens markedly in the northeastern quarter of the quadrangle. In Hole 2 (Figure 4) the base of the Dry Branch Formation was never reached, with ninety feet of the characteristic Irwinton Sand lithology encountered without interruption. Control on the base of the Dry Branch Formation is uncertain because drill hole information and outcrop offer only sketchy contacts with the underlying Huber Formation. This lithology was recognized by Smith (1979) but was not separated from the overlying Tobacco Road Sand and was placed in the Barnwell Group.

The Tobacco Road Sand overlies the Dry Branch Formation in the Jackson area. This unit is correlative with similar lithologies in western and central Aiken County and central Georgia (Nystrom and Willoughby, 1982a; Nystrom and Willoughby, this volume; Kite, this volume; Huddlestun and Hetrick, 1978). In the Jackson quadrangle, this unit has been previously mapped as the Hawthorn Formation by Siple (1967). Smith (1979) recognized the Tobacco Road Sand (Huddlestun and Hetrick, 1978) and the lithologies of the Dry Branch Formation (Huddlestun and Hetrick, 1979) but mapped these units together as the Barnwell Group.

The Tobacco Road Sand is typically a deep red, medium- to coarse-grained, clayey to very clayey, subangular quartz sand. The unit is characteristically semi-indurated and commonly expresses itself topographically as a bench-former. Because of weathering, most of the bedding which may have been present has been obliterated. Burrows of the *Callianassa* variety are occasionally discernible.

The base of this unit is generally marked by a zone of coarse sand, rounded and discoidal pebbles, and kaolin balls. This lithology is best exposed in a borrow pit north of Jackson, S.C. (Figure 5). The pebble zone was encountered in auger drilling, which provided further control on the base of the Tobacco Road Sand.

It is suggested that the Tobacco Road Sand and the Dry

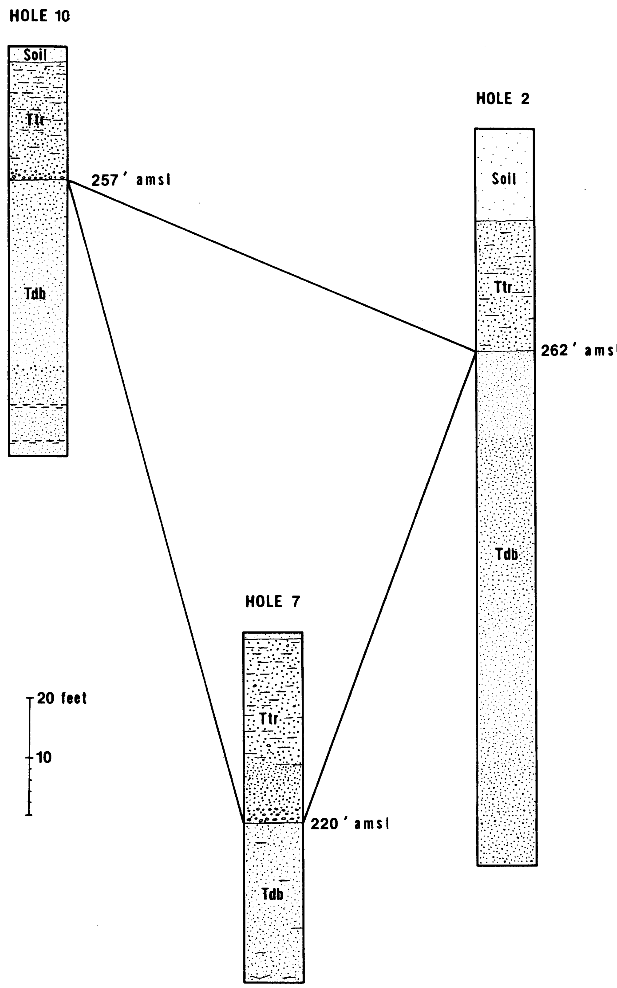

Figure 4. Auger hole columns.

Hole 2 Location: 2.1 miles N 22º of the intersection of State Highway 125 and Aiken County Road 62 Collar elevation: 298' amsl Total depth: 126 ft. Drill log - description		**Hole 7** Location: .25 miles N 37º W of the intersection of State Highway 125 and Aiken County Road 62 Collar elevation: 253' amsl Total depth: 60 ft. Drill log - description		**Hole 10** Location: .85 miles N 24º E of the intersection of State Highway 125 and Aiken County Road 1409 Collar elevation: 280' amsl Total depth: 66 ft. Drill log - description	
0 - 16.5' Residuum	Sand, coarse-grained clayey, reddish-brown color	0 - 15' Residuum	Sand, coarse-grained, clayey, reddish-brown color	0 - 2.5' Residuum	Sand, fine to medium-grained, slightly clayey, tan color
16.5 - 35.5' Tobacco Road lithology	Sand, clayey, medium- to coarse-grained, orangish-brown color	1.5 - 7' 7 - 33' Tobacco Road lithology	Sand, very clayey coarse-grained, deep red color, pebbly Sandy, clayey, medium- to very coarse-grained, yellowish-orange color; coarsens downward, also, less clayey with depth; last 3 feet, very pebbly (pea gravel)	2.5 - 23 Tobacco Road lithology	Sand, very clayey, medium- to very coarse-grained, subangular, deep red to orangish-red color; in lower 2 feet, a pebble zone is present, composed of rounded and discoidal pea gravel
36.5 - 126' Dry Branch (Irwinton Sand) lithology	Sand, loose, well-sorted, slightly micaceous, fine- to medium-grained, light yellow to mustard yellow	33 - 60' Dry Branch (Irwinton Sand) lithology	Sand, loose, generally fine- to medium-gained, coarsens downward, mustard yellow to yellowish-brown color; some white clay laminae in last 3 feet	23-36 36-66' Dry Branch (Irwinton Sand) lithology	Sand, loose, very fine-to fine-grained, mustard yellow to white color Sand, loose, generally very fine- to fine-grained, occasionally coarsening, mustard yellow to white color; at 57', and again at 64', thin, plastic clay beds were encountered (brown to lavender in color)

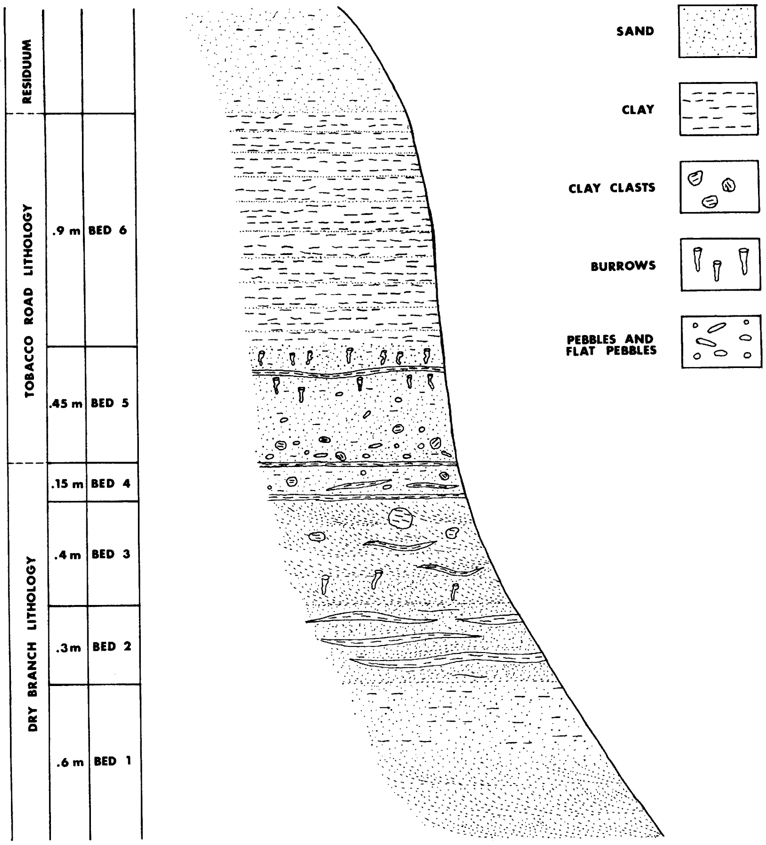

Figure 5. Measured section from eastern wall of borrow pit, located 1.2 km N60º E of the junction of Highway 125 and S.C. 1409 near Jackson, S.C.

The following is a lithologic description of the basal Tobacco Road Sand and the Irwinton Sand Member of the Dry Branch Formation exposed near Jackson, S.C. (see Figure 5).

Residuum	Bed 7	Sand (Surficial sand of the soil zone), medium- to coarse-grained clayey, reddish-tan color.
Tobacco Road	Bed 6	Clay, beds 2-4 cm thick, blocky, off white/gray color; clay beds separated by thin iron-rich sand partings.
	Bed 5	Sand, medium- to coarse-grained clayey quartz sand, poorly sorted, burrowed, reddish orange in color; thin clay bed separates this lithology from pebble zone (lower .35 m), smooth quartz pebbles rounded to discoidal, kaolinitic clay clasts abundant, matrix of pebble zone is clayey sand as above but with poorer sorting, some burrows.
Dry Branch (Irwinton Sand)	Bed 4	Clay, thin continuous beds enclosing discontinuous clay laminae and clay clasts in orange, clayey medium-grained quartz sands, scattered pebbles are present.
	Bed 3	Sand, massive, medium-grained quartz sand, micaceous, orangish-tan to light yellow in color, high-angle crossbeds (20-25 degrees) dip to south-southeast, scattered clay clasts (4-9 cm) and discontinuous clay laminae present, occasional burrows.
	Bed 2	Sand, loose, fine- to medium-grained micaceous quartz sand, interbedded with discontinuous light brown clay laminae and beds (from 1-2 mm up to 2-3 cm.
	Bed 1	Sand, loose, slightly clayey in upper .2 m, fine-grained very micaceous quartz sand, yellow/orange to white color; high-angle cross bedding, groundwater action has created prominent Liesegang banding.
Total section thickness 2.80 m………………....(9.2 ft.)		

Branch Formation be considered a single depositional package. Together, these two units underlie and make up the very noticeable lobes of the Aiken Plateau.

A single Quaternary unit has also been mapped. It is composed of fluvial sands which occur in the Hollow Creek valley and a Pleistocene (?) river terrace deposit which overlies and truncates (at approximately 140') the Middendorf Formation. The Savannah River terrace deposit is a series of well-bedded and highly variable, sands, clays and gravels.

Tuomey (1848) examined the strata at Silver Bluff and believed them to be Eocene in age. Newell, et al. (1980) assign the same strata a probable Sangamonian age, based mainly on geomorphological relationships.

An upland gravel of unknown age (Plio-Pleistocene ?) is present in a few areas in the northeast corner of Jackson quadrangle. Siple (1967) recognized these as alluvial gravels of Pliocene age. Though not found in place, it is apparent that this gravel unit caps some of the interstream divides and has moved downslope. While this may be the same lithology mapped by Smith (1979) as the Citronelle Formation, the areas where this upland gravel is found are different from those mapped as Citronelle Formation by Smith. These gravels are best observed 1.2 miles N 55º E of the Highway 125 – County Road 1409 intersection.

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CRETACEOUS, TERTIARY, AND PLEISTOCENE (?) STRATIGRAPHY OF HOLLOW CREEK AND GRANITEVILLE QUADRANGLES, AIKEN COUNTY, SOUTH CAROLINA

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INTRODUCTION

The Hollow Creek – Graniteville area in southwestern Aiken County (Figure 1) is one of South Carolina's primary mineral-producing regions, from which kaolin has been produced since 1852 (Smith, 1949). The deeply incised topography and the numerous active, inactive, and abandoned kaolin pits provide exposures that make Hollow Creek and Graniteville quadrangles (Figures 2, 3) an ideal area to establish surface control for stratigraphic studies.

This report on the stratigraphy of the area is part of a continuing effort to prepare an up-to-date state geologic map of South Carolina.

CRETACEOUS SEQUENCE

Introduction

In northwestern Hollow Creek quadrangle and in central Graniteville quadrangle, a large area of the flower slopes of Horse Creek and its tributaries is underlain by sand and kaolin strata of Cretaceous age. These strata overlie crystalline Piedmont rocks that crop out locally along Horse Creek valley and Little Horse Creek valley in northern Graniteville quadrangle (Figures 1, 2 & 3).

Previous Work

Sloan (1904, 1908) recognized the "Hamburg beds" and

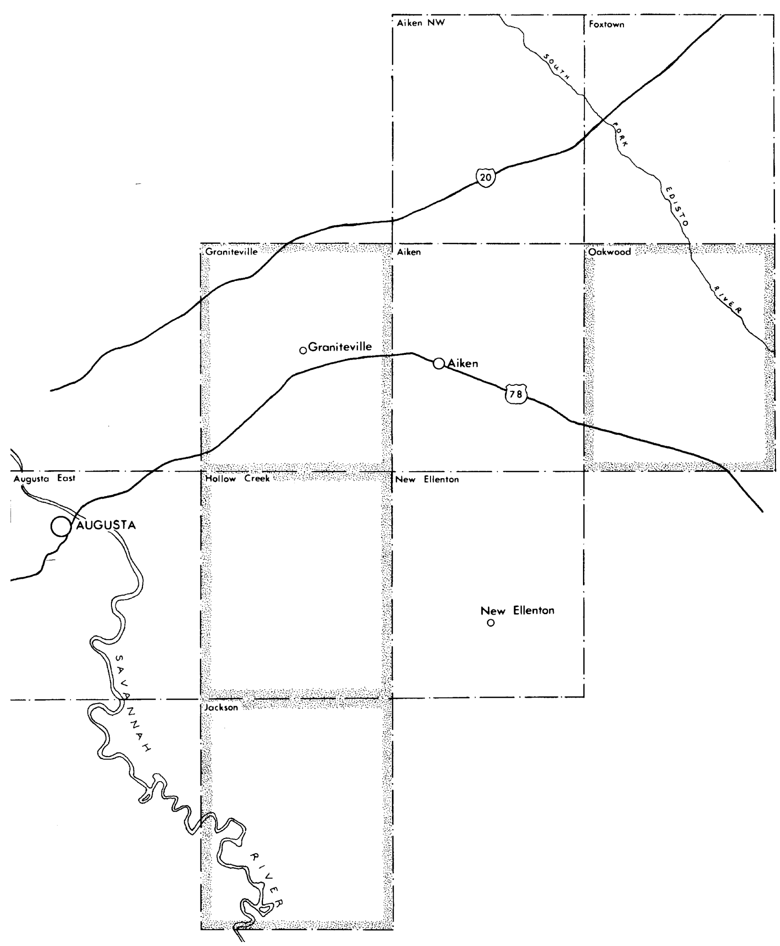

Figure 1. Index map to southwestern Aiken County.

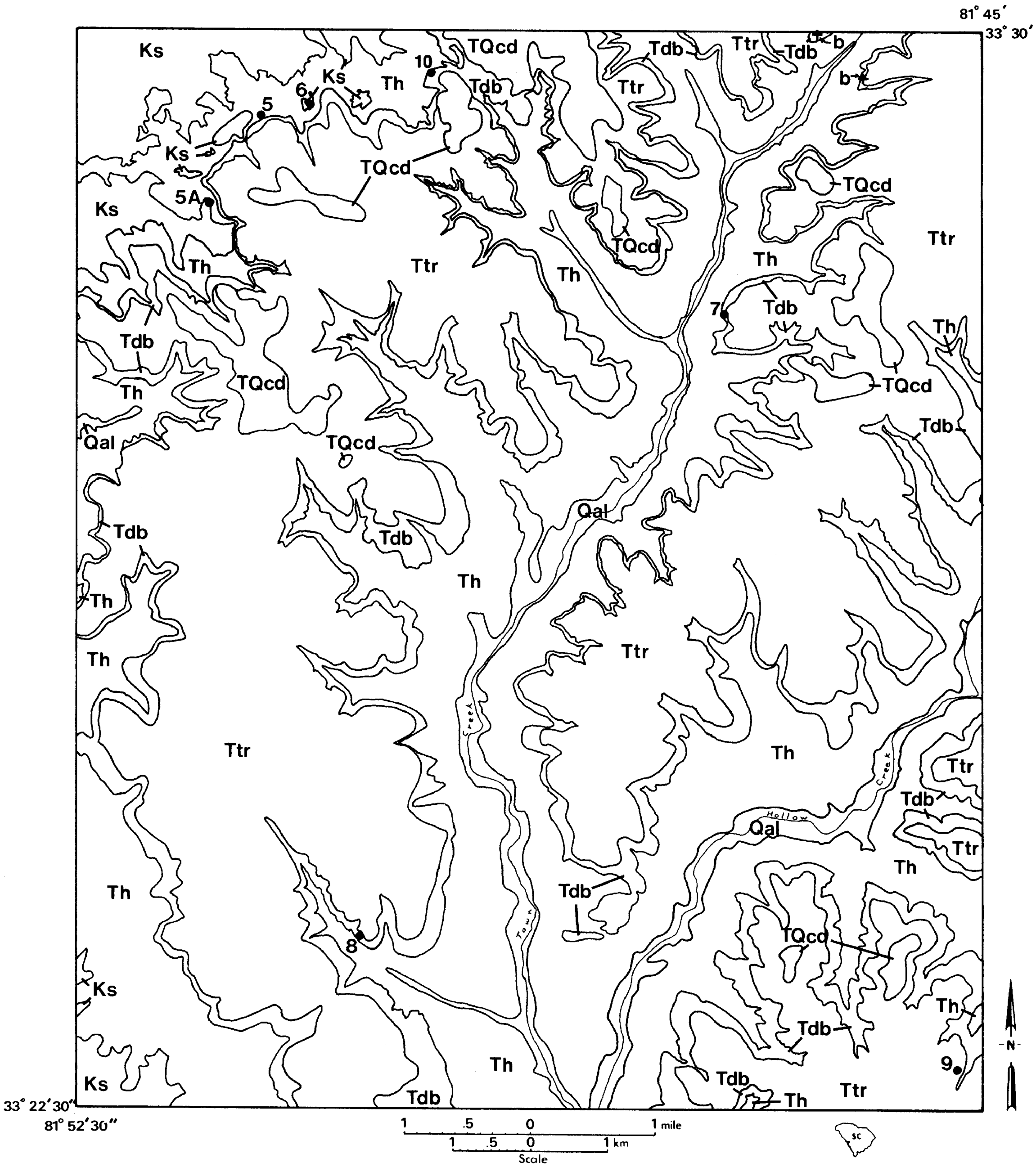

Figure 2. Geologic maps of Hollow Creek. , Aiken County, South Carolina; b(+) marks buhrstone localities; 5• numbered dots signify field trip stops. Ks = Cretaceous sequence; Th = Huber Formation; Tdb = Dry Branch Formation; Ttr = Tobacco Road Sand; TQcd = upland fluvial channel deposits; me = moved earth.

"Middendorf beds" in western Aiken County, he subdivided the Hamburg beds into lower and upper units, and he assigned both the Hamburg and the Middendorf sequences to the Lower Cretaceous. Berry (1914), based on evidence from fossil leaves from Langley and from Middendorf, assigned the Middendorf beds as a member of the Upper Cretaceous Black Creek Formation. Cooke (1926) included the Hamburg beds as a member of the Middendorf Formation, and Cooke (1936) later used the Tuscaloosa Formation, based on Lower Cretaceous strata in Alabama, to apply to all the beds of supposed Cretaceous age in Georgia and South Carolina. Lange (1940) and Siple (1967) followed the usage of Cooke (1936). Smith and White (1979) mapped the same strata as the Huber Formation, but they did tentatively use the Middendorf Formation locally to refer to the lower kaolinitic sequence in Aiken County.

Prowell and O'Connor (1978) used the Tuscaloosa Formation for strata in eastern Georgia and in western South

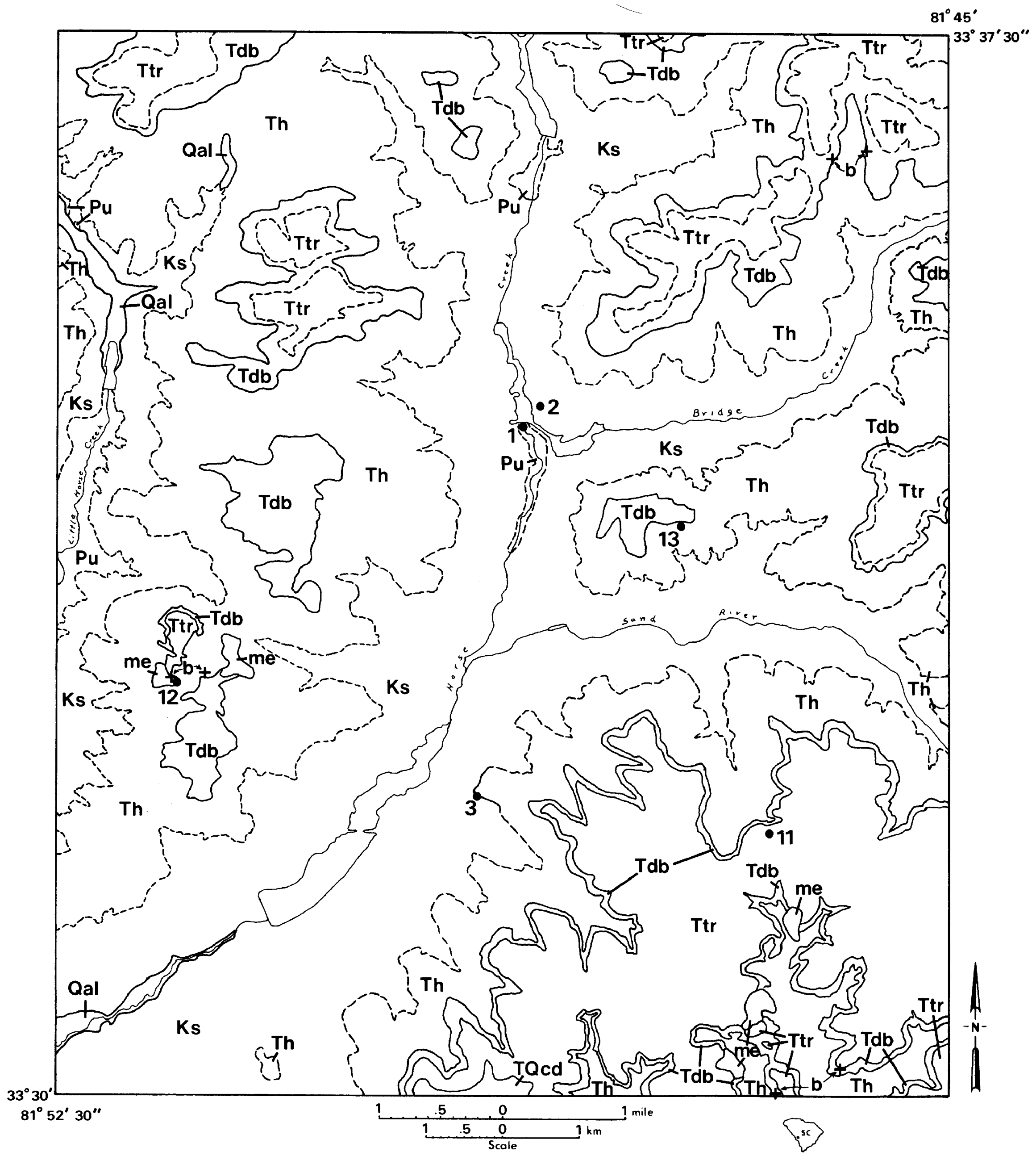

Figure 3. Geologic map of Graniteville quadrangle, Aiken County, South Carolina; b(+) marks buhrstone localities; 3• numbered dots signify field trip stops. Ks = Cretaceous sequence; Th = Huber Formation; Tdb = Dry Branch Formation; Ttr = Tobacco Road Sand; TQcd = upland fluvial channel deposits; me = moved earth.

Carolina, although they recognized that the same beds in parts of nearby eastern Georgia range in age from Late Cretaceous to middle Eocene (based on Tschudy and Patterson, 1975, and on written communications from N.O. Frederickson, 1977, and from R.A. Christopher, 1978). Faye and Prowell (1982) recognized the occurrence of Upper Cretaceous strata of Santonian to Maastrichtian age (equivalent to the Middendorf, Black Creek, and Peedee formations in South Carolina) near the Savannah River in eastern Georgia and in western South Carolina (based on written communications from R.A. Christopher). Faye and Prowell (1982) noted that sediments equivalent to the Middendorf and Black Creek formations are difficult to distinguish updip of the Savannah River Plant, and they did not use named formations on their cross-sections. Because of the difficulties and uncertainties in correlating these unfossiliferous, updip sands and clays, we concur with Buie and Schrader (this volume) in not assigning a formational name to these strata.

Figure 4. Medium-grained to very coarse-grained quartz sand with abundant muscovite, Cretaceous sequence, overlain unconformably by the basal Huber Formation. Pisolitic kaolin boulders occur at the unconformity. Stop 3.

Figure 5. Another view at Stop 3 showing pisolitic kaolin boulders at the unconformity.

Lithology

In the report area the Cretaceous strata consist mainly of white, cream, light gray, or tan, medium-grained to very coarse-grained, angular to subrounded, poorly sorted, kaolinitic, micaceous quartz sand (Figure 4, 5). Quartz granules and pebbles are common and are characterized by an abundance of smoky quartz. Kaolin balls are also common, and fine to coarse, dark heavy mineral grains are fairly abundant.

Muscovite in the Cretaceous sands occurs as fine to coarse flakes. At some exposures flakes up to 1 cm in diameter are common. We have not noted feldspars in any of the Cretaceous strata of the report area. Lang (1940, p. 34-40) reported the following heavy minerals from the test hole at J.M. Huber Corporation's Paragon pit, from the sequence that we have mapped as Cretaceous: kyanite, sillimanite, staurolite, tourmaline, zircon, rutile, monazite, ilmenite, and magnetite. Siple (1967, p. 25) reported the following heavy minerals from the Tuscaloosa Formation (Cretaceous strata plus the Huber Formation): ilmenite, tourmaline, rutile, zircon, monazite, and garnet.

Bedding of the sands and gravels is characteristically irregular and discontinuous. Cross-bedded and channeled beds of fine- to coarse-grained sands occur in no orderly sequence and grade laterally into one another or pinch out over relatively short distances.

There are two kaolin-bearing stratigraphic sequences in western Aiken County: a lower sequence of Cretaceous age

Figure 6. Cretaceous kaolin ("soft clay") showing characteristic conchoidal fracture. Stop 5.

Figure 7. Tertiary kaolin of the upper Huber Formation ("hard clay") showing characteristic hackly fracture. Stop 5.

and an upper sequence, of uncertain, post-Cretaceous age at the base and of middle Eocene (Claibornian) age at the top (Buie, 1978, 1980; Buie and Schrader, this volume). Buie (1978) tabulated and discussed the characteristics of the two types of kaolin, and we have noted in the commercial kaolin of Aiken County the same gross physical characteristics. Kaolins from the Cretaceous sequence ("soft clay"; Figure 6) are generally bright white to cream; show conchoidal fracture breaking into large (up to 2 cm), smooth blocks in mining pits; flake readily into smooth, conchoidal or subconchoidal chips when pressure is applied to hand specimens; and adhere readily to the hands. Kaolins from the Huber Formation ("hard clay"; Figure 7) are white to cream or light gray, generally duller or less reflective than the Cretaceous kaolins, show irregular, hackly fracture into small-sized chunks; form firm, rounded surfaces rather than smooth, conchoidal chips when pressure is applied to hand specimens; and adhere to the hands less readily than the Cretaceous kaolins.

