A Revision of the Lithostratigraphic Units of the Coastal Plain of Georgia

The Miocene Through Holocene

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LIST OF ILLUSTRATIONS

ILLUSTRATIONS (CONTINUED)

ILLUSTRATIONS (CONTINUED)

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ABSTRACT

Twenty-four formally defined lithostratigraphic units are described in this report: one group, thirteen formations, and ten members. In addition, two unnamed formations are briefly described, one informal unit described as "beds" is recognized, and three undifferentiated stratigraphic units and three kinds of undifferentiated deposits are described. Two named formations are new: the Cypresshead Formation and the Statenville Formation. Five formations that previously had been abandoned are reintroduced: the Parachucla Formation, Marks Head Formation, Altamaha Formation, Nashua Formation, and Satilla Formation. One informal member has been formalized and raised to formation rank, the Coosawhatchie Formation; and one formation has been raised to group rank, the Hawthorne Group. Seven named members are new: the Tybee Phosphorite, Berryville Clay, Ebenezer, and Meigs Members of the Coosawhatchie Formation; the Tiger Leap and Porters Landing Members of the Parachucla Formation; and the Screven Member of the Altamaha Formation. The Charlton, previously a formation, is reduced in rank to a member of the Coosawhatchie Formation.

The lithostratigraphy is described in terms of the Miocene-Holocene structural framework of Georgia. Four major structural elements are described: the Southeast Georgia Embayment, the Gulf Trough-Apalachicola Embayment, the Piedmont Slope, and the Ocala Platform. Two minor features are also described: the Beaufort Arch and the Ridgeland Trough. During the Miocene through Holocene, the Georgia Coastal Plain is determined to be structurally stable, with evidence of only minor uplift or subsidence.

Three geomorphic features that coincide with the geographic limits of lithostratigraphic units are described, the Pelham Escarpment, Orangeburg Escarpment, and Sea Island Escarpment (new name).

Twelve marine terraces are described and their relationships with the underlying lithostratigraphic units are discussed. Two marine terraces are reintroduced: the Claxton and Hazlehurst terraces of Cooke (1925). Three marine terraces are new: the Waycross, Argyle, and Pearson terraces; and three terraces are redefined: the "Talbot", "Wicomico", and Okefenokee terraces.

ACKNOWLEDGMENTS

Stratigraphic work that culminated in this report was initiated in 1972. During the past 15 years, many geologists on the staff of the Georgia Geological Survey have contributed to the results of this project. Mr. S.M. Pickering, Jr., former State Geologist of Georgia, encouraged and supported the early phases of this project. Dr. W.H. McLemore, State Geologist of Georgia, has continued in the encouragement and support of this project to its completion. I wish to express thanks to Mr. C.W. Hendry, former State Geologist of Florida, for sharing the resources of the Florida Geological Survey, and to Dr. T.M. Scott of the Florida Geological Survey for his time in discussion and his company in the field. I also wish to acknowledge the cooperation of the staff of the South Carolina Geological Survey, and especially of Mr. Paul Nystrom, Jr. Special thanks are extended to Mr. Gerald S. Grainger of Southern Services, Inc. for providing access to cores of Georgia Power Company. I acknowledge as well the generosity, cooperation, and assistance of Mr. H.E. Gill of the Georgia District of the United States Geological Survey. Dr. V.J. Henry of Georgia State University has assisted and cooperated with the author for many years on Plio-Pleistocene stratigraphic problems in the coastal area of Georgia. Ms. M.E. Hunter and the late Mr. J.E. Banks were most generous with their time spent in discussion of Miocene paleontological data and stratigraphy of the north Florida-south Georgia area.

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INTRODUCTION

More than forty years have passed since Cooke (1943) presented the last comprehensive compilation of the stratigraphic units of the Coastal Plain (Fig. 1) of Georgia. That work represented the culmination of the efforts of many early investigators, including W.H. Dall, G.D. Harris, T.W. Vaughan, E. Sloan, J.O. Veatch, L.D. Stephenson, H.K. Shearer, C.W. Cooke, and J. Gardner. "The Geology of the Coastal Plain of Georgia" of Cooke (1943) also represents the culmination of a point of view of stratigraphic terminology that differs from that of the late twentieth century. Prior to the publication of the "Classification and nomenclature of rock units" (Committee on stratigraphic nomenclature, 1933), there had been no codification of stratigraphic terminology in North America, although policy was established in the U.S. Geological Survey as early as 1903 (United States Geological Survey, 1903). In the Coastal Plain of the southeastern United States, during the first half of the twentieth century, lithostratigraphic units, and formations in particular, were not based as much on lithologic content, as on stratigraphic association, stratigraphic position, and fossil content (United States Geological Survey, 1903; Grabau, 1924; Committee on stratigraphic nomenclature, 1933; 1939). Geologic time, therefore, was inherent in the concept of lithostratigraphic units. As a result of this looser usage of lithostratigraphic units and the lack of a codification of stratigraphic terminology, lithostratigraphic units in the first half of the twentieth century were variable in concept and application. Stratigraphic terminology was treated differently by different authors and there was a lack of uniformity in treatment of lithostratigraphic units.

The stratigraphic codes of 1961 and 1970 (American Commission on Stratigraphic Nomenclature, 1961; 1970), however, required that **only** lithology, "observable physical features", be used as the criterion on which to base lithostratigraphic definition and recognition.[1] As a result of these two codes and their gradual acceptance by geologists, there has been a reorientation in approach to lithostratigraphic terminology, and the adoption of a more consistent stratigraphic usage. For example, the old concept of the "Hawthorn formation" of Cooke (1943) was based on type of fauna, age implications of the fauna, and gross lithology (Cooke and Mossom, 1929; Cooke, 1936, 1943, 1945; Puri and Vernon, 1964). As a result of the preoccupation by geologists with fauna and age of formations, the "Hawthorn perhaps is the most misunderstood formational unit in the southeastern United States. It has been a dumping ground for alluvial, terrestrial, marine, deltaic, and pro-deltaic beds of diverse lithologic units in Florida and Georgia ...." (Puri and Vernon, 1964, p. 145). Lithologically the concept of the Hawthorne in the past has consisted of relatively pure carbonates(limestone and dolostone in southern Florida), phosphatic sands and clays that may or may not be calcareous or dolomitic, phosphatic clays and fuller's earth, and cross-bedded sands and gravels of fluvial origin. It has been possible, in this report, to conform to the stratigraphic codes of 1961, 1970, and 1983 and to subdivide the Hawthorne Formation of earlier authors into five named formations and one unnamed formation.

The use of well-cuttings (Herrick, 1961; Herrick and Vorhis, 1963; Applin and Applin, 1944, 1964) for recognition of stratigraphic units and for stratigraphic correlation has resulted in the construction of the subsurface stratigraphic framework of Georgia. Prettyman and Cave (1923) presented the first study of subsurface deposits based on well-cuttings, but full use of these materials was not made until Cushman (from approximately 1917 through 1951) had developed the taxonomy and shown the biostratigraphic utility of the smaller foraminifera. Applin and Applin (1944, 1947, 1964, 1967), Applin and Jordan (1945), E.R. Applin (1955), P.L. Applin (1952), Herrick (1961) and Herrick and Vorhis (1963) made invaluable contributions to the understanding of the stratigraphic framework of the Georgia Coastal Plain and, as a result of these contributions, the chronostratigraphic framework of the deeper subsurface of the Georgia Coastal Plain has been largely elucidated.

Since the middle 1960's, the availability of cores has added a large amount of stratigraphic information to our knowledge of the shallow subsurface, allowing lithostratigraphic recognition and correlation not normally possible in Georgia from scattered outcrop sections alone. For the present revision, seventy-eight cores (Figs. 2, 3, and 4) were examined, and all were at least partially logged and described. Sixty-three of the cores are from Georgia (Figs. 2 and 3), fourteen are from northern Florida (Fig. 4), and one is from southern South Carolina (Fig. 3).

Similarly, in recent years, employing more groups of microfossils for the solution of stratigraphic problems has contributed greatly to the biostratigraphic and chronostratigraphic delineation of the Georgia Coastal Plain deposits. During the first four decades of this century, only macrofossils (mollusks, echinoids, corals, vertebrates) had been employed in the biostratigraphic subdivision of Coastal Plain deposits. After the 1930's, however, various microfossil groups, including the smaller benthic foraminifera, ostracodes, palynomorphs, diatoms, radiolarians, planktonic foraminifera, nannofossils, and dinoflagellates were also employed.

It is now possible to further refine the stratigraphic framework of the Georgia Coastal Plain because of the more precise and refined stratigraphic codes available to modern stratigraphers; the greater wealth of Coastal Plain well cuttings; electric logs, and cores; and the larger assortment of paleontological tools with which to subdivide the

[1]In the 1983 code the concept of stratigraphic position has been reintroduced into the concept of lithostratigraphic units.

Figure 1. Location map of the Georgia Coastal Plain.

Explanation of Symbols on Figure 2

Type Localities and Principal Reference Localities

A ..... Dogtown Member of the Torreya Formation; LaCamellia fuller's earth mine Gadsden County, Florida

B ..... Charlton Member of the Coosawhatchie Formation; Stokes Bridge on St. Marys River Nassau County, Florida

C ..... Meigs Member of the Coosawhatchie Formation; Thomas County, Georgia

D ..... Statenville Formation; Alapaha River Echols County, Georgia

E ..... Altamaha Formation; Upper Sister Bluff on the Altamaha River, Appling County, Georgia

F ..... Screven Member of the Altamaha Formation; Wayne County, Georgia

G ..... Cypresshead Formation; Wayne County, Georgia

H ..... Satilla Formation; Satilla Bluff on the Satilla River, Camden County, Georgia

Reference Localities

a ...... Ebenezer Member of the Coosawhatchie Formation; core Wayne 2 (GGS-3512), Wayne County, Georgia

b ...... Charlton Member of the Coosawhatchie Formation; core Charlton 2 (GGS-3185), Charlton County, Georgia

c ...... Statenville Formation; Alapahoochee River, Echols County, Georgia, and Hamilton County, Florida

d ...... Altamaha Formation; Lower Sister Bluff, Altamaha River, Appling County, Georgia

e ...... Altamaha Formation; Lower Fort James Bluff, Altamaha River, Wayne County, Georgia

f ...... Altamaha Formation; bluffs on the Oconee River at highway Ga. 46 crossing, Wheeler County, Georgia

g ...... Altamaha Formation; Berryhill Bluff on the Oconee River, Treutlen County, Georgia

h ...... Screven Member of the Altamaha Formation; road cut on highway US 84, Wayne County, Georgia

i ...... Screven Member of the Altamaha Formation; Upper Sister Bluff on the Altamaha River, Appling County, Georgia

j ...... Cypresshead Formation; Linden Bluff on the Altamaha River, Wayne County, Georgia

k ...... Cypresshead Formation; road cut on highway US 301 at Trudie, Brantley County, Georgia

l ...... Satilla Formation; Roses and Bells Bluffs on Bells River, Nassau County, Florida

m ..... Satilla Formation; Reids Bluff on St. Marys River, Nassau County, Florida

n ...... Satilla Formation; Crooked River State Park, Camden County, Georgia

Core Sites and Well Sites*

1 ...... Wayne 1; Wayne County, Georgia**

a ...... Wayne 2 (GGS-3512); Wayne County, Georgia

2 ...... Wayne 3; Wayne County, Georgia

3 ...... Wayne 4; Wayne County, Georgia

b ...... Charlton 2 (GGS-3185); Charlton County, Georgia

4 ...... Cumberland Island 1 (GGS-3426); Camden County, Georgia

5 ...... Coffee 3 and 4 (GGS-3539 and 3541); Coffee County, Georgia

6 ...... Berrien 10 (GGS-3542); Berrien County, Georgia

7 ...... Colquitt 3 (GGS-3179); Colquitt County, Georgia

8 ...... Colquitt 5 and 9 (GGS-3199 and 3535); Colquitt County, Georgia

9 ...... Colquitt 10 (GGS-3544); Colquitt County, Georgia

10 ..... well cuttings (GGS-600); Montgomery County, Georgia

11 ..... Washington 8 (GGS-1178); Washington County, Georgia

12 ..... Washington 10 (GGS-1182); Washington County, Georgia

13 ..... Washington 17 (GGS-1189); Washington County, Georgia

14 ..... AMCOR 6002; continental shelf

15 ..... COST GE 1; continental shelf

16 ..... JOIDES J-1; continental shelf

17 ..... JOIDES J-2; continental shelf

*Cores and well-cuttings are available for examination at the Georgia Geologic Survey in Atlanta, Georgia.

**Core has been destroyed.

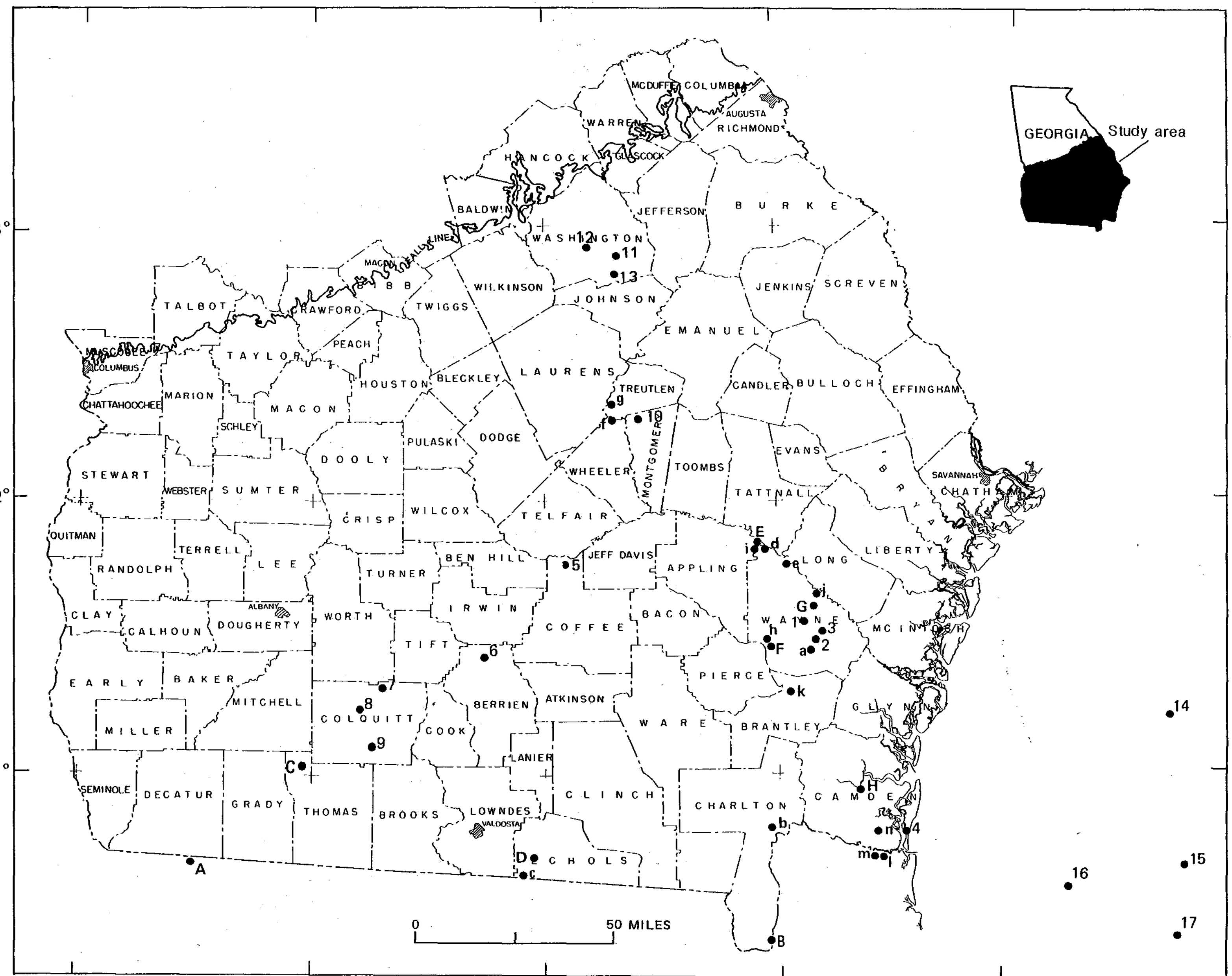


Figure 2. Location map of type localities, reference localities, core sites, and well sites in the Coastal Plain and continental shelf of Georgia exclusive of the Savannah River area.

Explanation of Symbols on Figure 3

Type Localities and Principal Reference Localities

I ...... Parachucla Formation; Porters Landing on the Savannah River, Effingham County, Georgia

I ...... Porters Landing Member of the Parachucla Formation; Porters Landing on the Savannah River, Effingham County, Georgia

J ...... Tiger Leap Member of the Parachucla Formation; Tiger Leap Bluff on the Savannah River, Screven County, Georgia

K ..... Marks Head Formation; Marks Head Run, Effingham County, Georgia

L ..... Berryville Clay Member of the Coosawhatchie Formation; Effingham County, Georgia

M ..... Ebenezer Member of the Coosawhatchie Formation; Ebenezer Landing on the Savannah River, Effingham County, Georgia

N ..... Tybee Phosphorite Member of the Coosawhatchie Formation; core Chatham 10 (GGS-1394), Tybee Island, Chatham County, Georgia

Reference Localities

o ...... Parachucla Formation; core Effingham 10 (GGS-3108), Effingham County, Georgia

o ...... Tiger Leap Member of the Parachucla Formation; core Effingham 10 (GGS-3108), Effingham County, Georgia

p ...... Coosawhatchie Formation of eastern Georgia; Savannah River, Effingham County, Georgia

q ...... Berryville Clay member of the Coosawhatchie Formation; core Effingham 14 (GGS-3155), Effingham County, Georgia

q ...... Ebenezer Member of the Coosawhatchie Formation; core Effingham 14 (GGS-3155), Effingham County, Georgia

r ...... Tybee Phosphorite Member of the Coosawhatchie Formation; core Chatham 3 (GGS-1341), Chatham County, Georgia

s ...... Cypresshead Formation; railroad cut at Birds, Effingham County, Georgia

Core Sites and Well Sites

18 ..... Screven 1 (GGS-1170); Screven County, Georgia

19 ..... Screven 4 (GGS-1007); Screven County, Georgia

20 ..... Screven 8 (GGS-3198); Screven County, Georgia

21 ..... Georgia Power Company cores B3**, B21**, B22**; Screven County, Georgia

22 ..... Effingham 3 (GGS-2175); Effingham County, Georgia

o ...... Effingham 10 (GGS-3108); Effingham County, Georgia

23 ..... Effingham 11 (GGS-3109); Effingham County, Georgia

24 ..... Effingham 12 (GGS-3110); Effingham County, Georgia

25 ..... Effingham 13 (GGS-3140); Effingham County, Georgia

q ...... Effingham 14 (GGS-3155); Effingham County, Georgia

26 ..... Effingham 6 (GGS-2179) and Georgia Power Company core B40**; Effingham County, Georgia

27 ..... Georgia Power Company core B41**; Effingham County, Georgia

28 ..... Chatham 1 (GGS-1164); Chatham County, Georgia

r ...... Chatham 3 (GGS-1341); Chatham County, Georgia

N ..... Chatham 10 (GGS-1394); Chatham County, Georgia

29 ..... Chatham 13 (GGS-1445); Chatham County, Georgia

30 ..... Chatham 14 (GGS-3139); Chatham County, Georgia

31 ..... Chatham 15 (GGS-3138); Chatham County, Georgia

32 ..... Chatham 17 (GGS-3554); Chatham County, Georgia

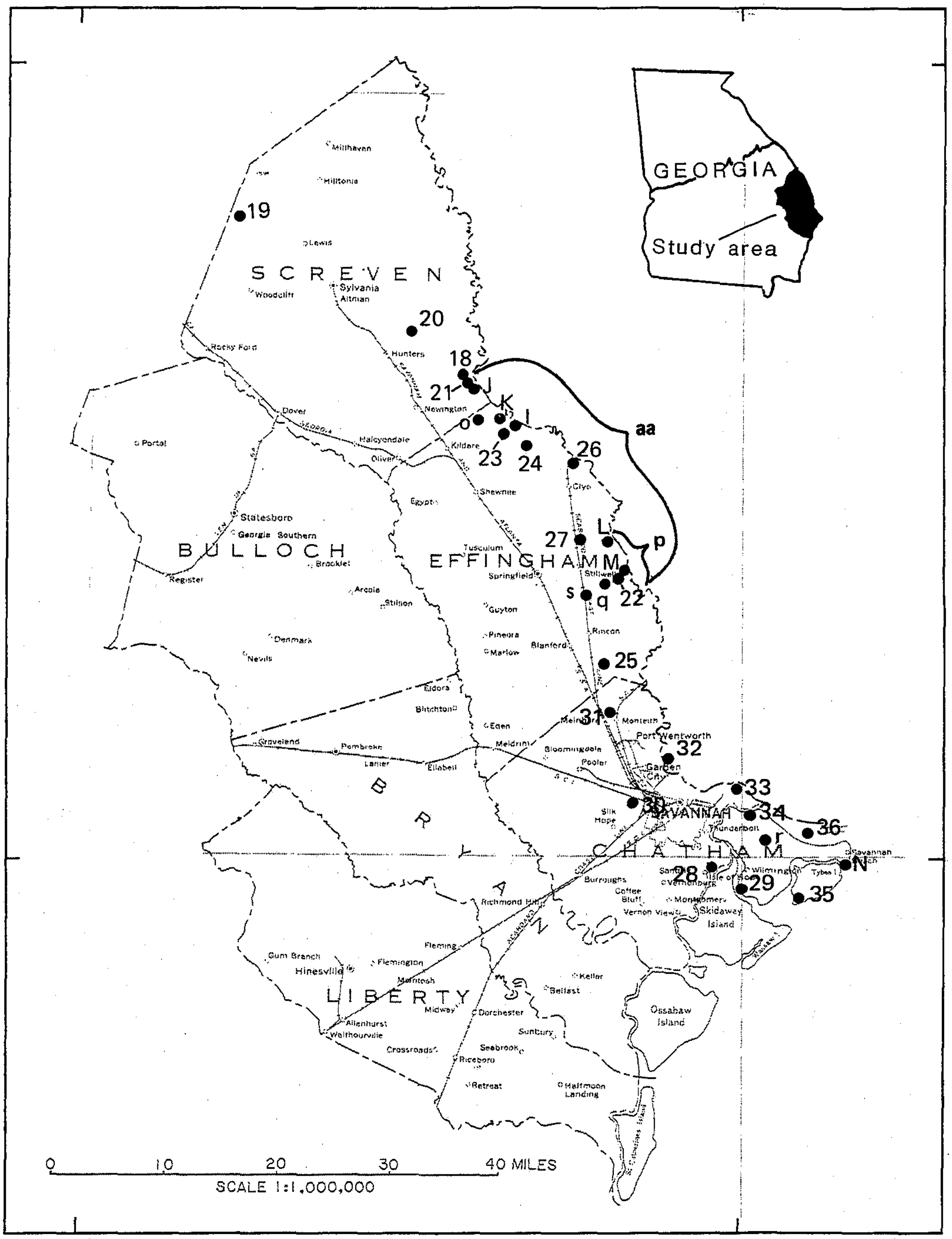
33 ..... cores from Elba Island in the Savannah River, B13**, B25**, B30**; Chatham County, Georgia

34 ..... core, U.S. Geological Survey Test Well 6; Chatham County, Georgia

35 ..... Petit Chou 1; Chatham County, Georgia

36 ..... well-cuttings, GGS-772 and GGS-381; Chatham County, Georgia

**Cores have been destroyed



Base from U.S. Geological Survey
State base map, 1:1,000,000

Figure 3. Location map of type localities, reference localities, core sites, and well sites in the Savannah River area of the Coastal Plain of Georgia.

Explanation of Symbols on Figure 4

Type Localities and Principal Reference Localities

O ..... Chattahoochee Formation; Gadsden County, Florida

P ..... Hawthorne Group, Alachua County, Florida

Q ..... Torreya Formation; Rock Bluff on the Appalachicola River, Liberty County, Florida

R ..... Sopchoppy Member of the Torreya Formation; Wakulla County, Florida

A ..... Dogtown Clay Member of the Torreya Formation; LaCamellia fuller's earth mine, Gadsden County, Florida

B ..... Charlton Member of the Coosawhatchie Formation; Stokes Bridge on St. Marys River, Nassau County, Florida

S ...... Miccosukee Formation; Jefferson County, Florida

T ..... Nashua Formation; St. Johns River, Putnam County, Florida

U ..... Alum Bluff Group; Alum Bluff, Liberty County, Florida

Reference Localities

t ...... Hawthorne Group; Devil's Millhopper, Alachua County, Florida

t ...... Hawthorne Group; Millhopper 1 (W-14641) core, Alachua County, Florida

u ...... Hawthorne Group; Brooks Sink, Bradford County, Florida

v ...... Hawthorne Group; Varnes 1 (W-14280) core, Bradford County, Florida

w ..... Hawthorne Group; Suwannee River at White Springs, Hamilton and Columbia Counties, Florida

c ...... Statenville Formation; Alapahoochee River, Echols County, Georgia and Hamilton County, Florida

x ...... Statenville Formation; Suwannee River near Cones Bridge, Hamilton and Columbia Counties, Florida

y ...... Statenville Formation; Betty 1 (W-15121) core, Jennings, Hamilton County, Florida

z ...... Miccosukee Formation; Green 1 (W-6937) core, Leon County, Florida

l ...... Satilla Formation; Roses and Bells Bluffs on Bells River, Nassau County, Florida

m ..... Satilla Formation; Reids Bluff on St. Marys River, Nassau County, Florida

Core Sites*

P ..... Hawthorne 1 (W-11486); Alachua County, Florida

37 ..... Wall 1 (W-7457); Liberty County, Florida

38 ..... Wall 2 (W-7458), Gadsden County, Florida

39 ..... Suber 1 (W-7539); Gadsden County, Florida

40 ..... Owenby 1 (W-7472); Gadsden County, Florida

41 ..... Gregory 1 (W-7528); Gadsden County, Florida

z ...... Green 1 (W-6937); Leon County, Florida

42 ..... Ashville 1 (W-6561); Jefferson County, Florida

y ...... Betty 1 (W-15121); Hamilton County, Florida

t ...... Millhopper 1 (W-14641); Alachua County, Florida

v ...... Varnes 1 (W-14280); Bradford County, Florida

43 ..... Trail Ridge 3 (W-10473); Baker County, Florida

44 ..... Cassidy 1 (W-13815); Nassau County, Florida

45 ..... National Lead 1 (W-12360); Bradford County, Florida

46 ..... Baywood 1 (W-8400); Putnam County, Florida

*Cores are available for examination at the Florida Geological Survey in Tallahassee, Florida

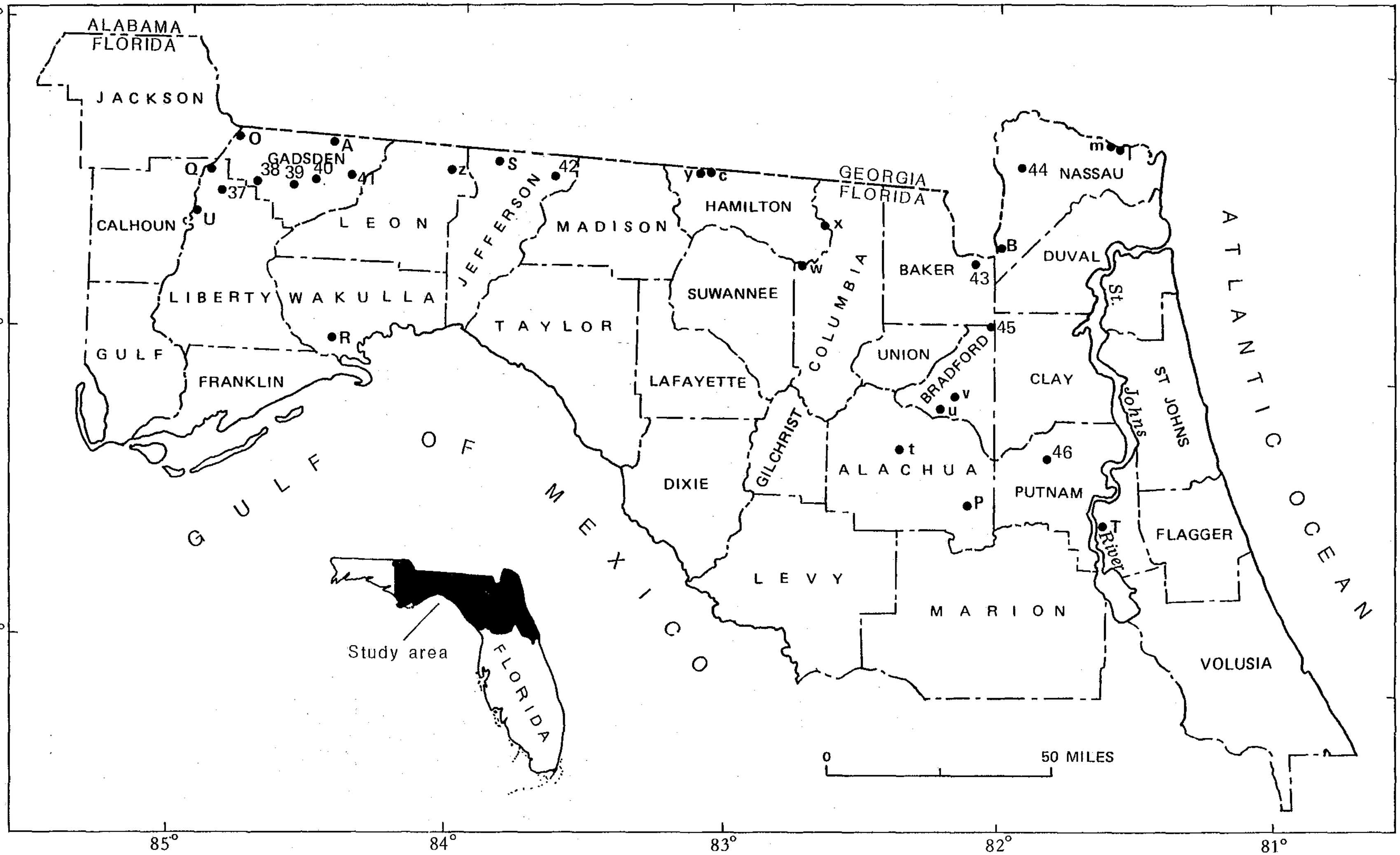


Figure 4. Location map of type localities, reference localities, and core sites in north Florida.

sections biostratigraphically and chronostratigraphically and to establish correlation. Twenty-four formally defined Neogene lithostratigraphic units are described in this report. These include one group, thirteen formations, and ten members. Two unnamed formations are described where there is sufficient information to indicate the presence of a formation, but not sufficient information formally to propose a new formation. In addition, an informal unit, known as the Wabasso beds, is recognized, and three kinds of undifferentiated deposits and three undifferentiated stratigraphic units are described. Two named formations are new: the Cypresshead and Statenville Formations. Five named formations that had been abandoned in the past are reintroduced in this report: the Parachucla, Marks Head, Altamaha, Nashua, and Satilla Formations. One previously informal member, the Coosawhatchie Formation, is raised to formation rank, and one formation is raised to group rank, the Hawthorne Group. Seven named members are new: the Tybee Phosphorite, Berryville Clay, Ebenezer, and Meigs Members of the Coosawhatchie Formation; the Porters Landing and Tiger Leap Members of the Parachucla Formation; and the Screven Member of the Altamaha Formation. One unit previously of formation rank has been lowered to the rank of member, the Charlton Member of the Coosawhatchie Formation.

Standard field and laboratory procedures were followed throughout the investigation that led to this report. In field descriptions, the terminology of Ingram (1954) is used for bedding thickness, the Wentworth (1922) scale for grain size, and the Munsell Color System for describing sediment or rock colors (Rock-Color Chart Committee, 1963). Field approximations for describing degrees of sand sorting are employed in this report.

THE MIOCENE TO HOLOCENE STRUCTURAL FRAMEWORK OF GEORGIA

The Georgia Coastal Plain (Fig. 1) is a relatively stable segment of the Atlantic Coastal Plain of eastern North America. The presence of relatively thick Miocene deposits (200-600 feet) of coastal to inner continental shelf origin (i.e., sediments deposited at or immediately below the sea level of their time) over most of the Georgia Coastal Plain indicates that there was minor subsidence and deposition to non-subsidence and non-deposition with minor subsequent erosion during the period of geologic time covered in this report. Subsidence and sediment accumulation, however, were periodic in that some intervals of geologic time are well-represented in the geologic column of the Coastal Plain, whereas sediments of other periods of time are uniformly absent, or have not been detected and identified (compare with Pl. 1). According to this model, subsidence and sediment accumulation in the Georgia Coastal Plain occurred during the early to middle Aquitanian, early to middle Burdigalian, and early Serravallian (see Pl. 1). During Pliocene, Pleistocene, and Holocene times, there is evidence of subsidence and minor sediment accumulation only in the coastal region. For the Pliocene, this region includes both the present Atlantic coastal area east of the vicinity of the Orangeburg Escarpment and Trail Ridge, and also the southern tier of counties in southwestern Georgia. During the late Pleistocene and Holocene, there appears to have been slight subsidence, if any, only in the coastal counties of eastern Georgia and on the continental shelf.

There is evidence of minor tectonic uplift in the Coastal Plain only in western Georgia. Coastal marine deposits believed to be mainly of late Pliocene age (Miccosukee Formation) occur at relatively high elevations (i.e., above 300 feet [91 m] above sea level) along the Pelham Escarpment near Pelham in Mitchell County, Georgia. Although Miocene deposits occur at elevations of more than 500 feet (152 m) above sea level immediately south of the Fall Line Hills in Georgia, these deposits are fluvial in origin (Altamaha Formation) and could have been deposited originally at relatively high elevations (above the contemporary sea level). Excluding the vicinity of Pelham, Georgia, where uplift can be inferred, all Miocene marine deposits of continental shelf origin (Hawthorne Group, Chattahoochee and Cooper Formations) generally occur at elevations of less than 200 feet (61 m) above modern sea level. As a result, over most of the Georgia Coastal Plain, uplift cannot be inferred from the present elevations of the deposits of marine origin.

The structural setting of the Georgia Coastal Plain was relatively simple during Late Tertiary time in Georgia. Four large-scale structural elements influenced sedimentation patterns and, therefore, the stratigraphy: (1) the Southeast Georgia Embayment, (2) the Gulf Trough-Apalachicola Embayment, (3) the Piedmont Slope, and (4) the Florida Platform (Fig. 5). Two structural elements, the Beaufort Arch and the Ridgeland Trough, are small-scale structures and appear to have had little or no influence on contemporary regional sedimentation patterns. These various structural elements of the Georgia Coastal Plain will be discussed in order.

Southeast Georgia Embayment

The Southeast Georgia Embayment (Fig. 5) (Toulmin, 1955, p. 29), also referred to as the Okefenokee Embayment of the Atlantic Basin (Pressler, 1947; Applin and Applin, 1967), the Savannah Basin (Murray, 1961), the Atlantic Embayment of Georgia (Herrick and Vorhis, 1963), and the Atlantic Embayment (Weaver and Beck, 1977), is a shallow, broad embayment or basin in the Coastal Plain of eastern Georgia (Fig. 5). The Southeast Georgia Embayment appears to have subsided relative to the surrounding regions (Cape Fear Arch in North Carolina, Piedmont Slope, Central Georgia Uplift of Pressler [1947], Suwannee Saddle of

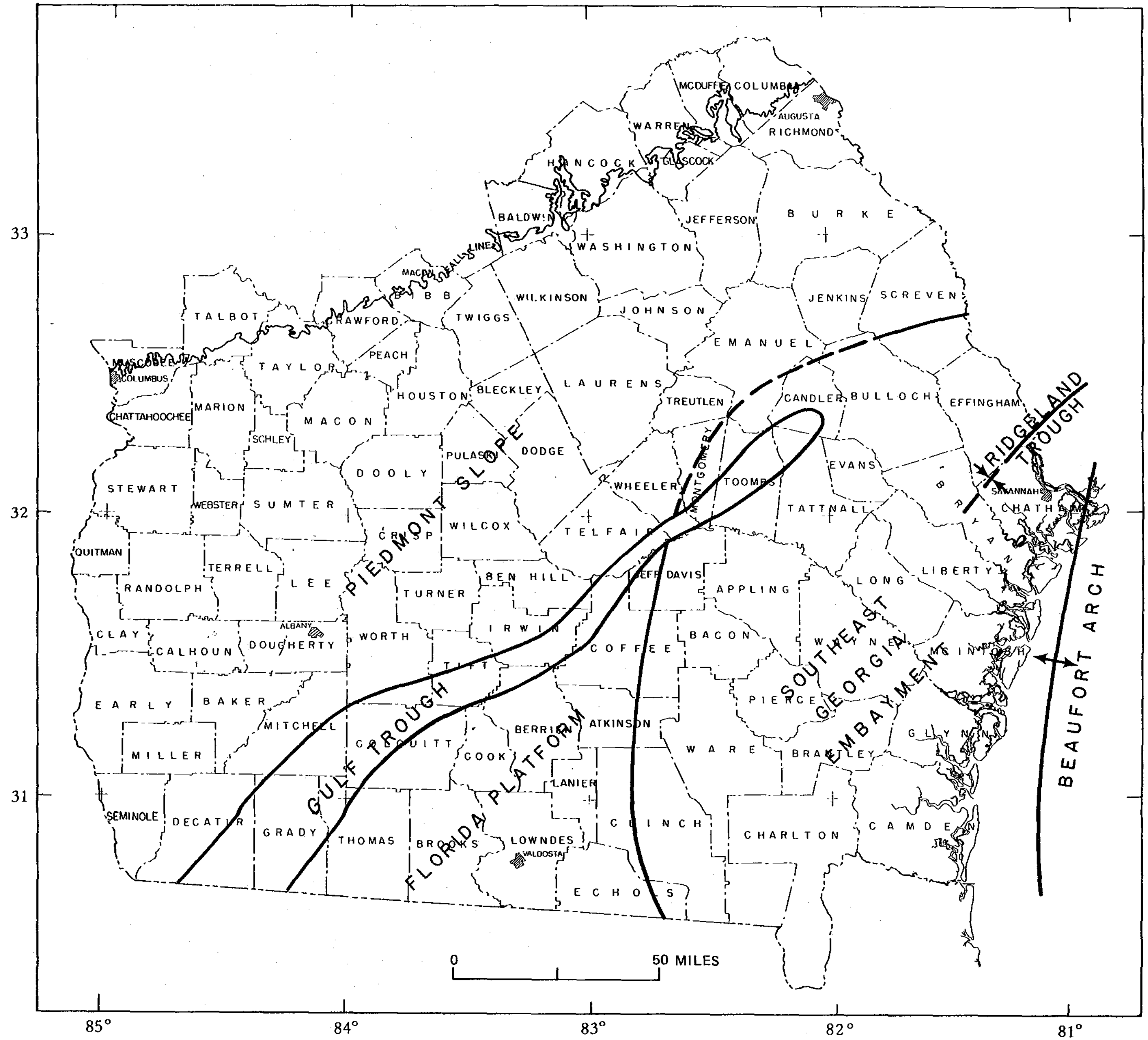


Figure 5. Major Upper Tertiary structural features of Georgia.

Applin and Applin [1967], Ocala Platform in Georgia and Florida, and the Peninsular Arch [Applin, 1951] and Sanford High [Vernon, 1951] in Florida). Subsidence appears to have been episodic within the Southeast Georgia Embayment. Deposits of some periods are exceptionally thick (e.g., the Miocene), whereas deposits of other periods show no evidence of differential thickening across the embayment (e.g., the Plio-Pleistocene) (compare with Herrick and Vorhis, 1963; Applin and Applin, 1967; Vorhis, 1974; Cramer and Arden, 1980). Based on the above studies, it also appears that the Southeast Georgia Embayment configuration, the position and configuration of depocenters, and the volumes of sediment accumulation varied considerably over time.

For the Miocene in Georgia, the inner limits of the Southeast Georgia Embayment are the foot of the Piedmont slope and the Ocala Arch (Fig. 5). The inner limits of the embayment can be approximated as extending from the vicinity of Beaufort, South Carolina (Straley and Richards, 1950; Straley, 1955), westward through Screven and Emanuel Counties, Georgia, thence southwestward through the lower Oconee and Ocmulgee Rivers area, and finally southward through Coffee, Atkinson, Clinch, and Echols Counties (Fig. 5). The Southeast Georgia Embayment also extends into northeastern Florida where it, or a segment of it, has been called the Jacksonville Basin (Goodell and Yon, 1960; Scott, in press).

Gulf Trough-Apalachicola Embayment

The Gulf Trough-Apalachicola Embayment is a northeast-southwest trending linear structure in southern Georgia and the eastern panhandle of Florida (Fig. 5). Although the Gulf Trough (Herrick and Vorhis, 1963, p. 55; Hendry and Sproul, 1966; Sever and others, 1967; Patterson and Herrick, 1971; Weaver and Beck, 1977; Zimmerman, 1977; Gelbaum, 1978; Gelbaum and Howell, 1982: Miller, 1982) and the Apalachicola Embayment (Pressler, 1947, p. 1853, 1856, fig. 1; Toulmin, 1955; Hendry and Sproul, 1966; Patterson and Herrick, 1971; Schmidt and Clark, 1980; Schmidt, 1984) generally have been treated separately in the past and have been given separate names, they are treated as one geologic feature in this report (also see Patterson and Herrick, 1971). The Gulf Trough and Apalachicola Embayment have common northwestern and southeastern margins, and they have common stratigraphic and structural characteristics. The only distinction known to this author between the Gulf Trough and the Apalachicola Embayment is the width of the structure. Near the coast in western Florida, the Apalachicola Embayment is wide, extending from westernmost Wakulla County in the east to Bay County in the west, a linear distance of approximately 90 miles (145 km) (also see Schmidt and Clark, 1980; Schmidt, 1984). The width of the structure diminishes northeastward and is approximately 35 miles (56 km) across near the Georgia-Florida state line; approximately 15 miles (24 km) across in Colquitt County, Georgia, between 10 and 15 miles (16 and 24 km) across in Berrien County, and approximately 5 miles (8 km) across in northern Coffee County (compare with Gelbaum and Howell, 1982). As applied in the past, the Gulf Trough is that component of the structure that is approximately 20 miles (32 km) across or less, and is largely confined to Georgia. The Apalachicola Embayment is that part of the structure that broadens to the southwest and has been confined to Florida.

The Gulf Trough-Apalachicola Embayment is bounded on the east by the Florida Platform but trends into the western part of the Southeast Georgia Embayment in eastern Georgia (Fig. 5). In southwestern Georgia, the Gulf Trough-Apalachicola Embayment is bounded on the west by the Piedmont Slope, and in Florida it is bounded on the northwest by the Chattahoochee Arch (Schmidt and Clark, 1980; Huddlestun, 1984).

The Gulf Trough-Apalachicola Embayment is characterized by unusual thicknesses of deposits within the structure, compared with the correlative deposits on the flanks and adjacent to the structure, and by an apparent different and unique stratigraphy. Exceptionally thick Miocene and Oligocene deposits have been reported from the trough-embayment by Moore (1955), Applin (1960), Herrick, and Vorhis (1963), Owen (1963b), Sever (1964, 1966b), Gremillion (1965), Sever and Herrick (1967), Patterson and Herrick (1971), Weaver and Beck (1977), Zimmerman (1977), Gelbaum (1978), Gelbaum and Howell (1982), Schmidt (1984), and McFadden and others (1986) indicating that the trough-embayment was a localized depocenter during at least parts of the Oligocene and Miocene. Although the information on the lithostratigraphy of the Gulf Trough-Apalachicola Embayment is still incomplete, lithostratigraphic anomalies are indicated. Both the type areas of the pre-Miocene Tallahassee limestone of Applin and Applin (1944) and the Gadsden limestone of Moore (1955) are from within the Gulf Trough-Apalachicola Embayment in Gadsden County, Florida. The lithology of the two units — fine grained, calcarenitic limestone with common smaller benthic foraminifera (Moore, 1955, p. 71-80; also see Applin and Applin, 1944, p. 1688) — is distinct from the presumably correlative units adjacent to the trough-embayment, and the two units (notwithstanding the use of the name Tallahassee limestone by Applin and Applin, 1944) are not found outside of the trough-embayment. Similarly, the lithologies of the Oligocene carbonates within the Gulf Trough referred to by Sever and Herrick (1967) and Zimmerman (1977) as Marianna Limestone are not characteristic of that formation. These Gulf Trough carbonate deposits are not, lithostratigraphically, the same as the Oligocene carbonate units adjacent to the trough, and they apparently constitute a distinct and separate formation. The Miocene fuller's earth deposits of southwestern Georgia and Gadsden County, Florida, also are restricted to the Gulf Trough-Apalachicola Embayment, and the Meigs Member of the Coosawhatchie Formation (new name) is known to occur only in the trough or on its northern flanks. Contrary to earlier reports (Herrick, 1961; Herrick and Vorhis, 1963; Gelbaum and Howell, 1982), but consistent with the observation of Moore (1955) and Zimmerman (1977), there is no Ocala lithostratigraphic unit or Ocala lithology within the Gulf Trough-Apalachicola Embayment.

There has been considerable controversy on the origin of the Gulf Trough-Apalachicola Embayment (Patterson and Herrick, 1971). The two most widely held views on the origin of the trough-embayment are (1) that it is tectonic in origin and is bounded by faults (and is, therefore, a graben or half-graben structure) (Moore, 1955; Sever, 1962, 1966a, 1966b; Gremillion, 1965; Hendry and Sproul, 1966; Tanner, 1966; Cramer and Arden, 1980; Gelbaum and Howell, 1982; Miller, 1982), or (2) that it is sedimentary in origin (Chen, 1965; Zimmerman, 1977). As observed by Patterson and Herrick (1971, p. 13), "none of the reports in which faults outlined above were proposed present adequate supporting evidence. Insofar as the authors of this article are aware, most of these faults are hypothetical". The above observation also holds for subsequent reports where the Gulf Trough is interpreted as being a fault-bounded structure (Cramer and Arden, 1980; Gelbaum and Howell, 1982; Miller, 1982). To date, all geologic models of the fault-bounded Gulf Trough-Apalachicola Embayment are based on the premise that abrupt thickening or thinning of deposits, especially accompanied by lithofacies change, can best be explained by faulting.

In contrast, the model preferred by Chen (1965) and Zimmerman (1977) is that an ocean current, analogous to the present Gulf Stream, scoured and eroded the seafloor under the current, thus producing a topographic trough or channel. I consider the current model of Chen (1965) and Zimmerman (1977) for the origin of the Gulf Trough-Apalachicola Embayment, the more likely of the two models. Isopach maps and structural contour maps presented by Herrick and Vorhis (1963) and Applin and Applin (1967) show no indication of anomalous thickness distributions or structural irregularities on the upper surfaces of Upper Cretaceous and Paleocene-lower Eocene units in the Gulf Trough-Apalachicola Embayment area. The spacing of the control points (wells) is sufficiently close so that fault displacements of several hundred feet or more (more than 100 m) should be evident on the maps. The top of the Cretaceous especially should be relatively easy to identify, and thickness and contouring anomalies should be most apparent and easily detected on that datum. Yet, neither Herrick and Vorhis (1963) nor Applin and Applin (1967) show any indication of systematic irregularities. As a consequence, this author concludes that there is evidence that the top of the Cretaceous and probably Paleocene and lower Eocene deposits have not been displaced in the Gulf Trough-Apalachicola Embayment. Therefore, it would be unlikely, under the above constraints, that the stratigraphic anomalies in the overlying Eocene through Miocene deposits would have originated through faulting.

Because there appear to be no structural or stratigraphic anomalies associated with the Gulf Trough-Apalachicola Embayment earlier than the Eocene (certainly none is associated with the Upper Cretaceous deposits [see Applin and Applin, 1967]), the time span of the Gulf Trough Apalachicola Embayment is considered in this report to be confined to the interval from the middle Eocene into the middle Miocene. An older Triassic through Cretaceous structural feature, centered in the Apalachicola River area of Florida and generally referred to under the same name as the younger Tertiary Apalachicola Embayment (Murray, 1961; Applegate and others, 1978; Gray, 1978), is considered in this report to be a separate and independent geologic feature. This Mesozoic structure, referred to as the Chattahoochee Embayment by Cramer and Arden (1980) (also Gray, 1978), is characterized by thick Triassic, Jurassic, and Lower Cretaceous deposits. Although this Mesozoic embayment is centered in the same area as the younger Apalachicola Embayment, the older structure is much larger, contains a much thicker section, and includes all of southwestern Georgia (see Gray, 1978).

Piedmont Slope

The Piedmont Slope (from Cramer and Arden, 1980, fig. 3) is a loosely defined segment of the Coastal Plain in Georgia characterized by a structurally simple wedge of Coastal Plain sediments over a consistently southward to southeastward dipping basement (Fig. 5). The northern limit of the Piedmont Slope is the Fall Line. The downdip or southern margin of the Piedmont Slope is a poorly defined area that approximates a change, or reduction, in the rate of dip of the basement, that is, a slight flattening out of the slope of the basement. This slope change is irregular but generally occurs along a trend from the southwestern corner of Georgia (the vicinity of Seminole and Decatur Counties), northeastward through Screven County (compare with Herrick and Vorhis, 1963, figs. 3, 6, 10, 14, 16, 18), and is close to and parallel with the trend of the Gulf Trough-Apalachicola Embayment. The Piedmont slope merges into the Southeast Georgia embayment in the east, the Gulf Trough-Apalachicola Embayment and, based on Gray (1978) and Cramer and Arden (1980), into the older Chattahoochee Embayment in the central and southwestern Coastal Plain.

Ocala Arch

The name Ocala Uplift (Hopkins, 1920; Gunter, 1921, p. 18-19; Cooke, 1945, p. 5-6; Vernon, 1951, p. 54-56; Puri and Vernon, 1964; and Hendry and Sproul, 1966) has been used interchangeably with the name Ocala Arch (Murray, 1963) in the past. I prefer the word "arch" to "uplift" in describing the structure because it cannot be clearly demonstrated that any part of the structure has undergone tectonic uplift at any time in its history. In order to show that there has been tectonic uplift of the platform, marine deposits on the arch would have to occur at elevations significantly above that at which sea level would stand today if there were no significant glacial ice (i.e., the deposit would probably be more than 300 feet [91 m] above present sea level). In all areas of the Ocala Arch in Georgia, all Miocene or older marine deposits in the geologic section occur below the elevation of 300 feet (91 m) above sea level. Therefore, uplift cannot be supported for the arch in Georgia. Similarly, in most areas of the Ocala Arch in Florida, the entire geologic section and reconstructed upper, presumably eroded, parts of the sections occur well below the elevation of 300 feet (91 m). Only at the present high part of the arch in Citrus and Levy Counties, Florida, could there be any possibility of tectonic uplift. There, middle Eocene carbonates are exposed at elevations of 25 feet (7.6 m) or less on the Pamlico terrace. Based on Vernon (1951, p. 118, 142, 158) the reconstructed maximum thickness for the Ocala Group in Citrus and Levy Counties is approximately 150 feet (46 m), and for the younger Suwannee Limestone, approximately 120 feet (37 m) (Vernon, 1951, p. 176). Although Vernon (1951) reported Hawthorne deposits in the Citrus-Levy County area, an average thickness of the Hawthorne in adjacent Alachua County may be construed to be approximately 100 feet (30 m) (Vernon, 1951, Fig. 33). In parts of Marion County, northwest of Ocala, an approximate average thickness near 50 feet (15 m) of lower Hawthorne sediments has been identified. Using the preceding estimated figures, one might assume that the reconstructed maximum thickness of upper Eocene through Miocene deposits in the Citrus-Levy County area could be approximately 450 feet (137 m). When added to the actual elevation of exposed middle Eocene beds in the area (25 feet or less), the upper elevation of this reconstructed section could stand at approximately 475 (145m) above sea level. Therefore, if the estimates of the thicknesses of the upper Eocene through Miocene deposits are accurate, and if all of these deposits covered the part of the Ocala Arch under Citrus and Levy Counties, then there could be evidence for minor uplift of no more than 175 feet (53 m). If, on the other hand, the thicknesses of the upper Eocene through Miocene deposits in Citrus and Levy Counties have been overestimated, or Miocene deposition never occurred in the area, then it can be argued that there is little or no evidence for uplift even in the structurally high areas of the Ocala Arch.

The Ocala Arch (Fig. 5) is a structurally stable arch that underlies the northern peninsula of Florida. Its northern limb extends into southern Georgia in Brooks and Lowndes Counties where it merges with normal continental margin structure. It trends southeastward into southern Florida. The Ocala Arch, as envisaged in this report, did not originate, for the most part, through uplift of the crest of the arch, but mainly through greater subsidence along the margins of the arch. The Ocala Arch is continuous with the Peninsular Arch of Applin (1951), and the Ocala Arch and Peninsular Arch constitute one structural entity (also see Murray, 1963, p. 98-100; compare with Chen, 1965, Figs. 7-12; Puri and Vernon, 1964, Figs. 2 and 3). The arch was "rejuvenated" periodically during periods of regional tectonism and it is evident that the crest of the arch shifted through time. The general location, however, of the arch in northern Florida remained constant. The name Ocala Arch is preferred to Peninsular Arch because the name Ocala has priority (i.e., Hopkins, 1920, as opposed to Applin, 1951).

The Florida Platform (Fig. 5) is an expansion of the concept of the Floridian Plateau (Vaughan, 1910b; Cooke and Mossom, 1929; Cooke, 1945) and the Florida-Bahama Platform (Owens, 1960; Chen, 1965). The Florida Platform of this report consists of the predominantly carbonate sediments that overlie the Florida basement and caps the structurally high Ocala Arch (and also caps the South Florida Basin of Murray, 1963, p. 101-103). As such, the Florida Platform is not a structural feature but rather the mass of flat-lying deposits lying on exotic continental basement (African basement rather than North American basement) with structural features superimposed on the basement. The Ocala Arch is the core of the Florida Platform in the northern part of the Florida peninsula.

The Florida Platform is bounded on the west by the Gulf of Mexico basin, on the east by the Blake Plateau-Florida Straits, and on the south by the Florida Straits (overthrust sheet or high-angle, tilted fault blocks of the Antilles according to Owens, 1960, and Chen, 1965). The northern boundary of the Florida Platform shifted through time due to facies change between the platform carbonates and the continental shelf clastics, and to changing configuration between the platform and the continental shelf to the north. The geomorphic or physiographic expression of the Florida Platform through much of the duration of the Coastal Plain province was a shallow water carbonate bank, much like the Bahama Banks of today. As a result, the Florida Platform constitutes a subprovince of the Coastal Plain, with a characteristic stratigraphy that, through much of the Cretaceous and Tertiary, was distinct from that of the adjacent continental shelf to the north (compare with Applin and Applin, 1944; Richards and Palmer, 1953; Cole and Applin, 1964). During the Eocene and Oligocene the northern margin of the Florida Platform coincided with the southern flanks of the Suwannee Straits or the Gulf Trough-Apalachicola Embayment. At that time the platform constituted a topographic (or bathymetric) high and formed a large bank or series of large banks. In the early Miocene, however, the northern margin of the Florida Platform (or banks) became more diffuse due to the inundation of the continental shelf by terrigenous clastics from the nearby Piedmont uplands. After the early Miocene, the Florida Platform neither stood out topographically nor depositionally in Georgia and, geomorphically, the platform was incorporated into the clastic shelf province of the southeastern Coastal Plain. During the Miocene, the northern margin of the Florida

Platform coincided with the southern flanks of the Gulf Trough-Apalachicola Embayment to the north and west, and with the Southeast Georgia Embayment to the north and east (Fig. 5).

The modern configuration of the northern part of the Florida Platform, as defined in this report, originated in the Miocene with the differential subsidence of the Southeast Georgia Embayment. Lithologies of upper Eocene and Oligocene formations are not significantly different between the platform area and the adjacent Southeast Georgia Embayment and the Florida Platform. Similarly, the thickness distributions of the upper Eocene and Oligocene deposits also show no changes in the vicinity of the Florida Platform and Southeast Georgia Embayment (compare with Applin and Applin, 1944; Herrick and Vorhis, 1963; Cramer and Arden, 1980).

