UPPER EOCENE STRATIGRAPHY OF CENTRAL AND EASTERN GEORGIA

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ABSTRACT

The Barnwell is herein raised to group status consisting, in Georgia, of three formations. These are, in ascending order, the Clinchfield Formation, the Dry Branch Formation, and the Tobacco Road Sand. The Clinchfield Formation contains four formally recognized members. These include, in east-central Georgia, the Riggins Mill and Treadwell Members, and in eastern Georgia, east of the Ogeechee River, the Albion Member and Utley Limestone Member. The Dry Branch Formation consists of three interfingering and intergradational lithofacies that in the areas of their typical development are formally recognized as members. These include the Twiggs Clay, Irwinton Sand, and Griffins Landing Members. In central Washington County, Georgia, the Tobacco Road Sand contains the Sandersville Limestone Member at its base.

The Ocala is formally recognized as a group in Georgia. In central Georgia the Ocala Group is represented by a lower Tivola Limestone and an upper Ocmulgee Formation separated by the Twiggs Clay Member of the Dry Branch Formation. In southern Georgia the Williston and Crystal River Formations of the Ocala Group are considered to be lateral equivalents of the Tivola Limestone and Ocmulgee Formation, respectively.

The Barnwell Group is of late Eocene Jacksonian age, but there is some reason to believe that the Clinchfield Formation could be of late middle Eocene Claibornian age. Regionally, two parts of the Jacksonian are recognized, a lower Jacksonian and an upper Jacksonian. In Georgia, the Dry Branch and probably the Clinchfield Formations of the Barnwell Group, and the Tivola Limestone and Williston Formation of the Ocala Group are lower Jacksonian. The Tobacco Road Sand of the Barnwell Group and the Ocmulgee and Crystal River Formations of the Ocala Group are upper Jacksonian.

The Barnwell Group can be visualized as an upper Eocene sand lithosome of the southern Atlantic Coastal Plain laterally equivalent to the relatively offshore carbonate lithosome (Ocala Group), and to the clay lithosome (Yazoo Group) of the Mississippi Embayment and eastern Gulf Coastal Plain. The three lithosomes appear to interfinger in central Georgia where the Clinchfield Formation, Irwinton Sand Member of the Dry Branch Formation, and the Tobacco Road Sand represent the Barnwell sand lithosome; the Twiggs Clay appears to represent an eastern extension of the Yazoo clay lithosome from which it is now separated by erosional removal in western Georgia; the Tivola Limestone and the Ocmulgee Formation represent the Ocala carbonate lithosome.

INTRODUCTION

The object of this report is to establish an internally consistent and reproducible stratigraphic framework for the outcropping and shallow subsurface upper Eocene deposits of central and eastern Georgia (Fig. 1). In establishing this framework, it has been necessary to revise the stratigraphic terminology of the upper Eocene deposits under investigation. These include the sand and clay deposits previously called the Barnwell Formation and some of the far updip Ocala carbonate deposits.

We have made an effort to make this stratigraphic revision consistent with: (1) the local, natural stratigraphic framework as we perceive it, (2) established usage, and (3) recommended principles and practices set forth by the American Commission on Stratigraphic Nomenclature (1970), the North American Commission on Stratigraphic Nomenclature (1983), and by the International Subcommission on Stratigraphic Classification (1976). Inevitably, we have not fully succeeded in forming a stratigraphic terminology that is happily consistent with all three constraints. This problem, however, is both inherited from the accidents of the evolution of the terminology and from the limitations of the existing systems of stratigraphic classification.

Although this study concerns only the upper Eocene deposits of the inner Coastal Plain of Georgia, the marine middle Eocene and upper Eocene deposits of the inner Coastal Plain of eastern Georgia and western South Carolina historically have been inextricably bound. Therefore, for purposes of presenting a historical perspective, it is necessary to include discussion of the middle Eocene stratigraphic terminology and correlation as well as that of the upper Eocene.

The upper Eocene stratigraphic framework of Georgia has been in serious need of revision for many years. These deposits, especially the Barnwell, have been poorly understood and the stratigraphic terminology that had been developed has not been uniformly applicable or has been confusing in many areas and at many sites. This is the case in spite of the fact that these deposits were observed and commented on as early as the 1840's by Charles Lyell (1845). The reasons for this state of knowledge are many:

(1) No type locality had been designated by the original author or by subsequent knowledgeable investigators of the Barnwell Sand; the type locality of the McBean Formation has been only approximately delineated and the type deposits are not well exposed; the type locality of the Lisbon Formation is so distant from the eastern Georgia-western South Carolina area that few investigators of these deposits examine the type locality and trace the deposits in the field to the particular area of investigation.

(2) Natural outcrops are rare and found only as scattered exposures along the major rivers. Human enterprise, on the other hand, has produced many excellent but temporary exposures in the kaolin mining areas as well as along roads.

(3) The Barnwell deposits are thin and lie near the surface in the outcrop area. The sands are typically unconsolidated, loose, very permeable, and have been considerably altered both mineralogically and chemically by ground-water conditions.

(4) Earlier authors' concepts of formations, especially those of C. W. Cooke, were different from our present lithostratigraphic concepts. Formations as understood and applied by Cooke were quasichronostratigraphic-biostratigraphic units whose recognition was based on fossil content or assumed biostratigraphic equivalency. If two deposits had different lithologies but similar or identical faunas, only one formation name was applied (for example, 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]).

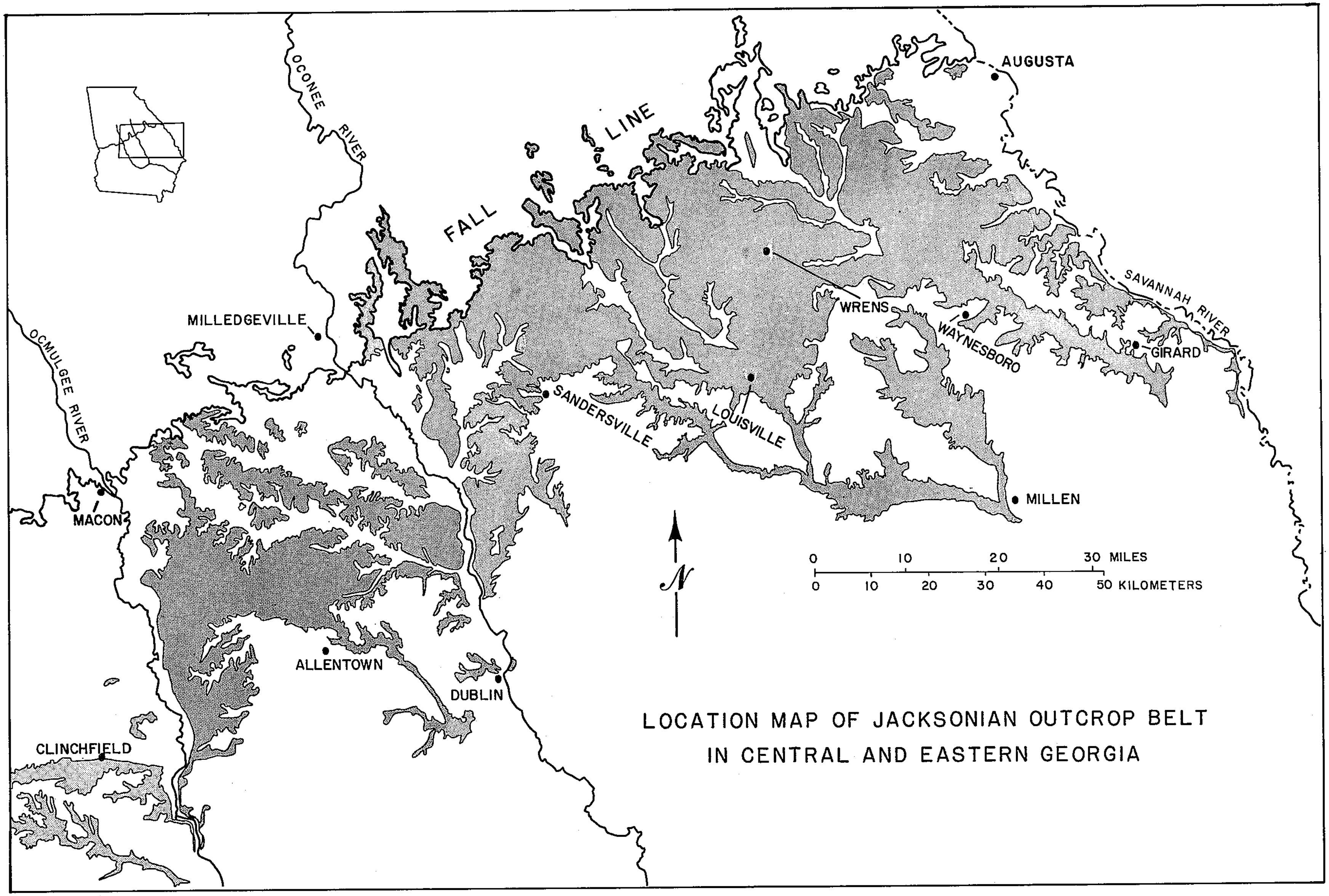


Figure 1. Location map of the Jacksonian outcrop belt in central and eastern Georgia.

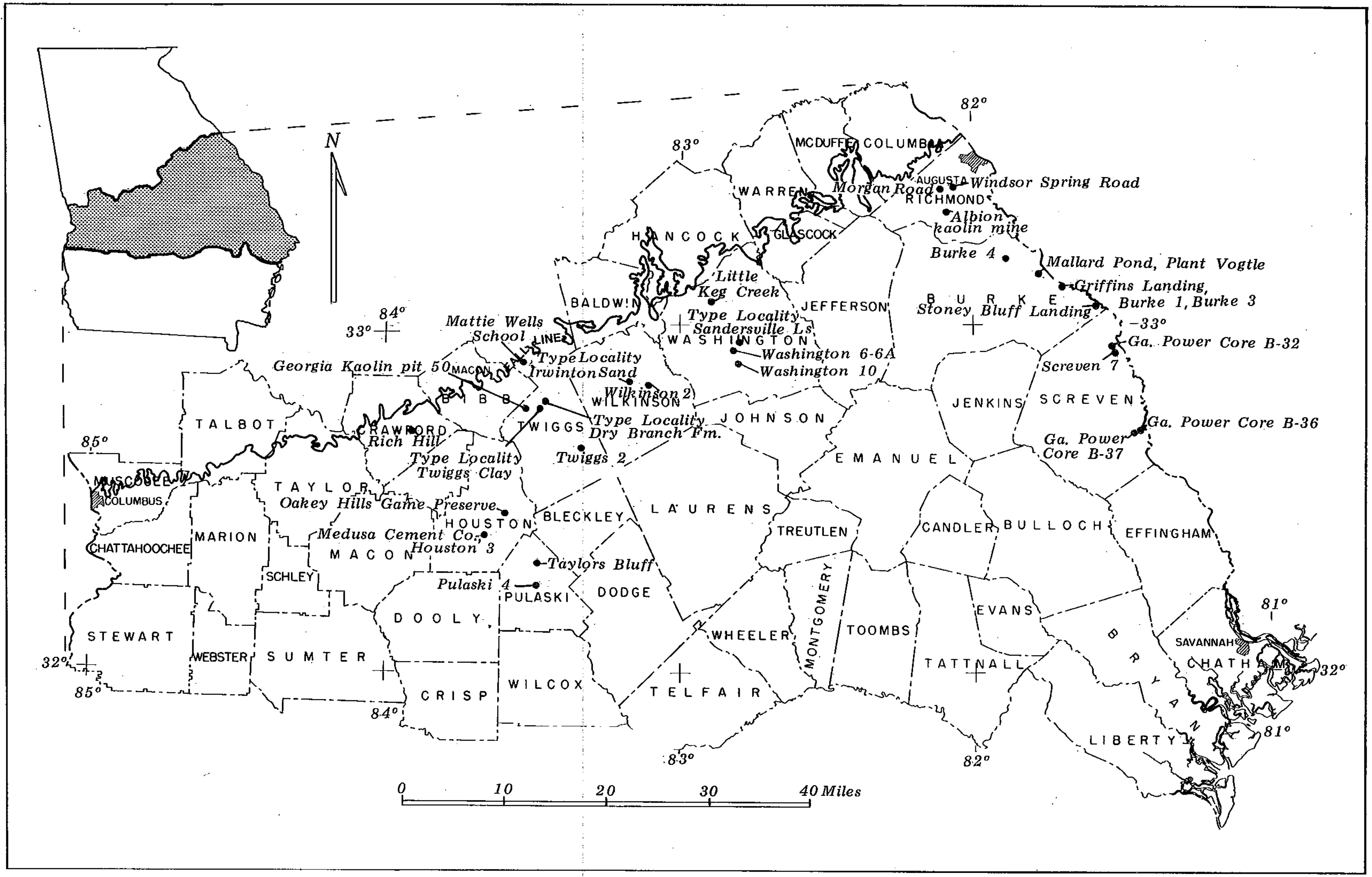


Figure 2. Location map of Jacksonian reference localities, type localities, and core sites in Georgia.

(5) Most of the upper Eocene sediments in western South Carolina and eastern Georgia are noncalcareous and nonfossiliferous even before weathering, resulting in intrinsic difficulty in treating these deposits biostratigraphically and chronostratigraphically.

The investigation of the upper Eocene deposits of central and eastern Georgia, of which this stratigraphic revision is a part, was initiated in 1972 when work on the Geologic Map of Georgia (Georgia Department of Natural Resources, 1976) began. The basic working model of the Barnwell Group described in this report was more or less defined by 1974. Field work did not consist of one extended field excursion, but rather was done as necessity demanded and as time permitted. The data collected during one field trip session was generally fully digested and the results and implications discussed, further problems and questions defined, and new objectives determined before the next trip to the field. Field work done in this fashion extended intermittently from 1972 until 1979. The working model of the upper Eocene deposits that has evolved has undergone field checking as well as numerous adjustments to accommodate further field and drill core information.

Standard field and laboratory procedures were followed throughout this investigation. In our field descriptions we used Ingram's (1954) terminology for bedding thickness, the Wentworth (1922) scale for grain size, field approximations for describing degrees of sorting, and the Munsell Color System for describing sediment or rock colors (Rock-Color Chart Committee, 1963).

HISTORICAL REVIEW

The quasichronostratigraphic-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 that has been developed by the authors over the past ten years (Huddlestun and Hetrick, 1978; Huddlestun and Hetrick, 1979). The lithostratigraphic framework is as follows. For the marine middle Eocene, only the Lisbon Formation is recognized in the inner Coastal Plain of eastern Georgia and western South Carolina. The Lisbon Formation is equivalent to the concept or meaning of the McBean Formation of previous authors. However, the McBean Formation of previous authors is not entirely equivalent lithostratigraphically to the Lisbon Formation of this report. In the Savannah River area, the Lisbon Formation is typically a fine, rarely coarse, well-sorted, massive-bedded, microfossiliferous and sporadically macrofossiliferous, argillaceous, calcareous sand or argillaceous calcarenite with scattered lenses of impure limestone and, rarely, impure clay. The McBean is considered by the present authors to be a member of the Lisbon Formation and is characteristically an impure limestone (see Brantly,1916, p. 44-55) that is restricted only to the McBean-Shell Bluff area in Georgia. The McBean limestone member grades laterally into the Blue Bluff member of the Lisbon Formation (Huddlestun, in review; also see Huddlestun, 1981; and Brantly, 1916, p. 54). The Blue Bluff member is a very thinly layered to laminated, fine-grained, microfossiliferous, argillaceous, silty calcarenite.

The Barnwell Group consists of 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 by the Albion Member (Carver, 1972) in Richmond County. The Dry Branch Formation consists of three members: the Twiggs Clay Member, Irwinton Sand Member, and Griffins Landing Member. 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.

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.

Sloan (1908) named the "Barnwell phase," a quasichronostratigraphic 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 entirely consistent with the lithologies of the Barnwell as presently exposed in the Savannah River area of Georgia and South Carolina.

Veatch and Stephenson (1911, p. 235-284) named the McBean Formation for middle Eocene Claiborne-age deposits exposed along McBean Creek in the vicinity of the community of McBean, Richmond County, Georgia (also see Huddlestun, 1982, p. 24). They (Veatch and Stephenson, 1911, p. 242) presented five measured sections exposed in ravines on the south side of McBean Creek in Burke County. The part of the five sections that is still exposed is the Barnwell (Tobacco Road?) residuum in the upper part of the sections. Only at the mouth of the northernmost ravine is the McBean limestone member still exposed. However, it would appear that the only McBean limestone in sections 3, 4, and 5 of Veatch and Stephenson is bed 1 for each section. The rest of the overlying McBean (p. 242) is evidently Twiggs clay lithofacies of the Dry Branch Formation, based on the authors' knowledge of the McBean and Dry Branch lithologies and of their knowledge of the particular area discussed by Veatch and Stephenson (1911, p. 242). In retrospect, it would appear that the initial definition and application of the name McBean rendered both the McBean and Barnwell formations ambiguous to later authors by the probable inclusion of what later would be recognized as the lower part of the Barnwell (Cooke and Shearer, 1918; LaMoreaux, 1946b, p. 53) in the type section of the McBean.

Veatch and Stephenson (1911, p. 267-284) also extended the Congaree of Sloan (1908) into Georgia as a member of the McBean Formation (Fig. 3). 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 of subsequent authors to the Congaree and McBean, respectively.

The main concept of the Barnwell Sand that Veatch and Stephenson (1911, p. 285-296) adopted from Sloan (1908) consisted of deeply weathered red sand that commonly contains beds of chert, fossiliferous chert, and chert-cemented sandstone (buhr sands) 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 and at high elevations. Correlation indicates that the deeply weathered red sand is residuum of the Tobacco Road Sand. Therefore, 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 had been clearly and unambiguously included in the McBean Formation and assumed to be of middle Eocene age (Fig. 3).

Brantly (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 at Shell Bluff on the Savannah River. The percent limestone in these nine samples ranged from approximately 70 percent to 87 percent, 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 (Fig. 3). They showed this transferral 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 Clairbornian 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).

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 (1908) and included the deposits that formerly had been assigned to those "formations" in 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) definitely can be 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.

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."

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 Formation and Barnwell Formation 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, 1946a, 1946b; 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 northernmost 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. Similarly, 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 (Fig. 3). 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

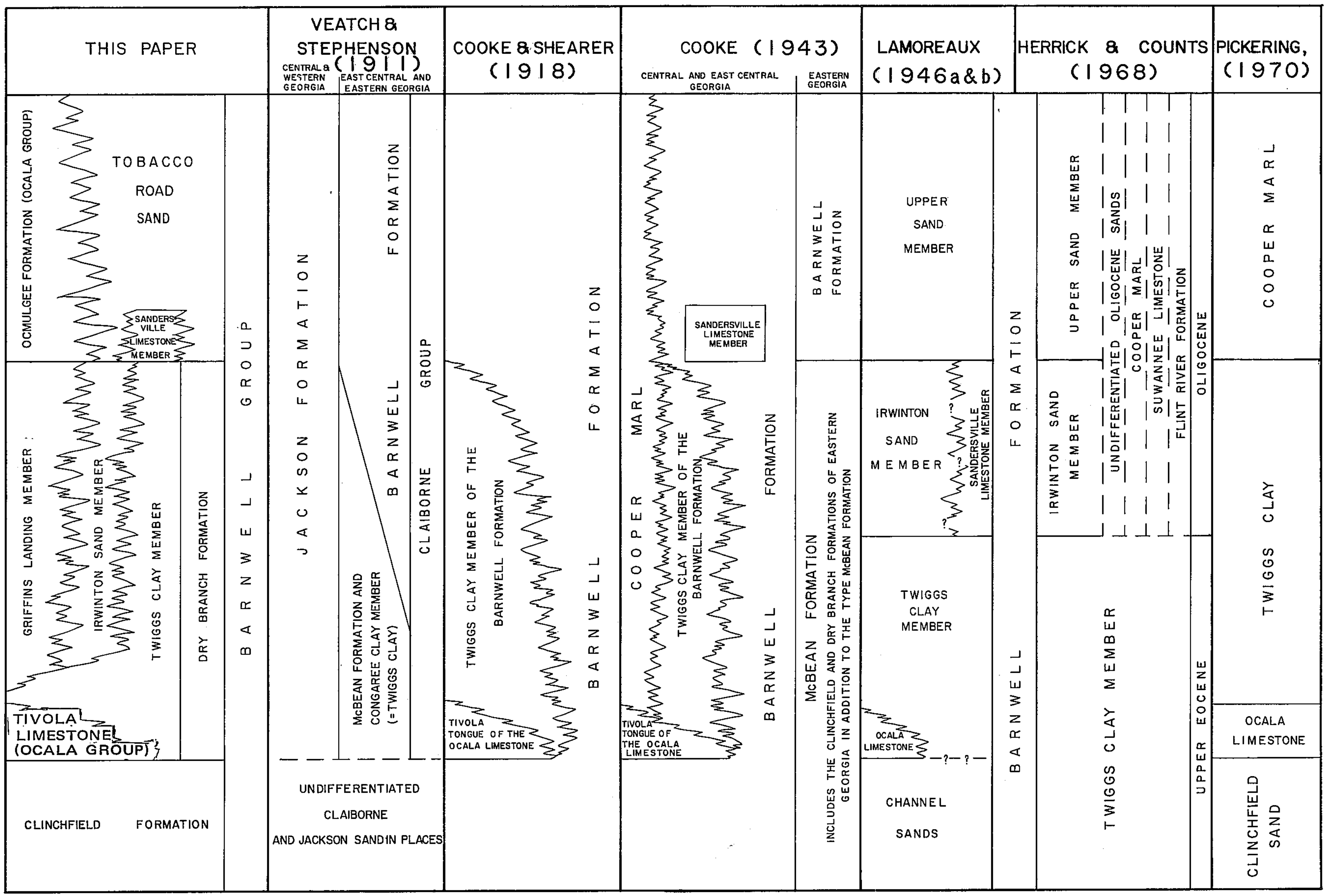


Figure 3. Chart of Jacksonian stratigraphic usage and terminology in Georgia.

sands were understood to be late Eocene in age and, by definition, Barnwell Formation because they overlie the Ocala Limestone of unquestioned late Eocene age (Cooke, 1943, p. 66, 67). Therefore, 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 (it is replaced by a 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 Members) 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).

Cooke and Munyan (1938, p. 792) and Cooke (1943, p. 74-77) were the first to recognize the distinctive features of the upper limestone of the Jacksonian deposits exposed on the Ocmulgee River above Hawkinsville in Pulaski County, and at Millen in Jenkins County. They correlated these limestones with the Cooper Marl of South Carolina on the basis of the then-understood age of the Cooper Marl (Cushman, 1935), to some extent on stratigraphic position in Georgia, and on the basis of lithology. Since then, however, there has been considerable uncertainty as to the stratigraphic relationships of the limestone, especially in the Houston-Pulaski Counties area. Much of the uncertainty must have originated with Cooke's (1943) discussion of these deposits along the Ocmulgee River and between Hawkinsville and Clinchfield. Pertinent points of his discussion are as follows:

(1) Cooke (p. 74) correlated these deposits with the Cooper Marl of South Carolina, most of which subsequently were determined to be of Oligocene age.

(2) He (p. 76) correlated the Cooper Marl, as he understood it on the Ocmulgee River, with the lower part of the Twiggs Clay at Clinchfield.

(3) He (p. 73, 74) suggested that the limestone exposed at water level at Hawkinsville and upriver from Hawkinsville may be Ocala Limestone (= Tivola Limestone). However, he mapped these limestones as Cooper Marl.

(4) He (p. 76, 77) was uncertain as to the stratigraphic relations of the deposits at Taylors Bluff and at Hawkinsville, referring to the massive limestone at Taylors Bluff as "supposed Ocala limestone." He "suspected" that the soft marly limestone intervening between the Flint River formation at Hawkinsville and the supposed Ocala Limestone at Taylors Bluff represented the Cooper Marl. Furthermore, he (p. 77) implied that bed 4 of Veatch and Stephenson (1911, p. 305) at Taylors Bluff is Ocala Limestone based on the reported presence of *Amusium ocalanum*, a typical Ocala fossil. He considered the massive granular limestone that overlies bed 4 of Veatch and Stephenson to be "probably the Cooper Marl."

These observations are consistent with his comment (Cooke, 1943, p. 75) that "the Cooper Marl overlies the Ocala limestone with apparent conformity."

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 (1946a, 1946b) 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, 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 this report) west of the Ocmulgee River, because both units in their respective areas overlie the Twiggs Clay (Fig. 3).

Cooke and MacNeil (1952, p. 21-23) again redefined the McBean Formation in South Carolina. Their subdivision of the middle Eocene deposits paralleled Sloan (1908). Cooke and MacNeil's (1952) subdivision 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. The *Ostrea sellaeformis zone* 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 Cook 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 sellaeformis*, 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 observed 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 (personal commun., 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 include, in principle, 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 quasichronostratigraphic-biostratigraphic unit.

Cooke and MacNeil (1952) revised the age determination of the Cooper Marl in South Carolina to lower Oligocene, based on the presence of the small scallop *Chlamys cocoana* and the foraminifer *Bolivinella rugosa*. The ranges of both were thought at the time to be restricted to the Red Bluff Clay and equivalent deposits of earliest Oligocene age in Mississippi and Alabama.

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 (1967, 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 prominent parts of the 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 (?) Formation of Siple (1967) is evidently Twiggs Clay because no Congaree in the strict sense is known to occur in the Savannah River area and because the Dry Branch Formation does directly overlie the "Tuscaloosa Formation" in much of Aiken County (Nystrom and Willoughby, 1982). Furthermore, the "Fuller's earth appearance" of hackly gray clay, and "greenish-gray clay" (p. 47) is 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 in the Savannah River area included both the strict 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 sandy clay of the Tertiary Barnwell Formation" (Siple, 1967, Fig. 7, p. 27) is not Barnwell but rather deeply weathered, brownish-red "Tuscaloosa Formation" that stratigraphically overlies various kaolin lenses or beds. 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 or beds of impermeable clay. Similarly, Siple (p. 60) believed that *Ophiomorpha nodosa* (= *Halymenites major* of Siple) occurs only in the "Hawthorne Formation." It is the experience of the present authors that, in the Savannah River area, *Ophiomorpha nodosa* does not occur in the McBean Formation, is very rare in the Dry Branch Formation, and is not known in the fluvial "Hawthorne Formation" (Altamaha formation [see Huddlestun, 1981]).

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 and others (1969) are derived directly from Cooke and MacNeil (1952) and Siple (1967) and need no further discussion here.

Cooke's (1943) concept of the upper Eocene stratigraphic framework in the Clinchfield-Ocmulgee River area appears to have considerably influenced Carver (1966) and possibly Connell (1959). Carver (1966, p. 83-92) clearly considered the Cooper Marl to be an intermediate facies between the Twiggs Clay and the Ocala Limestone. According to this stratigraphic model, the Twiggs Clay and the Cooper Marl both conformably overlie the Ocala Limestone (Tivola Limestone of this report) and the Irwinton Sand overlies both the Twiggs Clay and the Cooper Marl. Similarly, Connell (1959, p. 65) described a section 0.25 mile (0.4 km) east of Taylors Bluff in which he determined that the Tivola Limestone as he understood it (Ocmulgee Formation of this report) overlies the Twiggs Clay.

Pickering (1966, 1970) recognized and defined the proper formational sequence of the marine deposits in the Perry-Hawkinsville-Cochran area (Fig. 3). In ascending order these are the Clinchfield Sand, Ocala Limestone (Tivola Limestone), Twiggs Clay, Cooper Marl (Ocmulgee Formation), Byram Formation Unit B (Marianna Limestone), Bryam Formation Unit A (Glendon Limestone), and Flint River formation (residuum of late Oligocene age). Pickering (1970, p. 11, 12) specifically noted that the Ocala Limestone (Tivola Limestone) and the Cooper Marl (Ocmulgee Formation) are separated in the section by 30 to 58 feet (9 to 18 m) of Twiggs Clay. A later investigation found the Twiggs Clay at Clinchfield to be over 100 feet (30 m) thick (Huddlestun and others, 1974). In addition, Pickering (1970, p. 7-9) defined and described the Clinchfield Sand, and he suggested (p. 33) the utility of the fossil *Periarchus quinquefarius* as a guide fossil in Georgia due to its apparent limited occurrence in a small part of the geologic section. Based on this observation, he suggested the correlation of the Cooper Marl (Ocmulgee Formation) with the Sandersville Limestone.

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 (Fig. 3).

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 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 and others, 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 and others, 1969). The Barnwell Formation of this stratigraphic model is 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 has generally been 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 by Cooke and Shearer (1918), LaMoreaux (1946a, 1946b), and Huddlestun and Hetrick (1978, 1979). 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.

REGIONAL STRATIGRAPHIC SYNTHESIS

AGE AND CORRELATION OF THE BARNWELL GROUP AND ASSOCIATED DEPOSITS OF GEORGIA WITH THE JACKSONIAN DEPOSITS OF MISSISSIPPI AND ALABAMA

In order to securely tie the Barnwell deposits of Georgia to the regional stratigraphic framework, they must be: (1) correlated to the provincial type sections or type area; (2) correlated to the cosmopolitan or European time-stratigraphic framework; and (3) defined in a common, or at least mutually understood, regional stratigraphic terminology. First of all, the Barnwell deposits have been understood to be late Eocene in age (Cooke and Shearer, 1918; Cooke, Gardner, and Woodring, 1943; LaMoreaux, 1946a, 1946b) because they contain a late Eocene fauna (Conrad, 1856; Harris and Palmer, 1946-1947). The principal reference area in the Coastal Plain for deposits of late Eocene age is in the State of Mississippi because quite early in the geological investigations of the region, rich molluscan faunas were collected and described from upper Eocene deposits in that state (Conrad, 1856). Subsequently, the documented molluscan assemblages allowed correlation and comparison with those of superjacent deposits and with surrounding areas.

Until now there has been no attempt to precisely correlate the Barnwell deposits of Georgia with the described upper Eocene deposits of Mississippi and Alabama, or with the worldwide biostratigraphic and time-stratigraphic zonation and correlation schemes that have been developed over the past few years (Bolli, 1957; Blow, 1969; Berggren, 1972; Hardenbohl and Berggren, 1978; Stainforth and others, 1975). In order to establish the upper Eocene Jacksonian stratigraphic framework from Mississippi through Georgia and to attempt to develop fine resolution correlation of the Barnwell Group with the typical upper Eocene Jacksonian of the western area, the senior author has measured, sampled, and described many critical upper Eocene sections in Mississippi, Alabama, Florida, and Georgia (Huddlestun, 1965; Huddlestun and Hetrick, 1978). Microfossil samples were collected from all of the localities visited and the senior author processed and examined all of the foraminiferal samples. In addition, macrofossils have been collected where present, and their *in situ* stratigraphic position has been documented.

Originally, the upper Eocene deposits of Mississippi were called the Jackson Formation from the city of Jackson in Hinds County, Mississippi (Conrad, 1856; Hilgard, 1860; Lowe, 1915). The Jackson Formation consisted of a richly fossiliferous basal sand (Moodys Branch Marl Member which contains the described shelly fauna) and an overlying, thick clay sequence (Yazoo Clay Member).The Jackson Formation was subsequently raised to group rank and the Moodys Branch and Yazoo Clay were likewise raised in rank to formations. In the eastern half of Mississippi the middle part of the Yazoo Clay becomes consistently sandy and, as a result, Murray (1947, 1948) proposed a four-part subdivision of the formation in that area. In ascending stratigraphic order these include the North Twistwood Creek Clay Member, the Cocoa Sand Member, the Pachuta Marl Member, and the Shubuta Clay Member. Murray and Wilbert (1950) proposed changing the sense of the name Jackson from Jackson Group (a lithostratigraphic unit) to Jacksonian Stage (a chronostratigraphic unit). Holland, Hough, and Murray (1952) proposed raising the Yazoo Clay to group rank to better accommodate the various subdivisions of the Yazoo in Louisiana, Mississippi, and Alabama.

Toulmin and others (1951), Huddlestun (1965), Huddlestun and Toulmin (1965), and Toulmin (1977) extended the Mississippi Yazoo subdivisions eastward into the central part of Alabama (Fig. 4; see also Cooke, 1926). However, east of central Alabama the Jacksonian outcrop belt passes southeastward into Florida and the Yazoo merges laterally by facies change into the Ocala Group (Fig. 5; Vernon, 1942; Moore, 1955; Puri, 1957). The Jacksonian

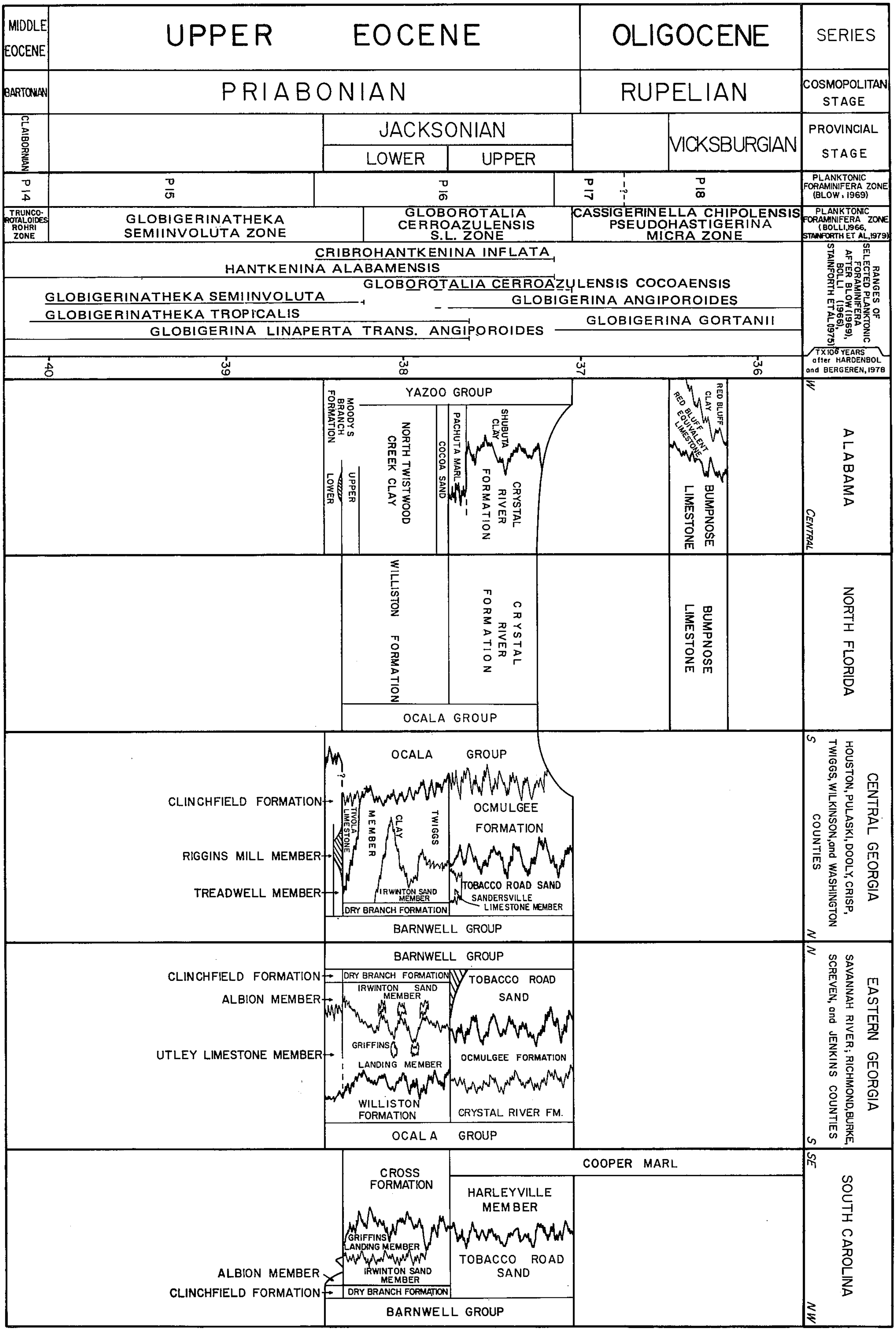


Figure 4. Correlation chart.

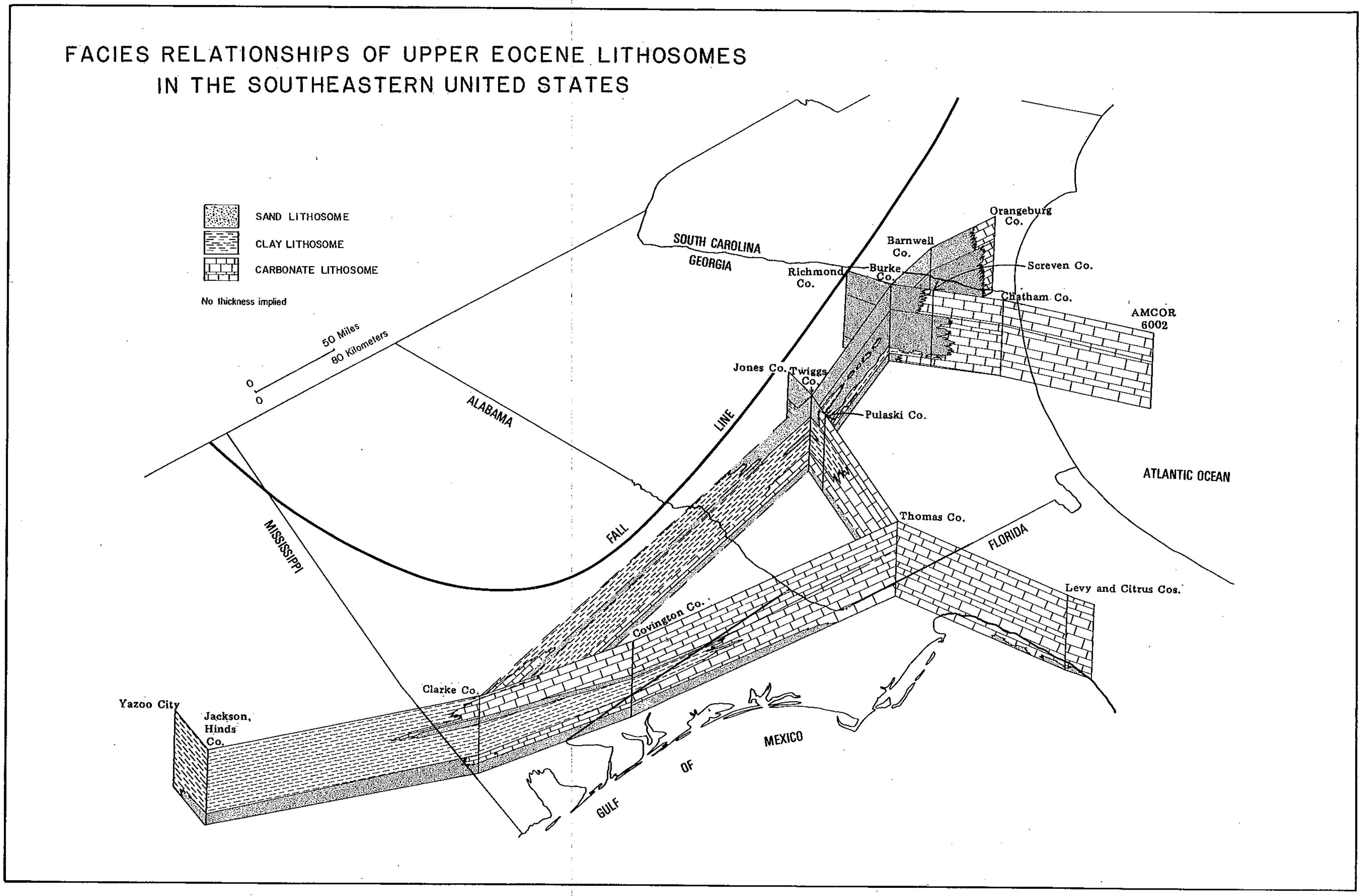


Figure 5. Facies relationships of upper Eocene lithosomes in the southeastern United States.

deposits from the vicinity of the Choctawhatchee River in Alabama to Dooly County in Georgia are represented by the carbonates of the Ocala Group. Only the lower part of the Moodys Branch Formation retains its sandy character across Alabama to the Chattahoochee River (Toulmin and LaMoreaux, 1963; Huddlestun, 1965; Huddlestun and Toulmin, 1965).

Eastward, the Jacksonian deposits in northern Dooly, Pulaski, Houston, and Crawford Counties, Georgia, i.e., in the area between the Flint and Ocmulgee Rivers, appear to be a composite series of intertonguing sediments consisting of Yazoo-type clays (Twiggs Clay) from the west, Barnwell-type sand (Clinchfield Formation and Irwinton Sand [= Roberta Sand of Connell, 1958]) from the east, and Ocala-type limestone (Tivola Limestone) from the south (Figs. 4 and 5). The Ocmulgee Formation is more reminiscent of the transitional facies between the Yazoo and Ocala that is most characteristically developed in southwestern Alabama. East of the Ocmulgee River in Georgia the Jacksonian deposits are represented mainly by the Barnwell Group.