Distribution

Surface mapping of the Cretaceous strata is a difficult task because surface exposures are few and because of the rarity of fossil-bearing or pollen-bearing beds. Cretaceous strata in northwestern Hollow Creek quadrangle and in southwestern Graniteville quadrangle have been mapped outward from the top of the Cretaceous kaolin beds in the active kaolin mines. Several data points have been used to tentatively outline areas probably underlain by Cretaceous strata in Graniteville quadrangle (Figure 3). The data points are: (1) the top of Cretaceous kaolin beds in the Langley-Bath area at elevations of 310 ft (94 m) to 320 ft (98 m); (2) pisolitic kaolin boulders at the Cretaceous-Tertiary contact at an elevation of ±310 ft (94 m) at Stop 3 of the Road Log; (3) the occurrence of smooth, chunky, conchoidally fractured kaolin ("soft clay") at an elevation of ±287 ft (87 m) in a ditch along Vaucluse Road (S-2-105) just each of Bridge Creek in Graniteville quadrangle; (4) a Late Cretaceous (late Campanian) pollen data from the top of kaolinitic beds exposed along U.S. Interstate 20 in Aiken Northwest 7½' quadrangle at an elevation of 409 ft (125 m) (David C. Prowell, personal communication, 1982); (5) outcrops of "soft clay" kaolin at an elevation of ±380 ft (116 m) in the bed of county road S-2-980 (dirt road parallel to and on the east side of Shaw Creek) in southwestern Aiken Northwest quadrangle; and (6) kaolin outcrops at an elevation of ±345 ft (105 m) around the edge of a small pond on Sage Mill Creek just north of I-20 in Graniteville quadrangle. The elevations, declining seaward, were then projected onto the Graniteville quadrangle map. The technique is essentially the same as for constructing subsurface cross-sections except that a map view is presented. Although there are inherent dangers in such a projections, the resulting map pattern serves as a departure point for discussion and can point out promising areas for additional work. In the Graniteville quadrangle, the projection suggests that quite a large area of Cretaceous strata is present.

HUBER FORMATION

Introduction

The Huber Formation was defined by Buie (1978) as comprising "all of the post-Cretaceous pre-Jackson strata in the kaolin mining districts of Georgia, northeast of the Ocmulgee River." Subsequent reports by Buie (1980), and Buie and Schrader (this volume) have provided additional information on both the Huber Formation and the Cretaceous sequence underlying it. The Huber Formation and the Cretaceous sequence underlying it. The Huber Formation extends into Aiken County, South Carolina (Buie and Schrader, this volume), and has been mapped in Hollow Creek and Graniteville quadrangles by the authors (Figures 1, 2 & 3), in Jackson quadrangle by Mittwede (this volume), and in Oakwood quadrangle by Kite (this volume).

Distribution

The Huber Formation occurs at the surface extensively in the Hollow Creek and Graniteville map areas. In Hollow Creek quadrangle the Huber is the oldest unit exposed except in the northwest and very southwest corners where Cretaceous strata occur. Along Town Creek and Hollow Creek the Huber underlies the broad slope areas extending from the flood plains to near the break in slope at the edge of the upland terrain underlain by the Tobacco Road Sand. Along the western edge of the quadrangle the Huber occurs on the upper part of the east slope of Horse Creek valley. In Graniteville quadrangle the Cretaceous strata occur in broad areas along the lower part of the valley, and the Huber underlies the upper slopes of Horse Creek and its major tributaries.

Thickness

In northwestern Hollow Creek quadrangle complete sections of the Huber Formation have been measured in three kaolin mines: the Pepper Branch (29.5 m thick), the McNamee No. 2 (20.25 m thick), and the Ideal (18.2 m thick). These three mines are Stops 5A, 5 and 6 respectively in the field guide (Nystrom, Willoughby, and Kite, this volume). The appendix to the field guide contains detailed descriptions of the measured sections. the three mines are situated relatively close together (Figure 2) so the measured sections indicate variation in thickness of the unit within a fairly local area. In large kaolin mines, in both South Carolina and Georgia, it is not uncommon to see as much as 6 m of relief on the surface of the Huber.

Exposures in the vicinity of southwestern Hollow Creek quadrangle suggest the base of the Huber Formation is at an elevation near 170'. Mittwede (this volume) encountered the base of the Huber in the subsurface at an elevation of 164' just to the south in northwestern Jackson quadrangle (see auger hole #3 in his Figures 1 and 3). Upslope in this area, the top of the Huber is marked by massive kaolin at an elevation of 320'. Therefore in the southwestern corner of Hollow Creek quadrangle the Huber Formation is about 45.7 m (150') thick.

Within Hollow Creek quadrangle no Cretaceous is known to occur at the surface except in the northwest and southwest corners so in most of the map area only minimum thicknesses of the Huber Formation can be obtained without subsurface techniques. Elevation differences between fluvial deposits along Town and Hollow Creek and the base of the Dry Branch Formation indicate a minimum thickness of 30.4 m for the Huber in the eastern half of Hollow Creek quadrangle. In Graniteville quadrangle (Figure 3) Cretaceous strata occur at the surface throughout much of the map area, but except for a few localities, the Cretaceous sequence-Huber contact is indefinitely known.

Lithology

The lower part of the Huber Formation is lithologically distinguishable from the underlying Cretaceous strata and the overlying sequence of the upper Huber. In Georgia Buie (1978) recognized a minor stratigraphic break near the middle of the unit. He described the sediments below the break as being more laminated and having more mica and dark heavy minerals than sediments above the break.

In Hollow Creek and Graniteville quadrangles the lower

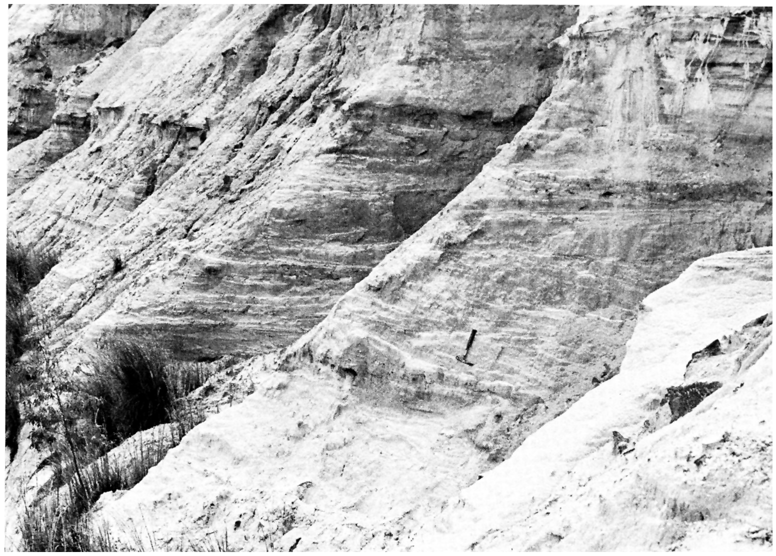

Figure 8. View showing exposures of the lower Huber Formation. Stop 5A.

Figure 9. Close-up view of cross-bedded fine sand in the lower Huber Formation. Stop 5A.

Huber is in general quite different from the upper part although in places transitional lithologies make it difficult to single out a specific horizon separating the two sequences. The lower Huber (Figure 8) is characteristically comprised of intercalated thinly laminated to thin-bedded, laterally continuous, subhorizontal, slightly undulatory clay layers and laminated to medium-bedded, fine- to medium-grained, moderately well sorted, micaceous, quartz sand with abundant fine-grained dark heavy minerals. Stratification is distinctively thinner, better defined, and generally has a more prominent horizontal aspect than layering in the upper Huber. There is, nevertheless, some fine cross-bedding in many of the sand beds (Figure 9). There are well-bedded clay sequences up to 0.6 m thick, which are internally thinly laminated to thin-bedded. Horizontal burrows occur between some layers. The clay strata generally contain some silt and fine sand. The sand in the lower Huber is typically clean and loose with little or no interstitial clay. Individual quartz grains are angular to subangular. The fine heavy minerals occur both disseminated and concentrated in thin laminae. The mica is fine to coarse grained. Large burrows 1 – 2 cm in diameter and locally abundant small burrows 2 – 3 mm in diameter are fairly common in the fine sands of the lower Huber. The burrows suggest a marine environment. In Oakwood quadrangle Kite (this volume) reports collecting shark teeth, ray teeth, and ray spines from the lower Huber.

Some beds in the upper part of the lower Huber are lithologically similar to some of those in the overlying upper Huber. Beds that occur in, but are not typical of, the lower Huber are fine- to coarse-grained, poorly sorted, cross-bed-

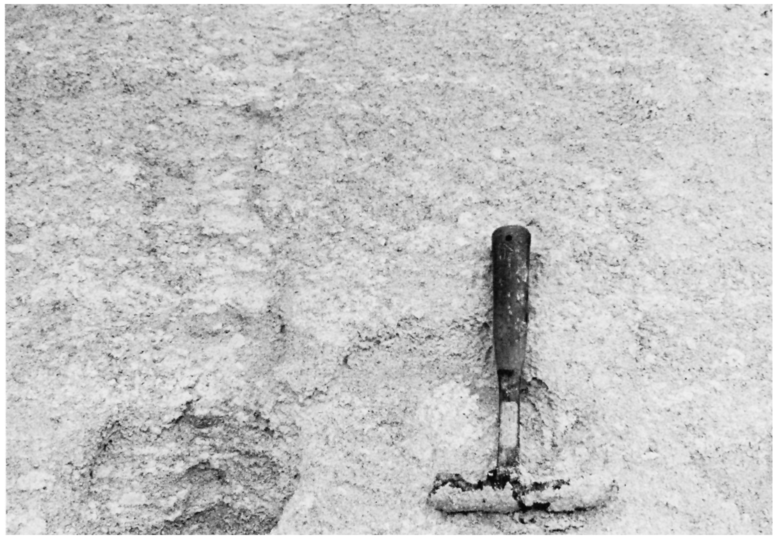

Figure 10. Close-up view of very coarse-grained, poorly sorted sand with clay balls in the upper Huber Formation, Stop 5.

ded, micaceous, and with flat clay rip-up clasts.

The upper part of the Huber commonly includes a sequence of very thick-bedded (1-2 m), fining upward kaolinitic sand layers. The base of each of these beds commonly includes a kaolin ball to kaolin boulder conglomerate with associated very coarse quartz sand, granules or pebbles, and dark heavy minerals. Many of the kaolin clasts are pisolitic. Interstitial kaolin is abundant and the beds are moderately indurated. Beds are typically poorly sorted, very coarse, grained, and crudely bedded near the base (Figure 10), but some layers fine upward to medium-grained, thinly bedded sand.

At most exposures of the top of the Huber Formation in both Hollow Creek and Graniteville quadrangles there is a massive kaolin bed. These beds are pure to sandy, locally pisolitic, cream to light gray in color, with orange to purple mottling, and characterized by a noticeably hackly fracture (Figure 7). Locally where purple mottling is enhanced there may also be some ferruginous concretions from abundant pea-sized spheroids, to irregularly shaped bodies greater than 10 cm in diameter. At many exposures in the northwestern part of Hollow Creek quadrangle the very top of the massive kaolin bed is dark gray to dark brown, locally pyritic, and in places contains abundant leaves or coal-like altered woody material.

DRY BRANCH FORMATION

Introduction

The Dry Branch Formation was named by Huddlestun and Hetrick (1979) for exposures near the community of Dry Branch in Twiggs County, Georgia. This type locality is only 0.6 miles (1 km) northeast of the Twiggs Clay type locality (Shearer, 1917) at the old pit of the General Reduction Company.

As proposed by Huddlestun and Hetrick (1979) the Dry Branch Formation includes three interfingering and intergrading but distinct lithofacies termed the Twiggs Clay (named by Shearer, 1917), the Irwinton Sand (named by LaMoreaux, 1946), and the Griffins Landing Sand (named by Huddlestun and Hetrick, 1979). They described the Twiggs Clay lithofacies as a "marine, montmorillonite clay"; the Irwinton Sand lithofacies as "a distinctly bedded sand and sand and clay"; and the Griffins Landing Sand as "a rudely bedded to massive-bedded, calcareous, fossiliferous sand." Of these three lithofacies only the Twiggs Clay and Irwinton Sand occur in the Hollow Creek-Graniteville area. Because of the interlayered and interfingered relationship of these lithofacies in our study area we follow Huddlestun's and Hetrick's (1979) suggestion that the Dry Branch lithofacies names be used simply as informal lithologic terms.

Previous Work

Prior to the work of ourselves in Hollow Creek and Graniteville quadrangles, Steve Mittwede in Jackson quadrangle (this volume), and Lou Kit in Oakwood quadrangle (this volume) the Dry Branch Formation had not been mapped with that name in South Carolina. Smith and White (1979), in their reconnaissance work in Aiken County, recognized the occurrence of the Dry Branch Formation but they lumped it with the Tobacco Road Sand as a single map unit, the Barnwell Group (Smith, 1979).

Previous workers recognized the strata we map as Dry Branch but they assigned those beds to the McBean Formation. Along Town Creek and Hollow Creek, in Hollow Creek and New Ellenton quadrangles, Cooke (1936, plate 2) mapped the Dry Branch sands below the Barnwell (Tobacco

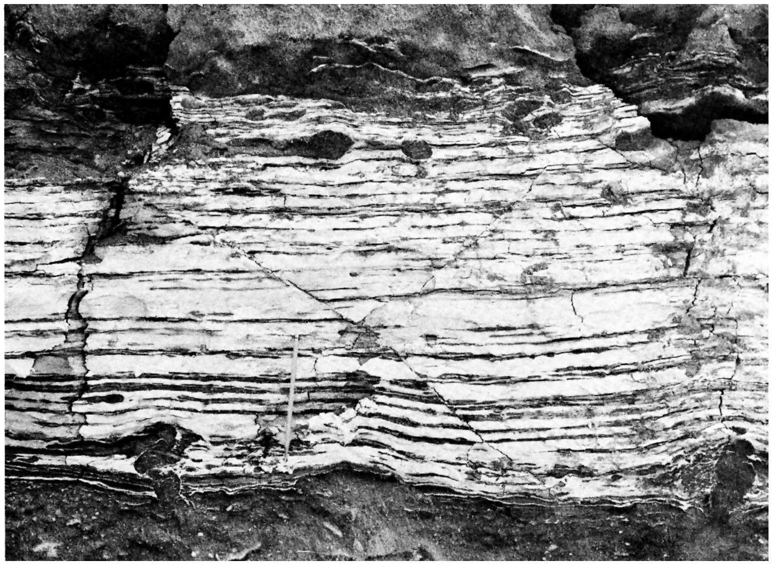

Figure 11. Close-up view of the Twiggs Clay lithology in the lower part of the Dry Branch Formation. The view shows a bed freshly exposed during mining operations. Pencil for scale. Stop 5.

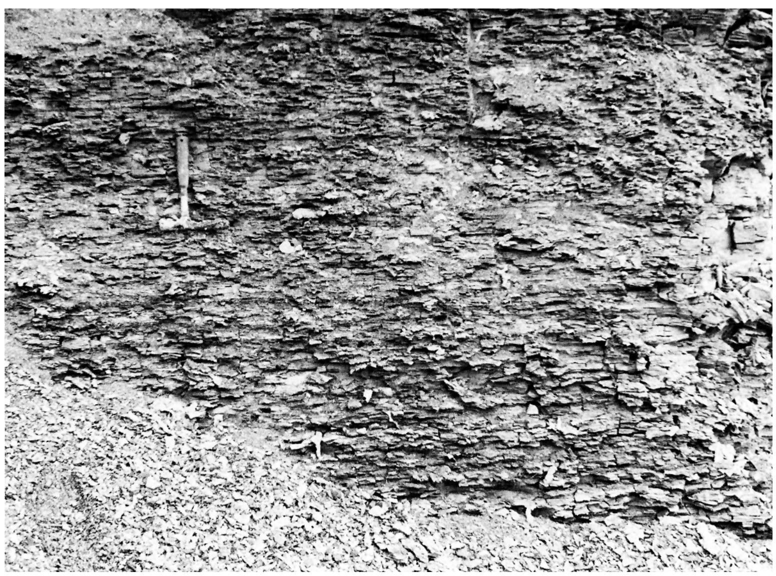

Figure 12. Twiggs Clay lithology in the lower part of the Dry Branch Formation. The view shows beds, not freshly exposed, that have begun to desiccate. Stop 5.

Road Sand) pebble zone as the McBean Formation. Lang (1940, p. 43) also believed the sands just below the Barnwell (Tobacco Road Sand) along Town Creek and on the south bank of Horse Creek were McBean, either as sands in the base of the Barnwell derived from the McBean or as isolated remnants of the McBean. In areas that are now Hollow Creek, New Ellenton, and Jackson 7.5-minute quadrangles (Figure 1) Siple (1967) mapped the strata immediately below the Barnwell Formation (Tobacco Road Sand) as the McBean Formation. Thus Cooke (1936), Lang (1940), and Siple (1967) mapped as middle Eocene (McBean Formation) strata that are late Eocene or possibly younger in age (Zullo, Willoughby, and Nystrom, this volume; Harris and Fullagar, this volume).

In the deeply incised terrain of Hollow Creek and Graniteville quadrangles Horse Creek, Town Creek, Hollow Creek, and their larger tributaries have cut downward 200 to 300 feet below the surfaces of the adjacent upland divides. The broad, relatively flat uplands are capped by the resistant Tobacco Road Sand (though Neogene alluvial gravels locally overlie the Tobacco Road), and there is commonly a break in slope at the base of the unit. Since the major streams have cut well down into the Huber Formation, and along upper Horse Creek have even eroded through the Cretaceous to bedrock, the distribution of the outcropping Dry Branch Formation is along the higher parts of the slopes just below the base of the Tobacco Road Sand.Distribution

The Dry Branch Formation underlies all of Hollow Creek quadrangle and most of the Graniteville quadrangle. Whether the Dry Branch occurs in the northwest quadrant of the Graniteville quadrangle is uncertain.

Thickness

The Dry Branch Formation is 6.1 to 12.2 m thick over much of the Hollow Creek quadrangle. It may exceed 15.2 m in thickness in the vicinity of Huber Corporation's Ideal pit (Stop 6, road log this volume) where an incomplete 14 m section was measured. In the southeastern quadrant of the Hollow Creek map area the Dry Branch is 12.2 to 15.2 m thick. Nevertheless, at a number of exposures the unit is less than 3 m thick. The unconformable surface of the Huber Formation may have 6.1 m of local relief within a single large kaolin pit. The base of the Tobacco Road sand, furthermore, is characterized by broad scour features that have an amplitude of 6.1 m in the Pepper Branch and Barden pits (see road log, Stops 5A and 12, this volume). The relief at the base of the Tobacco Road combined with the irregular surface on the Huber results in fairly abrupt and unpredictable local thickening and thinning of the Dry Branch Formation. There is a general tendency for the unit to thicken down-dip.

Dry Branch – Huber Contact

At many exposures showing the Dry Branch – Huber contact, particularly in northern and western Hollow Creek quadrangle, the top of the Huber is massive kaolin. At such exposures the contact is sharp and prominent. In the southeastern quadrant of the Hollow Creek quadrangle the uppermost Huber Formation in many places consists of sands similar to those in the Dry Branch Formation. Furthermore, the distinctive Twiggs Clay lithology that is characteristic of the lower Dry Branch in most of Hollow Creek quadrangle is apparently absent or only sporadically developed. Thus in this area the Huber – Dry Branch contact is difficult to recognize.

At the base of the Dry Branch Formation in Hollow creek quadrangle there is generally a 0.3 to 0.61 m thick bed of yellow, pebbly sand. The lowermost 2 to 5 cm of this bed includes a concentration of dark brown to violet heavy minerals. In places a limonitic crust has formed. Quartz pebbles in the basal Dry Branch are subrounded to well-rounded and many are ellipsoidal or discoidal in shape generally aligned parallel to bedding. The sand fraction is poorly sorted, medium- to coarse-grained, and subangular to subrounded. Large burrows 1 – 3 cm in diameter occur locally. Thin, discontinuous, undulatory clay laminae occur in this basal bed in some exposures.

Lithology

In the lower Dry Branch the Twiggs Clay lithology typically occurs in well-layered sequences of very thin-bedded to thin-bedded, montmorillonitic clay from 1 to 2 m thick. The sequences may be gray, olive green, brown, purple, or cream colored. Individual clay layers are separated by brown to purple, thin parting planes 1 to 2 m thick comprised of micaceous, silty, well sorted, fine-grained, quartz sand. Horizontal burrows are common on the parting surfaces (Figure 11) . Where Twiggs Clay exposures are wet there is little real parting though layering may be prominent. Wet Twiggs Clay tends to be very plastic. Twiggs Clay samples removed from wet exposures desiccate rapidly. Dry exposures are generally characterized by a prominent bedding plane fissility where layers separate into thin brittle chips parallel to stratifcation (Figure 12). At some localities where there is no exposure the presence of Twiggs Clay sequences can be recognized by abundant thin clay chips in the soil. In places chert concretions weather out of Twiggs Clay sequences.

Another lithology common to the lower Dry Branch consists of layers of thinly laminated to very thin-bedded light tan quartz sands intercalated with cream white, wavy, discontinuous clay laminae 1 to 2 mm thick. The sand is moderately well sorted, fine- to medium-grained, and subangular. There is generally little mixing of the clay and sand in these beds, the thin clay laminae tend to be pure clay and sharply segregated from the sand which is also relatively pure sand. Many of these beds are about 30 percent clay and 70 percent sand.

Yellow, medium-grained to coarse-grained or very coarse-grained, prominently cross-bedded sand occurs interlayered with the Twiggs Clay lithology in the lower Dry Branch but is particularly characteristic of the middle to upper parts of the unit (Figure 13). The festoon crossbedding is defined by thin white clay laminae, and alternating medium-grained to coarse-grained sand textures. The sand is clean, loose, and has little or no interstitial clay. Large burrows 1 – 2 cm in diameter are locally abundant.

In Hollow Creek and Graniteville quadrangles the uppermost 1 to 2 meters of the Dry Branch Formation generally consists of inter-laminated sand and clay. The thin clay laminae are cream to tan-colored, wispy, discontinuous, and undulatory. The sand laminae may be moderately well sorted and fine- to medium-grained, or poorly sorted and medium- to very coarse-grained. At some localities, such as Stop 7 on Herndon Dairy's property, the lamination is poorly defined in the uppermost .3 meters and very coarse sand grains, granules, and pebbles occur intermixed with finer sand. This coarser material appears to have been bioturbated down into the top of the Dry Branch from the overlying very coarse-grained, pebbly, basal Tobacco Road Sand.

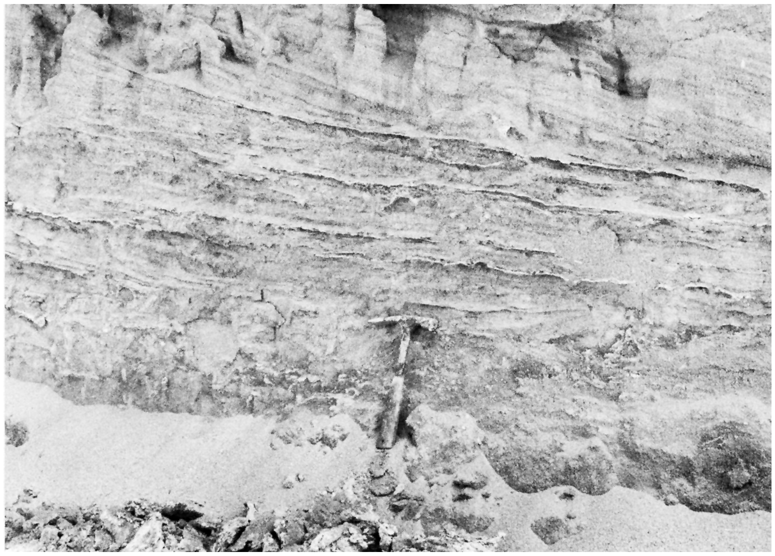

Figure 13. Dry Branch Formation. Loose, cross-bedded sands with clay laminae. The sands between clay laminae have little interstitial clay. Beds freshly exposed during mining operations. Stop 5.

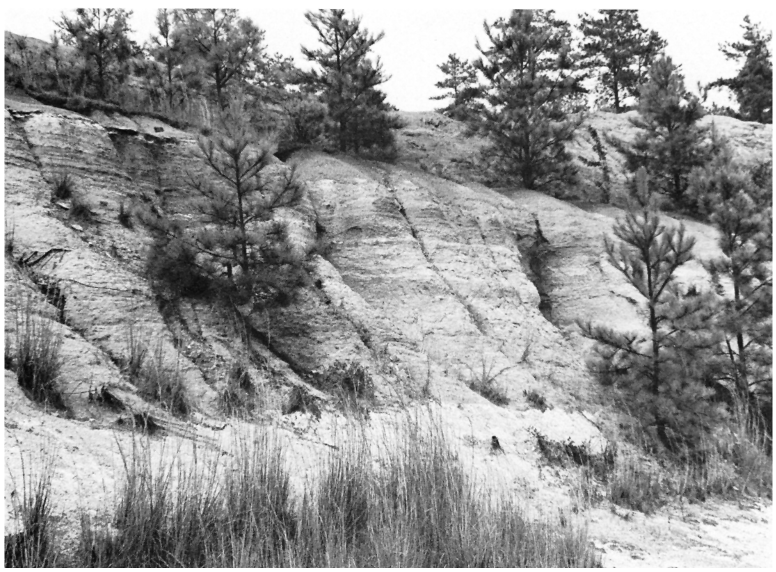

Figure 14. Section of the Dry Branch Formation. Here the Dry Branch lies unconformably on a kaolin bed (foreground, in broom straw) of the upper Huber Formation. The contact with the Tobacco Road Sand is not well shown but is present in the upper right-hand corner of the photograph. Stop 5A.

In eastern Georgia Huddlestun and Hetrick (1979, p. 19) noted the occurrence of a useful marker bed of thinly interbedded clay and fine sand in the top of the Dry Branch Formation, which could possibly be correlated with the above described uppermost Dry Branch lithology.

Age

The Dry Branch Formation was assigned a lower Jacksonian age by Huddlestun and Hetrick (1979) when they named the unit. Much of the evidence bearing on the age of the Dry Branch Formation has been collected from the Twiggs Clay. The Twiggs lithofacies of the Dry Branch Formation in Georgia was originally called the Congaree clay by Veatch and Stephenson (1911) who described the clay as the basal member of the McBean Formation and considered it oldest Claibornian in age. Shearer (1917) named the Twiggs Clay, classified it as a member of the Barnwell Formation, and assigned it to the Jacksonian. Cooke and Shearer (1918) cited fossil evidence for assigning the Barnwell to the late Eocene. Sloan (1908) originated the Barnwell Phase and placed it in the middle Eocene. Cooke (1943) followed the usage of Cooke and Shearer (1918) but restored part of the

Congaree clay to the McBean Formation, indicating that it might be of late Eocene age. In east-central Georgia LaMoreaux (1946) made the Twiggs Clay and Irwinton Sand members of the Barnwell Formation which he assigned to the late Eocene. Herrick and Counts (1968) working in eastern Georgia considered the Twiggs the updip clastic equivalent of the Ocala Limestone and therefore late Eocene in age. Yet they believed the Irwinton sand, also part of the Dry Branch Formation of Huddlestun and Hetrick (1979), to be the updip equivalent of the Cooper Marl and thus Oligocene in age. In central Georgia Pickering (1970) considered the Twiggs Clay as late Eocene in age. Carver (1972) assigned the Twiggs Clay, the Irwinton Sand and the Barnwell Formation to his Jackson Group of late Eocene age. Huddlestun, and others (1974) recognized the Twiggs Clay as a member of the Barnwell Formation and specified an early late Eocene age for it.