The lithologies of the Miocene deposits, however, do appear to have been influenced by their positions on the Florida Platform and adjacent basinal areas. The typical Parachucla, Marks Head, and Coosawhatchie Formations are restricted to the Southeast Georgia Embayment (compare with Figs. 10 and 11) except that the Parachucla Formation also extends southwestward into the Gulf Trough and onto the Piedmont Slope (Fig. 15). The Statenville Formation and unnamed lower Miocene dolostone, clay and sand occur only on the eastern margins of the Florida Platform in northern Florida and southern Georgia. The Chattahoochee and Torreya Formations are known to occur only on the western part of the Florida Platform and in or on the flanks of the Gulf Trough-Apalachicola Embayment in southwesternmost Georgia and northwestern Florida. The Meigs Member of the Coosawhatchie Formation, on the other hand, is known to occur only in and adjacent to the Gulf Trough in Georgia.

Beaufort Arch

The Beaufort Arch (Fig. 5) was originally called the Beaufort High by Heron and Johnson (1966, p. 54) for the structurally high occurrence of Early Tertiary carbonate rocks in Beaufort County, South Carolina. It had earlier been referred to informally as the Burton Arch by Siple (1956, 1965), and later briefly referred to as the Beaufort Arch by Colquhoun and others (1969, p. 4). In Georgia, Furlow (1969, p. 14) recognized the feature in eastern Chatham County and called it the Tybee High.

The Beaufort Arch is a low, broad, structural high extending south-southwestward from Beaufort County, South Carolina, onto the continental shelf (Fig. 5). The Beaufort Arch is present onshore in Georgia only in eastern Chatham County. South of Chatham County, the Beaufort Arch occurs only on the inner continental shelf and has been traced as far south as offshore Cumberland Island (Woolsey, 1976, p. 59, fig. 3; Foley, 1981, p. 48-49, fig. 20).

There are no known Tertiary thickness or lithofacies anomalies associated with the Beaufort Arch in Georgia prior to or subsequent to the middle Miocene (compare with Woolsey, 1976, p. 59; also see Pl. 2). The Tybee Phosphorite Member of the Coosawhatchie Formation occurs only on the crest of the arch in Chatham County, and thins and pinches out on the western flank of the arch. The distribution of the Tybee Phosphorite Member on the crest of the Beaufort Arch suggest that the arch stood as a topographic high on the continental shelf during middle Miocene time.

Ridgeland Trough

The Ridgeland Trough (Fig. 5) is a minor structural feature named the Ridgeland Basin by Heron and Johnson (1966, p. 54), and the Ridgeland Trough by Colquhoun and others (1969, p. 4). It was named for the town of Ridgeland in Jasper County, South Carolina, through which the trough trends in a northeast-southwest direction. The Ridgeland Trough is identifiable in Georgia in southern Effingham and northern Chatham Counties (Pl. 2), but has not yet been traced farther south in Georgia.

The Ridgeland Trough is a structural artifact. It is formed by the southeastward structural dip of the Coastal Plain and the concomitant thickening of Miocene deposits; and the northwestward structural dip on the western flank of the Beaufort Arch, and the concomitant thinning of Miocene deposits over the Beaufort Arch (see Pl. 2). The Ridgeland Trough has, therefore, the appearance of a synclinal feature formed by the Beaufort Arch interrupting the normal seaward or basinward structural dip on the Coastal Plain.

STRATIGRAPHICALLY SIGNIFICANT GEOMORPHIC FEATURES OF THE GEORGIA COASTAL PLAIN

Geomorphic (or physiographic) features in themselves may or may not be associated with stratigraphic changes, depending on the nature of the geomorphic feature. The geomorphic features to be discussed in this report (Fig. 6) have two kinds of stratigraphic changes associated with them: the physical termination of stratigraphic units by erosional truncation, and the termination of stratigraphic units because of facies change. In the first case (e.g., a simple cuesta), there is no apparent relationship between the present geomorphic feature and the original depositional environment or depositional geography. In the second case, where there is associated facies change, either the geomorphic feature or an ancestral condition was present during one or more depositional episodes. For example, a recurring or periodic, down-to-the-basin fault in the basement in a

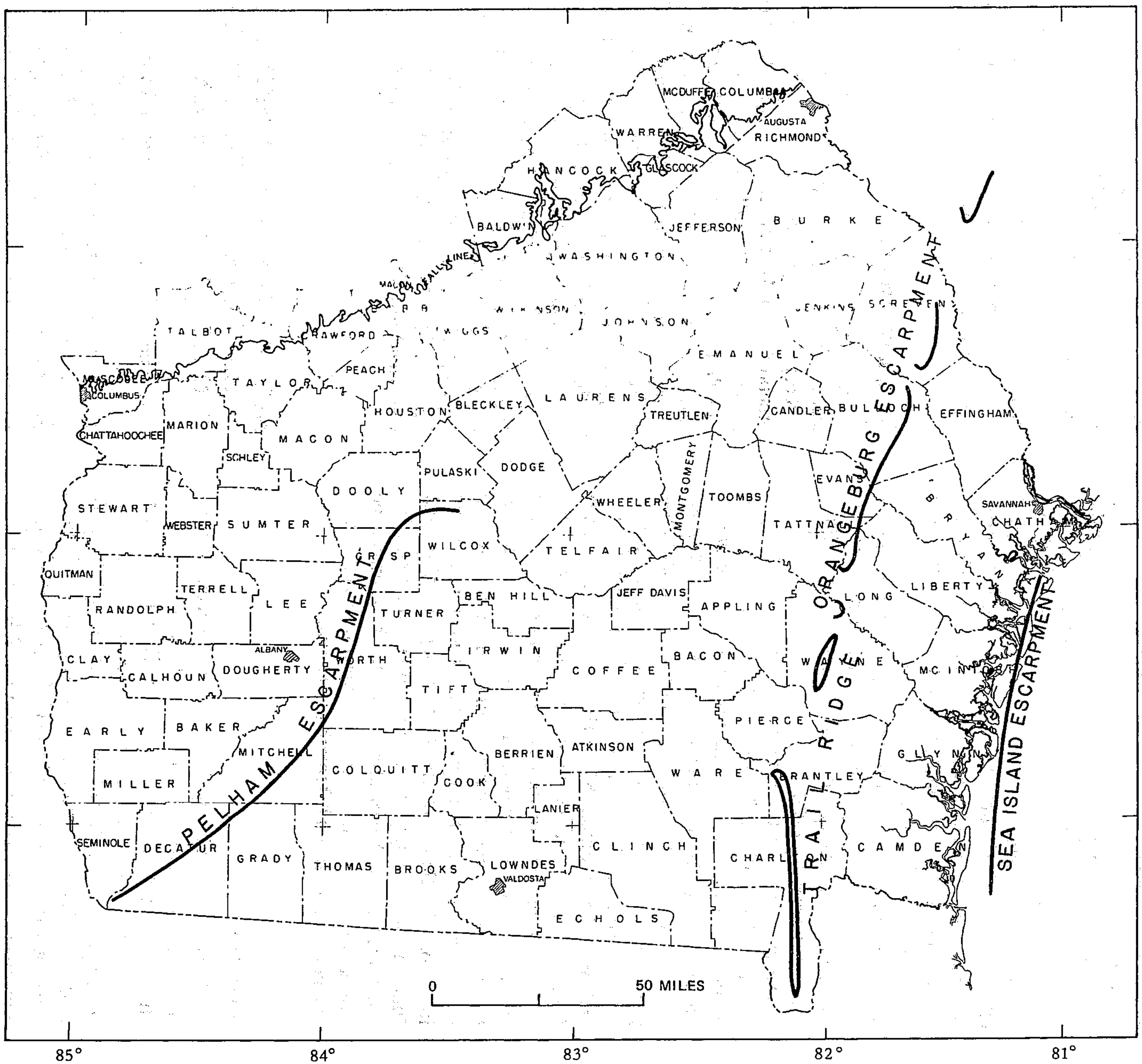


Figure 6. Stratigraphically significant physiographic features of the Georgia Coastal Plain.

coastal area could dictate a shoreline position or a facies-change position on the continental shelf at successive intervals in geologic time. A shoreline position for such a feature could result in a topographically conspicuous wave-cut escarpment. Three geomorphic features (escarpments) that have associated stratigraphic terminations are discussed in order.

Pelham Escarpment

The Pelham Escarpment (Fig. 6) was recognized but unnamed by Veatch and Stephenson (1911, p. 32) and Cooke (1925, p. 37), and has been called Curry Hill on both 1:62,500 and 1:24,000 quadrangle maps in Decatur and Grady Counties, Georgia. MacNeil (1947b) referred to the escarpment as "Solution escarpment", but Furcron and Fortson (1960) named the feature the Pelham Solution escarpment. The name has subsequently been shortened to Pelham Escarpment (Clark and Zisa, 1976; Clark, Zisa, and Jones, 1976).

The Pelham Escarpment is a cuesta that extends from the vicinity of Wilcox County, Georgia, southwestward to southwestern Decatur County, Georgia, where it merges into the eastern valley wall of the Flint River (Lake Seminole). Between the vicinities of Bristol and Chattachoochee, Florida, the Pelham Escarpment also forms the eastern wall of the Apalachicola River Valley, and large bluffs are formed where the river flows against the Pelham Escarpment. Between the vicinities of Chattahoochee, Florida, and Faceville, Georgia, the Pelham Escarpment forms the eastern valley wall of the Flint River (now Lake Seminole).

Various formations are present in the face of the Pelham Escarpment along its length. At Alum Bluff on the Apalachicola River, near Bristol, Florida, the lower Miocene Chipola Formation is overlain by the upper Pliocene Jackson Bluff Formation in the face of the escarpment, and the upper Pliocene Citronelle Formation caps the escarpment. The geologic section exposed in the face of the Pelham Escarpment rises northward into southwestern Georgia, exposing older formations. From Aspalaga Bluff in Gadsden County, Florida, northward into Decatur County, Georgia, the sections exposed in the bluffs of the Apalachicola and lower Flint Rivers consist of Chattahoochee Formation, overlain by Torreya Formation, and capped by Citronelle or Miccosukee Formations. From northeastern Mitchell County to its termination in Wilcox County, Oligocene limestones, or residuum thereof, occur at the base of the escarpment, and Altamaha Formation caps the escarpment.

From Decatur County to Crisp County, Georgia, the Pelham Escarpment separates the Tifton upland on the east from the Dougherty Plain on the west (Cooke, 1925; Clark and Zisa, 1976).

Orangeburg Escarpment

The name Orangeburg Escarpment (Fig. 6) was first applied by Pooser (1962, 1965) and Colquhoun (1962) to an escarpment that trends from Marlboro and Chesterfield Counties, South Carolina, near the North Carolina state line, southward through Orangeburg County to Allendale County in the Savannah River region. The Orangeburg Escarpment was described by Colquhoun (1965). Subsequently, Clark and Zisa (1976) recognized the Orangeburg Escarpment in Georgia. The name Orangeburg Escarpment (or scarp) has been used by most authors in South Carolina, but the name Citronelle Escarpment of Doering (1960) is still used by some (Colquhoun and others, 1983). In my opinion the name Citronelle for the escarpment in question is inappropriate because the escarpment was named by Doering (1960) for deposits (Altamaha Formation of this report; Hawthorne Formation of Cooke, 1936, 1943; Cooke and MacNeil, 1952; Siple, 1967) that were miscorrelated with the Citronelle Formation (named from the village of Citronelle in Mobile County, Alabama), an eastern Gulf Coastal Plain formation that occurs neither in Georgia nor South Carolina. The Orangeburg Escarpment was named for the town of Orangeburg, South Carolina, which is located on the escarpment. The name Orangeburg in this context has no stratigraphic implications. As a result, I prefer the name Orangeburg Escarpment to the name Citronelle Escarpment.

The Orangeburg Escarpment extends from North Carolina in the north, to the vicinity of the Altamaha River in Georgia in the south (Fig. 6). The escarpment is moderately dissected in Georgia, but the degree of dissection varies along its extent. In Georgia, the Orangeburg Escarpment trends southward from eastern Screven County, in the Savannah River area, through Bullock, Evans, and Long Counties (see Clark and Zisa, 1976). It is present immediately south of the Altamaha River in the vicinity of Jesup in Wayne County, but the face of the escarpment is deeply dissected there. Northwest of Jesup, the southern end of the Orangeburg Escarpment almost overlaps the northern end of Trail Ridge (Fig. 6).

The Orangeburg Escarpment is not only a geomorphic feature in Georgia, its position also coincides with or approximates stratigraphic boundaries. The Orangeburg Escarpment represents the eastern limits of the Miocene Altamaha Formation and the western limits of the upper Pliocene Raysor Formation (=Duplin formation of earlier authors) in Georgia (i.e., the Altamaha Formation is not known to occur east of the escarpment, and the Raysor Formation is not known to occur west of the escarpment). The western limits of the younger, upper Pliocene Cypresshead Formation generally occurs at the Orangeburg Escarpment, but the Cypresshead Formation also is known to occur in places a few miles west of the escarpment.

The Orangeburg Escarpment acts as a dividing line for the marine terraces in Georgia and South Carolina. The Okefenokee and higher terraces are found west of the line of the Orangeburg Escarpment-Trail Ridge south of the Satilla River. However, each successively higher terrace also occurs on the east side of the Orangeburg Escarpment progressively farther north (Figs. 56, 57) as a result of northward increasing elevation along the crest of the escarpment. Between the northernmost occurrence of a specific marine terrace west of the Orangeburg Escarpment and its southernmost occurrence east of the escarpment, there is a gap in the occurrence of that terrace, its elevation position occurring in the face of the Orangeburg Escarpment.

The origin of the Orangeburg Escarpment is not clear. It is certainly not, however, a simple erosional or solution cuesta like the Pelham Escarpment in southwestern Georgia. The following observations may contribute to an understanding of the Orangeburg Escarpment. (1) The Orangeburg Escarpment in Georgia occurs along a trend of lithofacies change involving middle Miocene (Serravillian) deposits (compare Fig. 6 with Figs. 31, 42, and 44). (2) The position of the Orangeburg Escarpment approximates the inner limits of the upper Pliocene Raysor Formation in South Carolina and Georgia (in the vicinity of the Altamaha River, it also marks the shoreward limits of the Raysor Formation [Fig. 47]). (3) The position of the Orangeburg Escarpment was overlapped in places by the upper Pliocene Cypresshead Formation (which overlies the Raysor Formation) (compare Fig. 6 with Fig. 50). (4) The positions of the Pleistocene marine terraces are influenced by the Orangeburg Escarpment (Figs. 56 and 57). (5) Trail Ridge, a sand ridge of coastal origin, extends southward along the same trend as the Orangeburg Escarpment, and the northern tip of Trail Ridge in Wayne County, Georgia, almost coincides with the southern limits of the Orangeburg Escarpment (Fig. 6). (6) The land elevations along the crest of the Orangeburg Escarpment diminish southward from approximately 300 feet (91 m) above sea level in northern South Carolina, to 230-250 feet (70-76 m) in Screven County, Georgia, to 140 feet (43 m) in Wayne County, Georgia, the southern end of the escarpment. In Wayne County, the crest of the Orangeburg Escarpment merges with the Waycross terrace, and the elevations on the crest of Trail Ridge in Wayne County are likewise 140 feet (43 m) above sea level.

The preceding observations indicate that, during the Miocene to Pleistocene, the position of the Orangeburg Escarpment periodically occupied a band of facies change from fluvial or shallow coastal waters on the west, to more open marine, inner continental shelf waters on the east, and that the present escarpment occurs in the vicinity of paleoshorelines. This line of recurring facies change suggests deep-seated structural control, possibly down-to-basin faulting in the basement.

The position of the Orangeburg Escarpment appears to have occupied the shoreline area during the period of Raysor deposition. But because the younger Cypresshead Formation occurs inland from the Orangeburg Escarpment in Bulloch and Wayne Counties, it is concluded that the present Orangeburg Escarpment did not exist during Raysor deposition and during Cypresshead deposition, or that the topographic relief on the escarpment was much lower during the Pliocene. On the other hand, the positions of all of the higher marine terraces (Okefenokee, Waycross, Argyle [new name], Claxton, Pearson [new name], and Hazlehurst terraces) are influenced by the Orangeburg Escarpment, and the position where each terrace passes from the west side of the escarpment to the east side of the escarpment occurs progressively farther north with each higher terrace (see Figs. 56 and 57). This phenomenon suggests that the Orangeburg Escarpment is a wave-cut escarpment that may not have existed with its present relief during late Pliocene time, but was constructed through increments during terrace construction events in the early and late Pleistocene (very roughly the period of construction of the higher terraces). It is also possible, however, that the Orangeburg Escarpment was constructed subsequent to deposition of the Cypresshead Formation, and was tectonically tilted to the south prior to the construction of the marine terraces. Available information does not allow selection between these two models at this time.

Sea Island Escarpment "new name"

The Sea Island Escarpment (Fig. 6) is a new name proposed herein for a buried escarpment that underlies the coastal area and inner continental shelf of Georgia. It has been detected only by seismic means (Woolsey and Henry, 1974, p. 167-168; Woolsey, 1976, p. 31-33; Foley, 1981, p. 20-24) and is not a present topographic feature. Therefore, the Sea Island Escarpment is in reality a paleoescarpment, but for brevity, will be referred to as an "escarpment" in this paper. The Sea Island Escarpment was a topographic feature probably from near the end of the Miocene through the early Pliocene, but was buried by prograding inner continental shelf deposits (unnamed Raysor-equivalent shelly sand) during the late Pliocene.

The Sea Island Escarpment extends in the north from southern coastal Chatham County, southward under St. Catherines, Blackbeard, and Sapelo Islands, and thence offshore as far south as the inner continental shelf off of Cumberland Island (Fig. 6).

The Sea Island Escarpment has been postulated as a wave-cut erosional escarpment that was cut during the interval between middle Miocene and Pliocene time (Woolsey, 1976; Foley, 1981). The sediments (or reflectors) in the escarpment have been called Hawthorne Formation (Woolsey, 1976) but are referred to here as the Coosawhatchie Formation. Large-scale clinoforms of the upper Pliocene Raysor-equivalent shelly sand overlie and occur seaward of the buried escarpment, and the lower Pliocene Wabasso beds appear to occur only seaward of the escarpment

(Huddlestun and others, 1982). It is suggested that the Sea Island Escarpment was cut during the late Miocene (Messinian) low-stand of the sea (compare with Huddlestun and Wright, 1977), either by wave action along the coast or by strong current action on the inner continental shelf. The early Pliocene sea level stand may have inundated the escarpment (deduced from the relatively deeper water, planktonic foraminiferal fauna of the Wabasso beds, but clastic input was not sufficient to bury the escarpment until late Pliocene time.

STRATIGRAPHY

Cooper Formation

Definition

The Cooper Formation (part of which is Miocene in age) is restricted to the continental shelf in the Georgia area, and consists of massive and structureless, generally unconsolidates, finely to very finely granular and even-textured, microfossiliferous, variably argillaceous limestone. The name Cooper was originally applied to calcareous deposits cropping out along the Cooper and Ashley Rivers in South Carolina (Tuomey, 1848). Sloan (1908, p. 462-464) referred to the Cooper variably as "Ashley-Cooper marls", "Cooper River marl", "Cooper marl", and "Ashley marl". He referred to the marl cropping out along the Cooper River as Cooper Marl, and the marl cropping out along the Ashley River he referred to as Ashley marl. Sloan (1908) considered the Ashley and Cooper marls to be lithologically similar enough that he included them also under the name Ashley-Cooper marl. He noted, however, that the Ashley marl tended to be more phosphatic than the Cooper marl. In addition, Sloan (1908, p. 463) considered the marl along the Cooper River to be of Eocene age whereas he suspected the marl along the Ashley River to be possibly of Oligocene age. Cooke (1936, p. 82-89) simplified the stratigraphic terminology by recognizing only the name Cooper Marl, noting, however, that the upper part of the formation is more phosphatic than the lower part.

The formation in Georgia previously referred to as Cooper Marl (Cooke and Munyan, 1938; Cooke, 1943, p. 74-77; Pickering, 1970, p. 13-14; Huddlestun and others, 1974, p. 9-10) is now called the Ocmulgee Formation (Huddlestun and Hetrick, 1986). The Ocmulgee Formation and the Cooper Formation of this report have little in common. The Cooper Formation in the type area in South Carolina and on the continental shelf of Georgia ranges from the upper Eocene (upper Jacksonian) to the lower Miocene (Aquitanian). The Ocmulgee Formation, on the other hand, is restricted to the upper Eocene (upper Jacksonian). The Cooper Formation extends from the Holly Hill and Charleston area of South Carolina southward on the continental shelf of South Carolina and Georgia (Fig. 7). The Ocmulgee Formation occurs only in a band south of the Fall Line Hills of Georgia from Houston and Pulaski Counties in the southwest, to Screven County in the Savannah River area. It is not clear at this time whether the Ocmulgee Formation grades laterally into the Cooper Formation in South Carolina, or whether the two units are stratigraphically separated. The Ocmulgee Formation has lithologic characteristics of both the Cooper and the Ocala Group. Like the Cooper Formation, the Ocmulgee tends to be granular, fine- to medium-grained and even-textured, tough and resistant to weathering, and very microfossiliferous. Like the Ocala Group, the Ocmulgee Formation is variably macrofossiliferous, and with a predominance of bryozoa. The Ocmulgee is lithologically more variable than the Cooper (Huddlestun and Hetrick, 1986), and the Ocmulgee is variably glauconitic, whereas the Cooper is variably phosphatic. The Ocmulgee Formation grades laterally seaward (southeastward) into the Crystal River Formation, and farther seaward, the Crystal River Formation grades laterally on the continental shelf into the lowest part of the Cooper Formation.

Type Section

The name Cooper is derived from the Cooper River north of Charleston, in South Carolina. No specific type locality has ever been designated for the Cooper, nor has the Cooper outcrop area along the Cooper River (or the Ashley River) been clearly delineated (compare with Cooke, 1936, p. 87, pl. 2). According to Ward (pers. com., 1984) and Ward and others (1979, p. 14), the exposures of the Cooper Formation along the Cooper River are poorly exposed and poorly preserved. As a result, Ward and others (1979, p. 14) proposed the section of Cooper Formation exposed in the quarry of the Giant Portland Cement Company near Holly Hill, Dorchester County, South Carolina, as a lectostratotype of the formation. In addition, Ward and others (1979, p. 14) designated as a reference section (hypostratotype) the Cooper Formation exposed in the bluff at Givhans Ferry on the left bank of the Edisto River in Dorchester County, South Carolina.

For reference purposes, the Miocene Cooper Formation occurs in the stratigraphic interval 289 feet to approximately 232 feet in the core AMCOR 6002 taken on the Georgia continental shelf.

Lithology

In the Georgia area, the Cooper Formation is known with certainty only from the core AMCOR 6002. The following description is based on the lithologies of the formation in that core. The Cooper consists of massive, structureless, granular, even-textured, finely granular to very finely granular, microfossiliferous, variably argillaceous, unconsolidated to slightly recrystallized limestone or "marl". Calcite or limestone is the predominant lithic component of the formation whereas clay minerals, fine-grained sand and silt, phos-

Figure 7. The areal distribution (subcrop) of the Cooper Formation under the continental shelf of Georgia.

phate, dolomite, and zeolite are minor or trace components of the lithology. The clay mineral suite of the lower part (upper Eocene and Oligocene) of the Cooper Formation in the core AMCOR 6002 is dominated by smectite with subordinate illite and kaolinite (J.H. Hetrick, pers. com., 1985). In the upper part of the Cooper Formation (Aquitanian, lower Miocene) in the core AMCOR 6002, however, the clay mineral suite also contains palygorskite and sepiolite (Hetrick and Friddell, 1984), apparently of detritial origin. Palygorskite is the dominant clay mineral near the top of the Cooper Formation in the core AMCOR 6002 (Hetrick and Friddell, 1984, p. 37, A37).

The upper part of the Cooper Formation appears to grade laterally westward into the Parachucla Formation of the Hawthorne Group under the inner continental shelf or coastal area of Georgia. In this area of facies change, the upper part of the Cooper would become more sandy, argillaceous, phosphatic, and dolomitic, with some stratigraphic intervals consisting predominantly of dolostone.

Stratigraphic Relationships

The Cooper Formation is restricted to the continental shelf in the Georgia area, but is probably continuous northward with the onshore Cooper Formation in the Charleston area of South Carolina. The upper part of the Cooper Formation under the Georgia continental shelf appears to grade laterally westward into the lower Miocene Parachucla Formation of the Hawthorne Group (see Fig. 11, Pls. 2, 3). The stratigraphic relationships of the Oligocene component of the Cooper with the onshore Oligocene section is unknown, however, due to lack of core control on the continental shelf. Because there are no Oligocene deposits present in the coastal area of Georgia south of the vicinity of Brunswick in Glynn County, it appears likely that the Oligocene component of the Cooper Formation thins westward and pinches out under the inner continental shelf off the southern coastal area of Georgia (Pls. 2,3). In the northern coastal area of Georgia, north of the vicinity of Brunswick, the upper Oligocene, Chickawashayan (Chatham) component of the Cooper likewise thins and pinches out under the inner continental shelf, whereas the lower Oligocene, Vicksburgian (Rupelian) component grades laterally westward into either the Lazaretto Creek Formation or into the Suwanee Limestone. There is no basis for speculation on the stratigraphic relationships between the upper Eocene component of the continental shelf Cooper Formation and the onshore Crystal River Formation, other than it appears that the lowest part of the Cooper Formation may grade laterally westward, by increase in coarse bioclastic material (primarily bryozoa), into the Crystal River Formation of the Ocala Croup.

In the core AMCOR 6002, the Cooper Formation is underlain by undifferentiated limestone of the Ocala Group and is overlain paraconformably by the Coosawhatchie Formation of the Hawthorne Group (Pls. 2, 3).

The upper part of the Cooper Formation is distinguished from the stratigraphically equivalent Parachucla Formation in being a finely granular, microfossiliferous, variably argillaceous limestone whereas the Parachucla Formation is a variably phosphatic, variably dolomitic or calcaerous, argillaceous sand or sandy clay. The overlying Berryville Clay Member of the Coosawhatchie Formation differs from the Cooper in consisting of thinly bedded to massive and structureless, variably phosphatic, variably diatomaceous, calcareous clay.

The thickness distribution of the Miocene part of the Cooper Formation under the continental shelf is unknown at this time due to insufficient core control. The thickness is at least 57 feet feet (17 m) in the core AMCOR 6002 but, due to uncertainty as a result of poor core recovery, it could be as much as 84 feet (26 m).

The environment of deposition of the Miocene component of the Cooper Formation was marine, middle to possibly outer neritic, continental shelf.

Age

The age of the Cooper Formation under the continental shelf of Georgia spans the latest part of the late Eocene (late Jacksonian) to the early Miocene (Aquitanian). The recognition of the early Miocene (Aquitanian) component of the Cooper Formation is based on the occurrence of the following species of planktonic formaminifera in the absence of *Cheilogumbelina cubensis:*

Globorotalia pseudokugleri
Globigerinita cf. *incrusta*
Globigerinoides primordius
Globigerina angulisuturalis.

The presence of *G. pseudokugleri* and the small and primitive *G. primordius* indicates that the Miocene Cooper in the core AMCOR 6002 is correlative with the Tiger Leap Member of the Parachucla Formation and not with the Porters Landing Member.

CHATTAHOOCHEE FORMATION

Definition

The Chattahoochee Formation generally consists of argillaceous, silty, finely sandy dolostone that is restricted to the western part of the Ocala Platform and to a small area between the Pelham Escarpment and Gulf Trough in southwestern Georgia (Fig. 10). As with most stratigraphic names that came into usage in the Coastal Plain of the southeastern United States in the last century, the name Chattahoochee evolved from casual mention, or from indefinite use as a sort of stratigraphic unit, to a stratigraphic unit that consistently can be identified in the field. As with other stratigraphic names originating at about the same time, the Chattahoochee Formation was never clearly defined by modern standards, and the application of the name by various authors was irregular. The name Chattahoochee was first used as the "Chattahoochee group" by Langdon (1889) and Foerste (1893). Dall (1892, p. 105-107) referred to the unit variously as "Chattahoochee group" and "Chattahoochee limestone", but Dall and Stanley-Brown (1894, p. 147-170) mostly called it the "Chattahoochee limestone" and used the name consistently in a lithostratigraphic sense. However, the application of the name varied from that of modern usage in the Apalachicola River area (the type area). For example, Dall and Stanley-Brown (1894, p. 163) included limestones (Ocheesee beds of Dall, 1892) of the lower calcareous phase of the Torreya Formation of the Hawthorne Group of this report in the Chattahoochee Formation. Because of its considerable impurities, Matson and Clapp (1909, p. 74-84) changed the unit term of the formation from Chattahoochee Limestone to Chattahoochee Formation, and this adjustment was followed by subsequent authors (Veatch and Stephenson, 1911; Matson, 1915; Brantly, 1916; Shearer, 1917; Sellards, 1917; Sellards and Gunter, 1918a, 1918b).

In spite of significant lithologic differences (compare with Dall, 1982; Matson and Clapp, 1909), the Chattahoochee Formation was abandoned in favor of the Tampa Limestone by Cooke and Mossom (1929, p. 79) because the Chattahoochee Formation appeared to be the same age as the Tampa Limestone. As a result, the name Tampa Limestone became widely applied in western Florida and Georgia for impure carbonates that overlie the Oligocene limestones, and underlie sands and clays of the Hawthorne and Alum Bluff (Mansfield, 1937; Vernon, 1942; Cooke, 1943, p. 86-89, 1945; MacNeil, 1944a, 1944b, 1944c, 1947a, 1947b; Fortson and Navarre, 1959; Herrick, 1961, p. 17-21; Owen, 1963b; Counts and Donsky, 1963). The concept of the Chattahoochee Formation as a distinct stratigraphic unit, however, was reintroduced by Puri (1953, p. 17-20) as the informal "Chattahoochee facies of the Tampa stage", and was later reintroduced as the Chattahoochee Formation by Puri and Vernon (1964, p. 118-123). Authors in Georgia, however, continued to use the name Tampa (Gremillion, 1965; Sever, 1966a, 1966b, 1969, 1972; Patterson and Buie, 1974; Weaver and Beck, 1977; also see Furlow, 1969, and Zimmerman, 1977) even though the Chattahoochee Formation had been reintroduced and the name applied in western Florida and Georgia (Hendry and Yon, 1958; Butler, 1963; Poag, 1972; Georgia Geological Survey, 1976).

As a result of the ambiguity concerning the names Chattahoochee and Tampa, I formally propose that the use of the name Tampa be abandoned in Georgia, that the dolomitic deposits in southwestern Georgia that had been called Tampa, in the sense of Cooke (1943), be included in the Chattahoochee Formation, and that the phosphatic, argillaceous, sandy carbonates at the base of the Miocene Series in southern and eastern Georgia, that have been related by some authors to the Tampa (Fortson and Navarre, 1959; Counts and Donsky, 1963; Furow, 1969) and by others to the Hawthorne (Wait, 1965; Wait and Gregg, 1973; Gregg and Zimmerman, 1974), be included in the Parachucla Formation.

The reasons for these proposals are as follows: (1) The lithostratigraphic unit, the Tampa Limestone (in the strict sense) is not present in Georgia. The Tampa Limestone is lithologically a finely sandy, variably fossiliferous limestone whereas the Chattahoochee Formation is more sandy and argillaceous and consists of a dolomitic fine-grained sand, clay and finely sandy dolostone with minor limestone. In contrast to the Tampa Limestone, the Chattahoochee Formation in Georgia is only sparsely fossiliferous. (2) Despite the widespread usage of the name Tampa in Florida and Georgia, the lithostratigraphic unit, Tampa Limestone, is known to occur only in the Tampa Bay area of Florida. The Chattahoochee Formation, on the other hand, occurs only in western Florida and in Georgia on the northwestern part of the Florida Platform, and the western flank of the Gulf Trough. The Tampa Limestone does not occur on the Florida Platform or east of the Florida Platform in peninsular Florida. Therefore, the Tampa Limestone and the Chattahoochee Formation are not continuous in outcrop or known occurrence, and evidence for interfingering or intergradation between the two units is lacking.

The basal carbonates of the Miocene Series in the subsurface of eastern Georgia are lithologically neither Tampa Limestone nor Chattahoochee Formation. These carbonates consist of phosphatic, sandy, variably argillaceous limestones and dolostones that locally are abundantly fossilferous. They are here included in the Tiger Leap Member of the Parachucla Formation (Hawthorne Group) because their overall lithology is compatible with that of the Tiger Leap in its type area in southern Screven County, Georgia.

The Chattahoochee Formation, as applied in this report, is approximately the same as that of Matson and Clapp (1909, p. 74-84) and Puri and Vernon (1964, p. 118-123), but differs significantly from the Chattahoochee Formation of Veatch and Stephenson (1911, p. 324-342). Deposits that constituted the Chattahoochee Formation of Veatch and Stephenson (1911) included not only Chattahoochee Formation of this report, but also residuum derived from various Oligocene limestones (later called Flint River formation by Cooke, 1935, 1943), Suwannee Limestone, some undifferentiated Oligocene limestone, Ocmulgee Formation (Huddlestun and Hetrick, 1986), and locally, some dolostones of the Hawthorne Group.

Type Section

The name Chattahoochee was taken from the town of Chattahoochee in Gadsden County, Florida. Although the name Chattahoochee had been used in a lithostratigraphic sense by earlier authors (Langdon, 1889; Dall, 1892; Foerste, 1893; Dall and Stanley-Brown, 1894), it was Matson and Clapp (1909, p. 74) who first referred the Chattahoochee Formation to a type locality, Chattahoochee Landing on the Apalachicola River at Chattahoochee, Florida (presumably the same as "old Chattahoochee Landing" of Dall and Stanley-Brown, 1894). All subsequent authors (Sellards and Gunter, 1909, 1918a; Mossom, 1925; Cooke and Mossom, 1929; Mansfield, 1937) accepted Chattahoochee Landing (or old Chattahoochee Landing) as the type locality of the Chattahoochee Formation.

There is uncertainty, however, concerning the site of the type section of the Chattahoochee Formation (i.e., the formation exposed at the type locality). Dall and Stanley-Brown (1894) presented two measured and described sections from "old Chattahoochee Landing", but the precise locations of the sections relative to the landing and the nearby bluffs are not clear from their descriptive. However, the sections must have been located between the river and the lower parts of the bluffs at Chattahoochee because the bases of the sections begin only 3 feet (1 m) above river level and extend to 26.5 feet (8 m) and 22.5 feet (6.9 m) above the river. Such a location is compatible with their comment that, "The exposures are mostly in gullies" (Dall and Stanley-Brown, 1894, p. 152), which would be true if the exposures occurred between the river and the bluffs.

All subsequent described sections from the "type locality" (G.D. Harris, in Maury, 1902; T.W. Vaughan, in Matson and Clapp, 1909; Sellards and Gunter, 1909, 1918a; Mossom, 1925; Cooke and Mossom, 1929; Mansfield, 1937; Cooke, 1945), however, differ from that of Dall and Stanley-Brown (1894) in that these later measured and described sections are from the roadcut in the bluff, at Chattahoochee, leading down to the landing (and later to the bridge over the Apalachicola River). The bases of all of these measured sections begin from 15 feet (4.6 m) to 25 feet (7.6 m) above river level and extend upwards to as much as 182 feet (55 m) above the river (in contrast to the sections of Dall and Stanley-Brown [1894] that begin near river level and extend upwards to 20 feet [6 m] above the river).

It is not clear whether this discrepancy is (1) the result of earlier exposures, measured and described by Dall and Stanley-Brown (1894), having been covered a few years later and being no longer accessible (the section of G.D. Harris was published in Maury [1902] eight years later), (2) whether the original site of "old Chattahoochee Landing" was accurately located by Dall and Stanley Brown,[1] or (3) whether the sections were mislocated and never existed at "old Chattahoochee Landing". However, since all subsequent authors (Matson and Clapp, 1909; Sellards and Gunter, 1909, 1918a; Mossom, 1925; Cooke and Mossom, 1929; Mansfield, 1937) accepted Chattahoochee Landing as the type locality of the formation, it logically follows that the section exposed (or once exposed) there is the stratotype of the formation. However, all of the authors subsequent to Matson and Clapp (1909) have applied the concept of "type locality" loosely to the Chattahoochee Formation and, except for Matson and Clapp (1909) and Sellards and Gunter (1909), did not distinguish between the locality below the bluff at "old Chattahoochee Landing" of Dall and Stanley-Brown (1894) and the "type locality" in the bluff. These two localities are not the same, and the sections exposed (or once exposed) there are not the same. In accordance with the various codes of stratigraphic nomenclature (American Commission on Stratigraphic Nomenclature, 1961, 1970; International Subcommission on Stratigraphic Classification, 1976; North American Commission on Stratigraphic Nomenclature, 1983), a type section (or type locality) must not be changed or amended (e.g., see North American Commission on Stratigraphic Nomenclature, 1983, Art. 22c). Therefore, it is concluded that the section exposed in the bluff along the road leading down to Chattahoochee Landing (or the old highway bridge) is not the type section of the Chattahoochee Formation, nor is that site the type locality of the formation. On the other hand, Sellards and Gunter (1909, 1918a), Mossom (1925), Cooke and Mossom (1929), and Mansfield (1937) referred to the section exposed in the roadcut in the bluff in the modern sense of a neostratotype (a new stratotype selected to replace an older one which has been destroyed or nullified [International Subcommission on Stratigraphic Classification, 1976, p. 26]) and principal reference locality.

None of the codes of stratigraphic nomenclature clearly address the difficulties in dealing with imprecise stratigraphic definition and usage in the years prior to stratigraphic codification. In the case of the Chattahoochee Formation, therefore, there is no simple and clear-out solution to the problem of the precise location of the type locality and type section. The solution to this problem requires a thorough understanding of the literature and stratigraphy of the formation, and balancing established stratigraphic usage and interpretation of the intent of the codes of stratigraphic nomenclature. Therefore, based on the above discussion, it is my interpretation that the type locality of the Chattahoochee Formation is at or near the site of Chattahoochee Landing (or "old Chattahoochee Landing"), between the Apalachicola River and the river bluffs at Chattahoochee, Florida, near the center of Section 32, T4N, R6W (see Fig. 7). The stratotype of the formation[2] (the original stratotype designated by the author at the time of establishment of a stratigraphic unit) is that section that was reported to be exposed in gullies at the type locality (see Dall and Stanley-Brown, 1894, p. 152). This section is no longer accessible. The principal reference locality of the Chattahoochee Formation is the roadcut in the bluff leading down to Chattahoochee Landing (or the old highway bridge) at

[1] Dall and Stanley-Brown (1894, p. 152) gave the site of "old Chattahoochee Landing" as Sec. 5, T3N, T6W, and about 1 mile above the railroad bridge. This location is internally inconsistent (see Fig. 7).

[2] Because a type section was not clearly designated by Dall and Stanley-Brown (1894), it is doubtful whether the stratotype can be considered to be the halostratotype.

Chattahoochee, Florida, in SW1/4, NE1/4, Sec. 32, T4N, R6W (see Fig. 8). The unit-stratotype (neostratotype) is that section of the Chattahoochee Formation exposed at the principal reference locality (see Matson and Clapp, 1909, p. 78-80).

Lithology

The dominant and characteristic lithic component of the Chattahoochee Formation is dolostone. Subordinate lithic components include quartz sand, clay, calcite, limestone, chert, mica, heavy minerals, phosphate, and fossils. The dolostone of the Chattahoochee Formation, commonly reported as limestone in the past (Dall 1892; Dall and Stanley-Brown, 1894; Matson and Clapp, 1909; Sellards, 1917; Sellards and Gunter, 1918a, 1918b; Mossom, 1925; Cooke and Mossom, 1929; Mansfield, 1937; Cooke, 1943, 1945; Puri, 1953; Puri and Vernon, 1964; Gremillion, 1965, 1966), is typically yellowish gray in color (5 Y 7/2 to 5 Y 7/1), uniform in texture, chalky to granular, rarely pelletal and foraminiferal, fine- to medium-grained, compact, prominently but rudely bedded*, and poorly to moderately consolidated and recrystallized. Limestone and calcite occur only rarely in the Chattahoochee Formation in Georgia, but are more common and widespread farther to the south and southwest in Florida. The dolomite in the Chattahoochee Formation appears to be secondary because the fossils that were once calcareous are now present only as molds and casts in the dolostone.

Fine-grained, well-sorted quartz sand and silt are characteristic of the Chattahoochee Formation. Typically the sand is evenly distributed throughout the dolostone, but it also occurs in medium to thick beds (Ingram, 1954) with variable admixtures of clay and dolomite. In some sections, significant proportions of the formation consist of fine-grained sand and clay (Cooke, 1943; Hendry and Yon, 1958, p. 28-33; Puri and Vernon, 1964, p. 121-122) and, in general, sand and clay appear to constitute a more significant component of the formation near the northern and eastern limits of the formation.

*Rude-bedding, as used in this report, is defined as bedding where the lithology change between beds is gradational over millimeters or centimeters. The bed contacts are, therefore, ill-defined and vague although the bedding may be prominent. This is in contrast to "fine", or sharply defined bedding, where the contacts between beds are very sharp or abrupt.

Clay occurs interstitially, in thin to thick beds of stratified or massive clay, and as clay intraclasts. At Forest Falls in Grady County, Cooke (1943, p. 92) reported most of the Chattahoochee Formation (Tampa of Cooke, 1943) as consisting of clay. Palygorskite and montmorillonite are the principal clay mineral components of the Chattahoochee formation, but kaolinite and illite occur in minor amounts (Gremillion, 1965, 1966; Weaver and Beck, 1977).

Chert occurs as nodules, concretions, and lenses within the dolostone, whereas mica, phosphate, and heavy minerals occur interstitially. Fossiliferous intervals are generally present but not common in the Chattahoochee Formation at any given site in Georgia. The frequency of occurrence of macrofossils in the Chattahoochee Formation in Georgia ranges from rare, scattered, fossil molds in the dolostone, to rich concentrations of fossil molds in scattered, thin to thick beds of dolostone. Most microfossils have been obliterated by dolomitization, but the benthic foraminifera *Sorites* and *Archaias* are locally common as molds and casts. The Chattahoochee Formation is more generally fossiliferous to the south in Florida where extensive faunal lists have been published from the type area (Dall and Stanley-Brown, 1894; Matson and Clapp, 1909; Mansfield, 1937; Cooke, 1945).

Characteristically, the Chattahoochee Formation is prominently bedded. Thickness of the beds is variable and ranges from thin to thick. The sediments within the beds are generally massive and devoid of primary sedimentary structures except for the intraclast beds, which are common and characteristic of the Chattahoochee Formation. The intraclasts variably consist of dolostone, limestone, or clay rubble (intraformational breccia or conglomerate) in matrices of dolostone, clay or sand. The intraclast beds range up to several feet (approximately 1 m) thick. Many are lenticular but there is some reason to think that a few intraclast beds may be widespread. The intraclasts typically range in size from granule-size to several centimeters (more than 1 inch) in diameter, and are characteristically angular although some are rounded.

Induration of the Chattahoochee Formation is variable. Typically the dolostone is lightly to moderately indurated, and forms resistant ledges in outcrop. Some dolostone, limestone, sand, or clay beds, however, are relatively unconsolidated, forming reentrants in outcrop.

Stratigraphic Relationships

The Chattahoochee Formation is restricted to that part of northern Florida that lies between the Choctawhatchee River in the west and the Suwannee River in the east, and to southwestern Georgia. In Georgia (Fig. 9), the western limit of the formation is the Pelham Escarpment where it occurs in outcrop between Chattahoochee, Florida, and the vicinity of Forest Falls in Grady County, Georgia. In the east it is found in sink-holes in southern Thomas and Brooks Counties, and in cores from eastern Thomas and western Brooks Counties. It is not present as far east as the Withlacoochee River in eastern Brooks County, where it appears to have graded into the Parachucla Formation. The Chattahoochee Formation occurs as far northeast as the vicinity of Moultrie in Colquitt County where it consists of sandy dolostone, dolomitic sand, and variably dolomitic clay. The Chattahoochee is not known to occur north and east of Colquitt County, and it is not known to occur in the Gulf Trough in Georgia. Available evidence indicates that the Chattahoochee Formation grades laterally eastward and northeast-

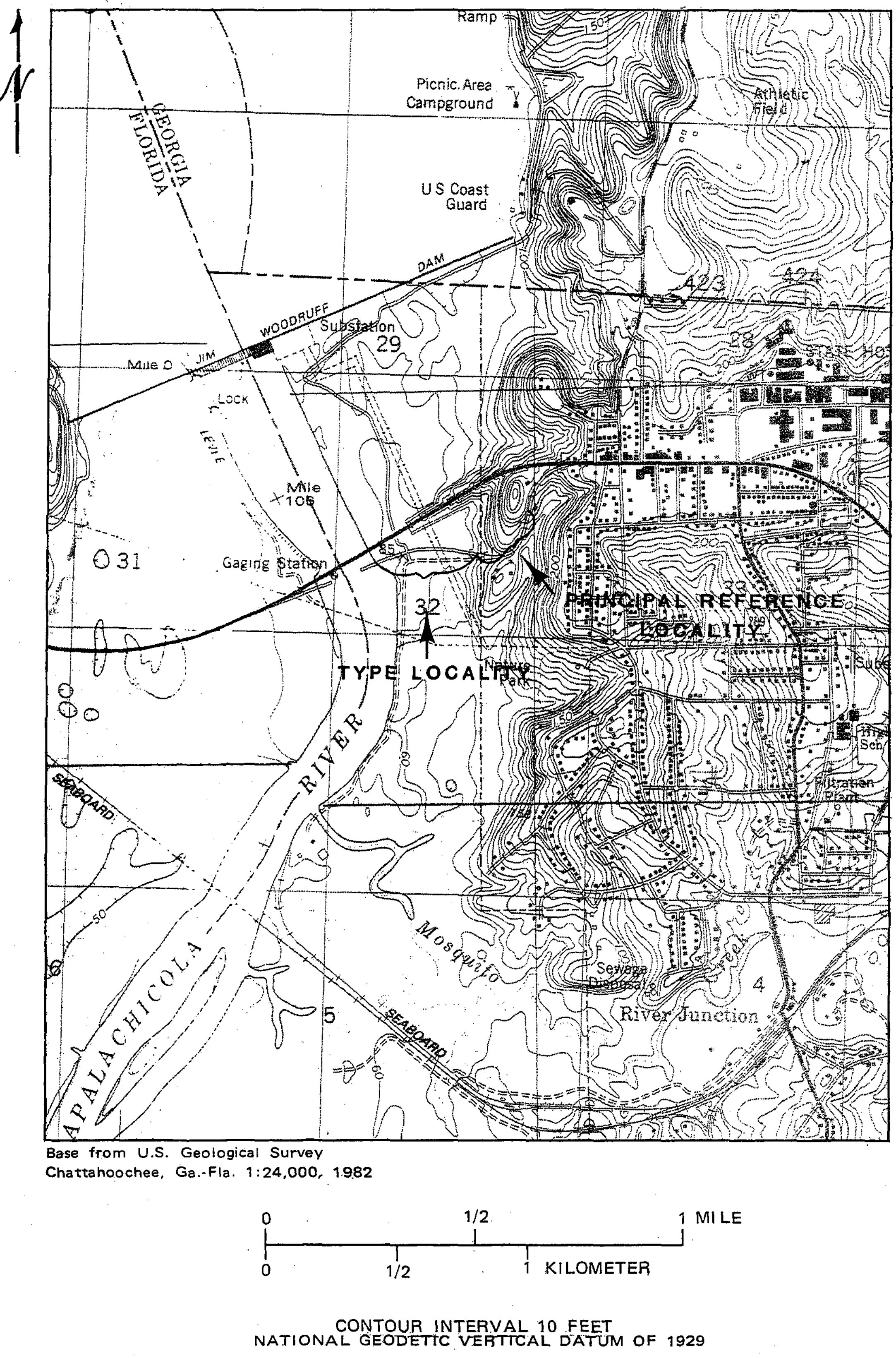


Figure 8. The type locality of the Chattahoochee Formation.

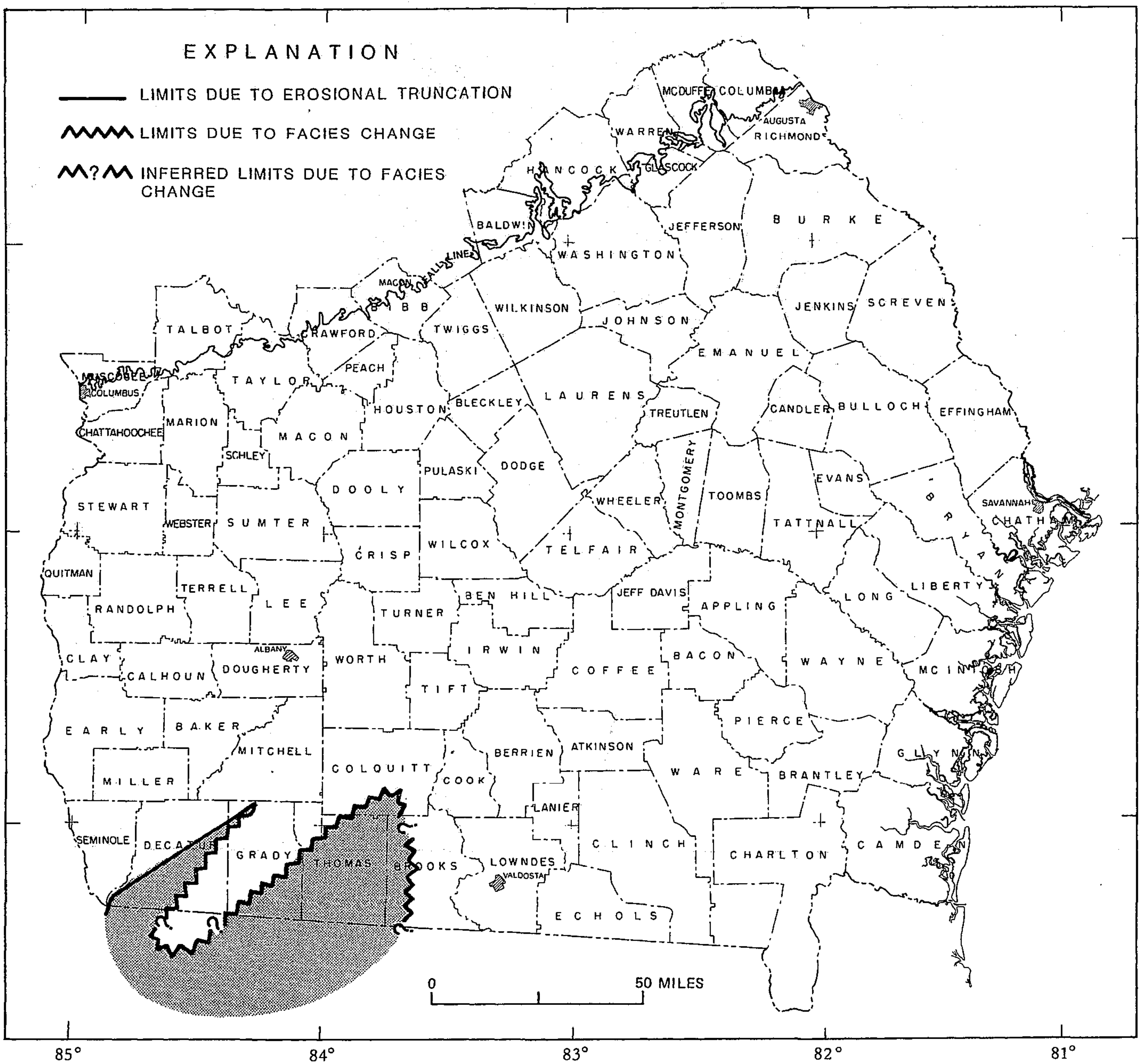


Figure 9. The areal distribution (outcrop and subcrop) of the Chattahoochee Formation in Georgia.

ward into fine sands, clays, dolostones and limestones of the Parachucla Formation (compare with Fortson and Navarre, 1959, p. 73-76; Herrick, 1961, p. 17-21; see Fig. 10).

The Chattahoochee Formation overlies the Suwannee Limestone east of the Gulf Trough, and Suwannee-equivalent limestone in and west of the Gulf Trough. In Georgia, the Parachucla Formation occupies the stratigraphic position of the Chattahoochee Formation within the Gulf Trough (Fig. 10). Generally the Chattahoochee Formation overlies the Oligocene units disconformably or paraconformably, but where the upper part of the Oligocene limestones have been dolomitized, the contact may be difficult to identify.

The Torreya Formation overlies the Chattahoochee Formation in Georgia. However, the nature of the upper contact of the Chattahoochee Formation in Georgia is not clear at this time. The conclusion of most authors has been that the Chattahoochee Formation (Tampa) (predominantly dolostone) is conformable with the Torreya Formation (Hawthorne of earlier authors) (predominantly sand and clay) (Cooke and Mossom, 1929; Cooke, 1943, 1945) although Mansfield (1937, p. 28) and Banks and Hunter (1973) regarded the contact disconformable at Chattahoochee. However, there is reputedly a considerable amount of fine sand and clay in the Chattahoochee Formation in Georgia (see Cooke, 1943, p. 87-89, 92). Because there are no known complete exposures of the Chattahoochee Formation in Georgia, and only one core (Colquitt 10, GGS-3544) shows the upper contact of the formation, it is not known, therefore, whether the upper part of the Chattahoochee Formation in Georgia consists generally of doloston, sand, or clay. The appearance of conformity between the Chattahoochee dolostones and "Hawthorne" sands or clays may be merely lithology change between dolostone and fine sand or clay within the Chattahoochee Formation. It is my observation, however, that in Florida, based on Florida Geological Survey cores, the dolostone of the Chattahoochee Formation extends to the top of the formation (as it does in the core Colquitt 10 [GGS-3544] in Colquitt County, Georgia), and the contact between the Chattahoochee and Torreya Formations is generally disconformable, and not conformable or gradational.

The Chattahoochee Formation is distinguished from the underlying Oligocene limestone in being finely sandy and argillaceous. The Oligocene limestones (or dolostones where locally dolomitized) are almost pure carbonates with no appreciable sand and clay. In addition, the Chattahoochee generally consists of dolostone whereas the Oligocene carbonates consist of limestone with local occurrences of dolostone at the top of the Series. The overlying Torreya Formation is distinguished from the Chattahoochee Formation in consisting of finely sandy limestone or noncalcareous argillaceous fine sand to finely sandy clay. Near the northern limits of its occurrence, the Chattahoochee Formation underlies noncalcareous and nondolomitic, variably siliceous, argillaceous fine sand and finely sandy clay of undifferentiated Hawthorne Group.

The Chattahoochee Formation grades laterally to the northeast, and on the flanks of the Gulf Trough, into the Parachucla Formation. The Parachucla Formation differs from the Chattahoochee Formation in generally being lithologically heterogeneous, consisting of finely sandy and variably argillaceous dolostones and limestones, and variably calcareous and dolomitic argillaceous sands and sandy clays. Locally the Parachucla Formation can consist predominantly of limestone, dolostone, or argillaceous sand, and the sand is generally calcareous and dolomitic to some degree.

The thickness distribution of the Chattahoochee Formation in Georgia is not known at this time because of insufficient outcrop and core control. Cooke (1943, p. 87, 88) reported 100 feet (30 m) of Tampa Limestone in Decatur County. Mansfield (1937, p. 31) reported at least 89.8 feet (27 m) of Chattahoochee Formation (Tampa) at the principal reference locality at Chattahoochee, Florida, and there is at least 90 feet (27 m) (also see Hendry and Yon, 1958, p. 28-33) of Chattahoochee Formation exposed at Jim Woodruff Dam at Chattahoochee. At Climax Cave in Decatur County, sandy dolostone of the Chattahoochee Formation is 24.5 feet (7.5 m) thick, but it not clear whether the overlying sandy clay is a part of the Chattahoochee Formation or Torreya Formation. The Chattahoochee is in excess of 50 feet (15 m) thick in a number of cores in Thomas and Brooks Counties, and is 42 feet (13 m) thick in the core Colquitt 10 (GGS-3544) in Colquitt County. If there are significantly thick beds of sand and clay in the Chattahoochee Formation in Georgia, and there is evidence that there are, then the formation probably ranges from 50 feet (15 m) to 100 feet (30 m) thick.