REGIONAL STRATIGRAPHIC RELATIONSHIPS

The Jacksonian in the Southeast can be divided into a lower Jacksonian and an upper Jacksonian, separated by a "marker zone" or discontinuity that generally is a conspicuous contact in the field (Huddlestun and Hetrick, 1978, p. 73, 74). This boundary or contact can be traced in the field from eastern Mississippi to central South Carolina (see Fig. 4). As stated elsewhere (Huddlestun and Hetrick, 1978), the authors believe that the origin of this boundary is a change in physical conditions on the continental shelf and a minor epeirogenic uplift in the Piedmont. There appears to be a minor and subtle fluctuation of sea level at the discontinuity, with a mild marine regression at the top of the lower Jacksonian followed by overlapping transgressive deposits of the Pachuta Marl in Mississippi and Alabama, a flat pebble bed at the base of the Tobacco Road Sand in eastern Georgia and western South Carolina, and a zone of phosphate pebbles and phosphatized fossils at the base of the Harleyville Member of the Cooper Marl in South Carolina. The sediments deposited after the transgression were consistently different lithologically from the sediments deposited earlier, thus indicating a permanent change in conditions on the continental shelf.

A second, less clearly defined boundary or contact representing an even more subtle event occurs in the lower part of the section that has commonly been assigned to the Jacksonian. The correlation of this boundary has not been reliably completed yet, but involves the upper Moodys Branch/lower Moodys Branch contact in Alabama, the Tivola-Dry Branch/Clinchfield contact in Georgia, and the Williston/Inglis contact in Florida. The problem of the Claibornian-Jacksonian boundary is also involved in the recognition of this contact.

The lower Jacksonian of our usage consists of those deposits underlying the "marker zone" or discontinuity, and the upper Jacksonian consists of those deposits overlying the "marker zone" or discontinuity. It is emphasized here that in the past the names "lower Jackson," "upper Jackson," "lower Ocala," and "upper Ocala" have been used in an approximate sense by many investigators. In reality, what appears to have been meant by these terms is "lower part of" and "upper part of." We have adopted similar but specific usage in this paper.

Traced eastward from eastern Mississippi, the upper Jacksonian includes the Pachuta Marl, Shubuta Clay, Crystal River Formation, Tobacco Road Sand, Ocmulgee Formation, and the lower part of the Cooper Marl (Harleyville and Parkers Ferry Members) (Fig. 4). Similarly, traced eastward from Mississippi the lower Jacksonian consists of the Moodys Branch Formation, North Twistwood Creek Clay, Cocoa Sand, Dry Branch Formation, Tivola Limestone, and Williston Formation. The formations underlying the lower, less clearly defined boundary include the "lower Moodys Branch Formation" of Huddlestun (1965) in Alabama, and the Clinchfield Formation in Georgia (Fig. 4).

The three formations that constitute the Barnwell Group conform to this regional three-part subdivision of the Jacksonian separated by regional contacts. The Tobacco Road/Dry Branch contact is the upper Jacksonian/lower Jacksonian boundary within the Barnwell Group. Beds of various distinctive lithologies are associated with this contact. These include greensand beds; beds and lenses of thinly interlayered, very fine sand and clay; limestone and chert beds; and dark-gray to black sulphurous clay, all at the top of the Dry Branch Formation. Overlying this is the discontinuous flat-pebble bed. These deposits suggest a period of diminished clastic sedimentation near the end of early Jacksonian time followed by deposition of a transgressing beach deposit near the beginning of late Jacksonian time. In the field, this "marker zone" allows ready recognition of the middle part of the Barnwell Group and is the easiest, and perhaps the only, contact consistently recognizable above the base of the Barnwell Group in Georgia and South Carolina.

The upper Jacksonian/lower Jacksonian boundary retains its identity going down the dip from the Barnwell Group into the Ocala Group. In the Pulaski County area, the Ocmulgee/Twiggs contact represents this boundary and farther down the dip in the subsurface, it is represented by the Crystal River/Williston contact.

The physical change between the Clinchfield and Dry Branch (this includes the Clinchfield/Tivola contact as well because we consider the Tivola Limestone of the Ocala Group to be facies related to the Dry Branch Formation and not to the Clinchfield Formation) is more subtle than the lower/upper Jacksonian contact and appears to be more commonly gradational. At many sites the Dry Branch (or Tivola)/Clinchfield contact is clearly gradational, but at some sites there is an abrupt change in lithology, suggesting a discontinuity.

The sets of lithologies, however, that distinguish the Clinchfield from the Dry Branch suggest that there was a fairly uniform, if subtle, change in nearshore environmental and depositional conditions at the end of Clinchfield deposition. These conditions were not repeated during the Jacksonian except on minor or local scales. For example, the widespread, poorly sorted, clayey, sandy, pebbly, shelly facies of the Riggins Mill; the Utley type of limestone lithology; the nodular, calcareous, fossiliferous, massive-bedded, argillaceous, fine to medium sand (upper bed of type Riggins Mill); and the spiculitic Albion-type lithologies are not repeated in either the overlying Dry Branch or Tobacco Road Formations. All this suggests that there was a subtle, very minor regional geological change that occurred near the end of Clinchfield deposition.

Similarly, the Twiggs Clay lithology, thin-bedded to laminated Irwinton Sand lithology, and Griffins Landing lithology are not found in significant occurrences in either the underlying Clinchfield

Formation or in the overlying Tobacco Road Sand. The distinctive Dry Branch lithologies appear to be largely restricted to the Dry Branch Formation. There is also no evidence, in the field or in cores, that the Dry Branch Formation (Twiggs and Irwinton lithofacies) grades laterally into the Ocmulgee Formation of the Ocala Group (see Fig. 6) as has been suggested in the past (Cooke, 1943; LaMoreaux, 1946a; Connell, 1959; Carver, 1966; Georgia Dept. Natural Resources, 1976). All of the field and core evidence indicates that the Ocmulgee Formation (Cooper Marl of earlier authors) grades laterally updip only into the Tobacco Road Sand. Furthermore, there is no unequivocal evidence that the Tobacco Road Sand grades downdip into Oligocene deposits as claimed by Herrick and Counts (1968) (also see Zullo and others, 1982). On the other hand, the Tivola Limestone of the Ocala Group grades laterally both updip and to the east into the Twiggs Clay Member of the Dry Branch Formation (Fig. 6). There is no evidence that the Tivola Limestone grades directly into the Irwinton Sand Member and, therefore, the Twiggs Clay can be viewed as an intermediate facies between the Barnwell sand facies (Irwinton) and the Ocala limestone facies (Tivola).

In summary, the three formations of the Barnwell Group and their equivalents are not significantly time transgressive with respect to each other as are the various facies within the formations. The formations do not appear to grade laterally into each other, nor to interfinger with one another up the dip, down the dip, or parallel to the shoreline (Fig. 6). The formation contacts appear to represent "marker zones" and appear to be roughly synchronous in Georgia and South Carolina. Deposition of each formation appears to have been initiated and terminated by regional geological "events" and not by facies migrations.

BIOSTRATIGRAPHIC DISCUSSION

The well-preserved, varied, and abundant mollusk-rich shell beds of the Moodys Branch Formation in Mississippi (Conrad, 1856; Harris and Palmer, 1946-1947; Dockery, 1977) are not found east of that state. Therefore, there has been no attempt yet to develop a mollusk-zoned biostratigraphic framework of the eastern Gulf and south Atlantic Coastal Plain. On the other hand, the Barnwell deposits do contain rare and scattered mollusk-bearing beds and check lists from various sites have been presented (Veatch and Stephenson, 1911; Cooke and Shearer, 1918; Cooke, 1943). The echinoids, particularly of the genus *Periarchus*, have been more useful in internal correlation within Georgia and between Georgia and the eastern Gulf Coastal Plain. However, caution must be exercised in employing *Periarchus* for correlation purposes since it appears to occur only in nearshore sands. Correlation based on *Periarchus*, therefore, is in part correlation based on similarity of environment.

The senior author has based the regional, Jacksonian biostratigraphic correlation primarily on planktonic foraminifera, and to a lesser extent on the benthic foraminifera (Fig. 4). Furthermore, he has adopted and merged the tropical planktonic zonation schemes of Bolli (1957), Blow (1969), Berggren (1972), and Stainforth and others (1975).

In the State of Mississippi, the only stratigraphic units in which we have not found adequate planktonic foraminiferal assemblages for correlation purposes are the North Twistwood Creek Clay and Cocoa Sand, both of early Jacksonian age. However, the Dry Branch Formation in Georgia and the Cocoa Sand in Alabama, which are equivalents to the two Mississippi units respectively, locally contain adequate planktonic foraminiferal assemblages for correlation studies and for calibration of evolving species and assemblages.

Paleontologically, the base of the Jacksonian is defined easily on planktonic foraminifera, where they are present. The underlying Claibornian strata are characterized by the almost ubiquitous presence of the early Tertiary (upper Paleocene through middle Eocene) hispid planktonic foraminifera, *Truncorotaloides* and *Acarinina*, and the subgenus *Globorotalia (Morozovella)*. For the upper Claibornian deposits underlying the Jacksonian (excluding the Gosport Sand which contains a very sparse planktonic foraminiferal suite) these include: *Globorotalia (Morozovella) spinulosa, Truncorotaloides topilensis, and T. rohri*. These species, except for the related form, *T. inconspicua*, are totally absent in the overlying Jacksonian strata.

The critical planktonic foraminifera that are present in the Moodys Branch Formation at Riverside Park, the main reference locality in Jackson, Mississippi, include: *Globigerinatheka semiinvoluta, G. tropicalis, Cribrohantkenina inflata, Hantkenina alabamensis, Globigerina linaperta-angiporoides, Globorotalia cerroazulensis* and *G. increbescens*. *Globigerinatheka semiinvoluta*, and *C. inflata* are restricted to the upper Eocene, whereas *G. tropicalis, G. cerroazulensis*, and *G. increbescens* are reported to occur also in the youngest middle Eocene. However, these species are characteristic of the upper Eocene and not of the middle Eocene. This association restricts the Moodys Branch Formation to approximately the transition from zones P15 and P16 of Blow (1969) (see Fig. 4).

In most places, lower Jacksonian deposits, including the Moodys Branch Formation, contain a sparse planktonic foraminiferal assemblage. The single exception to the spotty occurrence of planktonic foraminifera in the lower Jacksonian is the almost ubiquitous presence of the species *Truncorotaloides inconspicua* (Howe) (also see discussion of *T. rohri* in Stainforth and others, 1977, p. 223), which ranges from the base of the *Cubitostrea sellaeformis* zone of the Lisbon Formation (Oman, 1965) through the Jacksonian and lower Vicksburgian Stages. The lower part of the Moodys Branch at Claiborne Bluff (Dellet sand of Stenzel, 1952) and upper Moodys Branch Formation on the Conecuh River in Covington County, Alabama, do however, contain diverse planktonic foraminiferal assemblages identical to those at the type locality of the formation. Some planktonic foraminifera are present in the Clinchfield Formation at the type locality. These include *Globorotalia cerroazulensis pomeroli, Globigerinatheka* sp., *Globigerina linaperta, G. eocaena, G. officinalis*, and *G. ouachitaensis*. This assemblage is not diagnostically Jacksonian, however. The above species, although present in Claibornian deposits, do not occur at Clinchfield with the typically Claibornian hispid species. The Claibornian hispid species occur at Clinchfield in the underlying Lisbon Formation which is present in cores and can be seen from time to time dredged up and deposited on spoil heaps in the quarry.

The North Twistwood Creek Clay of Alabama is not known to contain planktonic foraminifera, except for the ubiquitous *Truncorotaloides inconspicua*. Sparse assemblages of planktonic foraminifera, however, are known from the Dry Branch Formation. The most varied of these assemblages is from the Griffins Landing Member in the core Burke 1 (GGS-1171) at Griffins Landing. At a depth of 145 feet in the core, approximately 42 feet (13 m) above the base of the Dry Branch, the following assemblage has been observed: *Globorotalia cerroazulensis cocoaensis, G. incre-*

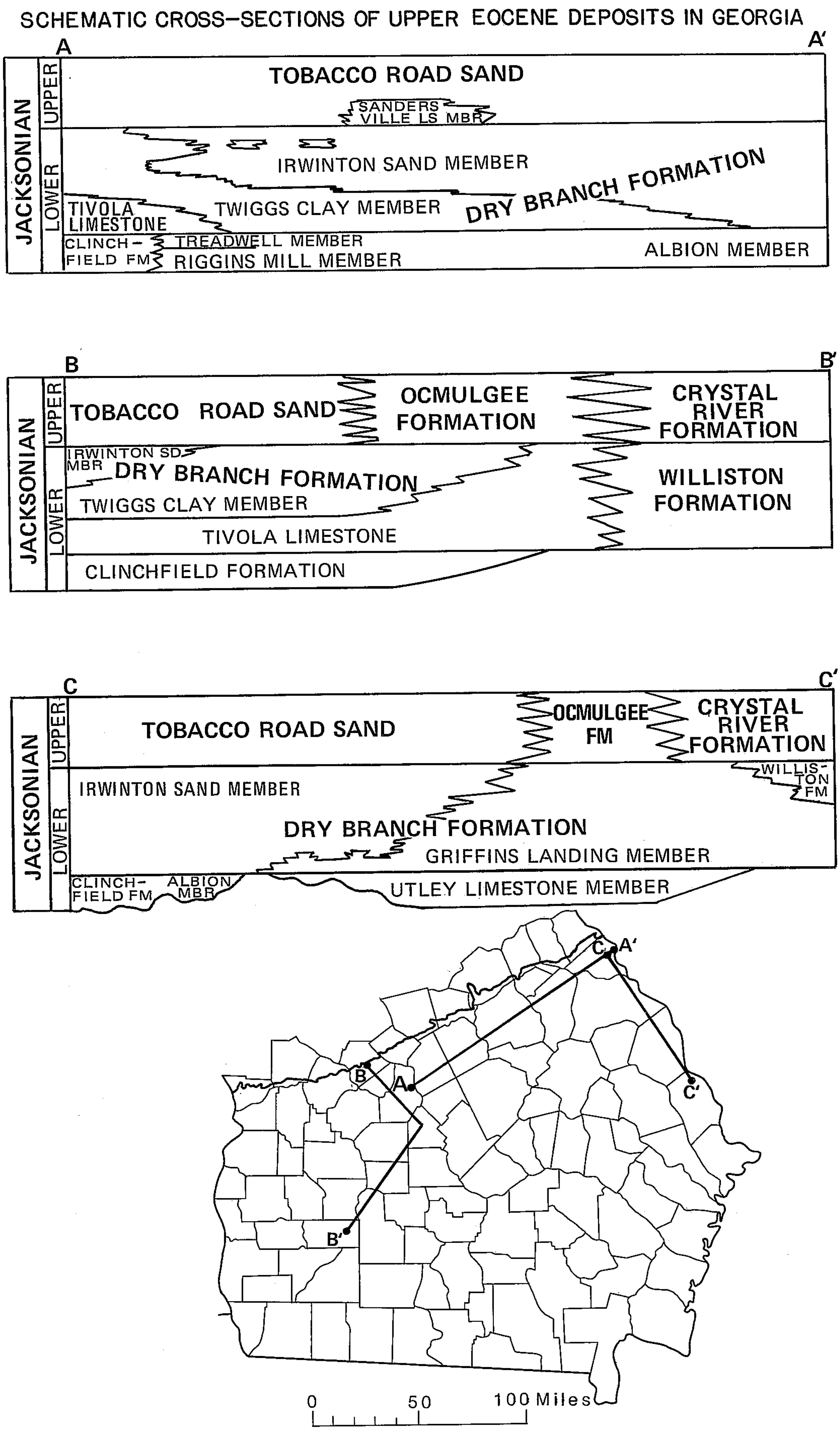


Figure 6. Schematic cross-sections of upper Eocene deposits in Georgia.

bescens, *Truncorotaloides inconspicua*, *Globigerinatheka tropicalis*, *Hantkenina alabamensis*, *Globigerina linaperta*, *G. eocaena*, G. *tripartita*, G. *ouachitaensis*, *Globorotaloides suteri*. Elsewhere (for example, in the uppermost part of the Twiggs Clay at Clinchfield, from clay between beds of greensand; in the core Houston 3 [GGS-3097]; and from the Griffins Landing Member from a depth of 145 feet in the core Screven 7 [GGS-1175]). small assemblages dominated by *Globorotalia increbescens*, *G. eocaena*, and *G. tripartita* have been observed.

Because planktonic foraminifera are so abundantly represented in upper Jacksonian deposits in the southeastern United States, the senior author has utilized them more than the other kinds of fossils in establishing correlation. The chief differences among planktonic foraminiferal assemblages between lower and upper Jacksonian consist of the following: *Globigerinatheka semiinvoluta*, though very rare, *G. tropicalis*, *Globigerina linaperta*, *Globorotalia cerroazulensis cerroazulensis*, and primitive *G. cerroazulensis cocoaensis* are characteristic of the lower Jacksonian (also see Fig. 4). *Globigerinatheka*, *Globigerina linaperta-angiporoides* and *Globorotalia cerroazulensis cerroazulensis* are very rare to absent in upper Jacksonian assemblages, whereas *G. cerroazulensis cocoaensis* is common and typical. *Cribrohantkenina inflata* ranges throughout the Jacksonian but, probably due to facies, is absent in most places in the lower Jacksonian. It is present only in the most open-marine, planktonic microfossil-rich facies of the upper Jacksonian, including the Pachuta Marl in Mississippi, the Shubuta Clay, and more rarely, the Ocmulgee Formation. *Globigerina gortanii*, the index fossil for the uppermost Eocene zone P17 of Blow (1969) is very rare in the Shubuta Clay in Mississippi and western Alabama. It is also found, very rarely, in the upper part of the Ocmulgee Formation. This zone is not present in the Crystal River Formation of central Alabama and western Florida.

In contrast to the strong distinction between middle Eocene and upper Eocene planktonic foraminifera, there is less contrast between the benthic foraminiferal assemblages of the Claibornian and the Jacksonian. This is especially a problem in eastern Georgia where the Clinchfield or Dry Branch Formations directly overlie the Lisbon Formation. Both these lower Jacksonian and Claibornian benthic foraminiferal assemblages reflect a prevailing similarity of paleoecological conditions and are dominated by such long ranging species as the following:

Textularia dibollensis
T. adalta
Nonion advenum
N. inexcavatum
N. micrus
Florilus hantkeni
Discorbis assulata
Valvulineria jacksonensis
V. texana
Gyroidina soldanii octocamerata

This Lisbon Formation in Georgia does, however, contain the index fossil *Cibicides westi* (also see Herrick and Vorhis, 1963, and Herrick, 1961, 1964).

The "*Scutella*" bed of the older literature, an acme zone of *Periarchus lyelli*, can be traced discontinuously in outcrop from Jackson, Mississippi, to the Savannah River. We emphasize, however, that the "*Scutella*" bed is not a total-range zone, nor a concurrent range zone; it is a peak zone. *Periarchus lyelli* ranges from the middle Eocene Lisbon Formation to the lowest subdivision of the Jacksonian. This lowest Jacksonian subdivision includes the Moody's Branch Formation in Mississippi, the Dellet sand of Stenzel (1952), and probably the Clinchfield Formation in Georgia. In those units, *P. lyelli* can be exceedingly abundant; in some places it dominates the lithology of the sediment. However, the "*Scutella*" bed appears to be lenticular, and the zone of abundant *P. lyelli* is discontinuous in outcrop. In some places, within the above-mentioned units, *P. lyelli* may be a minor constituent or even absent.

Periarchus lyelli appears to have evolved into *P. pileussinensis* between the lower and upper Moodys Branch Formation in Alabama (also see Toulmin, 1977, p. 121), and within the Tivola Limestone in Georgia. *Periarchus* is very rare in the upper Moodys Branch in Alabama, but *P. pileussinensis* is common to abundant in the equivalent Tivola Limestone in Georgia. *Periarchus pileussinensis* ranges from the upper Moodys Branch/Tivola to the lower part of the upper Jacksonian, the Pachuta Marl in Mississippi and Alabama, and the lowest Tobacco Road in Georgia (*P. pileussinensis* has not yet been observed in the lowest Ocmulgee Formation in Georgia suggesting, perhaps, that the oldest Tobacco Road is slightly older than the oldest Ocmulgee). In Georgia, *P. pileussinensis* appears to evolve into *P. quinquefarius* in the lowest part of the Tobacco Road, based on our observation at two localities (Huddlestun and Hetrick, 1978, p. 69). *Periarchus pileussinensis*, then, is a guide fossil of the Cocoa Sand and Pachuta Marl in Mississippi and Alabama (uppermost lower Jacksonian and lowermost upper Jacksonian) and of the Tivola Limestone and calcareous zones in the Twiggs Clay (lower Jacksonian). *Periarchus quinquefarius* is characteristic of the upper Jacksonian in Georgia, but *Periarchus* is absent from the equivalent mud clay facies, Shubuta Clay in Mississippi and Alabama, and from the open-marine carbonate shelf facies, Crystal River Formation in Alabama, Georgia, and Florida.

The upper Eocene molluscan faunas of the southeastern United States, east of the State of Mississippi, are not well documented at this time and are even less well understood in their regional and temporal context. Partly as a result of this, there has been a lingering Claibornian-Jacksonian boundary problem. The problem involves the fossil assemblages immediately above and below the contact and the recognition of an unconformity. The Claibornian-Jacksonian boundary problem has been addressed in Alabama (Cooke, 1939; Gardner, 1939; Stenzel, 1940) and was temporarily settled mainly by the identification of an unconformity in the field (MacNeil, 1946, 1947a, 1947b; Stenzel, 1952). The problem also involves the recognition and correlation of the Gosport Sand and Moodys Branch Formation and their faunas, and according to L. Ward (personal commun., 1981), the faunal problems across the Gosport-Moodys Branch /Claibornian-Jacksonian boundary have not yet been completely resolved in Alabama.

The Claibornian-Jacksonian boundary problem, involving the recognition of an unconformity and the age implications of the superjacent fauna, has recently been encountered in North and South Carolina (Ward and others, 1978; Baum and others, 1978; Ward and others, 1979; Baum and others, 1979.)

To a large extent the most critical of the faunal elements involved in the Claibornian-Jacksonian boundary problems are the Mollusca. Indeed, in Georgia the Mollusca have contributed their own

Claibornian-Jacksonian boundary problem that has never really been resolved but has been neglected, forgotten, or ignored (Veatch and Stephenson, 1911; Cooke and Shearer, 1918; Cooke, 1943; MacNeil, 1947b; Herrick, 1961; and LeGrand, 1962). The chief problem of the known molluscan fauna of the Barnwell Group based on faunal lists presented by Veatch and Stephenson (1911), Cooke and Shearer (1918), and Cooke (1943) consists of an apparent lingering presence of species that are known mainly from older deposits; principal of these is the Gosport Sand of southwestern Alabama. Such species as *Venericardia alticostata*, considered to be a guide fossil of the Gosport Sand, *Bathytormus protextus*, *Glycymeris staminea*, *Callista perovata*, and *Crassatella alta* all have previously been considered to be indicative of the Claibornian and not of the Jacksonian. However, these species (except for *C. alta*) are especially characteristic of the Riggins Mill Member of the Clinchfield Formation in Georgia (for faunal lists, see Cooke and Shearer, 1918; Veatch and Stephenson, 1911). In contrast to this evidence as to the Claibornian age suggested by the above species, *Nemocardium nicolletti*, reported only from Jacksonian strata elsewhere (Palmer and Brann, 1965, 1966; Toulmin, 1977; Dockery, 1977), occurs in association with them. In Georgia, these atypical ranges do not appear to be restricted to the Clinchfield Formation. Cooke and Shearer (1918, p. 66) and Cooke (1943, p. 64, 65) reported essentially the same molluscan assemblage, i.e., consisting of *Venericardia alticosta*, *Glycymeris staminea*, *Bathytormus protextus*, and *Callista perovata* in association with *Periarchus quinquefarius* from the vicinity of Old Town, 8.4 miles (13.5 km) southeast of Louisville in southern Jefferson County, Georgia. The lithology of the associated sediments, geographic location (Cooke, 1943, p. 64-65), and elevation of occurrence are only consistent with the upper Jacksonian Tobacco Road Sand.

It would appear, based on reported faunal lists, that even the molluscan assemblage of the Tobacco Road Sand, where one is present or can be identified, has more in common with the older Claibornian, and the Gosport Sand in particular, than with the temporally more closely related Moodys Branch Formation of Mississippi. One possible explanation is that the typical Gosport molluscan fauna that is characteristically found in sand deposits was indigenous to the southern Atlantic Coastal Plain, or continental shelf. The fauna migrated westward into the eastern Gulf Coastal Plain along with the westward expansion of its preferred sandy bottom environment. The subsequent inundation of the eastern Gulf Coastal Plain by the upper Eocene Yazoo clay muds terminated the fauna in the western area. However, where the environment remained suitable, as in the Barnwell sands, the fauna continued to flourish through the rest of the Eocene. Another possible explanation is that the Tobacco Road molluscan fauna is distinct from the Gosport fauna but was derived directly from the Gosport fauna. The Tobacco Road molluscan species may have acquired, through evolution, subtle morphological distinctions ignored by the early paleontologists.

STRATIGRAPHY

BARNWELL GROUP

DEFINITION OF STRATIGRAPHIC TERMINOLOGY

Although most investigators agree on the recognition of various named lithostratigraphic subdivisions of the upper Eocene in the Coastal Plain, agreement on the stratigraphic ranking of the named subdivisions has not been achieved and is in an unsettled state. This must reflect, on one hand, different philosophical approaches by different investigators and, on the other hand, different stratigraphic characteristics of different regions. For example, in the interior of the Mississippi Embayment upper Eocene deposits are still called the Jackson Formation, whereas in Mississippi the Jackson is still recognized as the Jackson Group (Dockery, 1980). Similarly, in Georgia in recent years, Carver (1966, 1972) considered the Barnwell Formation to be a subdivision of the Jackson Group.

In this study, we are adopting the following stratigraphic ranking. We are employing the name Jackson in the chronostratigraphic sense proposed by Murray and Wilbert (1950) because (1) recognition of a stage is based on paleontological correlation and not on lithologic identification, and (2) the overall lithologies of the Barnwell sandy deposits in Georgia are so strikingly different in physical appearance and physical properties from the equivalent clay deposits in Mississippi that to include them in the same lithostratigraphic unit seems to us unreasonable. We emphasize that we do not question the current usage of the name Jackson in the group sense in Mississippi because, in its type area, a chronostratigraphic unit name may have been derived from an earlier lithostratigraphic unit name. In all probability in the type area and in the type region, the lithostratigraphic unit boundaries will approximate the chronostratigraphic unit boundaries.

We consider the Barnwell to be a group in this study because we recognize two formal lithostratigraphic categories of the Barnwell that are of lesser lithostratigraphic rank than that of group (i.e., member and formation).

Finally, we must point out that we consider all of the Jacksonian deposits to be of late Eocene age and all known upper Eocene deposits in the Coastal Plain to be contained in the Jacksonian Stage (as opposed to Cheetham, 1957; and Deboo, 1965). On the other hand, although the Jacksonian Stage is entirely contained in the upper Eocene Priabonian Stage (see Fig. 4; Hardenbohl and Berggren, 1978), the Jacksonian Stage of the Coastal Plain is equivalent only to the upper part of the upper Eocene Series (see Fig. 4).

We propose that the Barnwell Sand (Formation) of earlier usage be raised in lithostratigraphic rank to Barnwell Group. This reranking is needed to accommodate the first order and second order stratigraphic subdivisions (formations and members) of the Barnwell Group. These formations are in ascending order: the Clinchfield Formation, the Dry Branch Formation (new name), and the Tobacco Road Sand.

There is no known adequate or useful reference section of the Barnwell Group in Barnwell County, South Carolina. The typical Barnwell Sand in Barnwell County is residuum (moderate reddish brown, 10 R 4/6), the original unit having been considered to be of late Eocene age by Cooke (1936, p. 89). This kind of material is of little use in terms of stratigraphic correlation and is of no use in paleogeographic and paleoecological reconstruction.

The railroad cut 1 mile (1.6 km) east of the railroad station at Barnwell has been used as a reference locality (Cooke, 1936) and a type locality (Connell, 1968) for the Barnwell Formation. However, the formation exposed at this locality is residuum of the Altamaha formation. Almost all of the original sedimentary fabric has been obliterated, leaving only vague stratification and a pebbly, coarse sand layer intact.

We have preserved the earlier concept of the Barnwell in that we understand the Barnwell Group to be dominantly a sand deposit of late Eocene age. In this respect the Barnwell Group represents the upper Eocene of the southern Atlantic Coastal Plain (see p. 12). The Clinchfield Formation, the Irwinton and Griffins Landing Members of the Dry Branch Formation, and the Tobacco Road Sand are simply subdivisions of the sandy Barnwell lithosome (Fig. 5). Although we consider the Twiggs Clay to be part of the Barnwell Group, we recognize that it is probably an easternmost tongue of the Yazoo clay lithosome. The western facies of the Twiggs Clay is practically identical lithologically, paleontologically, and in stratigraphic position to the lowest subdivision of the Yazoo Group, the North Twistwood Creek Clay of Alabama and Mississippi.

It is desirable for identification and correlation purposes to have at least a reference section for a lithostratigraphic unit, even at group rank. We therefore propose the large roadcut on Windsor Spring Road in Richmond County, Georgia, to be a reference section for the Barnwell Group in Georgia (see Figs. 8 and 9). This locality was chosen because, in Georgia, it is a completely exposed Barnwell section nearest to the type area in Barnwell County, South Carolina. For east-central Georgia, an excellent but incomplete reference section is the roadcut on Linton Road in the southern valley wall of Little Keg Creek, 6.2 miles (10.0 km) northwest of the Sandersville city limits in Washington County (see Figs. 10 and 11).

LITHOLOGY

The lithology of the Barnwell Group is dominated by quartz sand; other mineral components are subordinate. In the western area, however, montmorillonite clay (Twiggs Clay) may dominate the lithology of the group. Minerals or lithologies that are normally subordinate may dominate the lithology of particular beds or lenses in the group. These include clay (both montmorillonite and kaolinite), limestone, greensand, lignite, opal-cristobalite, chert, sandstone, and gravel. Shells, mica, hydrated iron oxides, and wad (hydrated MnO_2) may be locally conspicuous. Other accessory lithic components of the Barnwell include aragonitic shells, pyrite, flecks of carbonaceous matter, siliceous microfossils (diatoms and sponge spicules), and small, rarely large, marine vertebrate phosphatic bone debris (fish teeth, scales, and bones).

The quartz sand of the Barnwell Group ranges in grain size from very fine to very coarse and locally contains lenses of gravel and mixtures of pebbles. The sorting of the sand component ranges from very well sorted to very poorly sorted. In general, the fine and very fine sands are very well sorted. Commonly, as the upper limit of the grain size of the quartz sand increases, the lower limit of the grain size decreases (becomes finer). As a result, with increasing grain size within the Barnwell Group, the sorting deteriorates, producing very poorly sorted sediments. The extreme of this situation results in lithologies consisting of pebbly, granully to clayey, fine to coarse sand. This relationship is not invariable, however, in that some beds or lenses of well-sorted, coarse or very coarse sand may be common locally.

Typical Barnwell lithologies have prominent bedding that ranges from horizontal (thick bedded, thin bedded, indistinctly to clearly bedded, laminated) to cross-bedded of various kinds and degrees. Some deposits may show little bedding, probably due to bioturbation. These include the Griffins Landing Member of the Dry Branch Formation, parts of the Tobacco Road Sand, parts of the Clinchfield Formation, and the Sandersville Limestone Member of the Tobacco Road Sand.

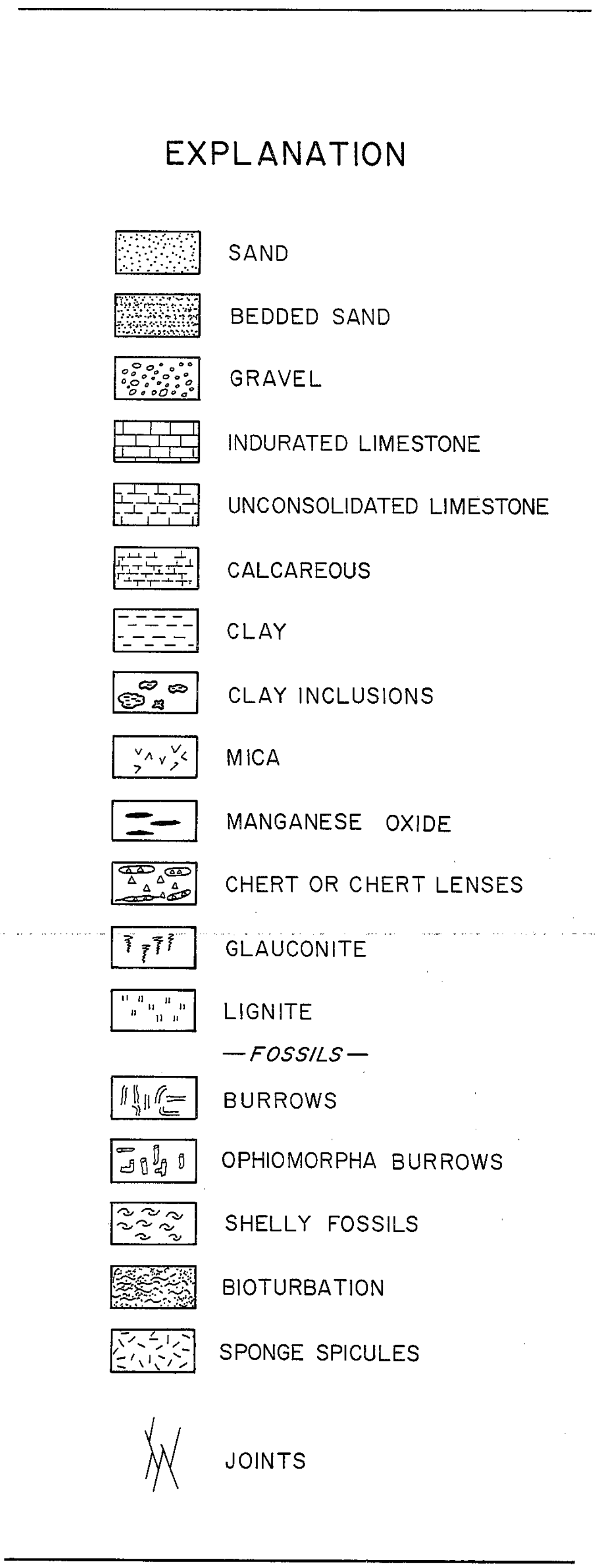


Figure 7. Lithology symbol explanation.

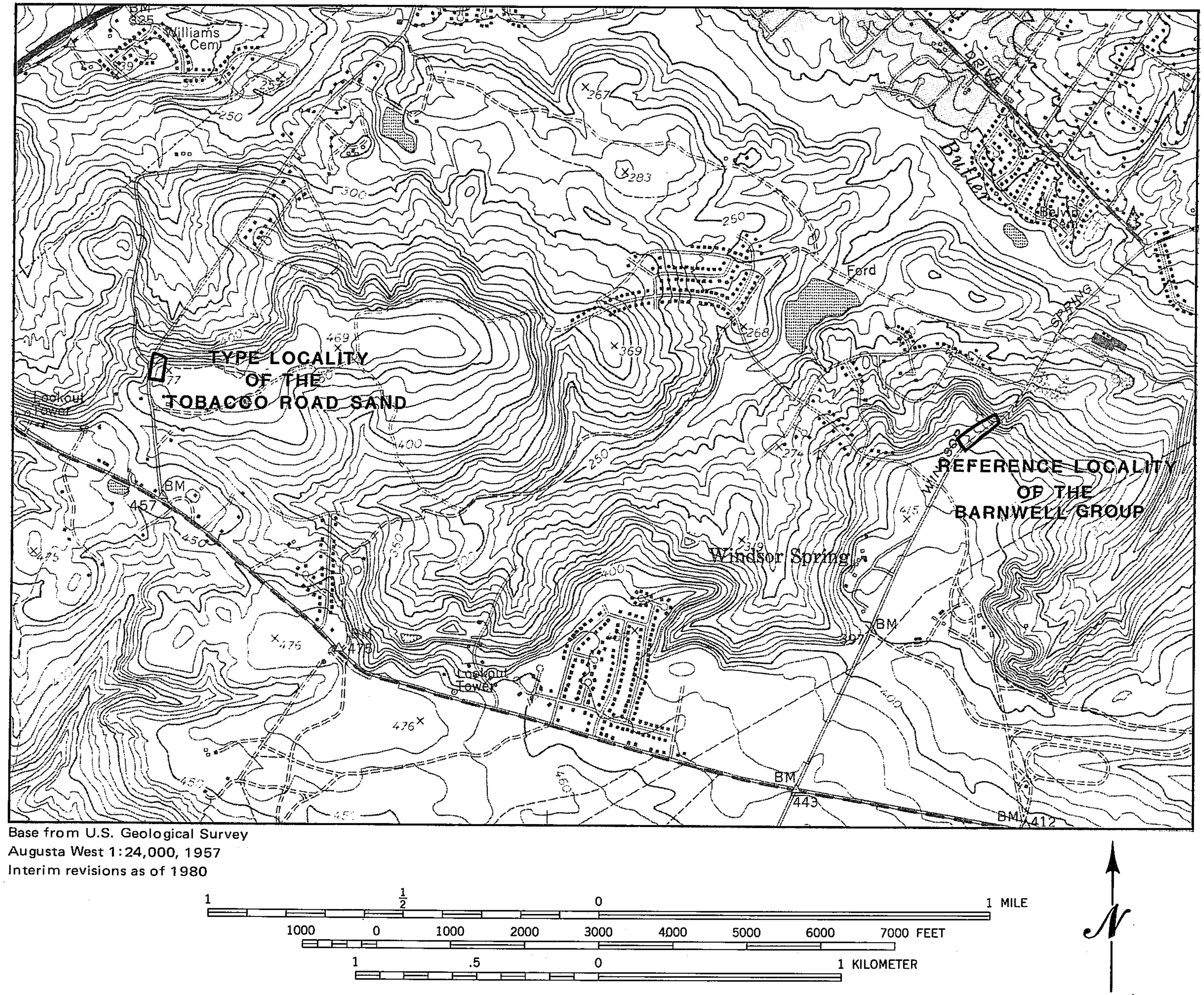


Figure 8. Location map of Windsor Spring Road, reference locality for the Barnwell Group in Georgia; and Morgan Road, the type locality of the Tobacco Road Sand, Richmond County, Georgia.

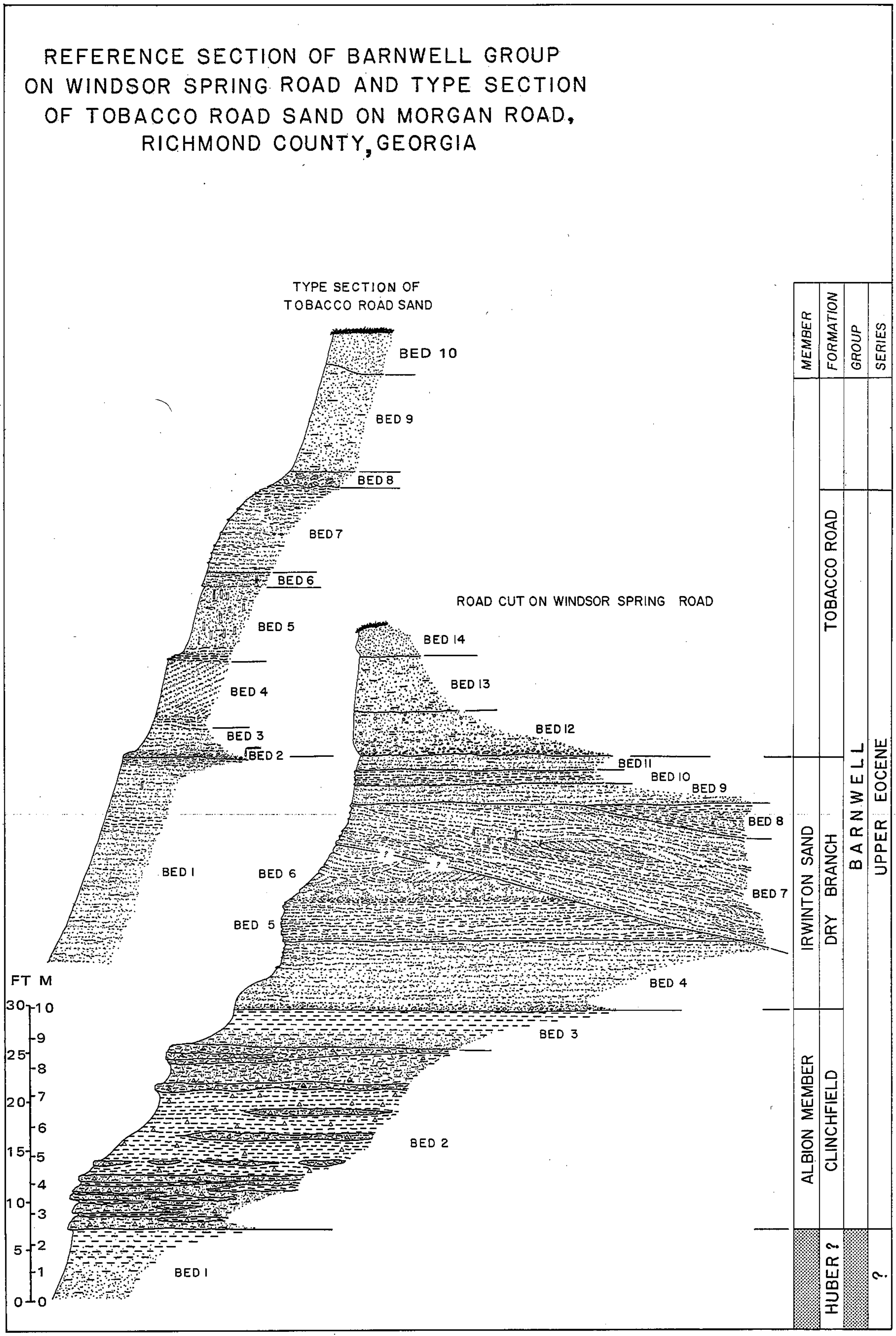


Figure 9. Measured sections of the Barnwell Group on Windsor Spring Road and the Tobacco Road Sand on Morgan Road, Richmond County, Georgia.