Siple (1967, Plate 1) mapped the Dry Branch in southern Hollow Creek quadrangle as part of the McBean Formation which he assigned a late Claiborne age following Cooke and MacNeil (1952). He did not encounter the Twiggs Clay lithofacies in the Hollow Creek-Graniteville area, but he did observe "fullers earth" (see road log, Stop 14) north of Aiken, and tentatively suggested it might be either Congaree Formation of lower Claibornian age or possibly Black Mingo Formation of early Eocene or Wilcox age (Siple, 1967, p. 46 and 47). Heron, Robinson, and Johnson (1965) assigned this clay to the Black Mingo Formation.

Cooke and MacNeil (1952, p. 22) stated that "the deposits of Claiborne and Jackson age have never been properly delimited in either eastern Georgia or South Carolina." One of the chief reasons for the stratigraphic confusion that has occurred in this region has been the misidentification of the several fullers earth horizons that occur here in Clairbornian and Jacksonian age strata, and further east toward the Congaree River, in Paleocene strata.

Prowell and O'Connor (1978) reported that palynological analyses of Twiggs Clay samples from eastern Georgia have shown that the clay is late Eocene (Clairbornian (?) to Jacksonian). Newell, and others (1980) also stated that pollen collected from numerous localities in the Augusta area date the Twiggs as Jacksonian (upper Eocene – 40 m.y.).

Thus since the Twiggs Clay lithofacies of the Dry Branch Formation was first named by Shearer in 1917, most workers in Georgia have assigned to it a Jacksonian or early Jacksonian age.

Harris and Fullagar (this volume), however, provide evidence that the upper Twiggs Clay (part of the Dry Branch Formation) is considerably younger than previously thought. They sampled the upper Twiggs Clay bed at the Medusa Portland Cement Company in Houston County, Georgia for authigenic glauconite. Glauconite from the sampled horizon yielded a Rb-Sr isochron age of 23 ± 0.2 m.y. indicating deposition at the end of the Oligocene or the beginning of the Miocene. Fossil evidence by Zullo, Willoughby, and Nystrom (this volume) also suggests a late Oligocene or early Miocene age for the Dry Branch Formation. This evidence is based on the identification of a barnacle in the uppermost Dry Branch with a species from the North Carolina Belgrade Formation considered to be lower Miocene (Zullo, 1979) or upper Oligocene (Ward, and others, 1978).

TOBACCO ROAD SAND

Previous Work

Huddlestun and Hetrick (1978) named the Tobacco Road Sand as a stratigraphic unit, to which they assigned a late Eocene age, that consists predominantly of medium-grained to coarse-grained quartz sand with subordinate amounts of clay, mica, chert, calcite, and rarely glauconite. The type locality of the Tobacco Road Sand is on the east side of Morgan Road, 0.35 mile (0.56 km) north of the junction of Morgan Road and Tobacco Road, south of Augusta in Richmond County, Georgia.

Cooke (1936, p. 62; 1943, p. 90) described the Barnwell Sand or Barnwell Formation as fine to coarse, reddish, pebbly sand or as fine to coarse, tough, argillaceous, red sand with flat, polished beach pebbles. Lang (1940, p. 43-45) described the Barnwell Formation as buff to deep-red, clayey sand, and he emphasized the presence of very smooth, well polished quartz pebbles. The descriptions of Cooke (1936, 1943) and Lang (1940) generally approximate a description of the present Tobacco Road Sand. LaMoreaux (1946a; 1946b, p. 63, 64) described the "upper sand member of the Barnwell formation" as coarse red sand with flat, polished beach pebbles at the base; he was the first to recognize separately the beds that are now called the Tobacco Road Sand.

Huddlestun and Hetrick (1979) discussed the history of the term "Barnwell" in South Carolina and Georgia, raised the Barnwell Formation to the Barnwell Group, and included within it the Clinchfield Sand at the base, the Dry Branch Formation, and the Tobacco Road Sand. Diagnostic late Eocene fossils have been described from the Clinchfield Sand and Dry Branch Formation (see Huddlestun and Hetrick, 1979 for references), and they (Huddlestun and Hetrick, 1978, 1979) considered the Tobacco Road Sand also to be late Eocene in age, based on the sporadic occurrence of the echinoid Pariarchus quinquefarius.

Lithology

The Tobacco Road Sand is a sand body composed predominantly of medium-grained to very coarse-grained, angular to subrounded, poorly sorted to moderately well sorted, quartz sand, with abundant quartz granules and pebbles, and with abundant interstitial clay that gives a light orange-red to red color to the formation in its typical exposures (Figure 16). Medium-grained to very coarse-grained quartz sand dominates in the Tobacco Road, but some very fine-grained to fine-grained quartz sand occurs throughout.

The characteristic color of the Tobacco Road is due to a significant content of orange-red clay that occurs as an interstitial filling, but the clay is seldom so abundant that it fills all pore spaces or is matrix-forming. Minor amounts of bedded clay also occur in the Tobacco Road, as clay stringers and as clay laminae (Figures 17, 18). Clay stringers are irregular, wispy concentrations of white clay, presumably now kaolin, that are only a few mm thick and a few cm in length; they are seldom abundant but can be an aid in recognizing original bedding. The irregular, wispy clay stringers are common near the base of the formation and can be seen in exposures that are not deeply weathered. White to purple bedded clay laminae with silt and fine sand, and up to 1 cm thick, occur in the upper Tobacco Road but they are not common. The bedded clay layers will be seen at Stop 9 in southeastern Hollow Creek quadrangle, and can be seen along isolated road cut exposures in upland areas elsewhere in Hollow Creek quadrangle.

Based on observations of two rare, unweathered exposures, Huddlestun and Hetrick (1978, p. 63) concluded that the offshore facies (see below) of the Tobacco Road Sand, "before it was oxidized and leached, considered mainly of unfossiliferous, massive-bedded, bioturbated, slightly argillaceous, glauconitic, slightly micaceous, greenish-gray sand." Presumably the orange-red or deep red color that is typical in most exposures of the Tobacco Road Sand is derived from weathering of non-quartz mineral grains, chiefly glauconite, that were part of the original sediment. Typical weathered, clay-rich, moderately well indurated, orange-red or deep red sand exposures of the Tobacco Road are at Stops 7, 8, 9, 11, and 12 of the Road Log (this volume). Atypical, relatively unweathered, clay-poor, loose, unconsolidated, white to cream sand, with burrows outlined by white clay, in the Tobacco Road are present at the Conger pit (Stop 11) and in the "high wall" in the Barden pit (same property as Stop 12).

The base of the Tobacco Road Sand generally includes abundant coarse to very coarse quartz sand and noticeable to abundant quartz granules and pebbles (Figure 15). Pebbles are up to 5 or 6 cm in dimension. The most well-rounded pebbles are discoidal or ovoid in shape. The basal or discoidal pebble zone was described or mentioned by Cooke (1936, p. 90; 1943, p. 62, 63), Lang (1940, p. 43-45), LaMoreaux (1946a, p. 10; 1046b, p. 63, 64), Herrick and Counts (1968, p. 38), Carver (1972, p. 168), Huddlestun and Hetrick (1978, 1979), and Smith (1979, p. 19, 22). Although the discoidal or ellipsoidal pebbles are most characteristic of the basal Tobacco Road, angular or subangular pebbles may be quite common or even predominant at a given exposure.

Distribution

In Hollow Creek quadrangle and southern Graniteville quadrangle the Tobacco Road Sand lies conformably or with apparent slight disconformity on the Dry Branch Formation. Huddlestun and Hetrick (1978, p. 63) noted that the basal pebble zone occurs in the updip, nearshore facies of the Tobacco Road and that a zone of cherty, silicified limestone, sandy limestone, or calcareous sand occurs sporadically at the base of the Tobacco Road in the offshore facies. LaMoreaux (1940a, 1940b) considered that the discoidal pebbles in the base of the Tobacco Road (his "upper sand member of the Barnwell formation") were derived from the crystalline Piedmont and were worn and accumulated as flat beach pebbles. Apparently, then, the discoidal beach pebbles accumulated at the base of the Tobacco Road in updip, nearshore areas while calcareous sediments, now largely altered to chert, were being deposited in offshore areas. In addition to the well-known pebble zone at the base of the Tobacco Road Sand, a bed of well-rounded, discoidal or ovoid pebbles also occurs locally at the base of the Dry Branch Formation; local elevations of the contact and the lithologies of the beds associated with a pebble zone can be used to distinguish between the two formations.

Stratigraphic relations at the base of the Tobacco Road in northern Graniteville quadrangle are unclear at present. At the southwest side of the Barden kaolin pit (Stop 11) the Tobacco Road Sand lies directly on massive kaolin of the upper Huber Formation and the Dry Branch Formation is absent, but at the base of the "high wall" farther north on the same property, 3-5 m of loose, unconsolidated, fine- to coarse-grained yellow or yellow-orange sand of the Dry Branch Formation is present above kaolin of the upper Huber Formation and below the coarse, pebbly red sand of the Tobacco Road. The Tobacco Road does extend to the northern edge of Graniteville quadrangle, based on exposures and an auger hole (S.C.G.S. Aiken County # 30) at Graniteville fire tower and on similar elevations above 500 ft (152 m) in the northernmost, western part of the quadrangle. At locality 3 of Zullo, Willoughby, and Nystrom (this volume) in northeastern Graniteville quadrangle, sand and reddish residuum with a basal discoidal pebble zone lie directly on kaolin of the upper Huber Formation. The basal pebble zone here could be either Tobacco Road of Dry Branch, but the Dry Branch Formation does occur to the northeast, in Aiken Northwest quadrangle (locality 2 of Zullo, Willoughby, and Nystrom, this volume; and at the other localities in the quadrangle) and at localities in Foxtown quadrangle. Whether the absence of the Dry Branch Formation in the Barden pit is an isolated situation or whether the Dry Branch pinches out beneath the Tobacco Road in updip areas elsewhere is a topic for continued investigation, but one that is made difficult by the intense weathering of the more updip strata.

Fossils

Fossiliferous, silicified or silica-cemented sandstones occur in the upper part of the Dry Branch Formation overly-

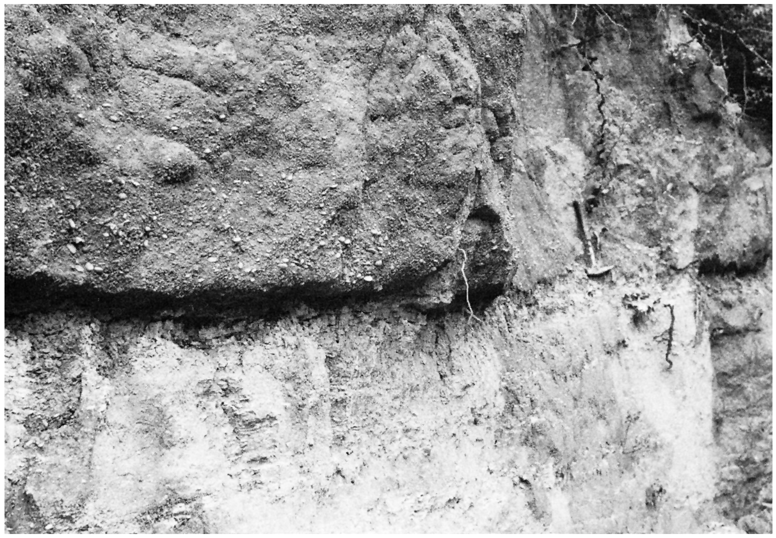

Figure 15. Discoidal quartz pebble bed at the base of the Tobacco Road Sand. The upper part of the Dry Branch shown here is sand with clay laminae. Hammer (right) for scale. Kaolin haul road in Dixie Clay Company's McNamee No. 2 pit.

Figure 16. Tobacco Road Sand lying on the Dry Branch Formation. Notice the relief on the contact. Bushes and small pine trees (upper right) for scale. Stop 11.

ing the Twiggs Clay lithology at locality 4, in northeastern Hollow Creek quadrangle, and at locality 2 in southern Aiken Northwest quadrangle, of Zullo, Willoughby, and Nystrom (this volume). Fossiliferous, silicified rocks at localities 1 and 3 (Graniteville quadrangle) of Zullo, Willoughby, and Nystrom (this volume) could be from either the Dry Branch Formation or from the lower Tobacco Road Sand. Thus, at present the evidence for fossiliferous, silicified rocks in the base of the Tobacco Road in Aiken County is not certain. At any rate, the barnacle-bearing, silicified rocks in Aiken County, South Carolina are updip, nearshore deposits as compared with the down-dip, offshore limestones and cherts that are known from the base of the Tobacco Road Sand in Washington and Burke counties in Georgia (Huddlestun and Hetrick, 1978, p. 63, 65; 1979).

Age

Huddlestun and Hetrick (1978) assigned a late Eocene (Jacksonian) age to the Tobacco Road Sand based on the occurrence of the echinoid *Periarchus quinqueferius* at localities in the base of the Tobacco Road, in the Sandersville Limestone Member of the Tobacco Road, and in the "Cooper Marl" of Georgia. Huddlestun and Hetrick (1978, p. 67, 68) considered the Tobacco Road Sand to be the updip equivalent of the "Cooper Marl" of Georgia, which includes a P16 planktonic foraminiferal assemblage and probably is equiva-

Figure 17. Lower part of the Tobacco Road Sand showing poorly sorted, medium-grained to very coarse-grained sand with clay balls. Dark tone is from abundant interstitial clay. Stop 11.

Figure 18. Upper part of the Tobacco Road Sand showing fine-grained, clayey sand with clay laminae and rip-up clasts. Stop 9.

lent, in part, to planktonic foraminiferal zone P17 as well. Thus Huddlestun and Hetrick (1978) regard the Tobacco Road as latest Eocene (Priabonian or Bartonian; Jacksonian) in age. Huddlestun and Hetrick (1978, p. 58) and Huddlestun (this volume) differentiate the "Cooper Marl" of Georgia from the typical Cooper Marl of South Carolina.

Upland Fluvial Channel DepositsZullo, Willoughby, and Nystrom (this volume) present evidence suggesting a late Oligocene or early Miocene age for the Dry Branch Formation and Tobacco Road Sand, based on a barnacle species recovered from localities in the Dry Branch Formation and possibly the Tobacco Road Sand in western Aiken County as well as from the Balgrade Formation of North Carolina. Harris and Fullagar (this volume) present evidence based on a Rb-Sr glauconite isochron from samples of the Twiggs Clay in central Georgia for an age of 23.0±0.2 m.y., or near the Oligocene-Miocene boundary.

UPLAND FLUVIAL CHANNEL DEPOSITS

Introduction

In Hollow Creek and Graniteville quadrangles (Figures 1, 2 and 3) there are fluvial channel deposits of coarse gravel and poorly sorted sand irregularly and discontinuously occupying some of the high areas of the interfluves. The deposits occur up to 18 km (11.2 mi.), measured perpendicularly, from the present Savannah River channel. Except for Quaternary alluvial sediments along present stream channels, these deposits represent the youngest map unit in the study area. In most places the unit lies on the Tobacco Road Sand, but at some localities erosional processes associated with deposition of the unit have channeled through the Tobacco Road Sand and the gravelly sediments lie directly on the Dry Branch Formation. Deposits of the unit are most abundant and thickest in the northern part of Hollow Creek quadrangle where locally they are a little more than 6.1 m thick. A stratigraphic section measured at the Chicora pit (see Appendix to the field guide, Stop 10, this volume) is capped by 6.4 meters (21 feet) of gravelly sand including 1.5 meters (5 feet) of cobbly residuum and soil. The best exposure of the unit (Figure 19) is in a cut on the north side of a kaolin haul road, approximately 100 meters south of the Chicora pit. In the roadcut interlayered gravels and sands lie unconformably on the Dry Branch Formation at an elevation of 420 to 430 feet. At the west end of the cut there is a sharp scour-surface contact (Figure 20).

Previous Work

The upland fluvial channel deposits were noted by Sloan (1904, p. 79; 1908, p. 479) in the Hollow Creek-Graniteville area. He included them in his Lafayette Phase which he assigned a Pleistocene age. McGee (1891) had already mapped the Lafayette Formation through the Aiken-Augusta area in tracing the unit across the upper Atlantic and Gulf Coastal Plains. He believed the unit was Miocene to Pliocene in age (McGee, 1891, p. 498) He certainly included the channel deposits in the Lafayette Formation in western Aiken County, but his description (McGee, 1891, p. 484) suggests he also included the Tobacco Road Sand as part of the same formation. The term Lafayette Formation was formally abandoned in 1915 when the type locality in Lafayette County, Mississippi was found to be Eocene in age (Doering, 1976). Sloan (1908), however, recognized the gravel deposits constituted a distinct and separate unit and did not associate them with his underlying Barnwell Phase (Tobacco Road Sand) which he classified as middle Eocene.

Cooke (1936) did not mention in his text or show on his maps any indication of the occurrence of the upland channel deposits. These sediments were recognized, however, by Lang (1940, p. 45, 46) who described them as "Gravel of another type, which reaches the size of cobbles." He was uncertain whether the sediments were part of the Barnwell Formation (Tobacco Road Sand) or not, and suggested they may have been deposited during one of the Pleistocene erosional cycles.

Doering (1960, 1976) mapped the Citronelle Formation, which he assigned to the early Pleistocene, as a regional surface unit mantling a large part of the southeastern Coastal Plain including most of Aiken County. There is no evidence he recognized the upland fluvial channel deposits in western Aiken County as a distinct unit, rather he mistakenly believed (Doering, 1960, p. 189) that Cooke's (1936) Barnwell sand (Tobacco Road Sand) was his early Pleistocene Citronelle Formation and the youngest mappable unit in the area.

The term "Citronelle Formation" was also used by Smith and White (1979) but in a sense different from Doering (1960, 1976). On their Aiken County reconnaissance map, Smith and White (1979) delineated the channel deposits but designated them "Citronelle Formation." Yet Smith (1979) indicated they were discontinuous and described them as unconformably overlying late Eocene strata of the Barnwell Group (the Tobacco Road Sand and the Dry Branch Formation).

Siple (1967, p. 62, 63), in his geological report on the Savannah River Plant and surrounding area, described the same gravel deposits referring to them as "alluvial deposits of late Tertiary age." He noted they occurred irregularly on interstream divides in deposits from 5 to 20 feet thick. He did not, however, delineate these deposits on his geologic map.

Northeast of the Congaree River Colquhoun (1965) observed similar fluvial deposits occurring at elevations up to 450 and 500 feet. He assigned these to the Citronelle Formation and indicated a pre-late Miocene age.

Sloan (1908, p. 479) recognized near the Congaree the same high-level gravelly sediments and described them, as well as analogous deposits adjacent to the Wateree and Pee Dee rivers, as part of his Lafayette Phase.

Distribution

In the northern part of Hollow Creek quadrangle there are a few localities where original bedding (Figure 19) is exposed and the deposits are unequivocally "in place". These sites are all on high parts of the interfluves and range in elevation from 390 to 440 feet. Most commonly one encounters lag gravels with the sand component largely removed by weathering and erosion. These deposits occur at elevations up to 460 feet. Nevertheless, some of the highest parts of the interstream divides, at elevations up to 480 feet, are not capped by the gravel deposits. Therefore, the deposits did not blanket the entire region but were originally confined to meandering channels that spread the gravels irregularly over a locally broad area. Along the interfluves in the southern part of Hollow Creek quadrangle lag gravel deposits occur on the high areas at elevations between 350 and 370 feet, 80 to 90 feet lower than the range of elevations in the northern part of the quadrangle. Although there is a general tendency for the deposits to occur at the lower elevations toward the southern part of the map area, there appears to be no significant variation in elevation within local areas on the interfluves. Mass movement processes, however, have caused some lag gravels to be transported downslope.

Figure 19. Quartz cobble beds in upland fluvial channel deposits. Stop 10.

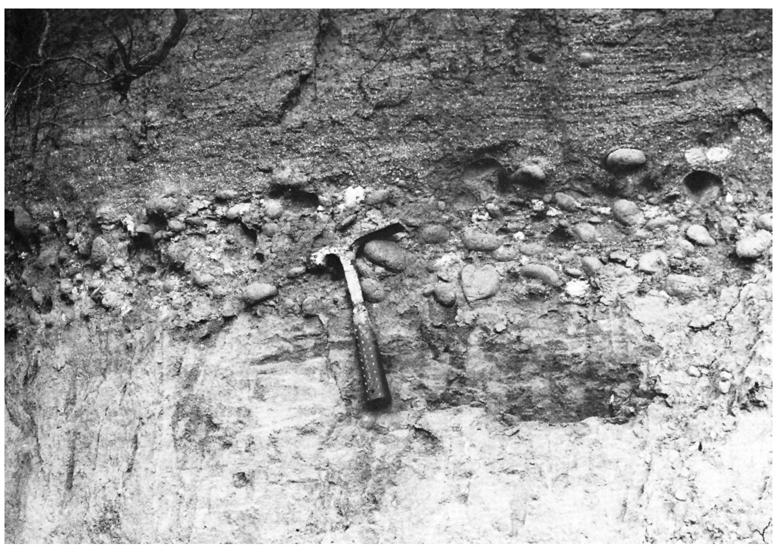

Figure 20. Unconformable contact between upland fluvial channel deposits and upper Dry Branch Formation. Notice the white, weathered clay granules and pebbles in the upland fluvial channel deposits as well as the quartz cobbles at the base. Stop 10.

Lithology

The upland fluvial channel deposits typically consist of light pinkish orange, indurated, gritty quartz sand irregularly interbedded with pebble-cobble layers (Figure 19). Although lag gravels derived from this unit may consist largely of pebbles and cobbles, exposures "in place" are predominantly comprised of sand. The pebble-cobble fraction makes up only 25 to 35 percent of the sediments.

The quartz sand component is distinctive for the white flecks or grains of kaolin that occur within it. The angular outline of some of these grains suggest they were originally feldspar now altered to kaolin. The sand is clayey, micaceous, poorly sorted, and medium- to very coarse-grained with some quartz granules. The quarts sand grains are subrounded to angular. The sand fraction includes some dark heavy minerals. Much of the clay in the sand is in the form of kaolin grains, though there is also considerable matrix-forming red clay.

The pebbles and cobbles, except for some clay clasts in this size range, are entirely comprised of quartz. They are rounded to well-rounded, subspherical, generally from 3 to 10 cm in diameter, and vary from coarsely crystalline smoky or milky white quartz, to granular tan quartz. As a result of prolonged weathering many of the cobbles break easily into fine fragments when tapped with a hammer.

The irregular stratification that characterizes this unit is prominently defined by the gently inclined pebble-cobble layers that stand out in relief on exposure surfaces (Figure 19). These layers generally range from 10 cm to 0.6 m thick, but bed thickness varies laterally within a single exposure, and layers bifurcate and coalesce erratically. The cross-bedded sand interlayers may be thicker or thinner than the pebble-cobble beds.

The scouring at the base of the unit, the inclined layers of pebbles and cobbles interbedded irregularly with poorly sorted immature sand, the cross-bedding, and cut and fill structures, all indicate fluvial channel deposition.

ACKNOWLEDGMENTS

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FIELD GUIDE TO THE STRATIGRAPHY OF THE HOLLOW CREEK – GRANITEVILLE AREA, AIKEN COUNTY, SOUTH CAROLINA

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INTRODUCTION

The purpose of the field trip is to examine the Cretaceous, Tertiary, and Pleistocene (?) stratigraphy in part of the kaolin mining district, southwestern Aiken County, South Carolina, and to discuss the age and origin of the stratigraphic units there. The all-day trip on Saturday, October 9 will visit ten stops showing local feldspathic bedrock, Cretaceous and lower Tertiary kaolinitic units, exposures of the upper Eocene (?), Oligocene (?), or Miocene (?) Dry Branch Formation and Tobacco Road Sand (Barnwell Group), and Pleistocene (?) upland fluvial channel deposits. The half-day trip on Sunday, October 10 will visit four stops showing three exposures of lower Tertiary kaolinitic strata and three exposures of the Barnwell Group sediments, including a distinctive fossil hash facies.

Please bring your own hard hat for our visits to active kaolin mines.The field trips on both Saturday, October 9 and Sunday, October 10, 1982 will assemble in the parking lot of Ramada Inn on the north side of U.S. Highway 1 and U.S. Highway 78 (Richland Avenue West) in Aiken, South Carolina. Both trips will be by bus only. Departure promptly at 8:00 a.m. is planned for both days.

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J.M. Huber Corporation, Dixie Clay Company, the Graniteville Company, Southern Railway, Gordon Farmer of Augusta Concrete Block Company, Herndon Dairy proprietors, Wallace B. Cassels, and other private landowners have generously permitted access to their properties for the field trip.

ROAD LOG – SATURDAY TRIP

Meet in parking lot of Ramada Inn on the north side of U.S. Highway 1 and U.S. Highway 78 (Richland Avenue West) on the west side of Aiken, South Carolina. Leave parking lot at 8:00 a.m., Saturday, October 9, 1982.

Mileage Cumulative	Interval	Itinerary
0		Leave parking lot. Turn right (west) onto U.S. 1 & U.S. 78.
1.0	1.0	Get in right turn lane.
1.2	0.2	Turn right onto Gregg Highway (S.C. S-2-895).
2.5	1.3	Pass under electric powerlines east of Graniteville.
3.65	1.15	Come to stop. "T" intersection with Canal Street (S.C. 191) in Graniteville. Turn right (north)
3.85	0.2	Cross bridge over canal. Mileage here may vary because of new bridge being built.
3.95	0.1	Cross railroad tracks.
4.25	0.3	Cross canal again, and park on dirt road and on pullover immediately past bridge on right (east) side of road.

Stop 1. Cross road carefully, walk south across highway bridge over canal, then enter wooded path on right (west), just past the bridge, to the dam and spillway to Flat Rock Pond. Discussion by Ralph Willoughby.

The Graniteville granite in the spillway of Flat Rock Pond and along Horse Creek at this stop varies from fresh to weathered. The sediment accumulating in the bed of Horse Creek below the spillway, when not disturbed by heavy flow of water, consists largely of kaolin weathered from the granite, and little weathered feldspar is present. The setting provides an obvious example for the ultimate source of kaolin in the sediments of western Aiken County.

Stop 2. Go back to buses, walk to railroad tracks and follow tracks northward to railroad cuts at south end of railroad siding. Discussion by Ralph Willoughby.