The Chattahoochee Formation was deposited on the inner continental shelf in an open-marine environment. Based on the macrofossil lists of Matson and Clapp (1909) and Mansfield (1937), it appears that the preserved molluscan fauna of the Chattahoochee Formation in its type area is of moderate to low diversity. The foraminiferal fauna, where one can be extracted from scattered calcareous beds, is characterized by low diversity and high faunal dominance by a few species. In addition, the common occurrence of the foraminifera *Sorities* sp., *Archaias* sp., and other peneroplids indicates shallow-water, well-aerated, clear, tropical to subtropical conditions with a climate probably similar to that of southern Florida today.

The prevalence of intraclast beds within the Chattahoochee Formation would suggest sporadically high-energy conditions, consistent with paleontological evidence for a shallow-water environment. However, the absence of mudcracks and ripple marks indicates that water-depth was not extremely shallow or intertidal. The gradational contacts between beds and the lack of well-defined thin bedding and lamination suggests good mixing and homogenization of the sediments due to infaunal bioturbation (except for the intraclast beds).

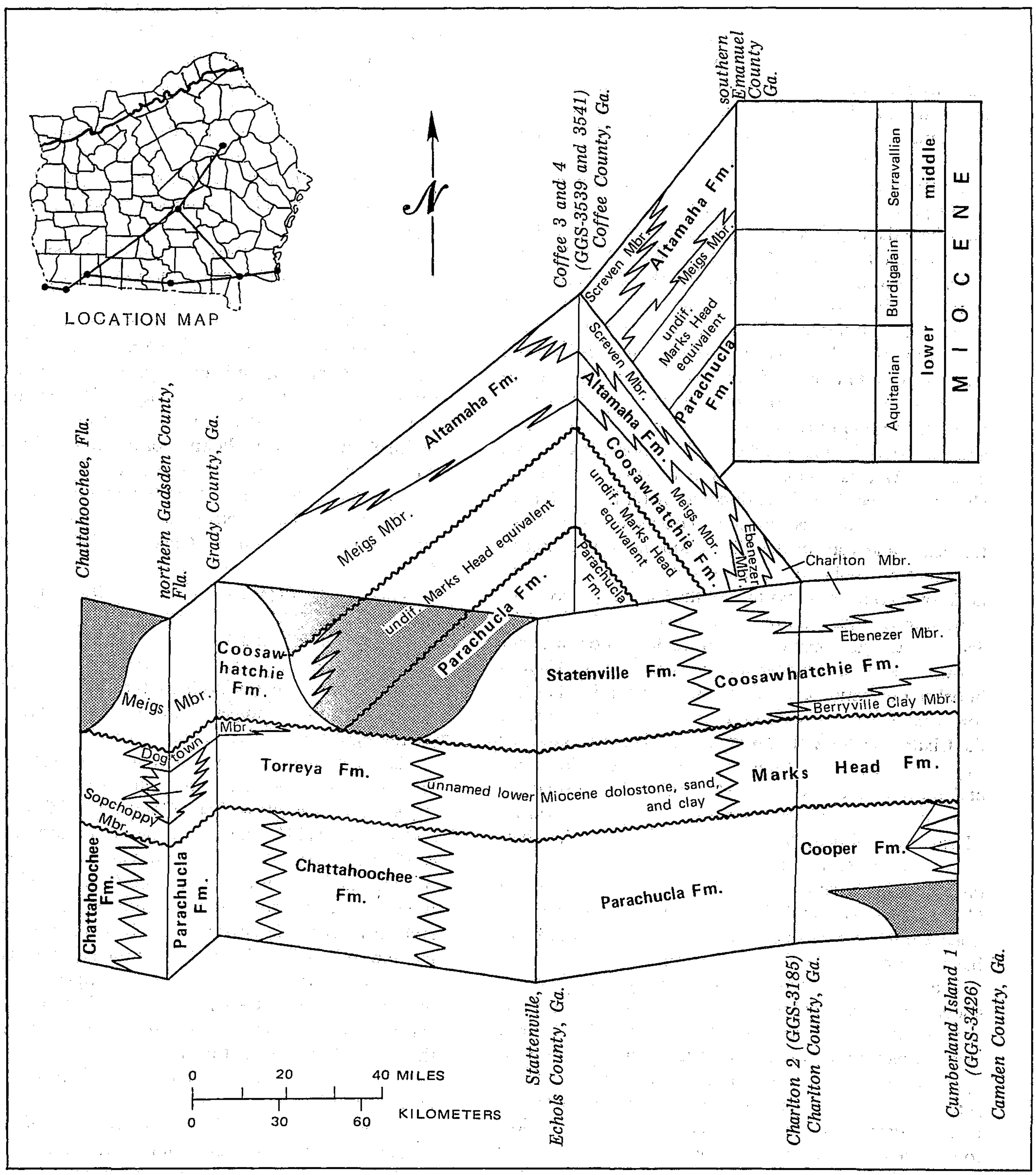


Figure 10. Fence diagram showing stratigraphic relationships of the Miocene deposits of southern and western Georgia.

Age

The Chattahoochee Formation and the Tampa Limestone of Florida have somewhat similar molluscan faunas; therefore, the two formations have traditionally been correlated. The Tampa Limestone is generally more fossiliferous than the Chattahoochee Formation. As a result, there have been many paleontological investigations on the Tampa Limestone (Heilprin, 1887; Dall, 1890-1903, 1892, 1898, 1915; Mansfield, 1937) and no paleontological investigations exclusively devoted to the Chattahoochee Formation. Consequently, the assigned age of the Chattahoochee Formation has varied with the assigned age of the Tampa Limestone. The age of the Chattahoochee Formation has generally been believed to be early Miocene (Dall and Harris, 1892; Dall and Stanley-Brown, 1894; Cooke and Mossom, 1929; Mansfield, 1937; Cooke, 1943, 1945; Puri, 1953; Puri and Vernon, 1964) except for the period 1896-1929 when it was believed to be Oligocene in age (Dall, 1896, 1915; Maury, 1902; Matson and Clapp, 1909; Veatch and Stephenson, 1911; Sellards, 1917; Sellards and Gunter, 1918).

It has recently been suggested (Butler, 1963; Poag, 1972), based on comparisons of ostracode faunas between the Chickasawhay Formation of Alabama and Mississippi, and the Chattahoochee Formation of western Florida, that the Chattahoochee Formation is late Oligocene and equivalent to the Chickasawhay Formation. The presence of the foraminiferal genera *Discorinopsis* and *Valvulina,* two taxa not previously known to occur above the Oligocene in the southeastern United States, supports an Oligocene age assignment for the Chattahoochee (Huddlestun, 1984). Physical correlation and lithology suggests, however, that the Chattahoochee Formation is a part of the lower Miocene. The Chattahoochee Formation occurs in the same stratigraphic position as the Aquitanian Parachucla Formation (Figs. 10 and 11) and grades eastward and northeastward into the Parachucla. The Chattahoochee Formation is sandy and argillaceous, as are all of the Miocene deposits in Georgia; it contains palygorskite; and it is sparsely phosphatic, which is an attribute of the Miocene deposits and not of the Oligocene deposits of southwestern Georgia.

The Chattahoochee Formation does not contain planktonic foraminifera, and other planktonic microfossils have not been reported. Therefore, the age of the formation cannot yet be assigned on purely *in situ* paleontological grounds. The presence of benthic faunas best known in the Oligocene is real but can be interpreted as an extension of the ranges of some Oligocene taxa of benthic microfossils. In the case of the Oligocene ostracodes in the Chattahoochee (Butler, 1963; Poag, 1972), the Miocene deposits overlying the Chickasawhay and Paynes Hammock Formations in Mississippi and western and central Alabama are noncalcareous and do not contain calcareous microfossils. Therefore, the taxa and ranges of the calcareous microfossils in the lower Miocene in that area are unknown, but it would be expected that that basal Miocene, Aquitanian faunas would have many taxa in common with the underlying upper Oligocene.

The age of the Chattahooche Formation, as suggested in this report, is based on its physical correlation with the Parachucla Formation in the Gulf Trough, and with the Parachucla Formation of eastern Georgia. On this basis, the Chattahoochee Formation is early Miocene (Aquitanian) in age, and is probably correlative with planktonic foraminiferal Zones N4 and N5 of Blow (1969) (Pl. 1).

HAWTHORNE GROUP

Definition

It is herein proposed that the name Hawthorne be raised to group rank. The Hawthorne Group of this report includes all deposits previously called Hawthorne Formation in Georgia (Cooke, 1936, 1943; MacNeil, 1947a, 1947b; Fortson and Navarre, 1959; Owen, 1963; Counts and Donsky, 1963; Gremillion, 1965; Brooks and others, 1966; Furlow, 1969; Patterson and Buie, 1974; Georgia Geological Survey, 1976; Weaver and Beck, 1977) exclusive of those strata now included in the Altamaha Formation. Other names that have been used for all or parts of the Hawthorne Group in Georgia in the past, but are no longer applicable or useful, include Combahee (Sloan, 1908), Alum Bluff Formation (Veatch and Stephenson, 1911; Brantly, 1916; Shearer, 1917; Teas, 1921), Alum Bluff Group (Sever, 1966a, 1966b; Zimmermann, 1977), Duplin Marl of Counts and Donsky (1963) and Furlow (1969), Chipola Formation of MacNeil (1947a, 1947b), Miocene (undifferentiated) (Applin and Applin, 1964; Sever, 1972), and Neogene undifferentiated (Georgia Geological Survey, 1976).

The name Hawthorne was first applied in an informal lithostratigraphic sense as "Hawthorne beds" by Dall (1892, p. 107-111) for phosphatic deposits being mined near Hawthorne, Alachua County, Florida. Matson and Clapp (1909, p. 69-74) raised the unit to formation rank. Vaughan and Cooke (1915, p. 250-253) abandoned the Hawthorne Formation in favor of the Alum Bluff Formation because the Hawthorne deposits at White Springs on the Suwannee River in Hamilton and Columbia Counties, Florida, were more reminiscent of the Alum Bluff Formation of western Florida, which at that time was a better known stratigraphic unit than the Hawthorne. Cooke and Mossom (1929, p. 115-137) reintroduced the unit as the Hawthorne Formation of the Alum Bluff Group because the "Alum Bluff has since been raised to the rank of group, and as the Hawthorn formation differs from other formations in the group, it is now possible to restore the name Hawthorn formation to good standing." The Hawthorne Formation was formally extended into Georgia by Cooke (1936, 1943) but without mention of it being part of the Alum Bluff Group. The concept of the Hawthorne as a formation of the Alum Bluff Group, or of undifferentiated Alum Bluff Group in Georgia,

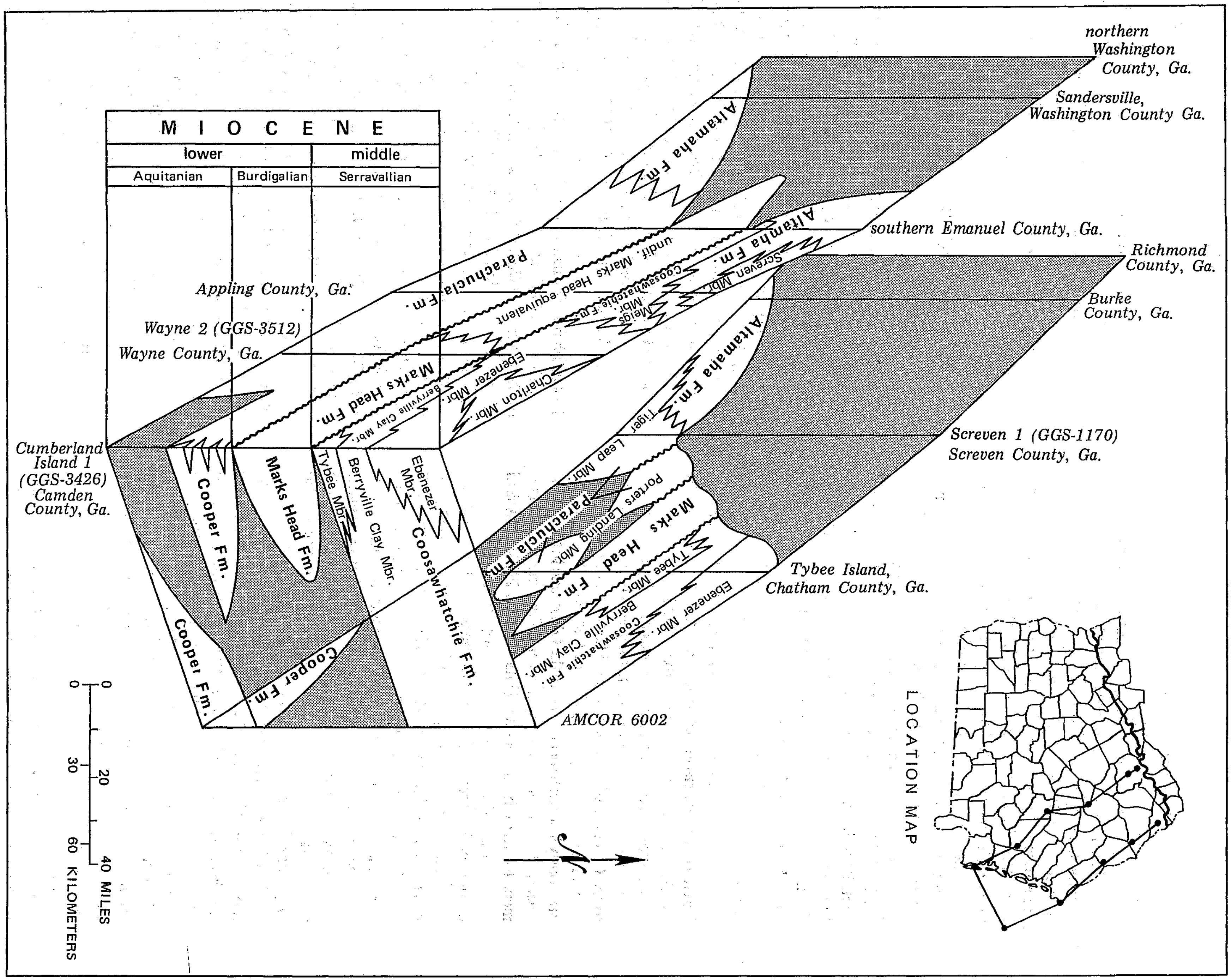


Figure 11. Fence diagram showing stratigraphic relationships of the Miocene deposits of eastern Georgia.

was applied by MacNeil (1947a, 1947b), Sever (1966a, 1966b), and Zimmerman (1977). The Alum Bluff Group, however, has not been generally adopted in Georgia for lithologic reasons and because of ambiguity in the definitions and usage of the name Alum Bluff (Gardner, 1926; Cooke and Mossom, 1929; Cook, 1943; Puri, 1953; Puri and Vernon, 1964).

I propose raising the Hawthorne to group rank in Georgia because the specific lithostratigraphic unit, or units, that constitute the type Hawthorne in Alachua County, Florida, are not present in Georgia. To restrict the name Hawthorne to the type lithostratigraphic unit would necessitate adopting another group name to apply to the various formations that had in the past been called Hawthorne Formation, and would result in more changes in stratigraphic terminology than are necessary. Therefore, retention of the name Hawthorne for this group serves to stabilize the stratigraphic nomenclature of the region.

Several lithologic parameters serve to distinguish the sediments of the Hawthorne Group. (1) Argillaceous sand and clay, rarely pure sand, are the dominant lithologies of the Hawthorne Group in Georgia. (2) Dolomite is the characteristic carbonate mineral of the Hawthorne; calcite is less common but locally dominant. (3) Generally, the Hawthorne is lacking in macrofossils. Locally there are casts and molds of macrofossils, but only rarely are calcareous macrofossils or microfossils preserved. (4) Most Hawthorne deposits are phosphatic, but the phosphate content declines in a westward direction, away from the Atlantic Ocean. Glauconite, on the other hand, is not known to occur in the Hawthorne. (5) The clays of the Hawthorne commonly contain an appreciable component of, and in places are dominated by, the magnesium-rich clay minerals, palygorskite and sepiolite. (6) Chert, siliceous claystone (opal-cristobalite), and diatomaceous sediments are locally common and conspicuous in Hawthorne Group deposits. Finally, (7) Hawthorne Group deposits are of marine, relatively shallow water, continental shelf origin that, in Georgia, grade laterally updip into fluvial deposits that are not Hawthorne. Neither sandy beach type deposits nor fluvial deposits occur within the mass of sediments included in the Hawthorne Group.

The Hawthorne Group is distinguished from the equivalent and adjacent Alum Bluff Group of western Florida (see Huddlestun, 1984) in four ways. (1) The Alum Bluff Group is never dolomitic, but is commonly calcareous and macro- and microfossiliferous. Shell beds formed of fossil shells consisting of original aragonitic shell material are a characteristic feature of the Alum Bluff Group. (2) Phosphate occurrence in the Alum Bluff Group is very minor and localized; whereas glauconite occurrence is scattered. (3) Alum Bluff clays are not known to contain palygorskite or sepiolite (Weaver and Beck, 1977). (4) Chert, siliceous claystone (opal-cristobalite), and diatomaceous sediments are not known to occur in Alum Bluff deposits.

The Hawthorne Group in Georgia and under the continental shelf of Georgia is divisible into five formally named formations with nine formally named members, and one unnamed formation. The formally recognized formations that constitute the Hawthorne Group are the Parachucla Formation with the Tiger Leap and Porters Landing Members, the Marks Head Formation, the Torreya Formation with the Dogtown and Sopchoppy Members, the Coosawhatchie Formation with the Tybee, Berryville, Ebenezer, Charlton and Meigs Members, and the Statenville Formation. The unnamed formation is a lower Miocene dolostone, clay and sand of south-central Georgia and northern peninsular Florida.

Type Section

The name Hawthorne was derived from the town of Hawthorne in Alachua County, Florida, approximately 15 miles (24 km) east of Gainesville, Florida. Dall (1892, p. 107-111) first used the name Hawthorne in a lithostratigraphic sense and referred to it as "Hawthorne beds". He did not explicitly designate a type locality for the unit, but stated that the Hawthorne beds were "being quarried and ground up as a fertilizer at Hawthorne, where the beds have a considerable thickness. For this reason I referred to these beds in my unpublished report as the 'Hawthorne beds', and to the chief facts of their occurrence in a paper read before the National Academy of Sciences in 1887. This name will, therefore, be adopted here for convenience in reference to the beds about to be described" (Dall, 1892, p. 108).

Matson and Clapp (1909, p. 69-74) accepted the concept of the Hawthorne stratigraphic unit of Dall (1892) and raised the rank of the Hawthorne beds to that of Hawthorne Formation. They also considered the pits at Hawthorne to be the type locality of the formation. Matson and Clapp (1909, p. 71) observed that "at the type locality near Hawthorne the rock is phosphatic and has been mined and crushed for use as a fertilizer." Most subsequent authors accepted the phosphate pits at Hawthorne as the type locality of the unit. Cooke and Mossom (1929, p. 130) later commented that "Old pits in phosphatic limestone about 3 miles west of Hawthorn and about 2 miles from Grove Park may be considered the type locality of the Hawthorn formation. They were opened in 1879 by Dr. C.A. Simmons of Hawthorn, who ground the material and used it as fertilizer. When visited by Cooke in 1913 the pits were so thickly overgrown that little could be seen except a few loose lumps of phosphatic limestone." In addition, E.C. Pirkle (1956, p. 200) noted, "At the time of Dall's visit, phosphatic rocks were being quarried near the town of Hawthorne in the old C.A. Simmon's pits. As these pits are the only ones in that area from which phosphatic rock has been quarried and ground up as a fertilizer, they must be the ones referred to by Dall. The pits are located between the towns of Grove Park and Hawthorne, about $1\frac{1}{2}$ miles south of State Road 20 in the eastern part of Section 31, T. 10 S., R. 22 E..... " Pirkle (1956, p. 202) likewise accepted the Simmons pits as the type locality of the Hawthorne.

Puri and Vernon (1964, p. 146), however, presented a different opinion concerning the type locality of the Hawthorne. They apparently interpreted Dall's expression, "adopted here for convenience in reference to the beds about to be described" (Dall, 1892, p. 108), as indicating that Dall had little or no opinion as to a type locality, and had no clear intention of designating a type locality for the Hawthorne. They, therefore, saw no reason to consider the C.A. Simmons phosphate pits as the type locality. Instead, they believed that the sections drawn by Johnson and published in Dall (1892, p, 108-109), because they were included in the discussion by Dall, were, in fact, the type localities. Puri and Vernon (1964, p. 146) concluded, therefore, "The later workers have generally ignored this [above] statement by Dall and have referred to the section at Hawthorne which was not even described by Dall and which does not even exist today as the type locality. The type sections really are the ones measured by Johnson and reproduced by Dall. The section at Devil's Mill Hopper and Brooks Sink are closest to the type area and should form the basis of later correlation." Puri and Vernon (1964, p. 146) went on to refer to the exposures at Brooks Sink in Bradford County, Florida, as a "cotype locality".

Because (1) W.H. Dall neither designated nor referred to type localities in general (one, therefore, must conclude that type localities or type sections were not a part of Dall's concept of stratigraphy), (2) type localities or type sections at the time of Dall's writing were rarely mentioned in the geologic literature, and (3) no stratigraphic code existed at the time to offer guidelines in establishing stratigraphic units, the modern codes of stratigrapic nomenclature (American Commission on Stratigraphic Nomenclature, 1961, 1970; International Subcommission on Stratigraphic Classification, 1972, 1976; North American Commission on Stratigraphic Nomenclature, 1983), therefore, can not be applied rigorously to Dall (1892) or to his contemporaries. In my estimation, in applying the name "Hawthorne beds" to a deposit with consistent lithology in a consistent stratigraphic position in northern Florida, Dall (1892) showed sufficient intent of naming a stratigraphic unit. In specifically citing the pits near Hawthorne (C.A. Simmons' phosphate pits) where the deposit was being mined for fertilizer, and in naming the unit after the town of Hawthorne, Dall (1892) showed sufficient intent to "designate" a type or reference locality. Other subsequent authors concurred in this evaluation (Matson and Clapp, 1909; Cooke and Mossom, 1929; Pirkle, 1956).

Based on this interpretation, the C.A. Simmons phosphate pits must be considered the type locality and stratotype of the Hawthorne Group (Fig. 12). There are no longer any exposures at the type locality, and there have not been any for many years. However, it is incorrect to conclude that an original stratotype must be accessible to be valid. According to the various codes of stratigraphic nomenclature (American Commission on Stratigraphic Nomenclature, 1961, Art. 13h; 1970, Art. 13h; North American Subcommission on Stratigraphic Nomenclature, 1983, Art. 22c), type sections, once designated (in this case, accepted), must not be changed, even though the type section is no longer accessible. In addition, there can be only one type section (or type locality) (American Commission on Stratigraphic Nomenclature, 1961, Art. 13h; 1970, Art. 13h; North American Commission on Stratigraphic Nomenclature, 1983, Art. 22c), and, therefore, the concept of a "cotype locality" is not valid.

Because there have been no exposures at the type locality of the Hawthorne for many years, I propose that the Florida Geological Survey core Hawthorne 1 (W-11486) serve as the neostratotype (principal reference section) for the Hawthorne Group. The core Hawthorne 1 (W-11486) was taken at the type locality of the Hawthorne (after Pirkle, 1956, p. 200) in SW¼, NE¼, Sec. 31, T10S, R22E in Alachua County, Florida. The Hawthorne Group occurs in the interval 4.5 feet to 135 feet in the reference core.

Sections of the Hawthorne discussed by Dall (1892) that are still locatable and, therefore, may serve as parastratotypes (supplementary stratotypes used in the original definition by the original author to aid in elucidating the holostratotype) include the section exposed in Devil's Millhopper near Gainesville, Florida, and the section of the Hawthorne exposed on the Suwannee River at White Springs in Columbia and Hamilton Counties, Florida. Other Hawthorne sections mentioned or described by Dall (1892) are either covered now or the directions to the sites are too vague for the sections to be located with certainty.

Other reference sections have been promoted by workers over the years. The two most commonly cited are the exposures of the Hawthorne in the lime sinks called Devil's Millhopper at Gainesville and Brooks Sink in Bradford County. Pirkle and others (1965, p. 10-14) and Scott (1982, p. 137-146) referred to Devil's Millhopper as a "cotype locality". As noted above, the concept of a "cotype locality" has no validity in North American stratigraphic terminology. However, Devil's Millhopper was cited by Dall (1892, p. 108) and, therefore, can be considered a parastratotype and reference locality for the Hawthorne Group. In addition, the Florida Geological Survey core Milhopper 1 (W-14641), taken at Devil's Millhopper and designated a "cotype" core (Scott, 1982), is proposed herein as a reference section and hypostratotype (a stratotype designated to extend knowledge of the unit to other geological areas or to other facies; also called a reference section) of the Hawthorne Group.

The section exposed at Brooks Sink in Bradford County, Florida, although evidently known to the early authors (Sellards, 1909, p. 240), was not generally cited until the description of the exposure by Pirkle (1956, p. 207-215). Later, Puri and Vernon (1964, p. 146-148), Pirkle and others

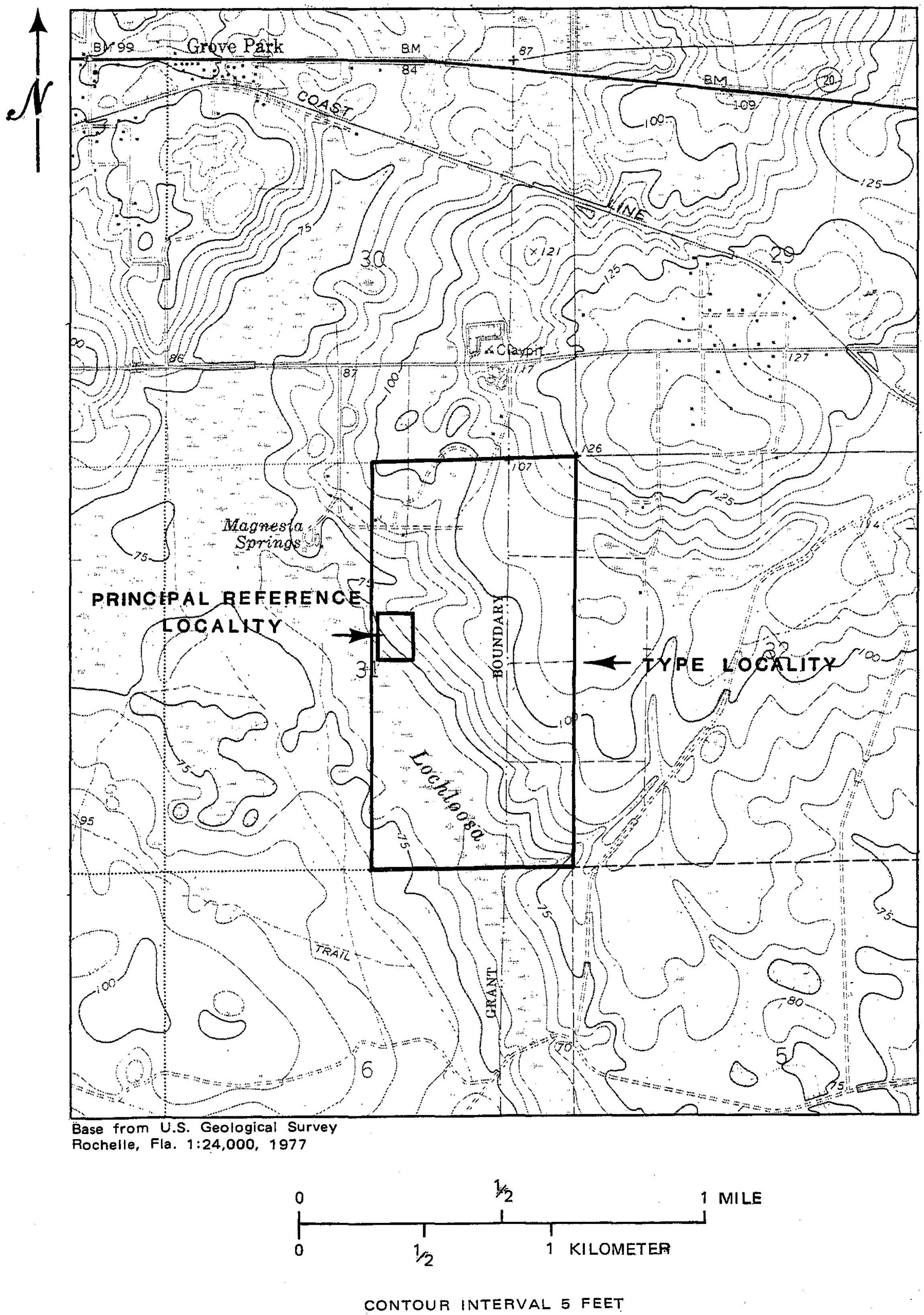


Figure 12. The type locality of the Hawthorne Group.

(1965, p. 15-19), and Scott (1982, p. 137-146) referred to Brooks Sink as a "cotype locality". It is proposed herein that the Brooks Sink section of the Hawthorne, and the core Varnes 1 (W-14280), taken near Brooks Sink (Scott, 1982), also serve as reference localities and hypostratotypes of the Hawthorne Groups.

All of these various sections of the Hawthorne Group in Alachua and Bradford Counties, Florida, are not lithologically representative of the Hawthorne Group in Georgia. However, exposures in the bluffs along the Savannah River from Tiger Leap Bluff in Screven County, to Old Wood Landing in central Effingham County, are lithologically representative of the eastern Georgia Hawthorne Group. Therefore, it is proposed herein that those sections of the Hawthorne Group exposed along the Savannah River in Georgia serve as a composite hypostratotype of the group for eastern Georgia (Fig. 3).

Lithology

The lithology of the Hawthorne Group is dominantly sand and clay. Subordinate lithic components of the Hawthorne Group include dolomite; dolostone; calcite; limestone; phosphorite; phosphate; silica in the forms of claystone (opal-cristobalite), chert, and siliceous microfossils; feldspar; heavy minerals; carbonaceous material and lignite; zeolites; and fossils. Locally, or in beds and lenses, dolostone, limestone, phosphorite, clay, or claystone constitute the dominant lithologies.

The quartz sand component of the Hawthorne Group generally dominates the clay component, but beds or lenses of relatively pure sand are rare in the Hawthorne Group. The sand of the Hawthorne is most commonly fine-grained and well-sorted.

The Hawthorne Group is characteristically argillaceous (see Weaver and Beck, 1977), and the clay occurs in all proportions to the sand. Beds and lenses of clay and sandy clay are common in the Hawthorne, and two members, the Dogtown Clay and Berryville Clay Members, consist principally of clay. Most commonly, however, the clay is interstitial to the sand, and the lithology of the sediment ranges from slightly argillaceous sand to sandy clay. The clay mineral suite of the Hawthorne Group consists of smectite (montmorillonite), illite, palygorskite, sepiolite, and kaolinite (Gremillion, 1965; Weaver and Beck, 1977; Hetrick and Friddell, 1984).

The carbonate content of the Hawthorne Group is variable (also see Weaver and Beck, 1977), being absent in some units and in some sections, and dominating the lithologies of some units in other sections. The most widely occurring and characteristic carbonate mineral of the Hawthorne Group in Georgia is dolomite. Calcite, although locally conspicuous and prominent, is not generally common in the Hawthorne Group in Georgia. Calcite constitutes the greatest proportion of the carbonate in the Hawthorne Group in the Savannah River area and in the continental shelf area. It is characteristic of the Tiger Leap Member of the Parachucla Formation and of the Torreya Formation, and it is locally prominent in the Porters Landing member of the Parachucla Formation and in the Charlton Member of the Coosawhatchie Formation. In all other units and in all other areas in Georgia, dolomite is the characteristic carbonate mineral of the Hawthorne Group.

The carbonate content of the Hawthorne Group generally increases southward across Georgia into Florida, where it is conspicuous in most subdivisions of the Hawthorne. The carbonate content of the Hawthorne also appears to increase seaward in Georgia, but this increase is not as noticeable as the increase in a southward direction. In addition, the dolomite content and proportion generally increase southward (with the exception of the Torreya Formation), and the calcite content tends to increase seaward so that the dolomite content is minor or absent on the continental shelf.

Phosphate is one of the most characteristic lithic components of the Hawthorne Group (also see Weaver and Beck, 1977), and the phosphate content of the group stands in sharp contrast to the nonphosphatic underlying, overlying, and adjacent formations and groups. The phosphate content of the Hawthorne Group is highest in the coastal area of Georgia and on the eastern margins of the Florida Platform. In general, the phosphate content decreases westward and upsection. It is very low or absent in southwestern Georgia and in the upper part of the Hawthorne in the central Georgia Coastal Plain. All of the known phosphate in Georgia consists of small, rounded, black, brown, amber, gray to buff grains or pellets of apatite. There are no known occurrences of hard rock phosphate or pebble phosphate in Georgia.

Siliceous sediments are also characteristic of the Hawthorne Group. Silica is most common in the form of siliceous claystone (opal-cristobalite) and siliceous microfossil-rich (diatoms, radiolarians, and silicoflagellates) sediments. Chert also occurs but is less common, and petrified wood occurs locally and rarely.

Stratigraphic Relationships

The Hawthorne Group underlies perhaps three-quarters of the Coastal Plain of Georgia and is, therefore, one of the most widespread lithostratigraphic units in the state. The western limit of the Hawthorne Group in southwestern Georgia is the Pelham Escarpment (Fig. 13). Farther north, the western limit approximates the Ocmulgee River although Hawthorne outliers occur west of the Ocmulgee River as far north as the vicinity of Hawkinsville in Pulaski County. Its northern limit in the subsurface approximates a trend eastward across Laurens County, central Emanuel County, and Screven County. The northern limit of the Hawthorne Group in Georgia represents a broad and ambiguous zone of facies change, in the subsurface, into the marginal marine to nonmarine Altamaha Formation. The Hawthorne Group extends northward into South Carolina and southward into

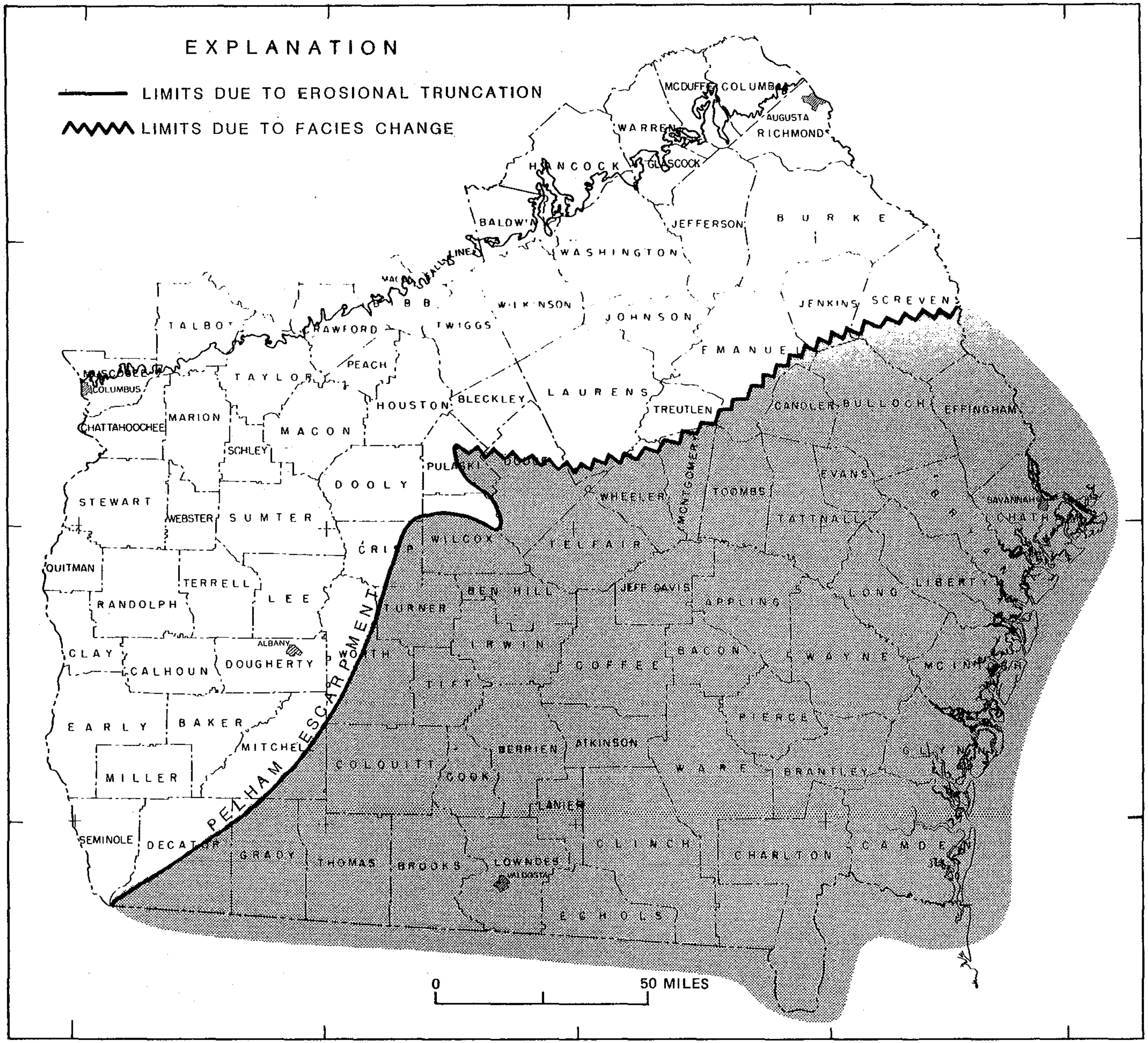


Figure 13. The areal distribution (outcrop and subcrop) of the Hawthorne Group in Georgia.

the eastern panhandle and peninsula of Florida, and it underlies the continental shelf of Georgia.

In most places, the Hawthorne Group overlies the Suwannee Limestone disconformably in Georgia. In southwestern Georgia, however, the Hawthorne Group paraconformably overlies the Chattahoochee Formation (Fig. 10) and in the region north of the occurrence of the Chattahoochee Formation, and west of the Gulf Trough, the Hawthorne Group disconformably overlies an unnamed, Suwannee-equivalent limestone. In Camden and parts of Glynn and Charlton Counties in the southeastern corner of the state, the Hawthorne Group disconformably overlies the Ocala Group. In Chatham County, the Hawthorne Group disconformably overlies a sandy stratigraphic equivalent of the Suwannee Limestone (Pl. 2), the Lazaretto Creek formation (Huddlestun, in review). On the continental shelf, the Hawthorne Group disconformably overlies the Cooper Formation.

The Hawthorne Group is overlain by several formations in Georgia (Pl. 1). Throughout most of its area of occurrence in Georgia, the Hawthorne Group is comformably overlain by the Altamaha Formation (Figs. 10 and 11). In the coastal area of eastern Georgia it is variously overlain disconformably by the Raysor Formation, Raysor-equivalent sand, Cypresshead Formation, or Satilla Formation. In southwestern Georgia, the Hawthorne Group is disconformably overlain by the Miccosukee Formation.

The Suwannee Limestone and other Oligocene carbonates are distinguished from the Hawthorne Group in consisting of relatively clastic-free, variably fossiliferous limestone and, less commonly, clastic-free dolostone whereas the Hawthorne Group consists of predominantly argillaceous sand and sandy clay. Where the basal Hawthorne consists predominantly of limestone and dolostone, the Hawthorne carbonates are sandy and variably argillaceous with some interbedded sand or clay. In southwestern Georgia, the Hawthorne is distinguished from the Chattahoochee Formation in consisting largely of finely sandy and variably argillaceous limestone, and argillaceous fine sand and finely sandy clay whereas the Chattahoochee Formation consists of finely sandy dolostone. Under the continental shelf of eastern Georgia, the Hawthorne Group is distinguished from the underlying Cooper Formation in consisting of variably calcareous clay whereas the Cooper Formation consists of massive and structureless, microfossiliferous, argillaceous, finely calcarenitic limestone.

The Hawthorne Group grades laterally updip or landward (and locally upsection) into the Altamaha Formation. The Altamaha Formation consists of variably siliceous, kaolinitic clays and kaolinitic claystones and argillaceous, pebbly, feldspathic, poorly sorted sands and sandstones that are devoid of phosphates, carbonates, high-magnesium clays, and fossils. The Hawthorne deposits, on the other hand, generally consist of variably phosphatic, variably dolomitic or calcareous, sporadically siliceous, fossiliferous to nonfossiliferous, argillaceous, well-sorted sand with variably magnesium-rich clays.

In southwestern Georgia and in eastern Georgia, the Hawthorne Group is overlain by the Miccosukee Formation and Cypresshead Formation respectively. The Miccosukee and Cypresshead Formations have similar lithologies and can be characterized as generally being nonphosphatic, noncalcareous, fine-grained sand with thin clay beds and laminae, and local occurrences of prominently crossbedded, medium-to coarse-grained, pebbly sand. The sand beds of the Miccosukee and Cypresshead are typically deficient in clay whereas the sand beds in the Hawthorne typically contain significant quantities of interstitial clay.

Locally in eastern Georgia, the Raysor Formation and Raysor-equivalent sand overlies Hawthorne Group deposits. The Raysor Formation is a variably fossiliferous and shelly, argillaceous, very calcareous fine sand to finely sandy limestone and the Raysor-equivalent sand is a fossiliferous, shelly, calcareous sand. Where the Satilla Formation directly overlies the Hawthorne Group, the Satilla consists of argillaceous fine sands with scattered occurrences of shells and other fossils, sandy clay, and clay beds with local occurrences of fossil oysters *(Crassostrea virginica)*. None of the above Plio-Pleistocene formations contain appreciable phosphate, dolomite, or magnesium-rich clay minerals.

The thickness distribution of the Hawthorne has been described by Weaver and Beck (1977). The greatest thicknesses of the Hawthorne Group in Georgia are found in the Southeast Georgia Embayment and in the Gulf Trough. It is thinnest on the crests of relatively stable or positive features such as the Florida Platform in southern Georgia and the Beaufort Arch in eastern Georgia. The average thickness of the Hawthorne Group in the Southeast Georgia Embayment is approximately 600 feet (183 m). In the Gulf Trough, however, the thickness distribution of the Group is variable, ranging from more than 700 feet (213 m) to as little as 200 feet (61 m). Part of this variation results from a real difference in the thickness of the Miocene deposits. In the southwestern part of the state, however, the Hawthorne Group is thinner because the lower and thickest part of the group grades laterally into the Chattahoochee Formation, which has never been considered to be a part of the Hawthorne Group. Elsewhere in Georgia, the Hawthorne Group is considerably thinner. In the Savannah River area, the thickness of the Hawthorne Group ranges from 0 feet in northern Screven County where it pinches out, to 215 feet (66 m) in southern Effingham County in the Ridgeland trough, to less than 65 feet (20 m) in coastal Chatham County on the Beaufort arch.

The environment of deposition of the Hawthorne Group was marine, continental shelf. The water-depth of Hawthorne deposits ranged from near sealevel with brackish-water faunas (based on the local abundance of the foraminifera *Ammonia beccarii, Elphidium* spp. and *Buliminella elegantissima*), to at least middle neritic with diverse, open-marine faunas (including relatively abundant and diverse planktonic foraminifera). The environment of the continental shelf water-mass was unique for the Georgia-Florida region during Miocene and early Pliocene time in that phosphates, magnesium-rich clays, and dolomitic sediments are characteristic of, and siliceous microfossils and siliceous sediments are locally abundant in, Hawthorne deposits.

The coastal configuration during the deposition of the Hawthorne Group was apparently different than it was during much of the Tertiary in Georgia. Sandy coastal/beach-type deposits (lithologically and genetically similar to Barnwell and Citronelle-Miccosukee-Cypresshead-type deposits) are absent in the Hawthorne Group. Because of the high clay content of the Hawthorne Group and the equivalent Altamaha Formation, it is probable that the coastal area was muddy and swampy and without well-defined barrier island systems.

Age

The time span of the Hawthorne Group in Georgia is from earliest Miocene (early Aquitanian Stage) through the early Pliocene (Zanclean Stage) (Pl. 1). Those stages identified in Georgia include the Aquitanian, Burdigalian, Serravallian, and Zanclean. The Langhian and Tortonian Stages have been identified to date on the continental shelf but not on the mainland in Georgia, and the Messinian Stage has not yet been identified with certainty anywhere in the southeastern United States. The specific ages of the various components of the Hawthorne Group will be discussed more fully in the following descriptions of each formation and member.

PARACHUCLA FORMATION OF THE HAWTHORNE GROUP (reintroduced and revised)

Definition

The Parachucla Formation of Sloan (1908, p. 273-274, 435, 465-466), referred to by him variously as Parachucla phase, Parachucla marl, Parachucla shale, Parachucla formation (p. 466), and Parachucla series (p. 327), is reintroduced herein as the lowest and oldest described formation of the Hawthorne Group in Georgia. The Parachucla of Sloan (1908) is expanded and revised here to include both the Combahee phase (in Georgia) of Sloan (1908, p. 274, 465-466) and the Parachucla marl and shale. The reasons for combining the Georgia Combahee and Parachucla into one formation are that (1) they are closely related lithologically, genetically, and temporally, and (2), they are lithologically more similar to each other than they are to the other overlying formations of the Hawthorne Group. The Parachucla of Sloan (1908) was never adopted by other workers, but was abandoned immediately after the name was proposed. Therefore, the Parachucla of Sloan (1908) can not be considered to ever have been an accepted or "formal" stratigraphic unit. Because Sloan (1908) appears to have used the name Parachucla more in a lithostratigraphic sense (marl, shale, and formation), because the name Combahee as Sloan (1908) applied it in Georgia is lithostratigraphically inconsistent with the Combahee that he described elsewhere from the type area in South Carolina, and because the deposits that comprise the Combahee and Parachucla of Sloan (1908) in Georgia constitute a lithostratigraphic unit of formation rank, the expansion of the name Parachucla to encompass both the Combahee and Parachucla of Sloan (1908) is justified. Moreover, in recognition and in honor of Earle Sloan's contributions to the Miocene of Georgia, I wish to retain the lithostratigraphic ranking of his name Parachucla as he apparently intended it.

Veatch and Stephenson (1911, p. 343) abandoned the names Parachucla and Combahee in Georgia because they considered these units to be "stratigraphic representatives of the Alum Bluff formation." However, Veatch and Stephenson (1911) were not consistent in their transferral of the Parachucla to the Alum Bluff in the type area of the Parachucla. At Sloan's main reference locality for the Parachucla at Porters Landing on the Savannah River, Veatch and Stephenson (1911, p. 371-372) transferred only the Parachucla marl of Sloan (1908, 273-274) to the Alum Bluff Formation. They included the overlying Parachucla shale in the Marks Head Formation. Cooke (1936, 1943) abandoned both the names Alum Bluff and Marks Head and replaced them with the name Hawthorne.

Elsewhere in Georgia, deposits included in the Parachucla Formation of the present report have been referred to as Tampa (Fortson and Navarre, 1959; Counts and Donsky, 1963; Herrick, 1961, p. 17-20; also see Furlow, 1969), Hawthorne Formation (MacNeil, 1947a, 1947b; Georgia Geological Survey, 1976; Weaver and Beck, 1977), and Miocene (undifferentiated) (Herrick, 1961).

The Parachucla Formation is divided into two formal members in Georgia: the Tiger Leap Member (= Combahee of Sloan, 1908) and the overlying Porters Landing member (= Parachucla marl and shale of Sloan, 1908).

Type Section

The name Parachucla was taken from the site of a boat landing on the Savannah River in Hampton County, South Carolina, that around the turn of the century was called Parachucla Landing. The name Parachucla has disappeared from local usage, and the current name of the boat landing is Stokes Ferry Landing. Stokes Ferry Landing is approximately 4.5 airline miles (7.3 km) downriver from Porters Landing in Georgia. Because Stokes Ferry Landing is located in the middle of the Savannah River Floodplain, there are no exposures of pre-Quaternary deposits at the landing.

Sloan (1908) did not explicitly designate a type locality for the Parachucla. However, it is clear that he considered the section exposed at Porters Landing the most significant and representative section he knew of: "The important geological relations of this locality were discovered by the writer, May, 1904; subsequently studied in detail in conjunction with Dr. Burns, of the Smithsonian Inst., June, 1904" (Sloan, 1908, p. 273). Because of the importance placed on the locality by Sloan (1908), and its proximity to the old site of Parachucla Landing, I designate Porters Landing on the Savannah River the principal reference locality of the Parachucla Formation (Fig. 14). Porters Landing is located in Effingham County, 2.7 miles (4.3 km) southeast of the Screven-Effingham County line on the Savannah River, and 6.5 miles (10.5 km) east-northeast of the community of Kildare in northern Effingham County (see also Sloan, 1908, p. 273-274; Cooke, 1936, p. 106-107). The Parachucla Formation is exposed in the lower parts of the bluffs at Porters Landing, from river level to approximately 20 feet (6 m) above mean-low-water. These sections, exposed immediately upriver and downriver from the boat landing, are herein designated the lectostratotype (unit-stratotype and principal reference section) and boundary-stratotype for the upper boundary of the formation. The core Effingham 10 (GGS-3108) is herein designated a reference section and locality for the Parachucla Formation (Fig. 3). The core interval from 27 feet to 147 feet is a hypostratotype (reference section) and lower boundary-stratotype for the formation. The site of the Effingham 10 (GGS-3108) core is 3.6 miles (5.8 km) west of Porters Landing on the shoulder of a paved county road 0.4 mile (0.65) south of the Effingham-Screven County line.

Lithology

The Parachucla Formation consists of sand, clay, calcite, and dolomite in varying admixtures. Sand is the primary lithic component of the formation, but limestone or dolostone can locally dominate the lithology of the formation. Clay, although prominent, is not known to dominate the lithology of the formation at any site. Other lithic components of the Parachucla Formation include fossil shells (both calcitic and aragonitic), phosphate, siliceous claystone and chert, mica, feldspar, zeolite, and lignitic flecks. Petrified wood occurs rarely in the type area.

The quartz sand typically is fine- to medium-grained and is well-sorted. In updip sections, however, feldspathic coarse-grained sand with pebbles occurs locally or in scattered beds. These feldspathic coarse-grained sands probably represent lithologies intermediate from Parachucla to Altamaha. Where sand occurs in discrete beds, the sand is never pure but is always argillaceous, calcareous, or dolomitic.

Clay is mostly interstitial in the sand, limestone, or dolostone. The occurrence of clay in discrete beds is characteristic of the Porters Landing Member, but rare in the Tiger Leap Member.

In the type area, the clay mineral fraction of the Parachucla Formation is dominated by montmorillonite whereas illite is commonly present in trace amounts, and palygorskite and sepiolite occur sporadically (see Weaver and Beck, 1977, p. 57, Fig. 20 for clay mineral distribution in the lower part of the Hawthorne section in the Savannah River area; also see Hetrick and Friddell, 1984). Both palygorskite and sepiolite are more prevalent in the clay fraction of the formation in the subsurface of the coastal area and in the central and southern Georgia Coastal Plain. Kaolinite occurs sporadically and only in trace amounts in the Parachucla Formation in the type area.

The Parachucla Formation is the only widespread formation of the Hawthorne Group in Georgia in which carbonate is a consistently occurring major component of the lithology. In the Savannah River area in Georgia, the carbonate occurs in moderate amounts as interstitial calcareous material, as fossil shells and other calcareous biogenic debris, and as limestone. The carbonate content increases both in a seaward direction to the southeast, and into the Southeast Georgia embayment to the south and southwest. In the southern coastal area of Georgia and in the Gulf Trough, limestone and dolostone constitute the greatest proportion of the Parachucla Formation. In general, the carbonate content is highest in the Tiger Leap Member, or, where the formation is undifferentiated, near the base of the formation. In the Savannah River area, calcite is the normal carbonate mineral and dolomite is rare or absent. Farther south, however, in the Southeast Georgia Embayment and in the Gulf Trough, dolomite and dolostone are also significant. In the southern coastal area of Georgia and in the southern part of the Gulf Trough, dolomite and dolostone are typical whereas calcite and limestone are rarely encountered.

Fossil shells, other than molds and casts, are not generally common in the Parachucla Formation in Georgia. However, fossil shells are common and characteristic in the lower part of the formation in a broad band from Savannah River in southern Screven and northern Effingham Counties, southwestward to the vicinity of Jeff Davis and Wheeler Counties. This band of abundant fossil shells continues southwestward to Berrien County as a richly fossiliferous, moldic limestone.

The Parachucla Formation is variably phosphatic, but it is less phosphatic than the overlying formations of the Hawthorne Group in Georgia. Although locally conspicuous, phosphate is absent from specific beds or stratigraphic intervals in the formation. Similarly, the Parachucla Formation contains scattered occurrences of siliceous claystone and chert. However, siliceous sediments are generally rare compared with the sediments of the overlying formations of the Hawthorne Group.

The Parachucla Formation in the Savannah River area is distinguished from the overlying Marks Head Formation in being less phosphatic and siliceous, in being more calcareous, and in having clays of differing physical properties. Except for the uppermost part of the formation, the Parachucla is considerably more calcerous and fossiliferous than

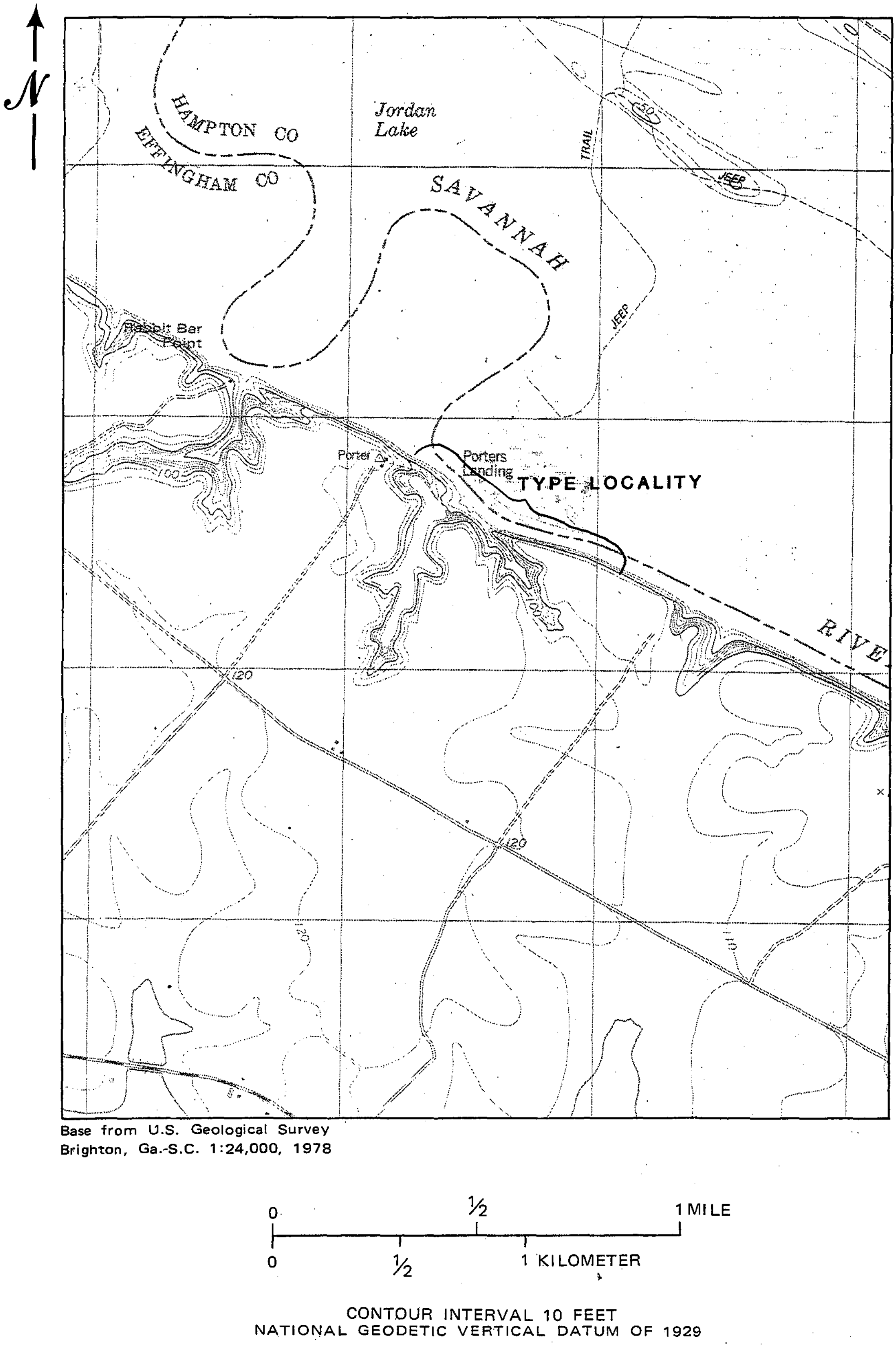


Figure 14. The type locality of the Parachucla Formation and the Porters Landing Member of the Parachucla Formation.

the Marks Head Formation. The Marks Head, on the other hand, is more dolomitic; fossiliferous beds, though present, are rare. The Parachucla clays are generally bluish-gray and are relatively heavy and dense due to their high montmorillonite content. In contrast, Marks Head clays are typically pale greenish-gray and are light-weight due to their high content of palygorskite.