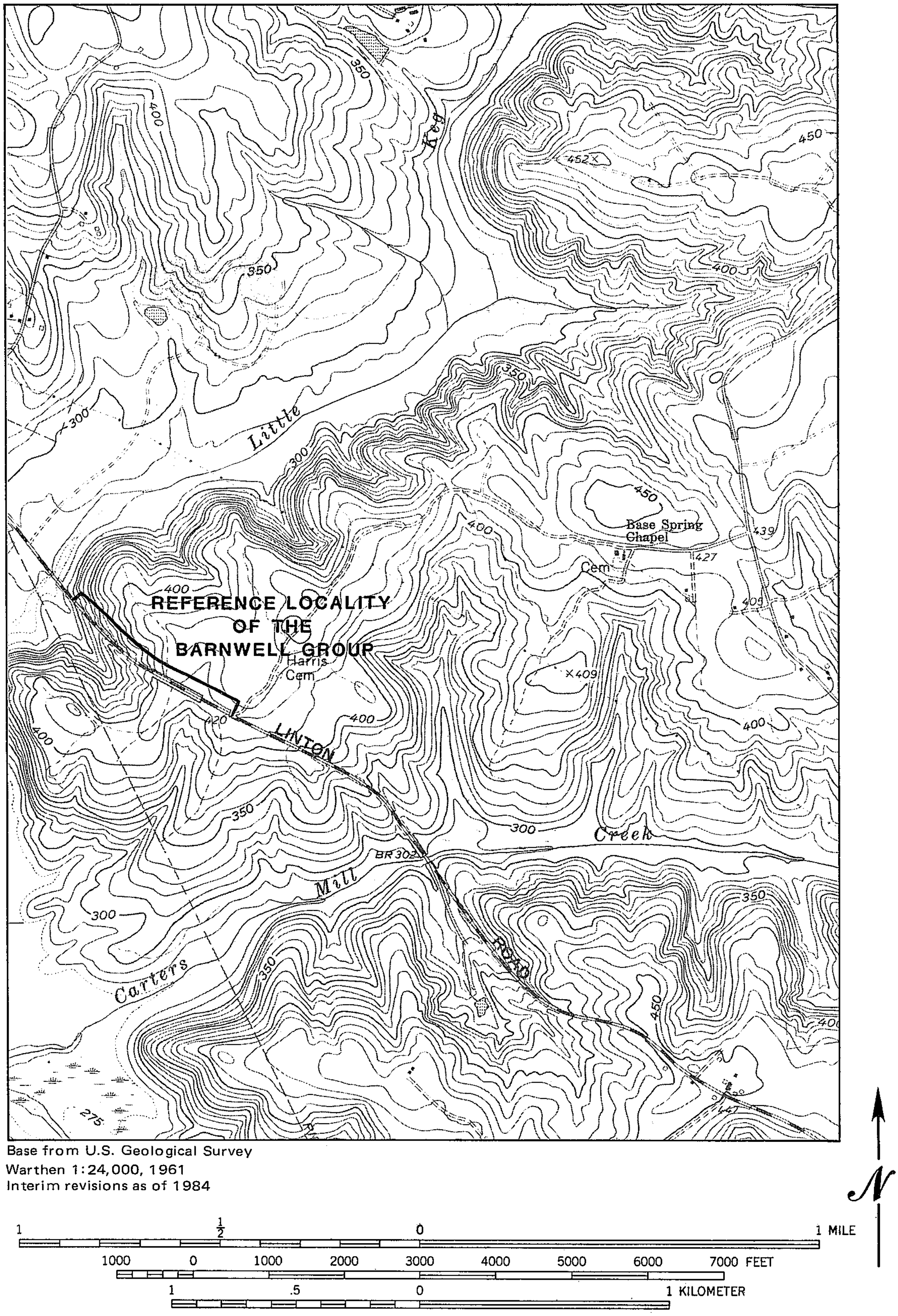


Figure 10. Location map of Linton Road, reference locality for the Barnwell Group in east-central Georgia.

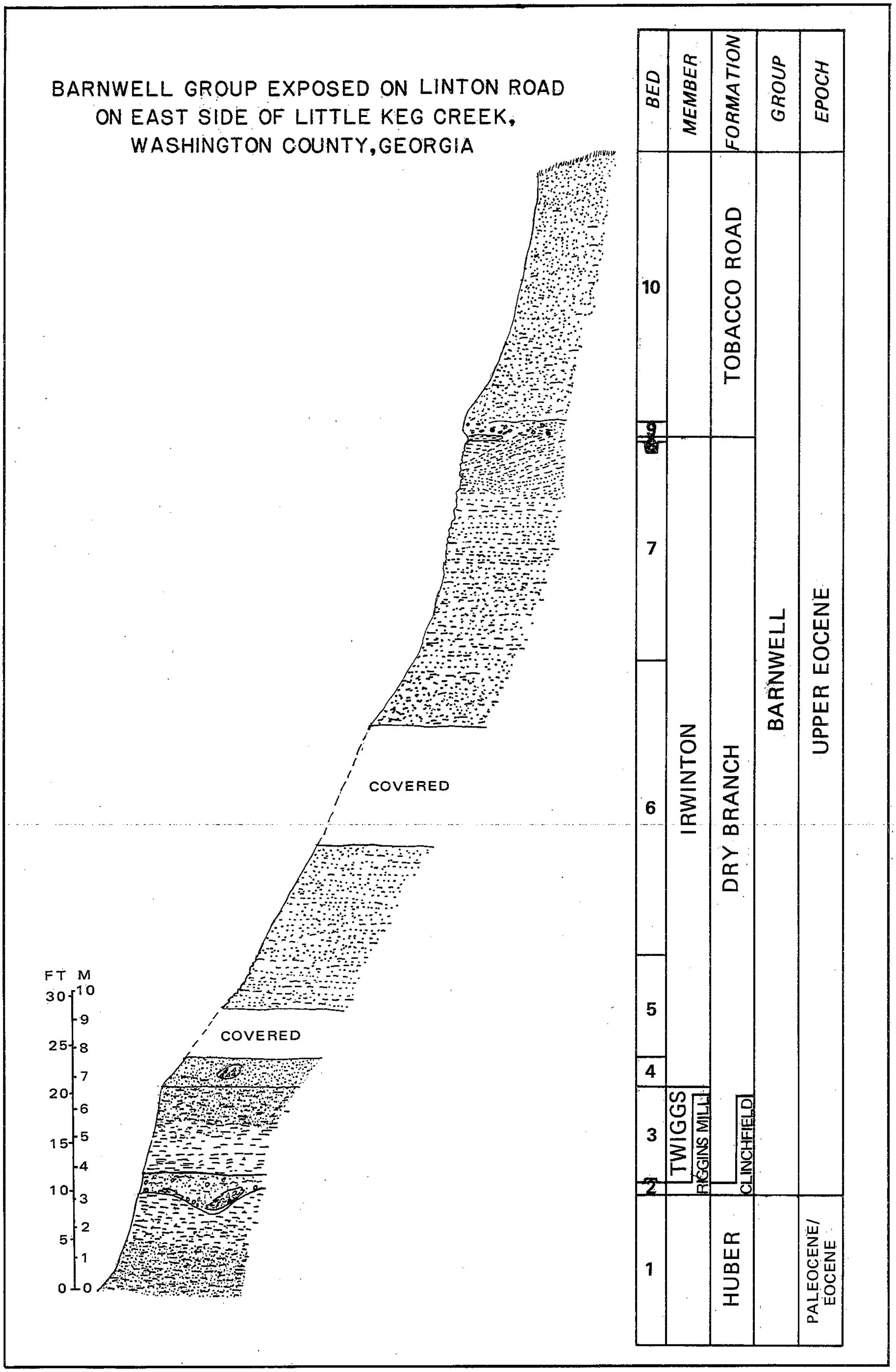


Figure 11. Measured section of the Barnwell Group on Linton Road, Washington County, Georgia.

AREAL DISTRIBUTION AND THICKNESS

The Barnwell Group extends from northern Dooly and Crawford Counties, Georgia, in the west to at least as far as Lexington and Orangeburg Counties, South Carolina. Its northern limit is the Fall Line and it grades downdip into the Ocala Group. In the Savannah River area the zone of facies change is in Allendale County, South Carolina, and Screven and northern Effingham Counties in Georgia. In the Ocmulgee River area, the zone of facies change is in southernmost Houston, Pulaski, Dooly, and Bleckley Counties, Georgia.

The Barnwell Group attains a maximum thickness of approximately 200 feet (61 m) in a belt slightly oblique to the Fall Line that extends from southern Burke and northern Screven Counties through Wilkinson and Twiggs Counties. In Twiggs, Wilkinson, and Laurens Counties, Georgia, where there is adequate thickness information, the Barnwell Group (excluding those areas thinned by erosion) varies in thickness from about 100 feet (30.5 m) to as much as 200 feet (61 m). The reason for this variability is not known. The Barnwell thins downdip from this belt as a result of facies change into the Ocala Group. It systematically thins updip toward the Fall Line. The minimum total thickness of the Barnwell Group occurs toward the east in Richmond County, Georgia, and Aiken County, South Carolina. The thinnest complete section of the Barnwell Group, consisting of both the Dry Branch Formation and the Tobacco Road Sand, is 40 feet (12 m) in Aiken County, South Carolina. In the vicinity of the Fall Line, the Barnwell Group appears to consistently thicken westward in Georgia. At Mattie Wells School in western Jones County, near Macon, the thickness of the entire Barnwell Group is at least 100 feet (30.5m) (Huddlestun and Hetrick, 1979, p. 83-89).

CLINCHFIELD FORMATION

Definition

The Clinchfield Formation of present usage was first described as a sand bed of uncertain Claiborne or Jackson age at Rich Hill, Crawford County, and in the vicinity of Dry Branch, Twiggs County (Brantly, 1916, p. 11, 12). Cooke and Shearer (1918, p. 53) made only passing reference to this sand bed. Later it was correlated with and referred to as the Gosport Sand (MacNeil, 1947a; Herrick, 1961; LeGrand, 1962). Pickering (1970) formally defined the Clinchfield Formation and Herrick (1972) discussed its age and correlation. The original description of the formation is as follows (Pickering, 1970, p. 7, 8):

> The Clinchfield Sand is a medium-grained, well-sorted.... poorly consolidated quartz sand. The sand is massive and no bedding or cross-bedding may be observed. Accessory minerals present are detrital carbonate, ilmenite, leucoxene, muscovite, hornblende, zircon, staurolite, epidote, and monazite. The total content of heavy minerals is less than one percent. The Clinchfield Sand grades upward into the Ocala Limestone, through a zone of sandy limestone lenses and sand beds approximately five feet thick. In this report, the top of the Clinchfield Sand is placed at the highest bed of unconsolidated sand.

Because the present authors have correlated the Clinchfield Sand of earlier usage with deposits in eastern Georgia which are more lithologically variable than the typical Clinchfield Sand, and which have hitherto been referred to simply as Barnwell, we are expanding the original definition and concept of the formation to include these deposits. In addition, we are changing the sense of the formation from Clinchfield Sand to Clinchfield Formation.

The type locality of the Clinchfield Formation is at the pit of the Medusa Cement Company at Clinchfield in Houston County (Fig. 12). The formation at this site, however, is only intermittently exposed during quarry operations because it is the overlying Tivola Limestone that is actively being quarried. Therefore, no specific exposure in the quarry at Clinchfield can be named or designated. We are also designating, as a reference section for the Clinchfield Formation, the 12 feet (4 m) of Clinchfield Formation exposed at Rich Hill in Crawford County, Georgia. The measured sections of the type section and reference section are given in Figures 13 and 14.

The Clinchfield Formation is the basal sand deposit of the Barnwell Group. In central Georgia, it is predominantly a quartz sand, but in eastern Georgia east of the Ogeechee River, the Clinchfield may be conspicuously less sandy.

We find it convenient to discuss the Clinchfield Formation under five subdivisions:

(1) typical Clinchfield Sand from its type area west of the Ocmulgee River,

(2) a lower Riggins Mill Member, and

(3) an upper Treadwell Member.

East of the Ogeechee River the Clinchfield Formation consists of:

(4) an updip, nearshore, spiculitic Albion Member in Glascock and Richmond Counties, Georgia, and Aiken County, South Carolina, and

(5) a downdip, offshore Utley Limestone Member in Burke and subsurface Screven Counties.

Lithology

In general, the unweathered exposures of the Clinchfield Formation west of the Ocmulgee River consist of fine to medium, well-sorted, calcareous, fossiliferous sand which can be referred to as the Clinchfield Sand. Based on limited information, small-scale primary sedimentary structures are lacking. The only bedding appears to be scattered, moderately thin to moderately thick beds of sandy limestone or calcareous sandstone. The Clinchfield sediments are typically structureless and very well mixed in terms of the lithologic components. Bioturbation and burrowing may be locally intense.

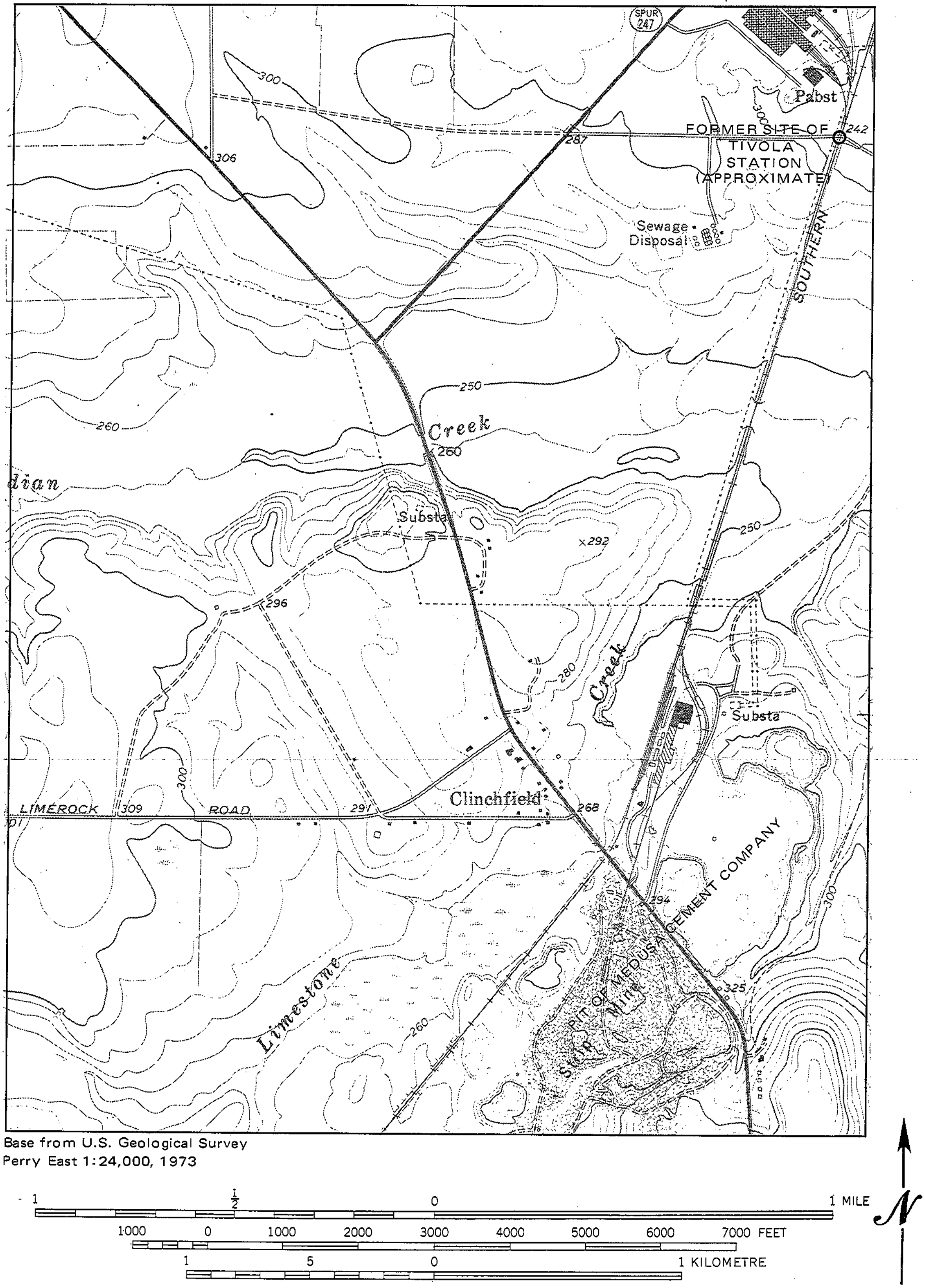
At most localities the quartz sand is soft and unconsolidated, so that recovery in coring operations is very poor and natural exposures are unknown. At some localities such as in the quarry at Clinchfield, the massive-bedded sand is locally cemented and indurated and contains abundant shell molds. Consequently, in the past, this particular lithology in the Clinchfield Formation has been misidentified with the shelly Gosport Sand of western Alabama that occurs between the Claibornian Lisbon Formation and the Jacksonian Moodys Branch Formation (MacNeil, 1947a; Herrick, 1961; LeGrand, 1962).

Thickness

The Clinchfield Formation west of the Ocmulgee River ranges in thickness from 9 to 35 feet (3 to 11 m) (Herrick, 1972, p. 6), but is generally between 10 and 20 feet (3 and 6 m) thick.

Paleontology

The undifferentiated Clinchfield Formation west of the Ocmulgee River contains the "*Scutella*" bed (*Periarchus lyelli* bed) of the



Base from U.S. Geological Survey
Perry East 1:24,000, 1973

Figure 12. Location map of the Medusa Cement Company pit, the type locality of the Clinchfield Formation and Tivola Limestone, and reference locality for the Twiggs Clay Member of the Dry Branch Formation, Houston County, Georgia.

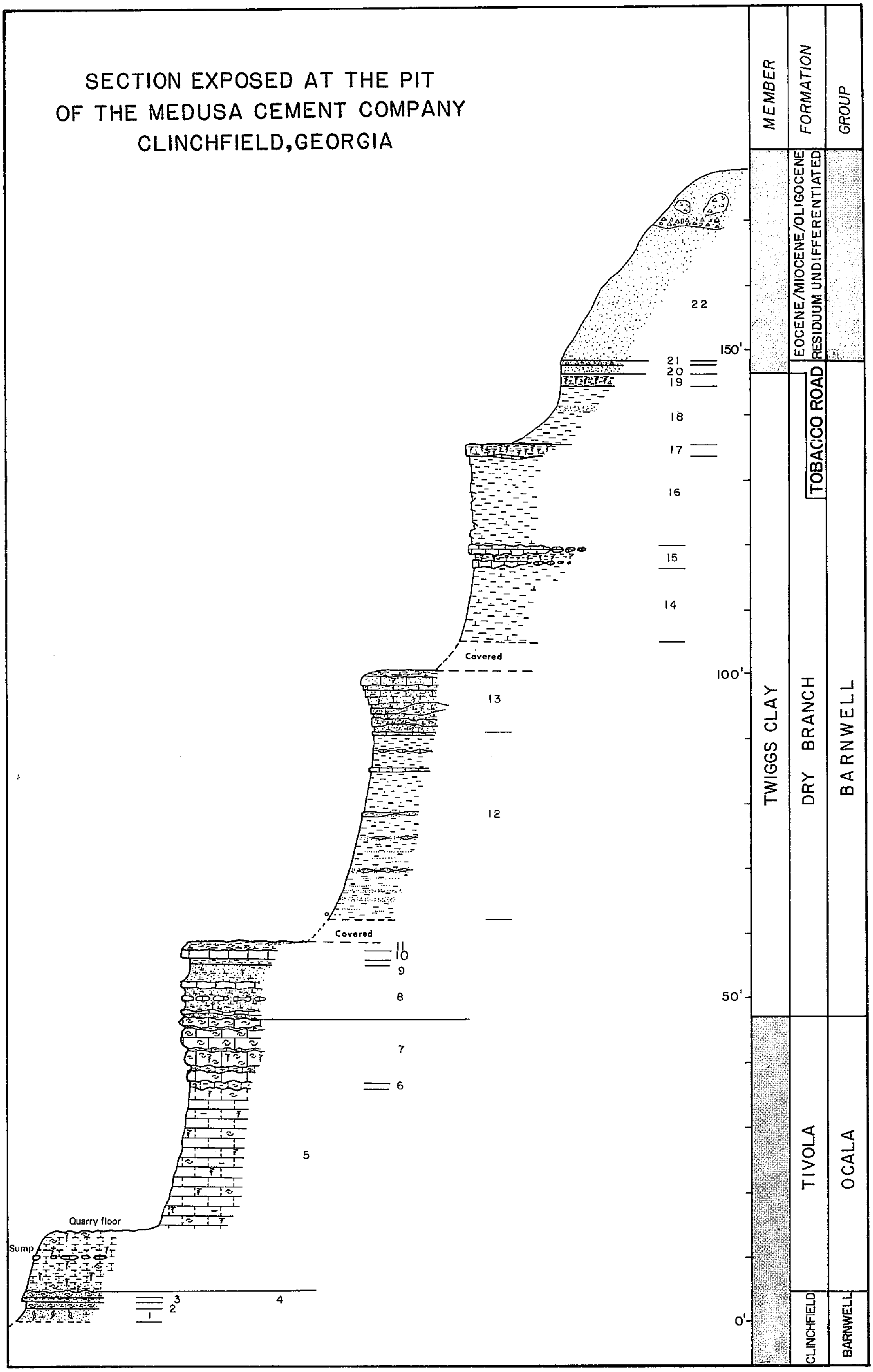


Figure 13. Measured section at the pit of the Medusa Cement Company, Houston County, Georgia.

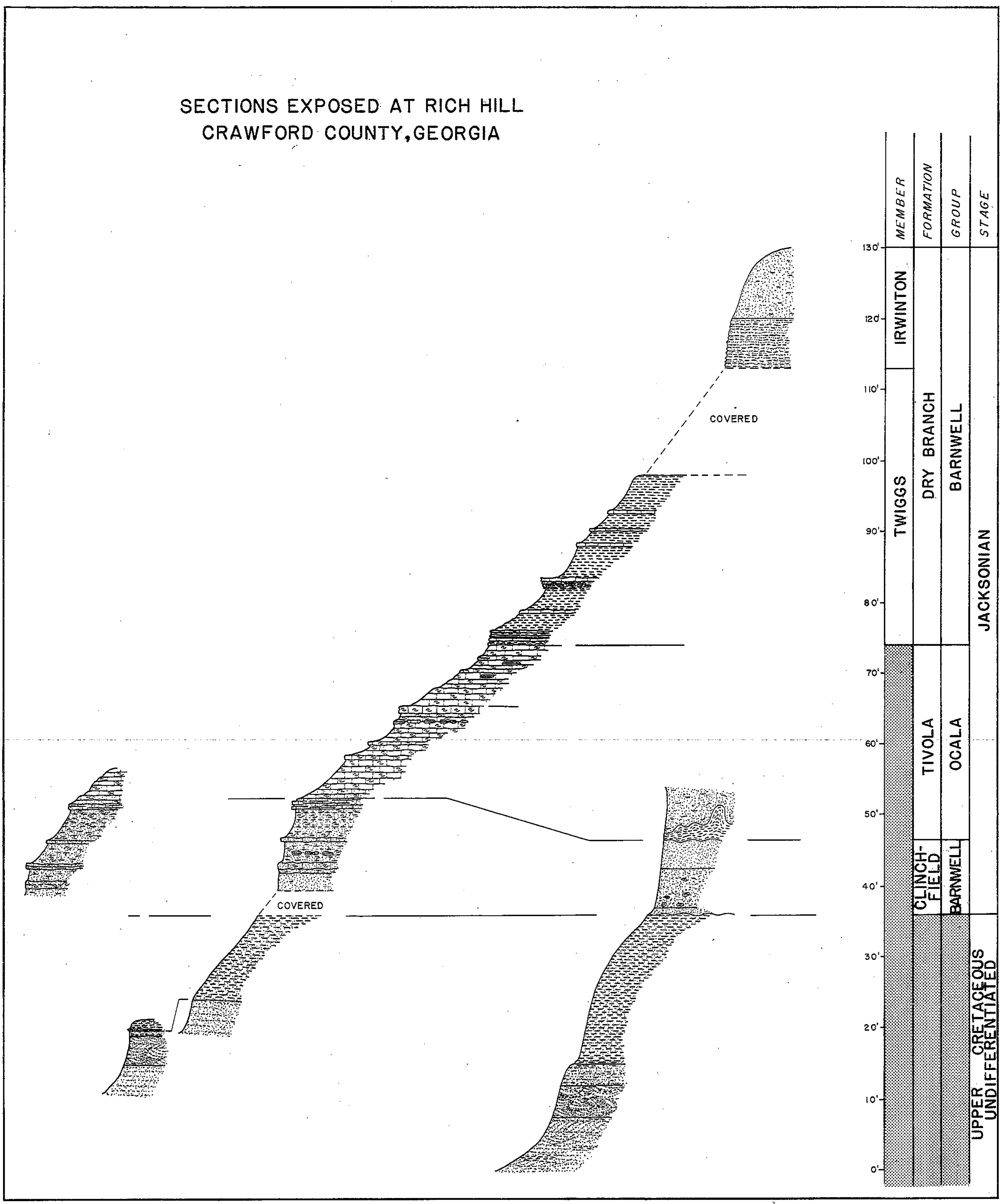


Figure 14. Measured sections of the exposures at Rich Hill, Crawford County, Georgia.

eastern Gulf Coastal Plain. Locally, *P. lyelli* is abundant in these sands, but more commonly it occurs in moderate to low abundance. Herrick (1972) has presented a check list of the benthic foraminifera from the type locality of the Clinchfield Formation.

Age

Traditionally, the Clinchfield Formation has been considered to be of late Eocene age (Pickering, 1970). In part, this age assignment probably originated in the Clinchfield being a natural part of the Barnwell lithostratigraphic unit, which has been considered to be of late Eocene age (Cooke and Shearer, 1918; Cooke, 1936, 1943). The late Eocene age was reinforced in a foraminiferal study of the Clinchfield Formation by Herrick (1972) in which he compared the foraminiferal fauna of the Clinchfield with the Moodys Branch Formation of Mississippi. On the other hand, the Clinchfield was identified with the Gosport Sand of late middle Eocene age by some earlier investigators (MacNeil, 1947a; Herrick, 1961; LeGrand, 1962). This correlation, at the time, was based not so much on faunal similarity as on gross lithology (fossiliferous sand) and stratigraphic position (between the Lisbon Formation and the Ocala Limestone or Barnwell Formation). However, the locally conspicuous Mollusca of the Clinchfield do have undeniable Gosport affinities (see Cooke and Shearer, 1918) and, therefore, the possible correlation of the Clinchfield Formation with the Gosport Sand cannot be ignored at this date. Because no comprehensive faunal studies have addressed this problem in the eastern Gulf Coastal Plain, one must conclude that the Claibornian-Jacksonian boundary problem has still not been resolved adequately (personal commun., L. Ward, 1981). In addition, the senior author has examined foraminiferal assemblages from the type locality of the Clinchfield Formation, the type area of the Riggins Mill Member, the Gosport Sand of southwestern Alabama, and the Moodys Branch Formation of Mississippi and Alabama. Except for differing proportions of species, he has found no way to distinguish the benthic foraminiferal populations of the three units upon casual inspection. Furthermore, planktonic foraminifera are very rare in the Gosport and in the Clinchfield and are as yet of little use in correlation. Therefore, in contrast to Herrick (1972), the senior author concludes that the Clinchfield benthic foraminiferal faunas are compatible with those of the Gosport Sand and the Moodys Branch Formation. For the purposes of this paper, then, we prefer to follow the conventional interpretation and include the Clinchfield Formation with the upper Eocene Series for two reasons: (1) the Clinchfield has traditionally been considered to be of late Eocene age, and there is some evidence to support this assignment, and (2) no rigorous faunal studies have addressed the Claibornian-Jacksonian boundary problem in Mississippi, Alabama, and Georgia.

Riggins Mill Member of the Clinchfield Formation (New Member)

Definition. The Riggins Mill Member of the Clinchfield Formation is named herein for Riggins Mill Road which passes 0.7 mile (1.2 km) northeast of the type locality. The type locality is the Georgia Kaolin Company Mine 50 in Twiggs County, and is at the intersection of two kaolin haul roads, 0.7 mile (1.2 km) southwest of the community of Treadwell; Georgia Kaolin Pit 50 is approximately 10 miles (16 km) southeast of Macon, Bibb County, Georgia. The type description of the Riggins Mill Member is provided in the Appendix (see also Figs. 15 and 16).

Lithology. The Riggins Mill Member is the basal deposit of the Clinchfield Formation over much of the outcrop area between the Ogeechee and Ocmulgee Rivers. At most sites, the entire Clinchfield interval consists of the Riggins Mill Member. In general, in its type area in western Twiggs County, the Riggins Mill consists of a poorly sorted, pebbly, argillaceous, fine to coarse sand that is locally calcareous and macrofossiliferous. Primary sedimentary bedding structures are not obvious and the deposit is typically massive bedded. Lithologic components appear fairly well mixed. On closer inspection, where the grain size is less coarse, this poorly sorted, pebbly sand is seen to contain rude[1] and vague stratification. The poorly sorted, pebbly, fossiliferous Riggins Mill lithofacies is easily identifiable even in deeply weathered exposures because weathering does not significantly affect the characteristic grain size (ranging from clay to pebbles) and high degree of mixing of the sediments.

Calcareous concretions or nodules of varying sizes, approximately 0.5 to 6 inches (1 to 15 cm) in diameter, and of roughly spherical shape, are characteristic of relatively unweathered Riggins Mill. The small nodules have the appearance of "popcorn." Where these calcareous nodules or concretions are exposed on a weathering surface, the surface appears knobby. These nodules probably originated, in part, during sedimentation because they commonly contain concentrations of shell molds and the sand distribution in them is different from that of the surrounding matrix.

In a few places where the Riggins Mill has been deeply weathered, the macrofossil hard parts have been replaced by silica. As a result, the siliceous pseudomorphs of the fossils lie scattered on the weathering surface in profusion. The degree of replication of the detail of the fossil shells is often very high. The fossils include gastropods, pelecypods, scaphopods, corals, bryozoans, barnacles, and echinoids.

In the type area of the Riggins Mill Member, in western Twiggs County, the middle part of the unit consists of a sandy, fossiliferous limestone that is virtually identical lithologically to the stratigraphically equivalent Utley Limestone Member of the Clinchfield Formation in Burke and Screven Counties. Although widespread in southeastern Bibb, northern Twiggs, and northwestern Wilkinson Counties, this limestone bed has not been observed east of the type area. Similarly, the upper bed of the Riggins Mill Member in northern Twiggs County, which consists of a finer grained, somewhat better sorted, clayey, very calcareous, massive-bedded, nodular, fossiliferous, fine to medium sand, appears to be restricted to the type area. However, if this bed were completely leached of calcite, it would probably appear as a finer textured, rudely layered variation of the typical Riggins Mill, and therefore may not be as geographically restricted as it appears from present field interpretations.

In many weathered exposures of the Riggins Mill Member, typical poorly sorted, pebbly Riggins Mill lithofacies grades upward or laterally into a less distinctive lithofacies. This lithofacies consists of sediments that range in lithology from a moderately well sorted to well-sorted, fine to medium quartz sand with vague to prominent stratification. The clay component of these sands, always a secondary constituent, ranges from being restricted to scattered clay laminae or partings, to comprising thin to moderately thick beds of relatively pure, stratified clay.

[1] In this paper, rude stratification is defined as stratification where the bedding contacts are gradational over 2mm or more. Rude stratification, or bedding, is especially characteristic of the coarse and poorly sorted sediments of the Barnwell Group.

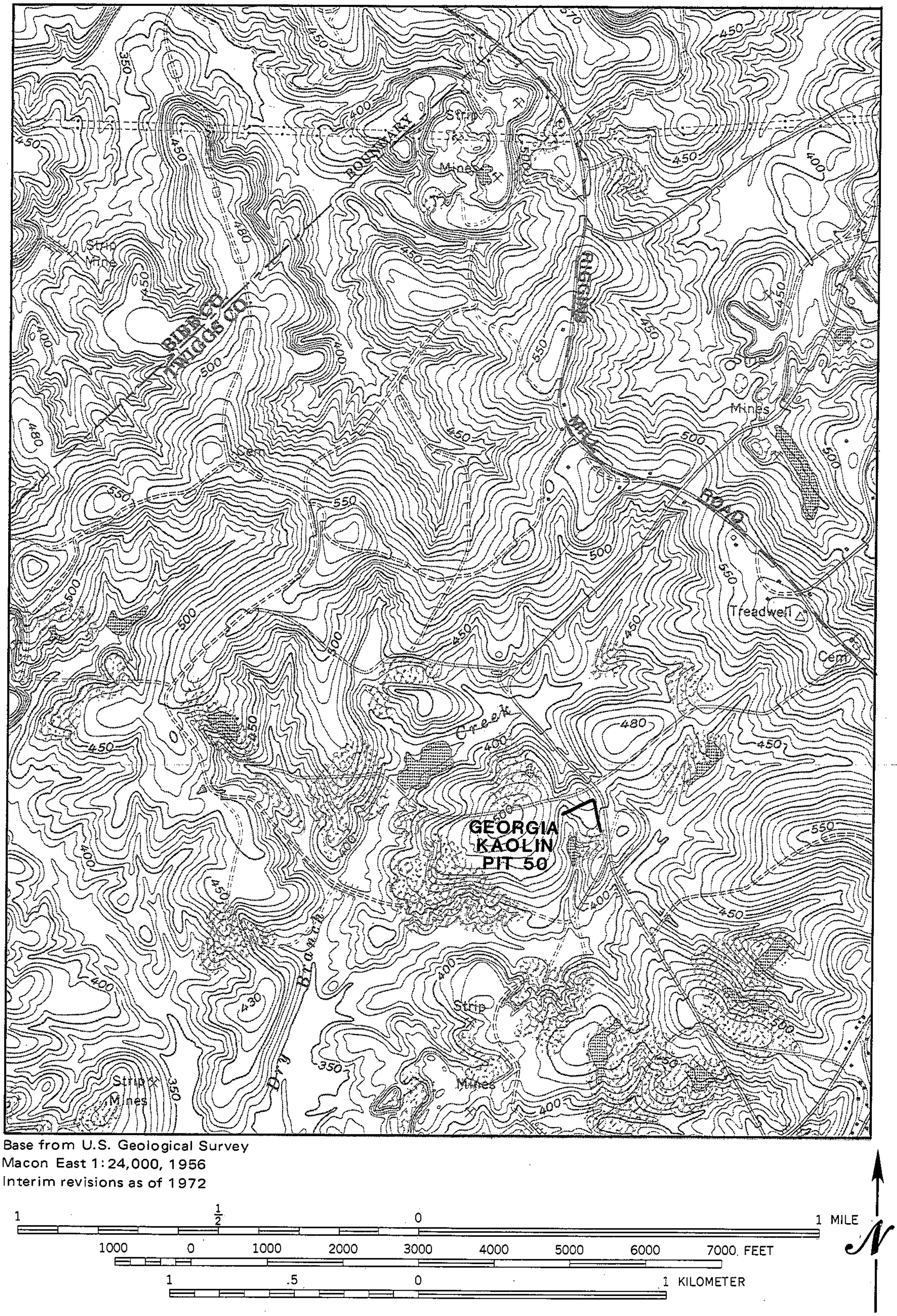


Figure 15. Location map of Georgia Kaolin Company's pit 50, the type locality of the Riggins Mill and Treadwell Members of the Clinchfield Formation, Twiggs County, Georgia.

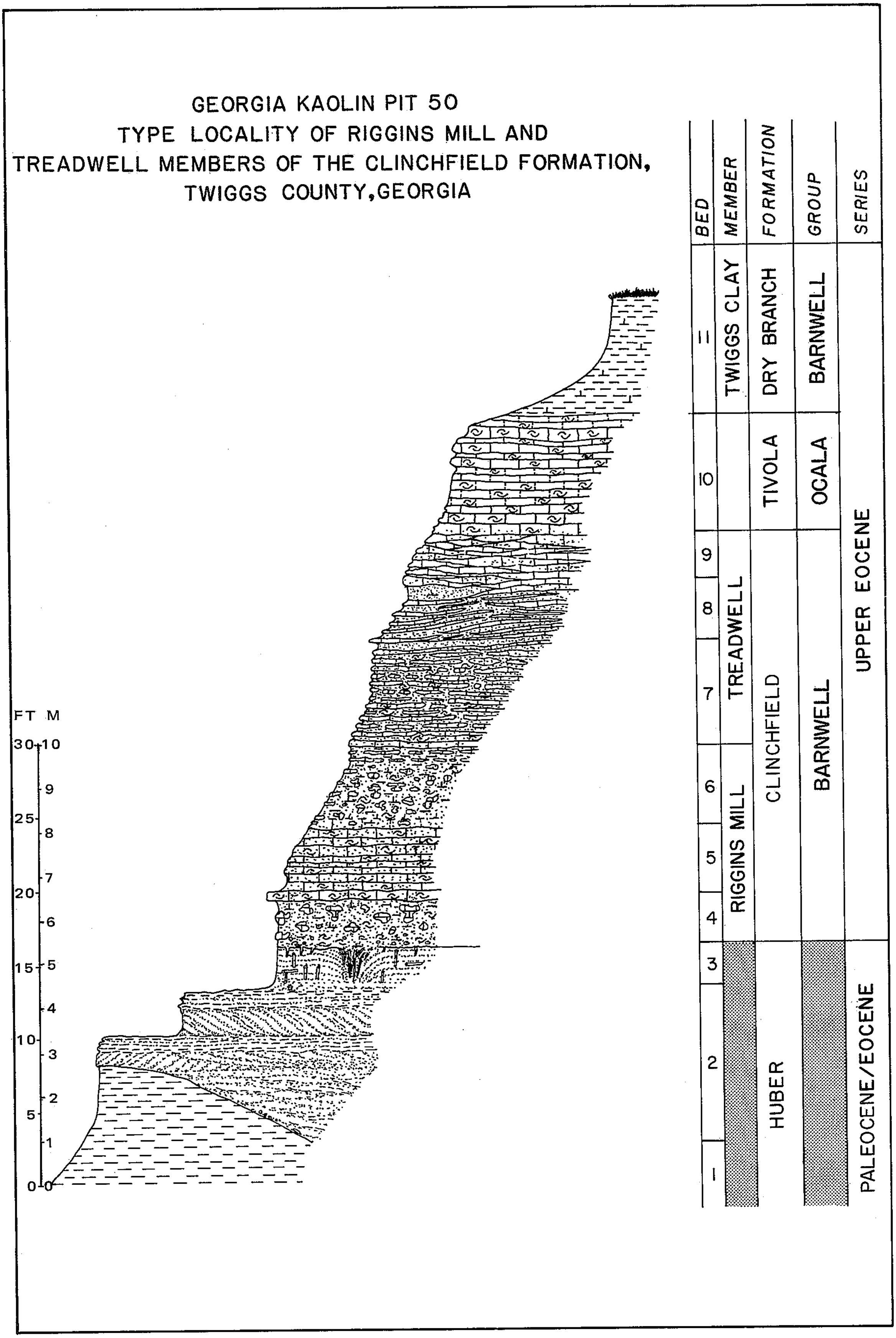


Figure 16. Measured section from Georgia Kaolin Company's pit 50, Twiggs County, Georgia.

Areal Extent and Thickness. The known western limits of the Riggins Mill Member of the Clinchfield Formation is the vicinity of the Ocmulgee River in central Georgia. We have identified the Riggins Mill as far east as central Washington County, but the eastern limits of the member are not known. It does not occur, however, in Burke or Richmond Counties where its equivalents, the Utley Limestone and Albion Members, are the sole representatives of the formation. The updip limit of the Riggins Mill Member is the Fall Line, and its downdip limit occurs in the shallow subsurface and has not yet been determined.

The known thickness of the Riggins Mill Member ranges from 0 to 17 feet (0 to 5 m).