The sediments in the railroad cut here are near the base of the local sedimentary sequence and are assigned to the Cretaceous. Two features are noteworthy: (1) kaolin beds and laminae are present in these sediments that accumulated only a few meters above granite bedrock; and (2) burrows are not present in

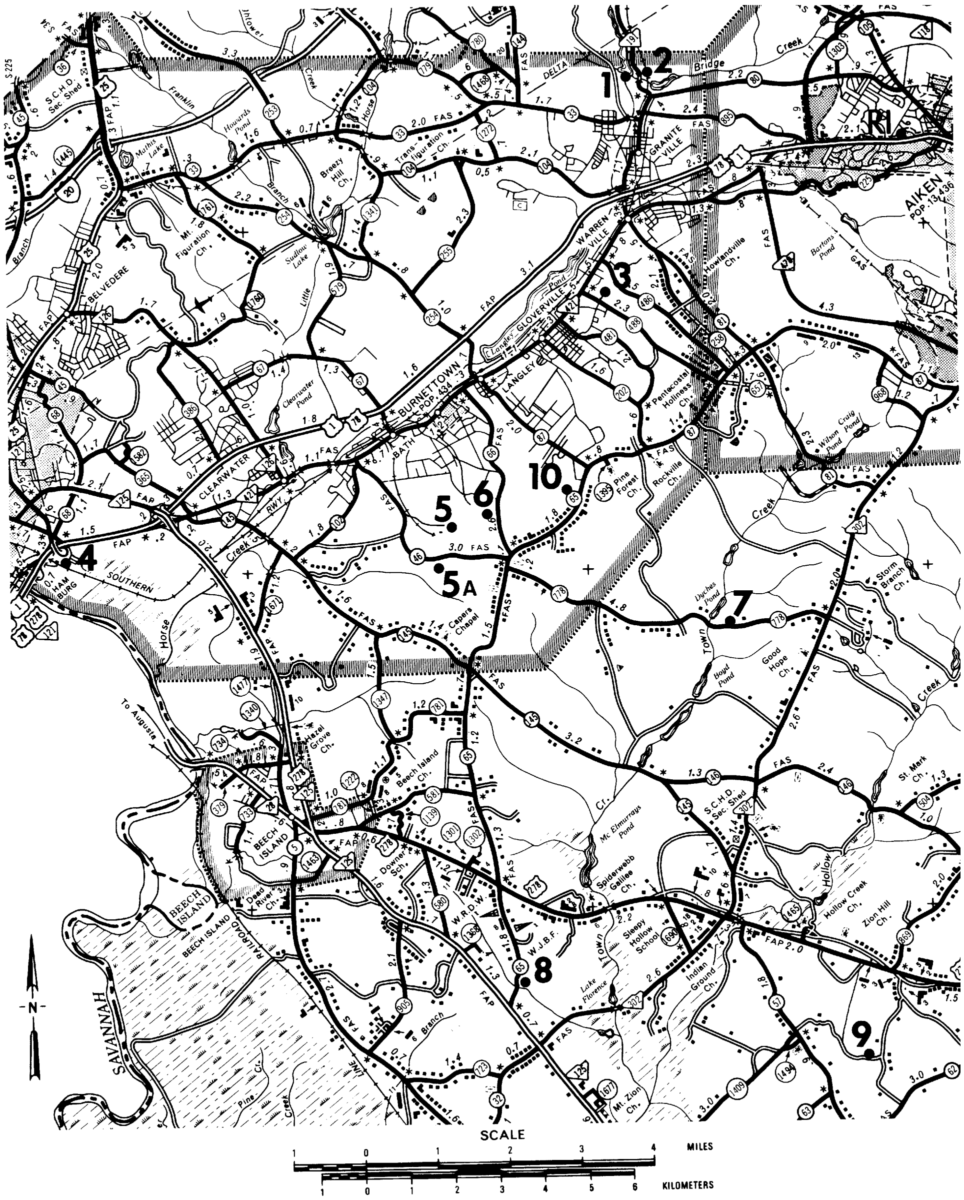

Figure 1. Highway map of a part of Aiken County, South Carolina, showing location of field trip stops for Saturday, October 9, 1982. RI is the location of Ramada Inn in Aiken, starting point for the field trip.

these Cretaceous sediments. The fine-grained, well sorted sands that occur in part of the exposure here are less characteristic of the Cretaceous stratigraphy than the coarser, less well sorted sands with kaolin balls.

Go back to buses. Turn buses around, drive south on S.C. 191 back to Graniteville.

4.85 0.6 Intersection with Gregg Highway on left. Continue straight (south) on S.C. 191.

5.0 0.15 Graniteville granite quarry (abandoned) is in woods across canal on right (east).

5.2 0.2 Bear right, cross railroad tracks then bear left. Downtown Graniteville; the Graniteville Company on right (east). Continue straight (south) on S.C. 191.

6.1 0.9 Traffic light at intersection. Turn right (south) on S.C. 421 or Augusta Road.

7.3 1.2 Turn left (east) on road S-2-488.

7.6 0.3 Turn left on dirt road.

7.75 0.15 Drive straight ahead to pit. Park buses. Stop 3 is straight ahead.

Stop 3. Discussion by Ralph Willoughby.

The contrast between the bright white, coarsely muscovitic, angular to subangular, very coarse to pebbly, non-burrowed, lower sands and the overlying cream to yellow-orange, silty, clayey, angular to subrounded, fine-grained sands of the lower Huber Formation is striking. The abundance of coarse mica, the abundance of angular to subrounded coarse quartz sand grains and pebbles, and the absence of burrowing are characteristic of Cretaceous strata in western Aiken County, and the presence of burrows differentiates Tertiary from Cretaceous strata. Pisolitic kaolin boulders in the base of the upper sequence (Tertiary; base of the Huber Formation) attest to the period of weathering and erosion that occurred between the time of deposition of the two stratigraphic sequences. The elevation of $\pm$310 ft (94 m) at the pit is comparable to the elevation of from 310 ft (94 m) to 320 ft (98 m) for the top of Cretaceous kaolin beds in the nearby McNamee, Pepper Branch, Ideal, and Paragon kaolin mines.

7.9 0.15 Return to hard-surface road. Turn right (west) on S-2-488.

8.2 0.3 Come to stop. Intersection with S.C. 421. Turn left (south) on S.C. 421.

11.7 3.5 Traffic light and intersection with county road S-2-62. Continue straight (south) on S.C. 421.

12.5 0.8 Bridge over railroad tracks

14.9 2.4 Road divides.

15.15 0.25 Enter U.S. 1

15.2 0.05 Bear right onto exit ramp to U.S. 1 & U.S. 78.

16.7 1.5 Get in left turn lane.

16.8 0.1 Turn left (south) into parking lot of K-Mart store. Go straight through, passing to the left of and behind the store building.

17.0 0.2 Bear right to stop sign. Come to stop at sign, then turn right (east onto paved road (Road S-2-895).

17.1 0.1 Bear right at intersection.

17.15 0.05 Turn left onto divided road. Then immediately take first left turn (south) after entering divided road. Gibbes Auto and Truck Sales on left.

17.3 0.15 Bear left.

17.4 0.1 Park in parking lot of August Concrete Block Company. Exit buses and walk eastward 0.1 mile to Stop 4.

STOP 4. Discussion by Paul Nystrom and Ralph Willoughby.

At this bluff about 3 m of Cretaceous kaolinitic sands are overlain by a thick sequence (nearly 10 m, excluding residuum) of fluvial sediments. These exposures are within the type area of Sloan's (1904, 1908) Hamburg Phase, though he did not specify a type locality. His description indicates the kaolinitic sands here were included in his Lower Hamburg strata which he assigned to the Lower Cretaceous. Cooke (1926) reassigned these sediments to the Middendorf and classified them as basal Upper Cretaceous. Later Cooke (1936) placed Middendorf strata under the name Tuscaloosa believing the Middendorf was just a northeastward extension of the Tuscaloosa. As used by Cooke (1936) the Tuscaloosa included all the kaolinitic strata (Cretaceous and Tertiary).

Not far from here Cooke (1936, p. 25) described a section measured up the bluffs northwest of U.S. Highway 1. The kaolinitic sands and clays he termed Tuscaloosa (Upper Cretaceous). The overlying sediments he assigned to the Pleistocene. On his geologic map (Cooke, 1936, plate 1) he showed small areas of Brandywine, Coharie, and Sunderland (Pleistocene) deposits in this area.

Turn around. Leave parking lot.

17.4 0.05 Bear left, then come to stop. Turn right (east) and enter U.S. 1 & U.S. 78. Pass under bridge and continue east on U.S. 1 & U.S. 78.

18.75 1.3 Turn right (south) onto S.C. 421.

19.0 0.25 Pass under bridge.

20.6 1.6 Clearwater Elementary School on left.

21.75 1.15 Highway bridge passes over railroad tracks.

21.9 0.15 Turn right (east) onto Dixie Clay Road (S.2-46).

22.9 1.0 Bear left (straight east) onto dirt road. Enter property of Dixie Clay Company.

23.2 0.3 Bear left at Y intersection and cross railroad tracks.

23.4 0.2 Dixie Clay kaolin plant on right, office on left. Continue straight, passing old country store on right.

23.5 0.1 Turn left (north) at Y intersection.

23.7 0.2 Bear right.

24.0 0.3 Park buses.

STOP 5. Proceed to the floor of Dixie Clay Company's McNamee #2 pit. Discussion by Paul Nystrom.

Kaolin has been mined from this tract since 1852 when the Bath Pottery Company had an operation undoubtedly located west of the present mine (Smith, 1949). Dixie Clay Company is currently mining kaolin from two levels in the stratigraphic section here. At the base of the section Cretaceous soft kaolin (see Buie, 1978, 1980; Buie and Schrader, this volume) is being mined from the floor of the pit. About 14 m upsection hard kaolin is being mined from the uppermost part of the Huber Formation (Tertiary, Claibornian or older; Buie, 1978). This pit is an excellent place to compare the differing characteristics of the two types of commercial kaolin.

In the southeastern wall of the mine approximately 45 m of section is exposed including the upper part of the Cretaceous sequence, a complete section of the Huber Formation, a complete section of the Dry Branch Formation, and the basal part of the Tobacco Road Sand.

The Cretaceous soft kaolin sequence is 7 to 8 m thick, and tan to cream-white; the uppermost meter is pisolitic. A characteristic subconchoidal fracture typifies the kaolin.

The Cretaceous sequence is unconformably overlain by the Huber Formation which is 20 m thick. At the very base of the Huber, coarse-grained dark heavy minerals in poorly sorted kaolinitic sand are concentrated on the uneven surface scoured into the Cretaceous kaolin. The lower 1.4 m of the Huber consists of poorly sorted, very coarse-grained and pebbly sand. Above this is a distinctive sequence about 6 m thick of intercalated, well-sorted, very fine- to fine-grained "sugar sands" and laminated to thin-bedded, laterally continuous, clay layers (Bed 4 in Appendix, Stop 5). If there are any Paleocene strata in this section they occur between the base of the Huber and the top of Bed 4. Above Bed 4 the kaolinitic sand strata are coarser, more poorly sorted, and some are distinctly fining-upward layers. The uppermost Huber bed is a massive kaolin layer about 6 m thick that has a characteristic hackly fracture.

The Huber Formation is unconformably overlain by the Dry Branch Formation of the Barnwell Group defined by Huddlestun and Hetrick (1979) and assigned to the late Eocene. Zullo, Willoughby, and Nystrom (this volume) and Harris and Fullagar (this volume) provide evidence that suggests the Dry Branch is late Oligocene or early Miocene in age.

The section here includes a little more than 13 m of the Dry Branch Formation. At the base of the formation is a 0.23 m thick bed of poorly sorted, coarse-grained and pebbly sand with dark heavy minerals concentrated at the base. A bed like this generally occurs at the base of the Dry Branch in Hollow Creek quadrangle and in southern Graniteville quadrangle. Several laminated to thin-bedded montmorillonitic clay sequences with micaceous, silty sand partings (Twiggs Clay lithology) occur in the lower part of the formation. Interlayered with the clay sequences and comprising much of the middle part of the unit are yellow, cross-bedded, coarse-grained, poorly sorted and moderately well sorted sand beds with little or no interstitial clay (Irwinton lithology). The upper 4 m of the Dry Branch includes two intervals of clay laminae intercalated with fine- to medium-grained sand separated by a 2.5 m thick bed of massive, indurated, coarse-grained to very coarse-grained orange-red sand.

Uncoformably overlying the Dry Branch Formation at the top of the section is the lower part of the Tobacco Road Sand. Both formations were defined by Huddlestun and Hetrick (1978, 1979) as units in the Barnwell Group and assigned to the late Eocene (Jacksonian). The proposed late Oligocene or early Miocene age for the underlying Dry Branch Formation (Zullo, Willoughby, and Nystrom, this volume; Harris and Fullagar, this volume) directly affects age interpretations for the Tobacco Road Sand.

A few scattered discoidal quartz pebbles and abundant flat, white to purple clay clasts occur at the base of the Tobacco Road. The lower part of the unit here is dark red-maroon, medium- to coarse-grained, poorly sorted sand.

LUNCH

Board buses and exit pit.

24.65	0.65	Bear right at intersection with other dirt road.
24.7	0.05	Pass by Dixie Clay office and plant.
24.9	0.2	Cross railroad tracks and bear right.
25.1	0.2	Bear left on dirt road.
25.15	0.05	Come to stop. Turn left (south) onto Dixie Clay Road (Road S-2-46).
25.95	0.8	Dirt entrance road to Dixie Clay Company's Pepper Branch pit on right (south).

STOP 5A. (Alternate)

In this pit Dixie Clay Company has mined soft kaolin from the top of the Cretaceous. About 45 meters of stratigraphic section was measured and described in detail in the northeastern corner of the mine (see Appendix, Stop 5A). As far as we know this is the thickest section of exposed strata in Aiken County. The units exposed include the uppermost part of the Cretaceous sequence (2.5 m), a complete section of the Huber Formation (29.3 m), a complete section of the Dry Branch Formation (8.5 m), and the basal part of the Tobacco Road Sand (2.4 m), excluding overlying residuum.

The pit is only about 1220 m SSE of Dixie Clay's

McNamee #2 pit and the same units are exposed in both pits, so the two sections are generally similar. The Huber is about 9 m thicker in the Pepper Branch pit and the Dry Branch is 4.6 m thinner. The uppermost bed in the Huber is a very thick (12.5 m) layer of massive kaolin but much of it is purple mottled, some of it is sandy, and the bed is of poor quality. The basal Tobacco Road Sand at the Pepper Branch pit is prominently cross-bedded, with abundant kaolin balls and many small clay-lined burrows about 2 mm in diameter. Sparse well-rounded, discoidal quartz pebbles occur at the base of the poorly sorted, fine-grained to very coarse-grained, pinkish red sand of the Tobacco Road.

Continue straight (east) on Dixie Clay Road.

27.1 1.15 Come to stop. Turn left (north) onto Pine Log Road (S-2-65).

27.15 0.05 Turn left (east) onto Huber Clay Road (S-2-66).

28.2 1.05 Turn left (east) onto dirt road to J.M. Huber Corporation's Ideal pit.

28.4 0.2 Aiken County landfill on right (west).

28.5 0.1 Bear right.

28.8 0.3 Park buses.

STOP 6. Exit buses at J.M. Huber Corporation's Ideal pit. Discussion by Aubrey L. Long, Ed L. Schrader, Charles H. Muir, and A. Richard Henderson.

About 36.4 meters of strata were measured and described in detail in J.M. Huber Corporation's Ideal mine (see Appendix, Stop 6). Units included in the section are the top of the Cretaceous sequence (.76 m), a complete section of the Huber Formation (18.9 m), and a thick but incomplete section of the Dry Branch Formation (14.2 m).

Board buses and exit pit.

29.4 0.6 Come to stop. Turn right (south) onto Huber Clay Road (S-2-66).

30.5 1.1 Come to stop. Turn right (south) onto Pine Log Road (S-2-65).

30.55 0.05 Dixie Clay road on right (west). Continue south on Pine Log Road.

30.75 0.2 Turn left (east) onto Herndon Dairy Road (S.-2-778). Entrance to Herndon's Dairy on left. Continue straight (east).

33.8 0.05 Cross over Town Creek.

34.2 0.4 Park buses.

STOP 7. Borrow pit on left (north) on Herndon Dairy's property. Discussion by Paul Nystrom.

The section exposed here includes upper Huber sand and clay strata, a complete section of the Dry Branch Formation, and the base of the Tobacco Road Sand. The upper Huber sequence includes laminated to thin-bedded, fine-grained, well sorted, micaceous sands with kaolin clasts, laminated to thin-bedded kaolin, and a massive kaolin bed at the top. Thin-bedded, fine-grained sand like this is more typical of the lower part of the Huber. Upper Huber sand is generally thick-bedded to very thick-bedded, medium-grained to very coarse-grained, and poorly sorted.

In the Dry Branch section there are several intervals of laminated to very thin-bedded montmorillonitic clay with partings of fine-grained, micaceous, silty sand (Twiggs Clay lithology). As is generally the case, these intervals occur in the lower part of the unit. Irwinton-like strata comprise the upper part of the Dry Branch here. These include horizontally bedded, cross-bedded, moderately well sorted, and poorly sorted layers, most with very thin, undulating, white clay laminae; some layers are prominently burrowed.

The basal Tobacco Road Sand is comprised of orange-red, indurated, poorly sorted, coarse-grained, clayey sand with quartz granules. This lithology is representative of the basal Tobacco Road in many exposures within the field trip area, and the abrupt change to this sediment marks the contact. At this locality there is no well-defined quartz pebble zone marking the base of the unit, though a few scattered pebbles occur.

Board buses and continue eastward on Herndon Diary Rad.

35.5 1.3 Come to stop. Turn right (south) onto silver Bluff Road (S.C. 302).

36.16 0.65 Good Hope Church on right.

36.6 0.45 Incised Carolina bay on right.

38.1 1.5 Storm Branch Road (S-2-146) intersects on right (west). Continue straight (south).

38.15 0.05 Old White Pond Road (S-2-146) intersects on left (east). Continue straight (south).

40.15 2.0 Come to stop. Traffic light and intersection with U.S. 278 at community of Hollow Creek. Turn right (west) onto U.S. 278.

41.4 1.25 Huber Formation exposed in road cuts.

41.6 0.2 Cross bridge over Town Creek.

42.3 0.7 Pass through community of Spiderweb.

43.4 1.1 Intersection with Pine Log Road (S-2-65). Turn left (south) onto Pine Log Road.

44.8 1.4 Park buses.

STOP 8. Borrow pit on the Cassels estate. Leave buses and follow path through the woods eastward to the pit. Discussion by Paul Nystrom.

A stratigraphic section 11 meters thick was measured and described in detail at this borrow pit (see Appendix, Stop 8), where part of the Dry Branch Formation and the basal part of the Tobacco Road Sand are exposed. The base of the Dry Branch is below the surface so the 7.9 m measured represents an incomplete section. Clay laminae intercalated with mainly fine-grained, well sorted sand and paper-thin silty sand partings comprise the lower 2.25 m of the exposed Dry Branch. Above the laminated interval is a sequence consisting chiefly of cross-bedded, medium- to coarse-grained locally well-burrowed sand. Two kinds of burrows occur, small ones 1-2 mm in diameter and large ones 10-25 mm in diameter. Pebbly sand beds occur at the base and at the top of the cross-bedded sequence. The uppermost meter of the Dry Branch is comprised of fine- to medium-grained and medium-grained sand with quartz granules and with wispy, discontinuous, undulatory clay laminae.

The Tobacco Road Sand unconformably overlies the Dry Branch Formation. A prominent pebble zone consisting of well rounded, ellipsoidal to discoidal quartz pebbles 5-20 mm in diameter marks the base of the Tobacco Road. Sand associated with the pebble zone is poorly sorted and medium-grained to very coarse-grained. Above the pebble zone the sand becomes medium-grained and moderately well sorted with faint, wispy clay laminae.

Board buses and continue south on Pine Log Road.

45.2 0.4 Come to stop. Intersection with S.C. 125. Turn left (southeast).

45.9 0.7 Turn left (northeast) onto Silver Bluff Road, S.C. 203.

47.2 1.3 Cross bridge over Town Creek.

49.1 1.9 Come to stop. Intersection with U.S. 278 at community of Hollow Creek. Turn right (east) onto U.S. 278.

49.3 0.2 Cross bridge over Hollow Creek.

51.2 1.9 Turn right (south) onto DeSoto Drive (S-2-1859).

51.6 0.4 Silver Bluff High School on right.

52.2 0.6 Turn left (south) onto dirt road. Turn left (east).

52.25 0.05 T intersection with another dirt road. Turn left (east).

53.15 0.9 Park buses.

STOP 9. Leave buses and see section. Discussion by Paul Nystrom.

Beginning at the base of the hill we measured and described 16.25 m of Tobacco Road Sand strata before we encountered residuum (see Appendix, Stop 9). This is the thickest section of Tobacco Road strata we have seen. Though the base of the unit is not exposed, the lowermost 2.8 m of Bed 1 is the same lithology observed at numerous outcrops in Hollow Creek quadrangle where the base can be seen. This suggests the lowest part of the exposed section lies just above the Dry Branch Formation. Bed 1 is purple, massive and indurated, poorly sorted, medium-grained to very coarse-grained sand with granules and a few scattered pebbles.

Above Bed 1 there are a variety of fine- to coarse-grained sand lithologies. In the middle part of the section most of the beds are burrowed, the burrows being 1-2 cm in diameter. Note that Bed 4 is lithologically identical to beds commonly found in the Dry Branch Formation.

There has been some discussion above whether the Tobacco Road Sand represents a transgressive or regressive sequence. This is a good place to examine the unit with an eye toward making a judgement on that question.

Board buses and continue on dirt road.

54.25 1.1 Y intersection with dirt road. Bear left.

54.4 0.15 T intersection with dirt road. Bear left.

54.5 0.1 Come to stop. Intersection with U.S. 278. Turn left (west) onto U.S. 278.

54.9 0.4 DeSoto Drive enters from left (south). Continue straight (west).

56.8 1.9 Cross bridge over Hollow Creek.

57.0 0.2 Intersection with Silver Bluff Road (S.C. 302). Turn right (north).

57.6 0.6 Y intersection. Bear left (northwest) onto Storm Branch Leg (S-2-145).

59.35 1.75 Y intersection. Bear left (west) on S-2-145.

59.7 0.35 Cross bridge over Town Creek.

62.5 2.8 Come to stop at intersection. Turn right (north) onto Pine Log Road (S-2-65).

64.1 1.6 Herndon Dairy Road (S-2-778) enters from right. Continue straight (north).

64.25 0.15 Dixie Clay Road (S-2-46) enters from left. Continue straight (northeast).

64.3 0.05 Huber Clay Road (S-2-66) enters from left. Continue straight (northeast).

65.6 1.3 Turn left (west) off of Pine Log Road onto dirt road. Enter property of J.M. Huber Corporation. Park buses and walk to outcrops and to Chicora

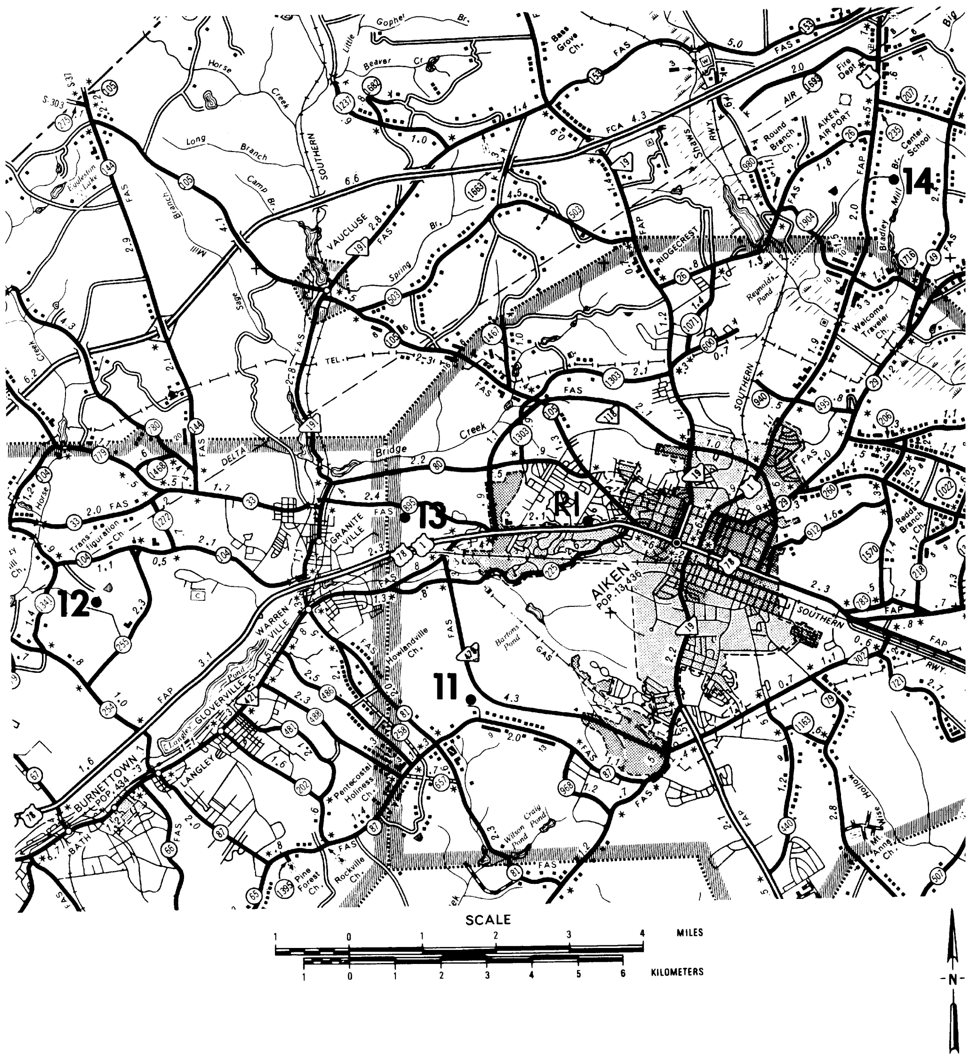

Figure 2. Highway map of a part of Aiken County, South Carolina, showing location of field trip stops for Sunday, October 10, 1982. RI is the location of Ramada Inn in Aiken, starting point for the field trip.

pit.

STOP 10. Discussion by Paul Nystrom.

At this pit hard kaolin is mined from the top of the Huber Formation. The 17.7 m section measured and described here (see Appendix, Stop 10) includes 4.7 m of massive kaolin, 6.6 m of the Dry Branch Formation, and 4.9 m of the upland fluvial channel deposits. The Tobacco Road Sand which occurs above the Dry Branch in surrounding areas has been completely removed by scouring associated with the deposition of these sediments.

The Huber kaolin is cream-colored to light gray, massive, pure, and has a hackly fracture characteristic of the Tertiary kaolins.

A pebbly sand with prominent, well rounded quartz pebbles up to 3 cm in diameter occurs at the base of the overlying Dry Branch. The lower third of the formation consists mainly of poorly sorted medium-grained to very coarse-grained sand with quartz granules and pebbles. In the middle and upper parts of the unit are sand beds with thin clay laminae. There is no Twiggs Clay lithology in this section of the Dry Branch.

The 4.9 m of channel gravel here is the thickest section of the unit that we know of. These sediments are distinguished by the well rounded, sub-spherical, quartz pebbles and cobbles 3-10 cm in diameter. Prominent lag gravels form over these deposits in many upland areas of Hollow Creek quadrangle and the southern part of Graniteville quadrangle. The best exposure we have found is located along the haul road just south of the Chicora pit.

Return to buses. Turn around, then turn left (north) onto Pine Log Road (S-2-65).

66.2 0.6 Y intersection. Road S-2-87 enters from left. Bear right (northeast).

69.0 2.8 Intersection with S-2-81. Continue straight (northeast) on Pine Log Road.