Stratigraphic Relationships

The Parachucla Formation underlies the eastern Coastal Plain of Georgia and extends northward into South Carolina, southward into northeastern Florida, and southwestward in the Gulf Trough (Fig.15). Its northern and western limits are defined by facies change into the lower part of the Altamaha Formation. In the north, this facies change extends from southern Screven County westward across central Emanuel County, and then southwestward into northern Montgomery and Wheeler Counties. There appears to be a broad "embayment" (see Fig. 15) where the updip limit of the Parachucla Formation bends in a more northwesterly direction into Dodge and Pulaski Counties. South of this area, the western limits of the Parachucla Formation trend across Wilcox, Turner, and Worth Counties. The Parachucla Formation grades laterally into the Chattahoochee formation on the flanks of the Gulf Trough in Colquitt County, but appears to extend into Florida within the Gulf Trough (Fig. 13). South of Colquitt County, the western limits of the Parachucla appear to coincide with the central part of the Florida Platform in eastern Brooks County. Limited stratigraphic information from this area suggests that the Parachucla Formation grades laterally westward into the Chattahoochee Formation in Brooks County.

The Parachucla Formation underlies the northern coastal area of Georgia. In the southern part of the coastal area, however, the Parachucla stratigraphic interval is represented by dolomitic clays and argillaceous dolostones that differ lithologically from the Parachucla Formation and which are most lithologically consistent with the Cooper Formation that occurs under the continental shelf of Georgia (Fig. 11).

The Parachucla Formation generally overlies the Suwannee Limestone disconformably in Georgia. However, in Chatham County it also disconformably overlies the Lazaretto Creek Formation (Huddlestun, in press), and in the southern coastal area, in Camden and parts of Glynn and Charlton Counties, it disconformably overlies the Crystal River Formation of the Ocala Group. In the Gulf Trough in Coffee and Berrien Counties, the Parachucla Formation disconformably overlies Suwannee-equivalent limestone.

The Marks Head Formation and stratigraphic equivalents disconformably or paraconformably overlie the Parachucla Formation over most of their area of occurrence in Georgia (Figs. 10, 11). Only in northernmost Effingham and southern Screven Counties is the Parachucla Formation known to be overlain by a younger formation, in this case the upper Pliocene Cypresshead Formation (Pl. 2). In the Gulf Trough, the Parachucla Formation is disconformably overlain by undifferentiated Hawthorne sands and clays that appear to be correlative with the Marks Head Formation.

The Parachucla Formation is distinguished from the stratigraphically equivalent Chattahoochee Formation of southwestern Georgia in consisting of sandy, argillaceous, variably phosphatic limestone and dolostone, or phosphatic, variably calcareous or dolomitic, argillaceous sand or sandy clay whereas the Chattahoochee Formation consists largely of finely sandy, variably argillaceous dolostone. The Parachucla Formation is distinguished from the stratigraphically equivalent upper part of the Cooper Formation, under the continental shelf of Georgia, in consisting of variably sandy and argillaceous, phosphatic limestone or dolostone, or variably calcareous, dolomitic, and phosphatic, argillaceous sand or sandy clay whereas the Cooper Formation consists of argillaceous, microfossiliferous, finely calcarenitic limestone.

The underlying Oligocene carbonates, including the Suwannee Limestone, consist predominantly of relatively pure, variably fossiliferous limestone with minor dolostone. The Oligocene Lazaretto Creek Formation in coastal Georgia is distinguished from the Parachucla in consisting of calcarenitic sand or sandy calcarenitic limestone that is locally phosphatic. Where the Parachucla Formation locally overlies the Crystal River Formation, the Crystal River is distinguished in consisting of relatively pure, bryozoan-rich limestone with variable concentrations of larger foraminifera.

In eastern Georgia, the Parachucla Formation is distinguished from the overlying Marks Head Formation in being less phosphatic, siliceous, and dolomitic, and in being more calcareous and fossiliferous. The Parachucla sands and clays are typically bluish-gray to dark bluish-gray, and the Marks Head sands and clays are typically pale greenish gray. The carbonate content of the Parachula Formation is relatively high and is consistently present within the Parachucla section whereas the carbonate content of the Marks Head Formation is low and carbonate is commonly absent. The characteristic carbonate of the Parachucla Formation is calcite whereas that of the Marks Head Formation is dolomite. However, in southwestern Georgia, dolomite is also characteristic of the Parachucla Formation.

In the Gulf Trough, Marks Head-equivalent deposits are lithologically heterogeneous but are typically lacking in carbonate. The underlying Parachucla Formation, on the other hand, is consistently calcareous or dolomitic, and is variably fossiliferous.

The greatest known thickness of the Parachucla Formation in its type area is 120 feet (37 m) in the reference core Effingham 10 (GGS-3108) in northernmost Effingham County. The Parachucla thins northwestward, up the dip, by facies change into the Altamaha Formation in Screven County. It also thins gradually down the dip from northern

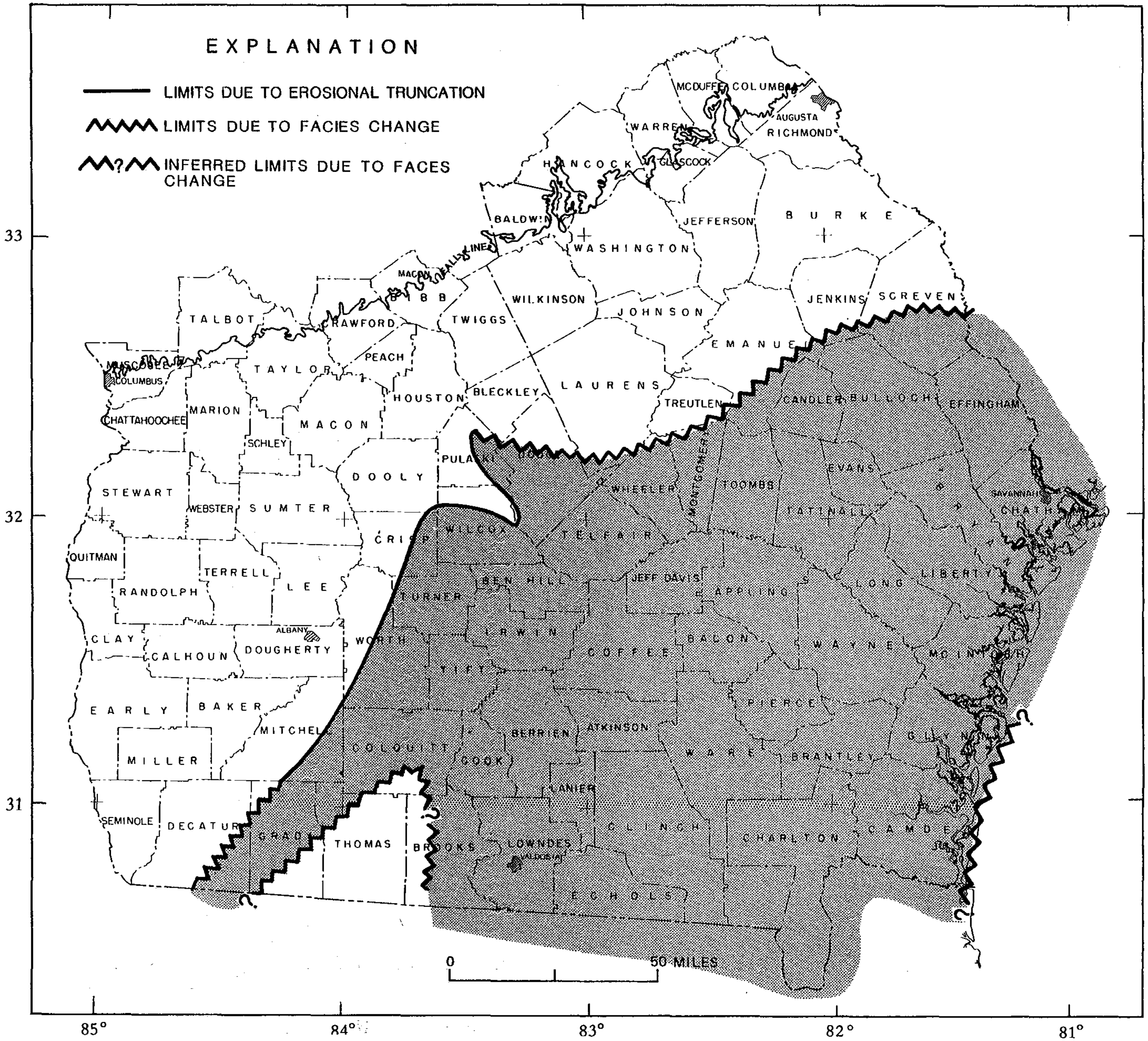


Figure 15. The areal distribution (outcrop and subcrop) of the Parachucla Formation.

Effingham County to southern Effingham County where locally it is absent due to pinchout (Pl. 2). In Chatham and southern Effingham Counties, the Parachucla Formation ranges from 0 to 17 feet (0 to 8 m) thick but averages about 10 feet (3 m) thick. In the subsurface of the coastal area of the Southeast Georgia Embayment, the Parachucla Formation is 177 feet (54 m) thick in the interval 453 feet to approximately 630 feet in the core Wayne 2 (GGS-3512) from Wayne County (Pl. 3). The stratigraphic equivalent of the Parachucla is 114 feet (35 m) thick in the interval 410 feet to 524 feet in the core Cumberland Island 1 (GGS-3426) from Cumberland Island in Camden County. In the Gulf Trough in southern Georgia, the Parachucla Formation is 309 feet (94 m) thick in the interval 258 feet to 567 feet in the core Coffee 4 (GGS-3541) in northern Coffee County; 280 feet (85 m) thick in the interval 324 feet to 604 feet in the core Berrien 10 (GGS-3542) in northern Berrien County; and at least 325 feet (99 m) thick in the interval 380 feet to total depth at 705 feet in the core Colquitt 3 (GGS-3179) in northeastern Colquitt County.

The environment of deposition of the Parachucla Formation was marine, continental shelf, inner to middle neritic.

Age

The age of the Parachucla Formation is early Miocene (Aquitanian). The planktonic foraminiferal assemblages from the Tiger Leap Member and the Porters Landing Member are significantly different in appearance, yet can not be separated by more than one planktonic foraminiferal zone. The Tiger Leap Member is assigned to Zone N4 of Blow (1969), which is the *Globorotalia kugleri* Zone of Bolli (1957) and also of Stainforth and others (1975). This age assignment is based on the occurrence of the following species:

Globorotalia pseudokugleri
Globigerina angulisuturalis
Globigerinoides primordius
Globoquadrina dehiscens
Globigerinita incrusta

Globorotalia pseudokugleri, G. angulisuturalis, and *G. dehiscens* are absent from the planktonic foraminiferal assemblage of the Porters Landing Member. However, the common occurrence and large size of *Globigerinoides primordius* in addition to the absence of species characteristic of younger zones suggests that the Porters Landing Member is possibly as old as late Zone N4, but no younger than Zone N5 (*Catapsydrax dissimilis* Zone of Bolli, 1957, and of Stainforth and others, 1975) (Pl. 1).

TIGER LEAP MEMBER OF THE PARACHUCLA FORMATION (new name)

Definition

The Tiger Leap Member is herein proposed as the lower member of the Parachucla Formation. It corresponds to the Combahee phase of Sloan (1908, p. 274, 465-466) as he described it along the Savannah River in Georgia. The name Combahee is not reintroduced in this report because Sloan described the sediments of the Combahee phase at Broxton Ford and Tobys Bluff on the Salkehatchie River in Hampton County, South Carolina (i.e., the critical reference localities for the Combahee deposits), as shales with fuller's earth and associated glauconite (Sloan, 1908, p. 327-328, 345, 435, 465). This lithology is inconsistent with Tiger Leap lithology as defined in this report. I have visited the approximate locations of Broxton Ford and Tobys Bluff and have not found any exposures along the Salkehatchie River. Therefore, the identity of the Combahee in its type area and the stratigraphic relationship of the type Combahee with the Tiger Leap Member are uncertain at this time.

The Tiger Leap Member of the Parachucla Formation corresponds to the lower part of the Alum Bluff Formation of Veatch and Stephenson (1911, p. 361-362, 370, 172) along the Savannah River in Screven and Effingham Counties. Cooke (1936, 1943), however, included the Tiger Leap Member of this report in the Hawthorne Formation.

Type Section

The name Tiger Leap is taken from Tiger Leap Bluff on the Savannah River in southern Screven County, Georgia. The type locality of the Tiger Leap Member is herein designated as the southern end of Tiger Leap Bluff, and the type section, or unit-stratotype (holostratotype) is that section of the Tiger Leap Member exposed at Tiger Leap Bluff (Fig. 16). The unweathered outcrop of the member currently exposed at Tiger Leap Bluff is only about 7 feet (2 m) thick and is the upper, noncalcareous part of the member. To my knowledge, however, this exposure is the best outcropping section of the member. Tiger Leap Bluff is located 0.75 mile (1.2 km) southeast of Blue Springs Landing on the Savannah River, and is 2.25 miles (3.6 km) northwest of the Screven-Effingham county line. A complete section of the Tiger Leap Member is present in the core Effingham 10 (GGS-3108), taken 3.2 miles (5 km) south of Tiger Leap Bluff on the shoulder of a paved county road 0.4 mile (0.65 km) south of the Screven-Effingham county line in Effingham County (Fig. 3). The interval 75 feet to 147 feet in the core Effingham 10 (GGS-3108) is herein designated as a reference section and parastratotype of the Tiger Leap Member. All of the characteristic lithologies of the Tiger Leap Member are present in the Effingham 10 core, and the core recovery of the member is approximately 85%.

Lithology

The Tiger Leap Member is a lithologically heterogeneous unit. However, it is the only stratigraphic unit in the Hawthorne Group in Georgia in which carbonate (calcite and dolomite, limestone and dolostone) consistently constitutes a major or significant part of the lithology. In its type area in southern Screven and northern Effingham Counties, Geor-

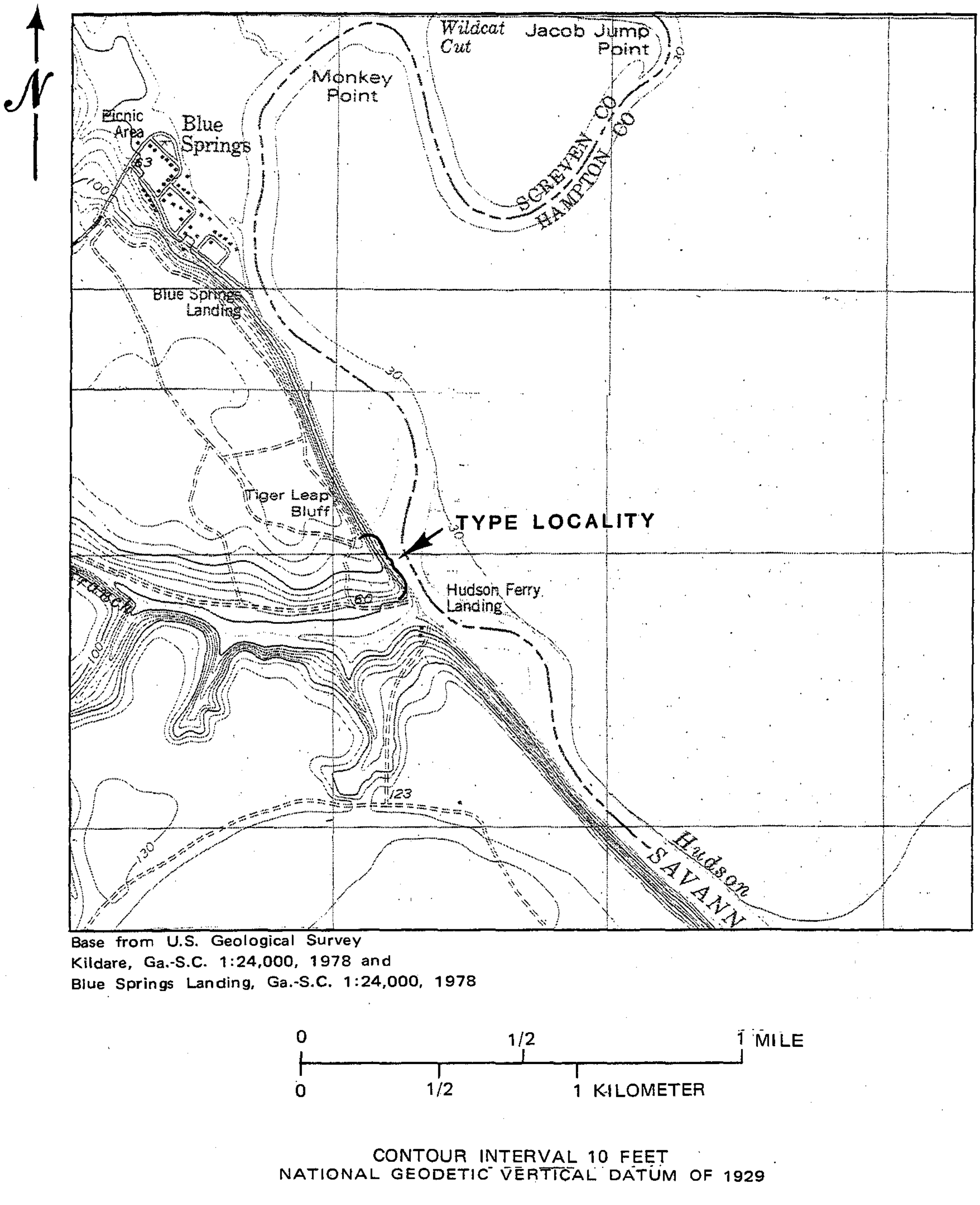


Figure 16. The type locality of the Tiger Leap Member of the Parachucla Formation.

gia, the Tiger Leap Member consists of limestone; calcareous shelly sand (shell bed); calcareous, microfossiliferous sand; noncalcareous, argillaceous sand; and noncalcareous, pebbly, prominently bedded, feldspathic sand. In addition to the above, lithologies that have been observed in the Tiger Leap Member elsewhere in the state includes dolostone and phosphatic sand and sandstone. Argillaceous, fine-grained, well-sorted sand that is variably phosphatic, micaceous, calcareous, dolomitic, and fossiliferous is the basic lithology of the Tiger Leap Member. Finely sandy limestone and dolostone that are variably fossiliferous, argillaceous, and phosphatic are other prominent lithology types of the Tiger Leap. Locally, limestone, dolostone, or both are the principal lithologies of the Tiger Leap Member. Subordinate lithic components of the member include clay, shells (both calcitic and aragonitic), phosphate, siliceous claystone, feldspar, mica, zeolite, and lignitic flecks. The clay mineral suite of the Tiger Leap is generally dominated by smectite. Palygorskite and sepiolite are prominent components of the clay mineral suite in the southern part of the Georgia Coastal Plain but occur sporadically and in minor amounts in the type area (Hetrick and Friddell, 1984). Illite is a common trace component of the clay mineral suite.

Stratigraphic Relationships

The Tiger Leap Member of the Parachucla Formation underlies most of the eastern Georgia Coastal Plain except for the coastal area (Fig. 17). In the Savannah River area, its northern limits are in the vicinity of Sylvania in Screven County, and its southern limits are in the vicinity of Clyo in Effingham County. The Tiger Leap Member grades laterally northwestward into the Altamaha Formation in Screven County, resulting in gradual thinning and pinch-out at the base of the Miocene section in northern Screven County (Fig. 11; Pl. 1, 2). In northern Effingham County, the Tiger Leap Member thins and pinches out southeastward either due to nondeposition or erosional truncation. Neither the Tiger Leap Member nor a stratigraphically equivalent unit is present in the Savannah River area southeast of the vicinity of Clyo. The shell bed of the Tiger Leap Member is widespread in the Savannah River area and is unique among Hawthorne lithologies in Georgia. The shell bed can be traced at the base of the Miocene deposits as far north as the vicinity of Sylvania in central Screven County (see Herrick, 1961, p. 346-351). Similarly, it can be traced in well-cuttings from the Savannah River area southwestward into Montgomery, Wheeler, and Jeff Davis Counties (also see Herrick, 1961; Weaver and Beck, 1977). Elsewhere in Georgia, the Tiger Leap Member has been identified in Wayne County in the core Wayne 2 (GGS-3512), in Coffee County in the core Coffee 4 (GGS-3541), in Berrien County in the core Berrien 10 (GGS-3542), and in Colquitt County in the core Colquitt 3 (GGS-3179). The Tiger Leap Member, therefore, probably underlies most of the Southeast Georgia Embayment area and the Gulf Trough. The northern limits of the member, based on current subsurface control, extend from Screven County westward through Emanuel County, northern Montgomery County, and into Dodge County. The eastern limits are known only in the Savannah River area. Farther south, the Tiger Leap Member or its stratigraphic equivalent appears to be absent in the coastal area of Georgia. The southern limits of the member are unknown at this time, but the member appears to be absent in the Suwannee River area of northern Florida (Fig. 17).

The Tiger Leap Member of the Parachucla Formation disconformably overlies the Suwannee Limestone and, in the Gulf Trough, it disconformably overlies Suwannee-equivalent limestone. The Tiger Leap Member is paraconformably overlain by the Porters Landing member of the Parachucla Formation (Fig. 11; Pl. 2). Between the Screven-Effingham county line and the vicinity of the Orangeburg Escarpment, the Tiger Leap Member is disconformably overlain by the upper Pliocene Cypresshead Formation, but north of the vicinity of the Orangeburg Escarpment, the Tiger Leap is overlain conformably and gradationally by the Altamaha Formation (Pl. 2).

The Tiger Leap Member of the Parachucla Formation is distinguished from the overlying Porters Landing Member in being consistently more calcareous or dolomitic, and in generally being less argillaceous. The Porters Landing Member generally contains beds of clay. Clay beds are rare in the Tiger Leap Member and are known to occur only in the lower part of the unit.

In the type area, the greatest thickness of the Tiger Leap Member is approximately 75 feet (23 m) in the reference core Effingham 10 (GGS-3108). The Tiger Leap Member thins northward and is approximately 22 feet (7 m) thick in the core Screven 8 (GGS-3198) in south-central Screven County. (Pl. 2). Southeastward from the core Effingham 10 (GGS-3108), the Tiger Leap thins in the subsurface to 40 feet (12 m) thick in the core Effingham 11 (GGS-3109) near Porters Landing, and to 25 feet (7.5 m) thick in the core Effingham 12 (GGS-3110) 3 miles (5 km) north of Clyo. The Tiger Leap Member is 103 feet (31 m) thick in the interval 527 feet to 630 feet in the core Wayne 2 (GGS-3512) in Wayne County; 147 feet (45 m) thick in the interval 420 feet to 567 feet in the core Coffee 4 (GGS-3541) in Coffee County; 215 feet (66 m) thick in the interval 389 feet to 604 feet in the core Berrien 10 (GGS-3542) in Berrien County; and at least 196 feet (60 m) thick in the interval 509 feet to total depth at 705 feet in the core Colquitt 3 (GGS-3179) in Colquitt County.

The environment of deposition of the Tiger Leap Member of the Parachucla Formation was marine, inner neritic continental shelf, and relatively nearshore.

Age

The age of the Tiger Leap Member of the Parachucla Formation is early Miocene (early Aquitanian) (Pl. 1). The

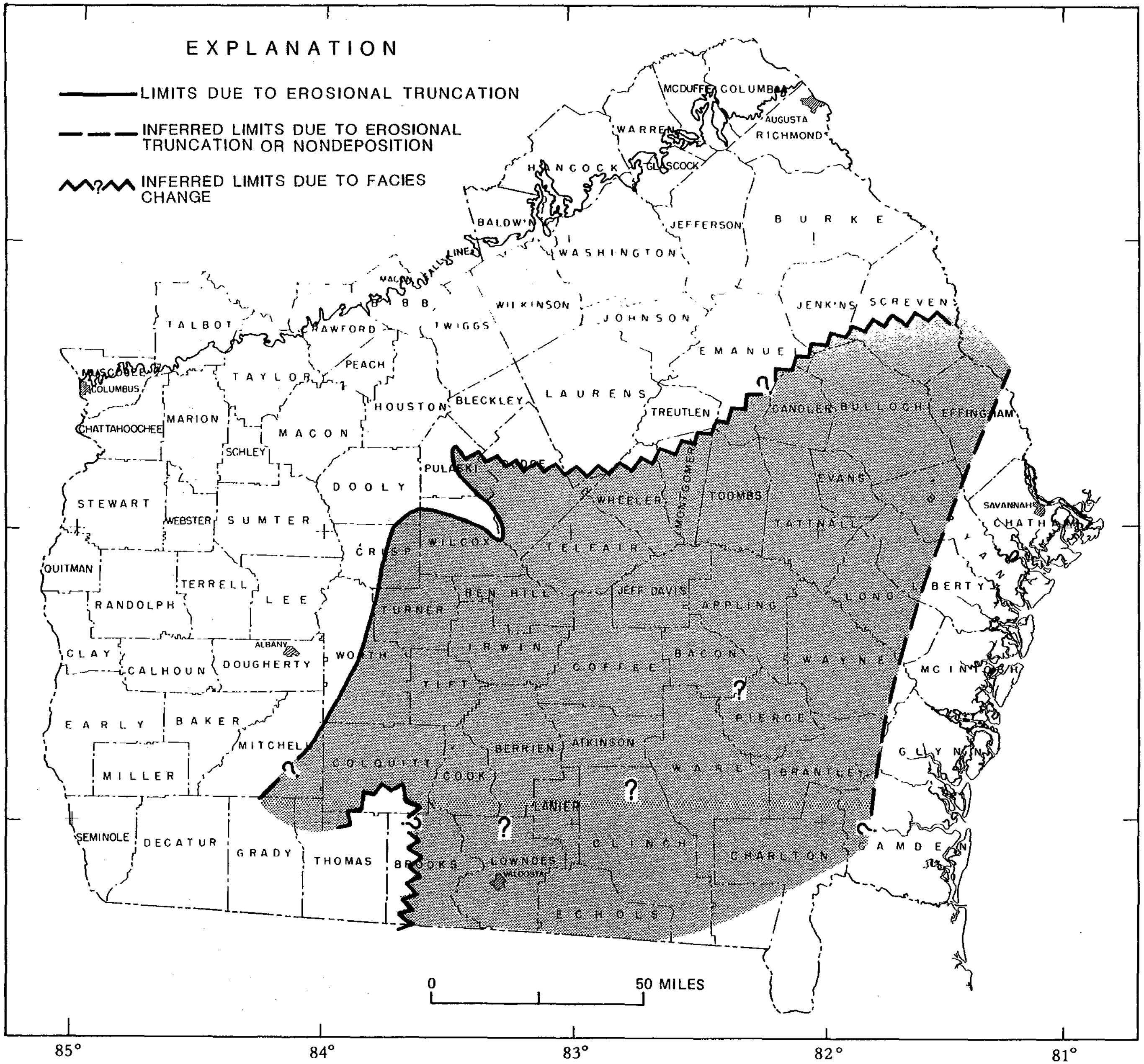


Figure 17. The areal distribution (outcrop and subcrop) of the Tiger Leap Member of the Parachucla Formation.

planktonic foraminifera from the gray, microfossiliferous, fine sand lithofacies of the member indicate that it is contained in the lower part of Zone N4 of Blow (1969) and in the *Globorotalia kugleri* Zone of Bolli (1957) and of Stainforth and others (1975) (Pl. 1). The following planktonic foraminifera have been identified from the microfossiliferous fine sand bed of the Tiger Leap Member in the cores Screven 1 (GGS-1170), Effingham 10 (GGS-3108), Effingham 11 (GGS-3109), and Georgia Power Company cores B3, B21, and B22:

Globorotalia pseudokugleri
G. mayeri
Globigerina angulisuturalis
G. praebulloides
G. ciperoenis
Globigerinoides primordius
Globigerinita juvenelis
G. incrusta
G. bradyi
Globoquadrina altispira globularis
G. dehiscens
Cassigerinella chipolensis

PORTERS LANDING MEMBER OF THE PARACHUCLA FORMATION (new name)

Definition

The Porters Landing Member is herein proposed as the upper member of the Parachucla Formation. The Porters Landing Member is identical to the combined Parachucla marl and Parachucla shale of Sloan (1908, p. 273-274, 466) and represents the original concept of the Parachucla. The name Parachucla was abandoned by Veatch and Stephenson (1911, p. 343) in favor of the name Alum Bluff of Matson and Clapp (1909, p. 91-95) because they believed the Parachucla to be a part of the Alum Bluff Formation. Veatch and Stephenson (1911, p. 371-373) included the "Parachucla marl" (fossiliferous flat-pebble bed) in the vicinity of Porters Landing in the Alum Bluff Formation. However, they included the overlying "Parachucla shale" (clays and sands) with the Marks Head Formation rather than with the Alum Bluff Formation (compare with Sloan, 1908, p. 273-274). Cooke (1936, 1943), on the other hand, abandoned both the names Alum Bluff and Marks Head in Georgia, and referred the entire Miocene section that underlies the Raysor Formation on the Savannah River to the Hawthorne Formation.

In Chatham County, Georgia, calcareous sand-sandy limestone in the subsurface that is provisionally assigned to the Porters Landing Member in this report, was called Tampa Limestone by Counts and Donsky (1963) and Tampa Limestone-equivalent by Furlow (1969).

Type Section

The name Porters Landing is taken from Porters Landing on the Savannah River, a boat landing in northern Effingham County. The type locality of the member is herein designated as the area immediately upriver and downriver from the boat landing, and the type section, or unit-stratotype (holostratotype), of the Porters Landing Member consists of those exposures of the Parachucla Formation in the bluffs at the type locality (Fig. 14). Porters Landing is also the boundary stratotype for the upper boundary of the member.

Porters Landing is located in northern Effingham County, 2.7 miles (4.3 km) southeast of the Screven-Effingham county-line on the Savannah River, and 6.5 miles (10.5 km) east-northeast of the community of Kildare (also see Sloan, 1908, p. 273-274; Veatch and Stephenson, 1911, p. 371-372; Cooke, 1925, p. 106-107). The Porters Landing Member of the Parachucla Formation is exposed in the lower parts of the bluffs at Porters Landing, from river level to approximately 20 feet (6 m) above mean-low-water stage of the river, where it is disconformably overlain by the Marks Head Formation. The unit-stratotype of the Porters Landing member is the same section as the designated unit-stratotype of the Parachucla Formation of this report.

Lithology

The Porters Landing Member of the Parachucla Formation consists predominantly of sand and clay. Other lithic components include calcite, limestone, dolomite, dolostone, mica, phosphate, siliceous claystone, zeolite, shells (only calcitic shells are known), and lignitic flecks and fragments. Characteristically in the type area in northern Effingham County, the Porters Landing Member is a thick-bedded, vaguely stratified to massive, noncalcareous, nonfossiliferous fine-to medium-grained sand and clay. Although quartz sand appears to be the dominant component of the member, clay is the characteristic component that serves to distinguish the member lithologically from the underlying Tiger Leap Member. Clay in the Porters Landing Member occurs both in discrete beds and interstitally in the sand. The bedded clay is typically medium to dark bluish-gray or dark greenish-gray (5 B 5/1 to 5 B 4/1), indistinctly layered and blocky, tough, bioturbated, and massive (as at the type locality), noncalcareous, and finely sandy to silty. In the type area, the clay mineral suite (Hetrick and Friddell, 1984) is strongly dominated by smectite whereas illite and kaolinite are minor but consistently present. Palygorskite and sepiolite are present in the type area, but only sporadically and in minor amounts. Clay occurs interstitially to the quartz sand in all proportions, from slightly argillaceous sand to finely sandy clay.

The quartz sand component of the Porters Landing Member is generally fine- to medium-grained and well-sorted. However, some beds at some sites are gravelly and pebbly, especially near the base and top of the member. The sediments of the pebbly beds, in contrast to the fine- to medium-grained sand beds, are poorly sorted and variably clayey. Sand of relatively high purity is not known to occur in discrete beds; rather, the sand is always argillaceous to some extent.

The basal Porters Landing Member in the type area consists of a discontinuous, poorly sorted, variably pebbly (with flat pebbles), slightly phosphatic, calcareous, macrofossiliferous, variably argillaceous sand that appears to be lenticular in nature. This fossiliferous flat-pebble bed is present at the type locality of the member north of the boat landing and is the "Parachucla marl" of Sloan (1908). It grades laterally downriver into nonfossiliferous, medium- to coarse-grained sand that is exposed at low stages of the river in the section immediately south of the boat landing. The bed also crops out in the bluffs near Marks Head Run and Spring Lake, an oxbow lake in the Savannah River floodplain, approximately 1.5 miles (2.4 km) northwest of Porters Landing. The basal Porters Landing Member is not calcareous and fossiliferous in the cores Effingham 10 and 12 (GGS-3108 and GGS-3110) taken near Porters Landing (Fig. 3).

In the type area, the Porters Landing Member of the Parachucla Formation is variably and weakly phosphatic. Phosphate is present but very inconspicuous in the stratotype, but is more prominent in the cores taken near the type locality. Siliceous claystone is also present in clay beds, but is not common in the member.

The Porters Landing stratigraphic interval in central Effingham County and Chatham County is represented by a massive, very calcareous, argillaceous, mircofossiliferous, well-sorted and fine-grained sand, to argillaceous, finely sandy limestone that is quite distinct lithologically from the typical porters Landing lithology of northern Effingham County. It also differs from typical Porters Landing lithology in that palygorskite is a common component of the clay mineral suite of this lithofacies in Chatham County (Hetrick and Friddell, 1984). This calcareous, fine-grained sand to sandy limestone lithofacies is tentatively assigned to the Porters Landing Member in this report.

In the southern coastal area of Georgia south of Glynn County, the Parachucla stratigraphic interval is occupied by phosphatic, dolomitic clays; dolomitic, argillaceous, fine sands; variably argillaceous dolostone; and minor calcite and limestone. This lithology is intermediate to Parachucla lithology and Cooper lithology. Limited paleontological evidence from Nassau County, Florida, suggests that the entire stratigraphic interval is correlative with the Porters Landing Member. This unit is included by T. Scott (in preparation) in the Penney Farms Formation.

Stratigraphic Relationships

The Porters Landing Member of the Parachucla Formation underlies most of the eastern Georgia Coastal Plain (Fig. 18). In the Savannah River area, the Porters Landing Member pinches out by truncation northwest of Porters Landing in southernmost Screven County, and it is not known to be present at Tiger Leap Bluff (Pl. 2). The Porters Landing Member also thins south (or seaward) of Porters Landing and locally pinches out in southern Effingham County. The calcareous lithofacies of the member reappears in central Chatham County and underlies the coastal area of that county.

The Porters Landing Member has been identified in Wayne County in the core Wayne 2 (GGS-3512), in Coffee County in the core Coffee 4 (GGS-3541), in Berrien County in the core Berrien 10 (GGS-3542), and in Colquitt County in the core Colquitt 3 (GGS-3179). The Porters Landing Member, therefore, probably underlies most of the Southeast Georgia Embayment area and the Gulf Trough. The western limits of the member, based on current subsurface control, extend from southernmost Screven County southwestward through southern Emanuel County, southern Dodge County, and into northern Colquitt County. The Porters Landing Member within the Gulf Trough appears to grade laterally into the Chattahoochee Formation on both flanks of the Gulf Trough in Colquitt County. The southern limits of the member are not known at this time, but the member does occur in outcrop (a parastratotype of the Hawthorne Group) on the upper Suwannee River at White Springs in northeastern Florida. The Porters Landing Member is thin at this site, and is not recognized elsewhere in the Suwannee area (pers. comm., T. Scott, 1985). In the southern coastal area of Georgia south of Glynn County, the Parachucla stratigraphic interval is occupied by phosphatic, dolomitic clays; dolomitic, argillaceous, fine-grained sands; variably argillaceous dolostone; and rare occurrences of argillaceous limestone. Limited paleontological evidence from the Florida Bureau of Geology core Cassidy 1 (W-13815) in Nassau County, Florida, suggests that this stratigraphic interval is correlative with the Porters Landing Member.

The Porters Landing Member conformably or paraconformably overlies the Tiger Leap Member (Fig. 11; Pl. 2). It is disconformably overlain by the upper Pliocene Cypresshead Formation in northernmost Effingham County and southernmost Screven County, and disconformably overlain by the Marks Head Formation elsewhere in the Savannah River area. In Chatham County, the Porters Landing Member disconformably overlies the Lazaretto Creek Formation (Huddlestun, in press).

The Porters Landing Member of the Parachucla Formation is distinguished from the underlying Tiger Leap Member in being characteristically more argillaceous than the Tiger Leap and generally containing beds of medium to dark bluish-gray to dark greenish gray clay. In addition, the Tiger Leap Member is consistently more calcareous or dolomitic than the Porters Landing Member and commonly contains fossiliferous beds and beds of limestone or dolostone.

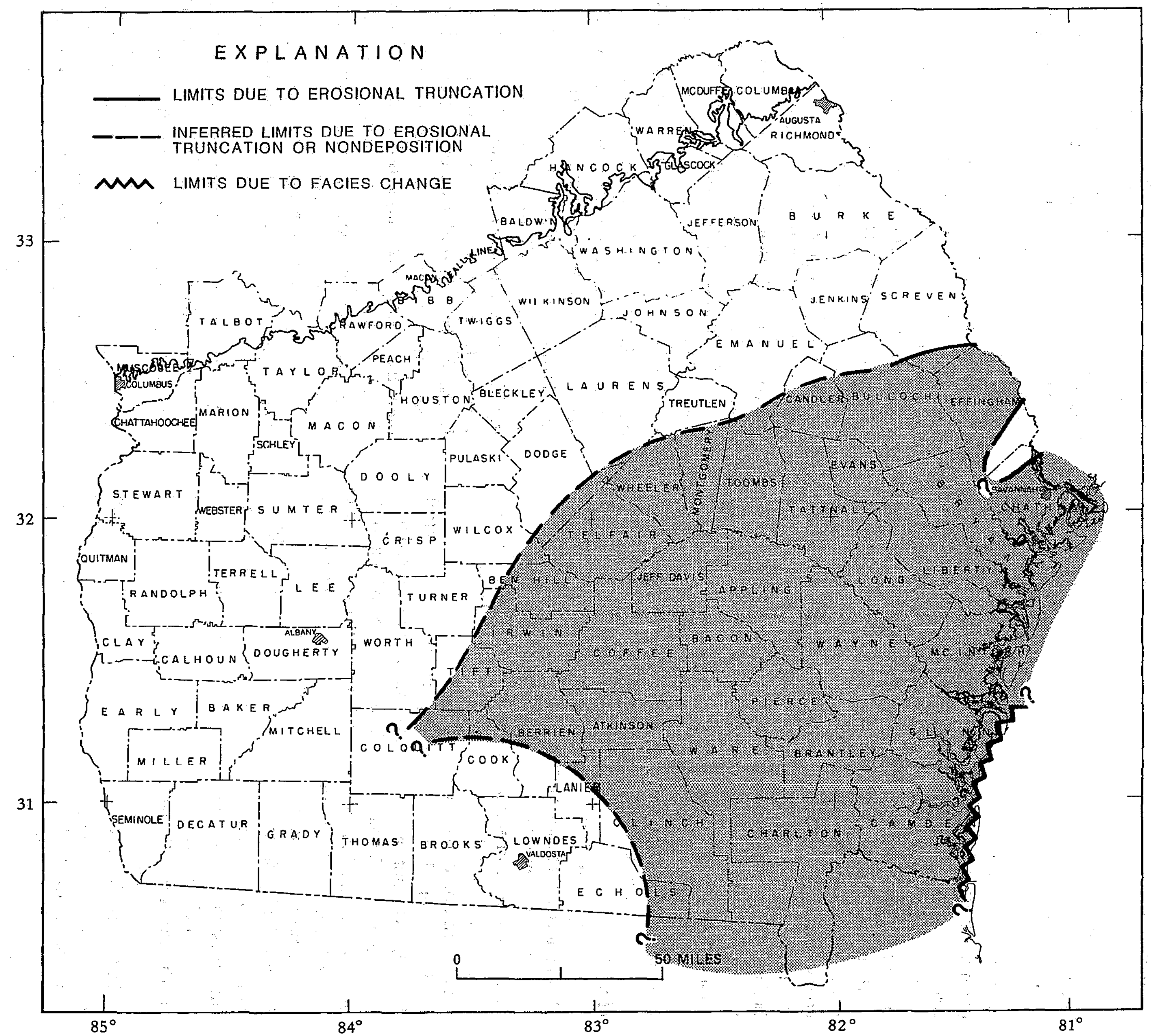


Figure 18. The areal distribution (outcrop and subcrop) of the Porters Landing Member of the Parachucla Formation.

There is evidence that there is substantial relief on the Parachucla Formation in its type area. In the core Effingham 11 (GGS-3109) taken 1.75 miles (2.8 km) southwest of Porters Landing, the Marks Head Formation is unexpectedly thick at 68 feet (21 m) compared with approximately 27 feet (8 m) at Porters Landing. Similarly, the elevation of the Marks Head/Parachucla contact is 37 feet lower in the Effingham 11 (GGS-3109) than it is at Porters Landing, and Porters Landing lithology cannot be positively identified in the core. The difference in the elevations of the Marks Head/Parachucla contact between Porters Landing and the Effingham 11 (GGS-3109) indicates a dip or inclination of approximately 21 feet per mile to the southwest, an unusually steep slope for Coastal Plain Miocene deposits. Therefore, it is suggested that the variation in thickness is more indicative of topographic relief on the Parachucla prior to deposition of the Marks Head Formation than of structural dip as a result of subsidence.

Approximately 20 feet (6 m) of Porters Landing member is exposed at the type locality at Porters Landing. It is not likely that the member is much thicker than this at Porters Landing because the fossiliferous flat-pebble bed exposed at the base of the section at Porters Landing is known to occur only at the base of the member and the bed is not known to be more than a few feet (less than 1 m) thick. In addition, Sloan (1908, p. 274) reported Combahee to be exposed under the "Parachucla marl" (fossiliferous flat-pebble bed) at Porters Landing although I have not seen the base of the flat pebble bed at the site. In the type area, the greatest thickness of sediments assigned to the Porters Landing Member is 48 feet (15 m) in the interval 27 feet to 75 feet in the core Effingham 10 (GGS-3108). The Porters Landing Member thins to 14 feet (4 m) in the interval 120 feet to 134 feet in the core Effingham 12 (GGS-3110). In the calcareous lithofacies of the member at Clyo in central Effingham County, the Porters Landing Member is 24 feet (7 m) thick in the interval 130 feet to 154 feet in the core Georgia Power B40; and it is 39 feet (12 m) thick in the interval 126 feet to 165 feet in the core Effingham 6 (GGS-2179). The Porters Landing Member appears to pinch out in southern Effingham County, but the calcareous lithofacies, which reappears in central Chatham County, ranges from 0 to 17 feet (0 to 8 m) thick, averaging about 10 feet (3 m) thick in Chatham County.

The Porters Landing Member is 74 feet (23 m) thick in the interval 453 feet to 527 feet in the core Wayne 2 (GGS-3512) in Wayne County; 162 feet (49 m) thick in the interval 258 feet to 420 feet in the core Coffee 4 (GGS-3541) in Coffee County; 65 feet (20 m) thick in the interval 324 feet to 289 feet in the core Berrien 10 in Berrien County (GGS-3542); and 229 feet (70 m) thick in the interval 280 feet to 509 feet in the core Colquitt 3 (GGS-3179) in Colquitt County.

The environment of deposition of the Porters Landing Member of the Parachucla Formation was marine, inner to middle neritic continental shelf. The shelf sediments appear to have been considerably more muddy during deposition of the Porters Landing Member than during deposition of the Tiger Leap Member.

Age

The age of the Porters Landing Member of the Parachucla Formation is early Miocene (Aquitanian) (see Pl. 1). The following planktonic foraminifera have been identified from the calcareous lithofacies of the member in the cores Georgia Power B40 and Effingham 6 (GGS-2179) from the vicinity of Clyo, and from the core Chatham 1 (GGS-535) in Chatham County:

Globorotalia mayeri
Globigerina praebulloides
G. ciperoensis
Globigerinoides primordius
Globoquadrina altispira globularis
Cassigerinella chipolensis

The planktonic foraminiferal suite of the Porters Landing Member differs from that of the Tiger Leap member in forming a greater percentage of the total foraminiferal fauna, and in being considerably less diverse. *Globigerina praebulloides* and *G. ciperoensis* constitute the largest part of the fauna, and *Globigerinoides primordius* is both large and well developed, and more numerous than in the older Tiger Leap Member.

Because the Porters Landing Member overlies the Tiger Leap Member, which contains a lower Zone N4 planktonic foraminiferal assemblage, and because the lower Zone N4 species *Globorotalia pseudokugleri* and *Glorigerina angulisuturalis* are not present in the Porters Landing Member whereas *Globigerinoides primordius* is both larger and more abundant, it is suggested here that the age of the Porters Landing Member is either upper Zone N4 (upper *Globorotalia kugleri* Zone) or lower Zone N5 (lower *Catapsydrax dissimilis* Zone). The absence of younger zonal species in the Porters Landing Member, such as *Globigerinoides quadrilobatus quadrilobatus, G. altiapertura, G. subquadratus,* and *Globoquadrina altispira globosa*, suggests that the member is not younger than Zone N5.

Planktonic foraminifera are very rare and consist only of juveniles in the exposed fossiliferous flat-pebble bed at the base of the Porters Landing member in northern Effingham County. Correlation between the typical, exposed Porters Landing Member and the subsurface calcareous lithofacies of the member is based on physical correlation between closely spaced cores (Pl. 2), stratigraphic position, and similarity of benthic foraminiferal assemblages north of the vicinity of Clyo. From Clyo southward, correlation is based on both planktonic and benthic foraminifera.

The benthic foraminifera, *Elphidium rota* and *Florilus struma,* previously considered to be characteristic of the upper Oligocene of the eastern Gulf Coastal Plain, are also characteristic species of the calcareous lithofacies of the Porters Landing Member. *Miogypsina* cf. *M. gunteri*, also thought to be restricted to upper Oligocene deposits in the

Southeast (Cole, 1941; Applin, 1960), was identified from the Porters Landing Member in the Georgia Power Company core B40. These species are not known to occur in the older Tiger Leap Member of the Parachucla Formation.

MARKS HEAD FORMATION OF THE HAWTHORNE GROUP (reintroduced)

Definition

The Marks Head Marl of Sloan (1908, p. 466-470) is herein reintroduced as the Marks Head Formation. In eastern Georgia, it is the middle formation of the Hawthorne Group. As defined herein, the Marks Head Formation is identical to the Marks Head marl of Sloan (1908, p. 273-274) in Georgia, but differs from that of Veatch and Stephenson (1911). The exposures of the Hawthorne Group along the Savannah River in the vicinity of Clyo and Sisters Ferry were mainly referred to as Miocene? (Undifferentiated) or were tentatively referred to the Miocene by Veatch and Stephenson (1911, p. 375). In this report, the outcropping Hawthorne sediments along the Savannah River near Clyo are assigned to the Marks Head Formation. In addition, Veatch and Stephenson (1911, p. 372-373) included the Parachucla shale of Sloan (1908) in the Marks Head Marl, but in this report the Parachucla shale of Sloan (1908) is the upper part of the Parachucla Formation in northern Effingham County, and underlies the Marks Head Formation.

Based on the fossil content of the Marks Head Formation as determined by Gardner (1925), Cooke (1936) abandoned the name Marks Head in favor of Hawthorne Formation, and the name Hawthorne has subsequently been applied to these deposits (Georgia Geological Survey, 1976; Weaver and Beck, 1977). Huddlestun (1973, 1981), however, has applied the name Marks Head informally. The Marks Head Formation of this report is in part the Hawthorne Formation of Counts and Donsky (1963), is largely the Hawthorne Formation of Furlow (1969) and McCollum and Herrick (1964), and appears to be the fuller's earth bearing unit of eastern Georgia of Weaver and Beck (1977, p. 56-63).

Type Section

The name Marks Head was taken from Marks Head Run (Sloan, 1908, p. 274), a deeply incised ravine in the bluffs overlooking the floodplain of the Savannah River (Fig. 19). The type locality of the Marks Head Formation is, by original designation (Sloan, 1908, p. 273), in Marks Head Run, and the type section, or unit-stratotype (holostratotype), of the Marks Head Formation is therefore in Marks Head Run. The type locality, Marks Head Run, is in northern Effingham County, 1.2 miles (1.9 km) northwest of Porters Landing (Fig. 19).

The Marks Head Formation is not well exposed at the type locality, and the lithologies exposed there (calcareous and macrofossiliferous) are not representative of the formation as a whole. The best exposure of the Marks Head Formation is at Porters Landing, 1.2 miles (1.9 km) southeast of the type locality (Fig. 14). This site is a reference locality and parastratotype of the formation (Sloan, 1908, p. 273). In addition, Porters Landing is herein designated the upper and lower boundary stratotype of the Marks Head Formation. At Porters Landing, the Marks Head Formation disconformably overlies the Parachucla Formation, and is disconformably overlain by the Raysor Formation.

Lithology

The Marks Head Formation consists of slightly dolomitic (rarely calcareous), phosphatic, argillaceous sand and sandy clay with scattered beds of dolostone, limestone, and siliceous claystone. In general, quartz sand appears to be the dominant lithic component of the formation, whereas clay is both a major and characteristic component. The sand-clay distribution of the Marks Head Formation reflects the tendency for grain sizes in the formation to become finer in a seaward direction. In outcrop in northern Effingham County, the Marks Head Formation consists predominantly of argillaceous sand, whereas in central Effingham County, the formation consists of interlayered finely sandy clay and argillaceous fine sand. In the subsurface in southern Effingham County and Chatham County, the Marks Head Formation consists predominantly of finely sandy clay with minor argillaceous sand.

Subordinate lithic components include dolomite, dolostone, calcite, limestone, phosphate, mica, zeolite, feldspar, siliceous claystone, shells, and rare, scattered, vertebrate bone debris.

The clay component of the Marks Head Formation occurs in discrete clay beds and interstitially in the quartz sand. The stratified clay occurs in laminae or streaks, thin beds, and thick beds, or as massive, finely sandy clay that constitutes the entire formation. Although the clay may appear to be massive and structureless, it is generally laminated with silt, fine mica, and fine phosphate scattered on the bedding planes. The clay mineral suite of the Marks Head Formation is dominated by palygorskite, with sepiolite and montmorillonite (smectite) as significant accessory clay minerals. Illite occurs in trace amounts in the Marks Head, and kaolinite is very rare (Weaver and Beck, 1977; Hetrick and Friddell, 1984). Thin beds or lenses of fuller's earth are locally scattered throughout the formation in the vicinity of Clyo in Effingham County, but none of them are thick enough to constitute commercial deposits. In the Savannah River area, the light-colored, light-weight, fuller's earth clays of the Marks Head Formation contrast with the dark bluish-gray, more dense clays of the Parachucla Formation, and with the olive-gray clays of the overlying Coosawhatchie Formation.

The quartz sand component of the Marks Head is generally fine-grained and well-sorted, but some beds of fine- to

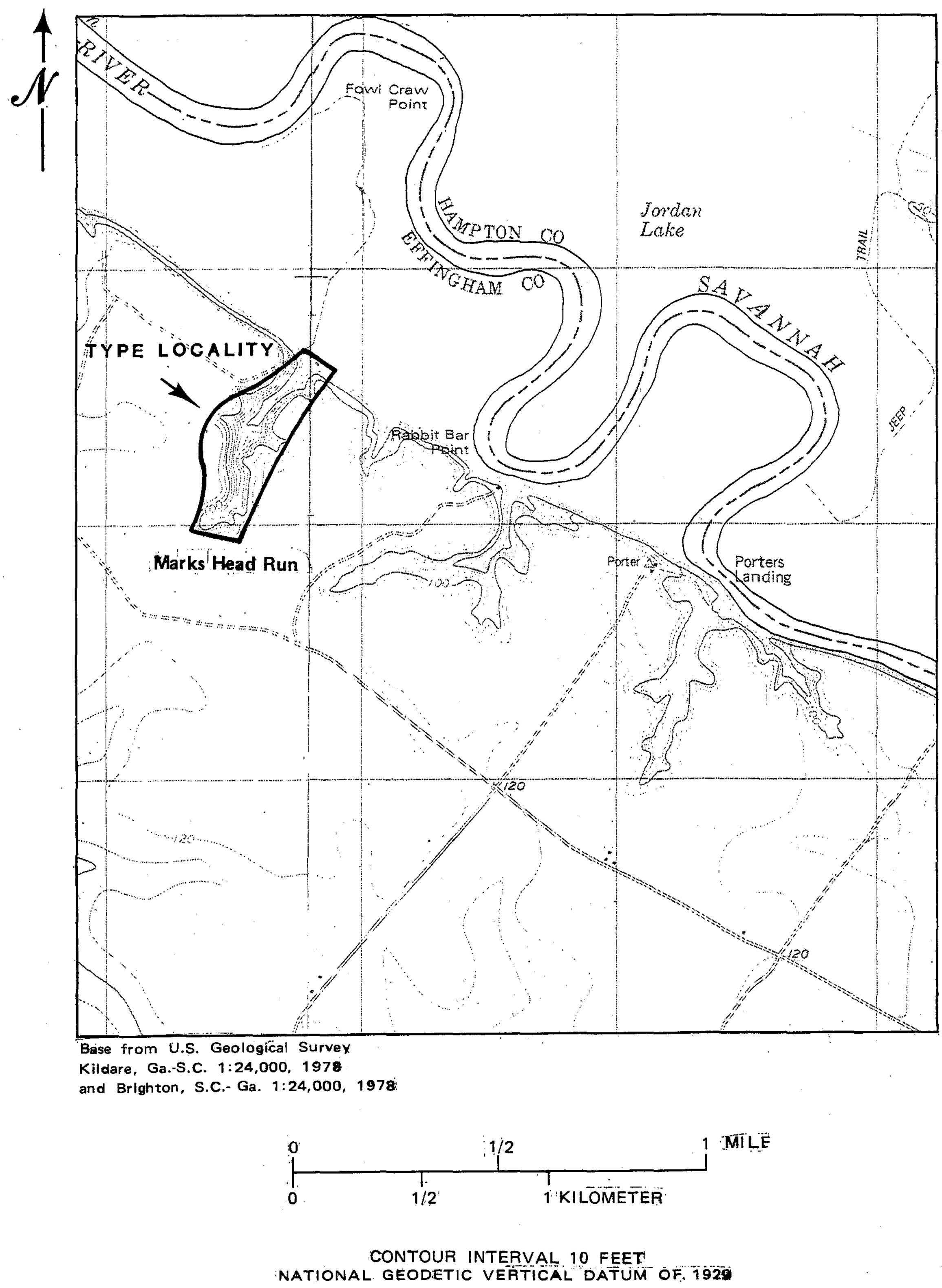


Figure 19. The type locality of the Marks Head Formation of the Hawthorne Group.

medium-grained, moderately sorted sand occur in northern Effingham County. In the Southeast Georgia Embayment, the upper part of the Marks Head Formation consists of coarse, pebbly, poorly sorted sand.