Paleontology. *Chlamys* cf. *membranosa* (*C. cocoana* of Glawe, 1974, p. 6-7, pl. 2, fig. 3, 5, 10, 11) is characteristic of the Riggins Mill Member and can be considered a guide fossil for the unit in Georgia. Although *C.* cf. *membranosa* occurs in other Eocene deposits in the Coastal Plain, the only other known occurrence of the fossil in the State of Georgia is a trace occurrence in the McBean Formation at Shell Bluff in Burke County. *Crassostrea gigantissima*, which occurs as scattered shell fragments, individuals, and in small oyster bioherms, also is characteristic of the Riggins Mill Member in its type area. *Periarchus lyelli* occurs only in the upper part of the Riggins Mill, and it occurs in low frequencies as scattered individuals or more commonly as scattered fragments. We have observed that *C. gigantissima* does not occur in the member where there is a diverse molluscan fauna, and that *P. lyelli* neither occurs with *C. gigantissima* nor with abundant and diverse molluscan faunas. It is our general observation that abundant *C. gigantissima*, *P. lyelli*, and rich and diverse molluscan faunas are commonly three mutually exclusive faunal elements in the Jacksonian deposits of Georgia. It also is of interest to note that, although the limestone bed in the Riggins Mill Member is virtually identical lithologically and in stratigraphic position to the Utley Limestone Member of the Clinchfield Formation in eastern Georgia, the Utley Limestone contains the "*Scutella*" bed (*P. lyelli* bed) and the limestone in the Riggins Mill does not.

Microfossils are common locally in the Riggins Mill Member and the member may contain a diverse suite of benthic foraminifera. Unfortunately, microfossil preservation is very poor at the type locality.

Treadwell Member of the Clinchfield Formation (New Member)

Definition. The Treadwell Member of the Clinchfield Formation is named for the community of Treadwell, 1.4 miles (2.3 km) southeast of the Bibb-Twiggs County line on Riggins Mill Road in northern Twiggs County, Georgia. The type locality is the Georgia Kaolin Company Mine 50, at the intersection of two kaolin haul roads, 0.7 mile (1.2 km) southwest of the community of Treadwell. The type description of the Treadwell Member is provided in the Appendix (see also Figs. 15 and 16).

Lithology. The Treadwell lithology typically ranges from a very calcareous sand to a sandy limestone. It is generally deficient in clay and tends to be more indurated by calcite than the underlying Riggins Mill Member or the overlying Tivola Limestone. The quartz sand component of the Treadwell is fine to medium grained and well sorted. The Treadwell Member is generally well stratified, in contrast to the typical Riggins Mill Member, and may be thin or thick bedded, and horizontal or cross-bedded. Lenses or thin layers of almost pure limestone or noncalcareous, well-sorted quartz sand may be interlayered with more typical lithologies.

The contact between the Riggins Mill and the Treadwell Members appears to be gradational at some sites (as at the type locality) and very abrupt at other sites, suggesting at least a local discontinuity. The absence of (1) foraminiferal suites, (2) a meager molluscan fauna, and (3) primary bedding generally undisrupted through faunal mixing in the Treadwell Member as compared to (1) locally diverse foraminiferal suites, (2) locally diverse molluscan suites, and (3) fairly intense bioturbation and biological mixing of the sediments in the Riggins Mill suggests that the Treadwell was deposited in shallower water and represented a biologically more restricted environment than that of the Riggins Mill.

Areal Extent and Thickness. It is possible that the Treadwell sediments represent a minor and subtle regression near the top of the Clinchfield, and at some sites may be represented only by a diastem. This interpretation is consistent with the observation that the Treadwell is known definitely only in northern Twiggs County and appears to be much more limited in its geographical occurrence than the Riggins Mill. Its area of known occurrence is only the Huber and Dry Branch area in northern Twiggs County. It has not been identified east of Jeffersonville in Twiggs County, but it may be present in the vicinity of Gordon in Wilkinson County, Georgia. The known thickness of the Treadwell Member varies from 0 to 14.5 feet (0 to 4.4 m).

Paleontology. The Treadwell Member of the Clinchfield Formation in central Georgia contains the "*Scutella*" bed (or *Periarchus lyelli* bed) of the eastern Gulf Coastal Plain. *Periarchus lyelli* is generally common to abundant in the Treadwell, and commonly is the only macrofossil present. In this member, the rarely occurring *Aequipecten spillmani* replaces *Chlamys* cf. *membranosa* of the Riggins Mill.

Albion Member of the Clinchfield Formation

Definition and Lithology. Carver (1972, p. 163-164) formally defined the Albion Member of the Barnwell Formation. The type locality of this unit is at the Babcock and Wilcox Albion Kaolin mine, approximately 1 mile (1.6 km) west of Hephzibah, Richmond County, Georgia (Fig. 17). His description of the Albion is as follows (Carver, 1972, p. 163-164):

> The Albion Member of the Barnwell Formation was informally defined in Sandy, Carver and Crawford (1966). The type section of the Albion Member is here designated as the section exposed in the Albion Kaolin Mine approximately 1 mile west of Hepzibah, Richmond County, Georgia (Section 12 of this report). The Albion Member consists of discontinuous lenses of spiculite, spiculitic clay and mudstone and opal-cemented sandy spiculite and spiculitic sandstone (Buie and Oman, 1963; Carver, 1968, 1966). Typical exposures of spiculite and spiculitic clays occur in the Albion Mine and in the section along Windsor Spring Road a mile north of Tobacco Road in Richmond County (Sandy, Carver and Crawford, 1966; Herrick and Counts, 1968). Opal-cemented rocks occur in the Albion Mine, in the abandoned Harbison-Walker Co. flint-kaolin pit near Gibson, Glascock County (Sandy, Carver and Crawford, 1966), and as float along Brier Creek at the crossing of U.S. Highway 1 on the west boundary of Richmond County.
>
> Fine-grained sediments of the Albion Member normally are massive to poorly bedded and megascopically structureless, but intraformational conglomerates (with 1 to 4 mm diameter fragments) occur in

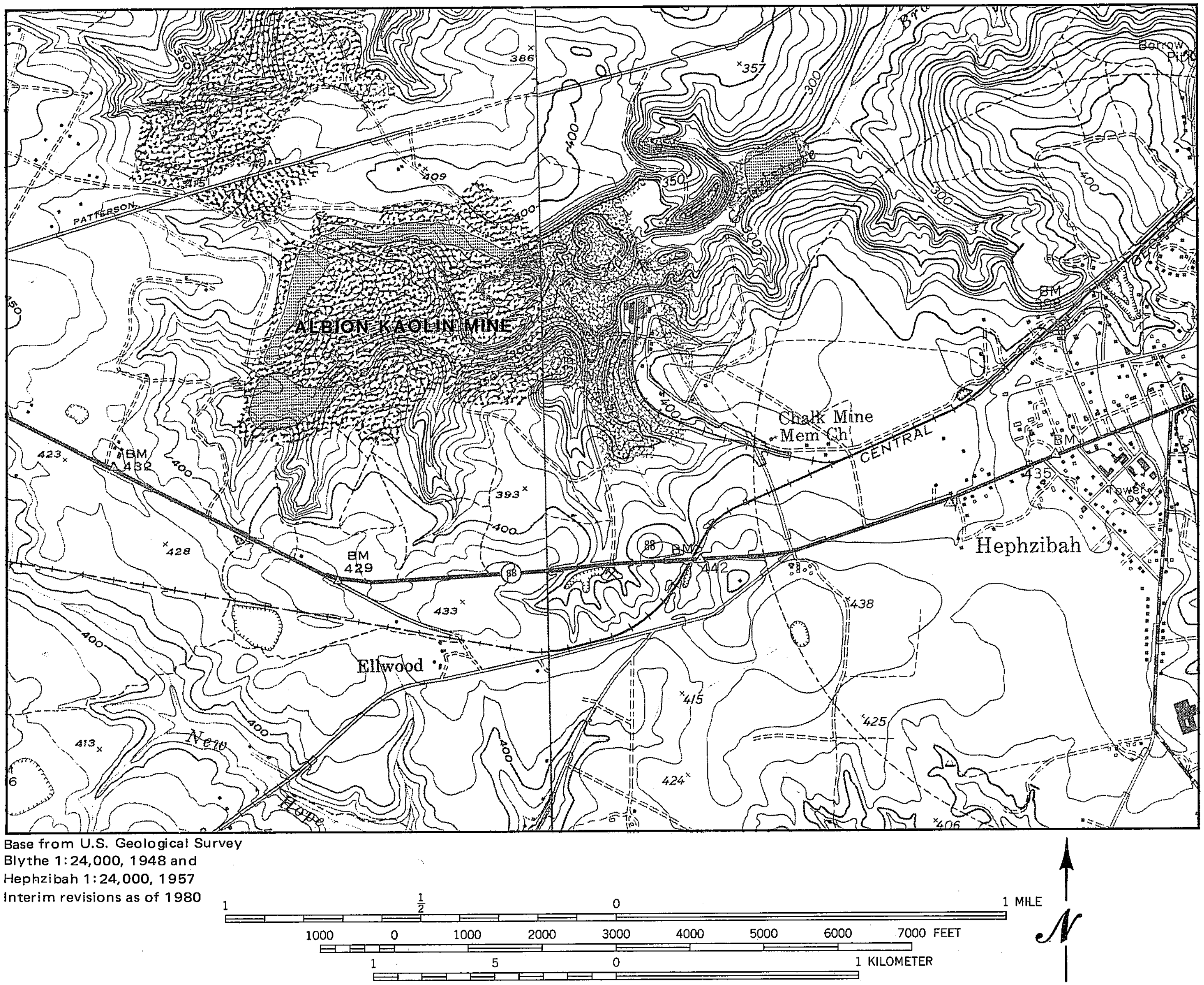


Figure 17. Location map of the Babcock and Wilcox Company's Albion kaolin mine, the type locality of the Albion Member of the Clinchfield Formation.

the Windsor Spring and Gibson sections. X-ray diffraction indicates that the underlying Middendorf Formation consists of mixtures of kaolinite and quartz, but the spiculitic clays and mudstones of the Albion Member are mixtures, in varying proportions, of opal, montmorillonite, quartz and kaolinite, with opal and montmorillonite dominant in most cases. The change in clay mineralogy across the Middendorf-Barnwell Formation boundary in the Albion Member outcrop area is evidence for a significant change in source materials, perhaps the introduction of volcanic ash, or a change in weathering conditions in the source area, and subtantiates the importance of the unit as a stratigraphic marker.

The mudstone and clays of the Albion Member contain abundant sponge spicules, which are one source of opal in the sediment. Separation and low-power microscopic examination of the coarser fractions of the spiculitic clays reveal that the tripartite spicule terminations of class Hyalospongia are common. Hyalospongia are an entirely marine class of sponges, and the presence of Hyalospongia firmly establishes the marine character of Albion Member sediments.

Opal-cemented units of the Albion Member are dominantly opal with varying amounts of clastic quartz and minor amounts of montmorillonite and kaolinite. One lens of opal-cemented sandstone in the Albion Mine grades laterally into marcasite-cemented gravel with montmorillonite fragments, pinching-out within a few feet of the lateral change in grain size. Silicified (opalized) plant fragments and carbonaceous matter are abundant in lower parts of the unit. Taken together, the thin, discontinuous nature of the units, the abundance of plant fossils, and the abrupt lateral transition to marcasite-cemented gravels strongly indicate an extreme near shore, perhaps tidal pool, origin for the opal-cemented clastics and spiculites of the Albion Member of the Barnwell Formation. This interpretation confirms the observation of Cavaroc and Ferm (1968) that richly spiculitic sediments are indicators of shoreline environments.

The Albion lithology is not a normal Barnwell type of lithology. There is, therefore, some question whether the relatively thick section of Albion at the Windsor Spring Road exposure in Richmond County should be considered a part of the Barnwell Group, and whether it is equivalent to the Clinchfield Formation and not to an older unit. Lithologically the Albion could just as well be a subdivision of the older Huber Formation. Consequently, correlation of the Albion with the Clinchfield Formation is a probability rather than a certainty. No calcareous fossils are present in the Albion that can be used for establishing correlation with the rest of the Jacksonian deposits. Only radiolarians (which have not been employed for correlation purposes in the upper Eocene), sponge spicules, and very poorly preserved diatoms have been reported from the Albion. The reasons for correlating the Albion with the Clinchfield are as follows:

(1) The Albion has traditionally been included in the Barnwell.

(2) Stratigraphic position. Both the Clinchfield Formation and the Albion occur beneath marginal marine deposits of known Jacksonian age and above kaolinitic sand deposits of early Tertiary age (Huber Formation).

(3) Facies. Both the Clinchfield Formation and the Albion are very shallow-water, nearshore deposits that occur at the base of a major marine transgression.

(4) Both the Clinchfield Formation and the Albion are quite variable in thickness and locally may be absent (this is common in the case of the Albion). The absences appear to be due to initial Jacksonian sedimentation in topographic lows on an earlier, pre-Jacksonian surface of some relief. The Dry Branch Formation, on the other hand, does not exhibit this style of thickness variability, suggesting that a surface with topographic relief did not develop between the time of Dry Branch deposition and the time of Clinchfield-Albion deposition. This suggests that the Albion is not an updip, nearshore facies of the underlying Claibornian Lisbon-McBean Formation because we would expect the upper surface of a nearshore Claibornian deposit to exhibit moderate relief.

(5) Finally, in the case of the Albion there is a very uniform abrupt change in lithology between the Albion and the overlying Dry Branch Formation, suggesting that the Albion is not a basal facies of the Dry Branch.

Areal Extent. The Albion Member of the Clinchfield Formation (a discontinuous unit) is present only in Glascock and Richmond Counties, Georgia, and in Aiken County, South Carolina. Its geographic occurrence, therefore, is only in the updip nearshore facies of the Jacksonian in eastern Georgia and western South Carolina (Fig. 6).

Thickness. The thickness of the Albion Member of the Clinchfield Formation varies from 0 to 22.5 feet (0 to 7 m). The thickest known section of the Albion Member is in the large roadcut on Windsor Spring Road south of Augusta in Richmond County, Georgia.

Utley Limestone Member of the Clinchfield Formation (New Member)

Definition. The name Utley Limestone Member of the Clinchfield Formation is taken from Utleys Cave and the type locality is at the upper end of Mallard Pond (Figs. 18 and 19). This location is on the property of Georgia Power Company's Plant Vogtle site, 1.3 miles (2.1 km) immediately east-southeast of the intersection of Hancock Landing Road and River Road, Burke County, Georgia. The only other exposure of the limestone known to the authors is at Utley Point (also see Cooke 1943, p. 57) on the Savannah River, 0.9 mile (1.5 km) east-northeast of Utleys Cave, also on the property of Georgia Power Company. Because the Plant Vogtle site is a nuclear facility, the security and restrictions of movement on the property are high and, therefore, access to the type locality is difficult. Unfortunately, there are no other known exposures of the member.

Lithology. The Utley Limestone Member is typically a sandy, glauconitic, slightly argillaceous, fossiliferous limestone with varying degrees of induration. In places the sand content is great enough to render the deposit a very calcareous sand or sandstone.

Areal Extent and Thickness. The Utley Limestone Member is known to occur only in Burke and northern Screven Counties, Georgia, but it is probably also present in western South Carolina as well. Like the Albion Member farther north and the rest of the Clinchfield Formation in east-central Georgia, the Utley Limestone is locally absent in its area of occurrence. Part of the patchy distribution of the unit may be due to its being deposited only in topographic lows on a surface of low or moderate relief. However, the Utley is also known to be cavernous (as at the type locality) and part of its absence must be due to solution.

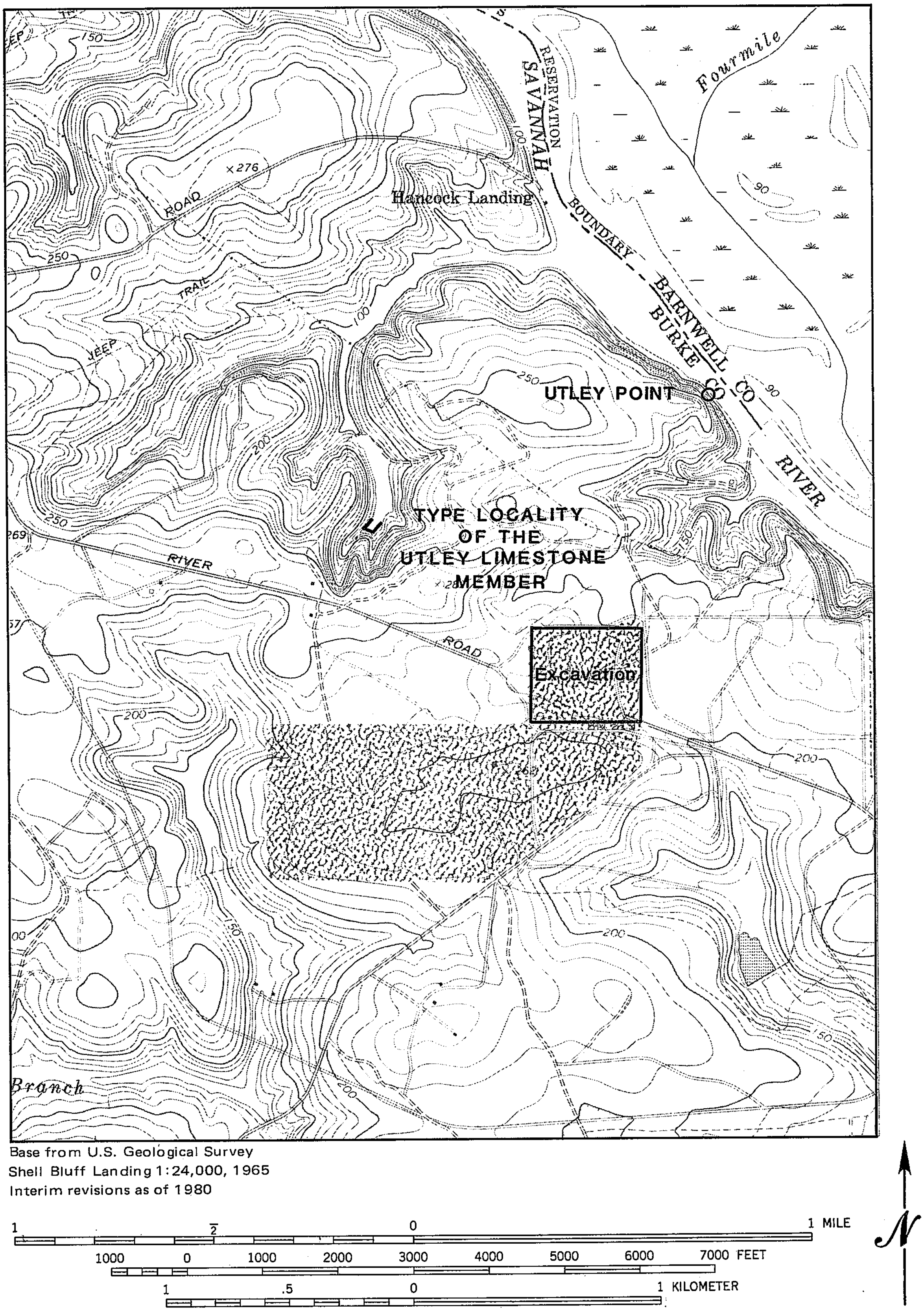


Figure 18. Location map of Mallard Pond, the type locality of the Utley Limestone Member of the Clinchfield Formation, and of the former excavation at Georgia Power Company's Plant Vogtle, Burke County, Georgia.

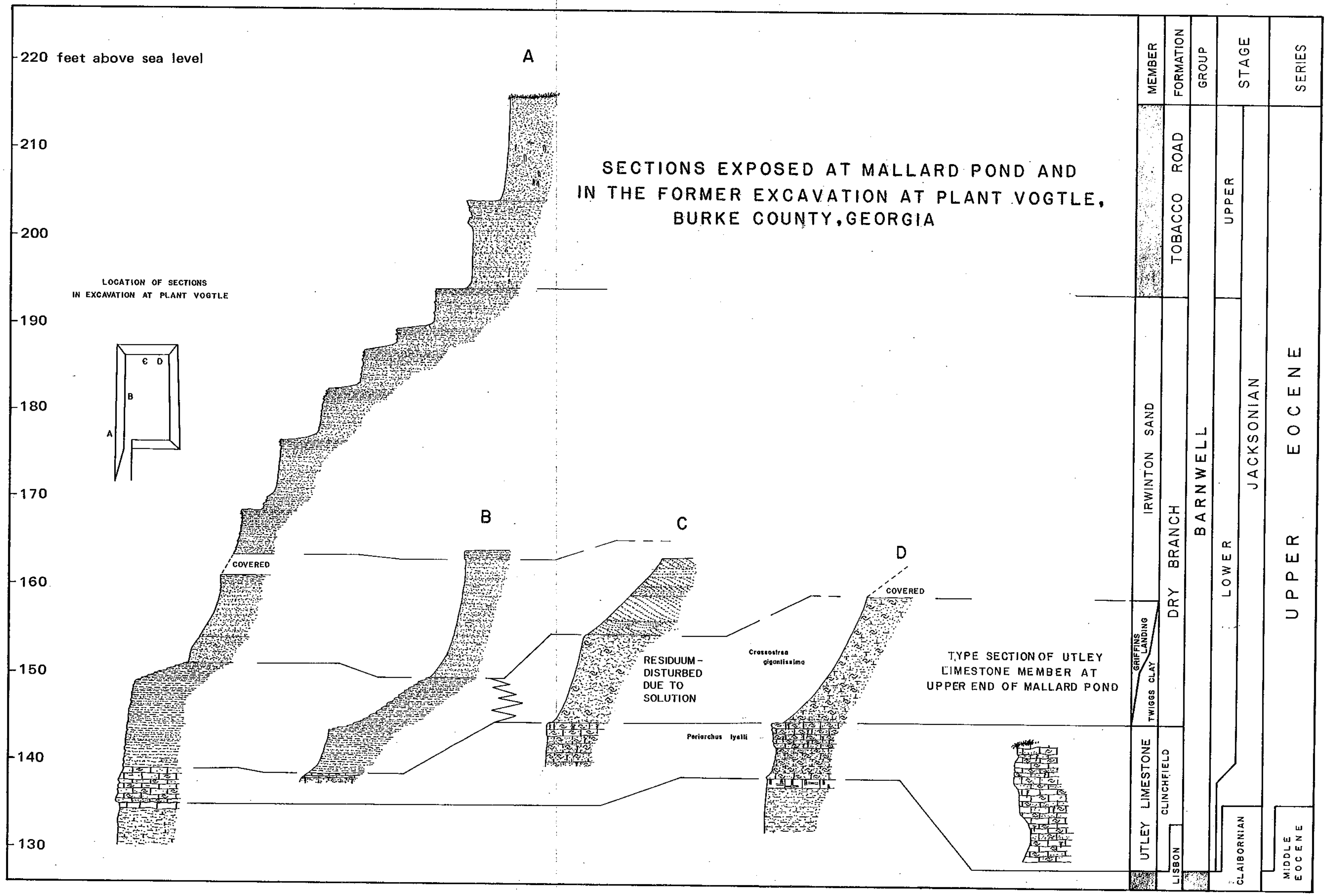


Figure 19. Measured sections of the exposures at Mallard Pond and from the former excavation at Plant Vogtle, Burke County, Georgia.

The known thickness of the Utley Limestone Member of the Clinchfield Formation varies from 0 to 36 feet (0 to 11 m). It is at least 13 feet thick (4 m) at the type locality, but the upper and lower contacts of the member are not exposed there.

Paleontology. The Utley Limestone Member of the Clinchfield Formation locally contains abundant *Periarchus lyelli* and, therefore, contains the easternmost occurrence of the "*Scutella*" bed of the eastern Gulf Coastal Plain.

DRY BRANCH FORMATION (New Formation)

Definition

The name Dry Branch Formation, a new stratigraphic unit, is taken from the community of Dry Branch, located on U.S. Highway 80, on the Bibb-Twiggs County line in Georgia. The type locality of the Dry Branch Formation is in Twiggs County, along an abandoned kaolin haul road at the entrance to an abandoned kaoline mine. The type locality is 0.6 mile (1 km) from the junction of the kaolin haul road and U.S. Highway 80 at the highway bridge over the Seaboard Coast Line Railroad, 2.3 miles (3.7 km) south of Dry Branch (Fig. 20). The type locality of the Dry Branch Formation is 0.6 mile (1 km) northeast of the type locality of the Twiggs Clay at the pit of the defunct General Reduction Company. The type description of the Dry Branch Formation is provided in the Appendix on p. 66 (see also Figs. 20 and 21).

Stratigraphic Relationships

The Dry Branch Formation consists of three distinct but interfingering and intergrading lithofacies, a marine montmorillonite clay lithofacies (Twiggs Clay), a distinctly bedded sand and sand-clay lithofacies (Irwinton Sand), and a rudely bedded, thick-bedded and massive, calcareous, fossiliferous sand lithofacies (Griffins Landing Member) (also see Fig. 6). In the areas of characteristic development of each of these lithofacies, they generally constitute the entire Dry Branch section. It is in such areas that it is useful to recognize these lithofacies as distinct, formal members of the Dry Branch Formation. In many areas of Georgia, however, a fine distinction between the lithofacies, due to complex interfingering and intergradation, is not possible. In those areas, for mapping purposes and purposes of discussion, it is best to distinguish only the formation and to recognize the facies subdivisions as informal lithofacies, lithosomes, or lithostromes.

In general, the Twiggs Clay is characteristic of the entire Dry Branch Formation west of the Ocmulgee River with the exception of the single Jacksonian outlier at Rich Hill in Crawford County. There the Irwinton Sand overlies the Twiggs Clay. Up to approximately 10 miles (16 km) east of the Ocmulgee River, the Twiggs Clay dominates the Dry Branch Formation. To the east of that, in outcrop, the Dry Branch becomes significantly more sandy, and the Twiggs Clay becomes characteristic only of the downdip and lower part of the formation.

The Irwinton Sand, on the other hand, is characteristic of the updip, outcropping Jacksonian in the areas near the Fall Line of eastern Georgia and western South Carolina. It does not extend very far downdip in the subsurface, nor does it extend west of the Ocmulgee River, except at the Fall Line.

The Twiggs Clay lithology and the Irwinton Sand lithology in the outcrop belt are very closely related, both spatially and in origin. The silty fine sand along the bedding planes of Twiggs Clay is essentially Irwinton "sand," and the clay laminae, thin clay layers, clay lenses, and detrital clay chips so characteristic of the Irwinton Sand are essentially Twiggs "clay." Curiously, sedimentary processes over large expanses of the late Eocene coastal area of eastern Georgia effectively and almost exclusively separated the fine and medium sand components of the incoming terrigenous clastic sediments from the almost pure clay component.

The Twiggs Clay and Irwinton Sand intertongue in the region immediately east of the Ocmulgee River (Fig. 6). In this area there appear to be two tongues of Twiggs Clay and two tongues of Irwinton Sand. The lower tongue of Twiggs Clay is the more persistent and extends across Georgia to the Savannah River at or near the base of the Dry Branch Formation. The upper tongue of the Twiggs Clay contains the type locality of the member. This tongue does not extend farther east than Jeffersonville in Twiggs County. East of Jeffersonville the tongue appears to break up into discontinuous lenses of Twiggs Clay within the general mass of Irwinton Sand.

The lower tongue of Irwinton Sand occurs near the middle of the Dry Branch Formation. It separates the lower and upper tongues of Twiggs Clay and extends as far west as the Ocmulgee River. The upper tongue of Irwinton Sand is discontinuous immediately east of the Ocmulgee River, but it appears to become continuous in the vicinity of Dry Branch. Where it is present, it occurs at the very top of the Dry Branch Formation. In most of east-central Georgia, the upper tongue of Irwinton Sand typically contains very pronounced horizontal bedding and cross-bedding and is associated closely with a generally thin, discontinuous bed of thinly interlayered fine-grained sand and clay at the top of the Dry Branch Formation.

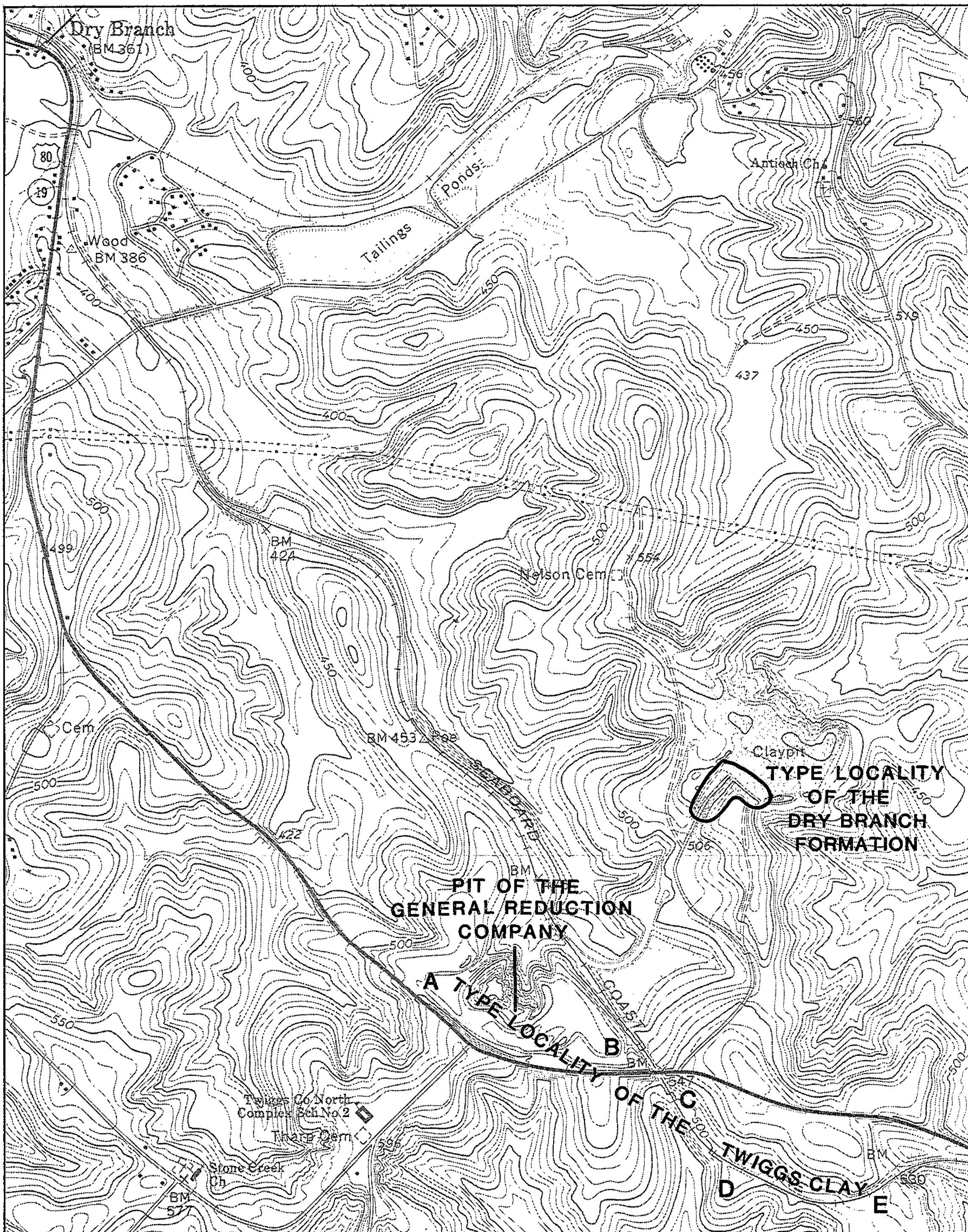
The general lithofacies patterns (from older to younger beds) within the Dry Branch Formation in central and east-central Georgia are listed below.

(1) The greatest probability of encountering Twiggs Clay (lower tongue of Twiggs Clay) is near or at the base of the Dry Branch Formation.

(2) Well-stratified Irwinton Sand and Irwinton scour-and-fill structures (tidal channels?) are most commonly encountered near the middle of the Dry Branch Formation (lower tongue of Irwinton Sand). Some channel development is found near the top of the formation, whereas some channels extend all the way to the base, having removed even the previously deposited Twiggs Clay. A calcareous, fossiliferous, argillaceous sand is consistently encountered in the middle of the Twiggs Clay west of the Ocmulgee River. The calcareous sand bed is probably the western expression of this dominance of the Irwinton Sand in the middle of the Dry Branch Formation.

(3) There is a discontinuous lenticular development of Twiggs lithology in the upper part of the Dry Branch Formation over much of eastern Georgia, above the main concentration of scour-and-fill structures (lower tongue of Irwinton Sand). The clay in the fuller's earth mine at Wrens in Jefferson County is probably representative of these upper Dry Branch "Twiggs" lenses. Immediately east of the Ocmulgee River, this clay development is represented by the upper tongue of Twiggs Clay.

(4) In east-central Georgia the Irwinton lithofacies is commonly developed near the top of the Dry Branch Formation (upper tongue of Irwinton Sand).



Base from U.S. Geological Survey
Dry Branch 1:24,000, 1973

1	½	0							1 MILE
1000	0	1000	2000	3000	4000	5000	6000	7000 FEET	
1	.5	0						1 KILOMETER	

Figure 20. Location map of the type localities of the Dry Branch Formation and the Twiggs Clay Member of the Dry Branch Formation, Twiggs County, Georgia.

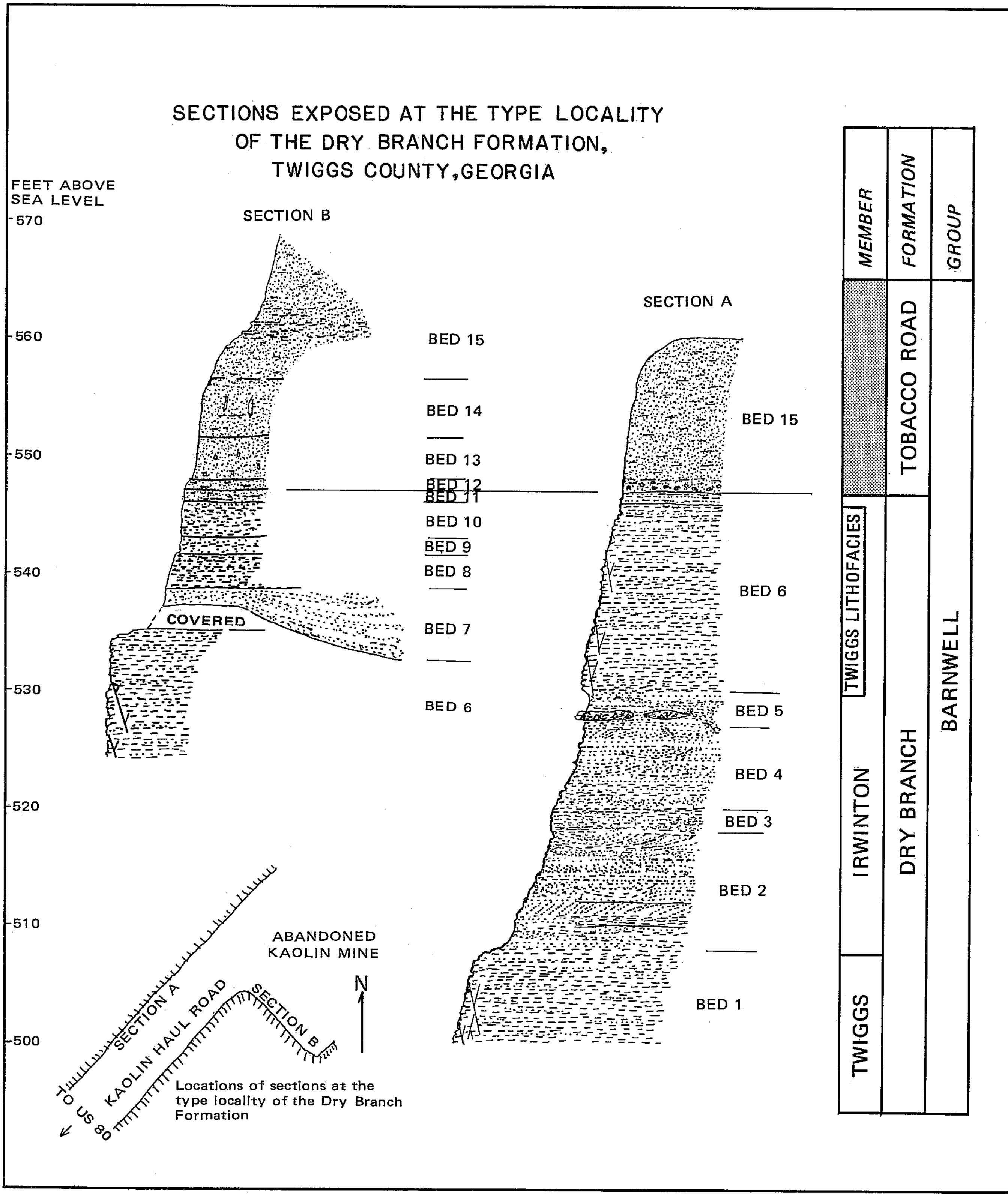


Figure 21. Measured sections of the Barnwell Group at the type locality of the Dry Branch Formation, Twiggs County, Georgia.

(5) There is a discontinuous but common occurrence of thinly bedded clay and thinly interlayered clay and fine-grained sand at the very top of the Dry Branch Formation in most of east-central Georgia, which is, therefore, a useful marker bed.

Although there are scattered layers or lenses of Griffins Landing lithofacies in the Dry Branch Formation west of the Ogeechee River, this unit is, for the most part, restricted to the area east of that river. The Irwinton and Griffins Landing lithofacies are so intimately intermixed in much of the Jacksonian outcrop belt in northwestern Burke County that regional separation of the two is impractical. One lithofacies may dominate the Dry Branch section at one site whereas, nearby, the other facies dominates. In southeastern Burke County, however, the Griffins Landing lithofacies consistently dominates the lower part of the Dry Branch section and, except for a thin, fairly consistent bed of Twiggs lithology near the base of the unit, the entire formation in the shallow subsurface in Screven County, Georgia, consists of Griffins Landing Member lithology.

The stratigraphic pattern that is apparent within the Dry Branch Formation in Burke and Screven Counties, Georgia, and Aiken County, South Carolina, is as follows (also see Fig. 6).

(1) The Twiggs Clay lithofacies is commonly, but not invariably, present near the base of the Dry Branch section;

(2) the Griffins Landing Member is thickest and constitutes a greater proportion of the Dry Branch Formation downdip;

(3) the Griffins Landing Member thins and is restricted to the lower part of the Dry Branch section updip;

(4) the Irwinton Member is thickest and constitutes a greater proportion of the Dry Branch Formation updip;

(5) the Irwinton thins and is restricted to the upper part of the Dry Branch Formation downdip (therefore, it appears in a general way that the Twiggs lithofacies represents a transgressive, offshore deposit; the Griffins Landing lithofacies appears to represent a maximum transgression, and the Irwinton, being nonfossiliferous, is regressive over the Griffins Landing [also see Herrick, 1964] and represents the most restricted marginal marine environment in the Dry Branch Formation); and

(6) in Aiken County, South Carolina, the basal bed of the Dry Branch Formation (Irwinton Member), where it lies directly on the Huber Formation, consists locally of a gravel with flat pebbles (this flat pebble bed is not to be confused with the flat pebble bed that occurs at the base of the overlying Tobacco Road Sand).

Areal Extent

The Dry Branch Formation extends from Dooly County, Georgia, in the west, to Lexington and Orangeburg Counties, South Carolina, in the east. It extends from the vicinity of the Fall Line in the north to a variable line of facies change with the Ocala Group (controlled by intertonguing relationships) in the shallow subsurface in the south. In the Savannah River area, this zone of the facies change occurs in northern Effingham County, Georgia. In the west, the zone of facies change extends from the vicinity of the Fall Line, downdip to the vicinity of Dooly or Crisp Counties, Georgia.

Thickness

The thickness of the Dry Branch Formation in Georgia ranges from less than 30 feet (9 m) to more than 180 feet (55 m). In Aiken County, South Carolina, the thickness of the Dry Branch Formation ranges from about 25 feet (8 m) to more than 46 feet (14 m) with an average thickness of approximately 31.5 feet (9.6 m) (Nystrom and Willoughby, 1982). In eastern Georgia and western South Carolina the Dry Branch Formation appears to thin systematically toward the Fall Line, being consistently thinnest in that area.

Paleontology and Age.

Deposits here referred to as the Dry Branch have been assigned ages from middle Eocene (Veatch and Stephenson, 1911; Cooke, 1936, 1943; Cooke and MacNeil, 1952; Siple, 1967; Colquhoun and others, 1969) to Oligocene and Miocene (Herrick and Counts, 1968; Ward and others, 1978; Zullo and others, 1982; and Harris and Fullagar 1982). We understand the age of the Dry Branch Formation to be late Eocene. The reasons, mentioned earlier (p. 13), are as follows. At the Medusa Cement Company quarry at Clinchfield in Houston County, the Twiggs Clay Member of the Dry Branch Formation is approximately 100 feet (30 m) thick. In the core Houston 3 (GGS-3079) taken at the crest of the escarpment at the quarry at Clinchfield, the senior author has identified the following planktonic foraminifera from a sample 8.5 feet (2.6 m) below the top of the Dry Branch Formation (Twiggs Clay Member). This sample is from a stratigraphic position equivalent to bed 18 (Huddlestun and others, 1974) and approximately 7 feet (2 m) below the sample dated by Harris and Fullagar (1982) as 23.0± 0.2 m.y. (early Miocene, Aquitainian):

Hantkenina alabamensis (immature)
Pseudohastigerina micra
Globigerina eocaena
Cheilogumbelina sp.