69.6 0.6 Entrance to J.M. Huber Corporation's Conger pit on left. Continue straight (east) on Pine Log Road.

70.1 0.5 Turn left (north) onto Huntsman Road.

70.4 0.3 Come to stop. Turn left (west) onto Hitchcock Parkway (S.C. 478).

72.8 2.4 Come to stop at 4-way stop intersection. Continue straight (north) on S.C. 478.

73.0 0.2 Get in right lane. Turn right (east) and enter U.S. 1 & U.S. 78.

73.85 0.85 Aiken bypass road (S.C. 118) intersects at left. Continue straight (east) on U.S. 1 & U.S. 78.

74.9 1.05 Turn left (north) into parking lot of Ramada Inn.

END OF DAY.

ROAD LOG – SUNDAY TRIP

Meet in parking lot of Ramada Inn on U.S. 1 & U.S. 78 in Aiken, S.C. Leave parking lot at 8:00 a.m. on Sunday, October 10, 1982.

Mileage Itinerary
CumulativeInterval
0Leave parking lot. Turn right (west) onto &.S. 1 & U.S. 78.

1.05 1.05 Aiken bypass road (S.C. 118) intersects on right. Continue straight (west) on U.S. 1 & U.S. 78.

1.7 0.65 Get in left lane.

1.9 0.2 Traffic light. Turn left (south) onto S.C. 478.

2.1 0.2 Come to stop at 4-way stop sign and intersection with S.C. 421. Continue straight (south) on S.C. 478.

4.55 2.45 Turn right (south) onto Huntsman Road.

4.85 0.3 Come to stop. Turn right (west) onto Pine Log Road.

5.3 0.45 Turn right (north) onto paved entrance and dirt road. Enter property of J.M. Huber Corporation. A walk from the entrance of the pit may be required.

5.6 0.3 Park. Leave buses and walk to J.M. Huber Corporation's Conger pit.

STOP 11. Discussion by A.L. Long, Ed L. Schrader, Charles H. Muir, and A. Richard Henderson.

Kaolin and sand of the upper Huber Formation, the Dry Branch Formation, and the lower part of the Tobacco Road Sand are exposed in the Conger pit. Burrows are noticeable in the upper Huber sands and in the Tobacco Road Sand. Where the surficial weathering (clay-enrichment) rind is scraped away from the Tobacco Road in the southwest corner of the pit, the fresh exposures with well-preserved bedding features and burrows probably represent very closely the original character of the formation.

Board buses. Turn around and return to paved road at entrance.

5.9 0.3 Turn right (west) onto Pine Log Road.

6.5 0.6 Turn right (northwest) onto road S-2-81.

9.05 2.55 Traffic light at intersection with S.C. 421. Warrenville. Continue straight (north) onto S.C. 191.

9.35 0.3 Pass under U.S. 1 & U.S. 78. Turn left (west) onto road S-2-104 just beyond underpass.

9.45 0.1 Pass entrance ramp to U.S. 1 & U.S. 78. Stay on road S-2-104.

11.45 0.2 J.M. Huber Corporation's Graniteville plant on right and Permenter pit on left. Continue straight (west) S-2-104.

11.85 0.4 Bear left (south) at Y intersection onto road S-2-255.

13.3 1.45 Turn right (west) onto dirt road and entrance to J.M. Huber Corporation's Barden pit.

13.7 0.4 Park. Leave buses and walk to exposures at the Barden pit.

STOP 12. Discussion by Ralph Willoughby.

Boulders at this site (SCGS A-001a) were piled together during kaolin mining operations. The silica-cemented sandstone blocks include abundant impressions and silica replacements of a barnacle species and less abundant impressions and silica replacements of a pectinid bivalve mollusk and of echinoderm plates. Silica-replacement fossils can be picked from the weathering residue in pockets of the rock. Remnants of the silica-cemented rock occur throughout the dump material of the mine. Unfortunately none of the rocks are exposed in place in present exposures of this mine, but they were moved from overlying the kaolin beds and therefore should represent either the Dry Branch Formation or the Tobacco Road Sand. Coarse, red Tobacco Road Sand lies directly on kaolin of the upper Huber Formation in the corner of the pit a short walk west-northwest from here (see Appendix, Stop 12), and the Dry Branch Formation lies above kaolin of the upper Huber Formation and below the Tobacco Road Sand elsewhere in the pit.

These silica-cemented, fossiliferous sandstone blocks are a local occurrence of the "buhrstones" of upland areas in western Aiken County noted by Sloan (1904). Board buses and return to paved road.

14.05 0.35 Turn left (north) onto road S-2-265.

15.4 1.35 Bear right (north) at Y intersection.

15.45 0.05 Y intersection with road S-2-104. Turn right (east) onto S-2-104.

15.5 0.05 Y intersection with road S-2-104. Turn right (east) onto S-2-104.

15.9 0.4 J.M. Huber Corporation's Graniteville plant on left and Permenter pit on right. Continue straight (east) on S-2-104.

17.9 2.0 Pass entrance ramp to U.S. 1 & U.S. 78. Continue straight on S-2-104.

18.0 0.1 Come to stop. Madison. Turn left (north) onto S.C. 191.

18.7 0.7 Downtown Graniteville. Graniteville Company on left.

19.0 0.3 Traffic light. Continue straight (north) on S.C. 191.

19.15 0.15 Turn right (east) onto Gregg Highway (S-2-895).

19.95 0.8 Turn right (sough) into Graniteville Cementery.

20.1 0.15 Park. Leave buses and walk eastward through woods to Stop 13.

STOP 13. Discussion by Ralph Willoughby.

Kaolin and sands of the upper Huber Formation are seen at this massive exposure. The section (see Appendix, Stop 13) was measured almost directly underneath the power lines. Despite Siple's (1967, p. 26, 27, Figure 7) recognition of Barnwell Formation on Tuscaloosa Formation (the upper Huber Formation of our usage) here, we regard the entire exposure, including the red sands overlying the massive, white kaolin beds, as in the upper Huber Formation. The interpretation is based largely on the assignment of our Bed 7 (presumably equivalent to Siple's "beds of laminated clay" to the Huber Formation rather than to the Dry Branch Formation or the Tobacco Road Sand.

20.25 0.15 Board buses and turn around. Turn left (west) onto Gregg Highway (S-2-895).

21.0 0.75 Come to stop at intersection with S.C. 191. Turn right (north).

21.25 0.25 Intersection with Trolley Line Road. Turn right (east).

23.5 2.25 Traffic light. University of South Carolina, Aiken, campus on right. Turn left (north) onto S.C. 118 (Aiken bypass).

24.6 1.1 Traffic light at intersection with Vaucluse Road. Continue north on S.C. 118.

26.8 2.2 Traffic light at intersection with S.C. 19. Continue east on S.C. 118 (U.S. 1 & U.S. 78 truck route).

27.7 0.9 Get in left lane.

27.8 0.1 Traffic light at intersection. Turn left (north) onto U.S. 1 & U.S. 78.

30.1 2.3 Cross bridge over dirt road.

32.0 1.9 Turn right onto dirt road

32.2 0.2 Park buses. Walk eastward in woods road 0.4 mile to Stop 14.

STOP 14. Discussion by Ralph Willoughby.

Exposures at the base of the pit consist of fullers earth that we resognize as the Twiggs Clay lithology of the Dry Branch Formation. Earlier mining extended eastward to the bed of Bradley Mill Branch, where gouge scars from heavy-equipment loading buckets remain in the Twiggs Clay lithology.

Silica-cemented sandstone is present, in place, in a low wall at the north end of the pit, and includes abundant, excellently preserved, silica-replaced barnacle plates and rare pectinid mollusks. Pectinid impressions also are present at the top of the fullers earth in the base of the pit.

The locality has an interesting historical context. According to Heron, Robinson, and Johnson (1965, p. 50) the site was mined for "opal claystone" by Universal Clay Company. Heron, Robinson, and Johnson (1965, p. 50) referred the site to the Black Mingo Formation, which, following Cooke (1936, p. 41), they (Heron, Robinson, and Johnson, 1965, p. 19) considered as including all beds of Eocene strata older than the McBean Formation. Workers after Cooke (1936) have recognized strata of Paleocene age within the Black Mingo; see Powell and Baum (1981, p. 55) for a brief historical background. Siple (1967, p. 46-47) discussed the locality, with its hackly clay and overlying bed of indurated shell rock or coquina, and he tentatively suggested that it might be either the Congaree Formation of middle Eocene (Claibornian) age or possibly the Black Mingo Formation of early Eocene age. Zullo, Willoughby, and Nystrom (this volume) present evidence based on the barnacle species known from this locality and other localities in western Aiken County that suggests a late Oligocene or early Miocene age. We recognize the site as including the Twiggs Clay lithology and sands of the Dry Branch Formation, which Huddlestun and Hetrick (1979) assign a late Eocene age. Thus, according to the interpretation the reader prefers, the locality is either Paleocene, early Eocene, middle Eocene, late Eocene, late Oligocene, or early Miocene in age!

Last Stop. Return to buses, board, and turn around.

32.25 0.05 Turn left (south) onto U.S. 1 & U.S. 78.

36.55 4.3 Traffic light. Go straight.

36.65 0.1 Traffic light at intersection. Turn right (west) onto S.C. 118.

37.65 1.0 Traffic light at intersection with S.C. 19. Continue west on S.C. 118.

39.85 2.2 Traffic light at intersection with Vaucluse Road. Continue south on S.C. 118.

40.95 1.1 Traffic light at intersection with Trolley Line Road (S-2-80). Continue south on S.C. 118.

41.2 0.25 University of South Carolina, Aiken Campus, on right.

41.85 0.65 Traffic light at intersection. Turn left (east) onto U.S. 1 & U.S. 78.

42.9 1.05 Turn left (north) into Ramada Inn parking lot.

END OF FIELD TRIP.

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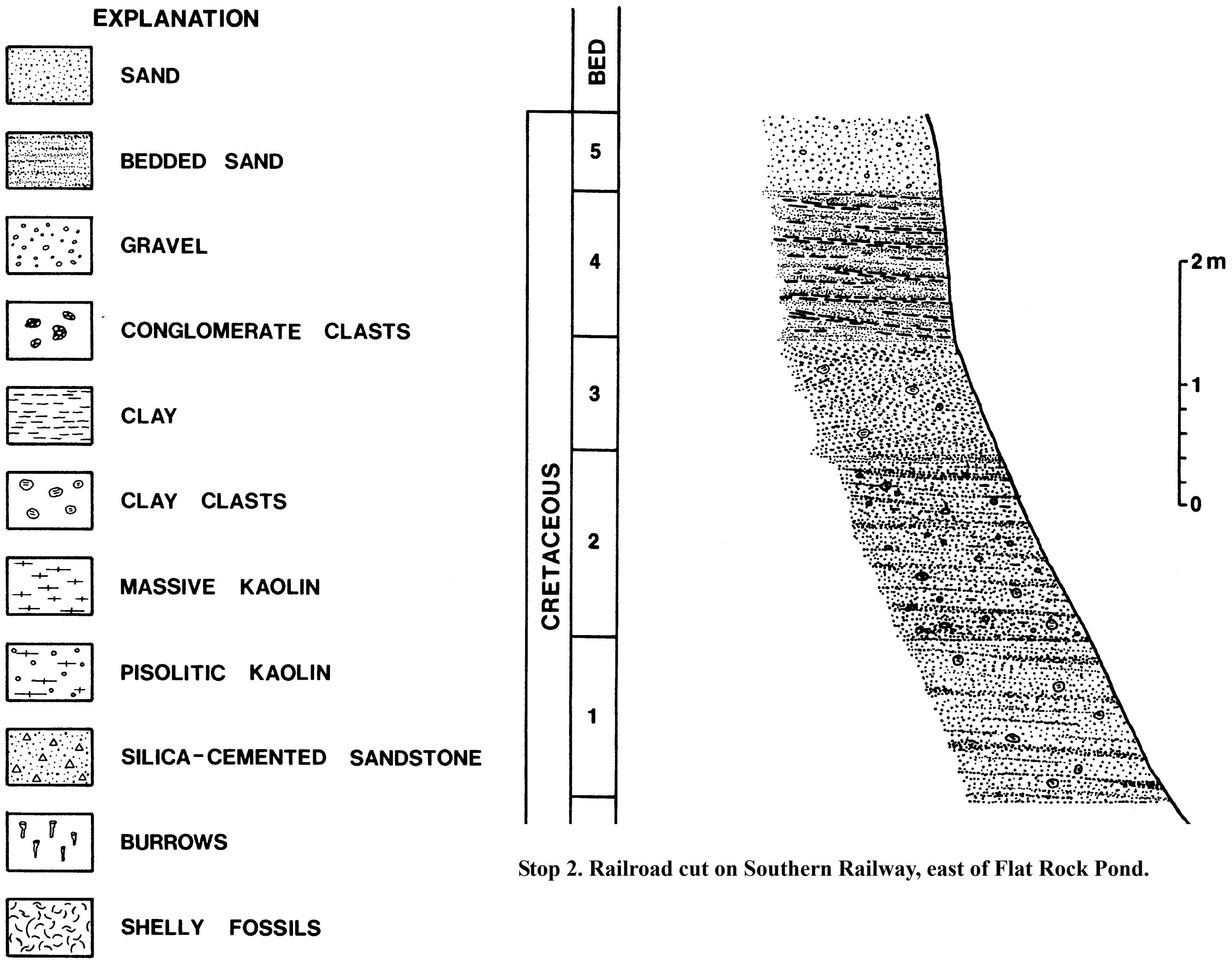
APPENDIX TO THE FIELD GUIDE

Prepared by L. E. Kite



Stop 2. Railroad cut on Southern Railway, east of Flat Rock Pond.

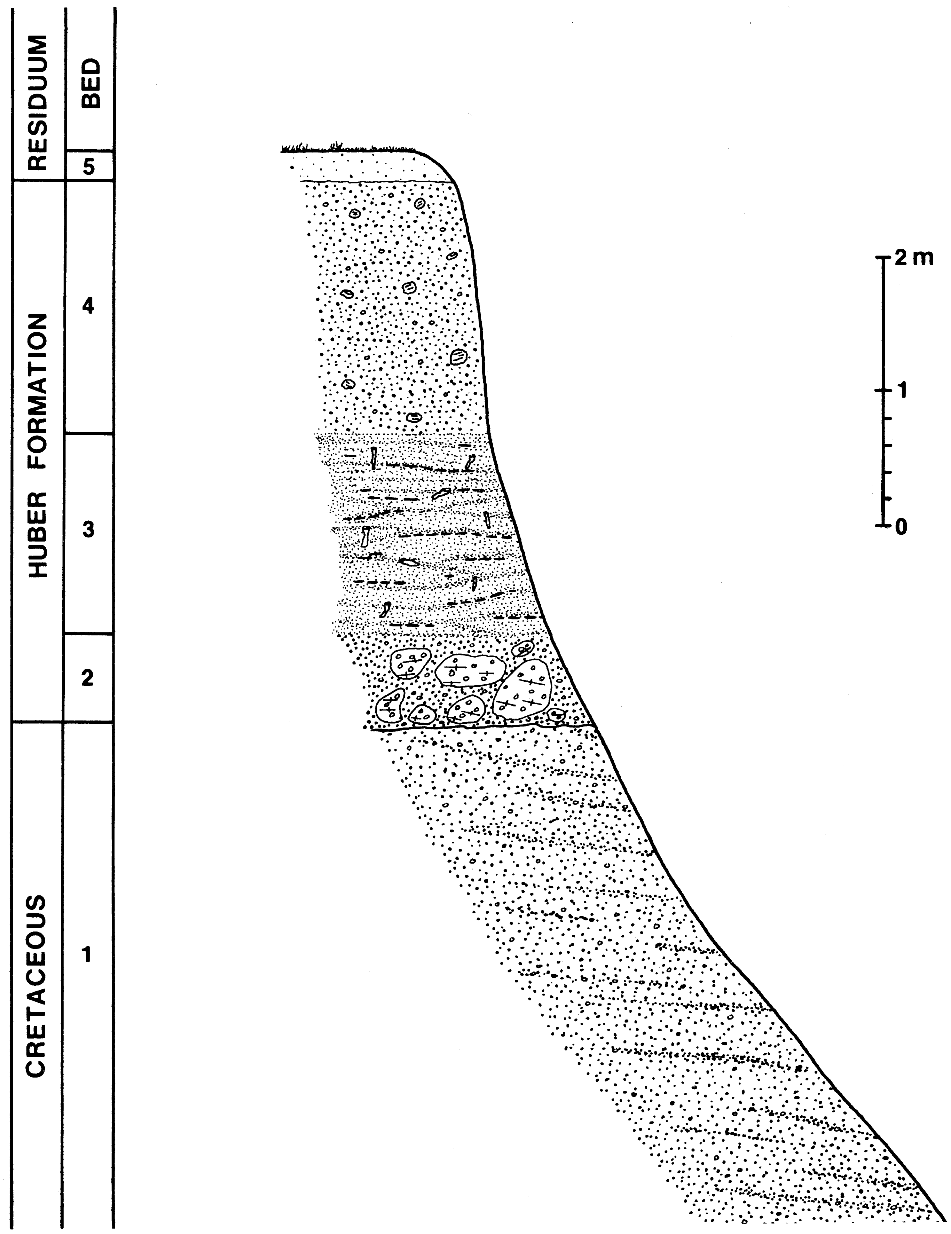
STOP 2

RAILROAD CUT

EXPOSURES ON SOUTHERN RAILWAY LINE APPROXIMATELY 0.70 MILE (1.14 KM) NORTH 5^{o} WEST OF THE INTERSECTION OF GREGG HIGHWAY (S-2-895) AND S.C. HIGHWAY 191 IN GRANITEVILLE, S.C. (NORTHERN GRANITEVILLE, S.C., 7.5-MINUTE QUADRANGLE).

Lithostratigraphic Unit and bed number	**Description**	**Thickness**
CRETACEOUS		
BED 5	Sand, medium-to coarse-grained, predominantly medium-grained, with abundant interstitial clay and with silt, fine, sand, and scattered very coarse quartz sand and quartz pebbles; angular to subrounded; moderately well indurated; cream-white to light yellow-orange or light yellow-brown.	.6 m (2.0 ft)
BED 4	Base of kaolin-bearing strata in a nearly vertical cliff. Sand and kaolin, interbedded, in alternating laminae and beds (0.5-3 cm) outlined with fine sand, heavy minerals, and high clay content; beds horizontal to gently inclined; firmly indurate. Sand is fine-grained, silty, with medium-to coarse-grained sand in some beds; with interstitial to matrix-forming kaolin clay and very fine-grained to fine-grained dark heavy minerals. Clay is kaolinitic, silty, with fine quartz sand, and with kaolin balls 0.5-5 cm in some layers.	1.2 m (3.9 ft)
BED 3	Sand, coarse-grained to very coarse-grained; moderately well sorted; angular to subrounded; with some fine-grained sand, interstitial kaolin clay and scattered kaolin clasts up to 3 cm; gently cross- bedded; loose to lightly indurated.	.9 m (3.0 ft)
BED 2	Sand, coarse-grained to very coarse-grained, with quartz granules and pebbles; angular to subrounded; moderately well sorted; with interstitial kaolin clay as well as sand-size grains and occasional pebbles, up to 5 cm; with muscovite grains, some up to 0.5 cm; with accessory very fine-grained to medium-grained dark heavy minerals; bedding subhorizontal; indurated; cream-white to yellow-brown in color. Upper 0.1 m includes layers of fine-to medium-grained sand and of course-grained to very coarse-grained sand, without abundant pebbles or granules.	1.5 m (4.9 ft)
BED 1	Sand, medium-to coarse-grained, mostly coarse-grained, moderately well sorted; angular to subangular; with interstitial kaolin clay and kaolin balls and pebbles, up to 5 cm; also with fine to coarse muscovite grains; bedding horizontal to subhorizontal; lightly indurated; white to cream.	1.3 m (4.3 ft)
	Covered interval.	1.6 m (5.2 ft)

		7.1 m (23.3 ft)



Stop 3. Borrow pit at trailer park south of Warrenville.

STOP 3

EROSIONAL UNCONFORMITY WITH PISOLITIC KAOLIN BOULDERS

EXPOSURES IN AN ABANDONED PIT, JUST NORTH OF A TRAILER PARK, 1.09 MILES (1.75 KM) SOUTH 20° WEST OF THE INTERSECTION OF S.C. HIGHWAY 421 AND RICHARDSON'S LAKE ROAD (S-2-81) IN WARRENVILLE, S.C. (GRANITEVILLE, S.C., 7.5-MINUTE QUADRANGLE).

Lithostratigraphic Unit and bed number	**Description**	**Thickness**
BED 5	Loose sand and soil.	.2 m (.7 ft)
HUBER FORMATION		
BED 4	Sand, medium-grained to coarse-grained, with some very fine-grained and fine-grained sand and with abundant quartz pebbles up to 3 cm; with interstitial clay and abundant kaolin balls up to 10 cm; poorly sorted; very stiff, well indurated; yellow-orange in color, mottled in upper 0.5-0.7 m.	1.9 m (6.2 ft)
BED 3	Sand, very fine-grained to fine-grained; silty, clayey; in laminae to thin beds and with prominent clay laminae; subhorizontal to gently dipping; with subhorizontal curving burrows 1-2.5 cm in diameter and smaller (to 0.7 cm in diameter), horizontal to vertical, kaolin-filled burrows; stiff, well indurated; cream-white where fresh to salmon pink or yellow where weathered.	1.5 m (4.9 ft)
BED 2	Bed of pisolitic kaolin, mostly pure pisolitic kaolin, as cobbles and boulders to 1.7 m in dimension; with subrounded to rounded, coarse-grained quartz sand and quartz pebbles; lightly indurated. Pisolitic zones are 0-2 m thick in other parts of this pit. Probable base of Tertiary strata.	.7 m (2.3 ft)
CRETACEOUS		
BED 1	Sand, medium-grained to very coarse-grained, with common quartz granules and pebbles, up to 2 cm; mostly angular to subangular but with the larger grains subrounded; with fine- to coarse-grained muscovite flakes; with very fine-grained and fine-grained dark heavy minerals in some layers, especially concentrated in lower 0.5 m; bedding gently inclined; very lightly indurated; bright white in color. Probable to of Cretaceous strata.	3.8 m (12.5 ft)

		8.1 m (26.6 ft)

STOP 4

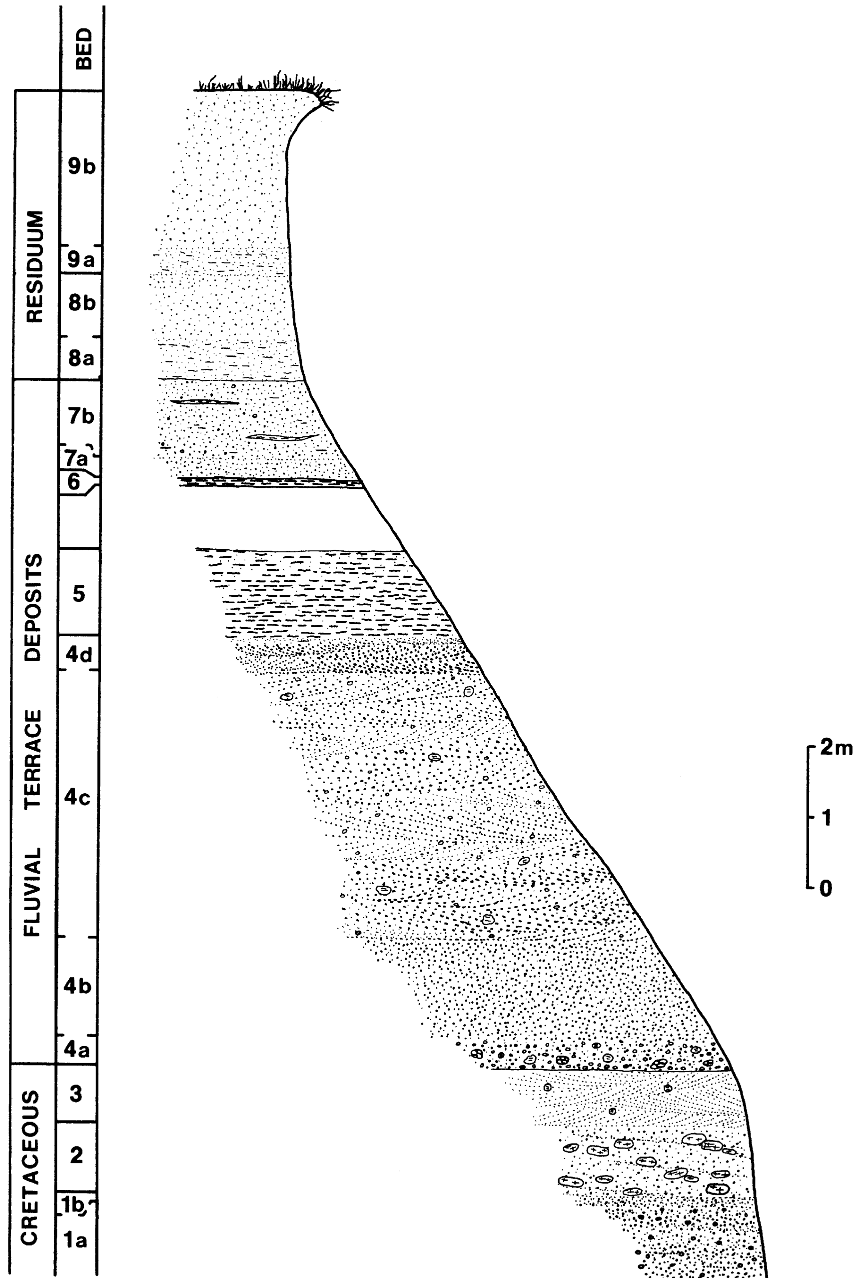
HAMBURG BLUFFS

0.59 MILE (0.96 KM) NORTH 52° EAST OF THE CENTER OF THE FOUR-LANE U.S. HIGHWAY BRIDGE ACROSS THE SAVANNAH RIVER (AUGUSTA EAST, GA.-S.C. 7.5-MINUTE QUADRANGLE).