Carbonate is a minor but widely occurring component of the Marks Head Formation. It occurs as intersititial dolomite or calcite, as thin beds or lenses (thick in the Southeast Georgia Embayment) of dolostone or limestone, as calcite concretions, and as shell material in fossiliferous beds. The most common form of carbonate is interstitial dolomite but in most subsurface sections, dolomitic intervals constitute a small proportion of the sections. Most commonly, the sands or clays of the Marks Head are noncalcareous and nondolomitic. Exceptionally, interstitial dolomite and, more rarely, interstitial calcite occurs throughout the Marks Head section. Scattered thin beds of argillaceous or sandy dolostone or limestone, and stratigraphic horizons with concentrations of concretions, large and small, are characteristic of the formation in northern Effingham County. Limited core information suggests that phosphatic, sandy, argillaceous dolostone beds are thicker in the Southeast Georgia Embayment, but they do not appear to constitute a greater proportion of the section there than elsewhere. Shelly, fossiliferous beds in the Marks Head Formation are known from the vicinity of Clyo north to the vicinity of the type locality. These beds, however, appear to be lenticular in nature and are not traceable over any large distance. The fossiliferous beds appear to be most prominent and thickest in the vicinity of Marks Head Run, and are thin and highly discontinuous in the Marks Head Formation at Porters Landing 1.2 miles (1.9 km) away.

The Marks Head Formation, in spite of its very fossiliferous type locality, is uniformly the least fossiliferous formation of the Hawthorne Group in eastern Georgia. If it were not for the fossiliferous type locality and a small area in the subsurface south of Savannah in Chatham County where the formation is calcareous and microfossiliferous, almost nothing would be known of the formation's fauna, correlation, and precise age.

The Marks Head Formation is characteristically phosphatic and, in the type area, phosphate is conspicuous. The P_2O_5 content, however, is not known to exceed a few percent and is, therefore, not considered commercial. Thin beds or lenses of olive-colored siliceous claystone are common in the type area, but appear to be less common in Chatham County and farther south in the Southeast Georgia Embayment.

In the coastal area, where the Marks Head Formation is disconformably overlain by the Coosawhatchie Formation, a fairly continuous marker bed of dolostone, palygorskite-bearing fuller's earth clay, or dolomitic fuller's earth occurs at the top of the Marks Head (dense, dolomitic limestone stringer of Furlow, 1969, p. 17).

Stratification in the Marks Head Formation is variable. Some intervals of the formation are prominently stratified and the bedding ranges from laminated to thick bedded. Where the sediments have been bioturbated, the sands and clays are generally incompletely mixed and the formation is massive. Less commonly, where bioturbation has been intense, the sands and clays have been completely mixed and the sediment is massive and structureless. Most commonly, the sediments of the Marks Head Formation are stratified with variable disruption of stratification due to bioturbation.

Stratigraphic Relationships

The Marks Head Formation occurs in the Savannah River area from northern Effingham County southeastward to the offshore, inner continental shelf of Georgia, and it underlies the coastal area from Chatham County to Camden County (Fig. 20). It extends some distance southward into northeastern Florida, and it is tentatively recognized in the subsurface as far north as the Coosawhatchie River at Dawsons Landing in Jasper County, South Carolina. The Marks Head thins and pinches out on the continental shelf of Georgia. It underlies the inner continental shelf, but the Marks Head stratigraphic interval is absent in the core AMCOR 6002 on the outer shelf. Its western or landward limits in Georgia south of the Savannah River region are not known at this time due to insufficient core control in the interior of the Southeast Georgia embayment. It is recognized, however, as far west as Wayne County, Georgia, in the embayment, and in Charlton County in the vicinity of Folkston. The Marks Head Formation does not occur as far west as the upper Suwannee River area in northern Florida, nor in the Gulf Trough in Coffee, Berrien, and Colquitt Counties, Georgia.

The Marks Head Formation disconformably overlies the Parachucla Formation in the type area of the two formations, and it disconformably or paraconformably overlies the Parachucla Formation, the calcareous lithofacies of the Porters Landing Member of the Parachucla Formation or the stratigraphic equivalent of the Parachucla Formation, in the southern coastal area of Georgia (Fig. 11). The Marks Head is disconformably overlain by the Cypresshead or Raysor Formations in northern and central Effingham County, and is disconformably overlain by the Coosawhatchie Formation elsewhere in Georgia.

The Marks Head Formation is distinguished from the underlying Parachucla Formation in being more phosphatic, siliceous, and dolomitic, and in being less calcareous and fossiliferous. In the type area, the Marks Head sands and clays are typically pale greenish-gray due to the color of the clay minerals palygorskite and sepiolite, whereas the Parachucla sands and clays are typically darker and bluish- to greenish-gray due to the color of the smectitic clays. Where the sediment is dry, as in cores, the physical properties of clay-rich Marks Head differs significantly from clay-rich Parachucla because of the different physical properties of palygorskite (Marks Head) and smectite (Parachucla).

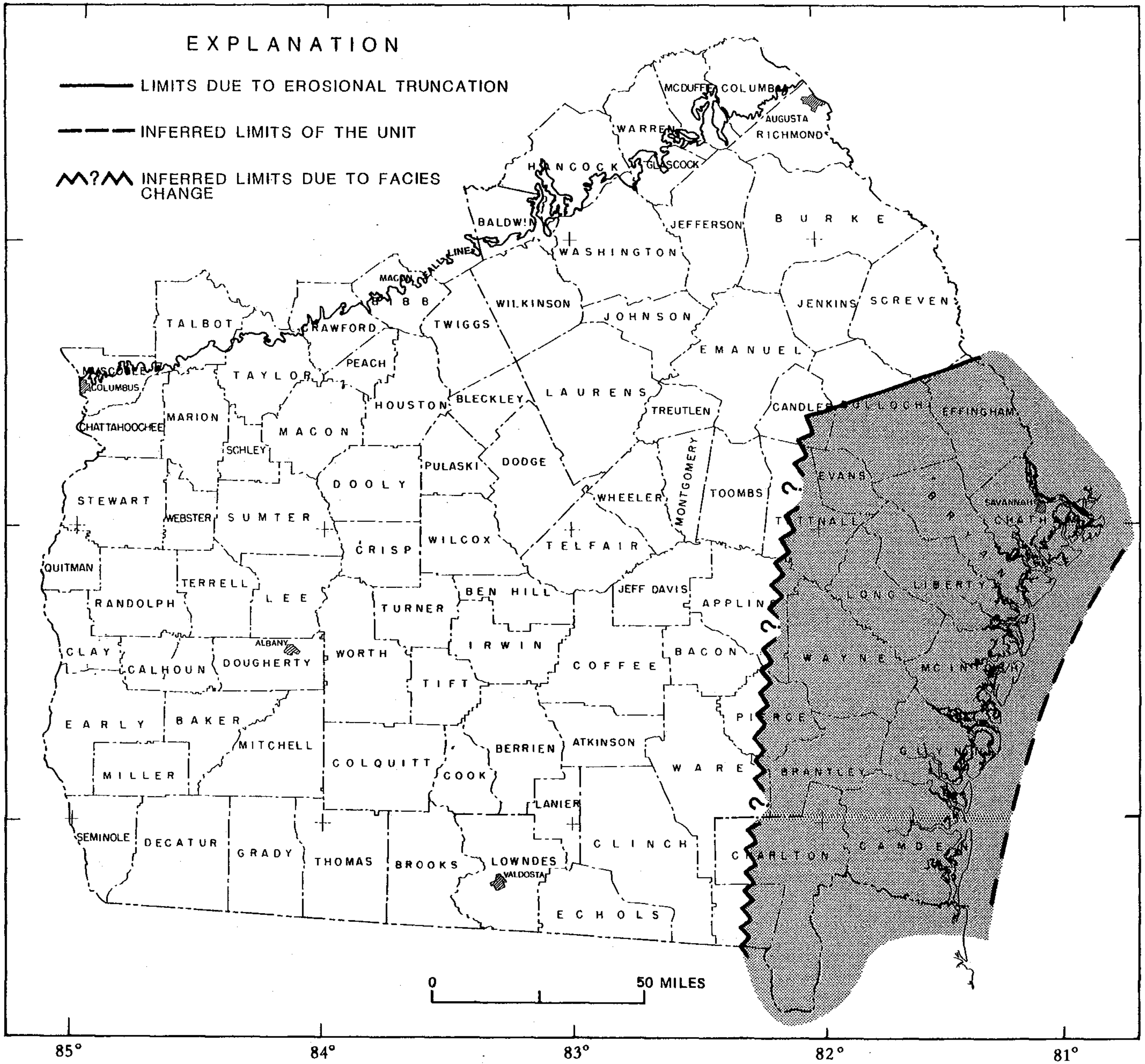


Figure 20. The areal distribution (outcrop and subcrop) of the Marks Head Formation.

The Marks Head Formation in distinguished from the overlying Coosawhatchie Formation in various ways. Where the Berryville Clay Member overlies the Marks Head, the Berryville differs in consisting of phosphatic, light to dark olive-gray smectitic clay. Phosphate and fine, vertebrate debris and fish-scales are commonly concentrated on bedding planes in the Berryville Clay. Also, there is commonly a bed of fuller's earth or dolostone at the top of the Marks Head Formation where it is overlain by the Coosawhatchie Formation. Where the Tybee Phosphorite Member overlies the Marks Head Formation, the Tybee is distinguished in consisting of sandy phosphorite that has the appearance of wet coffee-grounds. The Marks Head Formation in the coastal area, where it is overlain by the Tybee Phosphorite, consists of prominently bioturbated, phosphatic, slightly dolomite (locally calcareous), finely sandy, olive-gray, palygorskitic clay.

The thickness of the Marks Head Formation at the type locality is not readily measurable because the stratotype sections consist of small discontinuous exposures spread over a distance of approximately 500 feet (150 m) along a thickly wooded ravine. Sloan (1908, p. 274), however, reported that at least 15 feet (4.5 m) of section were exposed at the type locality (also see Veatch and Stephenson, 1911, p. 371).

At Porters Landing, the parastratotype and boundary stratotype for the formation, the Marks Head is approximately 27 feet (8 m) thick (Sloan, 1908, p. 273: compare with Veatch and Stephenson, 1911, p. 372-373). The Marks Head thins by truncation to the northwest, or landward, and is absent in the bluffs along Hudson Ferry Reach in northernmost Effingham County where the Cypresshead Formation directly overlies the Parachucla. The Marks Head Formation thickens southeastward, or seaward, in the Savannah River area and is 87 feet (27 m) thick in the interval 43 feet to 130 feet in the core Georgia Power B40, and 84 feet (26 m) thick in the interval 43 feet to 126 feet in the core Effingham 6 (GGS-2179), both near Clyo in central Effingham County (Pl. 2). The Marks Head Formation reaches a maximum thickness in the Savannah River area of 139 feet (42 m) in the core Georgia Power B41 in south-central Effingham County. From there, the formation progressively thins in a seaward direction. It averages about 25 feet (7.5 m) thick in coastal Chatham County (see Furlow, 1969; McCollum and Herrick, 1964). Neither the Marks Head Formation nor a stratigraphic equivalent is present in the core AMCOR 6002 on the outer continental shelf of Georgia (Pls. 2 and 3).

The Marks Head Formation thickens southward in the Southeast Georgia Embayment where it is 150 feet (46 m) thick in the interval 303 feet to 453 feet in the core Wayne 2 (GGS-3512) in Wayne County. It then thins southward to 125 feet (38 m) in the interval 325 feet to 450 feet in the core Charlton 2 (GGS-3185) at Folkston in Charlton County; it is only 36 feet (11 m) thick in the interval 374 feet to 410 feet in the core Cumberland Island 1 (GGS-3426) from Cumberland Island in Camden County, Georgia.

The environment of deposition of the Marks Head Formation was broadly marine, nearshore, inner continental shelf. In the type area of the formation in Effingham County, Georgia, the environment appears to have been brackish marine. At the fossiliferous type locality, the foraminiferal suite consists predominantly of either *Ammonia beccarrii* or *Buliminella elegantissima*, all other species constituting only a small proportion of the assemblage. The paleoenvironment indicated by the foraminiferal assemblage is consistent with the reported molluscan fauna (Veatch and Stephenson, 1911, p. 365; Gardner, 1925). It is also consistent with the abundance of the mussel *Mytilus* sp., a genus that flourishes in brackish water.

The clay mineral suite of the Marks Head Formation is compatible with the paleontological evidence for the paleoenvironment. The clay mineral suite of the formation is dominated by palygorskite (Hetrick and Friddell, 1984) which, according to Weaver and Beck (1977), originated in warm, coastal brackish to schizohaline water where the salinity of the watermass varied from hypersaline to brackish.

In the subsurface of the Savannah area, however, the Marks Head Formation is locally calcareous and contains a moderately diverse, open-marine, inner continental shelf, benthic foraminiferal fauna with a moderate planktonic foraminiferal fauna. Therefore, the offshore environment of the Marks Head Formation in the subsurface of coastal Georgia appears to have been inner continental shelf, relatively shallow water, but open-marine with normal to near normal salinity.

Age

The age of the Marks Head Formation is late early Miocene (Burdigalian) (see Pl. 1). The following planktonic foraminifera have been identified from the core U.S. Geological Survey Test Well 6 from southern Chatham County, and from the cores B13, B25, and B30 taken on Elba Island in the Savannah River in southern Chatham County:

Globorotalia mayeri
G. cf. *minutissima*
Globigerina praebulloides
G. cf. *woodi*
Globigerinoides quadrilobatus quadrilobatus
G. altiapertura
Globoquadrina altispira globosa
G. dehiscens
Globigerinita incrusta
G. juvenilis
G. uvula
Cassigerinella chipolensis

The planktonic foraminiferal assemblage of the Marks Head Formation is significantly different in appearance from that of the Parachucla Formation, and is similar to that of the Chipola Formation of western Florida (Akers, 1972; Huddlestun, 1984). It differs from the underlying Parachucla Formation principally in the typical development and common occurrence of *G. quadrilobatus quadrilobatus, G. altiapertura,* and *G. altispira globosa.* Forms resembling *Catapsydrax stainforthi* but with a very finely perforate test like that of *Globigerinita* and with a relatively high spire, and forms resembling *Turborotalita quinqueloba* are also characteristic and restricted to this stratigraphic interval in the Hawthorne Group. The presence of common and typical *G. quadrilobatus* and *G. altiapertura* indicates that the Marks Head Formation is not older than Zone N6 or N7 of Blow (1969) (= *Catapsydrax stainforthi* Zone and lower part of *Globigerinatella insueta* Zone of Bolli, 1957; and *C. stainforthi* Zone and *G. insueta* Zone of Stainforth and others, 1975; Pl. 1). The common occurrence of *G. altiapertura* in the Marks Head Formation and the absence of typical *G. altiapertura* in the latest Zone N7 Chipola Formation (Akers, 1972; Huddlestun, 1984) suggest that the Marks Head Formation is older than the Chipola Formation. This age is consistent with the correlation of the Marks Head Formation with the Torreya Formation of western Florida and southwestern Georgia, and with the stratigraphic position of the Chipola Formation disconformably overlying the Torreya Formation at Alum Bluff (Banks and Hunter, 1973; Huddlestun, 1984). It appears most probable, then, that the Marks Head Formation is contained in Zone N6 of Blow (1969) (see Pl. 1).

TORREYA FORMATION

Definition

The Torreya Formation was named by Banks and Hunter (1973, p. 355-363) for pre-Chipola, early Miocene age deposits in the eastern Florida panhandle. These deposits previously had been assigned to the Alum Bluff Formation (Matson and Clapp, 1909; Matson, 1915), Chipola Formation (Gardner, 1926; MacNeil, 1947a, 1947b) and Hawthorne Formation (Cooke and Mossom, 1929; Cooke 1943, 1945; Puri and Vernon, 1964; Hendry and Sproul, 1966). The Torreya Formation of this report is expanded to include all of the Hawthorne deposits of the eastern Florida panhandle and of southwesternmost Georgia (Decatur County) up to and including the fuller's earth beds (Dogtown Clay Member) near the top of the formation. The Torreya Formation contains two members: the Dogtown Clay Member in the upper part of the formation, and the Sopchoppy Member in the lower part of the formation.

Type Section

The Torreya Formation was named for Torreya State Park in northern Liberty County, Florida, the type locality being within the confines of the park (Banks and Hunter, 1973). The type locality and type section, or unit stratotype (holostratotype), is at Rock Bluff on the east bank of the Apalachicola River in SW 1/4, Sec. 17, T2N, R7W (Fig. 21; see also Sellards and Gunter, 1909; Mansfield, 1937; and Cooke, 1945, for measured sections and stratigraphic discussion).

Lithology

The Torreya lithology is typically an argillaceous, fine-grained sand/finely sandy clay that is variably calcareous and dolomitic. In outcrop, the carbonate component is generally absent due to leaching, and the physical appearance of the Torreya Formation is that of an indistinctly layered, pale green, clayey, fine-grained sand to sandy clay. The quartz sand, clay, and carbonate are generally present together in varying proportions. Only a few clay beds in the Dogtown Clay Member and a few limestone intervals in the lower part of the formation contain relatively few impurities.

Subordinate lithic components of the Torreya Formation include chert (opal-cristobalite), phosphate, heavy minerals (zircon, tourmaline, rutile, apatite, staurolite, kyanite, sillimanite, and opaques [Weaver and Beck, 1977], mica, K-feldspar, pyrite, wad (hydrated MnO_2), invertebrate macrofossils of various kinds (mostly molds and casts), petrified wood, fossil bone material, and rare calcareous and siliceous microfossils.

Quartz sand is the dominant component of the lithology and is commonly fine-grained and well-sorted. However, the grain-size of the quartz ranges from silt through medium, with a few reports of coarse-grained sand (coarse-grained, pebbly sand is contained in the overlying Miccosukee Formation which Cooke [1945] included in the Hawthorne Formation). I have not observed coarse sand, quartz pebbles, or gravel in the Torreya Formation. In addition, I have not found any poorly sorted quartz sand. Instead, the quartz sand is characteristically very well sorted in the Torreya Formation.

Palygorskite and montmorillonite are the dominant clay minerals of the formation (also see Weaver and Beck, 1977, p. 71-104). Some stratigraphic intervals are strongly dominated by montmorillonite. Subordinate clay minerals include sepiolite, illite, and kaolinite.

Calcite is the dominant carbonate mineral of the formation in the type area. Dolomite is commonly present at any given site, but it is always subordinate to calcite in the section. In outcrop (excluding both large bluffs along major rivers and also deep pits and quarries), the carbonate component of the formation has commonly been leached so that the outcropping lithology typically is lacking in carbonate. In the subsurface, below the leaching zone, however, calcite is an important component of the Torreya lithology. The Torreya Formation is the only formation in the Hawthorne Group of southwestern Georgia and northernmost Florida in which calcite is an important and consistent component of the lithology of the unit. Although subsurface control in southwestern Georgia is very meager, the calcite component of the formation appears to diminish and disappear northeastward from Florida into southwestern Georgia.

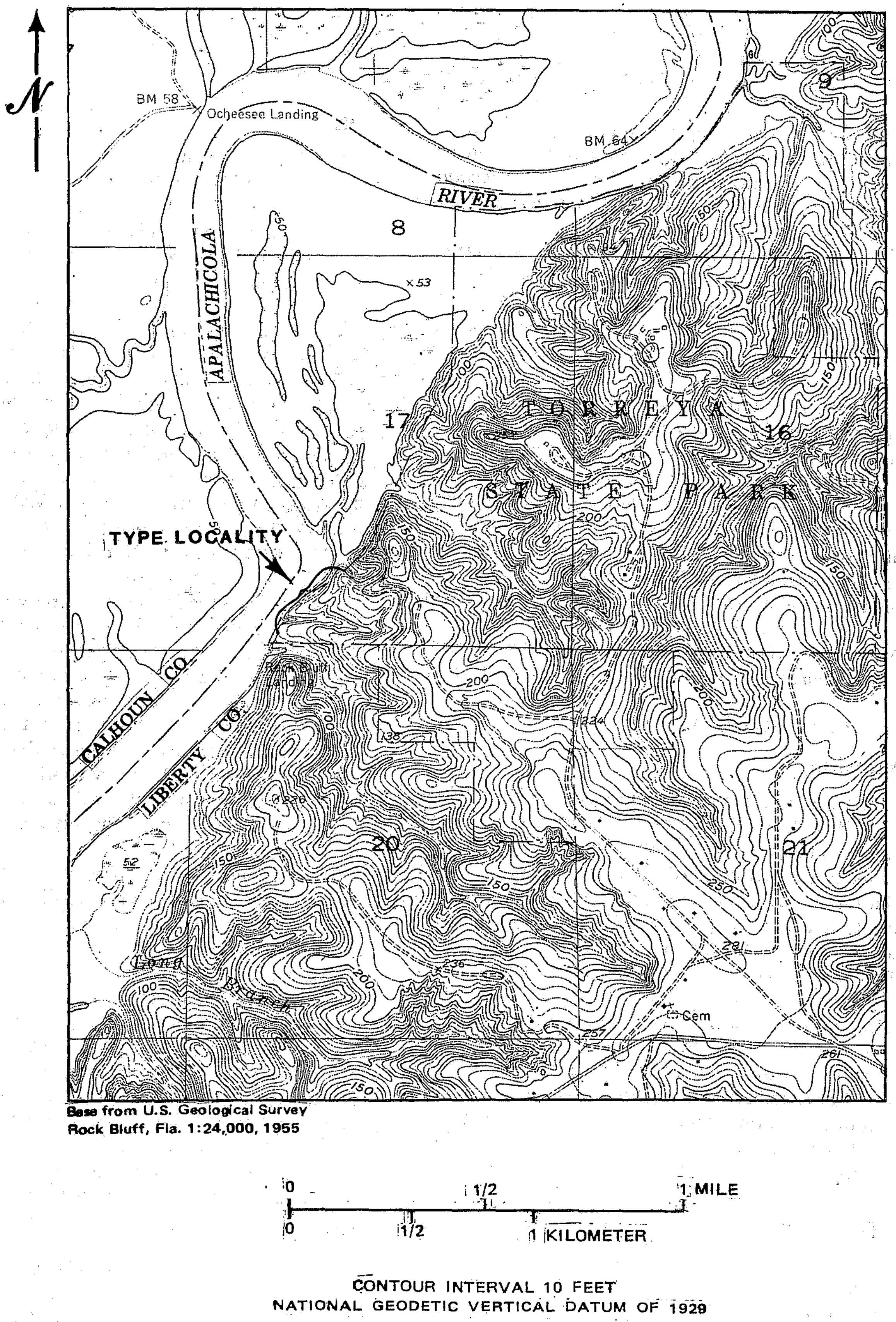


Figure 21. The type locality of the Torreya Formation of the Hawthorne Group.

Stratigraphic Relationships

The Torreya Formation is currently recognized only in the eastern panhandle of Florida east of the Apalachicola River, and in southwesternmost Georgia, in Decatur, Grady, and probably southern Thomas, Brooks, and Lowndes Counties (Fig. 22). The Torreya Formation grades laterally northeastward into variably dolomitic to noncarbonate-bearing clays and fine sands that are neither Torreya nor Marks Head in lithology.

The Torreya Formation disconformably or paraconformably overlies the Chattahoochee Formation in western Florida (Fig. 10), and is paraconformably overlain by the Chipola Formation at Alum Bluff (Banks and Hunter, 1973; Huddlestun, 1984). The contact relationships with the Chattahoochee Formation in Georgia are not established at this time. Where the upper part of the Chattahoochee Formation may be dominated by argillaceous, fine-grained sand, the contact with the overlying Torreya Formation, or its stratigraphic equivalent, may be paraconformable or apparently gradational. Similarly, the upper contact of the Torreya Formation in Georgia is not clearly established at this time. The Meigs Member of the Coosawhatchie Formation, exposed in the vicinity of Meigs in Thomas County, appears to extend into Gadsden County in the Gulf Trough. Where the contact between the Torreya and probable Meigs Member is exposed in the vicinity of Dogtown in Gadsden County, Florida, this contact appears to be conformable, or paraconformable. However, in cores farther south in Gadsden County, Berryville-type clay occurs in the stratigraphic position of the Meigs Member, and the contact between the Torreya and the Meigs Member also appears to be paraconformable. Elsewhere in southwestern Georgia the Torreya Formation is disconformably overlain by the Miccosukee Formation of late Pliocene age.

The Torreya Formation is distinguished from the other formations of the Hawthorne Group in being consistently calcareous (with subordinate dolomite) and consistently but variably fossiliferous in its type area. The deposits that are stratigraphically equivalent to the Torreya Formation farther to the northeast in the Gulf Trough in Georgia lack carbonate and are lithologically heterogeneous. The clay mineral suite of these deposits is variable and locally, or in parts of the sections, dominated by kaolinite, smectite, or palygorskite. Smectite is invariably present but kaolinite and palygorskite may be absent from parts of the sections or at some sites. In the Torreya Formation, on the other hand, the clay mineral suite is dominated by palygorskite and smectite, and either clay mineral may be absent in any part of the sections, or be the only clay mineral present (Weaver and Beck, 1977). The Torreya Formation is distinguished from the stratigraphically equivalent lower Miocene dolostone, clay and sand of the Alapaha and Suwannee Rivers area in that the carbonate of the unnamed formation consists of dolomite and only minor and scattered occurrences of fossiliferous sediments are known. In addition, there are thick beds of massive, unfossiliferous dolostone in the unnamed formation whereas dolostone comprises only a trace of the lithology of the Torreya Formation. The Torreya Formation and the stratigraphically equivalent Marks Head Formation are not known to be contiguous.

The overlying Meigs Member of the Coosawhatchie Formation is not known to contain carbonate and is more siliceous (and diatomaceous) than the Torreya Formation. The Meigs Member characteristically contains very thin bedding to lamination in the clay and fine sand beds whereas the Torreya Formation is generally thickbedded and massive.

The Torreya Formation is thickest in the Apalachicola Embayment where it averages about 200 feet (61 m). The thickest known section of Torreya Formation is 227 feet (69 m) near the axis of the Apalachicola Embayment in the Florida Geological Survey core Suber 1 (W-7539) in Gadsden County, Florida. The Torreya Formation thins abruptly at the eastern edge of the embayment in the vicinity of the Ochlockonee River. To the east of the embayment in Leon, Jefferson, and Madison Counties, Florida, the thickness of the Torreya Formation ranges between 50 and 100 feet (15 and 30 m). There is no thickness information of the Torreya Formation in Georgia.

The environment of deposition of the Torreya Formation was marine, nearshore, brackish to hypersaline. The common occurrence of intraclast beds in the Torreya Formation indicates that the sea bottom was frequently disturbed by periods of high wave or current energy. The low diversity of the benthic foraminifera (planktonic foraminifera are absent) and the occurrence of abundant *Ammonia beccarii* and *Elphidium* spp. (Brooks and others, 1966, p. 64) in the Torreya Formation indicates brackish water conditions. This conclusion is supported by the low diversity of the molluscan fauna and the prominence of oysters and scallops (Brooks and others, 1966, p. 64; Hunter and Huddlestun, 1982, p. 211-223), and by the occurrence of land mammal fossils in the Torreya Formation (Simpson, 1930, 1932; Colbert, 1932; Olsen, 1964a, 1964b; Hunter and Huddlestun, 1982, p. 218-219).

The clay mineral suite of the Torreya Formation is compatible with the paleontological evidence for the paleoenvironment. The clay mineral suite of the formation is dominated by palygorskite and smectite (see Weaver and Beck, 1977, p. 71-104). According to Weaver and Beck (1977), palygorskite originated in warm, coastal brackish to schizohaline water where the salinity of the watermass varied from hypersaline to brackish (schizohaline).

Age

The age of the Torreya Formation is early to middle Burdigalian, approximately in the middle part of the early Miocene (Hunter and Huddlestun, 1982). In Florida, the Torreya Formation contains two Hemingfordian land mammal faunas (Simpson, 1930, 1932; Olsen, 1964; Tedford and Hunter, 1984) that are believed to be between 17 and 19

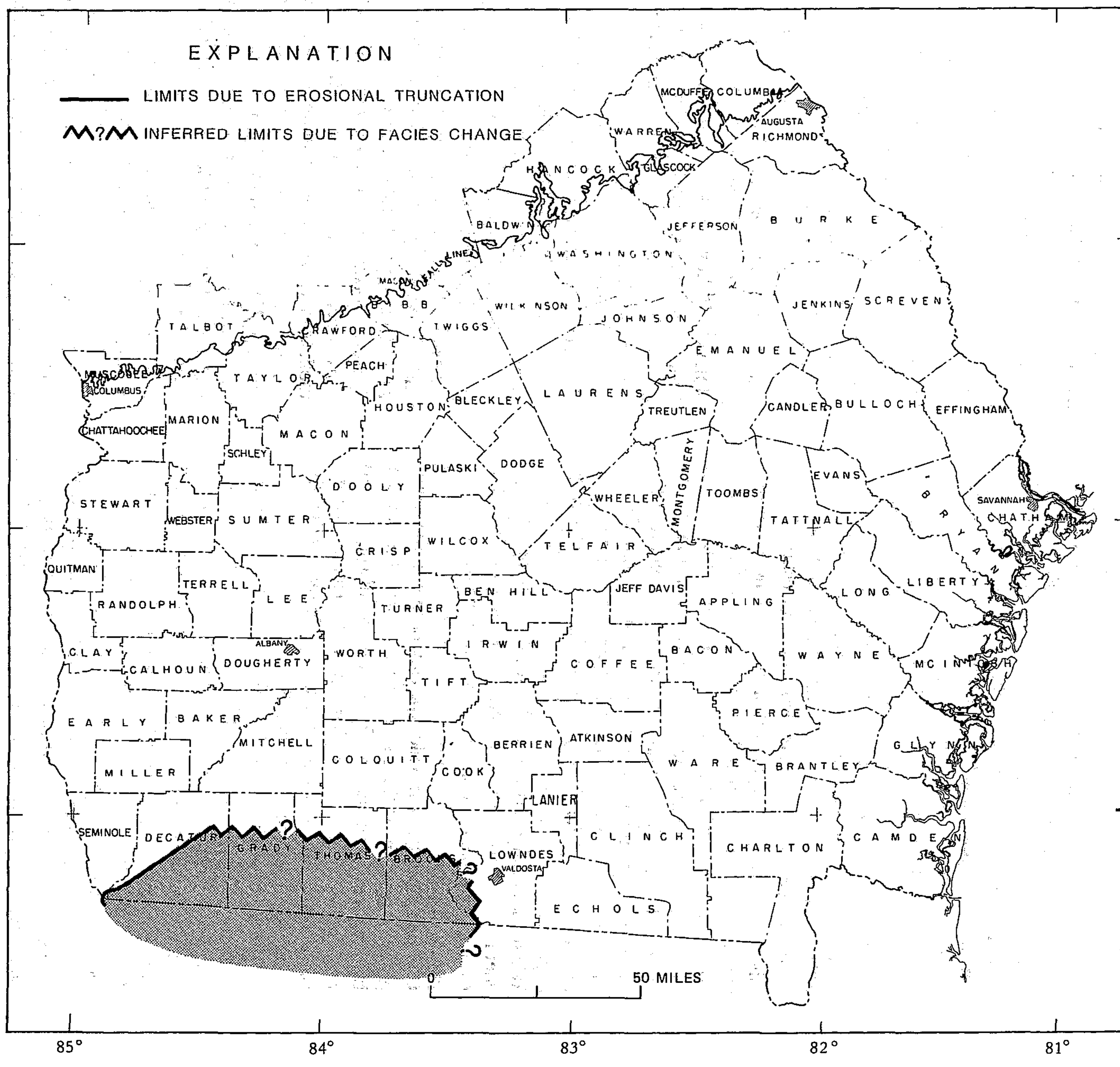


Figure 22. The areal distribution (outcrop and subcrop) of the Torreya Formation in Georgia.

million years old, indicating equivalency with planktonic foraminiferal Zones N6 or early N7 of Blow (1969) (Pl. 1). This is supported by stratigraphic evidence in that the Chipola Formation, which contains a late N7 planktonic foraminiferal fauna (Akers, 1972; Huddlestun, 1984), overlies the Torreya Formation with discontinuity.

SOPCHOPPY MEMBER OF THE TORREYA FORMATION

The "Sopchoppy limestone", informally introduced by Dall (1892, p. 119-120) and abandoned by Matson and Clapp (1909, p. 102), was informally reintroduced as the Sopchoppy Member of the Torreya Formation by Huddlestun and Hunter (1982, p. 210). The Sopchoppy Member is recognized in this paper as a formal lithostratigraphic unit and a subdivision of the Torreya Formation. The Sopchoppy Member previously has been included in the Chipola Formation (Matson and Clapp, 1909, p. 102, 103; Gardner, 1926) and the Hawthorne Formation (Cooke and Mossom, 1929; Weaver and Beck, 1977).

Type Locality

The name Sopchoppy was taken from the Sopchoppy River in Wakulla County, Florida. The type locality and type section, or unit-stratotype (holostratotype), of the Sopchoppy Member are herein designated as the exposures of fossiliferous, sandy limestone in Mill Creek adjacent to and under the bridge of an unimproved dirt road in the center of Sec. 34, T4S, R3W, approximately 7 miles (11 km) northwest of the village of Sopchoppy. The type locality is less than 0.1 mile (between 100 and 200 m) from the Sopchoppy River.

Lithology

The Sopchoppy Member was originally called a limestone by Dall (1892): It is my observation, however, that the Sopchoppy Member consists of several lithofacies along the Sopchoppy River. The two dominant lithofacies include a sandy, fossiliferous limestone (the original concept of the unit) and a tough, phosphatic, dolomitic sand. The two lithofacies are not completely exclusive.

The limestone lithofacies consists of a moldic, fossiliferous, variably sandy, variably phosphatic limestone. Characteristically the limestone is coarsely fossiliferous and most of the fossils consist of molds and impressions of pelecypods and gastropods. The foraminifera *Sorites* is also conspicuous in the limestone at the type locality. Not only has aragonite been dissolved from the shells but also calcite has been dissolved from pecten shells and foraminiferal tests. The only calcitic fossils that have not been visibly altered are the sand dollars (*Abertella floridana*) and the pelecypod *Carolia floridana.*

A clay component is not readily apparent in the limestone on casual inspection. However, Weaver and Beck (1977, p. 42) reported that the interstitial clay mineral components of the member (the clay sample came from the limestone at the type locality on Mill Creek) include palygorskite and trace amounts of montmorillonite.

The lithology of the phosphatic, dolomitic sand lithofacies appears to be uniform. Fine-grained, well-sorted quartz sand appears to dominate the lithology, but dolomite may occur in equal amounts. Fine- to very fine-grained, black to brown pelletal phosphate is scattered through the sediment. Larger grains, over 2 or 3 millimeters in diameter, are also present but are rare. The sediment is not noticeably argillaceous although it is probable that clay minerals occur intersitially.

The dolomitic fine-grained sand is very resistant to erosion and forms vertical faces along the river and along small tributary stream banks. Incision of the streams into this deposit produces deep, almost vertical-walled ravines that make access difficult. The dolomitic fine-grained sand is massive and shows no layering. It is bioturbated and appears to be incompletely to moderately well mixed. Small impressions of pelecypods are present but rare in this lithofacies, and the sediment is largely nonfossiliferous.

In Gadsden County, Florida, the only part of the Torreya Formation that is lithologically similar to the Sopchoppy Member is a dolomitic, phosphatic sand lithofacies that overlies the lower sandy limestone of the formation and underlies the Dogtown Clay Member. Like the Sopchoppy, the sediments of this lithofacies are characterized by vaguely layered or bioturbated, phosphatic, dolomitic sand with scattered intervals of limestone or dolostone. As a result of the apparent similarity, the dolomitic, phosphatic, sandy lithofacies underlying the Dogtown Clay Member in Gadsden County, Florida, is considered to be the Sopchoppy Member. As thus defined, the Sopchoppy Member probably extends some distance into southwestern Georgia in Decatur and Grady Counties, and underlies the Dogtown Clay Member (see Fig. 10).

Stratigraphic Relationships

The Sopchoppy Member of the Torreya Formation is exposed discontinuously along the Sopchoppy River from the vicinity of the village of Sopchoppy, for about 8 miles (13 km) up the Sopchoppy River and in tributary streams near the river. Outside this area there are no known exposures of the unit. The member appears to be restricted to the Apalachicola Embayment and its flanks, and appears to occur as far north as Gadsden County, Florida, and southern Decatur and Grady Counties, Georgia.

Neither the upper nor lower boundaries of the member are exposed in the type area. However, based on physical correlation with the Torreya Formation in Gadsden County, the Sopchoppy Member appears to be conformably overlain by the Dogtown Clay Member of the Torreya Formation, and is gradationally underlain by the lower fossiliferous, sandy limestones of the Torreya.

The Sopchoppy Member of the Torreya Formation is distinguished from the rest of the Torreya Formation in having a consistent carbonate component. The carbonate of the Sopchoppy Member is dominated by interstitial dolomite with subordinate occurrences of interstitial calcite, calcitic fossils, and limestone beds. Phosphate is also a consistent component of the Sopchoppy Member but appears to be lacking or present only in minor scattered concentrations in the rest of the Torreya Formation.

The greatest exposed thickness of the Sopchoppy Member in the type area is approximately 10 feet (3 m). Approximately 7 feet (2 m) is exposed at the type locality on Mill Creek.

As with the rest of the Torreya Formation, the environment of deposition of the Sopchoppy Member was marine, nearshore, and brackish to hypersaline. The presence of sand dollars (*Abertella floridana*), low diversity molluscan faunas (Gardner, 1926), and low diversity benthic foraminiferal faunas dominated by *Elphidium* spp., in addition to the reported occurrence of palygorskite (Weaver and Beck, 1977, p. 42), are all consistent with the above interpretation.

Age

No age studies of the Sopchoppy Member have been undertaken at this time, and the member is not known to contain any taxa restricted to narrow intervals of time. Therefore, in this report, the Sopchoppy Member of the Torreya Formation is assigned the same age as the rest of the formation, and is believed to be early Miocene (early to middle Burdigalian) (Pl. 1).

DOGTOWN CLAY MEMBER OF THE TORREYA FORMATION

Definition

The Dogtown Clay Member of the Torreya Formation was informally introduced by Huddlestun and Hunter (1982, p. 210) for the clay-rich interval in the upper part of the Torreya Formation in northern Liberty, Gadsden, and Leon Counties, Florida, and southern Decatur County, Georgia. Core and field information indicates that the Dogtown Clay Member is a laterally continuous unit across its area of occurrence (also see Sellards and Gunter, 1909). It grades upward into undifferentiated Torreya Formation and downward probably into the Sopchoppy Member, both the overlying and underlying Torreya being dominantly quartz sand. The commercial fuller's earth of Gadsden County, Florida, and Decatur County, Georgia, occurs within the Dogtown Clay Member, but only a small part of the Dogtown Clay Member contains a commercial-grade fuller's earth. In places where the commercial fuller's earth beds are separated into lower and upper beds, the intervening deposits are mainly sand, calcareous sand, limestone, dolomitic clay, and clayey dolostone.

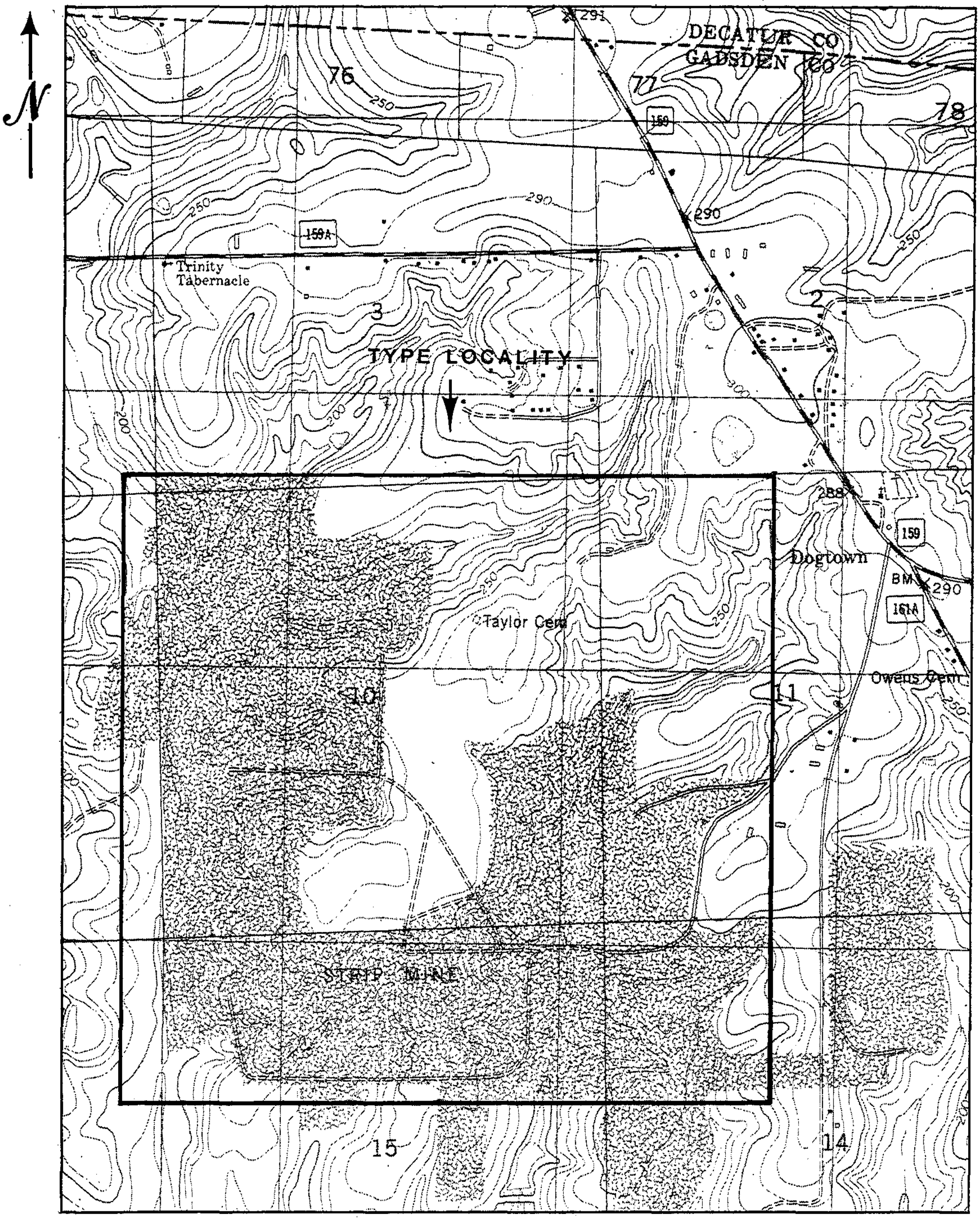
Type Locality

The name Dogtown was taken from the community of Dogtown in Gadsden County, Florida. The type locality of the Dogtown Clay Member of the Torreya Formation is the LaCamellia mine, 1 to 2 miles (1.5 to 3 km) southwest of Dogtown, and located in Sec. 15, T3N, R3W in Gadsden County (Fig. 23). The type section, or unit-stratotype (holostratotype), is that section of the Dogtown Clay Member exposed in the LaCamellia mine. Other reference localities and parastratotypes for the member include the exposures of the fuller's earth beds in the Gunn Farm mine of the Milwhite Company on the Florida-Georgia state line, 0.3 mile (0.5 km) west of highway Fla. 65 (Ga. 241), 9 miles (14 km) north of Quincy, Florida (also see Olson, 1966, p. 31-34, p. 58-65; Weaver and Beck, 1977, p. 100); and the exposure in the Midway mine, approximately 0.5 mile (0.8 km) northeast of the community of Midway in NE 1/4, Sec. 8, and SE 1/4, Sec. 5, T1N, R2W in Gadsden County, Florida (also see Weaver and Beck, 1977, p. 98-100).

Lithology

The lithology of the Dogtown Clay Member of the Torreya Formation is primarily clay (see Weaver and Beck, 1977, p. 71-97 for a thorough description and discussion of the member at its type locality). Palygorskite is the characteristic clay mineral of the member, but in specific beds montmorillonite may dominate the clay mineral suite. Sepiolite and illite are subordinate clay mineral components. In addition, the relative portions of the clay minerals fluctuate from bed to bed (Weaver and Beck, 1977, p. 73-104; Olson and others, 1966, p. 69-70). Other subordinate lithic components include quartz sand, calcite, dolomite, phosphate, mica, K-feldspar, pyrite, heavy minerals, rare fossil bones, and rare and scattered petrified wood. Locally, quartz sand, limestone or dolostone are the dominant lithologies present in specific beds. Clay beds, especially in the upper fuller's earth bed, may grade laterally into sandy clay or argillaceous sand (Weaver and Beck, 1977, p. 92-97).

The purity of the clay in the Dogtown Clay Member is variable. Relatively pure, palygorskite-rich fuller's earth is not present everywhere, however, and even minor amounts of quartz sand or carbonate render it noncommercial. The bedding characteristics of the clay vary from blocky, massive, and structureless; through massive, burrowed, and biologically disrupted (bioturbated); to thinly layered, laminated, and fissile. Where the clay is shaley, there is commonly a powdering of silt or very fine sand along the bedding planes or in lenses or patches. The purest grade fuller's earth clays are generally thin layered and laminated (Weaver and Beck, 1977, p. 71-104). In places the clay shows desiccation cracks, and intraclast zones are locally conspicuous.



Base from U.S. Geological Survey
Dogtown, Ga.-Fla. 1:24,000, 1982

0 1/2 1 MILE
0 1/2 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 23. The type locality of the Dogtown Clay Member of the Torreya Formation.

Stratigraphic Relationships

The Dogtown Clay Member of the Torreya Formation appears to be restricted to the interior of the Apalachicola Embayment in Florida, and the southern part of the Gulf Trough and flanks in Georgia (Fig. 24). The member is present in northern Liberty County, Gadsden County, and Leon County, Florida, and southern Decatur and Grady Counties, Georgia. The northern limit of the Dogtown Clay Member in Georgia is not established at this time because of insufficient core control. The fuller's earth deposits in northern Thomas County are not included in the Dogtown Clay Member but are a part of the Miegs Member of the Coosawhatchie Formation.

Within the Apalachicola Embayment in Florida, the Dogtown Clay Member occurs within the Torreya Formation. It gradationally overlies sediments tentatively assigned to the Sopchoppy Member, and is conformably overlain by fossiliferous, calcareous sediments of undifferentiated Torreya Formation. On the flanks of the Apalachicola Embayment in Leon County, Florida, however, the Dogtown Clay Member is disconformably overlain by either the Miccosukee Formation or the Jackson Bluff Formation.

The Dogtown Clay Member is a mappable clay body that occurs at or near the top of the Torreya Formation. It is distinguishable from the rest of the Torreya, which consists of variably calcareous or dolomitic, argillaceous, fine-grained sand with subordinate limestone, in consisting principally of clay with minor, local occurrences of sand and limestone.

The thickness of the Dogtown Clay Member is variable. Part of the variation in thickness must be due to lateral gradation of Dogtown clay lithology into sand beds adjacent to the top and bottom of the member. The Dogtown Clay Member is approximately 27 feet (8 m) thick at the type locality. The greatest known thickness of the member is 40.5 feet (12 m) in the Florida Geologic Survey core Suber 1 (W-7539) near the axis of the Apalachicola Embayment in Gadsden County. The known thickness range of the Dogtown Clay Member in Gadsden County is 15.5 feet (4.7 m) to 40.5 feet (12 m), and the average thickness is approximately 27 feet (8 m).

The environment of deposition of the Dogtown Clay Member of the Torreya Formation was marine, very near shore, and brackish to hypersaline. The presence of land mammal fossils (Simpson, 1930, 1932; Hunter and Huddlestun, 1982, p. 218) associated with the Dogtown Clay Member indicates close proximity to land.

Age

The Dogtown Clay Member of the Torreya Formation is locally fossiliferous and is included in the *Carolia floridana* zone of Hunter and Huddlestun (1982, p. 215-216). The commercial fuller's earth beds are not normally fossiliferous, but the sands, limestones, and dolostones that occur between the fuller's earth beds commonly are. In addition, Weaver and Beck (1977) reported that the upper fuller's earth bed locally grades laterally into fossiliferous sediments. The principal fossils found in the Dogtown Clay Member are mollusks, most of which occur as molds and casts. *Carolia floridana*, oysters, and *Chlamys* sp. near *C. acanikos*, however, are generally well preserved. Weaver and Beck (1977) reported sponge spicules and diatoms from the fuller's earth beds in the Attapulgus area in Decatur County, Georgia. Hemingfordian land mammal faunas have been reported and described by Simpson (1932) from the deposits defined here as the Dogtown Clay Member, and are now known as the Midway Fauna (Tedford and Hunter, 1984). The stratigraphic interval discussed by Simpson (1932) includes the sandy beds between the two fuller's earth beds as well as the overlying sands and limestones of the *Chlamys nematopleura* zone (Hunter and Huddlestun, 1982, p. 216-217) of the Torreya Formation.

The Dogtown Clay Member of the Torreya Formation is assumed here to be the same age as the rest of the Torreya Formation; that is, early Miocene (early to middle Burdigalian), equivalent to Zone N6 of Blow (1969) (see Pl. 1).

UNNAMED DOLOSTONE, CLAY, AND SAND OF THE HAWTHORNE GROUP

(Echols County)

Definition

This unnamed formation consists variably of dolostone, clay, and sand. It crops out along the lower Alapaha and Alapahoochee Rivers in the vicinity of Jennings in Hamilton County, Florida. It is not known to crop out in Georgia, but is believed to dip northeastward into the Southeast Georgia Embayment and to underlie the Statenville Formation in Echols County (Figs. 10 and 25, Pl. 1).

The deposits assigned to the unnamed dolostone, clay, and sand formation in this report were included in the Glendon Limestone (Mossom, 1925, p. 138-139), Tampa Limestone (Cooke and Mosson, 1929, p. 91) and Hawthorne Formation (Cooke, 1945, p. 149-150, 152-153; Olson, 1966, p. 80-83) in the past.

Reference Localities

In outcrop, the unnamed dolostone, clay, and sand formation is best exposed near the confluence of the Alapaha and Alapahoochee Rivers in Sec. 1, T2N, R12E, 1.5 miles (2.4 km) east of Jennings in Hamilton County, Florida, 1.25 miles (2 km) south of the Georgia-Florida state line. The formation is exposed for some distance along both rivers above their junction, and discontinuously for at least 2 miles (3.2 km) down the Alapaha River. The unnamed formation is also present in the interval 87 feet to 155 feet in the Florida Geological Survey core Betty 1 (W-15121), taken in NE 1/4, NW 1/4, Sec. 3, T2N, R12E at Jennings. The unnamed dolostone, clay, and sand formation crops out along the

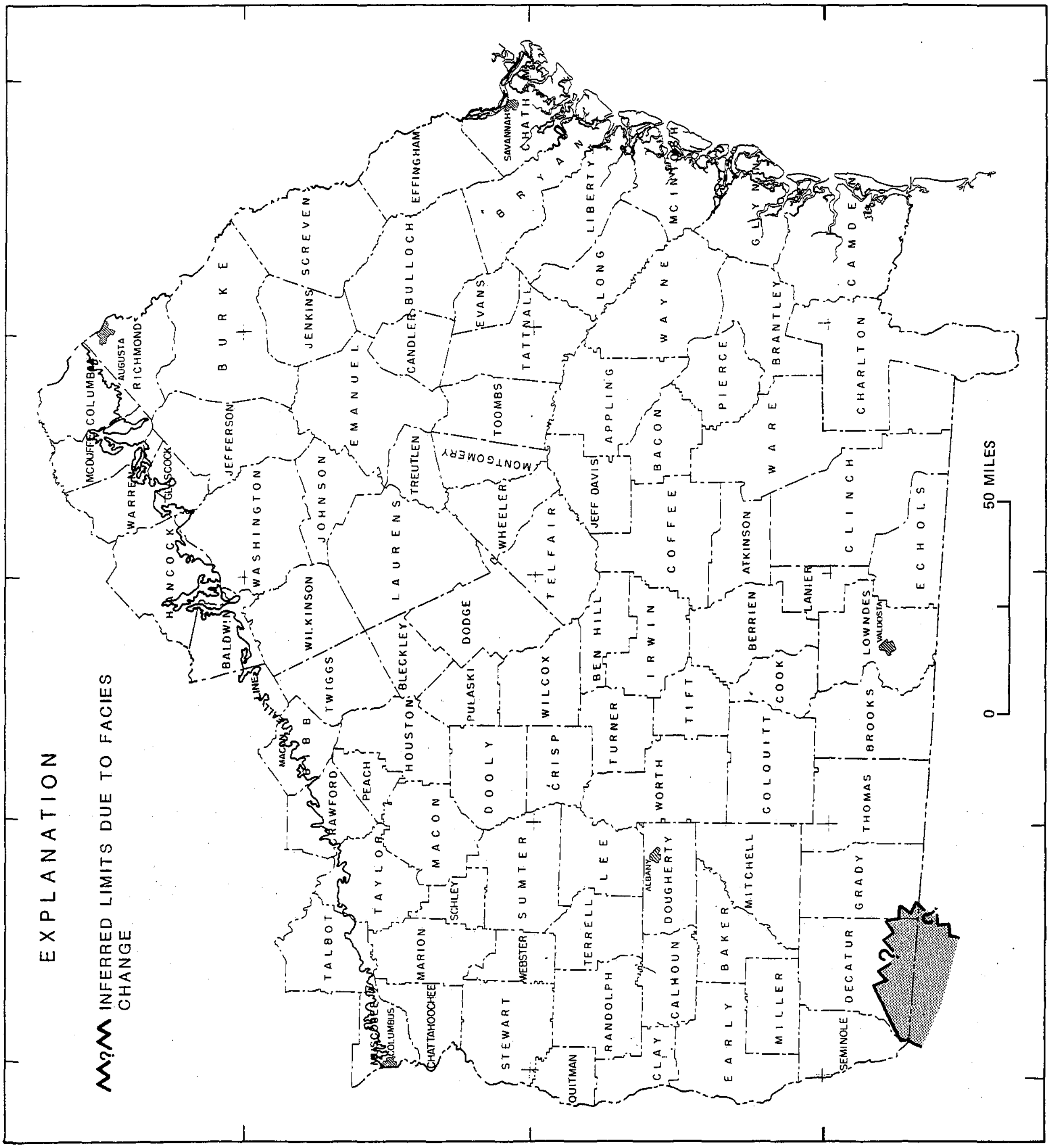


Figure 24. The areal distribution (outcrop and subcrop) of the Dogtown Clay Member of the Torreya Formation in Georgia.