At a depth of 18 feet (5.5 m) below the top of the Dry Branch Formation (Twiggs Clay Member) in the same core, stratigraphically equivalent to the upper part of bed 16 (Huddlestun and others, 1974), the senior author has identified the following planktonic foraminifera:

Hantkenina alabamensis
Pseudohastigerina micra
Globigerina eocaena
G. cf. *linaperta*
Globorotaloides suteri

At the type locality of the Griffins Landing Member, in Burke County, a sample from 145 feet in the core Burke 1 (GGS-1171) (approximately 42 feet [13 m] above the base of the Dry Branch Formation and 125 feet [38 m] below the top of the formation) contains the following planktonic foraminifera:

Hantkenina alabamensis
Globorotalia cerroazulensis cocoaensis
G. increbescens
Globigerinatheka tropicalis
Globigerina linaperta
G. eocaena
G. tripartita
G. ouachitaensis
Globorotaloides suteri
Truncorotaloides inconspicua

The planktonic foraminiferal assemblages from the Dry Branch formation from these cores in Houston and Burke Counties are strictly Eocene in age. Furthermore, the associations and frequencies indicate that they are late Eocene rather than middle Eocene in age.

Twiggs Clay Member of the Dry Branch Formation

Definition. The Twiggs Clay was named as a member of the Barnwell Formation by Shearer (1917, p. 158-174) for an outcropping fuller's earth clay deposit in the vicinity of Pikes Peak station in Twiggs County, Georgia. The Twiggs Clay represents a subdivision or lithofacies of the Dry Branch Formation that consists predominantly of montmorillonitic clay.

The Twiggs Clay was correlated with and called the Congaree member of the McBean Formation by Veatch and Stephenson (1911, p. 267-284). Shearer (1917) found that the "Congaree" clay overlies the Tivola Limestone (Ocala Limestone) in central Georgia and, therefore, could not be correlative with the Congaree Clay (Sloan, 1908) of South Carolina. As a result, Shearer (1917) changed the name from Congaree to Twiggs and correlated the associated sands (Irwinton Sand) with the Barnwell. This also required revision of the age of these particular deposits, and of the Barnwell Formation in general, from middle Eocene to late Eocene (Cook and Shearer, 1918).

Pickering (1970) recommended raising the Twiggs Clay to formation rank. Each of the three members of the Dry Branch Formation constitute the entire formation in the areas of their maximum development. However, because the three units interfinger and interlens in complex fashion in the largest part of east-central and eastern Georgia, we propose member status for the Twiggs, Irwinton, and Griffins Landing lithostratigraphic units, at least until more is known about the stratigraphic limits of the three units.

Shearer (1917) did not designate a type locality for the Twiggs Clay Member, but instead described seven localities in the vicinity of Pikes Peak station given as "map localities" A through G. The section in the pit of the General Reduction Company (map locality A) was the most thoroughly described and presumably the best exposed. Likewise, Cooke and Shearer (1918) did not specifically designate a type locality. However, their comment (p. 52) that "Exposures near Pikes Peak station, on the Macon, Dublin & Savannah Railroad, are regarded as typical" indicates that they intended a "type locality" to be the section exposed along the railroad tracks, from "map localities" B through E.

Because the type locality of the Twiggs Clay has never been formally and explicitly designated as such (also see Connell, 1966), we herein designate the exposures along the Seaboard Coast Line Railroad from "map localities" B through E of Shearer (1917, p. 165-174) the type locality of the Twiggs Clay Member of the Dry Branch Formation. In addition, the former fuller's earth pit (map locality A) appears to fall within the confines of the "type locality" as indicated by Cooke and Shearer (1918) and we are, therefore, including it in the type locality as well.

The section that was exposed in the fuller's earth pit (map locality A) and described by Shearer (1917, p. 166-167), and coordinated with map locality E of Shearer (1917) (Stop 9 of Huddlestun and Hetrick, 1979) and the type locality of the Dry Branch Formation is shown in Figure 22.

The location of the fuller's earth pit of the defunct General Reduction Company is adjacent to highway U.S. 80, 2.0 miles (3.2 km) south of Dry Branch in Twiggs County. The sections exposed along the railroad tracks (now the Seaboard Coast Line Railroad) extend to 1.0 mile (1.6 km) southeast of the former fuller's earth pit. Only "map locality" E of Shearer (1917) (Stop 9 of Huddlestun and Hetrick, 1979) and a section under the U.S. 80 highway bridge over the railroad tracks (map locality B) are still well exposed. Other sections described by Shearer (1917) are overgrown, although there are some useful exposures still accessible in the former fuller's earth pit. Our description of "map locality E" is given on p. 68.

It is apparent on examining our sections of the type area of the Twiggs Clay and the Dry Branch Formation (see Fig. 22, p. 39) that the Irwinton Sand is an integral part of the type deposits of the Twiggs Clay. It is also clear that:

(1) the type minable deposits of the Twiggs, fuller's earth clay, are overlain by Irwinton Sand;

(2) there is a thick section of Irwinton Sand underlying the type Twiggs Clay; and

(3) the type Twiggs Clay occurs near the top of the Dry Branch Formation, just below the Tobacco Road Sand.

This is in reverse order of the sequence as postulated by LaMoreaux (1946a, p. 58) and most subsequent investigators for the typical Twiggs-Irwinton stratigraphic relationships. We emphasize that the most persistent interval of stratigraphic occurrence of the Twiggs Clay is the lower tongue of the member near the base of the Dry Branch Formation. Therefore, we conclude that:

(1) the type stratigraphic concept of the Twiggs Clay is not consistent with the concept of the Twiggs Clay that has been developed by a number of investigators over the years (LaMoreaux, 1946a, 1946b; Carver, 1966, 1972; Pickering, 1970); and

(2) the type locality of the Twiggs Clay is in the upper tongue of Twiggs lithofacies, and, based on locally established stratigraphic usage, would necessarily be in the upper part of the Irwinton Sand Member of the Dry Branch Formation.

The type bed of Twiggs Clay can be looked upon as projecting laterally into an Irwinton Sand deposit. It is not correlative with the principal, lower bed of Twiggs Clay that we conceive as the Twiggs Clay Member of the Dry Branch Formation over most of eastern Georgia.

In an effort to stabilize the stratigraphic terminology of the Dry Branch Formation and the concept of the Twiggs Clay, and to make the concept of the Twiggs Clay consistent with established usage, we propose that the Twiggs Clay exposure in the pit of the Medusa Cement Company at Clinchfield in Houston County be a reference section for the Twiggs Clay Member of the Dry Branch Formation (see Figs. 12 and 13, p. 23 and p. 24). In this area the Twiggs Clay includes the entire Dry Branch stratigraphic interval and has always been recognized by various investigators as being of late Eocene age, and therefore, correlative with the type Jacksonian deposits farther west (Veatch and Stephenson, 1911; Shearer, 1917; Cooke and Shearer, 1918; Cooke 1943; Cushman, 1945; Pickering, 1970; Schmidt, 1977). In addition, the Twiggs Clay in this area is underlain and overlain by other distinctive Eocene lithostratigraphic units that contain distinctive Eocene faunas. Therefore, the upper and lower stratigraphic boundaries of the Twiggs Clay are clearly definable at Clinchfield.

Lithology. The Twiggs Clay is a pale-greenish, olive-green, bluish-gray, dark-gray, or locally, almost black, silty clay with hackly, blocky, shaley, subconchoidal to conchoidal fracture. Where the clay is almost pure and unaltered by weathering, it commonly displays a combination of blocky and conchoidal fracture, and where it is weathered, its fracture is pronouncedly hackly. Where the Twiggs Clay is sandy or silty, and especially where concentra-

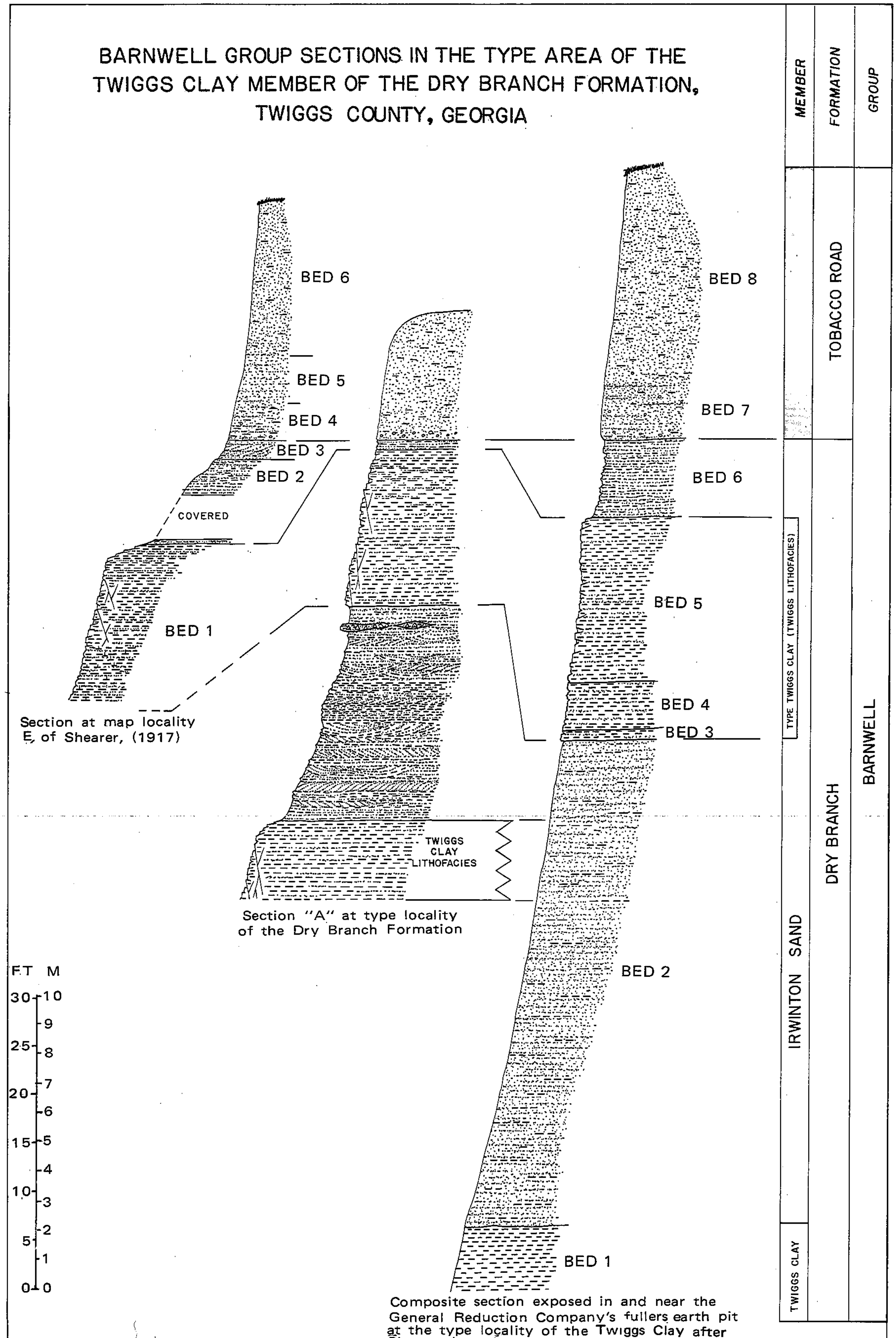


Figure 22. Measured sections of the Barnwell Group in the type area of the Twiggs Clay Member of the Dry Branch Formation, Twiggs County, Georgia.

tions of fine to very fine sand occur on bedding planes, the fracture can be fissile and shaley. The Twiggs Clay commonly displays jointing both in outcrop and in the subsurface, and at some locations it may be intensely jointed.

Some beds of Twiggs Clay may consist of almost pure montmorillonite clay with minor or trace amounts of illite and kaolinite. The kaolinite content (in unweathered Twiggs Clay) is always highest at the base of the Dry Branch Formation. Characteristically, the clay is impure. The impurities consist of quartz silt or sand, rare pebbles, finely disseminated or biogenic calcite, rare aragonitic mollusk shells, opal-cristobalite, glauconite, zeolite, pyrite, mica, lignite and flecks of carbonaceous matter, and apatite (in the form of small vertebrate bone debris, fish teeth and scales, and rarely *Zeuglodon* bones). Minerals that are normally subordinate may comprise the dominant lithologies in specific beds or exposures in this unit. Sand, greensand, chert, limestone, or lignite beds of varying thickness and extent are present locally.

An eastern and a western facies of the Twiggs has been recognized by some previous investigators. This regional division of the Twiggs Clay also applies to the clay that is updip or downdip, or upsection or downsection. The western, downdip, downsection facies of the Twiggs Clay is generally calcareous with some admixtures of sand, glauconite, mica, and finely disseminated pyrite. Sandy, glauconitic, fossiliferous (shelly fauna), thin limestone beds or layers, calcareous concretions, or calcareous, glauconitic, fossiliferous sandstone beds or layers are not uncommon within the section. Toward the base of the Twiggs Clay in the western facies, the clay becomes very calcareous and fossiliferous and is commonly referred to as "marl." Greensand beds are generally present near the top of the westernmost Twiggs Clay west of the Ocmulgee River and also in the vicinity of Allendale, Wilkinson County, east of the Ocmulgee River. These greensand beds are only slightly calcareous but are sandy and argillaceous and may contain scattered shell molds.

An eastern updip, upsection facies of the Twiggs Clay is characterized by a paucity of calcite and glauconite and the almost universal presence of unidimensionally disordered cristobalite (opal claystone of Heron and others, 1965; Carver, 1972). The opal-cristobalite in the clay is generally disseminated through the clay as fine particles. The source of this silica in the Twiggs Clay is siliceous microfossils, i.e., diatoms, radiolarians, and sponge spicules (Schmidt, 1977; Wise, and others, 1972; Wise and others, 1974; Weaver and Wise, 1974; Wise and Weaver, 1973). Evidently the environment of deposition of the eastern facies of the Twiggs Clay was conducive to the proliferation of diatoms, radiolarians, and sponges during late Eocene time, whereas the western facies of the Twiggs was not conducive to the proliferation of these organisms but rather to that of calcareous organisms.

Areal Extent and Thickness. The Twiggs Clay is thickest in the western area, being as much as 100 feet (30 m) thick at Clinchfield. In outcrop east of the Ocmulgee River, the Twiggs Clay interfingers with the Irwinton Sand and although the entire thickness of the Dry Branch may be as much as 180 feet (55 m) thick, the combined thickness of the distinct beds of Twiggs Clay is less, for example only 86 feet (26 m) thick at the type locality as opposed to the reported thickness of 100 feet (30 m) (Cooke and Shearer, 1918; Cooke, 1943). In the Savannah River area the Twiggs Clay becomes discontinuous and thin and is at most 10 feet (3 m) thick. This thinning is not a function of dip position or nearness to the shore because the Twiggs does not thicken downdip in Screven County. In the Savannah River area the updip Irwinton and Twiggs passes downdip into Griffins Landing and Twiggs, and thence into the Williston Formation of the Ocala Group. The Twiggs Clay remains uniformly thin and discontinuous throughout the Savannah River area and does not thicken down the dip.

Irwinton Sand Member of the Dry Branch Formation

Definition. The Irwinton Sand was named by LaMoreaux (1946a, 1946b) for a soft, commonly loose, fine to medium, well-bedded sand that conformably overlies the Twiggs Clay in Wilkinson, Twiggs, and Washington Counties, Georgia. The type locality of the Irwinton Sand is in gullies, now overgrown, on the west side of Ga. 29 (U.S. 441), 0.3 mile (0.5 km) south of the courthouse in Irwinton, Wilkinson County, Georgia (Fig. 23). The type description of the Irwinton is as follows (LaMoreaux, 1946a, p. 17):

> During this investigation it was noted that many dug wells throughout the "Red Hills" area obtained their water from a persistent bed of fine to coarse loose sand lying conformably on the Twiggs clay. It was also noted that the sand capped many of the uplands in the northern half of the area of outcrop of the upper Eocene deposits (see Plate 1). This sand bed, which is here named the Irwinton Sand Member of the Barnwell Formation, ranges in thickness from about 15 feet, along the northern margin of the outcrop area of the Barnwell Formation, to a maximum of 52 feet in the vicinity of Irwinton.

The lithologies of beds 3 and 4 in the type description of the Irwinton Sand at the type locality (LaMoreaux, 1946b, p. 58; also see Fig. 24 of this report) are those of weathered clay. The brief description of bed 3 is consistent with weathered Twiggs-type clay. The very terse description of bed 4 is ambiguous, but assuming that it is dominantly clay, it is unlikely that bed 4 represents the Tobacco Road because clay is a minor constituent in that formation in Wilkinson and Twiggs Counties. Therefore, it appears likely that beds 3 and 4 at the type locality of the Irwinton Sand represent a Dry Branch clay facies, i.e., Twiggs Clay lithofacies. It appears, then, that Twiggs Clay is an inherent lithology of the type Irwinton Sand just as the Irwinton Sand is an inherent lithology of the Twiggs Clay. Unfortunately, we have found no useful alternate reference locality in the near vicinity of Irwinton, Wilkinson County, Georgia, to substitute for the overgrown and inaccessible type locality.

We have found that the Roberta sand of Connell (1958), which overlies the Twiggs Clay at Rich Hill in Crawford County (Fig. 14), is inseparable from the Irwinton Sand in lithology and stratigraphic position. We therefore recommend that the name Roberta sand be abandoned in favor of the older, established name, Irwinton Sand.

Lithology. In the type area of this member in Wilkinson County and in east-central Georgia, the Irwinton Sand typically consists of fine to medium, well-sorted, almost pure quartz sand that shows well-developed small-scale, horizontal and cross-bedding. The coarser beds of Irwinton Sand tend to become progressively more poorly sorted as the maximum grain size of the quartz sand increases. Most exposures of the Irwinton Sand contain some thick beds, thin beds or lenses, and laminae of disrupted clay clasts of Twiggs-type montmorillonitic clay. In general, all the clay beds

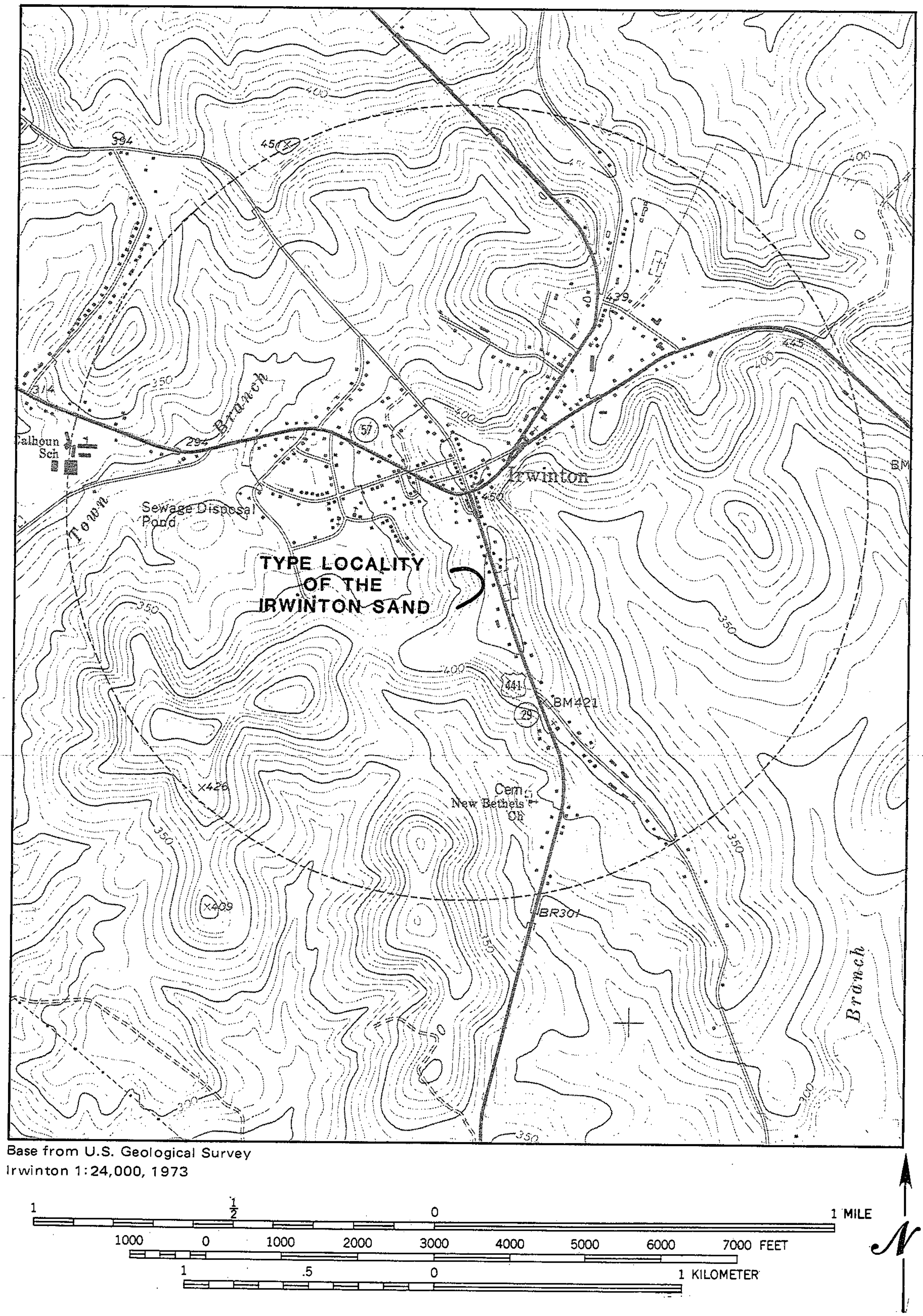


Figure 23. Location map of the type locality of the Irwinton Sand Member of the Dry Branch Formation, Wilkinson County, Georgia.

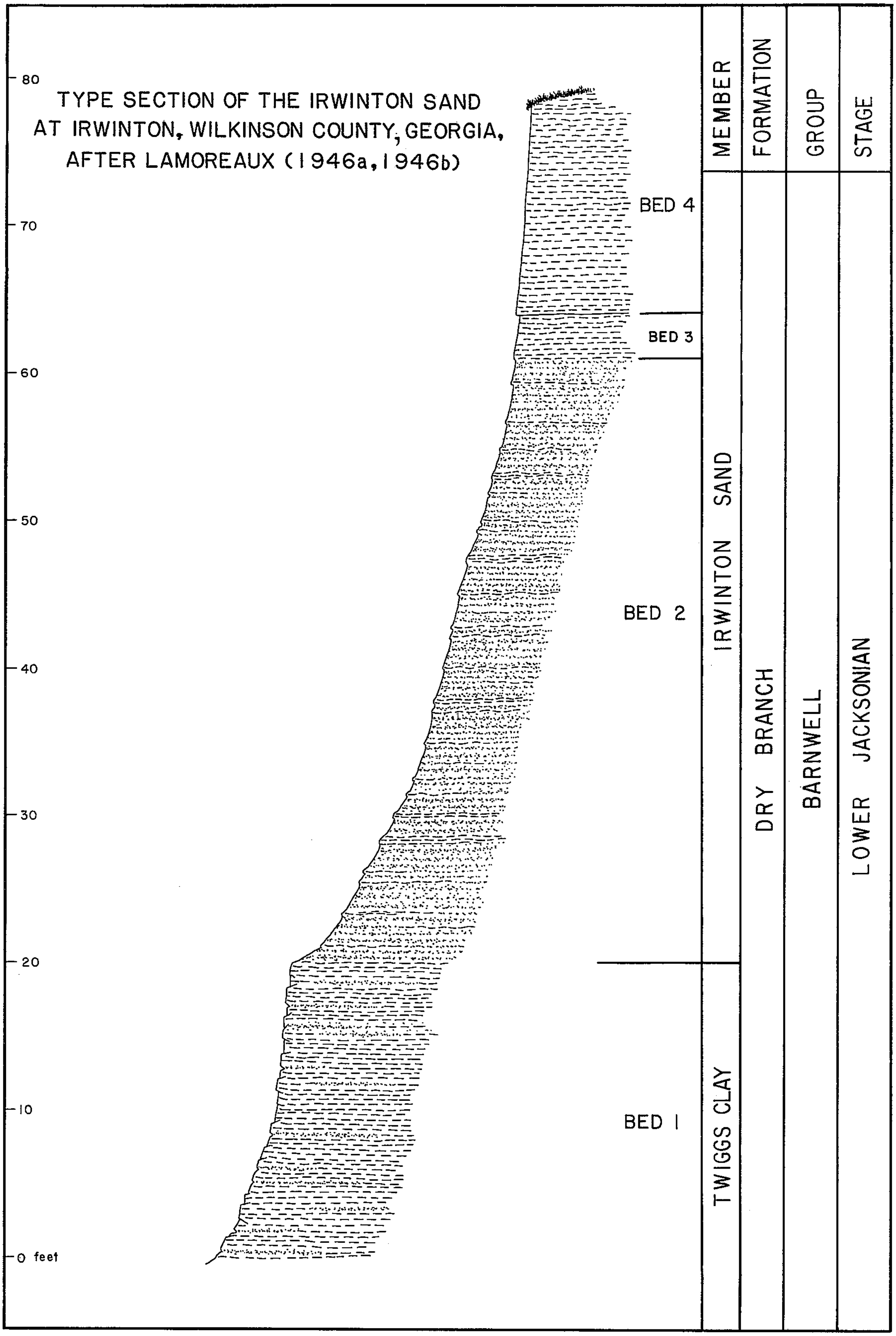


Figure 24. Measured section of the Irwinton Sand Member of the Dry Branch Formation after LaMoreaux (1946a, 1946b), Wilkinson County, Georgia.

within the Irwinton probably are lenses, but the thicker beds are more areally extensive than the thin beds, and the clay laminae are especially discontinuous laterally.

Accessory lithic components include clay that is mainly montmorillonite but contains minor amounts of illite and kaolinite. Some weathered beds of clay in the Irwinton are composed completely of kaolin, apparently altered from montmorillonite. All of the Irwinton clay beds known to the authors are of Twiggs Clay-type lithology. Other accessory minerals in the Irwinton Sand include heavy minerals (which are locally conspicuous), very minor mica, fossiliferous and nonfossiliferous chert and chert-cemented sandstone, calcite, and minor wad. Almost all of the Irwinton Sand known to the authors has been weathered to some degree. However, unweathered Irwinton is known from the cores Twiggs 2 (GGS-3174) and Wilkinson 2 (GGS-3175) and was found to be consistently slightly calcareous and microfossiliferous throughout, thus accounting for the scattered occurrence of beds or lenses of sandy fossiliferous chert on the weathering surface.

The Irwinton Sand is typically well bedded. Only in scattered beds in any given section are there thin layers of Irwinton that have been clearly bioturbated or burrowed, with observable mixing of the sand and clay components.

As noted above, the typical Irwinton Sand is fine to medium, and well sorted. However, there are some poorly sorted sand beds within the Irwinton, and some sections are dominated by medium to coarse, and rarely pebbly, poorly sorted sand. Typically, the Irwinton Sand is soft and unconsolidated, in some places even loose. In general, therefore, the Irwinton is a "slope-former." There are beds of chert-cemented sandstone, however, that are much more resistant to weathering and hold up ledges in roadcuts and old clay pits.

Fossils are generally rare in the Irwinton Sand. This is in part due to the usual leaching of the soft porous sands in the zone of water-table fluctuation. It is also due to conditions in the original depositional environment of the Irwinton where lack of bioturbation clearly indicates that conditions were unsuitable for the existence of an infauna. Scattered beds within the Irwinton are fossiliferous and a silicified molluscan fauna can be collected. Normally, however, the main fossil components of the Irwinton are shell fragments of clams and oysters.

Areal Extent. The westernmost occurrence of the Irwinton Sand is at Rich Hill in Crawford County, Georgia. This is also the only locality west of the Ocmulgee River where the Irwinton is known to occur. In general, the western limit of the unit or lithofacies may be taken to be the Ocmulgee River. The Irwinton Sand occurs as far east as Lexington and Orangeburg Counties, South Carolina. The northern limit of the member is the vicinity of the Fall Line, and it does not appear to extend as far down the dip as does the Twiggs Clay or the Griffins Landing Members.

Thickness. The thickness of the Irwinton Sand ranges from 40 to 70 feet (12 to 21 m) in east-central Georgia. However, in Richmond County, Georgia, and Aiken County, South Carolina, the thickness of the Irwinton Sand can be considerably less than 40 feet (12 m). At Windsor Spring Road in Richmond County, the Irwinton Sand is only 26 feet (8 m) thick, and at the Babcock and Wilcox Albion Mine at Hephzibah in Richmond County, it is only 9 feet (3 m) thick.

Griffins Landing Member of the Dry Branch Formation (New Member)

Definition. The type locality of the Griffins Landing Member of the Dry Branch Formation is at Griffins Landing on the Savannah River, 1.4 miles (2.3 km) north of the junction of Griffins Landing Road and River Road, and 5.2 air-miles (8.4 km) north of Girard, Burke County, Georgia (Fig. 25). A description and measured sections of the type locality of the Griffins Landing Member are given on p. 72 and p. 45 (Fig. 26), respectively.

Lithology. In general, the Griffins Landing Member is a fairly well-sorted, massive to vaguely and rudely bedded, calcareous sand. In updip areas thin limestone beds, clay beds or lenses, local oyster shell (*Crassostrea gigantissima*) beds and bioherms, and chert or silica-cemented sandstone (as at Stoney Bluff Landing) are common. Subordinate lithic components include montmorillonite clay, calcite, shells, zeolite, chert, mica, glauconite and wad.

In many places in outcrop and in cores, the Griffins Landing Member shows little primary sedimentary or biogenic structures. This is especially the case in the downdip, shallow subsurface in Screven County where the Griffins Landing Member consists of a thick-bedded, uniformly structureless, somewhat argillaceous, calcareous, microfossiliferous, well-sorted, medium sand. However, vague stratification is present in outcrop, as at Griffins Landing and in the shallow subsurface of Burke County.

In one area in the subsurface of eastern and southern Screven County, Georgia (in Georgia Power cores B36 and B37), the Griffins Landing Member of the Dry Branch Formation consists of a distinctive molluscan moldic, calcareous sandstone. This particular lithology is characteristic of some of the middle Atlantic Coastal Plain deposits, for example, some phases of the North Carolina upper Cretaceous Peedee Formation, the Spring Garden Member of the Castle Hayne Limestone (Ward and others, 1978), the New Bern Formation (Baum and others, 1978),and the Oligocene River Bend Formation (Ward and others, 1978) (Trent and Belgrade Formations of Baum and others, 1978).

Areal Extent. Although lenses of Griffins Landing lithology are known in the Dry Branch Formation in east-central Georgia west of the Ogeechee River, its contribution to the mass of Dry Branch sediments in that area appears to be negligible. For practical purposes, the Griffins Landing Member can be considered to be restricted to the area of Georgia east of the Ogeechee River. The updip limits of the member must occur between the community of Shell Bluff and McBean Creek in northern and eastern Burke County, and in the vicinity of Keysville, in northern and western Burke County. The Griffins Landing Member grades downdip into the Williston Formation of the Ocala Group in northern Effingham County. The eastern limit of the member is not known at this time, but lithologies characteristic of the member have been reported in southern Aiken and western Barnwell Counties, South Carolina (Cooke, 1936).

Thickness. The thickness distribution of the Griffins Landing Member of the Dry Branch Formation is not clearly defined because of inadequate core control in the downdip subsurface where the Griffins Landing Member is the principal member of the Dry Branch Formation and, in the outcrop area, because of complex

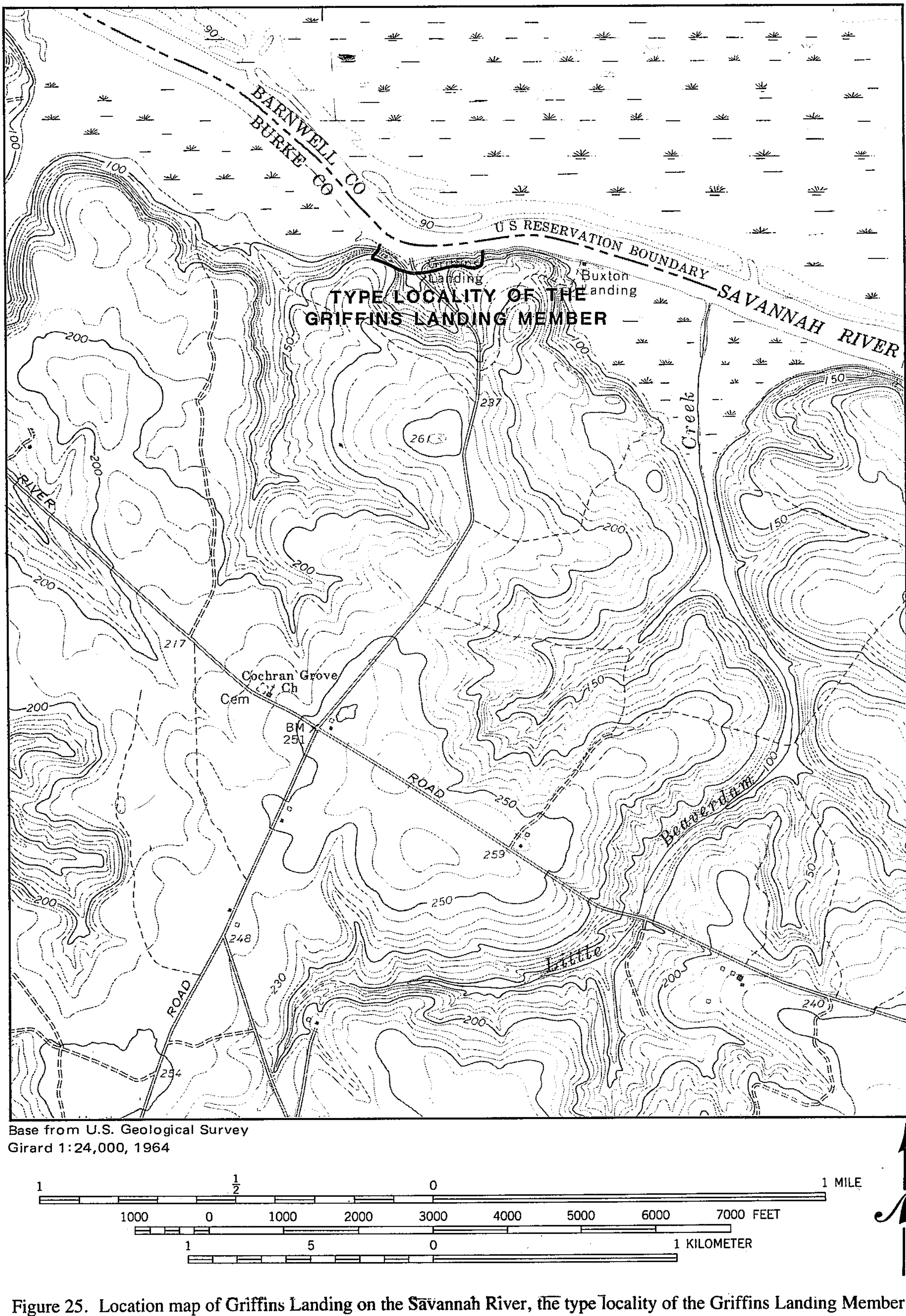


Figure 25. Location map of Griffins Landing on the Savannah River, the type locality of the Griffins Landing Member of the Dry Branch Formation, Burke County, Georgia.

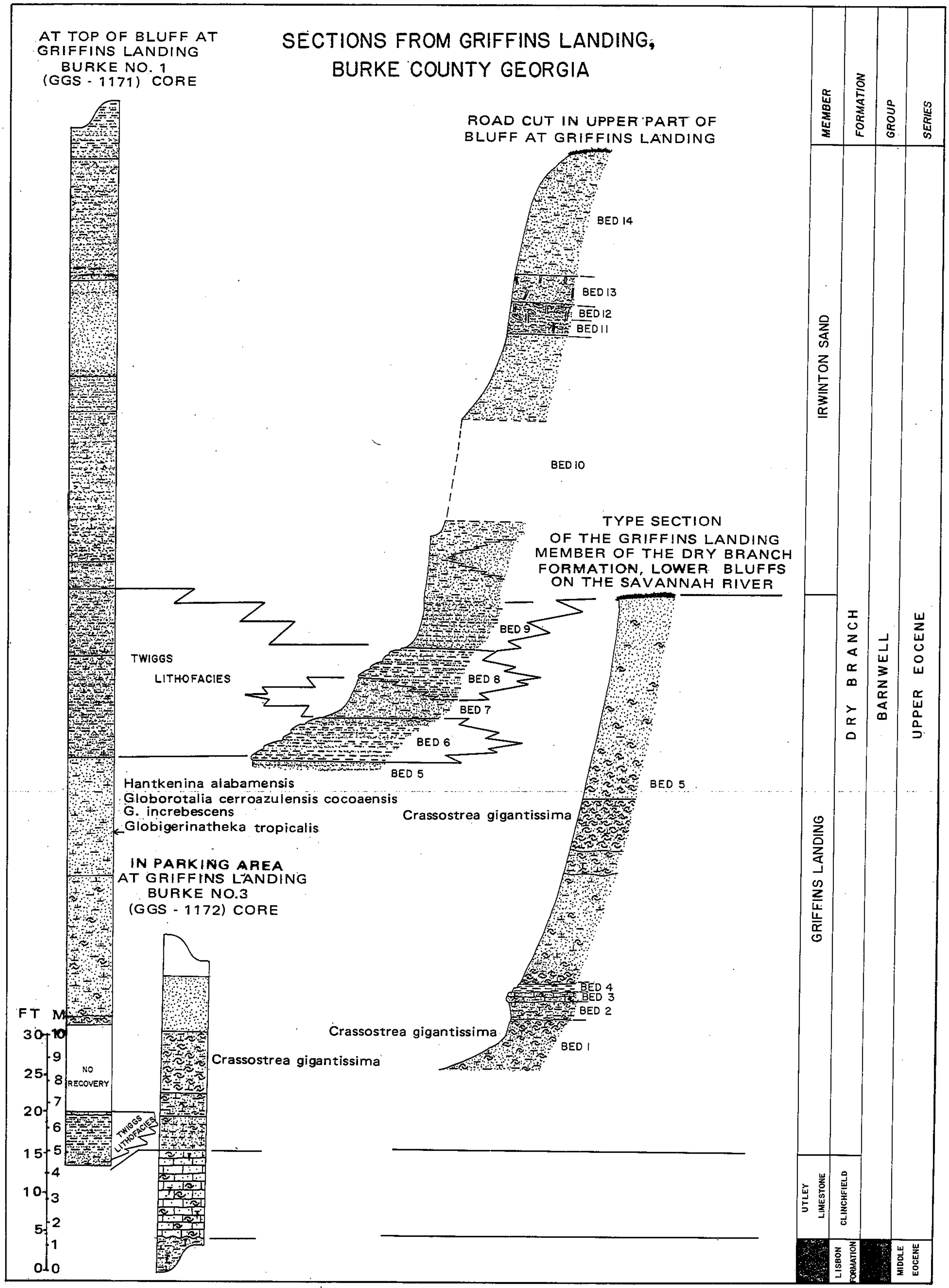


Figure 26. Measured sections of the Barnwell Group at Griffins Landing, Burke County, Georgia.

lateral and vertical lithofacies "interplay" between the Irwinton Sand and the Griffins Landing Members. For example, the total thickness of the Griffins Landing Member at the type locality, consisting both of subsurface and outcrop, is 72 feet (22 m). About 1 mile (0.6 km) north of the community of Shell Bluff in northern Burke County, in the core Burke 4 (GGS-1176), the Griffins Landing is 48 feet (15 m) thick. At the site of the excavation at Georgia Power Company's Plant Vogtle, between the communities of Shell Bluff and Griffins Landing, the Griffins Landing Member is not present at one corner of the pit. However, its stratigraphic position is occupied by 12 feet (3.7 m) of Twiggs Clay lithofacies. On the opposite corner of the pit, 14 feet (4.3 m) of Griffins Landing Member occupies the stratigraphic position of the Twiggs Clay, and no Twiggs Clay is present in that corner at all. The rest of the overlying Dry Branch Formation consists of 43 feet (13 m) of Irwinton Sand. Clearly, the thickness of the three lithofacies components of the Dry Branch Formation in Burke County can be very irregular.

Paleontology. One of the most characteristic features of the Griffins Landing Member in the outcrop area is the local abundance of *Crassostrea gigantissima*, both in living position, as at the type locality, and as oyster shell rubble. In the past, some investigators have attempted to use *C. gigantissima* as a guide fossil for specific deposits. We have observed that *C. gigantissima* is locally abundant in deposits of various Jacksonian units in Georgia (Clinchfield, Dry Branch, and Tobacco Road). *Crassostrea gigantissima* is a facies fossil and cannot be used for stratigraphic correlation except on either exceedingly broad or local scales.