Lithostratigraphic Unit and bed number	**Description**	**Thickness**
BED 9b	Residuum. Similar to Bed 8b. Top of bluff.	2.1 m (6.9 ft)
BED 9a	Residuum. Similar to Bed 8a.	.4 m (1.31 ft)
BED 8b	Residuum. Sand, fine- to medium-grained, subangular, moderately well sorted, with abundant interstitial clay.	.9 m (3.0 ft)
BED 8a	Residuum. Micaceous, clayey silt with very fine-grained sand, to micaceous, sandy, silty clay.	.6 m (2.0 ft)
FLUVIAL TERRACE DEPOSITS		
BED 7b	Sand, predominantly fine- to medium-grained, with some coarse sand and scattered quartz granules, very micaceous, moderately well sorted; with fairly abundant interstitial clay and local lenses of sandy clay 1 to 4 cm thick and up to 20 cm long; weathered, with clay mottling in upper 0.5 m. Beds 4 through 7 form a prominent slope.	1.1 m (3.6 ft)
BED 7a	Sand, fine-to medium-grained, moderately well sorted, with some mica and interstitial clay that increases locally to matrix-forming. Transitional from clay unit below to sandy layer above.	.3 m (1.0 ft)
BED 6	Clay, sandy, with some silt; stiff, gray.	.1 m (.3 ft)
	Covered interval.	.9 m (3.0 ft)
BED 5	Clay, silty, with very fine-grained to fine-grained sand; gray to light yellow-tan in color, mottled. Grades upward into sandy clay with little silt.	1.2 m (3.9 ft)
BED 4d	Sand, medium-to coarse-grained, with some fine-grained and very coarse-grained sand and fine- to medium-grained heavy minerals; moderately well sorted; crossbedded, in bed sets 1 to 5 cm thick; lightly consolidated; cream to yellow or pink in color. Upper 0.1 to 0.3 m grades into micaceous, clayey, silty, fine-grained quartz sand.	.5 m (1.6 ft)
BED 4c	Sand, fine-grained to very coarse-grained, subangular to rounded, with mica flakes, heavy minerals, interstitial clay, clay casts up to 4 cm, rounded and weathered feldspar grains up to 1.5 cm, and abundant quartz pebbles up to 3 cm; crossbedded, with dips up to 20°; lightly indurated, light yellow-tan in color.	3.8 m (12.5 ft)
BED 4b	Sand, predominantly medium-to coarse-grained, poorly to moderately well sorted; similar to Bed 4a except lacking cobbles or abundant pebbles.	1.4 m (4.6 ft)

BED 4a	Basal conglomerate, with fine-grained to very coarse-grained quartz sand and abundant quartz granules, pebbles, and cobbles; pebbles (up to 3 cm) and smaller grains subangular to rounded, cobbles (to 10 cm) well-rounded; with fine-to medium-grained clay casts and concentrated dark, heavy minerals, and some interstitial clay; also with some reworked clasts of granule and pebble conglomerate; poorly sorted; loose to very lightly indurated; light cream-orange in color. Base of terrace deposit.	.4 m (1.3 ft)
CRETACEOUS		
BED 3	Sand, fine-to medium-grained, with fine-grained to very coarse mica flakes, some fine-grained, dark heavy minerals, interstitial kaolin, and some kaolin balls up to 1.5 cm; moderately well sorted; crossbedded with beds dipping up to 20°; lightly indurated; cream in color. Top of Cretaceous strata.	.8 m (2.6 ft)
BED 2	Sand, fine- to coarse-grained, with flat kaolin clasts up to 7 cm by 12 cm in kaolin-cobble conglomerate with abundant, dark heavy minerals; lightly indurated; bedding poorly defined, subhorizontal, fining upward; white to light gray; pinches out laterally.	1.0 m (3.3 ft)
BED 1b	Similar to Bed 1 but with no quartz pebbles larger than 1 cm.	.1 m (.3 ft)
BED 1a	Sand, medium-grained to very coarse-grained, with abundant quartz granules, pebbles (up to 3 cm), and some fine sand; with interstitial kaolin and kaolin clasts up to 3 cm; with medium-grained to coarse-grained mica flakes and fine-grained to granule-sized (to 3 mm) dark heavy minerals; bedding massive, subhorizontal, poorly defined, fining upward; lightly indurated; cream to light gray. Prominent, inclined dark heavy mineral layer at 0.7 m.	1.1 m (3.6 ft)

		16.7 m (54.81 ft)



Stop 4. Hamburg bluffs on property of Augusta Concrete Block Co.

STOP 5

DIXIE CLAY COMPANY'S MCNAMEE NO. 2 PIT

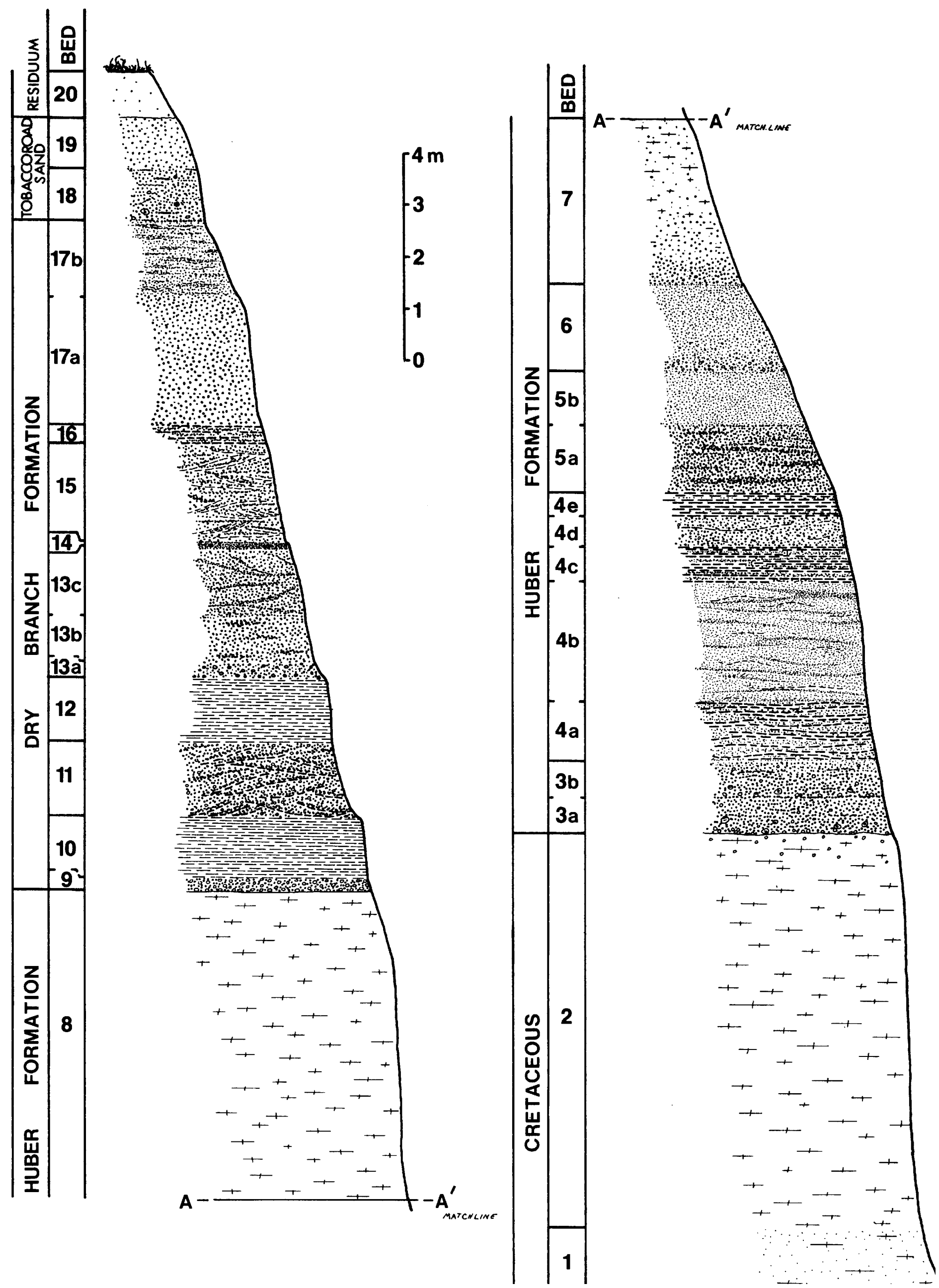
1.0 MILE (1.6 KM) NORTH 50 ^{o} WEST OF THE INTERSECTION OF DIXIE CLAY ROAD (S-2-65) AND PINE LOG ROAD (S-2-65) IN NORTHWESTERN HOLLOW CREEK, S.C. 7.5-MINUTE QUADRANGLE.

Lithostratigraphic Unit and bed number	Description	Thickness
BED 20	Soil horizon; sand, medium-to coarse-grained, poorly sorted; structureless, loose; color light gray.	.9 m (2.95 ft)
TOBACCO ROAD SAND		
BED 19	Residuum; sand, medium-to coarse-grained, poorly sorted; featureless; upper portion mottled; color red-orange to orange.	m (3.28 ft)
BED 18	Sand, medium-to coarse-grained, poorly sorted, angular to subangular grains; basal portion with few scattered discoidal quartz pebbles and abundant flat, white to purple clay clasts; abundant interstitial clay; indurated; color dark red-maroon.	m (3.28 ft)
DRY BRANCH FORMATION		
BED 17b	Sand, fine-to medium-grained, moderately well sorted, angular grains; with wispy clay enriched thin laminae; minor amount interstitial clay; color yellow.	1.47 m (4.8 ft)
BED 17a	Sand, coarse-grained, poorly sorted, angular grains; indurated; massive, color orange-red.	2.5 m (8.2 ft)
BED 16	Sand, clayey, laminated; interlayered with very thin clay beds.	.35 m (1.15 ft)
BED 15	Sand, medium-to coarse-grained; with crossbedding defined by thin clay laminae, color yellow.	1.9 m (6.3 ft)
BED 14	Sand, clayey; abundant clay clasts of red orange, purple, light gray and dark gray scattered throughout; massive, unstructured; color orange-red.	.09 m (.33 ft)
BED 13c	Sand, medium-to coarse-grained; mottled; color rust-brown to yellow.	1.33 m (4.36 ft)
BED 13b	Sand, coarse-grained moderately sorted, angular grains; clayey; color yellow.	.9 m (2.95 ft)
BED 13a	Pebbles, quartz, very well rounded, discoidal or ellipsoidal, up to 2 cm long; in a matrix of sand, medium-to very coarse-grained, poorly sorted, angular to subangular; color yellow-green to rust brown.	.30 m (1.0 ft)
BED 12	Clay, very thinly bedded; becomes sandy in uppermost .3 m.	1.22 m (4.0 ft)
BED 11	Sand, coarse-to very coarse-grained and pebbly, poorly sorted with some fine-to medium-grained fraction, angular to subangular grains; cross bedding defined by clay laminae and textural changes; color yellow.	1.43 m (4.7 ft)

BED 10	Clay, thin beds separated by sand laminae; prominent bedding plane fissility; color light gray clay with rust brown and purple sand.	1.2 m (3.9 ft)
BED 9	Sand, coarse-grained and pebbly, poorly sorted; dark heavy minerals concentrated at base.	.23 m (.75 ft)
HUBER FORMATION		
BED 8	Kaolin, pure clay with little or no sand; massive, stiff; hackly fracture when dry' color white to light gray, with some maroon to orange mottling.	6.0 m (19.7 ft)
BED 7	Sand, fine-to coarse-grained and granular, poorly sorted with pebbles in basal portion; distinct fining upwards sequence, clay increases from interstitial to matrix forming, uppermost portion of bed characterized by very sandy clay, kaolinitic, massive; color medium gray with .3-.9 m maroon band at base.	3.2 m (10.5 ft)
BED 6	Sand, fine-to coarse-grained, poorly sorted, with basal .3 m also containing very coarse sand, granules and pebbles; abundant muscovite flakes up to 10 cm; abundant dark heavy minerals; interstitial clay; distinct fining upwards sequence; unbedded; color light yellow.	1.68 m (5.5 ft)
BED 5b	Sand and clay, fine-to medium-grained quartz sand, angular to subangular grains; abundant mica, fine-to medium-grained; massive, unstratified, stiff, indurated; color medium gray weathered yellow.	1.04 m (3.4 ft)
BED 5a	Sand, medium-to coarse-grained, poorly sorted, with some quartz pebbles, angular to subangular sand grains; some fine-to coarse-grained dark heavy minerals; micaceous, flakes up to 5 mm; abundant interstitial clay; crude thin bedding defined by grain size variation from sand to pebbly sand with rounded kaolin balls 1 to 2 cm diameter, moderately indurated.	1.31 m (4.3 ft)
BED 4e	Clay, kaolinitic, thinly bedded; with laminae of very fine-to fine-grained sand.	.46 m (1.5 ft)
BED 4d	Sand, medium-to very coarse-grained with some granules and pebbles (up to 6 mm), some fine-grained sand fraction, poorly sorted, angular to subangular grains; gently undulating clay laminae.	.58 m (1.9 ft)
BED 4c	Clay, kaolinitic, laminated to thinly bedded; with thin interbeds of quartz sand, fine-grained, with some dark heavy mineral grains.	.67 m (2.2 ft)
BED 4b	Sand, very fine-to fine grained, well sorted angular to subangular; very fine-grained dark heavy minerals; micaceous; loose, little interstitial clay; with clay laminae; thinly bedded, subhorizontal and laterally continuous.	2.32 m 7.6 ft)
BED 4a	Clay, kaolinitic, irregular and wavy laminations to gently undulating thin beds.	1.16 m (3.8 ft)
BED 3b	Sand, very coarse-grained and pebbly, poorly sorted, angular to subangular grains, fining upwards sequence; abundant fine-to coarse-grained dark heavy minerals; with medium-to coarse-grained muscovite; kaolin clay clasts abundant in lower portion of bed; abundant interstitial kaolin; white kaolinitic clay laminae define horizontal to gently inclined bedding; color white to light gray.	.7 m (2.3 ft)
BED 3a	Sand, very coarse-grained with pebbles up to 15 mm, poorly sorted, angular to subangular grains, fining upwards sequence; abundant coarse-to very coarse-grained dark heavy minerals, particularly concentrated at base; some fin-to coarse–grained muscovite; abundant interstitial kaolinitic clay; irregular bedding; local small scale scouring into clay below; color white to light gray.	.7 m (2.3 ft)
CRETACEOUS		

BED 2	Kaolin, pure clay, soft, pisolitic in upper 1 m; very well developed conchoidal fracture; mottled in lower portion; color white to cream to tan.	7.67 m (25.39 ft)
BED 1	Clay, kaolinitic, silty, very micaceous; with fine-grained dark heavy minerals; massive; color cream to gray with yellow-brown mottling.	1.22 m (4.0 ft)

		44.5 m (146.2 ft)



Stop 5. Dixie Clay Co.'s McNamee #2 pit.

STOP 5A (ALTERNATIVE STOP)

DIXIE CLAY'S PEPPER BRANCH PIT

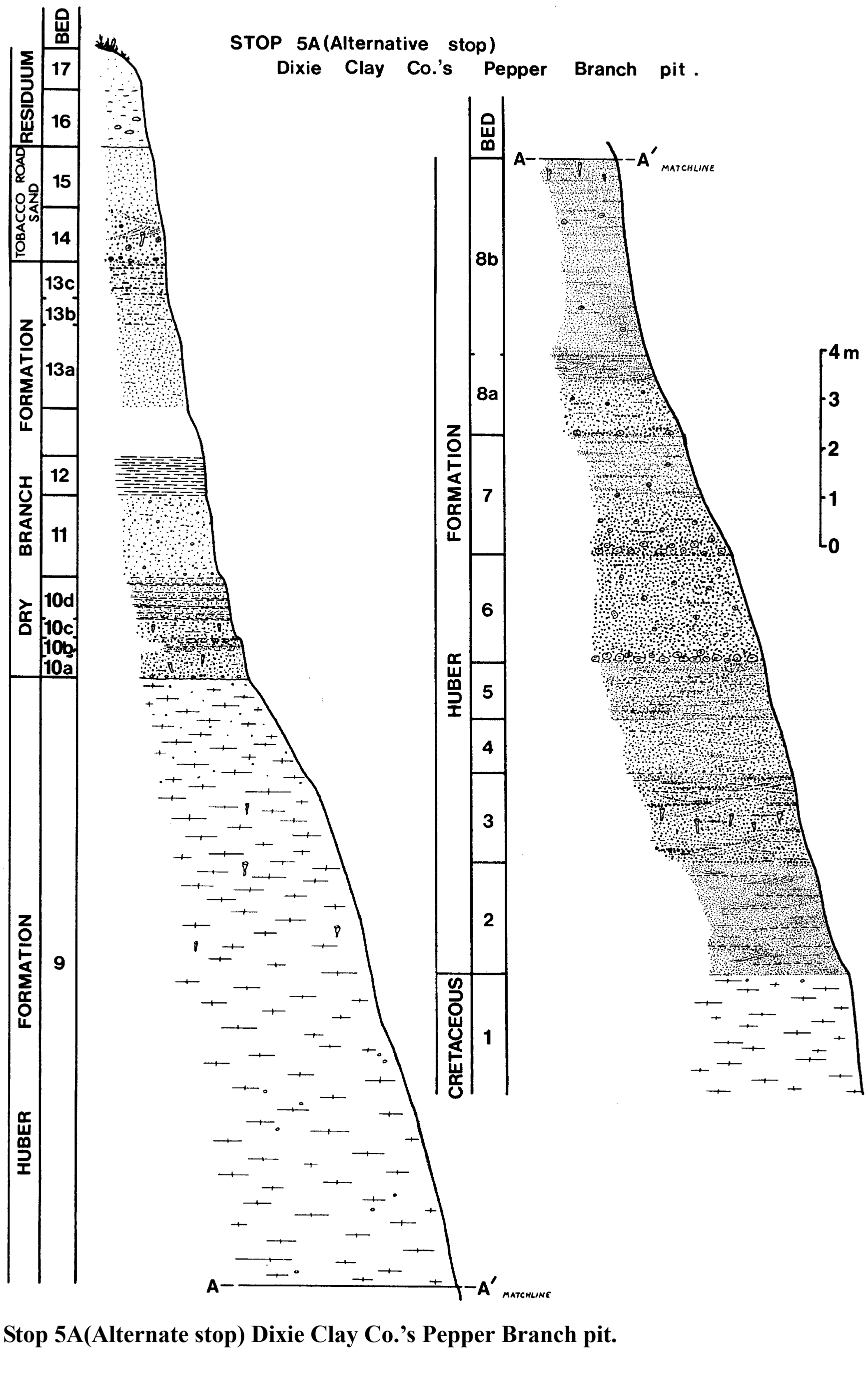
1.0 MILE (1.6 KM) SOUTH 86× WEST OF THE INTERSECTION OF DIXIE CLAY ROAD (S-2-46) AND PINE LOG ROAD (S-2-65) IN NORTHWESTERN HOLLOW CREEK, S.C., 7.5-MINUTE QUADRANGLE.

Lithostratigraphic unit and bed number	Description	Thickness
BED 17	Soil horizon; sand, fine-grained, moderately well sorted, angular to subangular grains; loose, structureless; color light gray.	.9 m (3.0 ft)
BED 16	Illuvial horizon; clay rich soil; contains rounded cobble material; weathered and mottled.	1.2 m (3.33 ft)
TOBACCO ROAD SAND		
BED 15	Residuum; sand, fine- to medium-grained, moderately sorted, subangular grains; clayey; indurated, color reddish-orange mottled with cream to light gray.	1.3 m (4.2 ft)
BED 14	Sand, fine- to very coarse-grained, poorly sorted, subangular grains; few rounded and discoidal pebbles at base; abundant kaolinitic clay clasts; prominently crossbedded; clayey; abundant burrows 2 mm in diameter, 20-30 mm long; indurated; color pinkish red.	1.1 m (3.5 ft)
DRY BRANCH FORMATION		
BED 13c	Sand, fine- to coarse-grained, poorly sorted; laminated to very thinly bedded; interlayered with clay laminae.	.7 m (2.33 ft)
BED 13b	Sand, fine- to coarse-grained, poorly sorted, subangular grains; wispy clay laminae to very thin clay beds which vaguely define stratification; color yellow-brown.	.55 m (1.8 ft)
BED 13a	Sand, fine- to medium-grained, poorly to moderately sorted, subangular grains; some fine-grained dark heavy minerals; few wispy thin clay laminae vaguely define layering; massive; well indurated; color yellow-brown.	1.7 m (5.6 ft)
	Covered interval.	.96 m (3.2 ft)
BED 12	Clay, montmorillonitic, characterized by very thin bedding plane fissility when dry; with chert concretions up to 10-12 cm diameter; color light brown.	.8 m (2.5 ft)
BED 11	Sand, fine- to coarse-grained, poorly sorted. Angular to subangular grains; quartz pebbles, 5-30 mm diameter, very well rounded, some discoidal; characterized by undulatory wispy clay laminae; clayey; discontinuous chert horizon, dove-gray to cream colored, in uppermost 3 cm of bed; color white mottled tan-brown.	1.6 m (5.4 ft)
BED 10d	Sand, fine- to medium-grained, moderately well sorted with some coarse- to very coarse-grained fraction, subangular grains; abundant fine-grained dark heavy minerals; loose; clay, as laminae and very thin beds separated by sand interlayers 2-15 mm thick; color tan to cream.	.8 m (2.75 ft)
BED 10c	Sand, medium- to coarse-grained with some granules, moderately well sorted, subangular to subrounded grains; medium-grained dark heavy minerals; few clay laminae; clay-lined burrows 10-12 mm diameter.	.4 m (1.33 ft)

BED 10b	Sand, fine- to medium-grained to medium- to coarse-grained, moderately well to well sorted, subangular to rounded grains; some fine- to medium-grained dark heavy minerals; interlayered with white clay laminae.	.2 m (.75 ft)
BED 10a	Sand, fine- to very coarse-grained with pebbles, poorly sorted, subangular grains; fine-grained dark heavy minerals; few cream colored clay laminae; basal 2-3 cm of purple, coarse- to very coarse-grained sand and quartz pebbles with abundant dark heavy minerals; sand above base is tallow-brown to pinkish.	.55 m (1.8 ft)
HUBER FORMATION		
BED 9	Kaolin, pure to sandy clay; massive, hackly fracture; basal 5 m is purple mottled, locally pisolitic and has abundant pea-sized ferruginous spheroids; above this is 2 m zone of white to light gray, with abundant burrows (2 mm diameter and 20-40 mm long) partially sand-filled; above this burrowed zone is 2.5 m of purple color, with abundant deep purple iron oxide concretions up to 3 cm in diameter, also many sand-filled burrows 2-3 mm in diameter; uppermost 2.2 m of bed is cream to light gray in color with medium- to coarse-grained sand throughout, also contains ferruginous concretions up to 10 cm in diameter.	12.3 m (40.3 ft)
BED 8b	Silt, very micaceous with fine- to very coarse-grained flakes; kaolin clasts, sand-sized and up to 2 cm diameter; laminated to thinly bedded; uppermost .6 m contains kaolin filled burrows 8 m diameter and up to 12 cm long; color cream to pale pink to yellow-color.	4.0 m (13.0 ft)
BED 8a	Sand, fine- to coarse-grained, poorly sorted; micaceous, fine- to coarse-grained flakes; fining upwards sequence, base marked by kaolin balls 2-5 cm in diameter, medium- to coarse-grained quartz sand with dark heavy minerals; very clayey, kaolin in form of sand-sized coarse- to very coarse-grained clasts; uppermost .6 m very thinly bedded with small scale crossbedding (2-5 cm).	1.65 m (5.4 ft)
BED 7	Sand, fining upwards sequence, medium- to very coarse-grained and poorly sorted to fine- to medium-grained and moderately sorted; very micaceous; base marked by kaolin ball conglomerate, kaolin balls up to .45 m, most 2-8 cm diameter, with abundant fine- to medium-grained dark heavy minerals in coarse- to very coarse-grained quartz sand; kaolin clasts, sand-sized to 3 cm in diameter, are abundant and scattered throughout bed; bedding increases from crudely defined in lower portion to moderately well defined and very thin beds in upper portion.	1.9 m (6.2 ft)
BED 6	Sand, coarse- to very coarse-grained, poorly sorted; with abundant coarse-grained mica and abundant kaolin clasts 5-20 mm in diameter; base marked by kaolin ball conglomerate with clay clasts up to 30 cm in diameter, some clay balls are pisolitic; poorly defined very thin bedding.	2.2 m (7.2 ft)
BED 5	Sand, fine - coarse-grained and poorly sorted to fine-grained, well sorted, angular grains; micaceous; clay present as laminae and very thin beds, but is absent in the uppermost portion of the bed; color white to cream.	1.2 m (3.8 ft)
BED 4	Sand, fine- to coarse-grained, poorly sorted, micaceous; some clay laminae present; some local crossbedding vaguely defined; color yellowish-white.	1.1 m (3.7 ft)
BED 3	Sand, fine- to coarse-grained, poorly sorted, micaceous with clay in very thin laminae to very thin beds; few discoidal kaolin clasts; abundant small burrows in middle portion; base marked by thin iron-stained horizon, color white to cream.	1.8 m (5.8 ft)
BED 2	Sand, fine-grained, well sorted; micaceous; with fine-grained dark heavy minerals disseminated throughout the bed and locally concentrated in thin laminae; thin bedding defined by horizontal clay laminae which are laterally continuous; small scale crossbedding poorly defined by sand; sand loose, no interstitial clay; color white.	2.3 m (7.5 ft)
CRETACEOUS		

BED 1	Kaolin, pure soft clay, few pisolites in uppermost portion; massive, poorly developed conchoidal fracture; color cream.	2.4 m (8.0 ft)

		43.61 m (142.4 ft)



Stop 5A(Alternate stop) Dixie Clay Co.'s Pepper Branch pit.