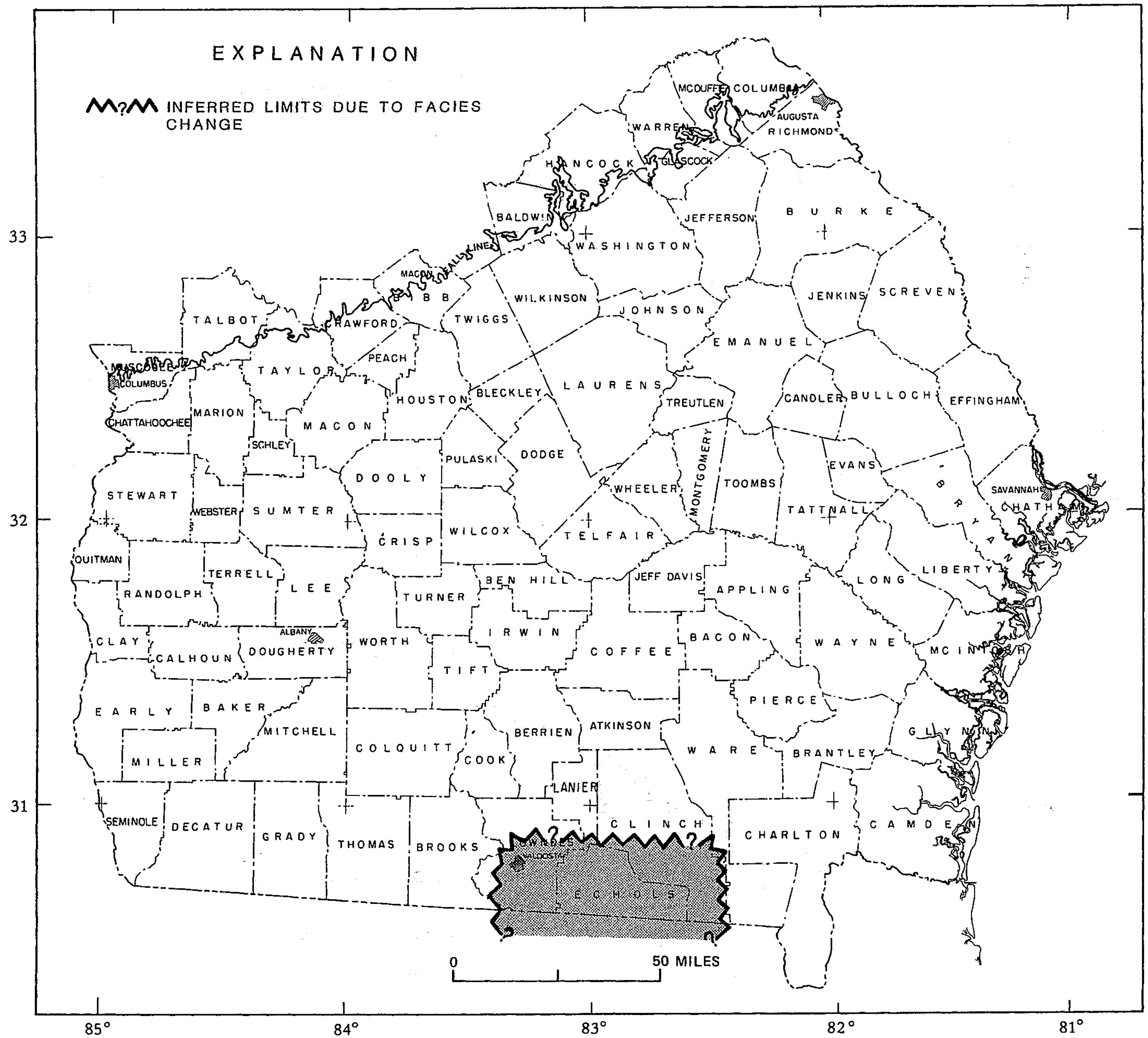


Figure 25. The inferred areal distribution (subcrop) of the unnamed lower Miocene dolostone, clay and sand of the Hawthorne Group in Georgia.

upper Suwannee River from the vicinity of the US 41 bridge east of White Springs, and extends for an unspecified distance upriver.

Lithology

In outcrop in Hamilton County, Florida, the unnamed dolostone, clay, and sand formation consists of thick-bedded, massive, tan to buff, saccharoidal dolostone with interbeds of argillaceous fine-grained sand and finely sandy clay. The massive dolostone is the most conspicuous and characteristic component of the formation. In general, the dolostone is thick-bedded, with some beds as much as 10 feet (3 m) thick. Intraformational, dolomite-cemented dolostone rubble or intraclast zones are locally conspicuous. Well-sorted, fine-grained sand and finely sandy clay are thinly and vaguely bedded. Farther down the Alapaha River in Sec. 7, T2N, R31E, there are some moldic, fossiliferous intervals in the dolostone with silica-replaced calcitic shells, and oyster (*Crassostrea normalis*) bioherms with silica-replaced shell material.

In the core Betty 1 (W-15121), approximately 2 miles (3.2 km) west of the Alapaha River outcrops, the ratio of dolostone to clay and sand is approximately 50/50. The dolostone beds range in thickness from less than 1 foot (0.3 m) to 15 feet (4.6 m), and the clay and sand beds range in thickness from approximately 1 foot (0.3 m) to 16 feet (4.9 m). The dolostone is massive and structureless with some intraclast zones and intervals of argillaceous dolostone. The clay is massive, variably dolomitic and intraclastic, and is largely sand-free. Quartz sand is a minor component of the formation in this core and is well-sorted and fine-grained. The beds of sand are massive, dolomitic, and argillaceous. The sediments are almost nonfossiliferous, and phosphate appears to be absent, in contrast to the overlying Statenville Formation.

There is some evidence that elsewhere this unnamed formation is much less dolomitic and more sandy and argillaceous. A core log presented by Olson (1966, p. 81-83) from Hamilton County, Florida, includes the stratigraphic interval of this formation. However, dolomite and dolostone are not included in the lithologic descriptions, but sand and palygorskite-bearing clay are prominent. Similarly, dolostone, although present and conspicuous, is not so prominent along the Suwannee River east of White Springs (compare with Cooke, 1945, p. 149-150; Brooks, 1966, p. 91).

In general, it appears that the lithology of this unnamed formation is variable, consisting dominantly of dolostone, clay, and sand; furthermore, in any given section or area, the proportions may vary widely. Subordinate lithic components include phosphate, chert, silicified shells, mica, and calcite. Palygorskite has been reported from sediments assigned to this unnamed formation (see Olson, 1966, p. 82).

Stratigraphic Relationships

At this time, the unnamed dolostone, clay, and sand formation is known to occur in Hamilton and Columbia Counties, Florida (Fig. 25). It is present in outcrop immediately south of the Georgia-Florida state line in Hamilton County, north of which it is suspected that the unnamed formation dips into the subsurface of Echols County. The northern limits of this formation are not yet known. The eastern limits must occur in eastern Columbia or western Baker Counties, Florida, because the Marks Head Formation occurs in the same stratigraphic position in the St. Marys River area in Florida and Georgia. The western limits of the unnamed formation appear to be the eastern part of the Florida Platform in Lowndes County, Georgia, and Hamilton County, Florida.

The unnamed dolostone, clay, and sand formation overlies the Parachucla Formation at White Springs on the Suwannee River in Columbia County, Florida, and a variably fossiliferous, sandy limestone in Hamilton County that appears to be assignable to the Parachucla Formation. The unnamed formation is overlain with sharp contact by the Statenville Formation in the core Betty 1 (W-15121), also in Hamilton County.

The unnamed dolostone, clay and sand formation is distinguished from the underlying Parachucla Formation in consisting of argillaceous fine sand with thick beds of massive dolostone that are rarely fossiliferous, and locally consists of sandy fossiliferous limestone. It is distinguishable from the stratigraphically equivalent Marks Head Formation in containing thick beds of massive dolostone and in being relatively nonphosphatic. Much of the dolomite in the Marks Head Formation is interstitial and thick beds of dolostone are not known to occur in the formation. The Marks Head Formation is consistently phosphatic. The unnamed dolostone, clay and sand is distinguishable from the stratigraphically equivalent Torreya Formation in being dolomitic rather than calcareous, in containing beds of nonfossiliferous dolostone rather than limestone, and in being generally nonfossiliferous rather than variably fossiliferous.

Approximately 10 to 15 feet (3 to 4.5 m) of the unnamed dolostone, clay, and sand are present in outcrop near the confluence of the Alapaha and Alapahoochee Rivers in Hamilton County, but neither contact is exposed there. The formation is 68 feet (21 m) thick in the core Betty 1 (W-15121). No other thickness information is available at this time.

The unnamed dolostone, clay and sand formation is distinguishable from the overlying Statenville Formation in being generally thick-bedded and massive, in containing little phosphate, and containing only fine-grained sand whereas the Statenville is prominently bedded and cross-bedded in the lower part, consistently phosphatic and locally abundantly phosphatic, and more coarsely sandy with scattered occurrences of quartz pebbles. The upper part of the Statenville Formation is more argillaceous than the unnamed dolostone, clay and sand and contains no carbonate.

Age

No paleontological criteria are available on which to base an age assessment of this formation at the present time. Stratigraphic position and lithological similarity, however, suggest a close stratigraphic relationship with the Torreya Formation on the western side of the Florida Platform, and with the Marks Head Formation of the Southeast Georgia Embayment. On this basis, it is suggested that the unnamed dolostone, clay, and sand formation is early Miocene (early to middle Burdigalian), and stratigraphically equivalent to the Torreya and Marks Head Formation (Fig. 10 and Pl. 1).

COOSAWHATCHIE FORMATION OF THE HAWTHORNE GROUP (formalized)

Definition

The Coosawhatchie Formation is herein formalized and raised in rank to that of formation. The Coosawhatchie Formation of this report is predominantly a phosphatic clay, sandy clay, argillaceous sand, and phosphorite that originally was called the Coosawhatchie clay member of the Hawthorne Formation (Heron, Robinson, and Johnson, 1965, p. 24). The Coosawhatchie was informally named for a distinctive clay deposit exposed in a railroad cut and at Dawsons Landing near the community of Coosawhatchie in Jasper County, South Carolina (Heron, Robinson, and Johnson, 1965, p. 24). The informal name has subsequently been adopted and extended into Georgia (Abbott, 1974; Ernissee, Abbott, and Huddlestun, 1977; Abbott and Andrews, 1979; Abbott and Huddlestun, 1980; Huddlestun, 1981). The Coosawhatchie is formally recognized as a formation in this report because of its lithologic distinctiveness and its widespread occurrence in southern South Carolina, Georgia, and northeastern Florida.

Previously, along the Savannah River in Effingham County, Georgia, the Coosawhatchie Formation of this report was included in undifferentiated Miocene by Veatch and Stephenson (1911, p. 375) and in the Hawthorne Formation (Cooke, 1936, p. 109; Georgia Geological Survey, 1976). Along the Altamaha River in Georgia, at and downstream from Bugs Bluff in Wayne County, the unit referred to here as Coosawhatchie Formation was variously included in the Alum Bluff Formation, Alum Bluff Formation?, and "Miocene or Oligocene?" by Veatch and Stephenson (1911, p. 360, 376, 377, 412-413), and in the Hawthorne Formation by Cooke (1943, p. 95, 100).

The stratotype of the Coosawhatchie Formation at Dawson's Landing on the Coosawhatchie River, South Carolina, was referred to the Parachucla Formation by Sloan (1908, p. 346).

The Coosawhatchie Formation is divided into five formal members: the Tybee Phosphorite Member (new name), the Berryville Clay Member (new name), the Ebenezer Member (new name), the Meigs Member (new name), and the Charlton Member. These members will be discussed separately.

Type Section

The name Coosawhatchie is derived from the community of Coosawhatchie in Jasper County, South Carolina (Heron, Robinson, and Johnson, 1965, p. 24). Heron, Robinson, and Johnson (1965) listed two localities where the Coosawhatchie clay was known to crop out, "exposures in the Atlantic Coast Line cut south of Coosawhatchie" and "Dawson's Landing on Coosawhatchie River." Although they indicated that their main reference locality was the railroad cut, Dawsons Landing is herein designated the type locality of the Coosawhatchie Formation because the formation there is better exposed, better preserved, more accessible than in the railroad cut, and has been used more as a reference locality than the railroad cut (Abbott, 1974; Ernissee, Abbott, and Huddlestun, 1977; Abbott and Andrews, 1979). The unit-stratotype (holostratotype), of the Coosawhatchie Formation is that section of the formation exposed in the low bluff at Dawsons Landing, located on the Coosawhatchie River 2.5 miles (4 km) south of the community of Coosawhatchie in Jasper County, South Carolina (Fig. 26; also see Abbott and Andrews, 1979, p. 226-227, Fig. 1). In addition to the exposure at the type locality, the interval 3 feet to 30 feet in the Dawsons Landing core taken by the South Carolina Geological Survey is herein designated a parastratotype of the formation. The core site is approximately 300 feet (91 m) from the bluff at the landing.

The unit-stratotype of the Coosawhatchie Formation exposes only 13 feet (4 m) of the formation (Abbott and Andrews, 1979, p. 227), and only the Berryville Clay Member of the Coosawhatchie Formation is present at the type locality. Although discontinuous, the section of the Coosawhatchie Formation is much more complete along the Savannah River in southern Effingham County, Georgia, than it is anywhere else in outcrop. Therefore, the series of exposures in the low bluffs along the Savannah River from Frying Pan Landing downriver to the vicinity of Old Wood Landing is herein designated a reference locality and composite parastratotype of the formation (Fig. 3).

Lithology

The Coosawhatchie is a lithologically heterogeneous formation that consists dominantly of clay and sand. Clay appears to be the dominant and characteristic lithic component of the formation, but sand is also important and locally dominates the lithology. Significant minor lithic components include phosphate, phosphorite, dolostone, limestone, and calcite. Other subordinate lithic components include dolomite, mica, siliceous claystone and chert, siliceous microfossils, zeolite, and scattered vertebrate debris.

Clay (Berryville Clay Member) predominates in the relatively more offshore area, under the present coast and continental shelf. The clay grades laterally landward, or west-

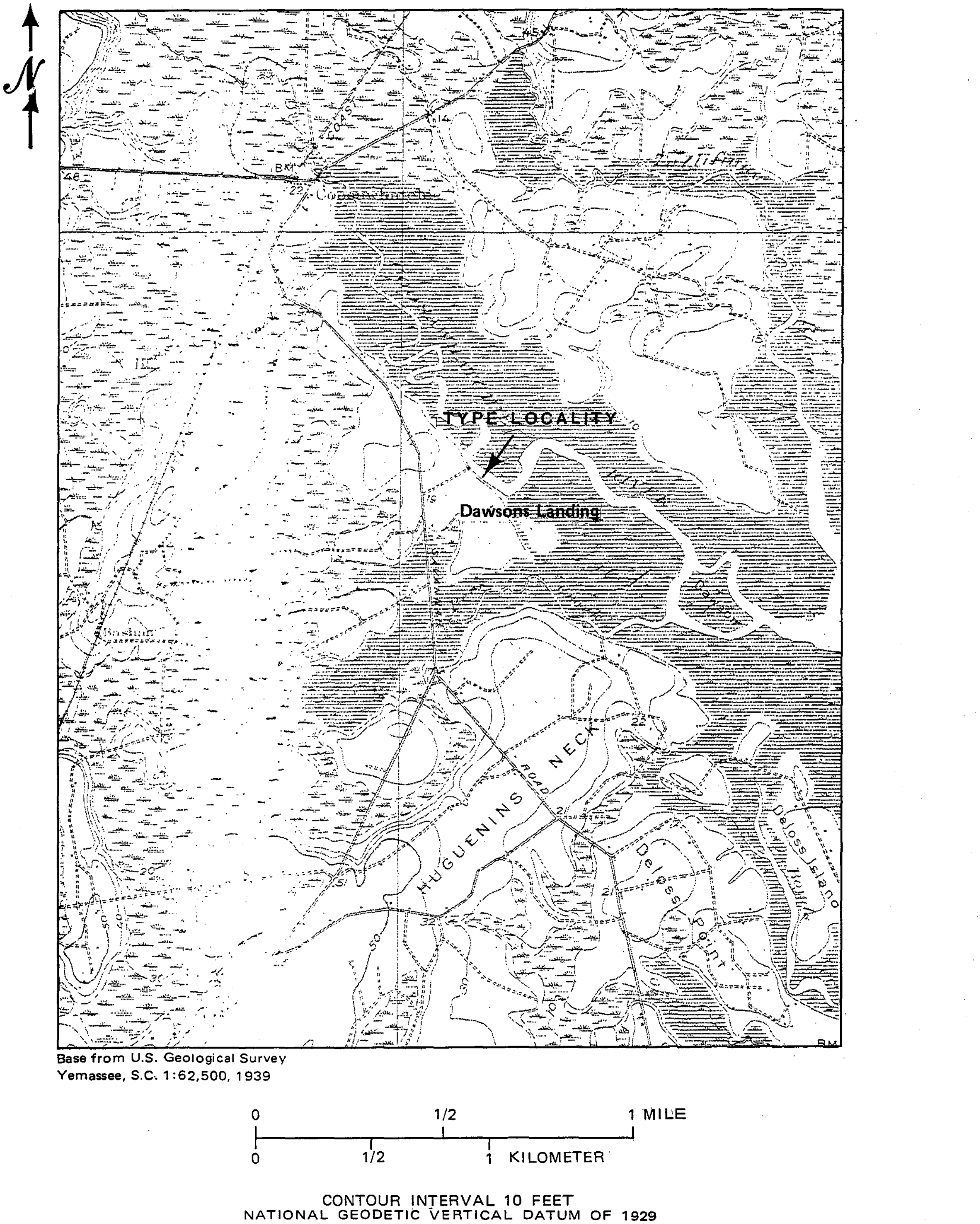


Figure 26. The type locality of the Coosawhatchie Formation of the Hawthorne Group.

ward, into more sandy, inner continental shelf, marine deposits where clay is less conspicuous (Ebenezer Member). Farther south in the Southeast Georgia Embayment, the upper part of the inner shelf sands (Ebenezer Member) grade laterally into estuarine or fluvial sandy clays, argillaceous sands and argillaceous sandstones in which the clay mineral suite is dominated by kaolinite (Altamaha Formation) (see Huddlestun, 1985).

The clay minerals of the Coosawhatchie Formation in the type area in South Carolina and along the Savannah River are dominated by smectite whereas illite, kaolinite, palygorskite, and sepiolite are all minor constituents (Heron, Robinson, and Johnson, 1965, p. 24, 26; Hetrick and Friddell, 1984; also see Weaver and Beck, 1977). Limited information indicates that the palygorskite and sepiolite content increases to the south in eastern Georgia (Hetrick and Friddell, 1984).

The carbonate content of the Coosawhatchie Formation is variable. North of the Altamaha River in Georgia, calcite and dolomite are very minor or lacking. However, the Berryville Clay Member is locally calcareous in the Savannah River area, and is generally calcareous offshore. South of the vicinity of the Altamaha River, the Coosawhatchie is slightly dolomitic with some scattered beds of dolostone. The Charlton Member in southeastern Georgia, however, is characteristically calcareous and dolomitic, and dolomite and dolostone become prevalent in the Coosawhatchie Formation in northeastern Florida.

The Coosawhatchie Formation is phosphoritic on the flanks or crests of structural highs, such as the Beaufort Arch in the northern coastal area of Georgia. Elsewhere, phosphate content of the Coosawhatchie Formation is moderate to minor.

Stratigraphic Relationships

The Coosawhatchie Formation is known to occur from southern South Carolina southward into northeastern Florida (Fig. 27). In the Savannah River area of Georgia, the western limit of the Coosawhatchie Formation is controlled by erosional truncation, and the formation extends updip only to the central part of Effingham County. Farther south in the Southeast Georgia Embayment area, the Coosawhatchie occurs as far west as the Ohoopee River area, where the Meigs Member crops out. The lower part of the Coosawhatchie Formation grades laterally westward into the Meigs Member and the upper part grades into the Altamaha Formation in the vicinity of the Orangeburg Escarpment. Farther south, the Coosawhatchie Formation underlies the St. Marys River area in Georgia and Florida, and appears to grade laterally westward into the Statenville Formation of the upper Suwannee River area (Fig. 11, Pl. 4). The Coosawhatchie Formation underlies most of the continental shelf of Georgia.

The Coosawhatchie Formation disconformably or paraconformably overlies the Marks Head Formation in Georgia, and paraconformably overlies the Cooper Formation on the outer continental shelf in the core AMCOR 6002 (Figs. 10 and 11; Pls. 2 and 3). The Coosawhatchie is generally overlain disconformably by the Cypresshead Formation in Georgia but is locally overlain disconformably by the Raysor Formation, unnamed Pliocene shelly sand, Wabasso beds, or Satilla Formation. In the core AMCOR 6002 on the outer continental shelf of Georgia, the Coosawhatchie Formation is overlain by undifferentiated upper Miocene sands of the Hawthorne Group (Pls. 2 and 3).

The Coosawhatchie Formation is distinguished from the underlying Marks Head Formation in consisting of olive-gray, phosphatic clays or brown phosphorite in the lower part and micaceous, slightly phosphatic, argillaceous, fine-grained sand in the upper part. In contrast, the Marks Head Formation consists of lighter colored phosphatic, slightly dolomitic, argillaceous sand to finely sandy clay. The clays of the Coosawhatchie differ in physical properties from that of the Marks Head because the clay mineral suite of the Coosawhatchie Formation is dominated by smectite with minor sepiolite and illite whereas the clay mineral suite of the Marks Head Formation is dominated by palygorskite and smectite. Generally there is a bed of fuller's earth or dolostone at the top of the Marks Head Formation in eastern Georgia which contrasts with the overlying dark, phosphatic clay or phosphorite. In the vicinity of the Gulf Trough in the central and southwestern Coastal Plain, the Coosawhatchie Formation (Meigs Member) is distinguished from the underlying undifferentiated lower Miocene Hawthorne deposits in containing laminated to thinly bedded, siliceous, diatomaceous clay whereas the underlying deposits are lithologically heterogeneous and typically thick-bedded and massive.

The Coosawhatchie Formation (Meigs Member) is distinguished from the overlying Altamaha Formation in containing laminated to thin-bedded, finely sandy, diatomaceous, smectitic clays with sporadic occurrences of phosphate, whereas the Altamaha Formation consists typically of thick-bedded and massive, feldspathic, nonphosphatic, kaolinitic clays and very poorly sorted to well-sorted sand and sandstone. The Coosawhatchie Formation (Ebenezer Member) is distinguished from the overlying Cypresshead in eastern Georgia in being thick-bedded and massive, commonly bioturbated throughout, slightly but consistently phosphatic, slightly to very micaceous, argillaceous (with clay mainly occurring interstitially); the sand-size is consistently fine-grained and well-sorted. In contrast, the Cypresshead Formation is only locally bioturbated and is commonly bedded (thin- to thick-bedded), nonphosphatic, nonmicaceous, and of widely varying sand-size (fine- to pebble-size). In addition, the clay within the Cypresshead Formation is more commonly distributed in laminae to thin beds, rarely to thick beds, and the interstitial clay fraction of the formation is minor.

In the Savannah River area of Georgia, in southern Effingham and northern Chatham Counties, the Coosaw-

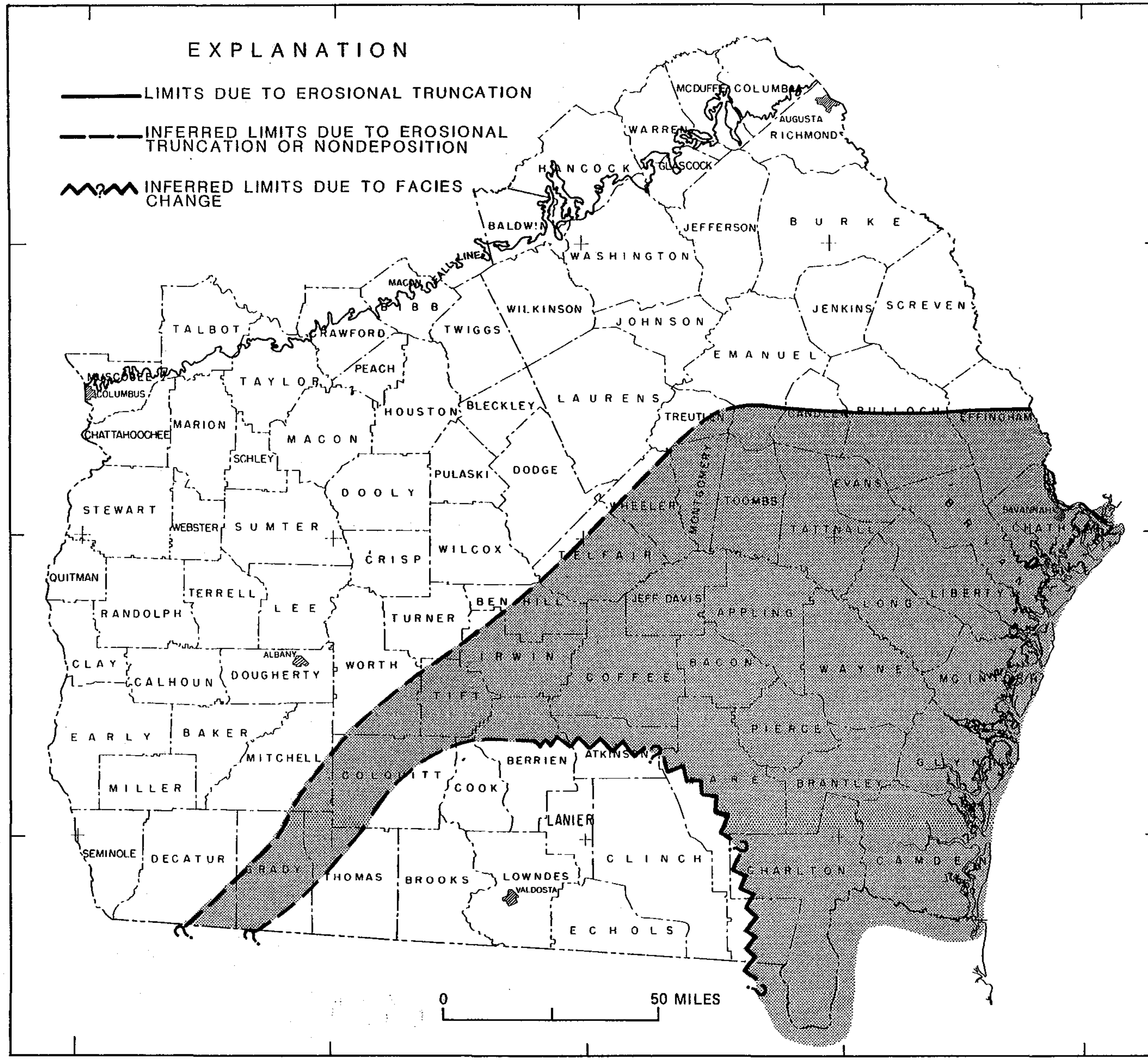


Figure 27. The areal distribution (outcrop and subcrop) of the Coosawhatchie Formation in Georgia.

hatchie Formation averages between 100 and 120 feet (30 and 37 m) thick. It is 27 feet (8 m) thick in the Dawson Landing core taken at the type locality in Jasper County, South Carolina. The Coosawhatchie Formation thickens southward and reaches its greatest known thickness in the Southeast Georgia Embayment where it is 284 feet (87 m) thick in the interval 90 feet to 374 feet in the core Cumberland Island 1 (GGS-3426) in Camden County; 275 feet (84 m) thick in the interval 51 feet to 325 feet in the core Charlton 2 (GGS-3185) at Folkston in Charlton County; 244 feet (74 m) thick in the interval 59 feet to 303 feet in the core Wayne 2 (GGS-3512) in Wayne County; and 175 feet (53 m) thick in the interval of approximately 57 feet to 232 feet in the core AMCOR 6002 on the continental shelf (Pl. 3).

Age

The Coosawhatchie Formation is middle Miocene (early Serravallian) in age (Pl. 1), based on the occurrence of the planktonic foraminifera *Globorotalia peripheroacuta* and *G. fohsi praefohsi.* The presence of these two species requires assignment to Zones N10 or N11 of Blow and Banner (1966, p. 286-302) and Blow (1969) (Pl. 1). The age of the formation will be covered more fully in the discussion of the age of the Berryville Clay Member.

BERRYVILLE CLAY MEMBER OF THE COOSAWHATCHIE FORMATION (new name)

Definition

The Berryville Clay Member is a new name, proposed herein for a clay subdivision of the Coosawhatchie Formation. Offshore, on the continental shelf, the Berryville Clay Member constitutes the entire Coosawhatchie Formation. The Berryville Clay, however, grades laterally westward (shoreward) into the Ebenezer Member and extends farthest inland at the base of the formation (Figs. 10, 11; Pl. 3). Only the Berryville Clay Member is present at the type locality of the Coosawhatchie Formation.

On the Savannah River, the Berryville Clay Member is exposed in outcrop only at Frying Pan Landing and in the low bluffs in the vicinity of Berry Landing. The section exposed at Frying Pan Landing has been included in undifferentiated Miocene by Veatch and Stephenson (1911, p. 375) and in the Hawthorne Formation (Cooke, 1936, p. 109; Georgia Geological Survey, 1976). The section exposed in the low bluff near Berry Landing has been referred to the Coosawhatchie Clay Member of the Hawthorne Formation by Ernissee, Abbott, and Huddlestun (1977) and Abbott and Andrews (1979).

Type Section

The name Berryville is taken from the small community of Berryville in eastern Effingham County, Georgia. The low bluff on the west side of the Savannah River in the vicinity of Berry Landing is herein designated the type locality of the Berryville Clay Member of the Coosawhatchie Formation (Fig. 28). The entire section exposed in the bluffs consists of Berryville Clay, and this is the type section, or unit stratotype (holostratotype), of the member. Nine feet (2.7 m) of Berryville Clay Member is exposed at the type locality, but neither the lower nor upper boundary of the member is exposed. The type locality is approximately 3 miles (5 km) east of Berryville.

The interval 116 feet to 163 feet in the core Effingham 14 (GGS-3155) is herein designated a parastratoytpe and lower and upper boundary stratotype of the Berryville Clay Member. In this core, the Berryville Clay is overlain conformably and gradationally by the Ebenezer Member at 116 feet, and is underlain disconformably or paraconformably by the Marks Head Formation at 163 feet. The core site of Effingham 14 (GGS-3155) is on the south shoulder of Ga. 275, approximately 2.75 miles (4.4 km) southwest of Ebenezer Landing, and approximately 4.8 miles (7.7 km) south of the type locality (Fig. 3).

Lithology

The Berryvillle Clay Member of the Coosawhatchie Formation consists principally of yellowish gray (5 Y 7/2) to light olive gray (5 Y 5/2), silty, phosphatic, calcareous in some areas, variably siliceous clay. Clay is the dominant lithic component of the member, whereas minor components of the lithology include quartz sand and silt, mica, phosphate, calcite, limestone, dolomite, lignitic flecks, scattered fine vertebrate debris, siliceous claystone and opaline cristobolite, traces of feldspar, zeolite, calcareous and siliceous microfossils, and rare shelly material in the type area (especially barnacle scutes). On casual inspection, the Berryville Clay appears to be massive, very thick bedded, and blocky. However, on close inspection, the clay is commonly thin-bedded to laminated, with dustings of silt, mica, phosphate, and fine vertebrate debris (especially fossil fish scales) along partings or bedding planes.

The clay mineral suite of the Berryville Clay Member is dominated by smectite in the type area. Subordinate clay minerals include illite with minor sepiolite, kaolinite, and palygorskite. Palygorskite is a more common component of the clay mineral suite in the offshore area of Georgia, and to the south in southern Georgia and northeastern Florida (Hetrick and Friddell, 1984).

The lower part of the member is commonly diatomaceous, and less commonly calcareous. Microfossils known to occur in the diatomaceous and calcareous phases of the member include diatoms, radiolarians, silicoflagellates, foraminifera, calcareous nannofossils, and ostracodes (also see Ernissee, Abbott, and Huddlestun, 1977). Where siliceous, the Berryville is generally a diatomaceous clay. Only rarely does it approach an argillaceous diatomite in lithology. Thin lenses

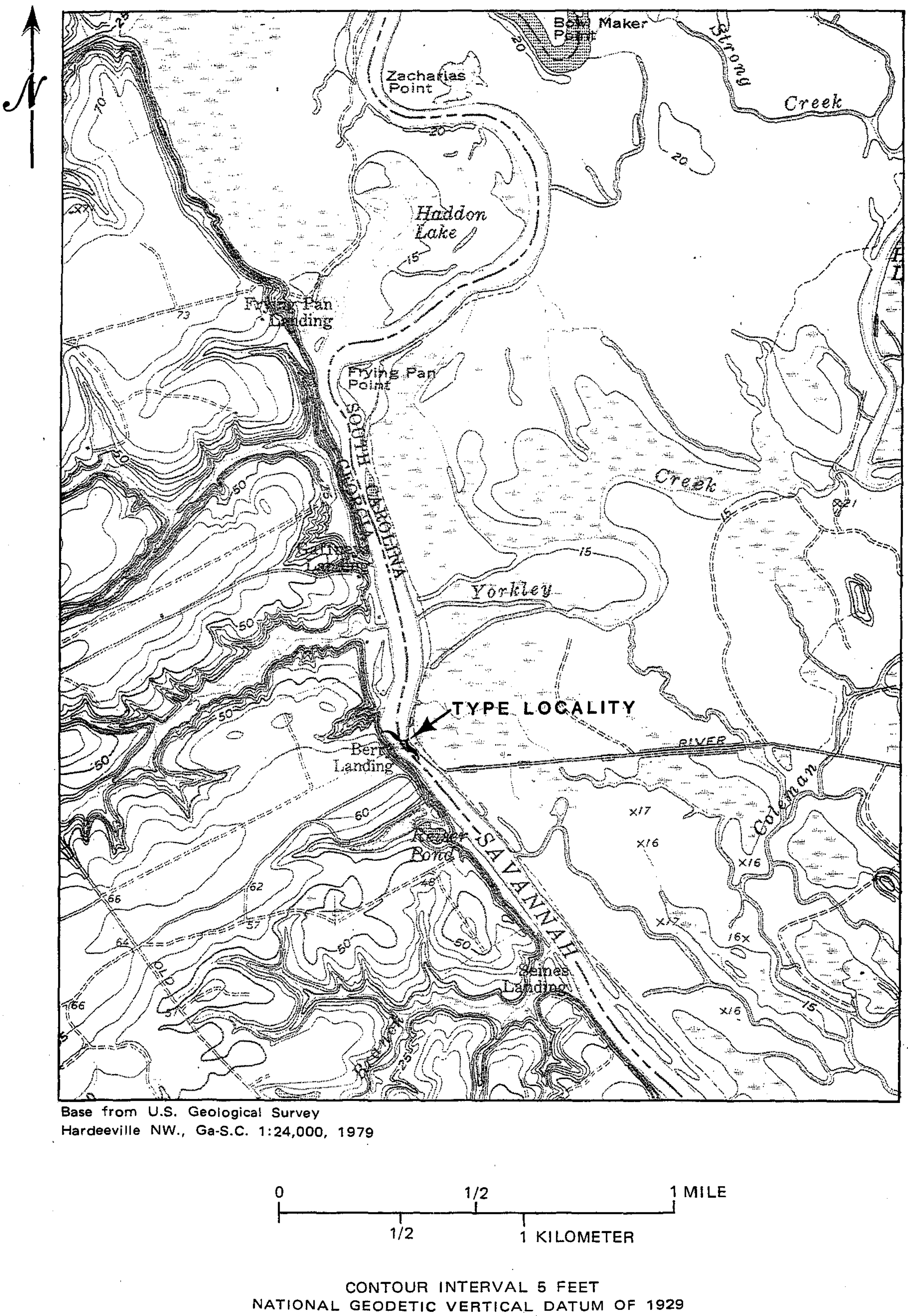


Figure 28. The type locality of the Berryville Clay Member of the Coosawhatchie Formation.

or layers of siliceous claystone are commonly present in the siliceous phases of the member whereas layers of dense, fine-grained limestone or lines of calcareous concretions occur in the calcareous phases. All of the known calcareous Berryville Clay is also diatomaceous, but much of the diatomaceous Berryville is noncalcareous. The known occurrence of calcareous material in the Berryville Clay Member is restricted to the Savannah River area and continental shelf area of Georgia.

Stratigraphic Relationships

The Berryville Clay Member of the Coosawhatchie Formation underlies the coastal area and the continental shelf of Georgia (Fig. 29). It extends from the vicinity of Coosawhatchie in Jasper County, South Carolina in the north, to northeastern Florida in the south. It progressively thins westward by facies change into the Ebenezer Member of the Coosawhatchie Formation (Figs. 10 and 11; Pl. 3) and is known to occur as a thin tongue at the base of the Coosawhatchie Formation as far west as the cores Wayne 2 (GGS-3512) in Wayne County in the Altamaha River area, and Charlton 2 (GGS-3185) at Folkston in Charlton County. In the Savannah River area, the updip limit of the member is defined by erosional truncation and not facies change. The Berryville Clay Member is not believed to occur west of the line defined by the above two cores and outcrop limits on the Savannah River.

The Berryville Clay Member of the Coosawhatchie Formation disconformably or paraconformably overlies the Marks Head Formation in Georgia, but paraconformably overlies the Cooper Formation on the continental shelf in the core AMCOR 6002 (Figs. 10 and 11; Pls. 2 and 3). Generally, the Berryville Clay is conformably and gradationally overlain by the Ebenezer Member of the Coosawhatchie Formation, but in the core AMCOR 6002, it is overlain by undifferentiated upper Miocene sands of the Hawthorne Group.

The Berryville Clay Member of the Coosawhatchie Formation is distinguished from the underlying Marks Head Formation in consisting of olive-gray, phosphatic, silty clay that is calcareous in some areas and commonly diatomaceous in the lower part. In contrast, the Marks Head Formation consists of lighter colored, phosphatic, slightly dolomitic, argillaceous sand to finely sandy clay. The Berryville clays differ in physical properties from the clays of the Marks Head because the clay mineral suite of the Berryville Clay is dominated by smectite and illite with minor sepiolite, whereas the clay mineral suite of the Marks Head is dominated by palygorskite and smectite. Generally, at the top of the Marks Head Formation, there is a bed of fuller's earth (palygorskite-rich) or dolostone, in contrast with the overlying dark phosphatic clay of the Berryville Clay Member. In the coastal area of Georgia, the underlying Tybee Phosphorite is distinguished from the Berryville Clay in consisting of massive and structureless, commonly bioturbated, brown, arenitic, sandy phosphorite that has the appearance of wet coffee-grounds.

The overlying Ebenezer Member of the Coosawhatchie Formation differs from the Berryville Clay Member in consisting of thick-bedded and massive, micaceous, slightly phosphatic, bioturbated, argillaceous, fine-grained, well-sorted sand. The Berryville Clay generally appears massive and structureless in outcrop or cores (when freshly cored and moist), but on closer inspection is seen to be very thinly layered to laminated and, upon drying, is generally fissile and shaley with well-defined bedding planes. In the type area, the clay mineral suite does not appear to differ between the Berryville Clay Member and the Ebenezer Member (compare with Hetrick and Friddell, 1984).

The Berryville Clay Member is at least 9 feet (2.7 m) thick at the type locality, but neither the upper nor lower boundary is exposed there. In cores in the type area, the thickness of the member averages about 50 feet (15 m) with the thickest known section being 54 feet (16.5 m) in the core Chatham 14 (GGS-3139). The Berryville Clay Member thickens in the coastal area southward toward the center of the Southeast Georgia Embayment, but core control in that area is inadequate to delineate its thickness distribution there. In coastal Bryan County, the Berryville Clay Member is 67 feet (20.5 m) thick, and its greatest known thickness onshore is 85 feet (26 m) in the core Cumberland Island 1 (GGS-3426) on Cumberland Island in Camden County. Offshore, where the Berryville Clay constitutes the entire Coosawhatchie Formation, it is 175 feet (53 m) thick in the core AMCOR 6002.

The environment of deposition of the Berryville Clay Member was marine, continental shelf, inner to probably middle neritic. The salinity of the associated water-mass was probably close to normal, based on the microfossil assemblages that occur locally (Ernissee, Abbott, Huddlestun, 1977; Abbott and Andrews, 1979; Abbott, 1980). This is consistent with the typical, but not total, absence of palygorskite in the Berryville Clay member which, according to Weaver and Beck (1977), requires a warm, shallow, coastal brackish to schizohaline environment. Abbott and Andrews (1979) and Abbott (1980) presented evidence for a cool water environment for deposition of the Berryville Clay Member. However, the planktonic foraminifera are strictly subtropical, suggesting either a mixing of different water-masses on the continental shelf or seasonal plankton blooms during the deposition of the Berryville Clay.

The olive-gray to olive-black color of the Berryville Clay, the common occurrence or abundance of small and delicate vertebrate bone debris and fish-scales along bedding planes, the characteristic thin bedding and lamination rather than bioturbation or homogenization of the sediments (due to an infauna), and the local occurrence of sulphosalts on outcrops of the clay are all indicative of an anaerobic, stagnant environment inimical to a bottom dwelling fauna (also see Abbott and Andrews, 1979). Locally, as at the type locality, some bioturbation is evident and the sediments are cal-

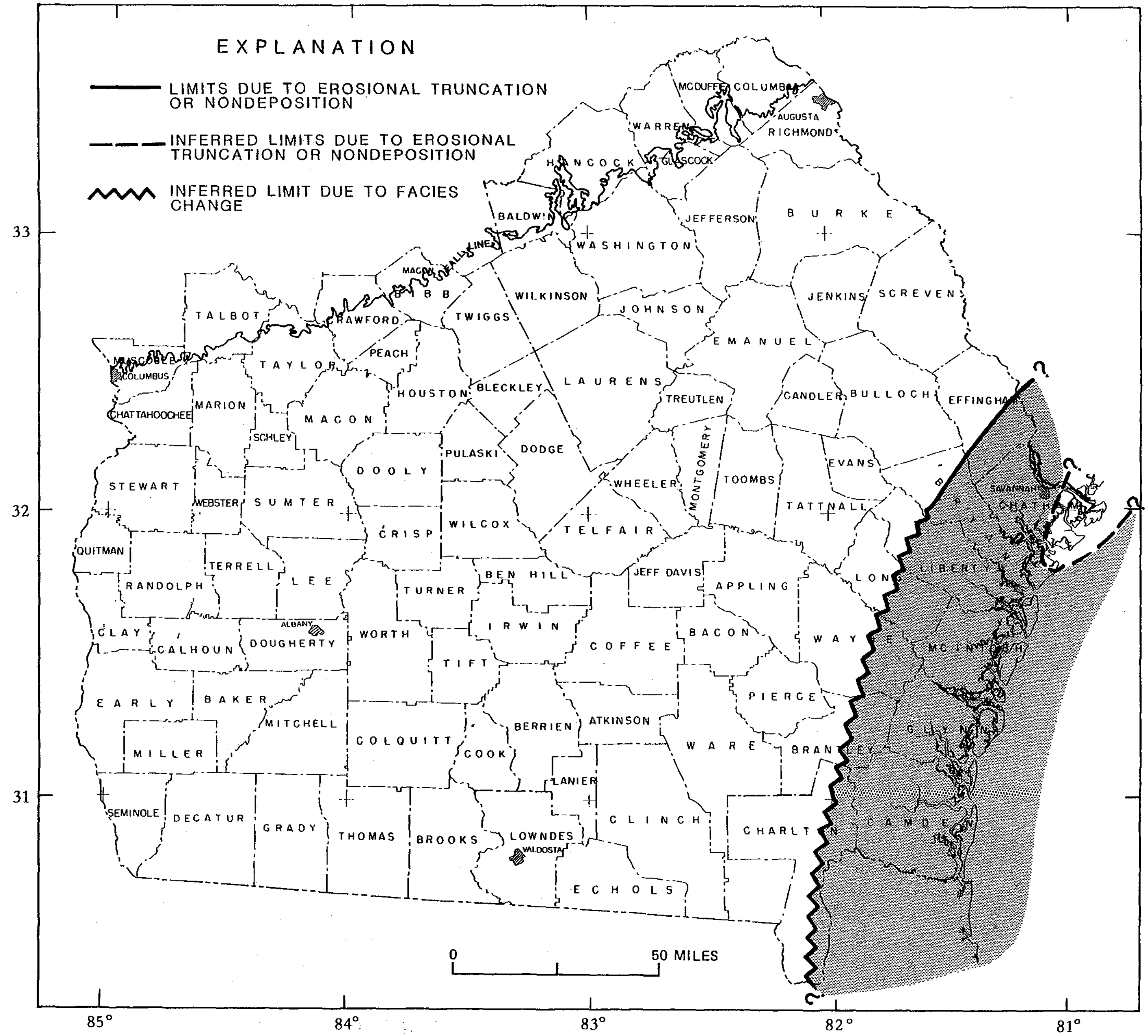


Figure 29. The areal distribution (outcrop and subcrop) of the Berryville Clay Member of the Coosawhatchie Formation in Georgia.

careous with a low diversity benthic fauna, indicating shallow-water, aerobic conditions.

Age

The age of the Berryville Clay Member of the Coosawhatchie Formation (Coosawhatchie clay member of the Hawthorne Formation of Heron, Robinson and Johnson, 1965; Abbott, 1974, 1978; Ernissee, Abbott, and Huddlestun, 1980) has been extensively discussed (Abbott, 1978; Ernissee, Abbott, and Huddlestun, 1977). The age of the member is middle Miocene (early Serravallian) (Pl. 1). The following planktonic foraminifera have been identified by the author from the stratotype section of the Berryville Clay Member near Berry Landing:

Globorotalia peripheroacuta
Globigerina praebulloides
G. druryi
Globerinoides quadrilobatus quadrilobatus
G. quadrilobatus sacculiferus
G. subquadratus
Globoquadrina altispira
Globigerinita juvenilis
Orbulina suturalis

The following planktonic foraminifera have been identified from the Berryville Clay in the cores Effingham 3 (GGS-2175), Effingham 13 (GGS-3140), and Effingham 14 (GGS-3155):

Globorotalia peripheroacuta
G. mayeri
Globigerina praebulloides
G. druryi
G. eamesi
Globigerinoides quadrilobatus quadrilobatus
G. quadrilobatus sacculiferus
G. subquadratus
G. c.f. *obliquus*
Globoquadrina altispira
Glorigerinita juvenilis
Sphaeroidinellopsis seminulina
Orbulina suturalis

The following planktonic foraminifera have been identified from the Berryville Clay in the core AMCOR 6002 from sample 7-2 (30-40 cm) on the continental shelf:

Globorotalia fohsi praefohsi (primitive)
G. peripheroacuta
G. mayeri
Globigerinita juvenilis
G. incrusta
Globoquadrina altispira
Sphaeroidinellopsis seminulina
Orbulina suturalis

The above associations are characteristic of planktonic foraminiferal Zone N10 or early N11 of Blow and Banner (1966) and Blow (1969) (lower part of *Globorotalia fohsi fohsi* Zone of Bolli, 1957; and Stainforth and others, 1975). The presence of well-developed *G. peripheroacuta* at the type locality and advanced *G. peripheroacuta* at 162 feet in the core Effingham 13 (GGS-3140) indicates that the type Berryville Clay is in Zone N10 or possibly earliest Zone N11 (Pl. 1). The presence of primitive *Globorotalia fohsi praefohsi* in sample 7-2, 30-40 cm from AMCOR 6002 indicates earliest Zone N11 in that core on the continental shelf.

Ernissee, Abbott, and Huddlestun (1977) suggested correlation of the Coosawhatchie Clay near Berry Landing on the Savannah River (holostratotype of the Berryville Clay Member of the Coosawhatchie Formation of this report) to upper Zone N11 to lower Zone N12 of Blow (1969). This zonal assignment was based on the identification of one foraminifer that is transitional from *Globorotalia peripheroacuta* and *G. fohsi praefohsi*. Re-examination of the microfossil slides indicates that the individual in question should more prudently be considered a morphologically advanced *G. peripheroacuta*. The evolutionary state of the *Globorotalia fohsi* lineage, and the presence only of *G. peripheroacuta* with very rare, primitive *G. fohsi praefohsi* render the Zone N12 assignment unlikely. Typical *G. peripheroacuta* is not present in shallow-water assemblages of Zone N12, such as is present in the Shoal River Formation of western Florida (Huddlestun, 1984). The White Creek beds of the Shoal River Formation contain a planktonic foraminiferal assemblage identical to that of the Berryville Clay Member, and with the same level of evolutionary development of the *Globorotalia fohsi* lineage (Huddlestun, 1984, p. 81-83). The overlying undifferentiated Shoal River Formation of western Florida, however, contains a typical Zone N12 planktonic foraminiferal suite with *G. fohsi fohsi, G. fohsi lobata*, and very rare *G. fohsi robusta* (Huddlestun, 1984, p. 67-72). The Zone N12 planktonic foraminifera of the Shoal River Formation, and especially the stage of evolutionary development of the *Globoratalia fohsi* population, are incompatible with the planktonic foraminiferal suite of the Berryville Clay Member of the Coosawhatchie Formation. Therefore, it is my conclusion that the Berryville Clay Member is in planktonic foraminiferal Zone N10 or earliest N11, but not Zone N12 as suggested by Abbott, Ernissee, and Huddlestun (1977), Abbott (1978), and Abbott and Andrews (1979).

EBENEZER MEMBER OF THE COOSAWHATCHIE FORMATION (new name)

The Ebenezer Member is a new name, proposed herein for the updip, argillaceous sand subdivision of the Coosawhatchie Formation. North of the Altamaha River, and elsewhere if the Charlton Member is locally absent, the Ebenezer Member constitutes the upper part of the Coosawhatchie Formation in eastern Georgia (Fig. 11; Pls. 2 and 3).

South of the Altamaha River, where both the Berryville Clay and Charlton Members are present, the Ebenezer is the middle member of the formation. Farther inland where neither the Berryville Clay nor Charlton Members are present, the Ebenezer Member constitutes the entire Coosawhatchie Formation (Figs. 10, 11; Pl. 1). The Ebenezer grades laterally eastward (seaward) into the Berryville Clay Member and extends farthest east in the coastal area at the top of the formation. Its eastern limits appear to be the Sea Island Escarpment or western flanks of the Beaufort Arch. The upper part of the Ebenezer Member appears to grade westward (shoreward) into the Altamaha Formation, and the lower part of the Ebenezer Member appears to grade westward into the Meigs Member of the Coosawhatchie Formation (Figs. 10, 11; Pl. 3).

The Ebenezer Member at Ebenezer Landing on the Savannah River, the type locality, was tentatively included in the Miocene by Veatch and Stephenson (1911, p. 375). Veatch and Stephenson (1911, p. 360, 375, 377, 412-413) included the deposits along the Altamaha River, both at and also downstream from Bugs Bluff in Wayne County, in the Alum Bluff Formation?, or "Miocene or Oligocene?". Cooke (1936, p. 109; 1943, p. 95, 100) and Georgia Geological Survey (1976) included these deposits in the Hawthorne Formation.

Type Section

The name Ebenezer is taken from Ebenezer Landing on the Savannah River in Effingham County, Georgia, and from Ebenezer Creek, which joins the Savannah River at Ebenezer Landing. Ebenezer Landing on the Savannah River is located at the end of Ga. 275, 7.5 miles (12 km) east of Springfield, Effingham County. The type locality of the Ebenezer Member of the Coosawhatchie Formation is the line of low bluffs immediately downriver from the boat landing (Fig. 30). The type section, or unit stratotype (holostratotype), of the Ebenezer Member is the section exposed in the bluffs at the type locality. Neither the lower nor the upper boundary of the member is exposed in the type section, and the Ebenezer Member constitutes the entire exposed 7 feet (2 m) of section in the bluffs.

The core Effingham 14 (GGS-3155) is herein designated a reference locality, parastratotype, and lower and upper boundary stratotype of the Ebenezer Member. In this core, the Ebenezer Member is overlain disconformably by the Cypresshead Formation at a depth of 59 feet, and is underlain comformably and gradationally by the Berryville Clay Member at 116 feet. The core site of the Effingham 14 (GGS-3155) is on the south shoulder of Ga. 275, approximately 2.75 (4.4 km) southwest of Ebenezer Landing in Effingham County (Fig. 3; Pl. 2). This core is chosen as a reference section for the member because the entire Ebenezer Member with both lower and upper boundaries is present in the core, and the core site is near (2.75 miles [4.4 km]) the type locality.

The core Wayne 2 (GGS-3512) in Wayne County is herein designated a reference locality and parastratotype of the Ebenezer Member in the central part of the Southeast Georgia Embayment (Fig. 2; Pl. 2). In this core, the Ebenezer Member is overlain disconformably by the Cypresshead Formation at 59 feet, and is underlain by the Berryville Clay Member at 270 feet. This core is chosen as a reference section for the Ebenezer Member because it contains the coarse sand lithofacies of the member that is characteristic of the Southeast Georgia Embayment.

Lithology

The Ebenezer Member of the Coosawhatchie Formation is typically a gray to olive-gray, slightly phosphatic, micaceous, argillaceous sand. Sand is the dominant lithic component of the member, whereas subordinate components are clay, mica, calcite, limestone, dolomite, dolostone, phosphate, siliceous claystone, feldspar, zeolite, and fine vertebrate debris. Typically, the sand is fine- to medium-grained, rarely medium- to coarse-grained; moderately to well-sorted, rarely poorly sorted; thinly and distinctly to indistinctly bedded rarely to bioturbated or structureless; and argillaceous. In the coarser grained lithofacies in the central part of the Southeast Georgia Embayment, the Ebenezer Member is more commonly medium- to coarse-grained, moderately to poorly sorted, thick- to medium-bedded, commonly massive and structureless, pebbly, feldspathic, and not conspicuously argillaceous.

Clay occurrence in the Ebenezer is mainly interstitial, but beds of sandy clay or siliceous claystone occur, though rarely, in some sections. More commonly, discrete layers of clay occur as discontinuous laminae (partings) 2 mm or less thick. The Ebenezer Member in the Savannah River area is especially argillaceous with thin interlayerings of micaceous fine sand and clay laminae. The clay content of the member diminishes southward and is minor and entirely interstitial in the Altamaha River area. In the southern part of the Southeast Georgia Embayment in Charlton and Camden Counties, the Ebenezer Member commonly is fine-grained, similar to the lithology in the type area, but is less argillaceous and more dolomitic.

The clay mineral suite of the Ebenezer Member, like that of the underlying Berryville Clay Member, is dominated by montmorillonite. Illite is a significant secondary clay mineral whereas palygorskite, sepiolite, and kaolinite are minor (compare with Hetrick and Friddell, 1984). However, in the southern part of the Southeast Georgia Embayment in southeasternmost Georgia and northeastern Florida, palygorskite and sepiolite are significant minor components of the clay mineral suite.

In the type area, dolomite and calcite are irregularly occurring minor lithic components of the Ebenezer Member. Interstitial calcite and thin beds of fine-grained, dense limestone or dolostone occur in the lower part of the member that is lithologically transitional with the Berryville Clay.

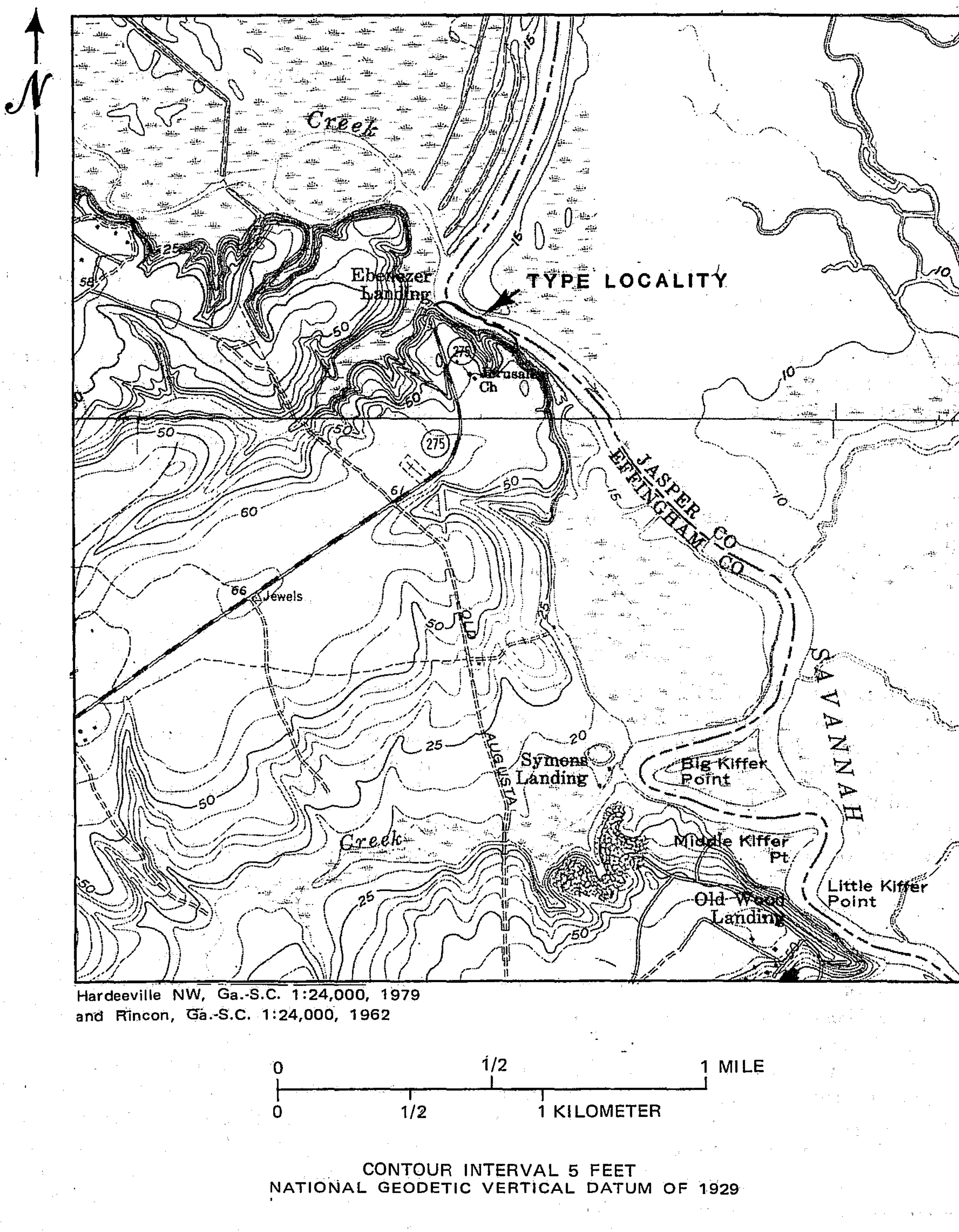


Figure 30. The type locality of the Ebenezer Member of the Coosawhatchie Formation.