Although the Griffins Landing Member is characteristically a sand, it does contain lenses of Twiggs-type clay. *Crassostrea gigantissima* bioherms appear to be associated with these clay beds or lenses. We have not observed oyster bioherms in the predominant, thick-bedded sand facies of the member.

TOBACCO ROAD SAND

Definition

The Tobacco Road Sand was named by Huddlestun and Hetrick (1978, p. 56-76) for upper Jacksonian deposits that previously had been called the upper sand member of the Barnwell Formation (LaMoreaux, 1946a, 1946b). The type locality of the Tobacco Road Sand is located on the east side of Morgan Road, 0.3 mile (0.6 km) north of the intersection of Morgan Road and Tobacco Road, Richmond County, Georgia (Fig. 8). The type description and measured section are presented on p. 74 and p. 19, respectively (Fig. 9).

Lithology

The Tobacco Road is predominantly a sand; all other lithic components (clay minerals, chert, calcite, limestone, mica, glauconite, heavy minerals, and wad) are only locally significant.

The most characteristic lithology of the Tobacco Road Sand is a burrowed and bioturbated, massive, moderately poorly sorted to poorly sorted, medium to coarse, pebbly, weathered sand. This particular facies of the formation is more prevalent in the downdip areas of the outcrop belt. Although most exposures show little or no bedding, vague bedding and disrupted thin bedding are probably the norm for the formation as a whole. In most places, however, this can be observed only on close inspection.

The bioturbated facies of the Tobacco Road Sand is not restricted to the downdip area but is also present near the Fall Line in a few places, for example, in Aiken County, South Carolina. On the other hand, in some downdip areas, for example, in southern Wilkinson and northern Laurens Counties, Georgia, the Tobacco Road can be very coarse grained, pebbly, and well stratified. This sort of facies distribution may be the result of a very irregular shoreline, possibly lobate and bird-foot deltas filling an open sound or lagoon, combined with topographic relief and shifting shoals on the sound bottom (compare with Huddlestun and Hetrick, 1978, p. 70, Fig. 8).

Lithologies of the Tobacco Road deviate from the pattern described above in two areas in Georgia: in Twiggs and western Wilkinson Counties, and in central and eastern Washington County. In both areas the formation is unusually fine grained. In Twiggs and Wilkinson Counties, the Tobacco Road typically consists of a fine to medium, well-sorted, vaguely bedded to nonstratified sand. The basal part of the unit, characteristically, is coarse grained, but is not especially pebbly, and flat pebbles, though present, are rare. In central and eastern Washington County, on the other hand, in addition to being exceptionally fine grained, the formation is well stratified, cherty, and clayey with the Sandersville Limestone Member occurring as the basal bed of the formation (Fig. 28). Strata are generally thin bedded to laminated with very thin layers, laminae, and partings of montmorillonite clay. To our knowledge, the unweathered clay in this facies of the Tobacco Road consists only of montmorillonite; kaolinite and illite have not been detected. The chert occurs either in thin lenses up to 1 inch (2.5 cm) thick and about 1 foot (30 cm) long, in masses of fossiliferous chert, or more commonly as massive to flaggy, chert-cemented sandstone. Chert also occurs as replacement silica in oyster shells (*Crassostrea gigantissima*). Wad is also very conspicuous in this facies. It would appear that the entire Tobacco Road Sand, in central and eastern Washington County (apart from that of the basal, distinctive Sandersville Limestone), was at one time unusually calcareous. Much of the original calcite has been replaced by silica; wad occurs as a by-product of the solution of calcite and the precipitation of silica (Rankama and Sahama, 1950, p. 647-652). The Tobacco Road in central and eastern Washington County is also unusually fossiliferous. In addition to the fossiliferous Sandersville Limestone, the large oyster, *C. gigantissima*, occurs in scattered concentrations in the overlying sands. In most places the sands are characteristically unfossiliferous, but the oysters, where present, are generally common and oyster bioherms may be large and packed with shells. Although the oysters are large, they are not as large as the oysters at Griffins Landing. Nor do they occur so clearly in living position. Where present, the oysters commonly are totally silicified.

A zone of flat pebbles occurs at the base of the Tobacco Road Sand in many places in east-central Georgia. Although discontinuous, this basal bed of the Tobacco Road is a very useful marker bed for locating the base of the formation and the top of the underlying Dry Branch Formation (Huddlestun and Hetrick, 1978, p. 65). In some downdip areas where the flat pebble bed does not occur, chert or (in central and eastern Washington County) limestone is commonly associated with the basal bed of the Tobacco Road. It appears that where the Tobacco Road lithology is typically developed and coarse grained in the updip area, the zone of flat pebbles is a reliable indicator for the base of the formation. However, where the formation is unusually fine grained and consists mainly of fine to medium, well-sorted sand, the basal bed, though it may be coarse, is not especially pebbly, and the zone of flat pebbles is absent. Of interest, too, in Burke County the basal cherty bed of the Tobacco Road Sand may underlie the coarse, poorly sorted sand that elsewhere is the basal bed of the formation.

Areal Extent

The westernmost known exposure of the Tobacco Road Sand is in the Oakey Hills Wildlife Preserve in southeastern Houston County. (See Huddlestun and Hetrick, 1978, p. 66.) It is possible that some of the sands overlying the basal *Periarchus quinquefarius*-bearing chert (which overlies the Twiggs Clay) at Clinchfield (see Fig. 10) represent the Tobacco Road Sand. In the east, the Tobacco Road Sand occurs in Aiken, northern Barnwell, and northern Orangeburg Counties, South Carolina. The northern limit of the formation is the vicinity of the Fall Line, although the outcrop belt appears to trend more east-west and away from the Fall Line between Augusta and Orangeburg. In the shallow subsurface it grades downdip over a very short distance into the Ocmulgee Formation of the Ocala Group. In the Savannah River area of Georgia, this zone of facies change occurs in northern Screven County. In the Ocmulgee and Oconee River areas in Georgia, the zone of facies change occurs respectively in southeastern Houston County and in Laurens County in the vicinity of Dublin.

Thickness

The greatest known thickness of the Tobacco Road Sand is 52 feet (16 m) in a roadcut at Newberry Creek, 2.8 miles (4.5 km) east of the community of Shell Bluff in Burke County, Georgia, and in a roadcut 2.8 miles (4.5 km) southeast of the intersection of U.S. 278 and Silver Bluff Road in Aiken County, South Carolina (Nystrom and Willoughby, 1982, p. 166-168).The formation may be significantly thicker because in some places it has been too deeply weathered for one to recognize the upper part with assurance. In most places, however, the average measurable thickness of the Tobacco Road Sand appears to be between 20 and 30 feet (6 and 9 m). The known minimum total thickness of the formation is 10.5 feet (3.2 m) at the Oakey Hills Wildlife Preserve in Houston County, Georgia (Huddlestun and Hetrick, 1978, p. 66).

Sandersville Limestone Member of the Tobacco Road Sand

Definition. The type locality of the Sandersville Limestone Member of the Tobacco Road Sand is in a small lime sink on the south side of Sandersville, 0.8 mile (1.3 km) south of the Washington County courthouse in Sandersville (Fig. 27; Cooke, 1943, p. 65, 66). An amended type description of the Sandersville Limestone and measured sections of the Barnwell Group exposed in the vicinity of Sandersville are presented on p. 76 and p. 49 (Fig. 28).

The Sandersville Limestone Member is a basal, lithologically very distinctive limestone phase of the Tobacco Road Sand that is restricted to a relatively small area in central Washington County, Georgia. It grades laterally in all directions into Tobacco Road Sand. Because downdip from central Washington County typical Tobacco Road sandy sediments occupy the basal Sandersville stratigraphic position, we have referred the Sandersville Limestone to a subdivision of the Tobacco Road Sand rather than to a subdivision of the Ocmulgee Formation, to which it is correlative.

Lithology. Typically, the Sandersville Limestone Member of the Tobacco Road Sand is a fairly pure limestone that is slightly and discontinuously sandy. Subordinate minerals include fine quartz sand; montmorillonite clay is present both as irregular-shaped, waxy, pale-green inclusions or clasts and as minor disseminated clay; some scattered, finely disseminated pyrite and scattered manganese oxide dendrites are present. Glauconite is known to occur only near the base of the limestone. Chert is known only from the upper part of the member and consists mainly of partially silicified oyster shells.

The Sandersville Limestone is characteristically thick bedded and massive. Vague bedding can be seen in some exposures. Where it is not abundantly fossiliferous, the limestone has a very characteristic brittle, irregular fracture and texture that is most reminiscent of "cottage cheese." Where fossils are abundant, the limestone is moderately, but not completely, indurated and recrystallized, and is very tough and mechanically resistant. Upon casual inspection, it does not appear to have considerable primary or secondary porosity, except at the top of the limestone. However, the cavernous condition of the limestone south of Sandersville would suggest that it is quite permeable.

The Sandersville Limestone is most coarsely fossiliferous, but irregularly so, in the upper part of the member. *Crassostrea gigantissima* (at the very top of the member), molds of mollusks, and echinoids (*Periarchus quinquefarius*) may be abundant. Characteristically, however, the limestone is only slightly to moderately fossiliferous with only scattered molds of small pelecypods, *Turritella* molds, and scattered *P. quinquefarius*.

Thickness and Areal Extent. Cooke (1943) reported 40 feet (12 m) of Sandersville Limestone based on borings. We have been able to identify a maximum of 19 feet (5.8 m) exposed at the old lime pit south of Sandersville. Forty feet (12 m) seems excessive for the unit and we think it is more likely that the upper, very calcareous part of the Dry Branch Formation was included with the Sandersville Limestone by Cooke (1943). In the core Washington 6-6A (GGS-1168), the Sandersville Limestone grades downward over about 15 feet (4.6 m) into calcareous Irwinton Sand, and the entire limestone/calcareous sand interval in that core is about 30 feet (9 m) thick. The Sandersville Limestone Member is restricted to a small area in central Washington County, Georgia.

OCALA GROUP

DEFINITION

In Georgia, any upper Eocene limestone that contains a characteristic "Ocala" fauna has been called Ocala Limestone, regardless of the particular limestone lithology. Thus Cooke (1915) first recognized the Ocala Limestone of Florida (Dall and Harris, 1892, p. 103-104) in the Bainbridge, Decatur County area. Later, Cooke and Shearer (1918), on the basis of gross lithology and fauna, extended the Ocala Limestone concept into central Georgia as far northeast as the vicinity of Gordon in Wilkinson County. They recognized that the Ocala in the far updip area is a thin extension or tongue of the downdip limestone body into the equivalent, clastic Barnwell Sand. They called it the Tivola tongue of the Ocala Limestone after the community of Tivola in Houston County, Georgia.

As a corollary of the need for an Ocala fauna for recognition of the Ocala Limestone, upper Eocene limestones that do not contain a typical Ocala fauna had not been included in the Ocala Limestone.

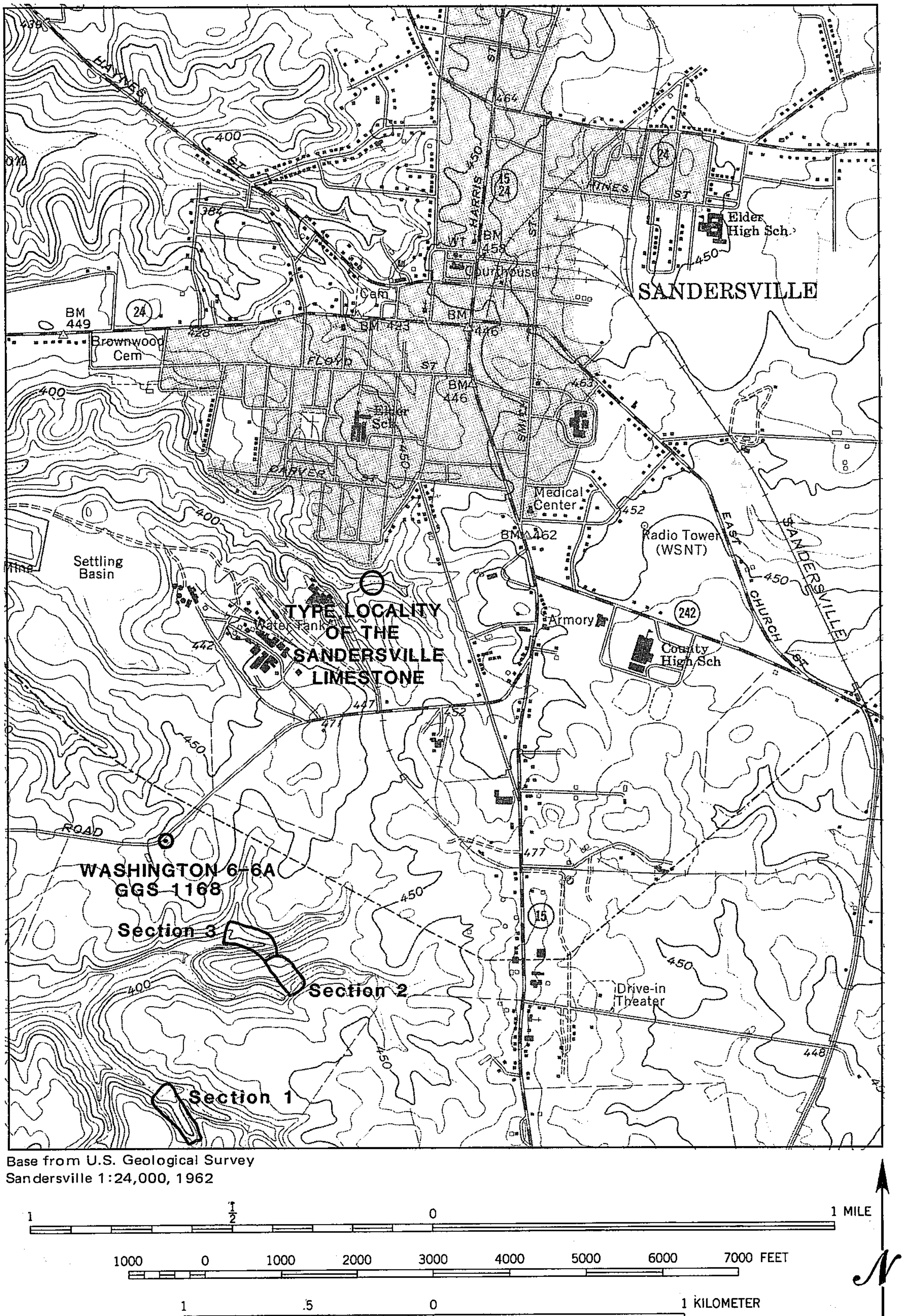


Figure 27. Location map of the type locality of the Sandersville Limestone Member of the Tobacco Road Sand, Washington County, Georgia.

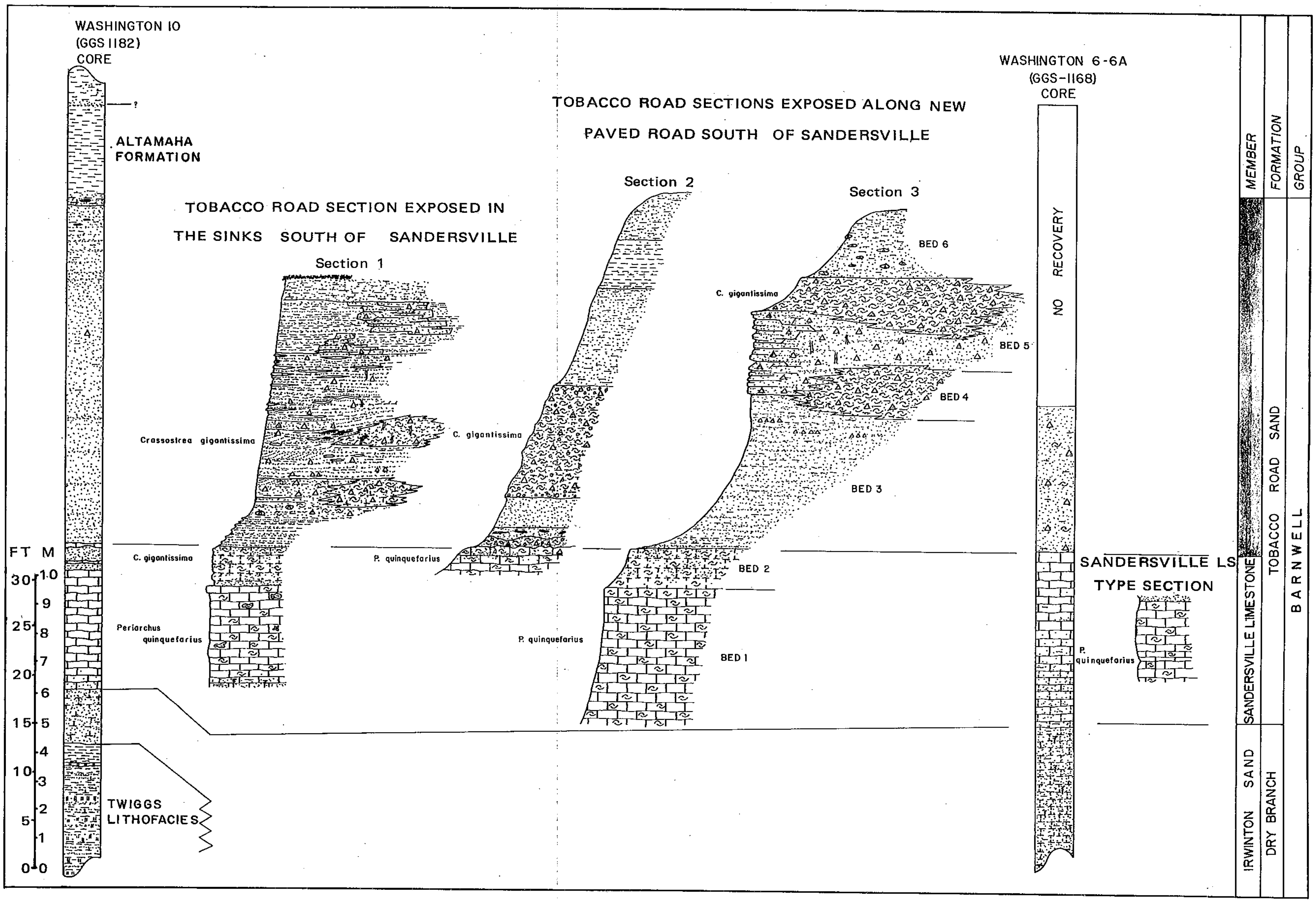


Figure 28. Measured sections in the type area of the Sandersville Limestone Member of the Tobacco Road Sand, Washington County, Georgia.

Therefore, the Sandersville Limestone Member and the Ocmulgee Formation had not been included in the Ocala Limestone. And because the Ocmulgee Formation does not contain a typical Ocala fauna, correlation with the upper Eocene has not been secure (see Herrick and Vorhis, 1963, p. 18, 19; Herrick and Counts, 1968).

We contend that an Ocala fauna is not justification in itself for determining the inclusion of a specific limestone deposit in the Ocala. Because we propose including two discrete and lithologically distinct limestone deposits in the Ocala on the basis of overall lithology and paleontological correlation, we find it useful to recognize the Ocala as a group of formations in the State of Georgia as has been proposed in Florida (Puri, 1953, 1957; Puri and Vernon, 1964). The Tivola Limestone has been recognized as a part of the Ocala body of sediments since 1918 (Cooke and Shearer, 1918) and has been considered as a member of the Ocala by Connell (1959). However, the Ocmulgee Formation has heretofore been correlated mainly with the Cooper Marl of South Carolina, with which it is lithologically similar. Only recently have definitive criteria firmly established its correlation with the Ocala Limestone and with upper Eocene deposits in general (Huddlestun and others, 1974, p. 2-9).

Subdivision of the Ocala has been effective for many years. Applin and Applin (1944, p. 1683-1685) first applied an informal subdivision to the Ocala Limestone in peninsular Florida and southern Georgia that was based both on lithology and fauna. Their subdivision consisted of an upper member and a lower member. The lower member, however, was not recognized in the subsurface of southern Georgia (Applin and Jordan, 1945).

Vernon (1951) also subdivided the Ocala Limestone, but his subdivision differed from that of Applin and Applin (1944). Vernon (1951) divided the Ocala into two formations, a lower Moodys Branch Formation and an upper "Ocala limestone (restricted)." The Moodys Branch was further subdivided into a lower Inglis Member and an upper Williston Member. According to Vernon (1951, p. 111), the Inglis Member is equivalent to the lower member of the Ocala Limestone of Applin and Applin (1944), but according to M. Hunter (personal commun., 1981), the Applins considered the Williston to be the same as their lower member.

Puri (1953, 1957) (1) raised the Ocala to group rank, (2) recommended that the name Moodys Branch Formation be abandoned in Florida, (3) raised the Inglis and Williston to formation rank, (4) named the upper part of the Ocala Limestone the Crystal River Formation, and (5) included the Inglis, Williston, and Crystal River Formations in the Ocala Group.

Some investigators (Cole and Applin, 1964; Hunter, 1976, p. 66-87) prefer to correlate the Inglis Formation with the Claibornian and refer it to an upper phase of the middle Eocene Avon Park Formation. The Inglis, however, has not been identified in Georgia, but the other two subdivisions of the Ocala, i.e., the Williston and Crystal River and their equivalents, are recognizable in most parts of the subsurface of south Georgia and have been recognized in Alabama. In Alabama, Huddlestun and Toulmin (1965) and Toulmin (1977) extended the name Crystal River Formation to deposits that had previously been called Ocala. They (Huddlestun and Toulmin, 1965) also recognized the correlation of the upper Moodys Branch Formation, an impure limestone, in Alabama with the Williston Formation (lower Ocala) of Florida, as Cheetham (1963) had done earlier.

The Williston and Crystal River Formations can be recognized in southwestern Georgia, in Wayne County in eastern Georgia, and south and east of the Gulf trough in Colquitt, Thomas, and Brooks Counties, Georgia. In southern Georgia, the Williston/Crystal River formational boundary occurs in a regionally consistent stratigraphic position with sand, sandstone, dolostone, or gypsum commonly occurring at or near the boundary. We interpret these lithologies in an otherwise predominantly limestone section as indications of a minor regression and temporarily more restricted marine conditions on the shelf. We also suggest that the Williston/Crystal River boundary in Georgia coincides with the lower/upper Jacksonian boundary (see p. 12).

In the outcrop area of updip central Georgia, the Tivola Limestone and the Ocmulgee Formation are clearly components of the lower and upper Jacksonian, respectively. As such, they reflect the change in environmental conditions precipitated by the minor geological event (see discussion, p. 12) at the end of early Jacksonian time. Therefore, according to this model, the Tivola is equivalent to part of the Williston Formation, and the Ocmulgee Formation is exactly equivalent to the Crystal River Formation and to the upper Jacksonian in general. This is consistent with Alabama upper Eocene stratigraphy where the known Crystal River Formation is precisely equivalent to and is identical with the upper Jacksonian (Huddlestun, 1965; Huddlestun and Toulmin, 1965).

TIVOLA LIMESTONE

Definition

Cooke and Shearer (1918) proposed the name Tivola tongue of the Ocala Limestone for a thin extension or tongue of the Ocala Limestone into the Barnwell Formation in central Georgia. In so doing, they did not name the formation Tivola but rather they gave that name to a particular geometry of the limestone, i.e., a "tongue." Connell (1959) shifted the sense of the name Tivola to that of a lithostratigraphic unit when he proposed the name Tivola Member of the Ocala Limestone for the distinctive bryozoan-rich limestone of the Tivola tongue. Connell (1959) did not, however, designate a type locality for the member.

It is our intent to formally propose herein that the Tivola be raised in lithostratigraphic rank to formation and be called the Tivola Limestone of the Ocala Group. It is furthermore our intent to relate the Tivola Limestone as closely as possible to the original concept of the Ocala Limestone of the Tivola tongue, and the Tivola Limestone as we define it is that bryozoan-rich Ocala limestone that occurs in the Tivola tongue of Cooke and Shearer (1918). The original reference section of the Tivola tongue of the Ocala Limestone, as given by Cooke and Shearer (1918, p. 56-58, 76), was in a "quarry of the Planters Limestone Company, near the crossing of the Georgia Southern & Florida Railway and the Perry-Fitzgerald branch of the Dixie Highway, 2 miles south of Tivola station," in Houston County, Georgia. Tivola station is no longer in existence, but its original location was approximately at the crossing of an unimproved road and the Southern Railroad tracks 0.1 mile (0.2 km) southeast of the Pabst Brewery, 1.7 miles (2.8 km) north of Clinchfield (Fig. 12).

The location of the "quarry of the Planters Limestone Company " as given by Cooke and Shearer (1918) is the same as the location of the quarry of the Medusa Cement Company at Clinchfield, and the present quarry at Clinchfield appears to have originated by expansion from that of the old Planters Limestone Company. As a result, we designate as the type locality of the Tivola Limestone of the Ocala Group the quarry of the Medusa Cement Company at Clinchfield in Houston County, Georgia (see Fig. 12).

We consider the Tivola Limestone to be a separate subdivision of the Ocala Group on the basis of its distinctive lithology (also see Connell, 1959). The type Tivola Limestone is characterized by the abundance of fine to coarse and robust bryozoan debris, which produces a characteristic rough, uneven, ragged, coarse, bioclastic texture. The Williston Formation, with which we believe the Tivola is equivalent, differs from the Tivola Limestone in being a more indurated and recrystallized limestone, much finer and even textured, more equigranular, and typically much less fossiliferous. Miliolid foraminifera in Florida, or an abundance of larger foraminifera of the genus *Nummulites* impart a characteristic texture to the rock. The Crystal River Formation is characteristically a somewhat softer, less consolidated, coarsely fossiliferous limestone (except for dolomitized intervals) that typically contains an abundance of larger foraminifera of the genus *Lepidocyclina*, with subordinate numbers of other larger foraminiferal genera *Pseudophragmina, Discocyclina,* and *Asterocyclina*. Where in abundance, these larger foraminifera impart a characteristic texture to the rock. Although larger foraminifera are present in the Tivola Limestone, they are never so uniformly numerous as to influence or dominate the lithology of the sediment.

Lithology

In general, the Tivola Limestone is a fine to coarse, uneven, rough, bioclastic textured limestone that has a very ragged fracture. Fossil bryozoan debris is always conspicuous even upon casual examination of the limestone, and, in places, small to large and robust bryozoan remains are so abundant that the sediment may be best regarded as a coquinoid bryozoan limestone. The uneven texture is due to the lack of size sorting of the bioclastic debris and rubble. Where large fossils such as pectens, echinoids (mainly *Periarchus pileussinensis),* oysters, and molluscan molds are abundant, the texture of the limestone is very coarse and rubbly. Where bryozoans are less abundant, the lithology, which then is reminiscent of Williston lithology, is dominated by fine to medium, even-textured, granular calcarenite of biogenic origin. Subordinate mineral components of the limestone include clay minerals (montmorillonite, kaolinite, and illite), glauconite, finely disseminated pyrite, and in the lower part, fine to medium quartz sand. In fresh exposures, the Tivola Limestone commonly is slightly indurated to unconsolidated, with 6 to 10 feet (2 to 3 m) of hard, rubbly limestone at the top of the formation in the type area. Even brief exposure to weathering, however, will case harden the unconsolidated limestone.

Updip at Rich Hill and east of the Ocmulgee River, the Tivola Limestone is finer grained, more calcarenitic, and less coarsely bioclastic. Even so, less robust bryozoan debris still dominates the lithology. The formation also is thinner and discontinuous east of the Ocmulgee River, partly due to facies change into the Twiggs Clay Member of the Dry Branch Formation, and partly due to local leaching and solution. Where the Tivola Limestone has been removed by solution, a brown, clayey, locally cherty residuum with wad occurs between the overlying Dry Branch Formation and the underlying Clinchfield Formation. The Tivola Limestone grades laterally to the east and north, and up section into the Twiggs Clay Member of the Dry Branch Formation (Fig. 6). This facies change results in lithologically intermediate clay-limestone sediments that in places are difficult to assign to either formation. It is this particular transitional lithology at Clinchfield that Cooke (1943) correlated with the Cooper Marl.

Areal Extent and Thickness

At this time, the Tivola Limestone is known to occur in outcrop or in the shallow subsurface in Crawford, Bibb, Pulaski, Houston, Bleckley, Twiggs, and Wilkinson Counties, Georgia. It is not known to occur east of the Oconee River. In its area of known occurrence, the thickness of the Tivola Limestone ranges from 0 to 42.5 feet (0 to 13.0 m).

OCMULGEE FORMATION (New Formation)

Definition

The Ocmulgee Formation is named herein for limestone exposures along the Ocmulgee River between Taylors Bluff and Hawkinsville in Pulaski County, Georgia. The type locality is at Taylors Bluff on the east side of the Ocmulgee River, 2.7 miles (4.3 km) north of Hawkinsville (Figs. 29 and 30). In addition, we designate as a reference locality the exposures of the Ocmulgee Formation on the west bank of the river at Opelika factory, a few hundred feet (about 100 m) south of the eastbound U.S. 341 highway bridge at Hawkinsville (Fig. 29). The Ocmulgee Formation is exposed intermittently at low river level between Taylors Bluff and Hawkinsville.

At Taylors Bluff, the type locality, the Ocmulgee Formation conformably overlies the Twiggs Clay Member of the Dry Branch Formation. The Dry Branch Formation dips under the river south of Taylors Bluff, and neither the upper nor the lower boundaries of the Ocmulgee crop out between Taylors Bluff and Hawkinsville. In the bluff at Hawkinsville, however, the Marianna Limestone of early Oligocene Vicksburgian age paraconformably overlies the Ocmulgee Formation. The Ocmulgee Formation dips under the river rather abruptly at Hawkinsville. From the south side of Hawkinsville southward along the river, only the Vicksburgian Marianna and Glendon Limestones are exposed.

The Ocmulgee Formation is the calcareous deposit that Cooke (1943) called the Cooper Marl and has been subsequently referred to under that name by many other investigators (LaMoreaux, 1946a; Herrick, 1961; Herrick and Vorhis, 1963; Carver, 1966, 1972; Herrick and Counts, 1968; Pickering, 1970; Huddlestun, and others, 1974). The Cooper Marl of Georgia, as understood by previous investigators, is synonymous with the Ocmulgee Formation. The change in formation name is justified because the principal deposit of the Cooper Marl in South Carolina is not laterally equivalent to the Ocmulgee Formation. The bulk of the Cooper Marl in South Carolina is late Oligocene in age, and so is mainly equivalent to the Suwannee Limestone in Georgia.

The Ocmulgee Formation and the lowest part of the Cooper Marl of South Carolina (the Harleyville and Parkers Ferry Members of Ward and others, 1979) differ in lithology. The Harleyville Member is characteristically more clayey and phosphatic, finer textured, and is less glauconitic and calcareous (see Ward and others, 1979, p. 18).

In addition, we consider the Ocmulgee Formation to be a nearshore facies or subdivision of the offshore Ocala Group. The Harleyville is a subdivision of the Cooper Marl. Because the Ocmulgee Formation is more closely related lithologically, genetically and geographically to the Ocala than to the Cooper, the use of the name Harleyville in Georgia would be terminologically inappropriate.

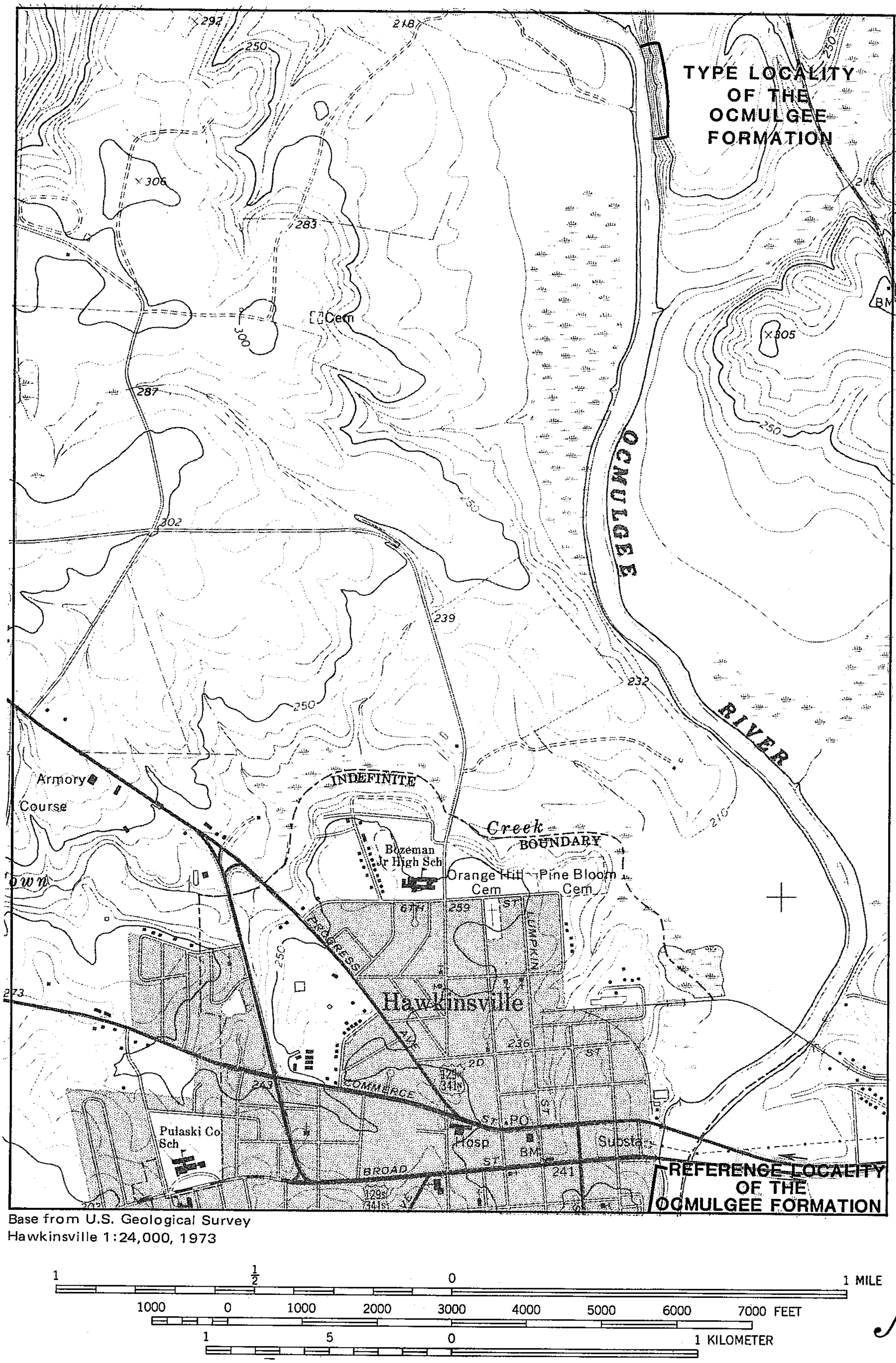


Figure 29. Location map of Taylors Bluff on the Ocmulgee River, the type locality of the Ocmulgee Formation. Pulaski County, Georgia.

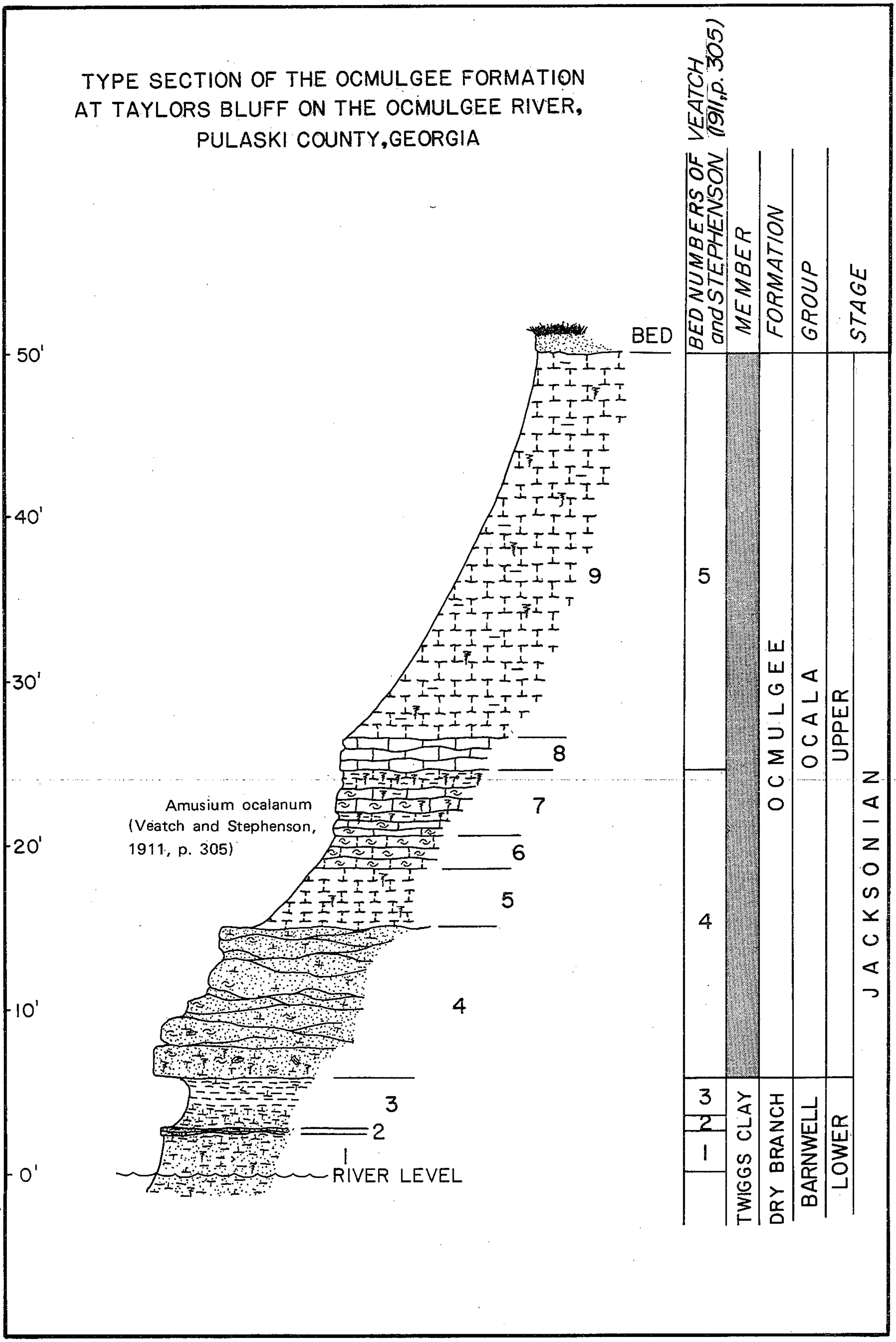


Figure 30. Measured section of the exposure at Taylors Bluff, Pulaski County, Georgia.

Lithology

The typical outcropping Ocmulgee Formation in the type area consists of a basal sandy, glauconitic, indurated limestone (not present at the type locality) overlain by tough, massive, glauconitic, granular, rather even textured, slightly argillaceous limestone. In the shallow subsurface, however, the typical lithology appears to be more argillaceous, softer, and more lithologically variable than it is in outcrop. This suggests that only the more calcareous, resistant beds in the unit are able to withstand deep weathering and are exposed at the surface for appreciable periods of time. In the shallow subsurface of Houston and Pulaski Counties, the Ocmulgee Formation ranges in lithology from a glauconitic, even-textured, granular to lutitic, very calcareous, glauconitic clay to an argillaceous, glauconitic, granular limestone. Both at the surface and in the shallow subsurface, bryozoans commonly occur in sufficient abundance to render a coarse, uneven, bioclastic texture to the otherwise even-textured, granular sediment.

Except for probable silicified Ocmulgee Formation in and around Dublin, Laurens County, Georgia, the Ocmulgee is not exposed between the type area (in Pulaski and Bleckley Counties) and Jenkins County in the vicinity of Millen and Magnolia Springs. In Jenkins County the exposed Ocmulgee Formation consists of argillaceous, unconsolidated but firm, richly microfossiliferous, rather even textured, granular limestone. What is known of the lithology in Jenkins County differs from the Ocmulgee Formation in the type area in being generally more clayey.

The Ocmulgee Formation does not crop out in the Savannah River area except possibly for chert outcrops at relatively low elevations in northeastern Screven County. The facies change between the Tobacco Road Sand and the Ocmulgee Formation occurs in northernmost Screven County in the subsurface. In the area adjacent to the Savannah River in eastern Screven County, the Ocmulgee Formation occurs in a narrow band about 10 miles (1.6 km) wide and trending northeast to southwest, approximately parallel to the Fall Line. The lithology of the Ocmulgee Formation, based on the cores Screven 7 (GGS-1175) and Georgia Power B32, is slightly indurated, fossiliferous limestone; very calcareous, calcarenitic, clayey, even-textured, granular limestone; loose to firm and compact, sandy, calcarenitic, variably bryozoan-rich, limestone; and slightly argillaceous, calcarenitic quartz sand. In the core Screven 7 (GGS-1175), the basal bed of the formation, a calcarenitic sand to sandy calcarenite, contains quartz pebbles.