STOP 6

J.M. HUBER CORPORATION'S IDEAL MINE

0.55 MILE SOUTH OF HUBER'S LANGLEY PLANT ALONG SOUTH CAROLINA SECONDARY HIGHWAY 66 IN AIKEN COUNTY, SOUTH CAROLINA

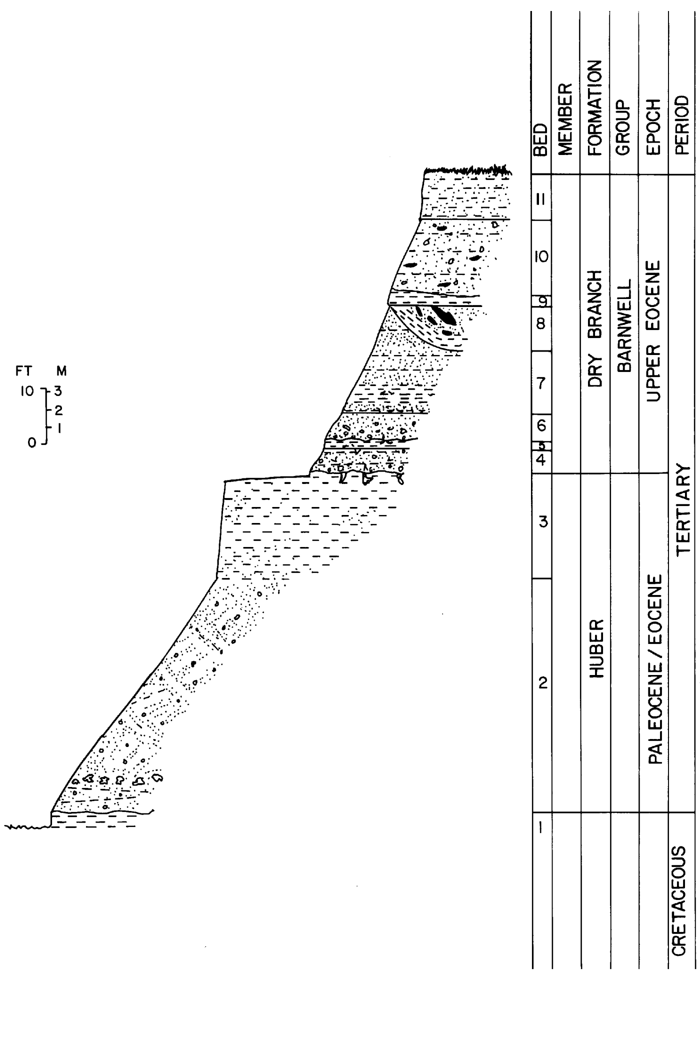
by

LAMAR LONG, ED SCHRADER, CHARLES MUIR (J.M. CORPORATION, CLAY DIVISION) AND A. RICHARD HENDERSON (STATE OF OIL AND GAS BOARD, MISSISSIPPI)

Lithostratigraphic unit and bed number	Description	Thickness
BED 11	Residuum: argillaceous sand, unconsolidated but firm; massive bedded; reddish brown color.	2.59 m (8.5 ft)
DRY BRANCH FORMATION		
BED 10	Sand and gravel: medium- to coarse-grained, moderately sorted, gravel mostly granules with some pebbles, some scattered clay wisps, becoming more abundant with depth, manganese oxide scattered throughout, concentrated at base forming a black maganiferous ledge. Appears to channel in to clay below.	3.96 m (13.0 ft)
BED 9	Massive to bedded clay, with fewer laminae than clay below, laminae present in upper 15-18 cm (6-7 in) buff colored (smectite?), clay highly cracked and fractured, shrinkage cracks probable.	0.91 m (3.0 ft)
BED 8	Sand and claystone: part of channel cut, coarse-grained sand and gravel with black manganese stain in top 0.67 m (2.2 ft) some of black-stained material causes ledges up to 0.61 m (2 ft) below is 12.7 cm (5 in) of ochre-colored to black claystone; underlying the claystone is 0.4 m (1.3 ft) 0.4 m of coarse-grained, subrounded buff to black manganese-cemented sand and gravel; bottom of channel cut is 0.7 m (2.6 ft) of bedded to massive clay, highly conchoidally fractured, laminae are iron-stained and silty, up to 1 mm thick.	2.32 m (7.6 ft)
BED 7	Sand and clay: top 1.74 m (5.7) is moderate yellowish-brown, medium- to coarse-grained sand with clay whisps up to 5 mm thick, moderately sorted, subangular to subrounded, the underlying 1.13 m (3.7 ft) is banded channel fill clay, fairly massive, irregularly bioturbated, contains silty to fine-grained sand stringers, upper 10.16 cm (1.4 ft) of fine- to medium-grained sand, bioturbated, primarily tan in color; and bottom 23 cm (0.75 ft) consists of alternating tan to brown silts and clays, 2-5 mm thick, highly mottled and bioturbated.	3.51 m (11.5 ft)
BED 6	Sand and gravel: a fining upwards sequence, top 1.25 m (4.1 ft) consists of alternating fine-grained sand to coarse gravel with some ironstone fragments within the fine portion, subrounded, some clay balls up to 5 cm (2 in) in diameter; bottom 0.46 m (1.5 ft) is a granular-sized gravel that grades upward into a coarse-grained sand, tan to dark brown in color, large lenticular shaped clay balls in sand, scattered within coarse gravel is ironstone fragments, contact with bed below is a highly irregular contact.	1.71 m (5.6 ft)
BED 5	Clay: massive but bedded clay with micaceous silt, within the clay some soft sediment deformation is evident above a silty zone approximately 1.9 cm (0.75 ft) thick, top 10 cm (4 in) is mottled with iron oxide, disturbance of sediment caused by probable bioturbation.	0.40 m (1.3 ft)

BED 4	Sand and gravel: alternating coarse-grained sand to gavel with a few clay drapes approximately 3 to 4 cm thick scattered throughout, various iron stains apparently oriented to bedding planes, iron concentration scattered throughout, kaolin balls up to 5 cm (2 in) in diameter concentrated in lower portion. Gravel concentrated in upper 15 cm (6 in) bottom 10 cm (4 in) consist of granular sized gravel alternately iron-cemented, micaceous throughout, mica flakes up to 5 cm in diameter.	1.37 m (4.5 ft)
HUBER FORMATION		
BED 2	Sand and gravel: crossbedded, medium- to coarse-grained sands and gravels, subrounded smoky quartz present, laminae of heavy minerals in sand fraction, soma kaolinitic zones; about 8.5 m (28 ft) deep color changes from grey and white to tan, at about 10.4 m (34 ft) is a zone 0.3 m (1.0 ft) thick of clay balls up to 30 cm (12 in) in diameter, below this zone, abundantly clay drapes that are not seen above the zone of clay balls occur in the sands and gravels, drapes vary in size fro laminae to beds.	13.11 M (43.0 ft)
CRETACEOUS		
BED 1	Kaolinitic clay, breaks with a conchoidal fracture, contact with above is irregular.	2.76 M (2.5 ft)

		36.43 M (119.5 ft)



Stop 6Huber's Ideal Mine

STOP 7

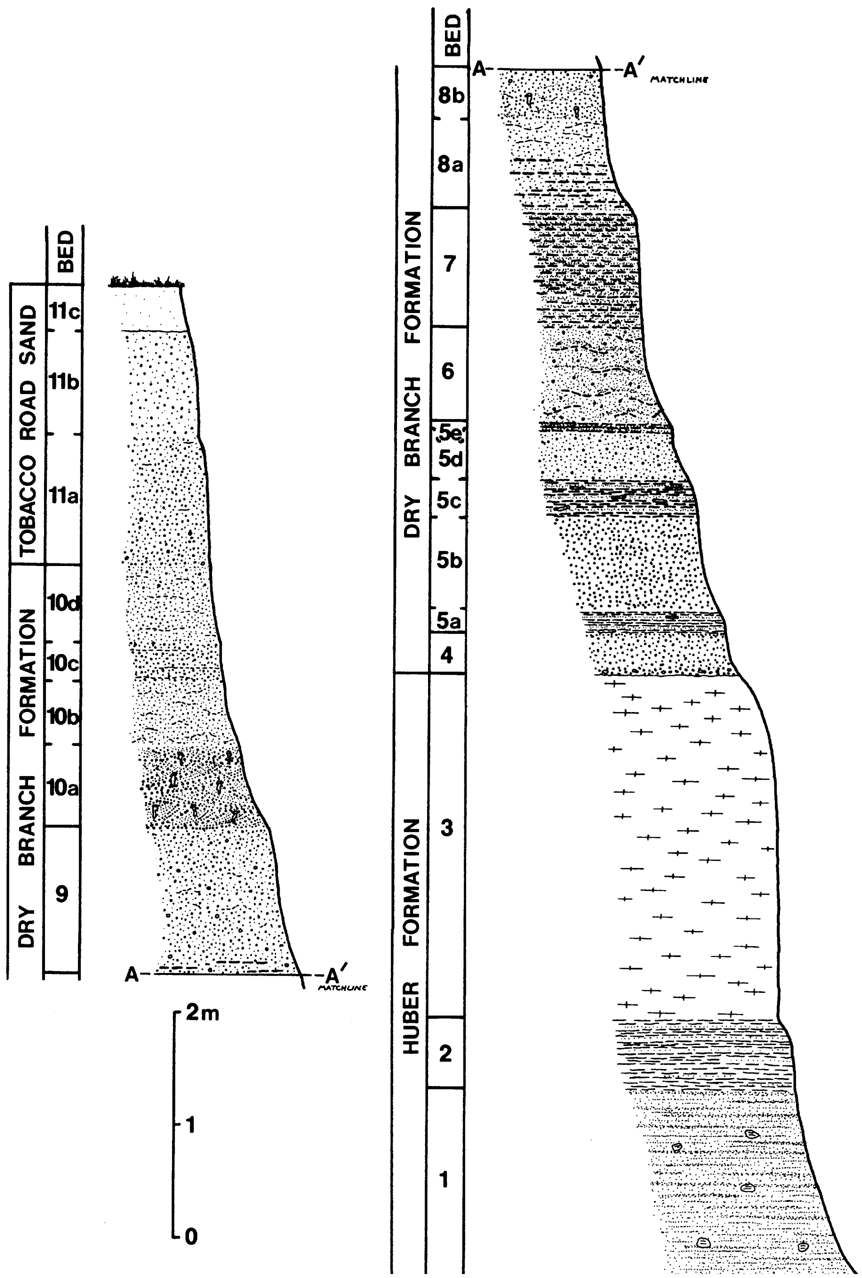
BORROW PIT OFF HERNDON DAIRY ROAD

1.32 MILES (1.12 KM) SOUTH 84× WEST OF THE INTERSECTION OF HERNDON DAIRY ROAD (S-2-788) AND SILVER BLUFF ROAD (S.C. HIGHWAY 302) IN NORTHEASTERN HOLLOW CREEK, S.C., 7.5 MINUTE QUADRANGLE.

Lithostratigraphic unit and bed number	Description	Thickness
TOBACCO ROAD FORMATION		
BED 11c	Sandy soil, loose.	.3 m (1.0 ft)
BED 11b	Residuum, sand, clayey, mottled and weathered.	.91 m (3.0 ft)
BED 11a	Sand, coarse-grained to granular, poorly sorted, grains subangular; some medium- to coarse-grained dark heavy minerals; a few scattered rounded quartz pebbles at base; abundant interstitial clay, indurated, a few thin wispy clay laminae which give a faint suggestion of stratification; color orange-red.	1.17 m (3.83 ft)
DRY BRANCH FORMATION		
BED 10d	Sand, fine- to medium-grained, moderately well sorted, with some coarse- to very coarse-grained sand, granules and pebbles in uppermost portion; appears transitional with overlying unit; with thin white clay laminae, undulatory and discontinuous; color orange-red.	.69 m (2.25 ft)
BED 10c	Sand, medium- to very coarse-grained, poorly sorted to moderately well sorted; with thin white clay laminae; bioturbated.	.36 m (1.17 ft)
BED 10b	Sand, fine- to medium-grained, moderately well sorted; with thin white clay laminae, undulatory and disrupted, bioturbated.	.59 m (1.92 ft)
BED 10a	Sand, fine- to coarse-grained, moderately sorted; with medium-0 to coarse-grained dark heavy minerals; with thin crossbeds alternating fine- to medium-grained and coarse-grained sand layers; many large (6-10 mm diameter) white clay lined burrows.	.76 m (2.5 ft)
BED 9	Sand, medium- to very coarse-grained, granular and pebbly, poorly sorted, subangular grains; basal portion with some white clay laminae; some disrupted clay laminae give evidence of bioturbation.	1.32 m (4.33 ft)
BED 8b	Sand, fine- to medium-grained, moderately well sorted; with uppermost .15 m of fine- to coarse-grained sand, slightly pebbly and poorly sorted; bioturbated, with distinct burrows.	.46 m (1.5 ft)
BED 8a	Sand, fine- to medium-grained, moderately well sorted, subangular grains; with fine-grained dark heavy minerals; white clay laminae discontinuous and undulatory; lower portion of bed with continuous montmorillonitic clay laminae 3-10 mm thick 6-10 cm apart; upper portion bioturbated.	.79 m (2.58 ft)
BED 7	Clay, montmorillonitic, laminations up to 1 cm thick; interlaminae of sand, fine-grained, well sorted, micaceous, with dark heavy minerals; horizontal burrows.	1.07 m (3.5 ft)

BED 6	Sand, fine-grained, well sorted, with very coarse grains and granules distributed throughout, subangular grains, fine-grained dark heavy minerals; slightly clayey, distinct discontinuous undulatory white clay laminae; color mottled cream white and yellow-brown, weathered very light tan.	.86 m (2.83 ft)
BED 5e	Clay, montmorillonitic, laminated, with some thin sand partings; color light gray to purple.	.1 m (.33 ft)
BED 5d	Sand, fine- to very coarse-grained, poorly sorted, subangular grains; abundant fine-grained dark heavy minerals; clayey color yellow-brown mottled.	.43 m (1.42 ft)
BED 5c	Clay, montmorillonitic, laminated to very thin bedded (5-25 mm thick); with thin partings of sand, fine-grained, well sorted, silty, micaceous, with fine-grained, dark heavy minerals; abundant horizontal sand-filled burrows, some containing coarse- to very coarse-grained sand. Color light gray to purple.	.33 m (1.08 ft)
BED 5b	Sand, coarse- to very coarse-grained, moderately well sorted, subangular grains; some dark heavy minerals; relatively clean with little interstitial clay; color orange-yellow.	.79 m (2.58 ft)
BED 5a	Clay, montmorillonitic, laminated to very thinly bedded; with thin interlaminae of sand, fine-grained and well sorted to fine- to coarse-grained and poorly sorted, silty, micaceous, with abundant fine-grained dark heavy minerals; some horizontal sand-filled burrows; color purple.	.23 m (.75 ft)
BED 4	Sand, medium- to very coarse-grained and granular, poorly sorted, subangular to subrounded grains, base marked by thin bed of limonite-cemented sand, coarse- to very coarse-grained and granular with pebbles, poorly sorted, subangular grains.	.36 m (1.17 ft)
HUBER FORMATION		
BED 3	Kaolin, massive; hackly, texture when dry; color light gray with purple mottling.	3.07 m (10.08 ft)
BED 2	Clay, kaolinitic, laminated to thinly bedded, with paper thin partings of silt.	.61 m (2.0 ft)
BED 1	Sand, fine-grained, well sorted, angular to subangular grains, micaceous with fine- to coarse-grained flakes; with kaolinitic clay clasts up to 25 mm diameter; laminated to thinly bedded, bedding defined by concentrations of fine-grained dark heavy minerals; sand is clean and loose; locally very thin discontinuous white clay laminae and burrows.	1.68 m (5.5 ft)

		16.88 m (55.32 ft)



Stop 7Borrow pit on Herndon Dairy property.

STOP 8

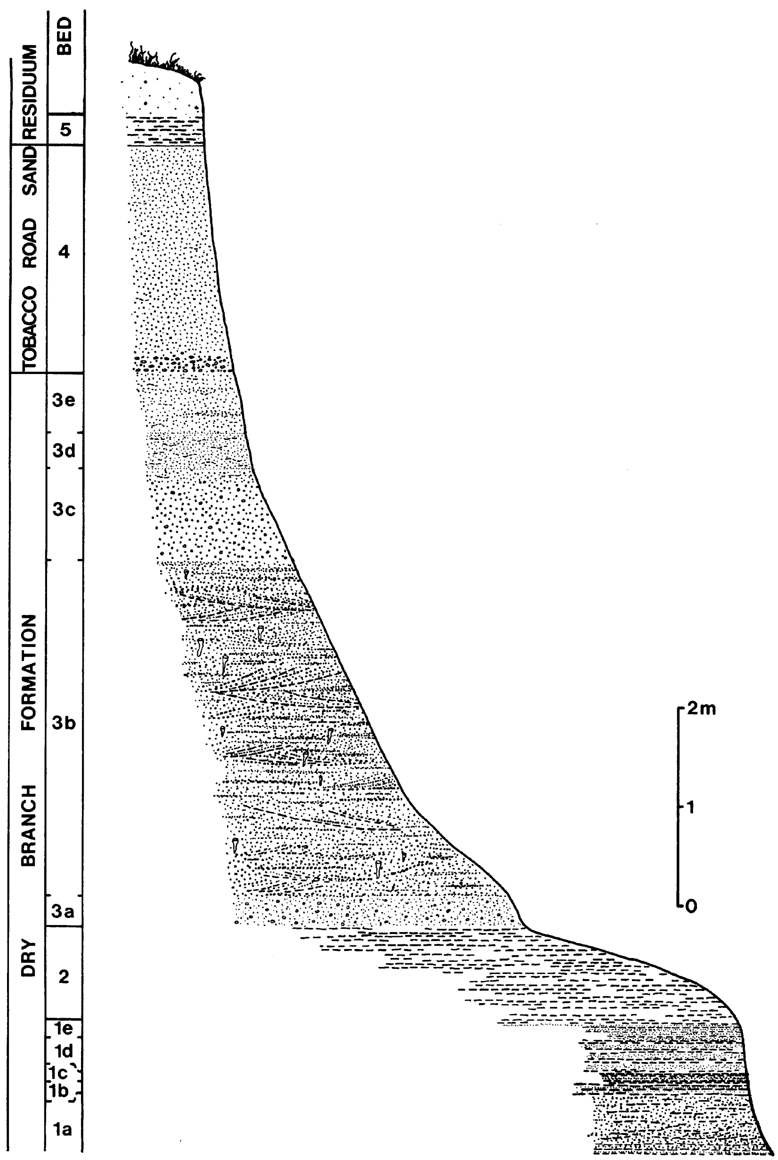
CASSELS PIT

0.8 MILE (1.48 KM) NORTH 14× WEST OF THE INTERSECTION OF S.C. HIGHWAY 125 AND SILVER BLUFF ROAD (S.C. HIGHWAY 302), IN SOUTHWESTERN HOLLOW CREEK, S.C., 7.5-MINUTE QUADRANGLE.

Lithostratigraphic unit and bed number	Description	Thickness
BED 6	Sandy soil, clayey, with abundant irregular plinthite nodules; color red.	.35 m (1.17 ft)
BED 5	Illuvial horizon, fissile clay when dry, color light tan to cream.	.3 m (1.0 ft)
TOBACCO ROAD SAND		
BED 4	Sand with basal pebble zone; pebble zone consists of well rounded and ellipsoidal to discoidal quartz pebbles 5-20 mm in size, in a matrix of sand, medium-grained to very coarse-grained, poorly sorted, clayey, pebble zone .18 m (7 in.) thick; sand, transitional with pebble zone below medium-grained sand to very coarse-grained with granules and small pebbles; grades up into medium-grained sand, fairly well sorted, grains subangular, few medium- to coarse-grained dark heavy minerals; faint wispy clay laminae undulatory and discontinuous, sand otherwise massive, unbedded; indurated; color orange red.	2.3 m (7.6 ft)
DRY BRANCH FORMATION		
BED 3e	Sand, medium-grained to granular, poorly sorted, subangular grains; characterized by some wispy clay laminae, discontinuous and undulatory, tan color; transitional with overlying pebble zone; color purple to tan.	.6 m (1.9 ft)
BED 3d	Sand, fine- to medium-grained, subangular, micaceous, clayey; characterized by wispy clay laminae that are undulatory and discontinuous; color purple to tan.	.36 m (1.2 ft)
BED 3c	Sand, granular to pebbly, poorly sorted, subangular grains; with some fine-grained to granular dark heavy minerals; clean and loose; color yellow-brown.	.92 m (3.0 ft)
BED 3b	Sand, medium- to coarse-grained; crossbedding defined by clay laminae; individual sand strata (10-25 mm) defined by texture, locally well burrowed, small burrows of 1-2 mm and large burrows 10-25 mm in diameter.	3.4 m (11.1 ft)
BED 3a	Sand, fine- to medium-grained; with pebbles; loose.	.3 m (1.0 ft)
BED 2	Clay, massive appearance, fissile when dry; locally laminated with faint paper thin partings of micaceous, very fine sand to silt; color purple, light brown, mottled to red.	.97 m (3.17 ft)
BED 1e	Sand, fine-grained, well sorted, subangular grained; with abundant fine-grained dark heavy minerals; very thin white clay laminae separated by 25 mm interlayers of sand.	.18 m (.58 ft)
BED 1d	Sand and clay interlaminated; clay laminae 1-4 mm thick, laterally continuous, color purple, tan and cream; sand, very fine-grained, well sorted, micaceous, with abundant fine-grained dark heavy minerals sand laminae 1-3 mm thick; color brown to yellow.	.34 m (1.12 ft)

BED 1c	Sand, medium-grained, well sorted, subrounded grains, clean; sand as an interlayer between thin clay beds; color yellow to brown.	.09 m (.29 ft)
BED 1b	Clay, laminated, laterally continuous laminae; color purple and gray; clay laminae separated by silty sand, very fine-grained, well sorted subangular grains, micaceous, with abundant very fine-grained dark heavy minerals, in paper thin to 2 mm thick laminae, color brown.	.13 m (.42 ft)
BED 1a	Sand and clay interlaminated; basal horizon (50 mm) of clay interlaminated with sand, fine-grained, well sorted, subangular grains, micaceous, with fine-grained dark heavy minerals; followed by horizon (28 cm) of sand, medium- to coarse-grained or very coarse-grained to granular, moderately sorted, with thinly laminated to thinly bedded clay which defines crossbedding in the upper portion of this horizon (25 cm) of sand, medium-grained and well sorted to medium- to very coarse-grained and poorly sorted, thinly bedded, clean, with thin clay laminae 2-10 mm thick; sand color yellow to brown to red.	58 m (1.92 ft)

		10.82 m (35.5 ft)



Stop 8Borrow pit on Cassels estate.

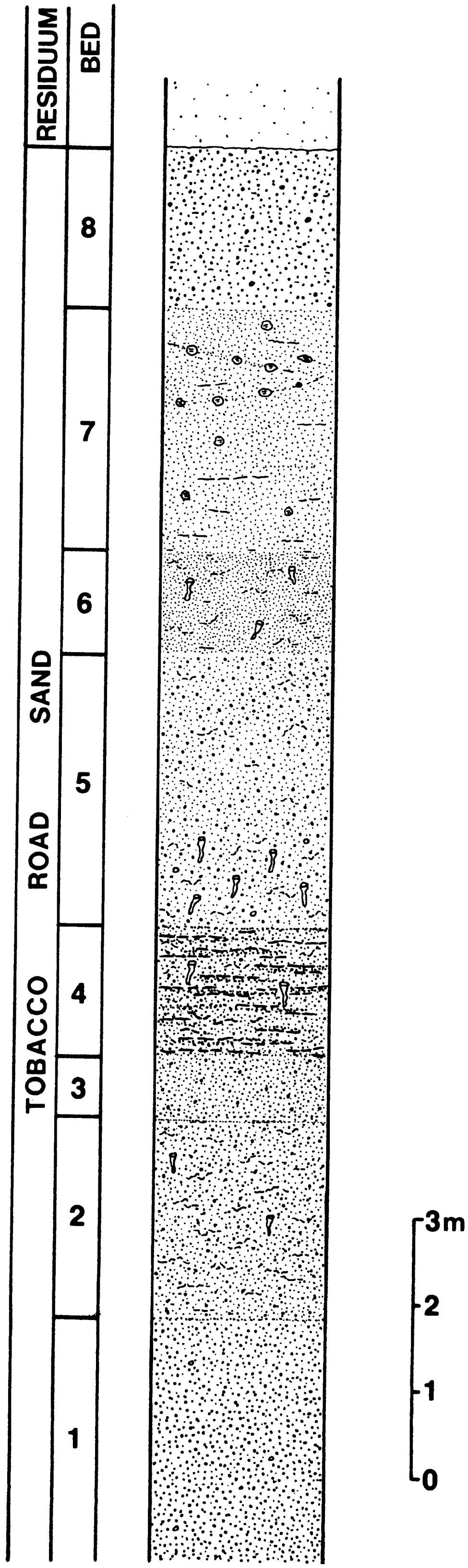
STOP 9

EXPOSURES ALONG DIRT ROAD IN SOUTHEASTERN HOLLOW CREEK 7.5-MINUTE QUADRANGLE

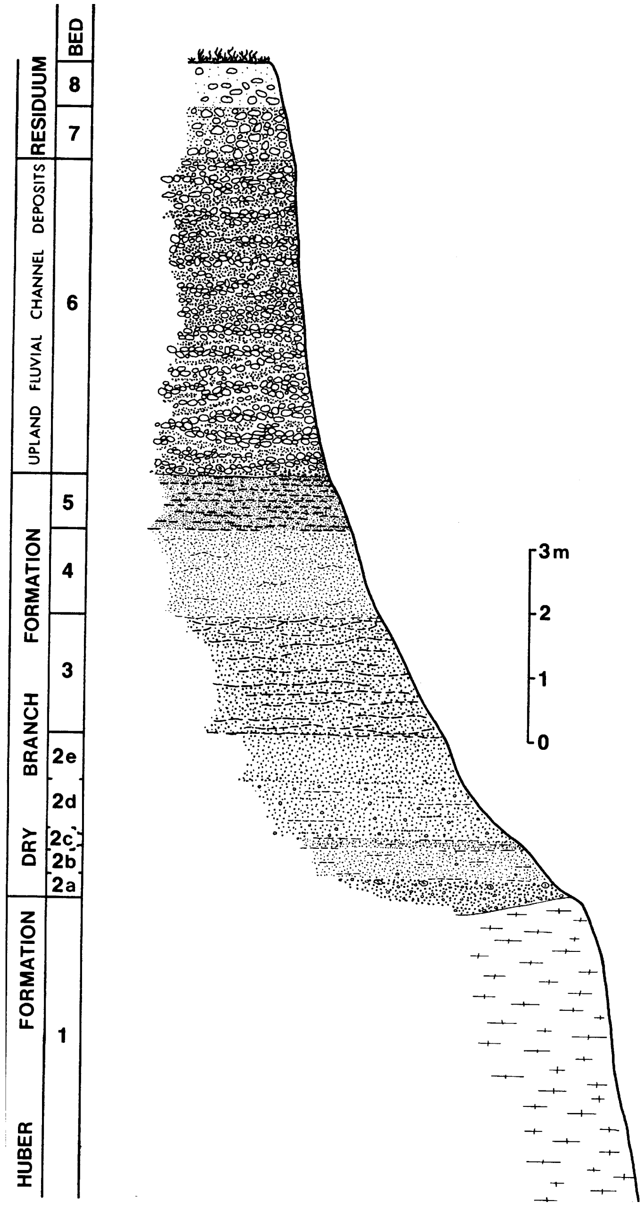
BASE OF EXPOSED SECTION IS 2.83 MILES (4.54 KM) SOUTH 47× EAST OF THE INTERSECTION OF U.S. HIGHWAY 278 AND SILVER BLUFF ROAD (S.S. HIGHWAY 302).

Lithostratigraphic unit and bed number	Description	Thickness
TOBACCO ROAD SAND		
BED 8	Sand, medium- to coarse-grained with some very coarse grains, poorly sorted, to moderately sorted, subangular grains; very abundant coarse-grained to granular white clay clasts; some fine- to medium-grained dark heavy minerals; color pink.	1.83 m (6.0 ft)
BED 7	Sand, very fine- to fine-grained, moderately well to well sorted; fine- to medium-grained white clay clasts; very fine- to fine-grained dark heavy minerals; abundant interstitial clay; discontinuous thin clay laminae which define stratification; some crossbedding defined by purple to light gray clay clasts; color orange-red.	2.75 m (9.0 ft)
BED 6	Sand, very fine- to fine grained, silty; micaceous with fine- to medium-grained flakes; some very fine- to fine-grained dark heavy minerals; fine- to medium-grained white clay clasts; abundant interstitial clay; irregular and discontinuous thin wispy clay laminae purplish gray n color; bioturbated with some distinct burrows.	1.14 m (3.75 ft)
BED 5	Sand, basal 1 m of bed fine- to very coarse- grained and granular with some well rounded pebbles up to 1.5 cm, poorly sorted, angular to subangular grains, micaceous, abundant interstitial clay; remainder of bed very fine- to fine-grained sand, with some coarse- to very fine- to fine-grained sand, with some coarse- to very-coarse-grained fraction, moderately sorted; entire bed characterized by irregular and disrupted clay segregations, a result of bioturbation, burrowing, which gives appearance of no stratification; color yellow-tan.	3.13 m (10.25 ft)
BED 4	Sand, fine- to coarse-grained, poorly to moderately sorted; with thin white clay laminae which are laterally continuous; and define stratification; locally laminae have been disrupted by bioturbation and burrowing, some distinct burrows 1-2 cm diameter; indurated; color yellow-orange.	1.47 m (4.83 ft)
BED 3	Sand, fine- to coarse-grained with some very coarse grains, poorly sorted, subangular; interstitial clay; unstratified and massive; indurated; color purple.	.66 m (2.17 ft)
BED 2	Sand, fine- to coarse-grained, poorly sorted, subangular grain; some fine-grained dark heavy minerals; interstitial clay; bioturbated with some distinct burrows 1-2 cm diameter; indurated; color orange-tan.	2.31 m (7.58 ft)
BED 1	Sand, medium- to very coarse-grained with granules, some fine-grained fraction and a few scattered pebbles, poorly sorted, angular to subangular grains; some fine- to medium-grained dark heavy minerals' slightly micaceous; few discontinuous purple clay laminae; unstratified and massive; indurated; color purple.	2.8 m (9.17 ft)

		16.09 m (52.75 ft)



Stop 9. Roadcut along unnumbered dirt road, SE corner of Hollow Creek 7.5' quad.