Minor interstitial dolomite is rare higher in the section, and most of the Ebenezer Member in the type area is devoid of carbonate. Dolomite content increases to the south, however, and scattered beds of dolostone and dolomitic sand are common in the member in the Altamaha River area. The Ebenezer Member is generally dolomitic in the southern part of the Southeast Georgia Embayment in Georgia and northeastern Florida.

South of the Altamaha River, the upper part of the Ebenezer Member grades laterally into a dolostone, limestone, and clay lithofacies that is referred to in this report as the Charlton Member of the Coosawhatchie Formation, but was earlier referred to as the Charlton Formation (Veatch and Stephenson, 1911; Cooke, 1943, 1945). The Charlton Member is a laterally continuous unit in the St. Marys River area. North of Camden and Charlton Counties, however, it appears to be laterally discontinuous. Within this area in Brantley, Wayne, and Glynn Counties, the lithologies of the upper part of the Coosawhatchie Formation range from typical Ebenezer Member through transitional lithologies (see section on the Charlton member) to typical Charlton Member.

The phosphate content of the Ebenezer Member is variable. The coarse, feldspathic lithofacies in the Altamaha River area is largely nonphosphatic (lithologically transitional to Altamaha Formation), whereas typical Ebenezer lithology is moderately to poorly phosphatic.

The Ebenezer Member is generally nonfossiliferous in Georgia. In the vicinity of its type locality, however, the member contains molds and casts of deposit-feeding pelecypods, similar to the underlying Berryville Clay Member. Also, subsurface dolostone beds in the Ebenezer Member in the Altamaha River area locally contain abundant molds and casts of mollusks. Macro- and microfossils with calcareous shells, however, are not known to occur in the member.

Stratigraphic Relationships

The Ebenezer Member is known to occur from the vicinity of the Savannah River in Georgia southward into northeastern Florida (Fig. 31). The eastern limit of the member in the Savannah River area is the western flank of the Beaufort Arch in central Chatham County (Pl.2). Farther south it appears to trend obliquely offshore and coincides with the Sea Island Escarpment. The western limit of the Ebenezer Member is not clearly defined at this time, but the member is known to occur in the Altamaha River area as far west as the vicinity of Jesup in Wayne county (Pl. 3), and in the core Charlton 2 (GGS-3185) at Folkston, Charlton County. West of the Orangeburg Escarpment, in the Altamaha River area, the Altamaha Formation occurs in the stratigraphic position of the Ebenezer Member. It appears, therefore, that the Ebenezer Member grades laterally westward into the upper part of the Altamaha Formation. Farther south, the western limits of the Ebenezer Member occur between the St. Marys River in the east and the upper Suwannee River in the west. The Ebenezer Member underlies the St. Marys River area but the Ebenezer stratigraphic position is occupied by the Statenville Formation on the upper Suwannee River.

The Ebenezer Member conformably and gradationally overlies the Berryville Clay Member (see Figs. 10 and 11; Pls. 2 and 3). If it occurs west of the pinchout of the Berryville Clay, it would disconformably or paraconformably overlie the Marks Head Formation in that area. The Ebenezer Member is generally overlain disconformably by the Cypresshead Formation in Georgia but is overlain by the Raysor Formation in the coastal area. In the St. Marys River area, the Ebenezer is conformably overlain by the Charlton Member.

The Ebenezer Member of the Coosawhatchie Formation is distinguished from the underlying Berryville Clay Member in consisting of thick-bedded and massive, micaceous, slightly phosphatic, bioturbated, argillaceous, fine-grained, well-sorted sand. In contrast, the Berryville Clay consists of olive-gray to dark olive gray, phosphatic silty clay that is generally thinly bedded to laminated, fissile to shaley. The stratigraphically equivalent Meigs Member of the Coosawhatchie Formation differs from the Ebenezer Member in containing beds of thinly layered to laminated, siliceous, diatomaceous, silty clay that is rarely phosphatic. The stratigraphically equivalent and overlying Charlton Member of the Coosawhatchie Formation is distinguished from the Ebenezer Member in containing thick to very thick beds of variably fossiliferous limestone, dolostone, and clay, and in typically containing little quartz sand or phosphate. The stratigraphically equivalent Statenville Formation is distinguished from the Ebenezer Member in containing prominently horizontal and crossbedded, variably phosphatic, fine- to coarse-grained, well-sorted to poorly sorted sand with thin to medium beds of fine-grained dolostone.

The overlying Cypresshead Formation is distinguished from the Ebenezer Member in being prominently bedded in many places (laminated to thin-bedded to thick-bedded), nonmicaceous, nonphosphatic, only locally bioturbated, and of widely varying sand grain size and sorting. In addition, the clay within the Cypresshead Formation is more commonly distributed in laminae and thin beds, and rarely in thick beds. Unlike the Ebenezer Member, where clay occurs mainly interstitially, the interstitial clay fraction of the Cypresshead Formation is minor.

Only 7 feet (2 m) of the Ebenezer Member of the Coosawhatchie Formation is exposed in the low bluffs on the Savannah River at the type locality. However, the Ebenezer Member is 62 feet (19 m) thick in the reference core Effingham 14 (GGS-3155) 2.75 miles (4.4 km) from the type locality, and the average thickness of the member in the type area is approximately 60 feet (18 m). The Ebenezer Member thins southeastward in the Savannah River area, probably due to post-Coosawhatchie, Miocene truncation, and is

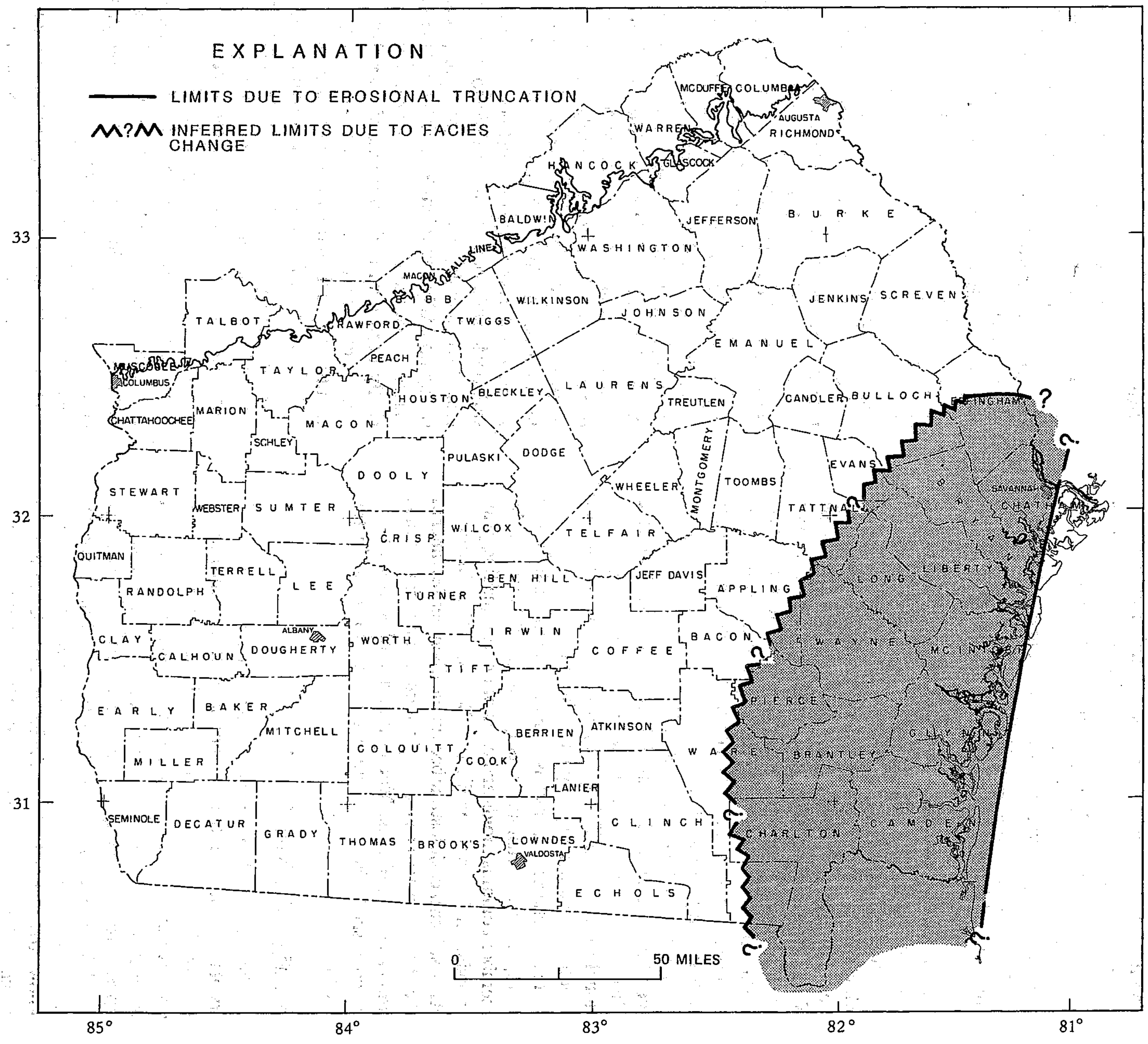


Figure 31. The areal distribution (outcrop and subcrop) of the Ebenezer Member of the Coosawhatchie Formation.

absent over the Beaufort Arch in Chatham County (Pl. 2). The member thickens southward in the Southeast Georgia Embayment and is 211 feet (64 m) thick in the reference core Wayne 2 (GGS-3512) and 234 feet (71 m) thick in the interval 60 feet to 294 feet in the core Wayne 4, both in Wayne County, Georgia. The Ebenezer Member thins south of the Altamaha River area and is 199 feet (61 m) thick in the interval 90 feet to 289 feet in the core Cumberland Island 1 (GGS-3426), and 169 feet (52) at Folkston in the interval 130 feet to 299 feet in the core Charlton 2 (GGS-3185). The thinning of the Ebenezer Member in the Charlton 2 (GGS-3185) is due to the upper part of the Coosawhatchie Formation being occupied by Charlton lithlology and not Ebenezer lithology. In the Charlton 2, the Ebenezer plus Charlton stratigraphic interval is 248 feet (76 m) thick.

The environment of deposition of the Ebenezer Member of the Coosawhatchie Formation was marine, continental shelf, inner neritic. The fine grain size of the sand and the large amount of interstitial clay together with the local presence of deposit-feeding pelecypods indicate that the substrate at the time of deposition was muddy and soft. The Ebenezer Member is interpreted here as being a relatively nearshore facies, intermediate to that of the offshore Berryville Clay Member and that of the coastal Meigs Member. Like the clay mineral suite of the underlying Berryville Clay, smectite and illite are the dominant clay minerals of the Ebenezer Member and palygorskite is either absent or a minor component. This suite is consistent with the interpretation of a relatively cool-water, nearshore (but not coastal) depositional environment for the Ebenezer Member.

Age

Other than scattered fine vertebrate debris, the only known fossils in the Ebenezer Member are molds and casts of mollusks in the argillaceous sands in the type area and in dolostone beds in the central part of the Southeast Georgia embayment. Because the Ebenezer Member is gradational with the Berryville Clay Member, both downsection and laterally, it is assumed here that the Ebenezer is the same age as the Berryville Clay. If that assumption is correct, the Ebenezer Member is middle Miocene (early Serravallian). It is equivalent to Zone N10 or early N11 of Blow and Banner (1966) and Blow (1969) (Pl. 1).

TYBEE PHOSPHORITE MEMBER OF THE COOSAWHATCHIE FORMATION (new name)

Definition

The Tybee Phosphorite Member of the Coosawhatchie Formation is a new name, herein proposed for the subsurface, basal phosporitic beds of the Coosawhatchie Formation in the coastal area of Georgia. The Tybee Phosphorite Member contains the commercial-grade phosphorite in coastal Chatham County (Furlow, 1969) and was referred to the Duplin Formation by Counts and Donsky (1963), McCollum and Herrick (1964), and Furlow (1969). The Tybee Phosphorite Member is recognized as a member of the Coosawhatchie Formation because it interfingers in a landward (northwestward) direction with, and grades up-section into, the Berryville Clay.

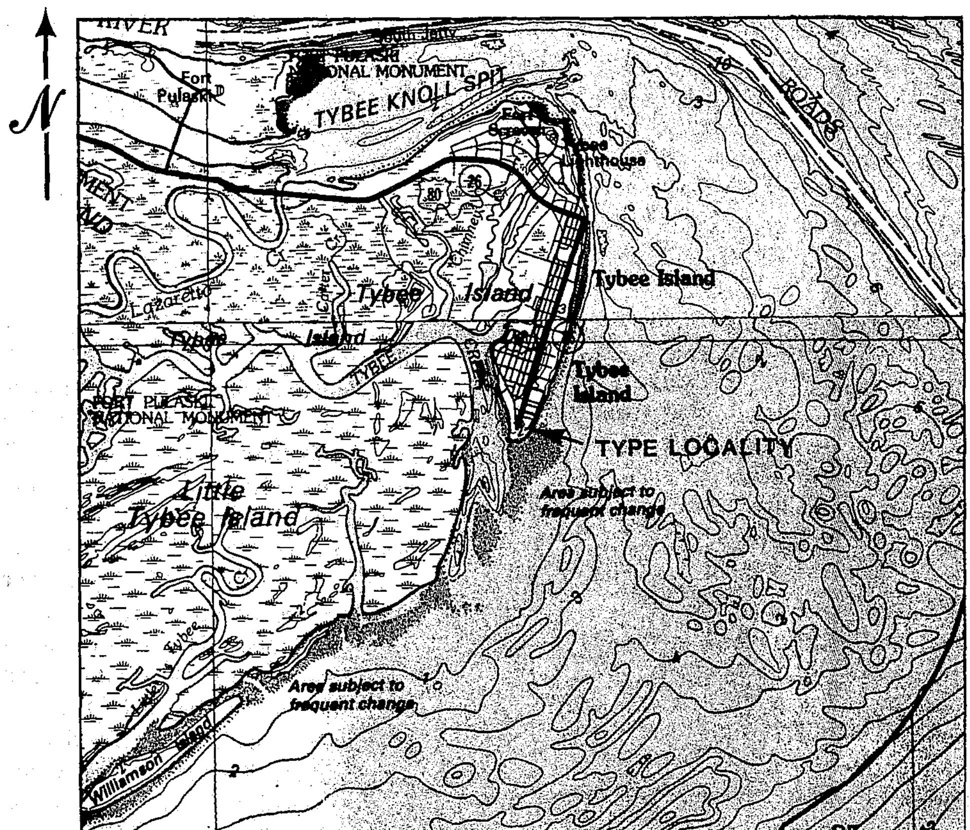
Type Section

The name Tybee is taken from Tybee Island, the northernmost Sea Island of Georgia. The core Chatham 10 (GGS-1394) is herein designated the type locality of the Tybee Phosphorite Member of the Coosawhatchie Formation (Fig. 32). The type section, or unit-stratotype (holostratotype), of the member is the interval 75 feet to 94 feet in the type core. The Tybee Phosphorite Member is disconformably overlain by the Satilla Formation at 75 feet and paraconformably underlain by the Marks Head Formation at 94 feet in the core Chatham 10 (GGS-1394). The core site of Chatham 10 (GGS-1394) is near the southern end of Tybee Island, approximately 100 feet (30 m) south of the termination of US 80 (Fig. 32; also see Furlow, 1969, Fig. 1).

The core Chatham 3 (GGS-1341) is herein designated a reference section and parastratotype of the Tybee Phosphorite Member. The Tybee Phosphorite occurs in the interval 85 feet to 117 feet in the core and is overlain conformably and gradationally by the Berryville Clay Member, and paraconformably overlies the Marks Head Formation. The Chatham 3 is designated a parastratotype because the core recovery is 100% in the Coosawhatchie Formation, and the stratigraphic relationship between the Tybee Phosphorite and Berryville Clay members can be observed in the core. The core site of the Chatham 3 (GGS-1341) is on Wilmington Island near highway U.S. 80, approximately 0.5 mile (0.7 km) south of the U.S. 80 bridge over Bull River (Fig. 3).

Lithology

The Tybee Phosphorite Member of the Coosawhatchie Formation principally consists of quartz sand and phosphate with minor clay and dolomite. The phosphate, which commonly is the dominant lithic component, typically consists of round to irregularly rounded, black to brown to amber-colored grains of apatite that range in size from about 1 mm to less than 0.1 mm. The phosphate is generally associated with abundant fine vertebrate debris (fish teeth, miscellaneous small bones, vertebrae, fish scales, etc.). Subordinate lithic components include quartz sand, clay, dolomite, dolostone, and mica. Scattered small quartz pebbles occur locally in the basal phosphorite, and scattered thin layers of sand, clay, or dolostone occur locally within the member. The dolostone layers in places contain molds and impressions of mollusks. The clay mineral suite consists of palygorskite and smectite, in approximately equal proportions, with some illite and minor sepiolite and kaolinite (Hetrick and Friddell, 1984).



Base from U.S. Geological Survey
Wassaw Sound, Ga. 1:100,000, 1980
and Beaufort, S.C.-Ga. 1:100,000, 1981

0 1 2 3 MILES

0 1 2 3 KILOMETERS

CONTOUR INTERVAL 2 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 32. The type locality of the Tybee Phosphorite Member of the Coosawhatchie Formation.

In cores, the lithology of the Tybee Phosphorite Member resembles a mixture of wet coffee-grounds and sandy, muddy sediment. The member generally is massive, structureless and uniform, or bioturbated and marbled. The color contrast, which highlights the bioturbation structures, results from the variation in concentration of light-colored quartz sand and dark-colored phosphate.

Stratigraphic Relationships

The Tybee Phosphorite Member caps the crest of the Beaufort Arch in Chatham County. The position of the eastern limit is unknown, but it occurs on the continental shelf off the coast of Georgia (Fig. 33). Its western limit in Chatham County is the western flank of the Beaufort Arch where the member separates into two thin tongues and grades laterally into the Berryville Clay Member (Pl. 2). The southern limit of the member is not clearly defined at this time, but several feet of Tybee Phosphorite occur below the base of the Berryville Clay Member in a core in coastal Bryan County and in the core Cumberland Island 1 (GGS-3426) on Cumberland Island in Camden County. This suggests that the Tybee Phosphorite Member may generally be present under the coast and inner continental shelf off Georgia.

The Tybee Phosphorite Member of the Coosawhatchie Formation disconformably or paraconformably overlies the Marks Head Formation in Georgia (Fig. 11; Pl. 2). It is conformably and gradationally overlain by the Berryville, Clay Member (Fig. 11; Pl. 2), but locally is disconformably overlain by the Wabasso beds of the Hawthorne Group or by the Satilla Formation.

The Tybee Phosphorite Member of the Coosawhatchie Formation is distinguished from the underlying Marks Head Formation in consisting of dark olive gray to olive-black, sandy phosphorite whereas the Marks Head consists of lighter colored, bioturbated, phosphatic, slightly dolomitic, finely sandy clay to very argillaceous fine-grained sand. Generally there is a bed of palygorskite-rich fuller's earth or dolostone at the top of the Marks Head Formation. The overlying and stratigraphically equivalent Berryville Clay Member differs from the Tybee Phosphorite in consisting of thinly bedded to laminated, silty, phosphatic clay. Where the Wabasso beds may directly overlie the Tybee Phosphorite, the Wabasso beds consist of phosphatic, calcareous, slightly argillaceous, silty fine-grained sand.

The Tybee Phosphorite Member is 19 feet (6 m) thick at the type locality in the core Chatham 10 (GGS-1394). The member averages about 20 feet (6 m) thick in coastal Chatham County, the type area, but is 33 feet (10 m) thick under southern Tybee Island in the core Petit Chou 1 (Fig. 2) (also see Furlow, 1969). The member thins northwestward in central Chatham County and splits into two thin tongues at the base of the Berryville Clay Member (Pl. 2). The upper tongue extends only a few miles inland from the present marsh, but the lower tongue extends into northern Chatham County as a thin basal bed (about 1 or 2 feet [0.3 or 0.6 m] thick) below the Berryville Clay Member. The Tybee Phosphorite is 7.5 feet (2 m) thick in coastal Bryan County, and 9 feet (2.75 m) thick in the core Cumberland Island 1 (GGS-3426).

The environment of deposition of the Tybee Phosphorite Member of the Coosawhatchie Formation was marine, probably shallow-water but far-offshore, continental shelf. The bioturbation to complete homogenization of the sediments indicates an active infauna during sedimentation. Scattered thin dolostone beds with molluscan molds also indicate the local presence of a meager fauna living upon the substrate. As a result, it is concluded that the environment of deposition of the Tybee Phosphorite was not anaerobic and stagnant as the adjacent Berryville Clay. However, the abundance of small vertebrate (presumably fish), fossil bone debris indicates that the overlying water-mass must have been highly productive in terms of marine life, and the abundance of the debris would suggest that the bottom environment could have been locally or periodically stagnant with putrifying material. It is also noted that the Tybee Phosphorite in Chatham County, Georgia, is found only on the Beaufort Arch, and it is possible that the arch was a topographic high on the continental shelf during the deposition of the Coosawhatchie Formation.

Age

No datable fossils are known to occur in the Tybee Phosphorite Member. However, diatomaceous Berryville Clay is known to occur between the two thin tongues of the Tybee Phosphorite in a core in coastal Bryan County. According to Dr. W.H. Abbott (personal communication, 1978), the diatom flora is typical of that of the Coosawhatchie Formation (Berryville Clay Member). Therefore, the age of the Tybee Phosphorite Member is inferred to be middle Miocene, early Serravallian (See Pl. 1), and equivalent to planktonic foraminiferal Zones N10 or early N11 (Blow and Banner, 1966; Blow, 1969).

CHARLTON MEMBER OF THE COOSAWHATCHIE FORMATION (revised and redefined)

Definition

The Charlton Formation of Veatch and Stephenson (1911, p. 392-400) is herein revised, redefined, and reduced in lithostratigraphic rank from a formation to a member. Previously, the Charlton was considered to be a formation younger than, and overlying, the Hawthorne (Cooke, 1943, 1945). Core information has shown, however, that the Charlton is a lateral lithofacies of the upper part of the Ebenezer member of the Coosawhatchie Formation. It is, therefore, a minor subdivision of the Hawthorne Group. The Charlton is recognized as a formal member of the

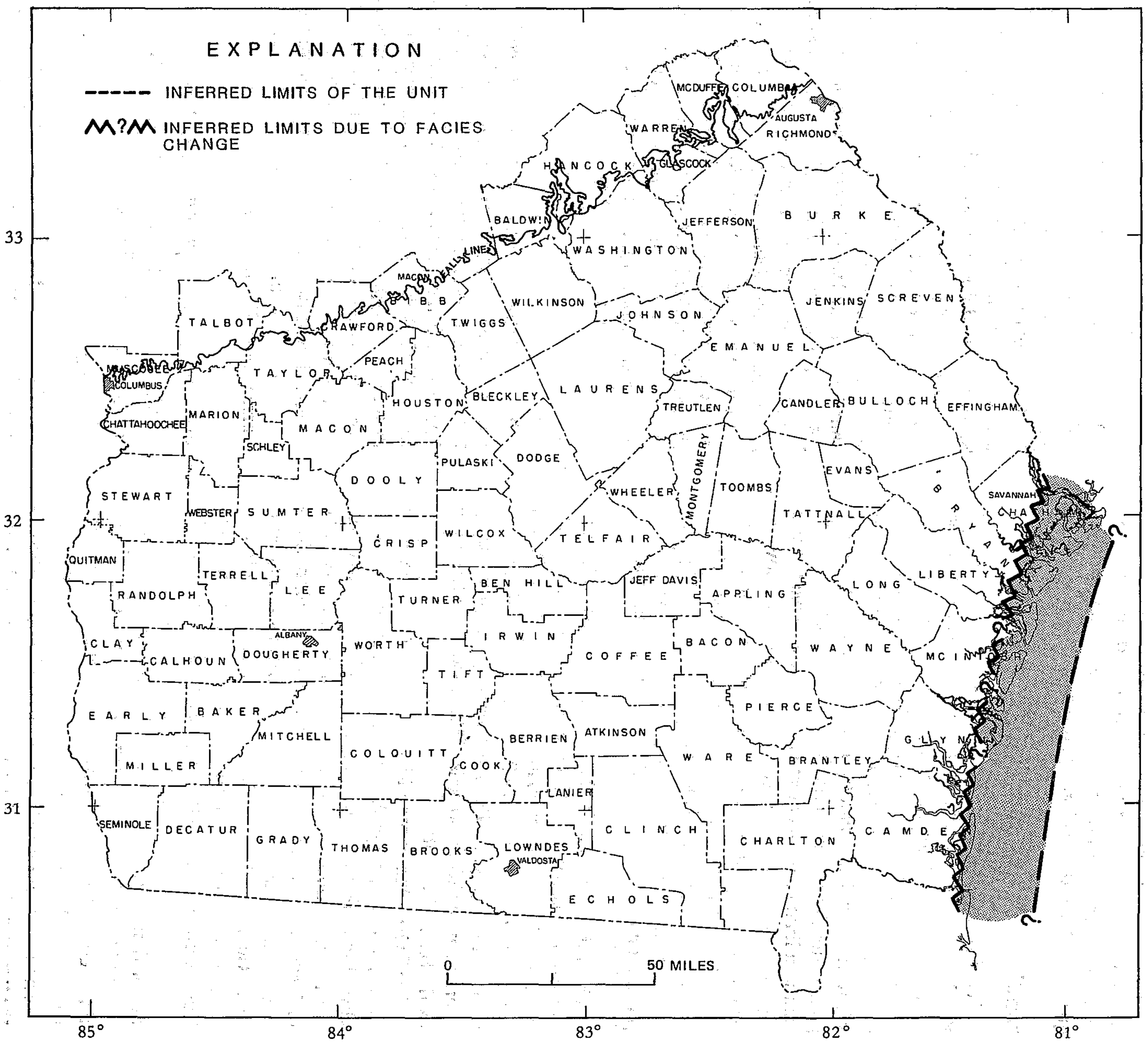


Figure 33. The areal distribution (subcrop) of the Tybee Phosphorite Member of the Coosawhatchie Formation in Georgia.

Coosawatchie Formation in this report because it grades both laterally and downsection into more typical Coosawhatchie sediments (Ebenezer Member) (Figs. 10, 11 and 58; Pl. 1); because the typical Charlton is lithologically distinctive; and because typical Charlton is restricted as a continuous and mappable unit only to the southeastern corner of Georgia in Camden, Charlton, and perhaps Brantley Counties, and in the northeastern corner of Florida in Nassau, Duval, and northern Clay and St. Johns Counties. North, west, and south of this area, Charlton lithofacies appears to occur discontinuously in the upper part of the Ebenezer Member. Also supporting the Charlton as a subdivision of the Hawthorne is the presence of palygorskite, a magnesium-rich clay mineral characteristic of the Hawthorne Group deposits. Palygorskite is one of the dominant clay minerals of the Charlton and is not known to occur in post-Hawthorne deposits, except as trace detrital components.

The Jacksonville limestone of Dall (1892, p. 124; also see Matson and Clapp, 1909, 108-114) at Jacksonville, Duval County, Florida, is part of the Charlton Member. Other calcareous deposits attributed by Dall (1892, p. 124-125) to the Jacksonville limestone, however, are not part of the Charlton Member but are included in various other units.

Type Section

The name Charlton was taken from Charlton County, Georgia. Veatch and Stephenson (1911, p. 392) applied the name Charlton "to an argillaceous limestone and clay formation exposed in the banks and bluffs of St. Marys River, from Stokes Ferry, 11 miles south of St. George, Charlton County, Georgia, to Orange Bluff, near Kings Ferry, Florida." The type locality of the Charlton as described by Veatch and Stephenson (1911) is, therefore, the stretch of St. Marys River from Stokes Ferry (now Stokes Bridge) to Orange Bluff (Figs. 2 and 4). Veatch and Stephenson (1911, p. 393-400) included 12 described sections in the type locality. They did not designate any particular section as the type section, and all of the sections appear to have been given equal weight as examples of the unit. The sections described by Veatch and Stephenson (1911), therefore, are interpreted here to constitute a composite stratotype.

To facilitate field and stratigraphic studies, the section of the Charlton Member exposed in the low bluff on the east side of the St. Marys River at Stokes Bridge (Stokes Ferry of Veatch and Stephenson, 1911) is herein designated the lectostratotype (unit-stratotype and principal reference section) of the Charlton Member of the Coosawhatchie Formation (Fig. 34). The lithology of the Charlton Member at Stokes Bridge is typical of the unit in the type area, and the site is currently the most accessible of Veatch and Stephenson's described Charlton sections. Only Charlton Member is currently exposed in the bluff, although Veatch and Stephenson (1911) briefly described the contact between the Charlton and the overlying formation which they assigned to the Satilla Formation. The residuum of this overlying formation is exposed in the roadcut in the eastern valley wall above Stokes Bridge. The residuum appears to be assignable to either the Cypresshead Formation or the Nashua Formation. The Satilla Formation does not occur as far west as the upper St. Marys River (Fig. 58). The site of Stokes Bridge is in NE 1/4, Sec. 30, T1S, R23E in Nassau County, Florida (also see Connell, 1968).

The core Charlton 2 (GGS-3185) is herein designated a reference locality and hypostratotype of the Charlton Member of the Coosawhatchie Formation. The Charlton Member occurs in the interval 51 feet to 130 feet and is overlain by the Cypresshead Formation and underlain by the Ebenezer Member of the Coosawhatchie Formation. The core site of the Charlton 2 (GGS-3185) (Fig. 2) is on the southwestern village limits of Folkston in Charlton County, 1 mile (1.6 km) from the center of town on the highway right-of-way of Ga. 23-121, and 2 miles (3.2 km) from the St. Marys River. This core is chosen as a hypostratotype because the entire member is present in the core (the core recovery in Charlton interval was approximately 58%), because both overlying and underlying units are present, and because the core site is near the type locality of the Charlton.

Lithology

Typical Charlton Member consists of clay, dolostone, and limestone. Clay appears to be the dominant lithic component. However, dolostone and limestone are more conspicuous in outcrop, probably because they are more resistant to erosion and persist longer in outcrop. Also, the clay, dolomite, and calcite commonly occur in varying combinations. Other subordinate lithic components of the Charlton Member include quartz sand, phosphate, and shells.

The clay component, more conspicuous in cores than in outcrop, generally is a dense, blocky, gray clay that is typically massive and structureless but in places is thinly stratified. The clay, where unweathered and unleached in cores, commonly contains varying proportions of dolomite or calcite. The clay mineral suite appears to vary widely from sample to sample (Hetrick and Friddell, 1984). In any given sample, the suite can be dominated by smectite, palygorskite, or illite. Kaolinite is unusually prominent for a subdivision of the Hawthorne Group in the coastal area. Sepiolite, however, is not known to occur in the Charlton.

Dolomite appears to be the more common carbonate of the Charlton Member, but locally, as in the reference core Charlton 2 (GGS-3185), calcite is the dominant carbonate. Dolostone is commonly of the tan, saccharoidal variety and generally contains abundant molds and impressions of a few species of small pelecypods. Fine-grained, layered, gray dolostone, similar to the fine-grained dolostone of the equivalent Statenville Formation, is also locally present, as at Limerock on the Satilla River in Brantley County. The dolostone and limestone beds of the Charlton range from thin-bedded to thick-bedded. Internally the dolostone or

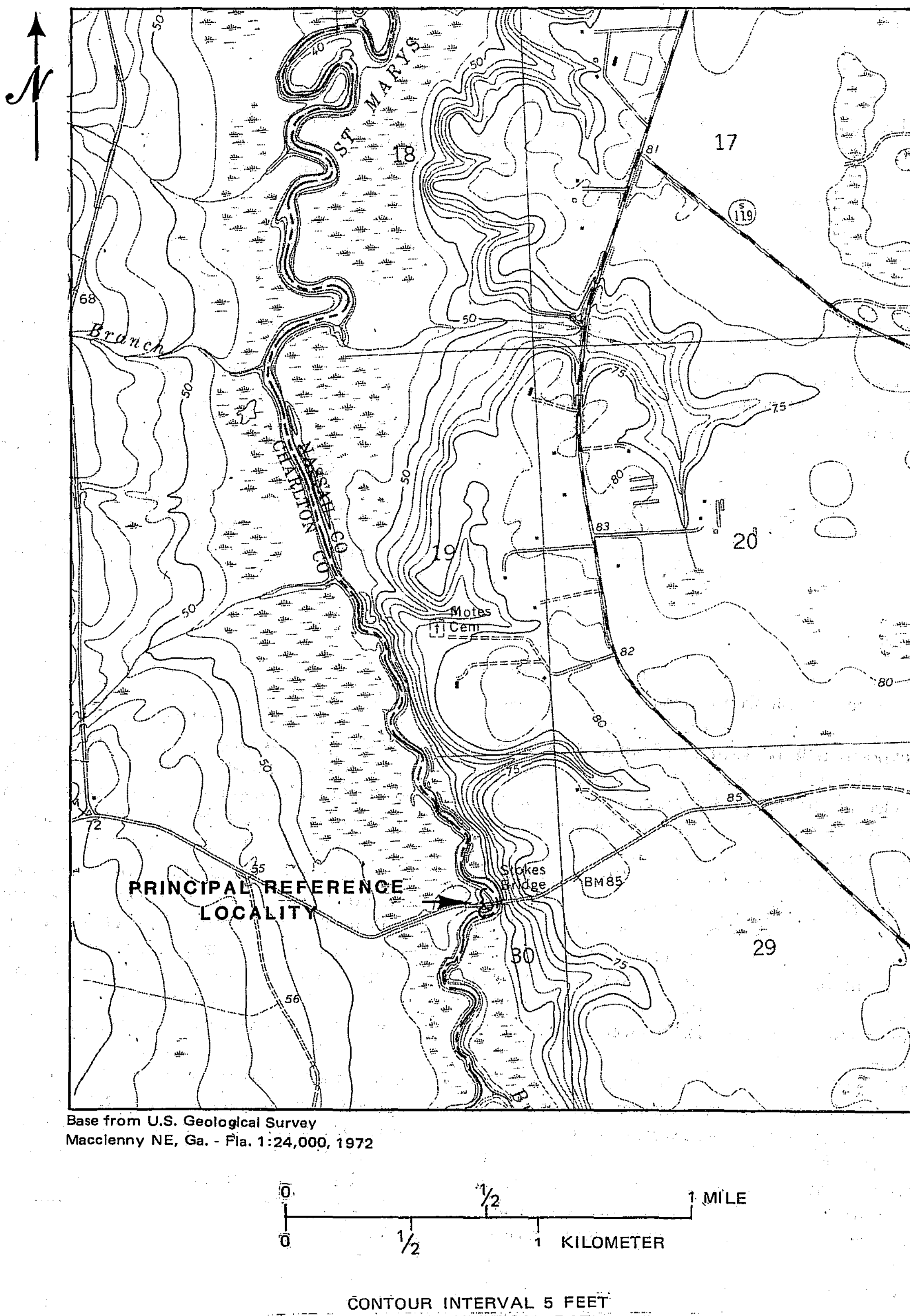


Figure 34. The principal reference locality of the Charlton Member of the Coosawhatchie Formation.

limestone generally is massive and structureless, but locally is stratified, ranging from laminated to thin-bedded.

The Charlton is exceptionally fossiliferous for a unit of the Hawthorne Group. The dolostones and limestones of the member are commonly, but not invariably, moldic and coquinoid, consisting of molds and impressions of small pelecypods. Some beds of the dolostone or limestone, such as those at the principal reference locality at Stokes Bridge, consist of a moldic ostracode coquina. The fossil assemblages of the Charlton, however, lack diversity, and commonly consist of only a few species. The only foraminifera the author has seen in the Charlton Member are the benthic species *Ammonia beccarii* and *Elphidium* spp., which indicate a brackish environment.

Typical Charlton lithology is sand- and phosphate-poor. Sand and phosphate are almost absent in the sections described by Veatch and Stephenson (1911) and from the core Charlton 2 (GGS-3185). Therefore, the low sand and phosphorite content, the high clay and carbonate (calcite, limestone, dolomite, dolostone) content, and the local abundance of fossils are the qualities that serve to distinguish the Charlton Member from the rest of the Coosawhatchie Formation, and from the rest of the Hawthorne Group in Georgia. Lithologies intermediate between typical Charlton Member and Ebenezer Member (e.g., in the core Cumberland Island 1 [GGS-3426] between the depths of 90 and 160 feet), range from phosphatic, sandy dolostone to phosphatic, dolomitic sand and sandstone. This lithology does not clearly fit either Charlton Member or Ebenezer Member, but is arbitrarily included in the Ebenezer Member in this report because of the presence of sand and phosphate.

Stratigraphic Relationships

As a continuous mappable unit, the Charlton Member of the Coosawhatchie Formation is restricted to parts of Camden, Charlton, and Brantley Counties, Georgia, and to parts of Nassau, Duval, Baker, Bradford, and Clay Counties, Florida (Fig. 35). North of this area, to perhaps the vicinity of the Altamaha River, and some distance south of this area in northeastern Florida, the Charlton lithofacies occurs discontinuously in the upper part of the Ebenezer Member.

The Charlton Member is disconformably overlain by the Satilla Formation under the Pamlico terrace, and by the Cypresshead Formation elsewhere in Georgia. The Charlton Member appears to be present under the eastern part of the Okefenokee Swamp, and in that area may be directly overlain by swamp deposits. Scattered remnants of the unnamed Rayser-equivalent shelly sand disconformably overlie the Charlton Member at some sites in the coastal area. The Charlton Member conformably and gradationally overlies the Ebenezer Member of the Coosawhatchie Formation.

At present, there is insufficient data to describe the thickness distribution of the Charlton Member. Veatch and Stephenson (1911, p. 394) reported about 6 feet (2 m) of Charlton at Stokes Bridge. The other sections of the Charlton that Veatch and Stephenson (1911, p. 394-400) measured on the St. Marys River range in thickness from 4 feet (1.2 m) to more than 15 feet (4.6 m). In the reference core Charlton 2 (GGS-3185) at Folkston, the Charlton Member is 79 feet (24 m) thick. It is 32 feet (10 m) thick in the Florida Geological Survey core Trail Ridge 3 (W-10473) in northern Baker County, Florida, and 49 feet (15 m) thick in the Florida Geological Survey core National Lead 1 (W-12360) in Bradford County, Florida (Fig. 4). In Wayne County, Georgia, where the Charlton lithofacies is discontinuous, it is 13 feet (4 m) thick in the core Wayne 3 (Fig. 2).

The environment of deposition of the Charlton Member of the Coosawhatchie Formation was brackish, coastal marine. The foraminiferal fauna of the Charlton consists of the brackish water foraminifer *Ammonia beccarii* with minor amounts of *Elphidium* spp. The low diversity of mollusk and ostracode faunas are consistent with the paleoenvironmental implications of the foraminifera (i.e., brackish water environment).

The variability of the clay mineral suite in addition to the unusual prominence of illite, strong presence of kaolinite, and the scattered dominance of palygorskite is compatible with the paleontological evidence for the environment of deposition. The strong presence of both illite and kaolinite are indicative of the proximity of a large river that drained the Piedmont (Dr. J.H. Hetrick, pers. com., 1986). The presence of palygorskite indicates local brackish to hypersaline water conditions. The characteristic low concentration or absence of quartz sand in the Charlton Member also indicates that the area of deposition of the Charlton was cut off from the direct supply of clastics from the river source. The characteristic occurrence of clay interlayered with dolostone and limestone in the Charlton suggests that the clay fraction of the river sediment load was periodically introduced into a relatively clastic-free coastal environment. In addition, the characteristic absence of phosphate in typical Charlton sediments suggests that the Charlton depositional environment was cut off from direct access to the normal marine, continental shelf watermass.

The environment model most consistent with the above constraints is a depositional environment analagous to that of the present Lake Ponchetrain in the Mississippi delta. The Charlton depositional environment is envisaged to be a large, brackish sound or a coastal semi-enclosed body of water, perhaps cut off from the river source by natural levees along a bird foot delta, and partially isolated from the normal shelf water by the presence of barrier islands or other possible obstacles (e.g., shoals).

Age

Veatch and Stephenson (1911, p. 392-400) provisionally placed the Charlton in the Pliocene on the basis of a few

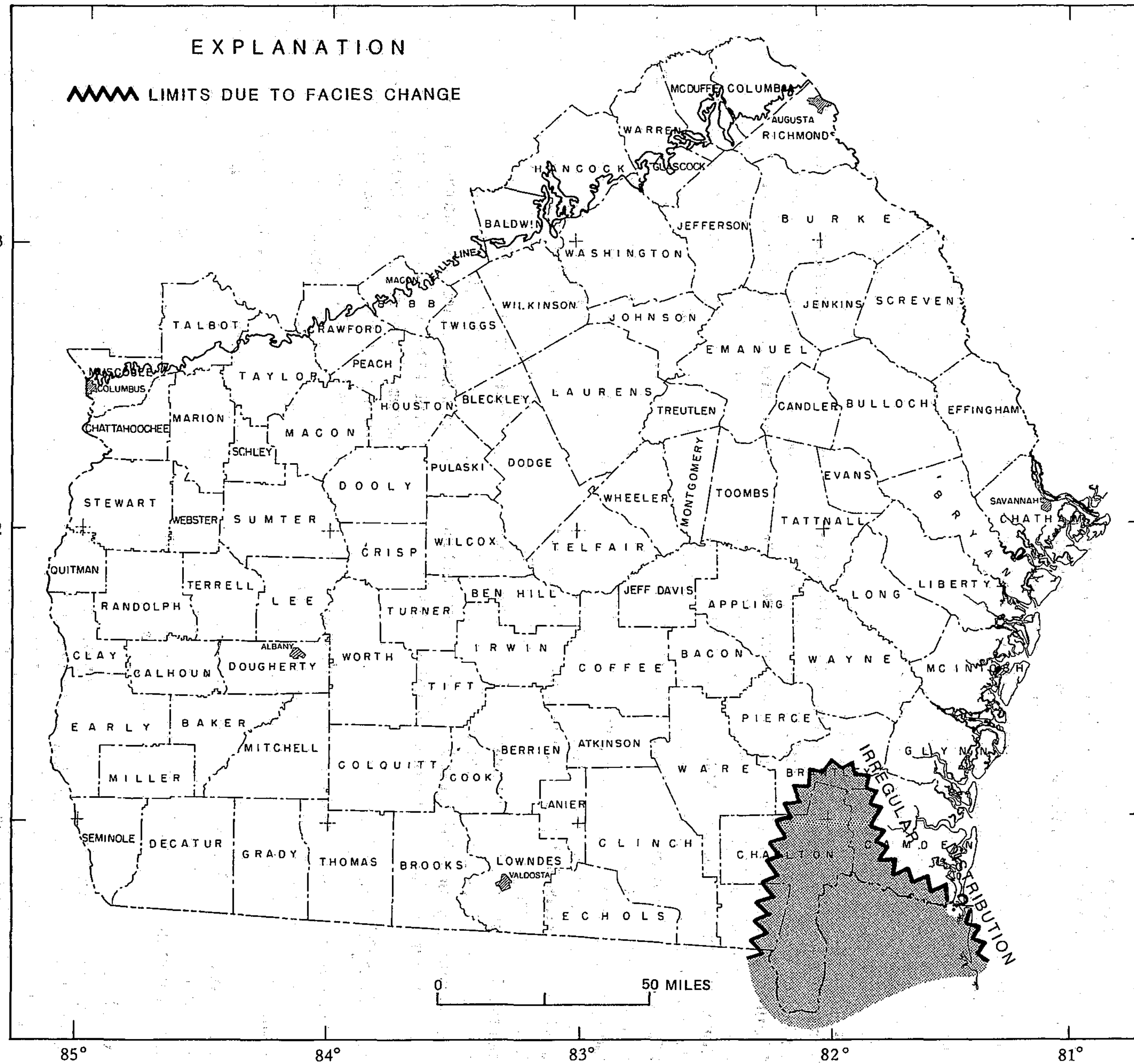


Figure 35. The areal distribution (outcrop and subcrop) of the Charlton Member of the Coosawhatchie Formation in Georgia.

molluscan and ostracode species. Cooke (1943, 1945) concurred with this appraisal. The fossils that would have indicated a Pliocene age for Charlton include *Pecten gibbus, Rangia cuneata, Chione cancellata,* and *Mulinia lateralis.* The fossil then identified as *P. gibbus*, a Pleistocene and Holocene species, was subsequently renamed *P. charltonius* by Mansfield (1936) and transferred to *Argopecten charltonius* by Waller (1969). The only known geographic occurrence of *A. charltonius* is within the Charlton Member and *A. charltonius* is, therefore, of little value in biostratigraphic correlation. Waller (1969), however, suggested that the Charlton is late Miocene based on the general similarity between *A. charltonius* and *A. choctawhatcheensis* of the *Arca* Zone of the upper Miocene Choctawhatchee Formation of western Florida. Supporting Waller's (1969) suggestion of an older age for the Charlton Member, I recently examined the fossil collections from the Charlton in the U.S. National Museum in Washington, D.C., and could find no Pleistocene or Pliocene species as described by Veatch and Stephenson (1911) and by Cooke (1943, 1945) (i.e., *Rangia cuneata, Chione cancellata,* and *Mulinia lateralis*). I have also not found these species in the Charlton, either in outcrops or cores. Therefore, there is no existing paleontological evidence, known to this author, for a post-Miocene age for the Charlton Member.

Because the physical stratigraphic relationships indicate that the Charlton is a lithofacies of the upper part of the Coosawhatchie Formation, the Charlton Member is here provisionally assigned the same age as the rest of the Coosawhatchie, (i.e., middle Miocene, early Serravallian [Pl. 1]). This report does not exclude a late Miocene age for the Charlton Member, as suggested by Waller (1969). Other than the similarity between *Argopecten charltonius* and *A. choctawhatcheensis* noted by Waller, however, no paleontological or physical evidence exists to suggest or support a late Miocene age for the Charlton member. On the other hand, no evidence, other than the appearance of gradational contacts between the Charlton and Ebenezer Members, exists to deny a younger Miocene or late Miocene age for the Charlton or Ebenezer Members.

MEIGS MEMBER OF THE COOSAWHATCHIE FORMATION (new name)

Definition

The Meigs Member of the Coosawhatchie Formation is a new name proposed herein for argillaceous, well-sorted, fine-grained sand and thinly bedded to laminated, variably siliceous and diatomaceous clay. At this time, the Meigs member has been recognized only along the trend of the Gulf Trough from northwestern Thomas County, where it is mined for fuller's earth at Meigs, through northern Coffee County to northern Toombs and southern Emanuel Counties, where it crops out in the lower Ohoopee River area.

The Meigs Member is included in the Coosawhatchie Formation because its lithology is most similar to that of the Coosawhatchie, and it is correlative with (Andrews and Abbott, 1985) and probably stratigraphically continuous with the Coosawhatchie in eastern Georgia. Like the Coosawhatchie Formation, the Meigs consists of silty clay (fuller's earth) and fine-grained, well-sorted sand. Lithologically, the clay phase of the Meigs Member most nearly resembles the stratigraphically equivalent clay at the type locality of the Coosawhatchie Formation at Dawsons Landing in South Carolina and, like the Berryville Clay Member, the fuller's earth clay in the lower part of the Meigs Member is characeristically diatomaceous.

In the past, the Meigs Member of the Coosawhatchie Formation was included with the Alum Bluff Formation (Veatch and Stephenson, 1911, p. 357-358; Shearer, 1917, p. 287-289) and with the Hawthorne Formation (Gremillion, 1965; Patterson and Buie, 1974; Weaver and Beck, 1977). The Meigs Member was mapped as Hawthorne Formation by Cooke (1939), and as "Chipola Formation and Tampa Limestone" by MacNeil (1947b). Sever (1966b) referred to this unit, in the vicinity of Meigs, as the "Upper Zone of the Alum Bluff Group".

Type Section

The name Meigs is taken from the village of Meigs in Thomas County, Georgia. The type locality of the member is the Singletary pit of the Waverly Mineral Products Company, 4.0 airline miles (6.4 km) southeast of Meigs and 1.75 miles (2.8 km) east of highway US 19, on the north side of Hansell Road, and in the southern valley wall of Oaky Woods Creek (Fig. 36). The entire section exposed in the Singletary pit is Meigs Member, and this is the type section, or unit-stratotype (holostratotype), of the member.

The Meigs Member of the Coosawhatchie Formation can also be seen in the lower parts of bluffs along the Altamaha River in Toombs County, Georgia, and in roadcuts at relatively low elevations (below approximately 150 feet above sea level) in the lower Ohoopee River area in northern Toombs and southern Emanuel Counties, Georgia.

Parastratotypes of the Meigs Member include the interval 77 feet to 110.5 feet in the core Coffee 3 (GGS-3539) and 78 feet to 111 feet in the core Coffee 4 (GGS-3541) in Coffee County, Georgia; the interval 123 feet to 160 feet in the core Berrien 10 (GGS-3542) in Berrien County, Georgia; the interval 125 feet to 214 feet in the core Colquitt 3 (GGS-3179) and 0 to 96 feet in the core Colquitt 9 (GGS-3535) in Colquitt County.

Lithology

Available information indicates that the Meigs Member of the Coosawhatchie Formation is a lithologically heterogeneous unit. Well-sorted, fine-grained sand is the dominant

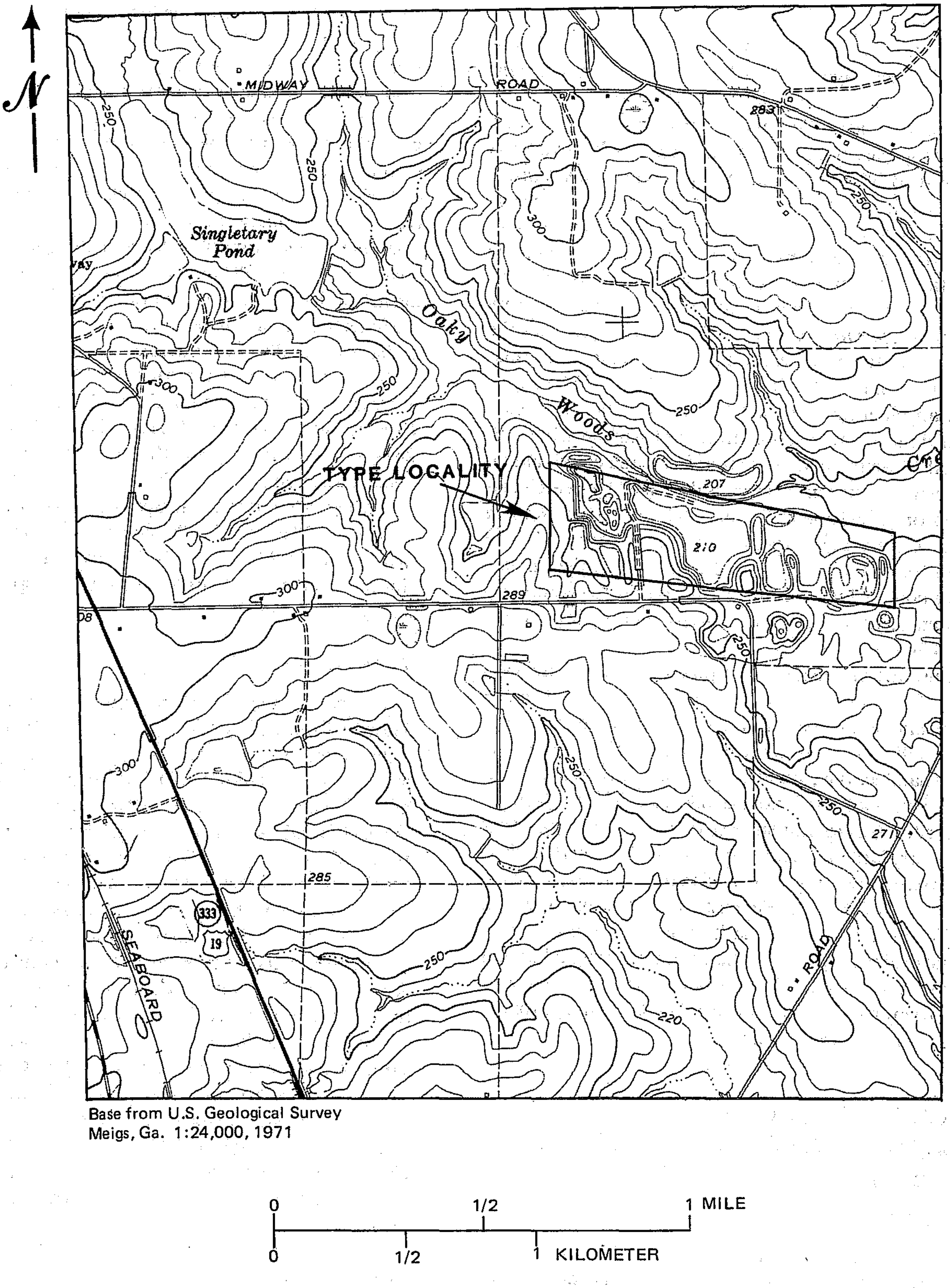


Figure 36. The type locality of the Meigs Member of the Coosawhatchie Formation.

lithic component of the unit, but clay is prominent and is the characteristic lithic component of the unit. Other subordinate lithic components include mica, chert, silica-cemented sandstone, wad (hydrated MnO_2), minor Na- and K-feldspar, heavy minerals, siliceous microfossils, and minor phosphate.

The quartz sand is typically fine-grained and well-sorted, but minor fine- to medium-grained sand has been observed. The sand beds are generally thin to thick, vaguely and rudely bedded to massive and structureless. Scattered small-scale cross-bedding has been observed in fine-grained sand sections. Relatively pure quartz sand is not known in the Meigs Member, and the sand is always argillaceous to some degree with minor to abundant interstitial clay. Where clay occurs in discrete beds, the clay is laminated with scattered fine-grained sand or silt layers, or with silt dustings on bedding planes. The laminated clay commonly is siliceous to a minor degree, and siliceous microfossils (diatoms, ebridians, sponge spicules, and probably very rare silicoflagellates) are common locally (Andrews and Abbott, 1985). The laminated clay beds are present in most sections and vary in thickness from a few feet (approximately 1 m) to as much as 48 feet (15 m) (Weaver and Beck, 1977, p. 105-118). The thick clay deposits are mined for fuller's earth in northwestern Thomas County. Montmorillonite generally is the dominant clay mineral component of this unit, but palygorskite may predominate in some beds. Sepiolite, illite, and kaolinite are minor clay mineral components. The occurrence of palygorskite and sepiolite is characteristic of the Meigs member in the southwestern part of its geographic occurrence whereas palygorskite and sepiolite appear to be minor or absent elements in the northeastern areas. Kaolinite is a significant clay mineral only in the upper part of the section (Weaver and Beck, 1977, p. 105-118; Patterson and Buie, 1974, p. 36-37).

Secondary silica is locally conspicuous in the Meigs Member. The silica is typically interstitial and acts as a cementing agent in argillaceous, fine-grained sands, finely sandy clays, and less commonly, in clay. In non-sandy sediments, the silicification is manifested as siliceous claystone or chert. The degree of induration of the siliceous sediments is variable. Some sediments entirely lack evidence of silicification. Most commonly, however, the sediments appear to be only slightly to moderately silicified, with such sediments being tough, moderately resistant, but crumbly and poorly coherent. Silicified sediments have not been seen in natural outcrops, probably due to weathering and leaching of the siliceous cementing agent. The source of the silica may be siliceous microfossils, because unaltered diatom frustules commonly are seen in various states of preservation in the nonsilicified clays. Diatoms or other siliceous microfossils are not apparent in the silicified, indurated sediments.