The general lithology of the Ocmulgee Formation in Georgia may well be more variable than is evident from outcropping lithologies and those seen in a few cores. Although the dominant lithology is an argillaceous, even-textured calcarenitic limestone, beds of dominantly clay and quartz sand components may be locally conspicuous. In addition, where the Ocmulgee Formation grades downdip into more richly macrofossiliferous, purer limestone of more typical Ocala aspect, these lithologies may interfinger, interlens, or intergrade.

Areal Extent

The known geographical limits of the formation extend from Houston and Pulaski Counties, Georgia, in the west, to at least as far east as the Savannah River. The updip limits of the formation appear to occur along a line extending approximately from southern Houston County, through the vicinity of Dublin in Laurens County, through northern Jenkins County and northern Screven County. The downdip limits of the formation are poorly known at this time. In the Savannah River area, in central Screven County, the Ocmulgee Formation grades southward into limestone lithology of more typical Ocala aspect. Between the Savannah River area and Pulaski County, this zone of facies change occurs in the subsurface where there is very poor stratigraphic control. Along the Flint River in Crisp County, however, the upper Jacksonian is represented by richly fossiliferous limestone. Except for the absence of larger foraminifera, this limestone contains a typical Ocala fauna and has, therefore, always been called Ocala Limestone (Cooke and Shearer, 1918; Cooke, 1943). On the other hand, the general lithologic aspect of the limestone, excluding the macrofossils, is very reminiscent of the Ocmulgee Formation. In addition, limestone exposed along a paved county road at Chokee Creek in northern Lee County, immediately west of Lake Blackshear, is identical lithologically to the Ocmulgee Formation and contains a typical Ocmulgee foraminiferal fauna (see Herrick and Vorhis, 1963, for Cooper Marl foraminiferal assemblage). It is our opinion that the limestone present along and in the vicinity of Lake Blackshear on the Flint River represents an intermediate facies between typical Ocmulgee Formation and typical Crystal River Formation.

Thickness

The thickness distribution of the Ocmulgee Formation is not clearly established due to insufficient subsurface control. At the type locality there is a maximum of 35 feet (11 m) exposed, but the upper contact of the formation is not present. In the core Pulaski 3 (GGS-3111) south of Hawkinsville, the Ocmulgee Formation is 19 feet (6 m) thick. However, in the core Screven 7 (GGS-1175) and the core Georgia Power B32 in eastern Screven County, the Ocmulgee is 87 feet thick (27 m) and at least 81 feet thick (25 m), respectively. The known thickness distribution of the Ocmulgee Formation, then, is between approximately 20 feet (6 m) and 90 feet (27 m).

REFERENCES

American Commission on Stratigraphic Nomenclature, 1970, Code of Stratigraphic Nomenclature: Amer. Assoc. Pet. Geol., Tulsa, Okla.

Applin, P. L., and Applin, E. R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: Amer. Assoc. Pet. Geol. Bull., v. 28, p. 1673-1753.

Applin, E. R., and Jordan, L., 1945, Diagnostic foraminifera from subsurface formations in Florida: Jour. Paleontology, v. 19, p. 129-148.

Baum, G. R., Harris, W. B., and Zullo, V. A., 1978, Stratigraphic revision of the exposed middle Eocene to lower Miocene formations of North Carolina: Southeastern Geology, v. 20, p. 1-19.

______ (eds), 1979, Structural and stratigraphic framework for the Coastal Plain of North Carolina: Guidebook for the 1979 Ann. Fieldtrip, Carolina Geol. Soc. and the Atlantic Coastal Plain Geol. Assoc., 111 p.

Berggren, W. A., 1972, A Cenozoic time-scale—some implications for regional geology and paleobiogeography: Lethaia, v. 5, p. 195-215.

Bolli, H. M., 1957, Planktonic foraminifera from the Eocene Navet and San Fernando formations of Trinidad, B.W.I.: U.S. Nat'l, Museum Bull. 215, p. 155-172.

Blow, W. H., 1969, Late middle Eocene to Recent planktonic foraminiferal biostratigraphy, *in* Bronnimann, P., and Renz, H. H., (eds.), Proc., First Int. Conf. Planktonic Microfossils, Geneva, 1967: E. J. Brill, Leiden, Holland, p. 199-421.

Brantly, J. E., 1916, A report on the limestones and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21, 300 p.

Buie, B. F., and Oman, C. H., 1963, Sponge spicules from Coastal Plain strata in Glascock and Richmond Counties, Georgia: Geol. Soc. Amer. Spec. Paper 73, Abs. for 1962, p. 2.

Carver, R. E., 1966, Stratigraphy of the Jackson Group (Eocene) in central Georgia: Southeastern Geology, v. 7, p. 83-92.

______ , 1968, Facies relationships in the Jackson Group of central and eastern Georgia: Geol. Soc. Amer. Spec. Paper 101, Abs. for 1966, p. 352.

______ , 1972, Stratigraphy of the Jackson Group in eastern Georgia: Southeastern Geology, v. 14, p. 153-181.

Cavaroc, V. V., Jr., and Ferm, J. C., 1968, Siliceous spiculites as shoreline indicators in deltaic sequences: Geol. Soc. Amer. Bull., v. 79, p. 263-272.

Cheetham, A., 1957, Eocene-Oligocene boundary, eastern Gulf Coast region: Trans., Gulf Coast Assoc. Geol. Soc., v. 7, p. 89-98.

______ , 1963, Late Eocene zoogeography of the eastern Gulf Coast region: Geol. Soc. Amer., Mem. 91, 113 p.

Cole, W. S., and Applin, E. R., 1964, Problems of the geographic and stratigraphic distribution of American middle Eocene larger foraminifera: Bull. Amer. Pal., v. 47, no. 212, p. 5-36.

Colquhoun,D. J., Heron, S. D., Johnson, N. S., Pooser, W. K. and Siple, G. E., 1969, Updip Paleocene-Eocene stratigraphy of South Carolina reviewed: South Carolina Div. Geol, Geol. Notes v. 13, p. 1-25

Connell, J.F.L., 1958, The Jackson Group of Georgia.—a preliminary report: Southwestern Louisiana Jour., v. 2, p. 321-347.

______ , 1959, The Tivola Member of the Ocala Limestone of Georgia: Southeastern Geology, v. 1, p. 59-72.

______ , 1966, Twiggs Clay Member of the Barnwell Formation (U. Eocene) type locality, *in* Catalogue of type localities: Trans., Gulf Coast Assoc. Geol, Soc., v. 16, p. 387-388.

______ , 1968, Barnwell Formation, *in* Catalogue of type localities: Trans., Gulf Coast Assoc. Geol. Soc., v. 18, p. 451-454.

Conrad, T. A., 1856, Observations on the Eocene deposits of Jackson, Mississippi, with descriptions of thirty-four new species of shells and corals: Acad. Nat. Sci., Philadelphia, Proc. 1885, v. 7, p. 275-263.

Cooke, C. W., 1915, The age of the Ocala limestone: U.S. Geol. Survey Prof. Paper 95, p. 107-117.

______ , 1926, The Cenozoic formations, *in* Smith, E. A., Geology of Alabama: Alabama Geol. Survey, Spec. Rept. 14, p. 274-279.

______ , 1936, Geology of the Coastal Plain of South Carolina: U.S. Geol. Survey Bull. 867, 196 p.

______ , 1939, Equivalence of the Gosport sand to the Moody's marl: Jour. Paleontology, v. 13, p. 337-340.

______, 1943, Geology of the Coastal Plain of Georgia: U.S. Geol. Survey Bull. 941, 121 p.

______ , 1945, Geology of Florida: Florida Geol. Survey Bull. 29, 339 p.

Cooke, C. W., Gardner, J. A., and Woodring, W. P., 1943, Correlation of the Cenzoic formations of the Atlantic and Gulf Coastal Plain and the Caribbean region: Geol. Soc. Amer. Bull., v. 54, p. 1713-1722.

Cooke, C. W., and Munyan, A. C., 1938, Stratigraphy of the Coastal Plain of Georgia: Amer. Assoc. Pet. Geol. Bull., v. 22, p. 789-793.

Cooke, C. W., and Shearer, H. K., 1918, Deposits of Claiborne and Jackson age in Georgia: U.S. Geol. Survey Prof. Paper 120, p. 41-81.

Cooke, C. W., and MacNeil, F. S., 1952, Tertiary stratigraphy of South Carolina: U.S. Geol. Survey Prof. Paper 243-B, p. 19-29.

Cushman, J. A., 1935, Upper Eocene foraminifera of the southeastern United States: U.S. Geol. Survey Prof. Paper 181, 88 p.

______ , 1945, A foraminiferal fauna from the Twiggs clay of Georgia: Contr. Cushman Lab. Foraminiferal Res., v. 21, Pt. 1, p. 1-11.

Dall, W. H., and Harris, G. D., 1892, Correlation papers-Neocene: U.S. Geol. Survey Bull. 84, p. 103-104.

Deboo, P. B., 1965, Biostratigraphic correlation of the type Shubuta Member of the Yazoo Clay and Red Bluff Clay and their equivalents in southwestern Alabama: Alabama Geol. Survey, Bull. 80, 84 p.

Dockery, D. T., III, 1977, Mollusca of the Moodys Branch Formation, Mississippi: Mississippi Geol., Econ. and Topographical Survey Bull. 120, 212 p.

______ , 1980, The invertebrate macropaleontology of the Clarke County, Mississippi, area: Mississippi Geol. Survey Bull. 122, p. 52-56.

Gardner, J. A., 1939, Recent collection of upper Eocene Mollusca from Alabama and Mississippi: Jour. Paleontology, v. 13, p. 340-343.

Georgia Department of Natural Resources, 1976, Geologic map of Georgia: Geol. and Water Res. Div., Atlanta, Ga., 1:500,000.

Glawe, L. N., 1974, Upper Eocene and Oligocene Pectinidae of Georgia and their stratigraphic significance: Georgia Geol. Survey Inf. Circ. 46, 27 p.

Hardenbol, J., and Berggren, W. A., 1978, A new Paleogene numerical time scale, *in* Cohee, G.V., Glaessner, M.F., and Hedberg, H.D., (eds.), Contributions to the geologic time scale: Amer. Assoc. Pet. Geol., Studies in Geol., no. 6, p. 213-234.

Harris, G. D., and Palmer, K. V., 1946-1947, The Mollusca of the Jackson Eocene of the Mississippi Embayment (Sabine River to the Alabama River): Bull. Amer. Pal., v. 30, no. 117, pts. I and II, 563 p., 65 pls.

Harris, W. B., and Fullagar, P. D., 1982, Rb-Sr glauconite isochron, Twiggs Clay Member of Dry Branch Formation, Houston County, Georgia, *in* Nystrom, P. G., and Willoughby, R. H., (eds.), Carolina Geol. Soc., Field Trip Guidebook 1982, p. 47-55.

Heron, S. D., Robinson, G. C., and Johnson, H. S., Jr., 1965, Clays and opal-bearing claystones of the South Carolina Coastal Plain: Div. of Geology, South Carolina State Devel. Board, Bull. 31, 66 p.

Herrick, S. M., 1961, Well logs of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 70, 462 p.

______ , 1964, Upper Eocene smaller foraminifera from Shell Bluff and Griffin Landings, Burke County, Georgia: U.S. Geologic Survey Prof. Paper 501-C, p. C64-C65.

______ , 1972 Age and correlation of the Clinchfield Sand in Georgia: U.S. Geol. Survey Bull. 1354-E, p. 1-17.

Herrick, S. M., and Counts, H. B., 1968, Late Tertiary stratigraphy of eastern Georgia: Georgia Geol. Soc. Guidebook, 3rd Ann. Field Trip, 88 p.

Herrick, S. M., and Vorhis, R. C., 1963, Subsurface geology of the Georgia Coastal Plain: Georgia Geol. Survey Inf. Circ. 25, 78 p.

Hilgard, E. W., 1860, Report on the geology and agriculture of the state of Mississippi: E. Barksdale, State Printer, Jackson, Miss., 391 p.

Holland, W. C., Hough, L. W., and Murray, G. E., 1952, Geology of Beauregard and Allen Parishes: Louisiana Geol. Survey Bull. 27, 224 p.

Huddlestun, P. F., 1965, Correlation of upper Eocene and lower Oligocene strata between the Sepulga, Conecuh, and Choctawhatchee Rivers of southern Alabama: Masters Thesis, Florida State University, Tallahassee, 101 p., 13 figs., 7 pls.

______ , 1981, Correlation chart of Georgia Coastal Plain: Georgia Geol. Survey, Open-File Rept. 82-1.

______ , 1982. The development of the stratigraphic terminology of the Claibornian and Jacksonian marine deposits of western South Carolina and eastern Georgia, *in* Nystrom, P. G.,. and Willoughby, R. H. (eds.), Geological investigations related to the stratigraphy in the kaolin mining district, Aiken County, South Carolina: Carolina Geol. Soc. Field Trip Guidebook 1982, p. 21-33.

______ , in review, A revision of the lithostratigraphic units of the Coastal Plain of Georgia: the Paleogene: Georgia Geol. Survey Bull. 105.

Huddlestun, P. F., and Hetrick, J. H., 1978, Stratigraphy of the Tobacco Road Sand-a new formation: Georgia Geol. Survey Bull. 93, p. 56-77.

Huddlestun, P. F., and Hetrick, J. H., 1979, The stratigraphy of the Barnwell Group of Georgia: Georgia Geol. Soc. Guidebook, 14th Ann. Field Trip, 89 p.

Huddlestun, P. F., Marsalis, W. E., and Pickering, S. M., Jr., 1974, Tertiary stratigraphy of the central Georgia Coastal Plain: Guidebook 12, Southeastern Sec., Geol Soc. Amer., 35 p.

Huddlestun, P. F., and Toulmin, L. D., 1965, Upper Eocene-lower Oligocene stratigraphy and paleontology in Alabama: Trans., Gulf Coast Assoc. Geol. Soc., v. 15, p. 155-159.

Hunter, M. E., 1976, Biostratigraphy, *in* Mid-Tertiary carbonates, Citrus, Levy, Marion Counties, west-central Florida: Southeastern Geol. Soc. Guidebook 18, p. 66-84.

Ingram, R. L., 1954, Terminology for the thickness of stratification and parting units in sedimentary rocks. Geol. Soc. Amer. Bull., v. 65, p. 937-938.

International Subcommision on Stratigraphic Classification (ISSC), 1976, International Stratigraphic Guide (Hedberg, H. D.. ed.): John Wiley and Sons, New York, 200 p.

LaMoreaux, P. E., 1946a, Geology of the Coastal Plain of east-central Georgia: Georgia Geol. Survey Bull. 50, 26 p.

______ , 1946b, Geology and ground-water resources of the Coastal Plain of east-central Georgia: Georgia Geol. Survey Bull. 52, 173 p.

LeGrand, H. E., 1962, Geology and ground-water resources of the Macon area, Georgia: Georgia Geol. Survey Bull. 72, 68 p.

Lowe, E. N., 1915, Mississippi, its geology, geography, soils, and mineral resources: Mississippi Geol. Survey Bull. 12, 335 p.

Lyell, C.,Jr., 1845, Observations on the white limestone and other Eocene or older formations of Virginia, South Carolina, and Georgia: Geol. Soc. London Quart. Jour., v. 1, p. 429-442.

MacNeil, F. S., 1946, the Tertiary formations of Alabama: Southeastern Geol. Soc., 4th Field Trip, Southeastern Alabama, 64 p.

______ , 1947a, Correlation chart for the outcropping Tertiary formations of the eastern Gulf region: U.S. Geol. Survey Oil and Gas Invs. Prelim. Chart 29.

______ , 1947b, Geologic map of the Tertiary and Quaternary formations of Georgia: U.S. Geol. Survey Oil and Gas Invs. Prelim. Map 72.

Moore, W. E., 1955, Geology of Jackson County, Florida: Florida Geol. Survey Bull. 37, 101 p.

Murray, G. E., 1947, Cenozoic deposits of central Gulf Coastal Plain: Amer. Assoc. Pet. Geol. Bull., v. 31, p. 1825-1850.

______ , 1948, Geology of DeSoto and Red River Parishes, Louisiana: Louisiana Geol. Survey Bull. 25, 312 p.

______ , 1963, North Twistwood Creek Clay—corrected name for North Creek Clay: Mississippi Geol., Econ. and Topographical Survey Bull. 95, p. 97-100.

Murray, G. E., and Wilbert, L.J., Jr., 1950, Jacksonian Stage: Amer. Assoc. Pet. Geol. Bull., v. 34, p. 1990-1997.

North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code: Amer. Assoc. Pet. Geol. Bull., v. 67, p. 841-875.

Nystrom, P. G., and Willoughby, R. H., 1982, Cretaceous, Tertiary, and Pleistocene (?) stratigraphy of Hollow Creek and Graniteville quadrangles, Aiken County, South Carolina, *in* Nystrom, P. G., and Willoughby, R. H., (eds.), Geological investigations related to the stratigraphy in the kaolin mining district, Aiken County, South Carolina, Carolina Geol. Soc. Field Trip Guidebook 1982, p. 80-113.

Oman, C. H., 1965, Micropaleontology of the Lisbon Formation of Alabama: PhD Dissertation, Florida State University, Tallahassee, 101 p., 10 pls.

Palmer, K.V.W., Brann, D. C., 1965, Part I. Pelecypoda, Amphineura, Pteropoda, Scaphopoda, and Cephalopoda: Catalogue of the Paleocene and Eocene Mollusca of the southern and eastern United States: Bull. Amer. Pal., v. 48, no. 218, p. 1-466, 3 pl.

______ ,1966, Part II. Gastropoda: Catalogue of the Paleocene and Eocene Mollusca of the southern and eastern United States: Bull. Amer. Pal., v. 48, no. 218, p. 471-1057, pl. 4-5.

Pickering, S. M., Jr., 1966, Stratigraphy and paleontology of portions of Perry and Cochran Quadrangles, Georgia: Masters Thesis University of Tennessee, Knoxville.

______ , 1970, Stratigraphy, paleontology, and economic geology of portions of Perry and Cochran Quadrangles, Georgia: Georgia Geol. Survey Bull. 81, 67 p., 14 pls.

Puri, H. S., 1953, Zonation of the Ocala Group in peninsular Florida:. (abs.) Program, Ann. Meeting, Amer. Assoc. Pet. Geol. and Soc. Econ. Pal. Min.

______ , 1957, Stratigraphy and zonation of the Ocala Group: Florida Geol. Survey Bull. 38, 248 p., 15 pls.

Puri, H. S., and Vernon, R. O., 1964, Summary of the geology of Florida and a guidebook to the classic exposures: Florida Geol. Survey Spec. Pub. 5, revised ed., 312 p.

Rankama, K., and Sahama, T. G., 1950, Geochemistry: The University of Chicago Press, Chicago, Ill., 912 p.

Rock-Color Chart Committee, 1963, Rock-color chart: Geol. Soc. Amer., New York.

Sandy, J., Carver, R. E., and Crawford, T. J., 1966, Stratigraphy and economic geology of the Coastal Plain of the central Savannah River area, Georgia: Guidebook, Field Trip No. 3, Southeastern Sec., Geol. Soc. Amer., 30 p.

Schmidt, W., 1977, A paleoenvironmental study of the Twiggs Clay (upper Eocene) of Georgia using fossil microorganisms: Masters Thesis, Florida State University, Tallahassee, 140 p.

Shearer, H. K., 1917, A report on the bauxite and fullers earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, 340 p.

Siple, G. E. 1967, Geology and ground water of the Savannah River Plant and vicinity, South Carolina: U.S. Geol Survey, Water-supply Paper 1841, 113 p.

Sloan, E., 1908, Catalogue of the mineral localities of South Carolina: South Carolina Geol. Survey, ser. 4, Bull. 2, 505 p.

Stainforth, R. M. Lamb, J. L., Luterbacher, H., Beard, J. H., and Jeffords, R. M., 1975, Cenozoic planktonic foraminiferal zonation and characteristics of index forms: Univ. Kans. Pal. Contr., Art. 62, 425 p.

Stenzel, H. B., 1940, The Yegua problem: Texas Bureau Econ. Geol. Bull. 3945, p. 847-910, pls. 48-51.

______ , 1952, Claiborne of western Alabama and eastern Mississippi: Guidebook, 9th Field Trip, Mississippi Geol. Soc., 90 p.

Toulmin, L. D., 1977, Stratigraphic distribution of Paleocene and Eocene fossils in the eastern Gulf Coast region: Geol. Survey of Alabama, Monograph 13, 602 p., 72 pls.

Toulmin, L. D., and LaMoreaux, P. E., 1963, Stratigraphy along Chattahoochee River, connecting link between Atlantic and Gulf Coastal Plains: Amer. Assoc. Pet. Geol. Bull., v. 47, p. 385-404.

Toulmin, L. D., LaMoreaux, P. E., and Lanphere, C. R., 1951, Geology and ground-water resources of Choctaw County, Alabama: Geol. Survey of Alabama Spec. Rept. 21, 197 p.

Veatch, O., and Stephenson, L. W., 1911, Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, 466 p.

Vernon, R. O., 1942, Geology of Holmes and Washington Counties, Florida: Florida Geol. Survey Bull. 21, 161 p.

______ , 1951, Geology of Citrus and Levy Counties, Florida: Florida Geol. Survey Bull. 33, 256 p.

Ward, L. W., Blackwelder, B. W., Gohn., G. S., and Poore, R. Z., 1979, Stratigraphic revision of Eocene, Oligocene and lower Miocene formations of South Carolina: South Carolina Div. Geol., Geol. Notes, v. 23. p. 2-32.

Ward, L. W., Lawrence, D. R., and Blackwelder, B. W., 1978, Stratigraphic revision of the middle Eocene, Oligocene, and lower Miocene-Atlantic Coastal Plain of North Carolina: U.S. Geol. Survey Bull. 1457-F, 23 p.

Weaver, F. M., and Wise, S. W., Jr., 1974, Opaline sediments of the southeastern Coastal Plain and Horizon A: Biogenic origin: Science, v. 184, no. 4139, p. 899.

Wentworth, C. K., 1922, A scale of grade and class terms for clastic sediments: Jour. Geol., v. 30, p. 377-392.

Wise, S. W., Jr., Buie, B. F., and Weaver, F. M., 1972, Chemically precipitated sedimentary cristobalite and the origin of chert: Ecologae Geol. Helv., v. 65, no. I, p. 157-163.

Wise, S. W., Jr., Ciesielski, P. F., Schmidt, W., and Weaver, R. M., 1974, Altered upper Eocene diatomite in the Coastal Plain of Georgia: Geol. Soc. Amer., Southeastern Mtg. Abs., p. 414.

Wise, S. W., and Weaver, F. M., 1973, Origin of cristobalite-rich Tertiary sediments in the Atlantic and Gulf Coastal Plain: Trans., Gulf Coast Assoc. Geol. Soc., v. 23, p. 305-323.

Zullo, V. A., Willoughby, R. H., and Nystrom, P. G., 1982, A late Oligocene or early Mocene age for the Dry Branch Formation and Tobaccco Road Sand in Aiken County, South Carolina?, *in* Nystrom, P. G., and Willoughby, R. H., (eds.), Geological investigations related to the stratigraphy in the kaolin mining district, Aiken County, South Carolina: Carolina Geol. Soc. Field Trip Guidebook 1982, p. 34-43.

APPENDIX

LITHOLOGIC DESCRIPTIONS OF BARNWELL GROUP EXPOSED IN ROADCUT ALONG WINDSOR SPRING ROAD, 1.1 MILES (1.8 KM) NORTH OF THE JUNCTION OF WINDSOR SPRING ROAD AND TOBACCO ROAD, RICHMOND COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
BED 14	Sand: argillaceous; unconsolidated but firm; massive-bedded; buff to tan color.	3.0 feet (0.9 m)
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 13	Residuum: argillaceous sand; tough, resistant to erosion; massive, structureless; color moderate reddish brown (10 R 4/6).	5.5 feet (1.7 m)
BED 12	Sand: argillaceous with clayey, wavy laminae and wisps; pebbly with abundant flat pebbles; quartz-sand component is medium, moderately poorly sorted; thin layering barely visible with faint, partially disrupted clayey laminae; bioturbation evident; main concentration of flat pebbles is in lower 1 ft (0.3 m); quartz pebbles of various rounded shapes up to 1.5 in. (3.8 cm) along long axis; pebbles display tendency toward horizontal orientation; in spite of apparent layering, bed is very massive; very tough and compact, almost hard; color moderate reddish brown (10 R 4/6).	4.5 feet (1.4 m)
DRY BRANCH FORMATION: IRWINTON SAND MEMBER		
BED 11	Sand: with scattered wavy, wispy, thin layers or laminae of sandy clay; sand is fine to medium, moderate- to well-sorted, poorly to well-mixed; vague stratification but massive; soft but coherent; does not fracture or separate along bedding planes.	1.5 feet (0.5 m)
BED 10	Clay and sand: finely micaceous; thinly bedded to laminated; clay laminated, blocky, sticky, and plastic but firm; fine to medium sand, well-sorted; bedding wavy, lenticular and undulatory; sand/clay about 50/50 overall, most clay in lower half of bed; grades downward into:	1.5 - 2.5 feet (0.5 - 0.8 m)
BED 9	Sand: fine to medium, moderate- to well-sorted, well- to poorly mixed; slightly argillaceous with scattered wispy, wavy, thin layers or laminae of sandy clay, appears somewhat bioturbated; grades downward into bed 8.	2.0 feet (0.6 m)
BED 8	Clay: with sandy clay and clayey sand, micaceous; clay thinly layered to laminated, some scattered, bioturbated, well-mixed, thin, clayey, micaceous sand layers or lenses up to 1 ft (30 cm) thick; bed appears to be a clay lens within the Irwinton; it is 3.5 ft (1.1 m) thick at the south end of the roadcut and it thins and pinches out northward.	0 - 3.5 feet (0 - 1.1 m)

BED 7	Sand: with discontinuous thin clay layers, laminae, and lenses (less than 1 in. [2.5 cm] thick), fine-grained mica, heavy minerals conspicuous; sand is fine to medium, generally well sorted where not stirred by scattered bioturbation; bed in general is thin-bedded with wavy and undulatory, thin clay layers, some low-amplitude, planar cross-bedding present; sand is typically loose and incoherent where freshly exposed but becomes firmer, more coherent and case-hardened on long exposure; where freshly exposed, the sand layers form reentrants between more prominent clay layers; separation between clay layers ranges from less than 1.0 in. to 6.0 in. (2.5 to 15 cm); some scattered burrows present in concentrations; bed is not present at north end of roadcut, either due to cross-cutting stratigraphic relationship with underlying beds (see Fig. 9), or due to lateral facies change into bed 6.	10.0 - 6.5 feet (3.0 - 2.0 m)
BED 6	Sand: some thin clay layers (up to 2 in. [5 cm] thick) and scattered, disrupted clay laminae; quartz sand ranges from fine to coarse, sorting ranges from well-sorted (fine to medium sand) to poorly sorted (coarse sand in discrete layers or lenses); bedding prominent, varying from horizontal layering to planar cross-bedding, scour-and-fill structures, and festoon cross-bedding; cross-bed sets range up to 3.0 ft (0.9 m) in amplitude; discontinuous zone of pebbly, poorly sorted coarse sand layer in basal 0.5 ft (15 cm) of bed; lower 1.5 ft (0.5 m) of bed slightly bioturbated with disrupted, scattered clay laminae; somewhat case-hardened and resistant due to prolonged exposure; bed 6 is present only at north end of the roadcut; grades downward into bed 5.	6.0 feet (1.8 m)
(TWIGGS CLAY LITHOFACIES)		
BED 5	Clay: very thinly layered to laminated with silty, finely micaceous, fine sand along bedding planes and interlayers; clay blocky, sticky, and plastic when moist, shaley and hard when dry; bedding undulatory, clay in outcrop has the appearance of etched wood, most clay concentrated in lower 2 ft (0.6 m) of bed, upper 2 ft (0.6 m) of bed has same bedding characteristics but consists of more well-sorted fine sand layers than clay layers (at south end of road-cut the bed separates into 3 clay layers with well-sorted, fine sand layers between); some rare scattered burrows; sand interlayers generally form thin reentrants between the projecting clay layers in outcrop; grades downward into:	4.0 - 3.5 feet (1.2 - 1.1 m)
BED 4	Sand: discontinuous thin clay layers and laminae up to 1/16 in. (2 mm) thick; greater concentration of clay laminae in upper half of bed; some heavy minerals present; sand fine to medium, well-sorted, almost incoherent; a thin layer of coarse, granully sand with scattered pebbles occurs at the base of the bed; bedding distinct but rather rude except where defined by discontinuous clay laminae, some small-scale planar cross-bedding with amplitudes up to 2 or 3 in. (5 to 7.6 cm) observed; abruptly overlies:	7.0 feet (2.1 m)
CLINCHFIELD FORMATION: ALBION MEMBER		
BED 3	Clay: waxy, blocky, tough, plastic and sticky when moist, almost pure clay in upper part, silty in lower part.	3.5 feet (1.1 m)
BED 2	Spiculitic claystone (see Sandy, and others, 1966), sandy, finely disseminated pyrite?, some phosphatic grains?; upper 3/5 of bed contains the most clay; massive except for crude organization into ledges; bed 2 divided into 2 parts: (2A) hard ledges that are concentrated toward the base and near the top, and are interlayered with and grade laterally into (2B), more argillaceous and less resistant to weathering than (2A);	19.0 feet (5.8 m)

	(2A) lowest ledge somewhat sandy, hard claystone with some undetermined dark grains; ledges in the lower part massive with rough, irregular, hackly fracture; ledges are darker in color than (2B), coloring agent may be finely disseminated pyrite; ledges above base are silty but are very dark colored, clayey, spiculitic, and with small light and dark inclusions (intraformational clasts?) imparting appearance of porphyritic rhyolite or dacite; fracture of upper ledges blocky, conchoidal to subconchoidal; lower contact with underlying formation very vague; (2B) claystone, tough, clayey, fine-grained, brittle with hackly and conchoidal fracture; moderately indurated but less resistant than (2A); massive, no apparent primary sedimentary structures; sparsely spiculitic.	
Pre-Upper Eocene BED 1	Clayey (kaolinite) sand to silty, sandy clay; fining upward from kaolinitic, moderately well sorted, medium to coarse sand to silty, tough but unconsolidated kaolin at top; little indication of primary sedimentary structures; massive.	7^{+} feet (2^{+} m)
		74.5 feet 22.7 m)

LITHOLOGIC DESCRIPTION OF BARNWELL GROUP EXPOSED IN ROAD CUT ON LINTON ROAD, ON THE EAST SIDE OF LITTLE KEG CREEK, 6.2 MILES (10 KM) NORTHWEST OF SANDERSVILLE, WASHINGTON COUNTY

Lithostratigraphic unit and bed number	Description	Thickness
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 10	Sand (residuum): argillaceous, scattered limonite-cemented sand nodules(plinthite) and irregular-shaped, submetallic, magnetic to nonmagnetic ironstone concretions or nodules (up to 1 cm in diameter), scattered quartz pebbles; sand is medium to coarse, poorly sorted; massive, no primary sedimentary or biogenic structures preserved; tough, dense, resistant, almost hard; color moderate reddish brown (10 R 4/6).	25.0 feet (7.6 m)
BED 9	Sand (flat pebble bed): argillaceous; sand is medium to coarse, poorly sorted with rounded quartz pebbles and flat pebbles, pebbles up to 1.5 in. (4 cm) in diameter, most pebbles 1 in. (2.5 cm) or less in diameter; no primary sedimentary or biogenic structures; appears well-mixed; tough, resistant, dense, almost hard; color moderate reddish brown (10 R 4/6).	1.3 feet (0.4 m)
DRY BRANCH FORMATION: IRWINTON SAND MEMBER		
BED 8	Clay: silty and finely sandy; tough but not resistant to weathering, forms a slight reentrant in outcrop; no distinct bedding observed; discontinuous.	0 - 0.5 foot (0 - 0.2 m)

BED 7	Sand: with discontinuous clay laminae and thin, discontinuous clay layers; variably medium-grained and well-sorted, and coarse-grained and poorly sorted (poorly sorted layers are more resistant to erosion than are well-sorted layers); well-bedded, varying from very thin-bedded with layers highlighted by thin clay laminae, to small-scale cross-bedding and festoon-bedding where the amplitude of the sets of inclined bedding is as much as 3 to 4 ft (.9 to 1.2 m); deeply weathered.	23.0 feet (7.0 m)
BED 6	Sand: massive residuum where deeply weathered, but faint traces of bedding present where less deeply weathered; bedding consists of vague, horizontal layering defined by contrasting sand-particle size that varies from medium to coarse; a few scattered discontinuous clay laminae still evident where the sediment is not too deeply weathered; weathers massive, even where bedding is evident; tough, hard and resistant; uppermost part of bed less resistant; color is moderate reddish-brown (10 R 4/6); the scattered clay laminae are pale yellowish-orange (10 YR 8/6); due to rolling topography, part of the bed is not exposed.	30.5 feet (9.3 m)
BED 5	Sand: coarse, poorly sorted with scattered angular to rounded quartz granules; thin, wispy, undulatory clay layers and laminae; deeply weathered but original horizontal bedding still evident due to thin clay layers and sand-size differences from layer to layer; tough, hard, and resistant; color moderate reddish-brown (10 R 4/6).	6.0 feet (1.8 m)
BED 4	Sand: poorly sorted, medium to coarse; some undulatory clay laminae; a few chert-cemented sandstone blocks appear to be out of place; part of bed may be slump of sand that has migrated downhill due to mass wasting; moderate reddish-brown (10 R 4/6).	3.0 feet (0.9 m)
TWIGGS CLAY MEMBER		
BED 3	Clay: weathered, ranges from fairly pure waxy clay to silty and sandy, purest in the lower part; some stratification noted; color light olive-gray (5 Y 6/1).	9.0 feet (2.7 m)
CLINCHFIELD FORMATION: RIGGINS MILL MEMBER		
BED 2	Clay and sand: clay is pebbly, limonitic, cherty, fossiliferous, with poorly sorted sand; sand is poorly sorted, clayey, limonitic with dispersed MnO_2; quartz pebbles subangular to subrounded, up to 1 in. (2.5 cm) in diameter, most pebbly at base of bed; limonite-cemented sand or clayey sand with scattered limonitic concretions near or at base of bed; scattered pockets of chert or siliceous pseudomorphs of mollusk shells and corals; MnO_2 staining along horizontal layers in some parts of the outcrop; where there are large concentrations of MnO_2, silicified fossils are rare or absent; conversely, MnO_2 is not prominent near large concentrations of silicified shells; bed varies from massive and devoid of primary sedimentary structures in most places, to stratified in other places, bedding where present is outlined by wispy clay laminae or thin layers, or by MnO_2-stained layers; color ranges from black (N1) to very dark yellowish orange (10 YR 4/6-5/6), to moderate reddish brown (10 R 4/6), to grayish-orange (10 YR 7/4), to yellowish-gray (5 Y 7/2); basal contact very irregular and undulatory.	1.5 - 4.0 feet (0.5 to 1.2 m)
HUBER FORMATION		
BED 1	Kaolinitic clay: blocky, hackly, brittle kaolin near top of bed; massive, no apparent primary sedimentary structures.	11^+ feet (3.4^+ m)
		110.3 - 113.3 feet (33.6 - 34.5m)

TYPE DESCRIPTION OF TREADWELL AND RIGGINS MILL MEMBERS OF THE CLINCHFIELD FORMATION, EXPOSED AT THE TYPE LOCALITY IN GEORGIA KAOLIN PIT 50, AT THE INTERSECTION OF TWO KAOLIN HAUL ROADS, 1.4 MILES (2.25 KM) SOUTHEAST OF THE BIBB-TWIGGS COUNTY LINE IN TWIGGS COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
BARNWELL GROUP: DRY BRANCH FORMATION TWIGGS CLAY MEMBER		
BED 11	Clay: calcareous, silty; hackly, blocky, subconchoidal to conchoidal fracture.	8^+ feet (2.4^+ m)
OCALA GROUP: TIVOLA LIMESTONE		
BED 10	Limestone: almost a bryozoan coquina, medium- to coarse-textured, bioclastic, calcarenitic; massive, only indication of original stratification is in very rudely layered, rubbly zones in top 2 or 3 ft (0.6 or 0.9 m) and basal 2 ft (0.6 m); moderately consolidated and indurated, irregular fracture; lower 2 ft (0.6 m) gradational with:	8.0 feet (2.4 m)
BARNWELL GROUP: CLINCHFIELD FORMATION TREADWELL MEMBER		
BED 9	Limestone: sandy, somewhat glauconitic, upper part with scattered concentrations of bryozoans resulting in a resemblance to the overlying Tivola: vaguely and very rudely bedded, stratification appears lenticular and undulatory; generally rubbly and moderately indurated or recrystallized, beds irregularly alternating hard and less hard; hard ledges or lenses consist of sandy to non-sandy, fairly well crystallized limestone; sandy lenses or patches relatively unconsolidated; quartz sand is minor constituent, patchy in distribution, some scattered small lenses of calcarenitic, glauconitic, well-sorted, fine to medium sand (glauconitic in more sandy patches); moderately fossiliferous with scattered patches of abundant *Periarchus lyelli; Aequipecten spillmani* present.	3.0 feet (0.9 m)
BED 8	Sand, calcareous sand, and sandy limestone: sand and limestone beds well-segregated into sand beds and limestone ledges; the hard ledges consist of sandy to nonsandy, fairly well recrystallized limestone; ledges vary from 1 to 9 in.(2.5 to 23 cm) thick; the less indurated to nonindurated sand layers and lenses between the hard ledges consist mainly of unconsolidated, calcareous, well-sorted fine to medium quartz sand; the softer sand forms recesses or reentrants upon weathering, these ranging in thickness from 1 in. (2.5 cm) to 1.5 ft (0.46 m) thick; thicker sand lenses occur toward the top of bed; sand shows fine-scale layering or laminations; bed 8 is very well layered with inclined bedding (cross-bedding and festoon-bedding) highlighted by strong development of alternating hard and soft layers; bedding somewhat undulatory; all strata appear to be discontinuous and lenticular except basal sand which can be traced around the pit; fossils relatively rare; no microfossils recovered from this bed.	5.0 feet (1.5 m)

BED 7	Sand and sandstone: calcareous, consists of alternating slabs or ledges of calcareous sandstone and tough, coherent calcareous sand; the hard sandstone ledges become less sandy and more calcareous upward in the section; the thinner ledges, especially the sandy ledges near the base of the bed, appear more as coalescing bands of calcareous sandstone nodules; these "ledges" are very irregular in shape and degree of induration, being only a little more calcareous and resistant or tougher than the adjacent, nonindurated, recessed sand; the quartz sand consists of medium to fine, well-sorted sand; sandstone fracture is slabby to very irregular; *Periarchus lyelli* is persistently common to abundant in this bed, *Aequipecten spillmani* rare; grades downward into Riggins Mill Member (Bed 6) by introduction and increase in clay content downward, by breakup of bands of nodules into separate nodules, and by domination of nonindurated clayey sand over nodules and bands of nodules; lithology change takes place over an interval of about 6 in. (15 cm).	5.5 feet (1.7 m)
RIGGINS MILL MEMBER		
BED 6	Sand: argillaceous, calcareous, some dispersed MnO_2, irregularly shaped limestone nodules or concretions occur throughout; quartz granules and pebbles scattered throughout but not common; scattered macrofossils; Sand-clay-calcite distribution irregular, patchy, and marbled with small irregular lenticular concentrations of dominantly sand, dominantly clay, or dominantly calcite (nodules); sorting is also irregular, ranging from well-sorted to poorly sorted; quartz sand component generally medium to fine with some irregular coarser concentrations; bioturbated; The gross appearance of the bed gives the general impression of being massive and structureless, but closer inspection shows a definite but vague and irregular stratification; The degree of coherence ranges irregularly from well-indurated (nodules or concretions) to compact but unconsolidated; moderately fossiliferous; macrofossils include scattered *Periarchus lyelli* and *P. lyelli* fragments, *Chlamys cf. membranosa* and scattered, rare, small, aragonitic molluscan shells; Color yellowish-gray (5 Y 8/1); grades downward into:	5.5 feet (1.7 m)
BED 5	Limestone: sandy, some scattered quartz granules and small pebbles; very fossiliferous with a diverse assemblage of pelecypods and gastropods in molds and casts; Quartz sand distribution somewhat patchy and irregular on a small scale; generally poorly sorted; scattered, irregular inclusions of dense, hard, fine-grained, conchoidal fracturing, almost pure limestone; Massive, little or no indication of bedding; basal 6 in. (15 cm) of bed consists of a very hard, dense, resistant, sandy limestone ledge, bed gets sandier, more argillaceous, and less indurated upward; grades upward into bed 6 by becoming more clayey, sandy, and less calcareous; Richly fossiliferous in lower part, becoming gradually less fossiliferous upward; first occurrence of *Periarchus* and *Chlamys cf. membranosa* is in upper part of the bed;	5.0 feet (1.5 m)
BED 4	Sand: clayey, calcareous, pebbly, fossiliferous; many sandy, popcorn-like calcareous concretions from 0.5 to 6 in. (1 to 15 cm) in diameter; many small, aragonitic shells scattered throughout the bed but they are especially well preserved and delicate in the basal 1 ft (30 cm);	3.0 feet (0.9 m)

Bedding rude, not obvious, but it is apparent on close inspection; stratification wraps around "popcorn" concretions; small shells are preferentially aligned horizontally, "popcorn" concretions also tend to be aligned;

Generally unconsolidated but firm except for "popcorn" concretions; concretions appear to have formed on sea floor because they do not contain as much quartz sand as the adjacent sediment; in addition the interior of the concretions contain coquinoid limestone, similar in lithology to the basal part of the overlying limestone bed;

Very poorly sorted; grain size ranges from interstitial clay to rounded pebbles up to 1.5 in. (3.8 cm) in diameter, especially poorly sorted and pebbly in the basal 1 ft (30 cm); sediment size decreases, abundance of pebbles decreases, and clay content increases upward; the upper 1 ft (30 cm) of the bed is decidedly clayey with irregular-shaped clay inclusions;

Very fossiliferous; fossils include scattered shells and shell fragments of *Crassostrea gigantissima*, corals, small pelecypods, gastropods, and scaphopods, shark teeth and ray teeth;

Color ranges from dark grayish-yellow (5 Y 7/4) to pale moderate-yellow (5 Y 8/6) where weathered;

Basal contact very irregular and undulatory with relief between 5 and 6 ft (1.5 -1.8 m); in places the contact appears conformable, in other places the contact appears to be a discontinuity.