Stop 10. Chicora pit, J.M. Huber Corporation property.

STOP 10

J.J. HUBER CORPORATION'S CHICORA PIT

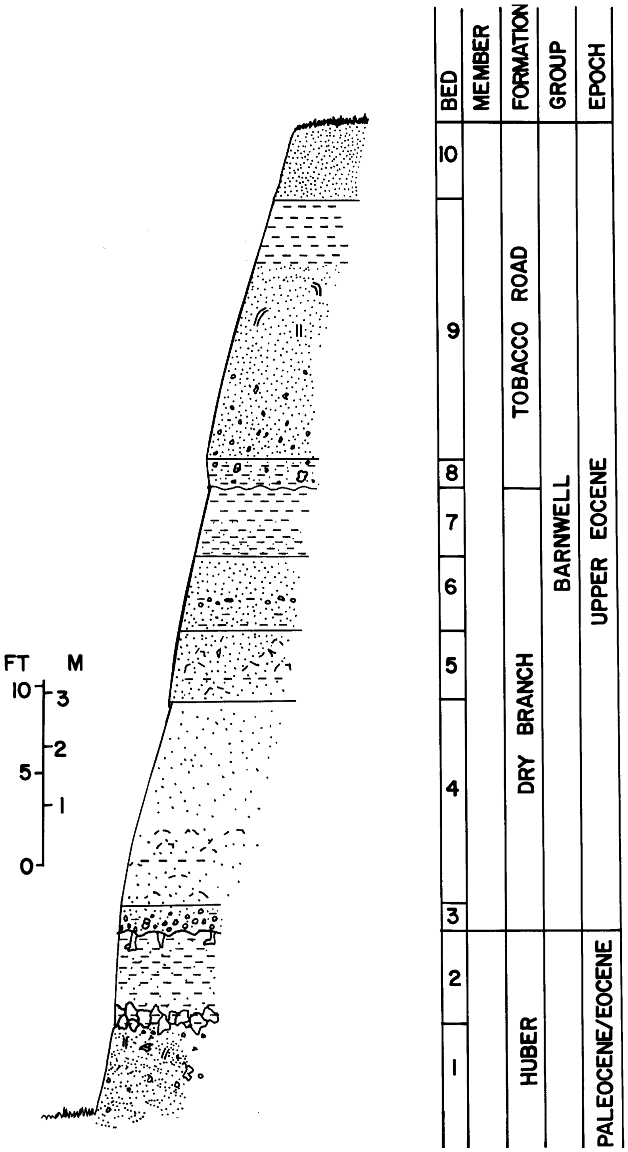
1.13 MILE (1.82 KM) NORTH 44× EAST OF THE INTERSECTION OF PINE LOG ROAD (S-2-65) AND HUBER CLAY ROAD (S-2-66) IN NORTHWESTERN HOLLOW CREEK, S.C., 7.5-MINUTE QUADRANGLE.

Lithostratigraphic unit and bed number	Description	Thickness
BED 8	Soil horizon; rounded quartz cobbles in loose sand matrix; color gray.	.7 m (2.3 ft)
BED 7	Residuum; rounded quartz cobbles in clayey sand matrix; color red.	.8 m (2.7 ft)
UPLAND FLUVIAL CHANNEL DEPOSITS		
BED 6	Quartz cobbles, 3-10 cm in diameter, rounded to well rounded; in a matrix of medium- to very coarse-grained and granular sand, poorly sorted, angular to subrounded grains; clayey, with sand-sized white clay grains; also some sandy micaceous clay clasts up to 40 cm in diameter; bedded with individual cobbled beds 10-60 cm thick; cobble beds are laterally discontinuous, coalescing and changing in thickness; color light pink-orange; abrupt contact with bed below.	4.9 m (16.0 ft)
DRY BRANCH FORMATION		
BED 5	Sand, fine-grained, well sorted, with minor coarse- to very coarse-grained fraction; some fine - to coarse-grained mica, thin clay laminae green and purple in color laterally continuous.	.8 m (2.7 ft)
BED 4	And, fine- to medium-grained, moderately sorted, subangular to subrounded grains, with some fine- to very coarse-grained mica; some fine-grained dark heavy minerals; few wispy discontinuous clay laminae; color purple to red.	1.3 m (4.4 ft)
BED 3	Sand, medium- to coarse-grained, moderately well sorted, subangular to subrounded grains; with abundant fine-grained dark heavy minerals; abundant laminated to thin-bedded clay, undulatory and continuous becoming discontinuous to upper .6 m; very little interstitial clay; color red to orange in lower 1.2 m, yellow to orange in upper .6 m.	1.8 m (6.0 ft)
BED 2e	Sand, fine- to very coarse-grained, poorly to moderately sorted; unstratified; color yellow to orange; gradational with bed below.	1.8 m (2.4 ft)
BED 2d	Sand, medium- to very coarse-grained with granules and pebbles throughout, poorly sorted; pebbles are up to 1 cm diameter, subrounded to well rounded; few very thin clay laminae poorly define a vague thinly bedded stratification; color red to yellow.	.9 m (2.8 ft)
BED 2c	Sand, fine- to coarse-grained with some very coarse-grained to granular fraction, poorly sorted, subangular to subrounded grains; very clayey; laminated; color brown.	.15 m (.5 ft)
BED 2b	Sand, fine- to medium-grained with very coarse-grained sand, granules and pebbles throughout; pebbles are well rounded and up to 1 cm diameter; with very thin discontinuous clay laminae; color brownish yellow.	.5 m (1.6 ft)
BED 2a	Pebbly sand, sand very coarse-grained and granular with minor medium- to coarse-grained fraction, poorly sorted, subangular to subrounded sand gains; pebbles up to 3 cm diameter and well rounded.	.3 m (1.1 ft)

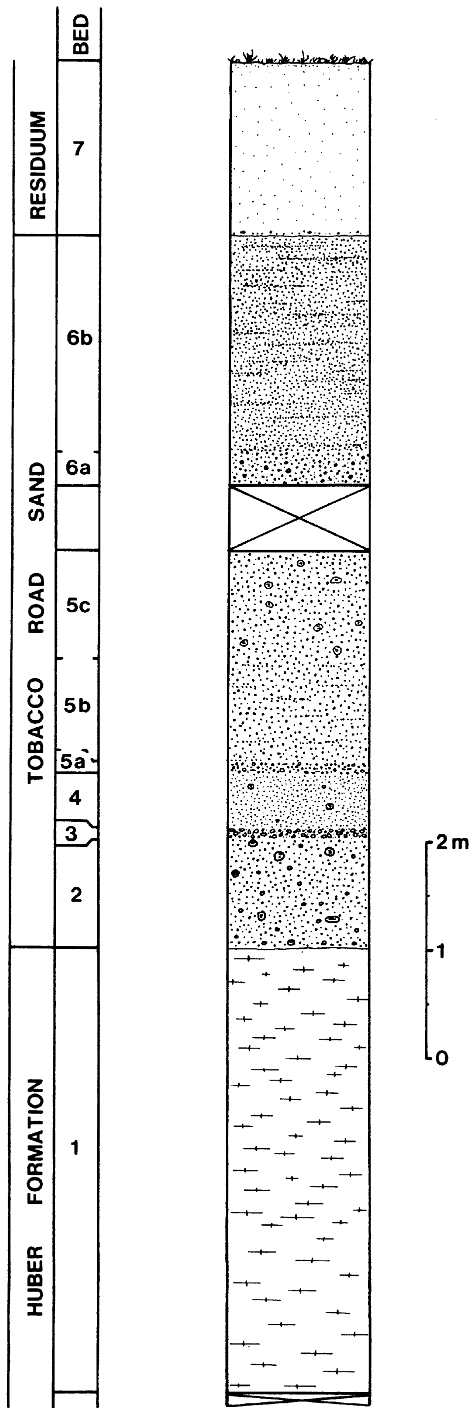
HUBER FORMATION

BED 1	Kaolin, pure clay massive, with a hackly fracture; color cream to very light gray with orange mottling.	4.7 m (15.3 ft)

		17.55 m (57.9 ft)



Stop 11. Huber's Conger pit.



Stop 12. Barden pit, J.M. Huber Corporation property.

STOP 11

J.M. HUBER CORPORATION'S CONGER PIT

1500 FEET NORTH OF PINE LOG ROAD, 2.5 MILES WEST OF INTERSECTION OF PINE LOG ROAD AND SILVER BLUFF ROAD

by LAMAR LONG, ED SCHRADER, CHARLES MUIR (J.M. HUBER CORPORATION, CLAY DIVISION) AND A. RICHARD HENDERSON (STATE OIL AND GAS BOARD, MISSISSIPPI).

Lithostratigraphic unit and bed number	Description	Thickness
TOBACCO ROAD FORMATION		
BED 10	Sand: fine-grained, moderately well sorted, subangular to subrounded. Abundant heavy minerals.	1.16 m (3.8 ft)
BED 9	Sand and clay: fining upwards sequence; very coarse-grained, angular to subrounded sand and scattered gravel in bottom 1.65 m (5.4 ft). Abundant fine-grained heavy minerals, scattered clay balls, buff to brownish red, red color along bedding planes and burrows. In top 7.6 cm (3 in) of sands extremely coarse sands decreasing in context; coarse-grained sand with scattered clay balls for next 0.9 m (3.0 ft), abundant fine-grained heavy minerals, buff to brownish red, red color along bedding planes and burrows; grades into poorly sorted, medium-grained sand for next 1.0 m (3.3 ft) subangular to subrouned. Predominantly buff-colored with vertical burrows. Red stain along bedding planes and burrows; grades in clay at top 0.82 m (2.7 ft).	4.37 m (14.3 ft)
BED 8	Clay: very poorly sorted sandy clay, reddish brown with some gray lenses, white discoidal clay balls up to 5 cm (2 in) in diameter, quartz grains up to 5 mm.	0.4 m (1.3 ft)
DRY BRANCH FORMATION		
BED 7	Slit and clay: fining upwards sequence, transition from sandy silt to silty clay, transition evident approximately 0.49 m (1.6 ft) from base. Light yellowish brown to gray with some red.	1.25 m (4.1 ft)
BED 6	Light yellowish brown clayey sand to coarse-grained quartz sand, in lower 0.90 m (3 ft) clay whisps are more abundant, within the clay matrix there are some thin pebble zones, pebbles are composed of elongate discoidal clay balls; at contact with unit below is light yellowish brown medium- to coarse-grained sand, subrounded to subangular, abundant clay whisps and lenses up to 2.5 cm (1 in) thick.	1.28 m (4.2 ft)
BED 5	Sand: fining upwards sequence, fine- to coarse-grained sand grading into clayey sand and silt at top, extreme bioturbation, slightly micaceous with occasional clay whisps which appear to mantle ripples, color in lower portion is moderate yellow brown abruptly changing to dark red in upper clayey zone.	1.19 m (3.9 ft)
BED 4	Sand: mauve-colored, medium- to coarse-grained quartz sand, angular to subangular at top grading to rounded to subrounded at bottom, moderate amount of heavy minerals scattered throughout at top, becoming less abundant as go down, moderate to well sorted, rare clay whisps, bottom 1.46 m (4.8 ft) is white, mauve to gray, orange-red, buff and purple, extreme amount of bioturbation: bottom 0.1 m (0.4 ft) is transitional with underlying unit.	3.45 m (11.3 ft)
BED 3	Sand: coarse- to very coarse-grained clayey sand with scattered gravel and clay balls, subangular, upper 12.7 cm (5 in) has fewer clay balls and gravel is absent.	0.38 m (1.2 ft)
HUBER FORMATION		

BED 2	Kaolinitic clay: gray, sandy, many *Callianassa* burrows with sand infilling burrows, at base of clay is conglomerate zone, contact with Barnwell Group is irregular with pebble zone along top of clay.	1.62 m (5.3 ft)
BED 1	Sand: cross-bedded, fine- to medium-grained quartz sand, micaceous with coarse quartz pebbles, clay balls, and fine-grained heavy minerals; the color of this bed is white to gray with orange iron stains, some sand-filled burrows 3 to 4.5 cm 0.1 to 1.5 in long and up to 3.8 cm (1.5 in) diameter.	1.55 m (5.1 ft)

		16.65 m (54.50 ft)

STOP 12

J.M. HUBER CORPORATION'S BARDEN PIT

BARNACLE-ROCK SITE IS 1.2 MILE (1.79 KM) SOUTH 24× WEST OF JACKSONVILLE CHURCH IN WEST-CENTRAL; GRANITEVILLE, S.C. 7.5-MINUTE QUADRANGLE. TOBACCO ROAD SAND LIES ON KAOLIN IN SOUTHWEST CORNER OF THE PIT, 0.06-MILE (0.10 KM) WEST-NORTHWEST OF THE BARNACLE-ROCK SITE. THE "HIGH WALL" ON THE PROPERTY AND MENTIONED IN THE TEXT WILL NOT BE VISITED BY THE FIELD TRIP BUT IS 0.3 MILE (0.5 KM) NORTH 16× EAST OF THE BARNACLE-ROCK SITE.

Lithostratigraphic unit and bed number	Description	Thickness
BED 7	Loose sand and soil: base characterized by abundant concentric iron concentrations (plinthites).	1.3 m (4.3 ft)
TOBACCO ROAD SAND		
BED 6b	Sand, predominantly medium-grained, well sorted, angular to moderately well rounded; with abundant interstitial clay; bedding horizontal, in faintly discernible thin beds; light orange-red in color, locally with a slight purple cast from some of the clays.	2.0 m (6.6 ft)
BED 6a	Sand, predominantly medium-grained to very coarse-grained; with some fine-grained sand; with abundant quartz granules and pebbles; up to 2 cm; with abundant interstitial clay and scattered white clay grains to 2 mm; quartz sand angular to subangular, quartz pebbles subrounded, discoidal to ovoid; light orange--red in color.	.3 m (1.0 ft)
	Covered interval.	.6 m (2.0 ft)
BED 5C	Same as Bed 5b except with scattered to common kaolin balls up to 1.15 cm.	1.0 m (3.3 ft)
BED 5b	Sand, as in Bed 5a except lacking quartz pebbles, clay balls, and clay stringers. Gradational from Bed 5a.	.9 m (3.0 ft)

BED 5a	Sand, medium- to very coarse-grained, with abundant quartz granules and pebbles up to 1.5 cm; sand angular to subangular, granules and pebbles subrounded to rounded; with scattered clay balls and short (up to 2 cm), white clay stringers; with abundant interstitial clay; bedding crudely defined; light orange-red in color.	.1 m (.3 ft)
BED 4	Sand, fine- to medium-grained, angular to subangular, moderately well sorted, with scattered quartz pebbles and clay clasts up to 1 cm; with abundant interstitial clay; massively bedded; light orange-red in color.	.5 m (1.6 ft)
BED 3	Discoidal quartz pebble layer. Matrix is same as in Bed 2, but with more abundant quartz granules and very abundant, concentrated, subrounded to very well rounded, discoidal to ovoid quartz pebbles. No sharp boundary with Bed 2.	.1 m (.3 ft)
BED 2	Sand, fine-grained to very coarse-grained, angular to subangular, with abundant quartz granules and pebbles to 5 mm; with abundant kaolin balls to 2 cm, rarely to 4 cm; with abundant interstitial clay; poorly sorted; bedding crudely defined by changes in grain size; light orange-red in color.	1.0 m (3.3 ft)
HUBER FORMATION		
BED 1	Kaolin, massive, light to dark gray, with local purple coloration. Locally this kaolin bed extends 2 to 3 m higher.	4.0 m (13.1 ft)
	Covered interval (up from water's edge in pit.)	(.3 ft)

		11.9 m (39.1 ft)

STOP 13

GRANITEVILLE CEMETERY HILL

EXPOSURES ARE ON SOUTH SIDE OF GREGG HIGHWAY (S-2-895) 1.08 MILES (1.73 KM) SOUTH 75× EAST OF THE INTERSECTION OF GREGG HIGHWAY (S-2-895) AND S.C. HIGHWAY 191 IN EAST-CENTRAL GRANITEVILLE, S.C., 7.5-MINUTE QUADRANGLE.

Lithostratigraphic unit and bed number	Description	Thickness
HUBER FORMATION		
BED 7	Clay, kaolinitic, with fine- to medium-grained quartz sand and muscovite flakes; weathered, mottled, white to light purple. Top of exposure.	.2 m (.7 ft)
BED 6	Residuum. Sand, very fine- to fine-grained, with present to abundant interstitial clay; with fine- to medium-grained muscovite flakes and very fine-grained dark heavy minerals; well sorted; weathered, yellow-tan in color.	.3 m (1.0 ft)
BED 5b	Clay, kaolinitic, rather pure, with very little silt of grit; made up of clay beds 1-10 cm thick separated by laminae or thin beds of fine- to medium-grained quartz sand; bedding distinct, subhorizontal to locally inclined 10°; white to cream. Beds 5a and 5b grade laterally into clayey, kaolinitic sand.	1.95 m (6.4 ft)

BED 5a	Clay kaolin matrix, with abundant medium- to coarse-grained quartz sand. Basal sandy layer.	.15 m (.5 ft)
BED 4	Kaolin, gritty, with minor silt and fine- to medium-grained quartz sand, occasional quartz granules to 3 mm, and with some muscovite flakes to 1 or 2 mm; fines upward by loss of the coarser quartz fraction and by decrease in percentage of finer quartz sand; gritty only in about the lower 1.6-2.0 m; massive; white or cream, locally with yellow-tan weathering mottles. The top of this kaolin bed is the prominent upper kaolin seen all around the wall of the pit.	4.0 m (13.1 ft)
BED 3b	Sand, fine- to medium-grained, with abundant interstitial clay, some muscovite flakes and fine-grained dark heavy minerals; well consolidated; yellow-tan in color.	.15 m (.5 ft)
BED 3a	Clay, silty, sandy, with very fine-grained and fine-grained quartz sand, sparse fine-grained dark heavy minerals, and silty or fin-grained muscovite flakes' stiff, firmly indurated, forming steep or intermediate slopes; bedding massive to first view but separated by laminae and thin beds; beds: cream where fresh to yellow-cream or yellow-tan weathered. Coarsens and darkens upward to bed 3a.	.15 m (.5 ft)
BED 2	Sand, very fine-grained to medium-grained with muscovite flakes up to 2.5 mm and sparse, fine-grained dark heavy minerals; interstitial clay almost lacking, clay laminae prominent on bedding surfaces (1-3 cm apart) in lower 0.6 m of unit but absent above; moderately well sorted to well sorted; loose, not indurated, slope-forming, white. Cream, or ocher-yellow in color. Upper 0.1-0.2 m of unit with ocher-yellow iron stains, uppermost 0-2 cm locally iron-cemented.	1.1 m (3.6 ft)
BED 1	Sand, predominantly medium- to coarse-grained, with some fine-grained sand and abundant quartz granules and pebbles up to 1.5 cm angular to subangular; with muscovite flakes to 3 mm, fine-grained dark heavy minerals, interstitial clay present but not abundant, and some clay clasts up to 1 cm, bedding subhorizontal, in loosely defined bedding units 0.5-6 cm thick; loose to very lightly indurated; white, cream, or light yellow-tan inn color. Some bedding layers marked by white clay (kaolin) laminae or thin beds. Clay beds locally to matrix-forming, up to 4 cm thick.	2.4 m (7.9 ft)

		10.4 m (34.2 ft)

STOP 14

FULLERS EARTH PIT SOUTHEAST OF AIKEN MUNICIPAL AIRPORT

0.51 MILE (0.82 KM) SOUTH 40× EAST OF THE INTERSECTION OF REYNOLDS POND ROAD (S-2-26) AND U.S. HIGHWAY 1 IN SOUTHERN AIKEN NORTHWEST 7.5-MINUTE QUADRANGLE. TWO SHORT SECTIONS WERE MEASURED.

Lithostratigraphic unit and bed number	STOP 14a Description	Thickness
BED 5	Residuum. Sand, fine-grained to very coarse-grained, with abundant quartz pebbles up to 2 cm; angular to moderately well rounded; poorly sorted; with abundant interstitial clay; also with abundant plinthite pebbles up to 2 cm; weathered, mottled, yellow-orange in color.	1.2 m (3.9 ft)
DRY BRANCH FORMATION		

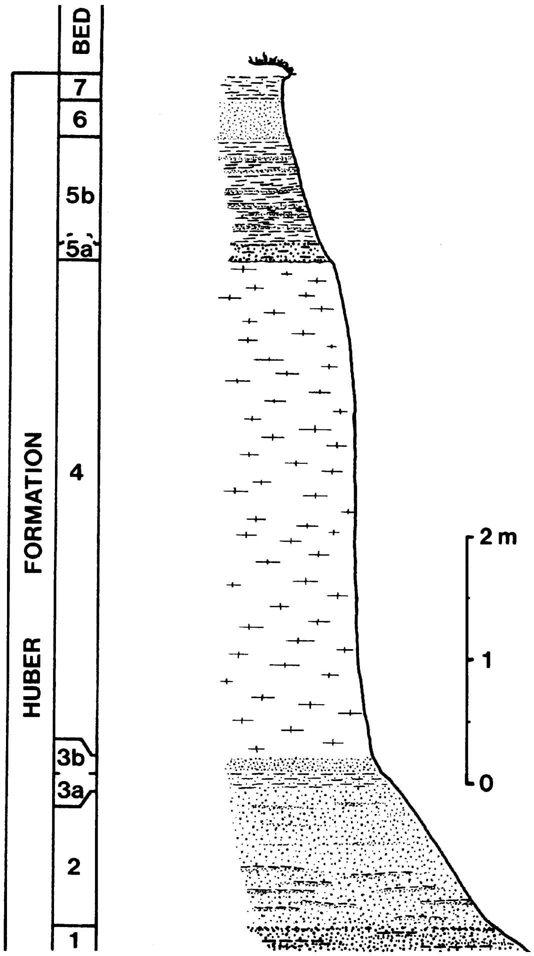
BED 4	Sand, fine- to medium-grained, with some coarse-grained quartz sand, granules, and pebbles; angular to subangular; with abundant interstitial clay with well rounded clay clasts up to 1.5 cm; poorly sorted; bedding well defined by irregular, wispy, sandy clay laminae and thin beds; weathered; sand intervals light cream-pink in color; clay beds medium gray where freshest, white, light gray, or light purple where more weathered.	2.2 m (7.2 ft)
	Covered interval.	3.3 m (10.8 ft)
BED 3	Clay, montmorillonitic, as in Bed 1.	.3 m (1.0 ft)
BED 2	Clay, dense, compact, silica-rich or partially silica-replaced; with conchoidal fracture; light gray to dark gray.	.4 m (1.3 ft)
BED 1	Clay, montmorillonitic, laminated to thin-bedded, with very minor silt of fine-grained quartz sand and muscovite flakes; dark olive-gray where freshly exposed, yellow-tan where weathered. Twiggs Clay lithology.	1.8 m (5.9 ft)

		9.2 m (30.1 ft)

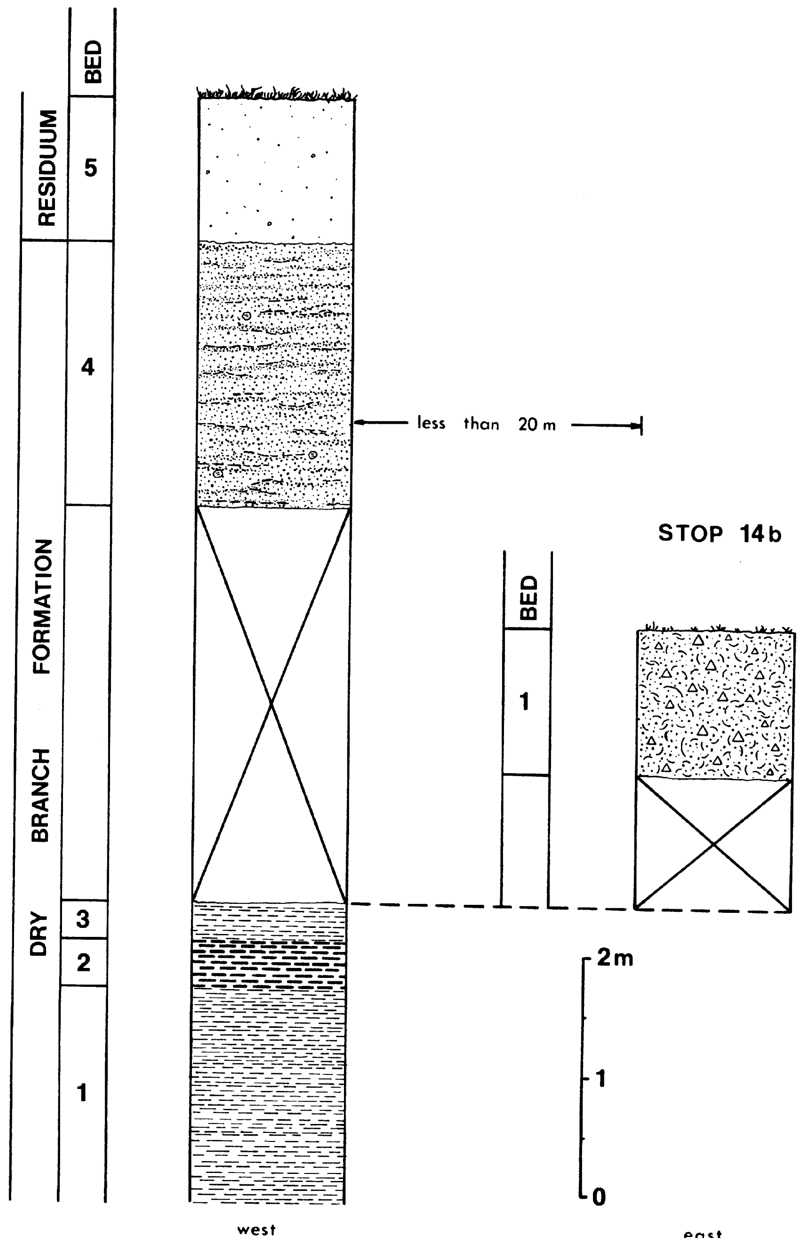
STOP 14B

Lithostratigraphic unit and bed number	Description	Thickness
BED 1	Silicified, fossiliferous rock and fragments weathered from it. Sand (and silica-cemented sandstone), fine-grained to very coarse-grained, with abundant quartz granules and pebbles up to 2.7 cm; sand angular to subrounded, pebbles to moderately well rounded; with some interstitial clay and with very, very abundant, silica-replaced, barnacle plates and fairly rare, silica-replaced, delicate, pectinid bivalve mollusk valves; poorly sorted; bright white were fresh, to dull yellow-buff where weathered.	1.2 m (3.9 ft)
	Covered interval.	1.1 m (3.6 ft)
	Base of section. Top of montmorillonitic clay in BED 3, STOP 14a, projects to this level.	

		2.3 m (7.5 ft)



Stop 13. Cemetery hill, east of Graniteville.



Stop 14a. Fuller's Earth pit south of Aiken Municipal Airport.