HUBER FORMATION

BED 3	Sand and kaolin clay: sand medium to coarse to very coarse; well-sorted to moderately sorted; the clay present in sand beds is concentrated along bedding planes as thin layers and laminae and in burrows; sand unconsolidated, commonly loose; very well-bedded, both inclined bedding and horizontal bedding present; *Ophiomorpha nodosa* common; peculiar funnel-shaped structures present associated with *Ophiomorpha*; in places the sand grades downward and along inclined bedding slopes into underlying bed; in other places it rests on underlying bed with fairly sharp contact; the basal bed consists of poorly to moderately sorted, medium to very coarse, pebbly sand with clay clasts; Lenses or pods of silty, finely micaceous kaolinitic clay (with high montmorillonite content) occur in upper part of bed 3 on opposite sides of the pit; the kaolinitic clay has hackly, blocky, conchoidal to subconchoidal fracture, and breaks into small blocks generally less than 1 cubic inch (2.5 cm^3) in size; massive-bedded; clay pods are part of Bed 3 in that *Ophiomorpha*-bearing sands lie adjacent to and underlie the kaolin pods; basal Riggins Mill overlies the lenses in the pit and is draped over them, with the upper surfaces of the pods riddled with animal borings from the overlying Bed 4.	3.0 - 6.0 feet (0.9 - 1.8 m)
BED 2	Sand and clay: finely micaceous; generally very fine to fine, some medium and, rarely, coarse quartz sand, well-sorted; sand and clay concentrated in discrete layers; clay thin-bedded to laminated, clay relatively more resistant to weathering than sand, as a result the sand and clay are very finely etched or sculptured by weathering of the pit face, displays very intricate and varied bedding (cross-bedding of various kinds); prints of plant leaves and stems are commonly found along clay parting planes.	5.0 - 16^+ feet (1.5 - 4.9^+ m)
BED 1	Kaolin: massive, breaks into large blocks with conchoidal fracture; pure kaolin; this is the bed being mined. Top of Bed 1 is very irregular and shows considerable relief; Bed 2 is reciprocally thin (5 ft [1.5 m]) where the top of Bed 1 is high, and is thick (16^+ ft [4.9^+ m]) where the top of Bed 1 is low.	8^+ feet (2.4^+ m)
		59-73 feet (18-22 m)

LITHOLOGIC DESCRIPTION OF THE UTLEY LIMESTONE MEMBER OF THE CLINCHFIELD FORMATION AT THE TYPE LOCALITY IN BURKE COUNTY, GEORGIA

Lithologic unit	Description	Thickness
CLINCHFIELD FORMATION:		
UTLEY LIMESTONE MEMBER	Limestone: variably sandy to almost pure limestone, somewhat glauconitic, probably a trace of clay mineral but its presence is not evident in the limestone lithology, some scattered dusting of very fine black grains or spots (pyrite or MnO_2?), scattered manganese oxide dendrites; Very richly fossiliferous with aragonitic fossils (mainly gastropods and pelecypods) occurring as molds and casts, calcitic fossils still intact; fossils include locally abundant *Periarchus* cf. *lyelli* (fairly thin periphery), crab claws are common, rare scallops (*Aequipecten spillmani*), bryozoans, ray teeth, and shark teeth; Sand distribution irregular and patchy; medium- and well-sorted; some scattered inclusions (clasts?) of almost pure, fine-grained hard limestone no more than 1 in. (2.5 cm) in diameter and irregular-shaped; Limestone is hard, indurated, and recrystallized with a large amount of primary porosity; some zones or lenses of very dense, impermeable limestone; the great amount of porosity probably results in the locally cavernous conditions in the relatively thin limestone; Limestone appears massive, very little indication of original stratification except for the parallel orientation of the larger shells (oyster fragments and *Periarchus*); most fossils occur in random orientation, also some irregularity in the distribution of fossils; Color ranges from yellowish-gray (5 Y 7/2) to pinkish-gray (5 YR 8/1) except for green glauconite grains.	13 feet (4 m)

LITHOLOGIC DESCRIPTION OF THE DRY BRANCH FORMATION AT THE TYPE LOCALITY, 2.3 MILES (3.7 KM) SOUTH OF DRY BRANCH, TWIGGS COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 15	Residuum: sandy, very tough, color moderate reddish-brown, (10 R 4/6).	3.5^{+} feet (1^{+} m)
BED 14	Sand: fine, well-sorted, even-textured, soft and unconsolidated; massive-bedded; some scattered, rare burrows; moderate amount of heavy minerals; color white to very pale-gray.	5.0 feet (1.5 m)
BED 13	Sand: medium to very coarse, loose and unconsolidated; poorly sorted; bioturbated, bedding still evident but indistinct, some clay laminae present; very light-gray to cream color.	3.5 feet (1.1 m)
BED 12	Sand: medium to coarse, moderately to poorly sorted, very rare flat pebbles; very tough and coherent.	1.0 foot (0.3 m)

DRY BRANCH FORMATION:
IRWINTON SAND MEMBER

BED 11	Sand: fine to medium, contains thin, discontinuous layers and laminae of clay.	1.0 foot (0.3 m)
BED 10	Sand and clay: prominently layered, clay layers up to 2 in. (5 cm) thick, sand layers and lenses of cross-bedded sand up to 1 in. (2.5 cm) thick; sand fine-grained, well-sorted.	3.0 feet (0.9 m)
BED 9	Sand: medium to very coarse; poorly sorted; some clay stringers in middle of bed.	1.5 feet (0.5 m)
BED 8	Clay: dense, coherent; thin, discontinuous lenses and/or layers of fine to medium sand, sand layers or lenses less than 1 in. (2.5 cm) thick.	3.0 feet (0.9 m)
BED 7	Sand: medium to coarse; loose and unconsolidated; moderate sorting; heavy minerals conspicuous; color very pale cream to white. Along the face of the cut this bed thickens to 6 ft (1.8 m). Where it is thickest the bed is clearly a channel deposit with well-layered sand and inclined bedding in the central part of the channel. Also in the channel are thin layers or lenses of chert-cemented sandstone.	1.5 - 6.0 feet (0.5 - 1.8 m)
BED 6	Clay: massive-bedded; well-jointed; blocky with subconchoidal fracture; thinly bedded on weathering surface, silt and silty fine sand along bedding planes (Twiggs Clay lithofacies).	16.0 feet (4.9 m)
BED 5	Sandstone: chert-cemented, coquinoid; sand medium to coarse; cross-bedded to conspicuously horizontal bedded; fossils consist mainly of silicified oyster fragments, some scallop fragments, and nondescript pelecypod fragments; bed appears to be a large lens because loose sand occurs in its stratigraphic position elsewhere in the cut.	3.0 feet (0.9 m)
BED 4	Sand: generally fine to medium; well-sorted; some wad (MnO_2) present; variable bedding structures: horizontal bedding, cross-bedding, festoon-bedding; clay layers present throughout, basal 2 ft (0.6 m) of bed has 1 to 4 in. (2.5 to 10 cm) thick clay layers, clay layers more common toward lower part of bed, cross-bedded sand layers between clay layers thicken upward in the section, increase in thickness from 2 to 3 ft (0.6 to 0.9 m) to 5.0 ft (1.5 m).	7.0 feet (2.1 m)
BED 3	Clay: clay interlayered with medium sand, approximately 75% of bed consists of clay, 25% consists of sand, the clay layers and some sand layers are up to 3 in. (8 cm) thick; sand layers are lenticular, clay layers are wavy and undulating, clay fissile, thinly bedded to laminated with very fine sand on parting planes; sand moderately to very well sorted.	2.0 feet (0.6 m)
BED 2	Sand: fine; prominently layered, festoon-bedded and horizontally bedded, inclined bedding marked by clay clasts or clay flakes; thin clay layers and laminae present, layers up to 1 in. (2.5 cm) thick; a clay layer is present in the middle of the bed and is about 1 ft (0.3 m) thick, clay is fissile and thinly bedded, some layers of sand in clay bed are up to 1 in. (2.5 cm) thick; some stringers of clay trail off into sand.	10.0 feet (3.0 m)
TWIGGS CLAY MEMBER BED 1	Clay: massive-bedded, well-jointed, blocky to hackly to subconchoidal fracture; thinly layered, very fine sand to silt on parting planes, some discontinuous sand layers up to 1 or 2 in. (2.5 or 5 cm) thick present in the upper part of bed.	8^{+} feet (2.4^{+} m)
		69 - 73.5 feet (21 - 22.4 m)

LITHOLOGIC DESCRIPTION OF THE TWIGGS CLAY AT THE CUT OF THE SEABOARD COAST LINE RAILROAD, MAP LOCALITY E (SHEARER, 1917) OF THE TYPE LOCALITY AT PIKES PEAK IN TWIGGS COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 6	Sand: deeply weathered residuum, tough and resistant, case hardened by secondary interstitial cementing agent (Fe_2O_3 and clay mineral of soil origin?); sand fine to medium, well-sorted; no bedding preserved, massive and structureless, holds up a vertical face; color moderate reddish brown (10 R 4/6).	15.5 feet (4.7 m)
BED 5	Sand: as above but not as deeply weathered and case hardened, interstitial cementing agent occurs irregularly, rather marbled; sedimentary nature more apparent, rudely but distinctly layered; sand is fine to medium and well-sorted, soft and loose (sugar sand) where interstitial cementing agent is lacking; color of pure sand is white (N 9) and sand with interstitial cementing agent is moderate reddish brown (10 R 4/6).	4.5 feet (1.4 m)
BED 4	Sand: slightly argillaceous; very coarse and granully, a few scattered small pebbles, very poorly sorted; rude bedding apparent on close inspection, generally gives the impression of being structureless and massive; tough and resistant due to weathering and some case hardening. In general, the Tobacco Road Sand, beds 4 to 6, are a fining upward sequence; due to case hardening by secondary interstitial material, beds 4 to 6 are relatively resistant to erosion and hold up vertical faces in outcrop.	4.0 feet (1.2 m)
DRY BRANCH FORMATION: IRWINTON SAND MEMBER		
BED 3	Sand: coarse, moderate- to well-sorted; unconsolidated, soft and loose; thinly bedded with horizontal layering and cross-bedding; some very thin, scattered, discontinuous clay layers, laminae, or chips.	2.0 feet (0.6 m)
BED 2	Sand and clay: thinly interbedded, fine-grained, clean, well-sorted quartz sand (layers equal to or less than about 1/8 in. [3 mm]), clayey fine sand, and fine sandy clay; individual layers no more than about 1 in. (2.5 cm) thick; sediment is tough but not resistant to weathering and erosion; 4.5 ft (1.4 m) of bed in lower part not exposed due to slump and tendency toward water seepage on the top of the Twiggs Clay.	8.5 feet (2.6 m)
TYPE TWIGGS CLAY BED OR LITHOFACIES		
BED 1	Clay: finely sandy to silty and micaceous, calcareous in lower 5.0 to 5.5 ft (1.5 - 1.7 m) of exposure; diatoms conspicuous on bedding planes in upper part above calcareous zone, less conspicuous in calcareous clay; some MnO_2 staining and dendrites on clay surface in upper part above calcareous zone; Clay thinly bedded to laminated with silty fine sand and mica concentrations along bedding planes (only a few quartz grains thick)	16^+ feet (4.9^+ m)

enhancing thinly bedded nature of the deposit; layers and laminae range in thickness from about 9 in. (23 cm) to less than 1/16 in. (2 mm), most layers less than about 1 in. (2.5 cm) apart; thicker layers (4.0 to 9.0 in.[13 to 23 cm]) display conchoidal to subconchoidal fracture; laminae of fine sand are obscure near the base of the exposure but weathering causes them to become more pronounced upward; thus the clay becomes more fissile upward; very shaley aspect of vertical weathering face;

The whole mass of clay is very well jointed with abundant vertical to near vertical joints, some joints less than 1 in. (2.5 cm) apart;

Dry clay is light-weight fuller's earth-type clay;

Microfossiliferous with poorly preserved foraminifera and ostracods occurring in lower calcareous part, diatom impressions common on bedding planes in upper part;

Unweathered calcareous clay varies from light olive-gray to olive-gray (5 Y 6/1 to 5 Y 4/1), upper diatomaceous clay is yellowish-gray (5 Y 7/2 to 5 Y 8/1); base of bed is not exposed in railroad cut.

50.5 feet (15.4 m)

LITHOLOGIC DESCRIPTION OF THE UPPER EOCENE DEPOSITS EXPOSED AT THE MEDUSA CEMENT COMPANY WEST QUARRY, CLINCHFIELD, HOUSTON COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
MIOCENE/OLIGOCENE/EOCENE (UNDIFFERENTIATED)		
BED 22	Sand: coarse to medium; argillaceous, cherty, boulders and cobbles of fossiliferous chert in the upper 10 ft (3.0 m); most boulders contain Chickasawhayan fossils, one boulder contains an apparent Vicksburgian fossil suite; sand deeply weathered; moderate reddish brown (10 R 4/6).	30 feet (9.1 m)
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 21	Sand: very cherty sand to sandy chert, deeply weathered, moderate yellowish orange (10 YR 7/6); scattered rare *Periarchus quinquefarius*.	0.75 foot (0.23 m)
DRY BRANCH FORMATION: TWIGGS CLAY MEMBER		
BED 20	Sand: manganiferous; unconsolidated; black (N1).	1.0 foot (0.3 m)
BED 19	Clay: sandy, cherty, glauconitic clay to sandy, clayey, cherty greensand; poorly mixed combination of coarse sand, leached sticky clay, coarse pelletal glauconite, and abundant chert concretions; bioturbated.	2.0 feet (0.6 m)
BED 18	Clay: noncalcareous; leached; sticky and plastic when wet; yellowish gray (5 Y 8/1); 1 ft (0.3 m) of unconsolidated sand 3 ft (0.9 m) below top of bed.	9.0 feet (2.7 m)

BED 17	Greensand: sandy, slightly argillaceous, calcareous; partially indurated; has 6 in. (15 cm) bed of calcilutitic limestone at base in places.	2.0 feet (0.6 m)
BED 16	Clay: calcareous toward base, noncalcareous toward top; blocky to conchoidal fracture; moderately well bedded; base of weathering in the present quarry wall, some lenses of blue clay remaining; weathered yellowish-gray (5 Y 8/1).	13.0 feet (4 m)
BED 15	Clay: very glauconitic, sandy, noncalcareous; contains angular clay clasts, very thinly bedded; a discontinuous, fine-grained, almost lithographic, calcilutitic limestone overlies and underlies the glauconitic clay bed in places, limestone beds pinch out by becoming concretionary and discontinuous.	4.0 feet (1.2 m)
BED 14	Clay: silty, calcareous; thinly bedded, almost massive when fresh, breaks into blocky chunks when exposed for a very short time; greenish-gray (5 GY 6/1 - 5 G 6/1).	11.5 feet (3.5 m)
	Covered.	4.5 feet (1.4 m)
BED 13	Sand to sandstone: very calcareous, glauconitic, some sandy marly limestone; sand medium to coarse; indurated beds 2 ft (0.6 m) thick or less, some intervals or layers of poorly mixed sand and fine-textured, indurated limestone and claystone; some layers abundantly macrofossiliferous, almost a coquina of molluscan molds; top 1 ft (0.3 m) of bed consists of a poorly mixed, fossiliferous, glauconitic, marly sand and clay; greenish-gray (5 GY 5/1) when fresh, grayish-orange to dark yellowish orange (10 YR 7/4 - 10 YR 6/6) when weathered.	9.5 feet (2.9 m)
BED 12	Clay: calcareous, fine to very fine sand, mica, glauconite, and fine, sand-size pyrite distributed in laminae or thin beds; most clay is blocky and hackly, some almost pure clay with conchoidal fracture; sandy and limey thin beds and laminae very characteristic of this interval; thin, 6 in. (15 cm) layers of dense, fine-grained limestone characteristic of the upper part of the interval; less clearly defined sandy, calcareous, micaceous, glauconitic, slightly pyritic layers and laminae more characteristic of the lower part. These layers appear less continuous and may have indurated lenses within them. Sediment within the layers is poorly mixed, often marbled, disturbed and apparently bioturbated; color of clay is greenish-gray (5 GY 6/1 to 5 GY 8/1 to 5 G 6/1); sandy layers and limestone layers are light-gray (N7).	29.0 feet (8.8 m)
	Covered.	3.5 feet (1.1 m)
BED 11	Clay to marl: very slightly sandy, glauconitic, very calcareous, bryozoan-rich clay; to a very clayey, bryozoan-rich glauconitic, sandy marl; greenish-gray (5 GY 6/1 - 5 G 5/1).	1.5 feet (0.5 m)
BED 10	Limestone: glauconitic; hard, dense, recrystallized; massive-bedded; uneven texture; yellowish-gray (5 Y 8/1).	1.5 feet (0.5 m)
BED 9	Clay: silty, calcareous, very slightly micaceous, some fine sand-size pyrite grains; blocky; dark greenish-gray (5 GY 5/1)	0.75 foot (0.23 m)
BED 8	Marl, sand, and clay: poorly mixed, fossiliferous, clayey, sandy marl; argillaceous fine sand; and marly clay; calcareous, slightly micaceous, macrofossiliferous; characteristically more marly and calcareous in lower part, more sandy and less calcareous in upper part; contains three silty, nonfossiliferous beds of limestone.	8.0 feet (2.4 m)

OCALA GROUP: TIVOLA LIMESTONE		
BED 7	Limestone: slightly glauconitic, abundantly fossiliferous; coarse, uneven-textured, rubbly, bioclastic; unevenly and rudely bedded, indurated, hard beds up to 2 ft (0.6 m) thick interspersed with thin, soft, granular, uneven-textured beds; *Lepidocyclina, Periarchus pileussinensis, Aequipecten spillmani*, and molds of mollusks commonly in a matrix of clastic bryozoan debris; color very pale-orange (10 YR 8/2) to pale yellowish- orange (10 YR 8/6).	10.0 feet (3.0 m)
BED 6	Limestone: bioclastic particle size strongly bimodal, plastic, lutitic matrix with bioclastic, commonly chalky, skeletal debris, consisting mainly of bryozoan debris with some *Aequipecten spillmani and Periarchus pileussinensis*; unconsolidated but coherent; color very pale-orange (10 YR 8/2) to almost white when slightly weathered.	1.0 foot (0.3 m)
BED 5	Limestone: very slightly glauconitic, some fine pyrite grains present; massive, no evidence of primary sedimentary or biogenic structures; medium- to coarse-textured, uneven-grained due to abundance of clastic bryozoan debris; very tough and brittle with irregular fracture due to abundance of bryozoan debris; more coarsely bioclastic, more apparent bedding, and sandy with frosted quartz granules toward the base of the bed, some apparently discontinuous, indurated, thin, rudely stratified limestone layers in the lower part of the bed; color very pale-orange (10 YR 8/2) to yellowish-gray (10 YR 9/4 - 5 Y 8/1); lower contact not exposed.	31.5 feet (9.6 m)
BARNWELL GROUP: CLINCHFIELD FORMATION		
BED 4	Sandstone: glauconitic, calcareous, with molds and casts of rather large mollusks; medium to coarse, poorly sorted, some scattered, angular quartz granules; rubbly, massive, no primary sedimentary or biogenic structures; indurated; *Crassostrea gigantissima, Periarchus lyelli*, large bryozoans, Manatee rib bones, and shark teeth present.	1.0 foot (0.3 m)
BED 3	Sandstone: poorly sorted, medium-grained; calcareous; extremely hard, dense, slightly fossiliferous; 2 to 4 in. (5 to 10 cm) of calcareous clay to claystone on top of bed; color grayish-orange to grayish-orange-pink (10 YR 7/4 - 5 YR 7/2).	0.75 foot (0.23 m)
BED 2	Sand: calcareous; coarse-grained; soft, unconsolidated; abundant chalky, aragonitic shells; grayish-orange (10 YR 7/4).	1.0 foot (0.3 m)
BED 1	Sand: medium-grained; very slightly argillaceous, calcareous; soft, unconsolidated; extensively and intricately burrowed; grayish- orange (10 YR 7/4).	2^+ feet (0.6^+ m)
		178.7 feet (54.3 m)

DESCRIPTION OF THE GRIFFINS LANDING MEMBER OF THE DRY BRANCH FORMATION EXPOSED AT GRIFFINS LANDING ON THE SAVANNAH RIVER, BURKE COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
BARNWELL GROUP: DRY BRANCH FORMATION IRWINTON SAND MEMBER		
BED 14	Residuum: sandy, clayey; massive and devoid of primary sedimentary and biogenic structures; tough and hard when dry; tough and sticky when moist; mottled maroon, orange and gray; lower contact indistinct due to severe weathering.	15^{+} feet (4.6^{+} m)
BED 13	Sand: very deeply weathered, medium-grained, moderately sorted; argillaceous with secondary interstitial cementing agent (Fe_2O_3), and clay mineral of soil origin?, wisps of disturbed clay or clayey discontinuous laminae, thin layers, or thin lenses, evidently bioturbated; very tough; color purple to gray; lower contact appears gradational but is very deeply weathered.	3.5 feet (1.1 m)
BED 12	Weathered sand and clay: interlayered, sand dominates; sand fine to medium, fairly well sorted; clay occurs as discontinuous thin layers and lenses up to 1 in. (2.5 cm) thick; clay layers are partially disrupted by scattered burrows and weak bioturbation; some scattered clay clasts; in general, the bed is well-layered; clay is white and probably kaolinized; sand is orange in color; lower contact gradational.	2.0 feet (0.6 m)
BED 11	Sand: deeply weathered, fine to medium. moderately to well-sorted; distinctly layered, some thin discontinuous clay layers, laminae, and lenses defining bedding planes; tough due to secondary hardening but nonindurated; color orange; grades downward into Bed 10.	2.0 feet (0.6 m)
BED 10	Sand: residuum, massive, no original primary sedimentary or biogenic structures preserved; sand is fine to medium; interstitial material or matrix Fe_2O_3 and clay mineral of soil origin?; in general the bed is resistant to erosion, but 13 ft (4.0 m) of the bed is very poorly exposed; color moderate reddish brown (10 R 4/6); grades downward into underlying bed by becoming less intensely weathered; one interval or lens in the middle of the section is a white, well-sorted, fine to medium, almost pure "sugar" sand that contains only irregular concentrations of hardened matrix.	33.5 feet (10.2 m)
BED 9	Sand: clayey, slightly micaceous, scattered MnO_2 dispersions; sand component fine to medium, well-sorted; rudely layered with some incomplete mixing of sand and clayey sand etched out on weathering surface; some intervals or zones display more or clearer bedding features; freshly scraped surface does not display layering clearly; some clay present as scattered, thin (up to 1/16 in. [1-2 mm]), very discontinuous clay lenses, laminae, or chips highlighting or defining bedding planes; sand is unconsolidated, sticky, and clayey; lower contact gradational with underlying bed.	7.0 feet (2.1 m)

BED 8	Clay and sand (Twiggs Clay lithofacies): dominantly clay, some MnO_2 dispersions; thinly interlayered to interlaminated, shaley; fissile texture with thin interlayers of fine sand and some fine mica along bedding planes or partings; finely micaceous, thin sand and clay layers generally well-separated texturally; lower part of bed more clayey, grades upward into Bed 9 by increase in thickness of sand layers, and by decrease in thickness and number, and disappearance of clay layers; Bed 8 appears to grade laterally and downward into Bed 7; therefore one bed appears to thicken at the expense of the other bed.	7.5 to less than 4.0 feet (2.3 to less than 1.2 m)
BED 7	Sand: clayey, some MnO_2 dispersions, scattered fine mica; sand fine to medium, well-sorted; sand and clay well mixed, massive; no visible primary sedimentary or biogenic structures; soft clayey texture; appears to both underlie and grade laterally into Bed 8, grades downward into Bed 6.	5.0 - 2.5 feet (1.5 - 0.76 m)
BED 6	Clay (Twiggs Clay lithofacies): interlayered with finely micaceous, silty fine sand, some MnO_2 dispersions; fissile, blocky, hackly, shaley, thinly bedded to laminated; clay layers 1 in. (2.5 cm) or less thick; most discrete clay layers (intervals between sand laminae) are 0.25 in. (6 mm) or less thick; basal 1 ft (30 cm) of bed is less well bedded, more poorly sorted, and is more coarsely sandy, with scattered quartz granules, than the rest of Bed 6. Bed 6 gets steadily more sandy upward; gradational over approximately 1 ft (30 cm) with bed 7; uppermost 1 ft (30 cm) sandy and bioturbated; partially or incompletely mixed fine sand and clay. Bed 6 appears to be, along the face of the outcrop, a thinly layered clay lens within a generally more massive-bedded clayey sand deposit (Beds 7 and 9); color yellowish-gray (5 Y 7/2).	5.5 feet (1.7 m)
GRIFFINS LANDING MEMBER		
BED 5	Sand: quartz sand component medium, fairly well sorted; argillaceous, micaceous, calcareous, heavy minerals present; some discontinuous thin layers of waxy pure clay; some irregular calcareous nodules; fossiliferous; stratified but layering subtle except for thin clay layers; fine shell material and oyster fragments tend to be aligned horizontally and define stratification; gross apppearance of bed is massive and structureless; burrows present in some exposures; bed is soft and easily eroded; therefore, exposures are intermittent and scattered along the face of the bluff. Where weathered, bed 5 consists of rudely layered, medium to coarse, well-sorted sand, layers about 1 in. (2.5 cm) or less thick; unconsolidated and soft; color ranges from orange to brown. Oyster shell beds or biostromes are scattered throughout with some, especially higher up in the bed, being noticeably discontinuous along the line of the bluffs; those 10 to 15 ft (3.0 to 4.6 m) above mean low water appear to be more continuous; some of the oyster shells in the beds occur in living position whereas shells in other beds appear to be jammed together in random orientation.	52.0 feet (15.9 m)
BED 4	Clay: very calcareous, finely sandy and micaceous with most of the fine-grained mica and silty fine sand along the partings or bedding planes; thin-bedded; blocky, hackly clay with conchoidal to subconchoidal fracture between bedding planes; clay that displays conchoidal fracture is waxy, laminated; grades downward into;	1.0 foot (30 cm)
BED 3	Limestone: argillaceous, contains fine sand and mica; tough, rubbly, but not heavily indurated; irregular fracture; no apparent sedimentary structures; color yellowish-gray (5 Y 8/1); grades downward over an interval of about 6 in. (15 cm) into:	1.0 foot (30 cm)

BED 2	Clay: very finely sandy, very calcareous, micaceous, fossiliferous; sand component fine, well-sorted; clay near the top of the bed massive with conchoidal fracture; no apparent sedimentary structures; hard and brittle when dry; plastic but tough when moist; oyster shells *(Crassostrea gigantissima)* present and in living position; mussel shell impressions locally common; softer than underlying and overlying beds, forms a reentrant; color ranges from yellowish-gray (5 Y 8/1) to light grayish-yellow (5 Y 9/4) to pale greenish-yellow (10 Y 8/2); grades downward into:	1.0 - 2.0 feet (30 - 60 cm)
BED 1	Clayey fine sand to very sandy clay: calcareous, micaceous, fossiliferous; massive, no apparent bedding; sediment fairly well mixed but some marbling of sand and clay present which is probably due to bioturbation; sediment unconsolidated but tough and compact; some clay lenses appear to be scattered randomly throughout the bed; oysters (*C. gigantissima*) very abundant, tend to occur in concentrations and in living position; some mussel impressions and barnacles present; color greenish-gray (5 G 6/1) when freshly exposed; where weathered the color ranges from yellowish-gray (5 Y 7/2) to dark yellowish-gray (5 Y 6/2) to light olive-gray (5 Y 6/1) to grayish-yellow (5 Y 8/4) to dusky-yellow (5 Y 6/4).	7^{+} feet (2.1^{+} m)
		138 - 143 feet (42.1 - 43.6 m)

**DESCRIPTION OF THE TOBACCO ROAD SAND
AT THE TYPE LOCALITY
ON THE EAST SIDE OF MORGAN ROAD, 0.3 MILE (0.6 KM)
NORTH OF THE JUNCTION OF
MORGAN ROAD AND TOBACCO ROAD, RICHMOND COUNTY, GEORGIA**

Lithostratigraphic unit and bed number	Description	Thickness
BED 10	Sand: (surficial sand of the soil zone), medium-grained, loose, pale-tan color.	4.5 feet (1.4 m)
BED 9	Residuum: fine sand, argillaceous; massive; soft but tough when moist, hard and brittle when dry, resistant to erosion; color moderate reddish brown (10 R 4/6).	10.0 feet (3.0 m)
BED 8	Sand: very poorly sorted; medium to coarse and pebbly, quartz pebbles up to 1 in. (2.5 cm) in diameter, rounded to subangular, some pebbles crumble under pressure; clayey, with irregular-shaped clay clasts up to 1.25 in. (3.2 cm); massive, no apparent sedimentary structures; very abrupt and irregular basal contact.	
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 7	Sand: fine to medium, moderately poorly sorted and medium-grained in lower 1 or 2 ft (0.3 - 0.6 m); rest of bed 7 is fine and well-sorted sand; bedding very distinct and undulatory; some small scale cross-bedding in the sand layers; conspicuous thin clay layers range in thickness from less than 1/16 in. to 1/2 in. (2 mm to 1 cm); a few clay clasts present; some clay layers disrupted and distorted; more closely spaced clay layers in upper 2 ft (0.6 m); where exposed sand is un-	9.0 feet (2.7 m)

weathered, it is soft, slightly coherent, and pale-yellow to cream in color; where the sand is weathered and casehardened, it is tough, resistant, and deep-red in color; lower contact of bed slightly undulatory and abrupt, varying from a knife-edge contact to gradational over approximately 1/16 in. (1-2 mm).

BED 6	Sand: medium-grained; somewhat argillaceous, micaceous, scattered quartz granules and thin clay chips; bedding varies from being distinct to being indistinct and disrupted; in some places the bed is bioturbated but the sediments are incompletely mixed; in other places bioturbation is not evident and the bedding is conspicuous, each layer varying from 1/32 in. (1 mm) to less than 1/2 in. (1 cm) in thickness; moderately to well-sorted; soft and coherent when moist and freshly exposed; weathers to a tough, resistant ledge-former; a few scattered burrows present; weathers gray to brownish-yellow; grades downward into bed 5.	1.5 feet (0.5 m)
BED 5	Sand: medium to coarse, some very coarse sand grains and quartz granules present; micaceous; discontinuous clay laminae and clayey sand layers, a few clay clasts present; sorting moderate to poor; layering present but indistinct and subtle; clay laminae slightly undulatory; scattered *Ophiomorpha nodosa* present throughout; base of bed consists of 6 in. (15 cm) of finely interlayered sand and clay; grades downward into bed 4.	7.5 feet (2.3 m)
BED 4	Sand: medium-grained, some coarse quartz sand grains scattered throughout; some heavy minerals present, very slightly argillaceous, quartz grains subrounded to rounded and frosted; fairly well sorted; very soft and incoherent where fresh, slightly coherent on weathered surface; very well bedded, consists of gently dipping (to the southeast) crossbed sets; individual layers vary from 1/32 in. (1 mm) to 1 in. (3 cm) in thickness.	6.0 feet (1.8 m)
BED 3	Sand: slightly argillaceous, micaceous, heavy minerals common; sand fine-grained, well-sorted; soft but slightly coherent; scattered clay laminae and thin layers up to 1/16 in. (2 mm) thick; clay layers become closer spaced toward top of bed.	3.5 feet (1.1 m)
BED 2	Gravelly sand with common flat quartz pebbles: pebbles well-rounded to subrounded, up to 2.5 in. (6 cm) in diameter; orientation of flat pebbles not always horizontal; sand medium to coarse; clay layers up to 1/2 in. (1 cm) in thickness scattered throughout bed; sorting is poor to moderate; gravelly sand soft and lacking coherence; clay confined to clay layers and not present as matrix of sand; lower contact sharp but conformable.	0.5 foot (0.2 m)
DRY BRANCH FORMATION: IRWINTON SAND MEMBER BED 1	Sand: medium-grained, moderately to well-sorted; only very slightly coherent; very slightly argillaceous, discontinuous clay laminae and thin layers scattered throughout bed, becoming closer spaced toward top of bed, a few clayey sand layers up to 2 in.(5 cm) thick are present; some scattered clay clasts and chips; quartz granules and pebbles present but scattered throughout; pebbles up to 1/2 in. (1 cm) in diameter; bedding subtle but distinctly horizontal, bedding surfaces are short, discontinuous.	21^+ feet (6.4^+ m)
		65.0 feet (19.8 m)

DESCRIPTION OF TOBACCO ROAD SAND AND THE SANDERSVILLE LIMESTONE MEMBER SOUTH OF SANDERSVILLE, WASHINGTON COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
BARNWELL GROUP: TOBACCO ROAD SAND		
BED 6	Clay and sand: clayey, fine silty sand to finely micaceous, silty clay; thin-bedded; inclusions, clasts, and lenses of waxy, pistachio-green clay, clay content increases upward in the bed; popcorn-shaped siliceous concretions or nodules scattered throughout, nodules up to 2 or 3 in. (5 to 8 cm) in diameter; color pale-green to pistachio-green with some maroon to brown mottling.	7.0 feet (2.1 m)
BED 5	Sandstone: chert-cemented; soft, friable, varying from weakly cemented, very friable, to moderately hard, friable sandstone, to hard siliceous sandstone; fine to medium, well-sorted, but coarse sand grains and granule-size quartz scattered throughout; generally rudely layered but where the sandstone is freshly exposed, layering is not obvious; generally nonfossiliferous but burrows present at some sites, and horizontally oriented shell hash present at other sites; bed 4 overlies, underlies, and occurs at the same elevations as bed 5; thickness variable.	0 - 15.0 feet (0 - 4.6 m)
BED 4	Sand: clayey, cherty, richly fossiliferous with silicified oysters (*Crassostrea gigantissima*); deeply weathered in outcrop and the matrix sediment is a residuum; no original sedimentary or biogenic structures, orientation of oysters in outcrop is random; most oyster shells are single valves, a few oysters are double-valved, therefore the deposit is probably a thanatocoenose; oyster concentration varies from very closely packed to moderately closely packed; thickness and stratigraphic position of oyster bed quite variable, ranging from the top of the Sandersville Limestone to near the top of the Tobacco Road section in Sandersville vicinity; Residuum is sandy, clayey with dispersed black MnO_2 and very abundant silicified oysters; bedding appears massive and chaotic; oysters weather out and are strewn over the surface of the outcrop; bed is a slope-former; color irregularly mottled brown, deep-red, black [MnO_2], with some pale-green clay pockets still intact.	0 - 11.5 feet (0 - 3.5 m)
BED 3	Sand: generally fine to medium, well-sorted, poorly exposed in outcrop; generally a slope-former; some MnO_2 concentrations; in the vicinity of the road cut, this bed is generally deeply weathered and little specific can be said of it; horizontal layering is evident in a few places; generally it is massive-bedded and argillaceous; thickness variable.	5.0 - 16.0 feet (1.5 - 4.9 m)
SANDERSVILLE LIMESTONE MEMBER		
BED 2	Limestone: sandy, especially toward top of bed; sand distribution patchy with some patches (up to a few cm in diameter) being a calcareous sand, and other patches or zones being devoid of sand; irregularly indurated with very sandy zones being soft and easily eroded, and sand-free limestone being hard and moderately indurated; very abundantly fossiliferous with oyster (*Crassostrea gigantissima*) producing a coarse bioclastic texture to the limestone; oysters occurring in random orientation; no primary sedimentary or biogenic structures preserved.	4.0 feet (1.2 m)

BED 1	Limestone: scattered small clasts (1-2 mm) or inclusions of pistachio-colored clay; hard, tough, moderately indurated and recrystallized limestone; varying degrees of recrystallization and hardness produces an uneven, hackly fracture surface that resembles cottage cheese; massive, no primary sedimentary or biogenic structures observed; variably fossiliferous; in some places few clearly distinguishable fossils, other places very coarsely fossiliferous, imparting a coarse, bioclastic texture to the limestone; casts and molds of small mollusks, *Turitella* and bryozoans generally common, solitary corals, stoney algae, rare scallops, and *Periarchus quinquefarius* observed; color very pale-orange 10 YR 8/2 - 9/2).	14.0 feet (4 m)
		41.0 feet (12.5 m)

In general, in the Sandersville area, beds 3, 4, 5, and 6 occur in the order given. However, their thicknesses vary considerably and any one of two beds may be absent at a given site. Beds 3 and 6 appear to be the basic lithologies of the Tobacco Road overlying the Sandersville Limestone Member in central and eastern Washington County, and the oyster bed or biostrome and the cherty sandstone appear to be local, but commonly occurring facies or lenses within the formation.

TYPE DESCRIPTION OF THE OCMULGEE FORMATION EXPOSED AT TAYLORS BLUFF ON THE OCMULGEE RIVER, PULASKI COUNTY, GEORGIA

Lithostratigraphic unit and bed number	Description	Thickness
OCALA GROUP: OCMULGEE FORMATION		
BED 9	Limestone: slightly argillaceous, slightly glauconitic; calcarenitic, fairly even textured, granular, medium-grained; very tough, resistant but not recrystallized; massive, no apparent primary sedimentary or biogenic structures; very microfossiliferous, macrofossils rare.	23.5 feet (7.2 m)
BED 8	Calcarenitic limestone: hard ledge, moderately recrystallized; texture as above.	2.0 feet (0.6 m)
BED 7	Alternating tough, fossiliferous limestone ledges and softer, argillaceous, glauconitic limestone reentrants; fossils in limestone consist of molds of mollusks; ledges are slightly argillaceous and glauconitic, reentrants are quite glauconitic and argillaceous with some zones that are clayey in texture, macrofossils are not present in clayey layers, top reentrant is calcarenitic in texture and is thinly but rudely bedded.	4.0 feet (1.2 m)
BED 6	Limestone: soft, nonresistant, but slightly recrystallized; fossiliferous with abundant molluscan molds.	2.0 feet (0.6 m)
BED 5	Limestone: slightly glauconitic; very soft, poorly exposed, covered in most places along the bluff.	3.5 feet (1.0 m)
BED 4	Sandstone: calcareous, fossiliferous, glauconitic and with scattered clay clasts near base; quartz sand is fine to medium, fairly well mixed; appears massive-bedded but thin, rude layering is visible; molluscan molds patchy in distribution, varies from abundant to rare, pelecypods dominate over gastropods; basal 2 ft (0.6 m) is fairly hard and resistant, rest of overlying sandstone is soft and friable and poorly exposed.	9.25 feet (2.8 m)

BARNWELL GROUP: DRY BRANCH FORMATION TWIGGS CLAY MEMBER		
BED 3	Clay and sand: upper 1.5 ft (0.46 m) is a slightly micaceous, calcareous clay with subconchoidal to conchoidal blocky fracture; scattered thin shelled mollusks; the clay grades downward abruptly into micaceous, very thinly lenticular, unevenly layered, thinly laminated, finely sandy, clayey calcarenite.	3.0 feet (0.9 m)
BED 2	Sandstone: very calcareous, clayey, variably macrofossiliferous, some scattered claystone clasts; generally poorly mixed sediment; indurated, forms thin ledge.	0.25 - 0.5 foot (7.6 - 15 cm)
BED 1	Sand: clayey, slightly glauconitic, slightly micaceous, calcareous, some finely disseminated pyrite?; sand fine to medium, well-sorted; sand and clay marbled, incompletely mixed, bioturbated, some vague bedding still discernible; generally massive; well-jointed; top 6 inches (15 cm) is very clayey, finely sandy, bioturbated limestone with conchoidal fracture.	2.25 feet (0.69 m)
		50.0 feet (15.2 m)