Burrows and clear evidence of bioturbation have not yet been observed in exposures in the Meigs area or in the various cores. However, both bioturbation and burrows are present in the sandy phase of this unit in northern Toombs County.

Stratigraphic Relationships

At this time, Meigs Member is known to occur only in or adjacent to the Gulf Trough (Fig. 37). Present information indicates that the unit occurs at least as far southwest as northwestern Thomas County, and at least as far northeast as northern Toombs and southern Emanuel Counties, Georgia. The southwestern limits of the Meigs Member are unknown at this time. In Gadsden County, Florida, sediments reminiscent of the Meigs Member occur in the upper part of the Hawthorne Group and overlie the Torreya Formation in fuller's earth pits. These upper Hawthorne Group deposits of Gadsden County also occur in the Florida Geological Survey cores Suber 1 (W-7573), Owenby 1 (W-7472), and Gregory 1 (W-7528) (Fig. 4). The basal clay bed of this unit in the Florida Geological Survey cores is lithologically similar to the Berryville Clay Member of the Coosawhatchie Formation of eastern Georgia. If the upper sands and clays of the Hawthorne Group in Gadsden County, Florida, represent the Meigs Member of this report, the Gadsden County stratigraphic equivalent is devoid of the characteristic thinly bedded to laminated, diatomaceous clay lithofacies.

It is not clear, yet, to what extent the Meigs Member occurs outside of the Gulf Trough. The outcrops of the unit in the vicinity of the Ohoopee River occur on the northern margin of the Gulf Trough (Fig. 37). On the southern flank of the Gulf Trough in Colquitt County, neither the Meigs Member nor a stratigraphically equivalent unit has been identified in the core Colquitt 10 (GGS-3144). However, 96 feet (29 m) of the Meigs Member are present in the Gulf Trough in the core Colquitt 9 (GGS-3535) 9 miles (14 km) northwest of the site of the core Colquitt 10. This presence suggests pinchout or abrupt facies change of the Meigs Member on the southern flank of the trough.

Because of stratigraphic position and biostratigraphic correlation, the Meigs Member is presumed to grade laterally eastward into the lower part of the Coosawhatchie Formation in the northern part of the Southeast Georgia Embayment (Fig. 11; Pl. 1). As yet, the area has no core control to confirm this correlation. In addition, because of an apparent stratigraphic association (mutual occurrence in stratigraphic sections) between the Meigs Member and the overlying Altamaha Formation (there is as yet no such evidence for a similar stratigraphic association between the Ebenezer Member of the Coosawhatchie Formation and the Altamaha Formation), it is suggested that the Meigs Member rather than the Ebenezer Member more likely occurs in the interior of the Southeast Georgia Embayment south of the Gulf Trough (i.e., in Jeff Davis, Appling, Bacon, and northern Ware Counties). In this model, Meigs Member would represent a lithofacies extension of the middle Miocene, inner Southeast Georgia Embayment deposits, southwestward along the Gulf Trough.

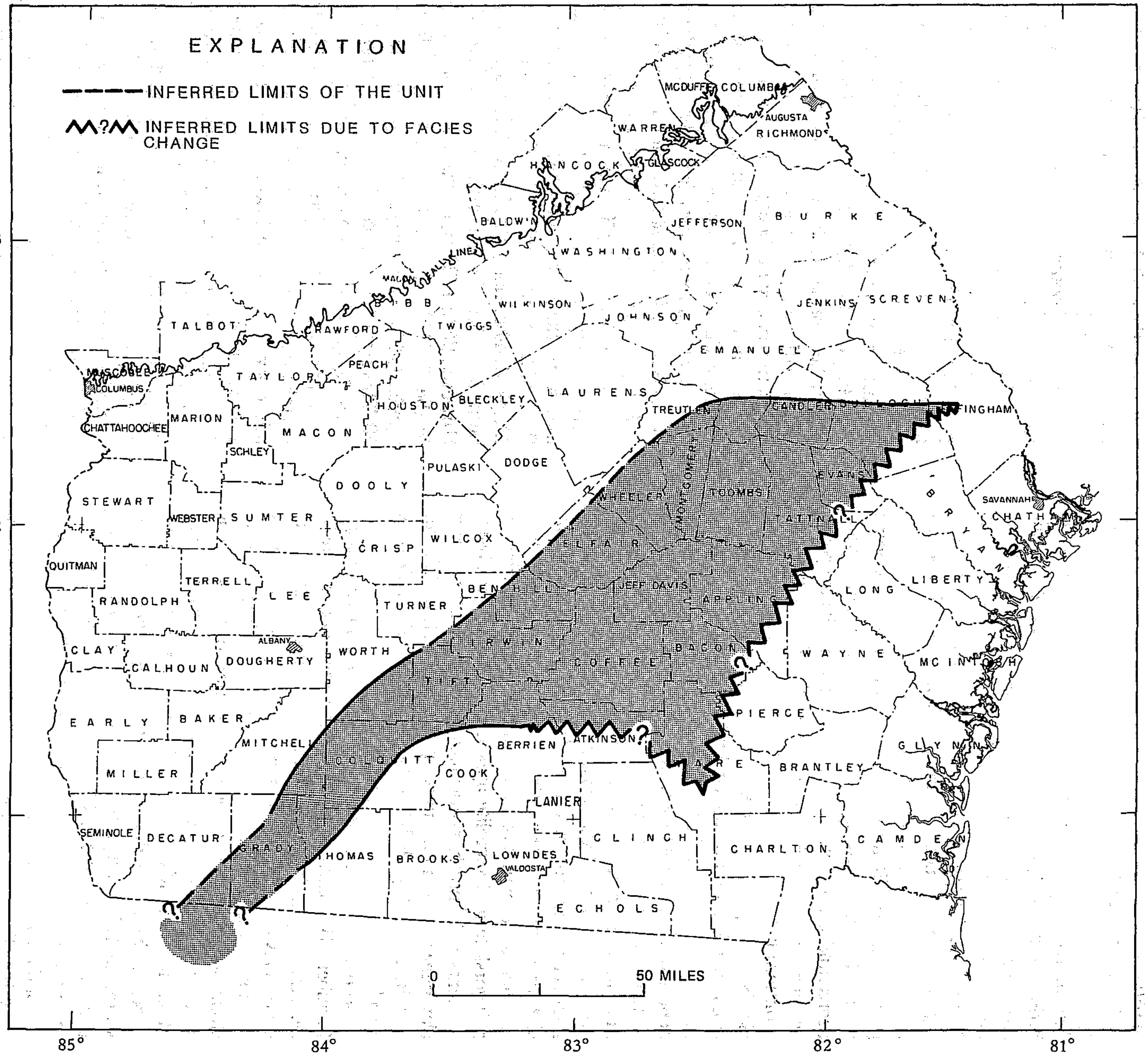


Figure 37. The areal distribution (outcrop and subcrop) of the Meigs Member of the Coosawhatchie Formation in Georgia.

The Meigs Member of the Coosawhatchie Formation overlies, in the Gulf Trough, lithologically heterogeneous Hawthorne Group sand and clay deposits that appear to be stratigraphically equivalent to the Marks Head Formation of eastern Georgia (Pl. 1). The Meigs Member is overlain conformably and gradationally by the Altamaha Formation from northeastern Colquitt County to southern Emanuel County. In central Colquitt County, the Meigs Member occurs to ground level, and in northwestern Thomas County, the Meigs Member is overlain disconformably by the upper Pliocene Miccosukee Formation, or by undifferentiated surficial or alluvial deposits.

The Meigs Member of the Coosawhatchie Formation is distinguished from the other members of the Coosawhatchie Formation in lacking carbonate, in lacking or containing only minor phosphate, and in being more siliceous and diatomaceous. The Meigs Member is distinguished from the underlying undifferentiated Hawthorne deposits by the presence of thinly layered to laminated diatomaceous clay (fuller's earth) near the base of the member. In contrast, the undifferentiated deposits are thick-bedded and massive throughout.

Thickness distribution information on Meigs Member is fragmentary. Available information indicates that the Meigs Member ranges from 47.5 feet (15 m) to 82 feet (25 m) in thickness in northwestern Thomas County (Patterson and Buie, 1974, p. 36-37; Weaver and Beck, 1977, p. 105-118). The maximum thickness of the unit in northwestern Thomas County is probably greater than that cited because the base of the unit has not been identified there. In cores in Colquitt County, the thickness of the Meigs Member is 96 feet (29 m) in the core Coffee 9 (GGS-3535) in the interval 0 to 96 feet, and 89 feet (927 m) in the core Colquitt 3 (GGS-3179) in the interval 125 feet to 212 feet. In northern Berrien County, Meigs Member is 37 feet (11 m) thick in the core Berrien 10 (GGS-3539) in the interval 77 feet to 110.5 feet; and 33 feet (10 m) thick in the core Coffee 4 (GGS-3541) in the interval 78 feet to 111 feet. The known thickness range of the Meigs Member is, therefore, 33 feet (10 m) to 96 feet (29 m), with an apparent systematic increase in thickness southwestward along the Gulf Trough.

The environment of deposition of the Meigs Member was shallow-water, coastal marine. According to Andrews and Abbott (1985) and Abbott, in Huddlestun (1985), the salinity of the water in which the Meigs Member of the Coosawhatchie Formation (Coosawhatchie equivalent of Andrews and Abbott, 1985) was deposited ranged from normal marine with no evidence indicating "any substantial deviation from normal marine salinity" (p. 64), through brackish to mainly fresh-water. In addition, Andrews and Abbott (1985, p. 65) noted that, "The freshwater taxa include forms ranging in preference from acidic to alkaline water . . . ".

Because of lack of sufficient core data south of the Gulf Trough and in the interior of the Southeast Georgia Embayment, it is not clear whether the Meigs Member was deposited only in a narrow strait connecting the Atlantic Ocean and the Gulf of Mexico (Gulf Trough), or whether shallow, water, marine conditions also prevailed south of the Gulf Trough as well.

Age

The age of the Meigs Member of the Coosawhatchie Formation is middle Miocene (Kanaya, *in* Gremillion, 1965, p. 44-45; Abbott, *in* Weaver and Beck, 1977, p. 109-110; Andrews and Abbott, 1985, p. 64; Abbott, *in* Huddlestun, 1985, p. 6-7). According to Andrews and Abbott (1985), the Meigs Member is in the upper part of East Coast Diatom Zone (ECDZ) 4 of Andrews (1978) and in Atlantic Margin Siliceous Microfossil Zone (AMSMZ) IV of Abbott (1978). Andrews (*in* Andrews and Abbott, 1985, p. 64) preferred to correlate ECDZ 4 with the upper part of planktonic foraminiferal Zone N9 of Blow (1969) and with the Langhian Stage, whereas Abbott (*in* Andrews and Abbott, 1985, p. 64) preferred to correlate AMSMZ IV with Zone N10 of Blow (1969) and also with the Langhian Stage.

In eastern Georgia, Ernissee, Abbott, and Huddlestun (1977) suggested correlation of the Coosawhatchie Clay near Berry Landing on the Savannah River (holostratotype of the Berryville Clay Member of this report) to upper Zone N11 or lower Zone N12 of Blow (1969). Abbott and Andrews (1979) later assigned these deposits to AMSMZ VI of Abbott (1978) and ECDZ 6 of Andrews (1978) while maintaining correlation with upper N11 or lower N12. However, *Globorotalia peripheroacuta*, the zonal fossil of N10, is the only member of the *Globorotalia fohsi* lineage[1] present in the type section of the Berryville Clay Member and in nearby cores, and the type Berryville Clay must be, therefore, assigned to Zone N10. Furthermore, the presence of morphologically advanced *G. peripheroacuta* suggests an upper Zone N10 assignment for the type Berryville Clay. It is also possible that, because of the small planktonic foraminiferal faunas in the relatively nearshore area, *G. fohsi praefohsi*, the zonal fossil of N11, may yet be found in the type area of the Berryville clay.

Morphologically primitive *G. fohsi praefohsi* and typical *G. peripheroacuta* are present in the Berryville Clay Member in sample 7-2, 30-40 cm (at a depth of 90 m below sea level) from the core AMCOR 6002 taken on the continental shelf of Georgia. Sample 7-2, 30-40 cm, therefore, is in lower Zone N11 of Blow (1969) and, based on the evolutionary development of the *Globorotalia fohsi* lineage, is slightly younger, or possibly the same age as, the Berryville section near Berry Landing. Abbott (1978, p. 24), however, assigned the interval 80.5 m to 92.5 m below sea level in the AMCOR 6002 to AMSMZ IV whereas he assigned the section near Berry Landing to AMSMZ VI (Abbott and Andrews,

[1]Zones N9 through N12 are based on evolutionary morphological changes in the *Globorotalia fohsi* lineage.

1979). This discrepancy in the correlation and zonal assignment may be the result of AMSMZ IV, V, and VI, and ECDZ 4, 5, and 6 all occurring within Zones N10 and N11 rather than in Zones N9 through N12 as indicated by Abbott and Andrews (1979) and Andrews and Abbott (1985) (W.H. Abbott, pers. com., 1986).

The Meigs Member of the Coosawhatchie Formation contains an AMSMZ IV and ECDZ 4 diatom flora (Andrews and Abbott, 1985; Abbott, *in* Huddlestun, 1985) and, therefore, is equivalent to Zone N10 or lower Zone N11. It seems unlikely to me that the Meigs Member is as old as Zone N9 as suggested by Andrews (*in* Andrews and Abbott, 1985), because I have seen an N9 planktonic foraminiferal assemblage (co-occurrence of *Globorotalia peripheroronda* and *Orbulina suturalis*) at only one site in the Shoal River Formation of western Florida (Huddlestun, 1984, p. 81-83). All of the other lower Shoal River (White Creek beds) and Coosawhatchie planktonic foraminiferal assemblages I have examined are either in Zone N10 or Zone N11. Zones N10 and N11 are in the lower part of the Serravallian Stage (Cita and Blow, 1969; Berggren and van Couvering, 1974; also see Berggren and others, 1985). A Langhian age for the Meigs Member, as proposed by Andrews and Abbott (1985), is not currently supported by correlation of the diatom zonation with the planktonic foraminiferal zonation.

STATENVILLE FORMATION OF THE HAWTHORNE GROUP (new name)

Definition

The Statenville Formation is a new formation proposed herein for prominently planar and trough cross-bedded, argillaceous, dolomitic, phosphatic sand exposed along the Alapaha River at Statenville in Echols County, Georgia. In the past, these deposits have been referred to the Alum Bluff Formation (Veatch and Stephenson, 1911, p. 353-354) and to the Hawthorne Formation (Cooke and Mossom, 1929, p. 125-126; Cooke, 1943, p. 94; 1945, p. 152-153; Puri and Vernon, 1964, p. 153). Brooks (1966, p. 74-78) described the deposits at the type locality at Statenville but did not assign them to any lithostratigraphic unit.

Type Section

The name Statenville is taken from the village of Statenville in Echols County, Georgia. The type locality of the formation is the low bluff on the east bank of the Alapaha River at Statenville (Fig. 38). The type section, or unit stratotype (holostratotype), of the Statenville Formation includes those exposures of the formation in the low bluff along the Alapaha River at Statenville north of the Ga. 94 bridge. Neither the upper nor lower boundaries of the Statenville Formation are exposed at the type locality.

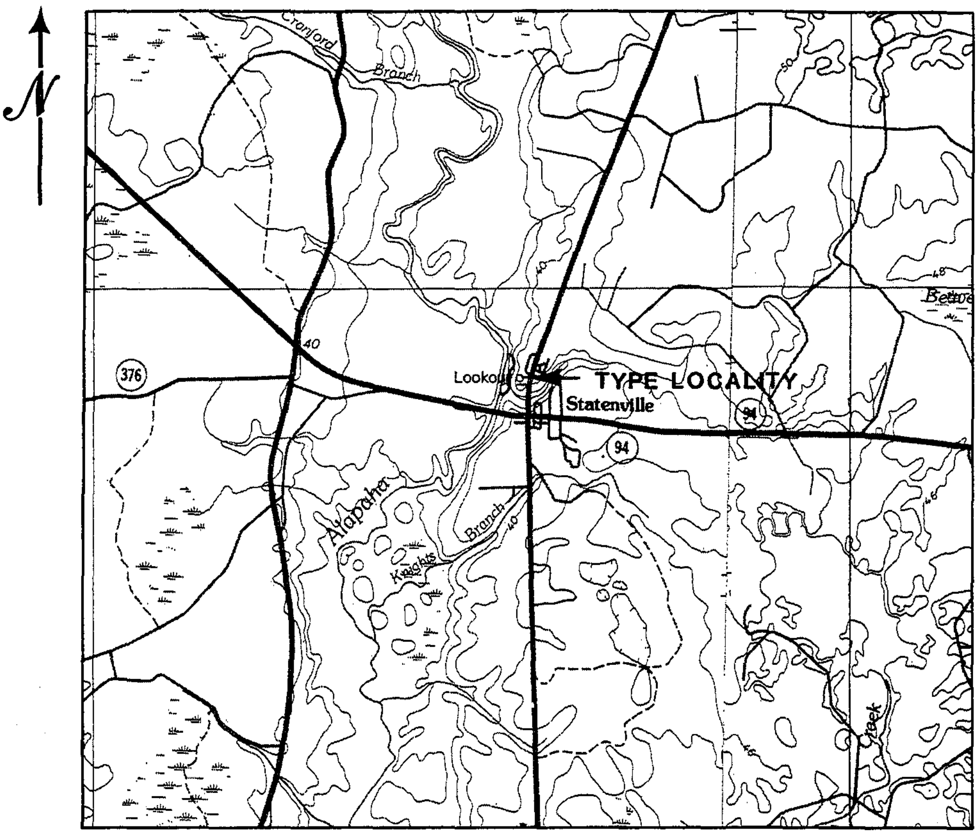
Three additional reference localities and parastratotypes are proposed herein. The interval 11 feet to 87 feet in the Florida Geological Survey core Betty 1 (W-15121) is herein designated a parastratotype and a lower boundary stratotype of the Statenville Formation. The boundary between the Statenville Formation and the underlying unnamed dolostone, clay, and sand occurs at a depth of 87 feet in the core. The core site of the Betty 1 (W-15121) is in NE 1/4, NW 1/4, Sec. 3, T2N, R12E in Jennings, Hamilton County, Florida. The second parastratotype includes those exposures of the Statenville Formation along the Alapahoochee River between the Ga. 135 bridge in southwestern Echols County, and the bridge over the river in NE 1/4, Sec. 224, T2N, R12E in Hamilton County, Florida, approximately 1 1/4 miles (2 km) northeast of Jennings. This stratotype consists of a series of exposures and is, therefore, a composite parastratotype. The third parastratotype is also a composite parastratotype and consists of those exposures along the Suwannee River, approximately 1 mile (1.6 km) above and below the former site of Cones Bridge (currently a boat landing) in Sec. 36, T1N, R16E in Hamilton and Columbia Counties, Florida.

Lithology

The Statenville Formation is a prominently cross-bedded, undulatory-bedded, to horizontal-bedded, dolomitic, phosphatic, argillaceous sand with scattered beds or lenses of clay and dolostone. Quartz sand is the dominant lithic component, whereas clay, dolomite, dolostone, phosphate, and mica are subordinate lithic components. The grain-size of the quartz sand ranges from fine to coarse, and the sorting ranges from well-sorted to poorly sorted. Quartz pebbles occur in the coarser beds or lenses of the formation, and flat pebbles have been observed among the quartz pebbles. The coarser, pebbly sand phases of the formation generally are the more poorly sorted.

Dolomite is characteristically conspicuous in the formation and is present both interstitially and in discrete, thin beds. Dolostone beds may be relatively pure (as in beds at the type locality) or sandy, argillaceous, and phosphatic. The bedded dolostone is typically buff to tan, fine-grained, saccharoidal, hard, and resistant to erosion. In outcrop the dolostone beds produce prominent ledges in contrast to the soft, nonindurated sand layers. Some beds consist of a dolostone conglomerate or breccia cemented by dolomite of similar lithology and appearance.

Phosphate is characteristic of and is commonly conspicuous in the Statenville Formation. The phosphate grains range from the typical small, black, brown, to amber-colored, rounded, sand-size apatite grains or pellets; to irregularly shaped, rounded, black, shiny, sand-size grains or small pebbles; to black, brown, orange, or buff-colored, irregularly shaped pebbles ranging from 1 to 5 cm in diameter. These coarser phosphate pebbles appear to be characteristically found in conglomerate beds cemented with dolomite and are more typical of the Suwannee River section



Base from U.S. Geological Survey
Okefenokee Swamp, Ga.-Fla. 1:100,000, 1980
and Valdosta, Ga.-Fla. 1:100,000, 1981

0 1 2 3 MILES

0 1 2 3 KILOMETERS

CONTOUR INTERVAL 5 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 38. The type locality of the Statenville Formation of the Hawthorne Group.

than the Alapaha River section. The Statenville Formation may be exceptionally rich in phosphate, and thin beds or lenses of phosphatic sediment (or phosphorite) are lithologically identical to the broadly correlative Tybee Phosphorite Member of the Coosawhatchie Formation. These beds have the color and appearance of wet coffee-grounds.

Clay is not conspicuous in the coarse, prominently cross-bedded lithofacies of the Statenville Formation and its occurrence there is mainly interstitial. The upper part of the formation generally is finer grained, however, (e.g., in the interval 11 feet to 53 feet in the core Betty 1 [W-15121]), and clay in this lithofacies occurs in discrete beds of thinly stratified or laminated silty clay. The clay beds range in thickness from less than 1 foot (0.3 m) to more than 8 feet (2.4 m). Massive fuller's earth clay of Shearer (1917, p. 284-287) is referred to the Statenville Formation of this report. The known clay mineral assemblages of the Statenville Formation includes montmorillonite and palygorskite (T. Scott, pers. com., 1983; also compare with Brooks [1966, p. 82]).

Characteristically the Statenville Formation is prominently bedded with the bedding standing out in bold relief. Bedding styles range from horizontal to undulatory to planar and trough cross-bedded with common cut-and-fill structures. Typically the bedding is enhanced or "highlighted", as at the type locality, by thin beds exposed as "sheets" of hard, resistant, fine-grained dolostone that stand out in relief as ledges. The softer, sandy sediment occurs in reentrants between the thin dolostone beds or "sheets". In this lithofacies, most discrete bed-units are less than a few inches (several centimeters) thick, and many are less than 1 inch (2.5 cm) thick.

Based on the core Betty 1 (W-15121) and field observation, the characteristic, prominently cross-bedded Statenville lithology apparently grades upward, and possibly laterally as well, into a less conspicuously bedded, less dolomitic to carbonate-free, variably phosphatic sand with local development of clay beds. This lithofacies is also well-bedded, but the bedding is not enhanced by the presence of resistant, thin dolostone beds. Bedding is marked by the distinction between clay beds and sand beds, or by the distinction between grain-size and sorting within the sand. These upper sands of the Statenville Formation are actively being mined for phosphate by the Occidental Chemical Company in Hamilton County, Florida.

The Statenville Formation is very sparsely fossiliferous. Molds and casts of mollusks occur locally in moderate frequency in the dolomitic beds. Fossils with calcitic shells. such as scallops, oysters, and barnacles are very rare. Voorhis (1974b) reported a meager assemblage of vertebrate fossils from the type locality of the formation. Vertebrate fossil debris, such as small fish teeth and bones, is not rare in the phosphatic beds of the formation, and the trace fossil *Ophiomorpha nodosa* is locally common in sand beds on both the Alapaha and Suwannee Rivers. Most beds and many sections of the Statenville Formation, however, are barren of visible fossils.

Stratigraphic Relationships

The Statenville Formation is known to occur in Echols County, Georgia, and in the upper Suwannee River area in Hamilton and Columbia Counties, Florida, and it probably underlies much of Clinch County, Georgia (Fig. 39). I northern and southern limits are unknown at this time, but its western limit occurs on the eastern part of the Florida Platform in eastern Lowndes County, Georgia, and western Hamilton County, Florida. Its eastern limit occurs in eastern Columbia or western Baker Counties, Florida, and probably southwestern Clinch County, Georgia. The boundary between the Florida Platform and the Southeast Georgia Embayment appears also to make the eastern limit of the Statenville Formation, because the Coosawhatchie Formation occurs in the Statenville stratigraphic position in the St. Marys River area (within the Southeast Georgia Embayment) in Florida and Georgia.

The Statenville Formation overlies the unnamed dolostone, clay, and sand in Hamilton County, Florida, and probably in Echols County, Georgia (Fig. 11). It occurs at the top of the geologic section in most of Echols County where it is overlain only by undifferentiated sands. In northwestern Echols County, the Statenville Formation is disconformably overlain by the Miccosukee Formation.

The Statenville Formation is distinguished from the Coosawhatchie Formation in the prominence of bedding (horizontal-, undulatory-, and cross-bedding), the common occurrence of dolostone, the local coarseness (with pebbles) and poor sorting of the sand, and the lithologic heterogeneity of the member (phosphatic sand beds, clay beds, dolostone beds, and phosphorite beds). The underlying unnamed lower Miocene dolostone, clay, and sand is distinguished from the Statenville Formation in consisting of thick beds of massive dolostone; massive, structureless, finely sandy clay; and massive, structureless, argillaceous sand; in being relatively nonphosphatic, and in the consistently fine grain-size of the sand.

At present there is meager information on the thickness distribution of the Statenville Formation. Brooks (1966, p. 76-78) reported 28.8 feet (9 m) of Miocene sediments (Statenville Formation) at the type locality in Statenville. At the present time, however, only 12 feet (3.5 m) of Statenville Formation is exposed there. Seventy-six feet (23 m) of Statenville Formation is present in the reference core Betty 1 (W-15121).

The environment of deposition of the Statenville Formation is believed to have been shallow water, coastal marine. The Statenville Formation is not known to be calcareous anywhere and, therefore, is not known to contain calcareous fossils. However, a small land mammal fauna has been described from the Statenville (Voorhies, 1947b), indicating

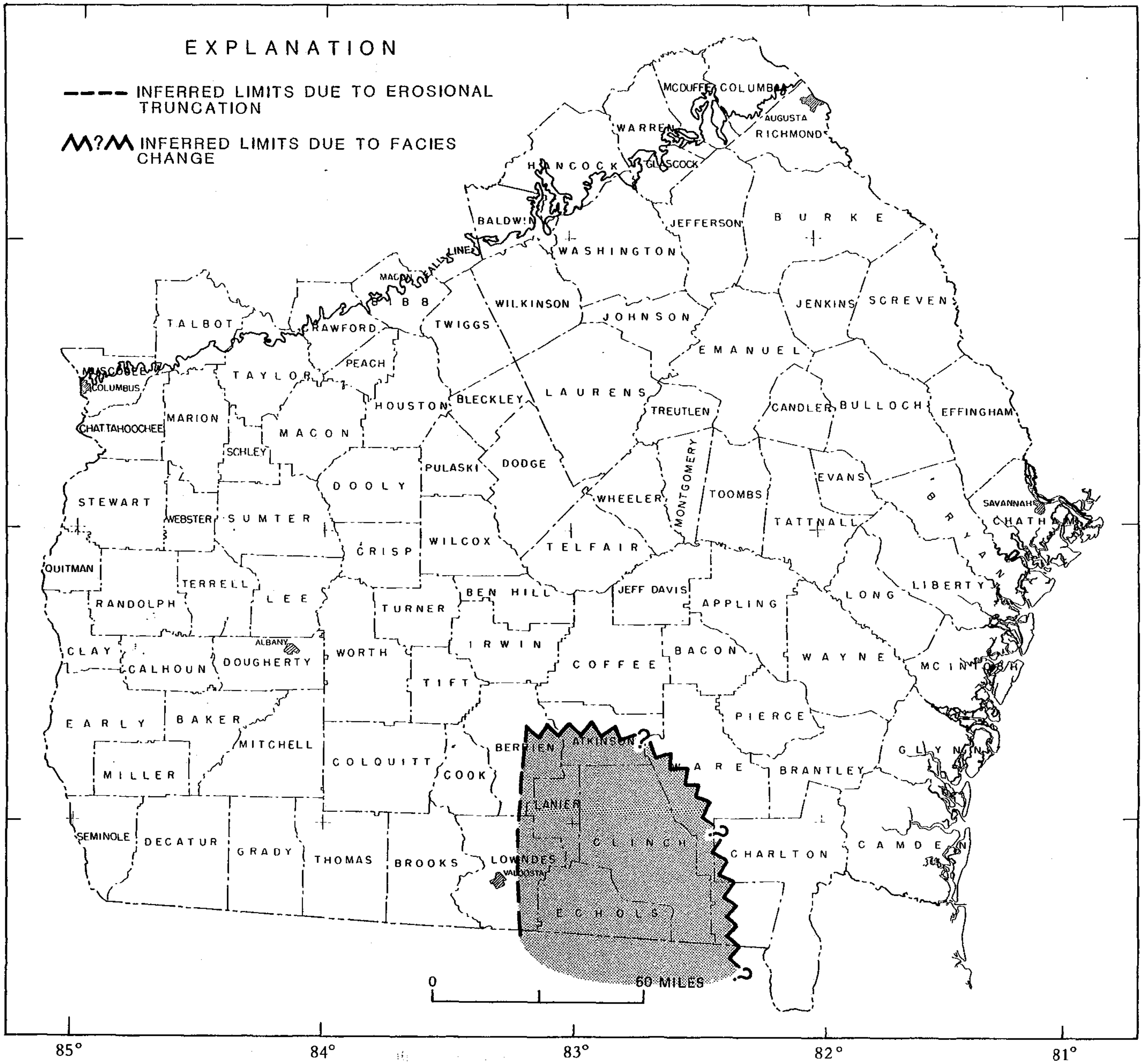


Figure 39. The areal distribution (outcrop and subcrop) of the Statenville Formation in Georgia.

proximity to land. The trace fossil *Ophiomorpha nodosa*, a burrow of the intertidal shrimp *Callianassa major*, is locally common in the Statenville, and is indicative of strand line to subtidal conditions and very shallow water.

The sedimentary structures of the Statenville Formation are compatible with a coastal origin. Large scale cross-bedding requires high energy, which in the marine environment must come from high current energy. In addition, channel cut-and-fill structures are locally conspicuous and these must be of tidal channel origin. The Statenville Formation is, therefore, considered to be a coastal, intertidal to subtidal marine deposit that grades seaward into shallow-water, inner continental shelf deposits (Berryville and Ebenezer Members of the Coosawhatchie Formation). The Charlton Member is considered to have been deposited during the marine regression that terminated Coosawhatchie deposition, and its precise stratigraphic equivalent is probably not represented in the coastal Statenville Formation that was deposited during the maximum extent of the middle Miocene transgression.

Age

The Statenville Formation contains a Barstovian land-mammal fauna (Voorhis, 1947b; Tedford and Hunter, 1984) at its type locality. According to Tedford and Hunter (1984), the Statenville land-mammal assemblage is early late Barstovian and its age is approximately 13 million years. This age determination is also consistent with the age of the Berryville Clay Member of the Coosawhatchie Formation that occurs in the Statenville stratigraphic position in eastern Georgia. The Berryville Clay Member contains a Zone N10 to N11 planktonic foraminiferal assemblage that is approximately 13 to 14 million years old (Berggren and van Couvering, 1974; Berggren and others, 1985; also see Pl. 1). It is concluded, therefore, that the age of the Statenville Formation is early late Barstovian, early Serravallian, middle Miocene.

UNDIFFERENTIATED COQUINA AND SAND OF THE HAWTHORNE GROUP (continental shelf)

Definition

This undifferentiated unit is identified only on the continental shelf in the COST GE-1 well (see Scholle, 1979). The areal extent, the position and nature of contacts, and the lithologic variation are unknown due to meager subsurface control on the continental shelf. This unit is not present in the core AMCOR 6002 (see Hathaway and others, 1976) where its stratigraphic equivalent is the Berryville Clay Member of the Coosawhatchie Formation. This undifferentiated middle Miocene unit does not appear to be present, although the lithologic discussion is inadequate (JOIDES, 1965), in the core JOIDES J-1 on the inner continental shelf off northeastern Florida. The lithology of this unit, however, is distinctive enough and thick enough, and its age and stratigraphic relationships are well enough defined, to warrant recognition of its existence and a brief discussion of the deposit. It is included in the Hawthorne Group with some reservation. The presence of sand, phosphate, dolostone, and chert is indicative of Hawthorne lithology. The presence of glauconite and ooids is exceptional for Hawthorne-type deposits.

Reference Section

This undifferentiated Hawthorne Group deposit is present in the interval 544 feet to 719 feet in the COST GE-1 well (Scholle, 1979) on the continental shelf. The location of the well site is approximately 74 miles (119 km) east of Jacksonville, Florida, at latitude 30° 27′ 07.6892″ north, and longitude 80° 17′ 59.1451″ west at a water depth of 136 feet (41.5 m) (Scholle, 1979, p. 1).

Lithology

The lithology of this deposit is dominated by water-worn, brecciated shell coquina, with oolitic pellets; gray, saccharoidal, hard limestone; olive-gray dolostone; quartz sand with grain-sizes up to small pebbles; some sandstone; chert; glauconite; and phosphate grains and pebbles (Rhodehamel, 1979, p. 24-26).

Stratigraphic Relationships

This lithologically distinctive deposit is known only from the COST GE-1 well which is located east of Nassau County, Florida, and southern Charlton County, Georgia (Fig. 2). The coquina is overlain disconformably or paraconformably by an unnamed upper Pliocene formation, and disconformably or paraconformably overlies undifferentiated Oligocene deposits (Poag and Hall, 1979, p. 49-51). The precise nature of the contacts is uncertain because the unit is known only from well-cuttings. The middle Miocene coquina occurs in the interval 544 feet to 719 feet in the COST GE-1, and is, therefore, 175 feet (53 m) thick.

The onshore stratigraphic equivalent of this undifferentiated coquinoid deposit, in the southern part of the coastal area of Georgia, is the Charlton Member of the Coosawhatchie Formation. There are also coquinoid phases of the Charlton Member, most commonly in the limestone and dolostone lithofacies. Because the Charlton Member is the only subdivision of the Hawthorne Group that displays an abundance of fossils in eastern Georgia, the Charlton Member may possibly grade laterally eastward (offshore) into the undifferentiated coquina and sand.

The presence of water-worn, brecciated shell coquina, oolitic pellets, and quartz pebbles indicates that this unit was deposited in shallow-water, relatively high energy conditions. The presence of planktonic microfossils, on the other hand, indicates near-normal marine salinities. It is not clear whether this unit was deposited in a nearshore, coastal environment, or on a shoal or offshore topographic high.

Age

Poag and Hall (1979, p. 49-50) identified the following planktonic foraminifera from samples referred to here as the undifferentiated middle Miocene coquina and sand:

Globorotalia peripheroronda
G. peripheroacuta (Zone N10-N11)
G. fohsi praefohsi (Zone N11-lower N12)
G. siakensis
Clavatorotella bermudezi (upper Zone N8-lower N10)
Globigerinoides sicanus (Zone N8-lower N9)
Orbulina suturalis

The upper part of this deposit is biostratigraphically equivalent to and correlative with the Coosawhatchie Formation (planktonic foraminiferal Zone N10 and N11 of Blow and Banner, 1966; Blow, 1969). However, the stratigraphic equivalent of the lower part of this unit (i.e., that part which contains Zones N8 and N9) is not known to occur in onshore Hawthorne Group deposits in Georgia. This stratigraphic interval is presumably contained in the hiatus between the Marks Head Formation and the Coosawhatchie Formation.

The age of the undifferentiated coquina and sand of the Hawthorne Group is early middle Miocene (Langhian and Serravallian). It is contained in planktonic foraminiferal Zones N8 or N9 to N11 (Pl.1).

UNDIFFERENTIATED UPPER MIOCENE SAND OF THE HAWTHORNE GROUP (Continental shelf)

Definition

Sediments of this deposit have been recognized at this time only in the core AMCOR 6002 on the outer continental shelf of Georgia (Hathaway and others, 1976). Little can be said of the nature of the deposit because of poor core recovery of the sand. The lithology of this unit is predominantly a sand, and it is, therefore, lithologically distinct from the underlying Berryville Clay. The undifferentiated upper Miocene sand is included in the Hawthorne Group in this report because it is phosphatic and it contains the clay minerals palygorskite and sepiolite (which are characteristic of the Hawthorne Group in Georgia).

Reference Section

This undifferentiated upper Miocene sand of the Hawthorne Group is present in the interval from approximately 138 to 193 feet (string depth) in the core AMCOR 6002 (Hathaway and others, 1976, p. 29-48) on the mid-continental shelf of Georgia. The location of the core site is approximately 46 miles (74 km) east of Brunswick, Georgia, at latitude 31°08.57′ north, and longitude 80°31.05′ west at a water depth of 106 feet (32 m) (Fig. 2). The interval in the core occupied by the unnamed upper Miocene sand is uncertain because core recovery was very poor, only 2 feet of recovery in core runs of 27 feet and 30 feet (3% recovery).

Lithology

This unit consists of sand with apparently minor clay. The recovered sand is variably calcareous, microfossiliferous, argillaceous, phosphatic, and is olive-gray in color. The clay mineral suite is dominated by kaolinite and illite. Smectite and palygorskite are significant but minor components in the unit in the core AMCOR 6002 (Hetrick and Friddell, 1984, p. 36-37).

This undifferentiated deposit differs from other units of the Hawthorne Group in consisting of microfossiliferous, calcareous, argillaceous sand. Of the Hawthorne units in Georgia, it resembles most closely the lower Pliocene Wabasso beds. The environment of deposition of this upper Miocene unit was open-marine, continental shelf.

Stratigraphic Relationships

This upper Miocene deposit is known to occur only in the core AMCOR 6002 on the mid-continental shelf off of Georgia. It is not known to have any correlatives onshore in Georgia, but extensive areas of southern Florida are known to be underlain by upper Miocene, phosphatic, calcareous, microfossiliferous clay and fine sand of similar lithology to this unnamed unit (T. Scott, personal communication, 1984).

The undifferentiated upper Miocene sand of the Hawthorne Group overlies the Berryville Clay Member of the Coosawhatchie Formation in the core AMCOR 6002, and is overlain by Pleistocene sands that are tentatively referred to the Satilla Formation (Pl. 2 and 3; see discussion, p. 281-283). Based on recorded depths of occurrence of this upper Miocene sand in the core AMCOR 6002 (138 feet to 195 feet in Hathaway and others, 1976, p. 33), the undifferentiated unit is no more than 57 feet (17 m) thick.

Age

The following planktonic foraminifera have been identified from samples 3-5, 40-50 cm and 3-4, 15-20 cm from AMCOR 6002:

Globorotalia menardii (sinistral)
Neogloboquadrina acostaensis
Globigerina nepenthes
G. praebulloides
G. apertura
Glorigerinoides quadrilobatus
G. obliquus

G. mitra
Globoquadrina altispira
G. dehiscens
Sphaeroidinellopsis seminulina
Globigerinella siphonifera praesiphonifera
Globigerinita glutinata
Orbulina universa

This assemblages is diagnostically late Miocene (Tortonian) in age, and is probably included in Zone N17 of Blow (1969) (Pl. 1).

WABASSO BEDS OF THE HAWTHORNE GROUP

Definition

The Wabasso beds is an informal name applied here to lower Pliocene, phosphatic, calcareous and microfossiliferous, variably argillaceous, silty, fine-grained to very fine-grained sand in the subsurface of the coastal area of Georgia. They are included in the Hawthorne Group because the Wabasso beds are lithologically similar to the other formations of the Hawthorne Group in eastern Georgia, but are distinguished from the other Hawthorne units in eastern Georgia, and especially the underlying Ebenezer Member of the Coosawhatchie Formation, in being characteristically a calcareous, silty, fine-grained sand, and in containing only minor clay. The Wabasso beds are not considered to be a formal, mappable lithostratigraphic unit at this time because they are known to occur only as erosional remnants and outliers in the shallow subsurface in Georgia, and in southern South Carolina. However, the unit appears to be thick and widespread in eastern and southern Florida and may, with the acquisition of more stratigraphic control in that area, be raised to the rank of formation in the future.

The Wabasso beds were referred to the Duplin Marl by Herrick (1976, p. 124-163) in well BFT 315 in Beaufort County, South Carolina, and wells GS-772 and GGS-381 in Chatham County, Georgia. Herrick (1976) did not, however, differentiate the "Duplin" Wabasso beds from Duplin formation (Raysor Formation of this report) at Doctortown in Wayne County, Georgia. Woolsey (1976, p. 65-66) recognized the discrete unit called Wabasso beds of this report, but referred to them as the Tybee facies of the Duplin formation. Huddlestun and others (1982, p. 184) referred to this unit informally as the Indian River beds.

Reference Section

The name Wabasso is taken from the community of Wabasso in northeastern Indian River County, Florida. The Florida Geological Survey core Phred 1 (W-13958) is suggested as a reference locality for this unit because it is one of the few known cores where the lithology of this unit can be examined and sampled. The Wabasso beds are present in the interval 128.5 feet to 211 feet in the core Phred 1 (W-13958). The core site is in the SW 1/4, SW 1/4, Sec. 16, T32S, R39W, in Indian River County, Florida, approximately 3.5 miles (5.6 km) south of the community of Wabasso (Fig. 3). Two feet of Wabasso beds were recovered in the cored interval 61 feet to 81 feet in the core Chatham 17 (GGS-3554) from Chatham County, Georgia (Fig. 2).

Lithology

Typically, the Wabasso beds consist of silty, fine- to very fine-grained sand that is variably phosphatic, calcareous, microfossiliferous, and argillaceous. Limited information suggests that clay, both interstitially and in discrete beds, is a minor component of the unit. In the core Phred 1 (W-13958) from Indian River County, Florida, the Wabasso beds consist of thinly layered to laminated, well-sorted, phosphatic sand with clay partings. The unit is calcareous in the upper part and weakly to noncalcareous in the lower part. There are some intervals of coarse-grained, well-sorted sand, and a 10-feet-thick bed of dark olive-gray, silty, laminated clay with gypsum bloom on the surface of the core.

The Wabasso beds are not known at this time to be macrofossiliferous, but foraminifera and other calcareous microfossils are present in the calcareous phases of the unit. The unit in the Phred 1 (W-13958) core is variably diatomaceous.

Stratigraphic Relationships

The Wabasso beds occur only in the coastal area of southern South Carolina, Georgia, and eastern Florida (Fig. 40). They are known in the subsurface from the vicinity of Beaufort, Beaufort County, South Carolina, in the north, to Indian River County, Florida, in the south. Based on seismic profiles (Woolsey, 1976) and limited core control, the Wabasso beds appear to be restricted to a relatively narrow belt on the seaward side of the Sea Island Escarpment that is slightly oblique to the present Atlantic coastline. Apparently, then, the Wabasso beds are present onshore in southern South Carolina and Chatham County, Georgia, but trend slightly obliquely to the Georgia coast. The unit occurs under the Georgia barrier islands in the northern coastal area, and would appear to occur a short distance offshore in the southern coastal area (Fig. 37). The eastern limit of the unit are not known, but lower Pliocene deposits of equivalent age have not yet been identified in offshore wells and cores.

The Wabasso beds are discontinuous in Georgia (Fig. 44). They are known only from two wells — one from Fort Pulaski (GGS-772) and one from northern Tybee Island (GGS-381) — from a core taken at House Creek on Petit Chou Island near the site of the Petit Chou Island core (see Furlow, 1969, Fig. 1 for sites of these wells and the Petit Chou Island core), and from the Fort Pulaski (GGS-3554) core. However, six other cores taken in the same area did not encounter the Wabasso beds, although reworked

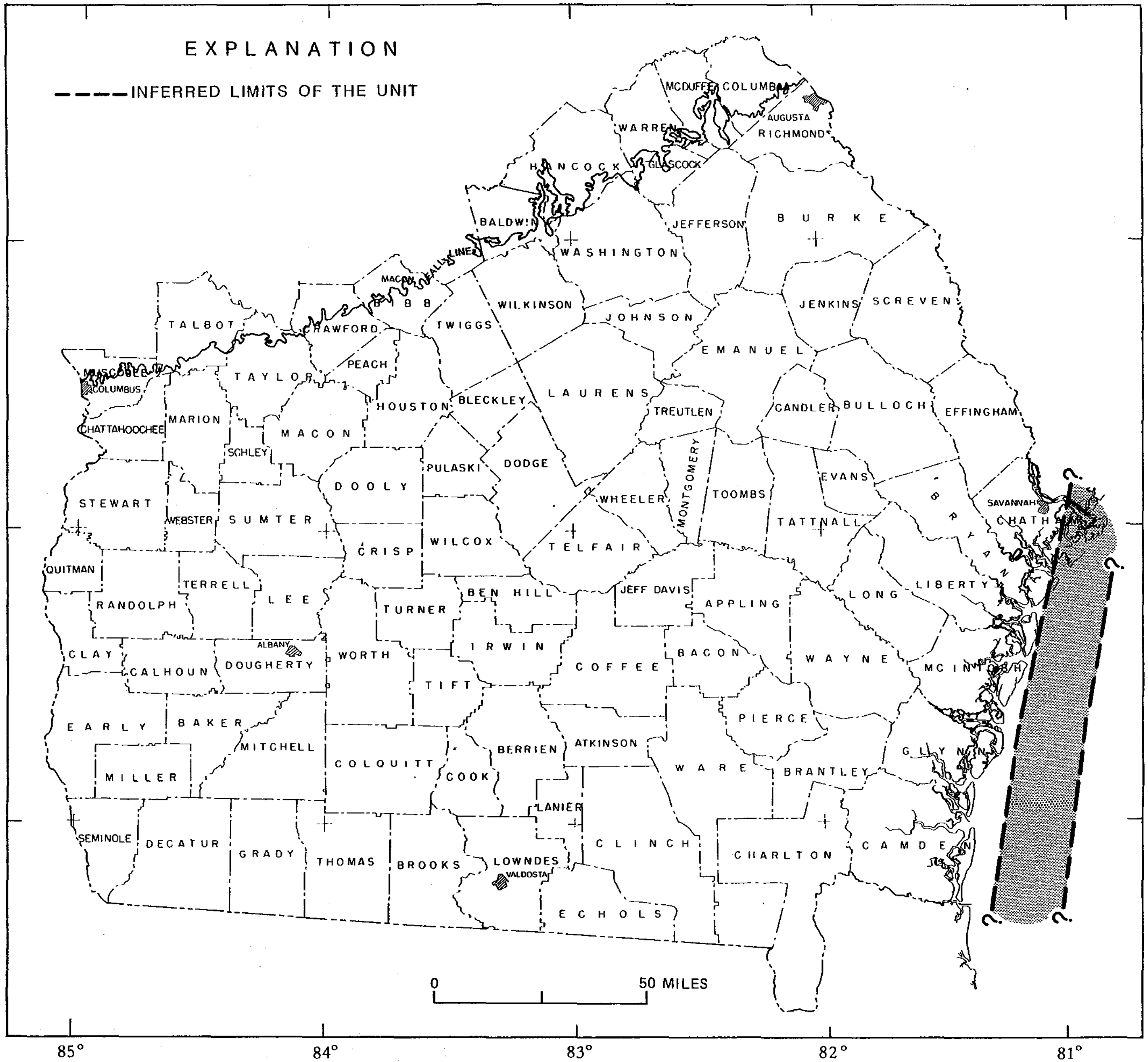


Figure 40. The areal distribution (subcrop) of the Wabasso beds of the Hawthorne Group in Georgia.

Wabasso planktonic foraminifera have been observed by the author from basal Satilla sediments in the core Chatham 13 (GGS-1445) from Chatham County. Therefore, the unit most likely occurs only as erosional outliers in the subsurface of eastern Chatham County. The Wabasso beds have not yet been identified from wells or cores elsewhere in Georgia.

In Chatham County, the Wabasso beds disconformably overlie the Tybee Phosphorite Member of the Coosawhatchie Formation, and are disconformably overlain by the Satilla Formation (Pl. 2). In the core Phred 1 (W-13958) in Indian River County, Florida, the Wabasso beds overlie an undifferentiated massive, phosphatic, calcareous, argillaceous, medium-grained sand of the Hawthorne Group, and are disconformably overlain by the lower Pleistocene Nashua formation.

Very little is known about the thickness of the Wabasso beds. The Wabasso beds that Herrick reported as Duplin Marl (1976, p. 129) are 40 feet (12 m) thick in Beaufort County, South Carolina, and 25 feet (7.5 m) and 28 feet (8.5 m) thick respectively in the wells GGS-772 and GGS-381 in Chatham County, Georgia. In the core Phred 1 (W-13958), the Wabasso beds are approximately 82 feet (25 m) thick.

The environment of deposition of the Wabasso beds in Georgia is open-marine, continental shelf. There is only a small component of brackish water species in the benthic foraminiferal assemblage indicating that the water-mass had near-normal salinities. In addition, the abundance of planktonic foraminifera and the relatively high diversity of the benthic foraminifera indicates that the environment of deposition of the Wabasso beds was the deepest water and most open-marine of all of the Hawthorne deposits of Georgia.

Age

The following planktonic foraminifera have been identified from the Wabasso beds in Georgia and Florida:

Globorotalia menardii (dextral)
G. margaritae margaritae
Neogloboquadrina acostaensis
N. humerosa
Globigerina nepenthes
G. bulloides
G. apertura
G. cf. *rubescans*
Globigerinoides quadrilobatus
G. obliquus obliquus
G. obliquus extremus
G. cf. conglobatus
Globigerinalla siphonifera
Globigerinita glutinata
G. uvula
Globoquadrina altispira
Sphaeriodidinellopsis seminulina
Orbulina universa

The co-occurrence of *Globorotalia margaritae margaritae* and *Globigerina nepenthes* is indicative of Zone PL1 of Berggren (1973). The dextral coiling directions of *Globorotalia menardii, Neogloboquadrina acostaensis,* and *N. humerosa* is characteristic of the upper part of Zone PL1. The Wabasso beds are, therefore, early Pliocene (Zanclean) is age (Pl. 1).

ALTAMAHA FORMATION (reintroduced, redefined, revised)

Definition

The Altamaha grit of Dall and Harris (1892, p. 81-82) and Harper (1906a, 1906b), and the Altamaha Formation of Veatch (1908, p. 71-74; 1909, p. 70-73) and Veatch and Stephenson (1911, p. 400-423), is herein reintroduced as the Altamaha Formation. As defined in this report, the Altamaha Formation is largely the same as the Altamaha grit of Dall and Harris (1892) and Harper (1906a, 1906b), and the Altamaha Formation of Veatch (1908), but it differs in some respects from the Altamaha Formation of Veatch (1909) and Veatch and Stephenson (1911). Veatch (1909) and Veatch and Stephenson (1911) included deposits in their Altamaha Formation that are now assigned to the Miccosukee Formation in southwestern Georgia and to the Cypresshead Formation in eastern Georgia. In other areas, Veatch and Stephenson (1911) assigned deposits to their Alum Bluff Formation that are included in the Altamaha Formation in this report. For example, the section exposed at Berry Hill Bluff on the Oconee River in Treutlen County is considered by this author to be typical Altamaha Formation but was included in the Alum Bluff Formation by Veatch and Stephenson (1911, p. 358).

Stephenson and Veatch (1915, p. 89-94) abandoned the Altamaha Formation in favor of the Alum Bluff Formation of western Florida because "The investigations of recent years have led to the conclusion that the bulk of the deposits included by Harper, Veatch, and Stephenson in the Altamaha Formation are of Oligocene age and are probably contemporaneous with a part of the Alum Bluff formation." The abandonment of the Altamaha Formation, therefore, was based on presumed age and correlation and not on lithologic characteristics or physical distinctions. In addition, replacing the name Altamaha with the name Alum Bluff in Georgia was also contemporaneous with, and probably related to, replacing the name Hawthorne with the name Alum Bluff in Florida (Vaughan and Cooke, 1914). This marks the beginning of the trend, in the southeastern Coastal Plain, in the systematic reduction of stratigraphic units based on lithology, in favor of stratigraphic units based on age and correlation. In accord with Stephenson and Veatch (1915), the name Alum Bluff Formation was applied to deposits that had been included in both the Altamaha and Alum Bluff Formations of Veatch and Stephenson (1911) (Brantly, 1916; Shearer, 1917; Teas, 1921; Prettyman and Cave, 1923). Later, Cooke (1939; 1943, p. 89-98) replaced the name Alum Bluff in Georgia with Hawthorne Formation (also see Cooke and Mossom, 1929; Cooke, 1936), and mapped the Altamaha Formation of this report with the Hawthorne Formation. Subsequent authors (Cooke, 1936, 1939, 1943; MacNeil, 1947a; Cooke and MacNeil, 1952; LeGrand and Furcron, 1956; Siple, 1967; and Herrick and Counts, 1968) referred to these deposits (both Altamaha Formation and Hawthorne Group of this report) under the name Hawthorne Formation. Other names that have been applied to the Altamaha Formation of this report include "Undifferentiated Miocene and Oligocene to Pleistocene inclusive" (Brantly, 1916); Brandywine, Coharie, and Sunderland formations (Cooke, 1939; 1943, p. 106-107); undifferentiated Miocene and Oligocene deposits (LaMoreaux, 1946a); residuum of Oligocene and Miocene formations (LaMoreaux, 1946b); "Duplin marl and Hawthorn formation" (MacNeil, 1947b); Citronelle Formation (Doering, 1960); Miocene (Undifferentiated) (in part) (Herrick, 1961); Recent to Miocene Series (in part) (Herrick and Vorhis, 1963); Ashburn formation (Olson, 1967); Neogene undifferentiated, Miccosukee Formation (in part), and Pleistocene-Pliocene sands and gravels (in part) (Georgia Geological Survey, 1976); and upland fluvial channel deposits (Nystrom and Willoughby, 1982b). The exposure of the Altamaha Formation in the railroad cut 1 mile (1.6 km) east of the railroad station at Barnwell, South Carolina, has been referred to the Barnwell Formation in the past (Cooke, 1936) and has been proposed as the type locality for the Barnwell Formation (Connell, 1968a). The Screven Member of the Altamaha Formation was informally introduced by Huddlestun (1981) as the Screven formation.

The Altamaha Formation is recognized as a formation separate from the Hawthorne and Alum Bluff Groups in this report because of its lithologic distinctiveness. Lithologically the Altamaha Formation is unique among formations in the southeastern Coastal Plain. The only other formations I know that resemble the Altamaha in any way are the "Tuscaloosa" Formation of the Chattahoochee River area, and some phases of the Cape Fear Formation. The Altamaha Formation consists of variably indurated to nonindurated, variably siliceous, kaolin-rich clays and argillaceous, pebbly, feldspathic sands of fluvial origin that are devoid of carbonates, fossils, phosphate, and magnesian clays. The Altamaha Formation is excluded from the Hawthorne Group because Hawthorne deposits generally consist of variably phosphatic, variably dolomitic or calcareous, rarely siliceous, fossiliferous to nonfossiliferous sands and variably magnesium-rich clays of marine, continental shelf origin. The Altamaha Formation is excluded from the Alum Bluff Group because Alum Bluff deposits generally consist of variably calcareous (never dolomitic), typically fossiliferous, nonsiliceous sands and clays (nonmagnesian) of marine, continental shelf origin. The Hawthorne Group is an Atlantic continental shelf deposit, the Alum Bluff Group is an eastern Gulf of Mexico continental shelf deposit, and the Altamaha Formation is a fluvial to upper estuary deposit.

The Altamaha Formation is a multideposit unit; that is, it was deposited during more than one depositional episode. The Altamaha Formation in the inner part of the Coastal Plain and in the Savannah River area is probably early Miocene (Aquitanian) in age, whereas the typical Altamaha Formation of the Altamaha River area is probably middle Miocene (Serravallian) in age. Furthermore, the Altamaha Formation in some regions is divisible into an upper and lower part. The lower part of the Altamaha Formation typically consists of thick bedded, massive sandy clays and argillaceous sands, and claystones and sandstones. The upper part consists of prominently cross-bedded, pebbly to gravelly sands with clay lenses, and appears to be of fluvial channel, cut-and-fill origin. In this report, the upper part of the middle Miocene Altamaha Formation (in the Altamaha and Satilla Rivers area) is named the Screven Member of the Altamaha Formation. The Screven lithofacies occurs locally in the lower Miocene Altamaha Formation, but it is discontinuous and absent over large areas.

Type Section

The name Altamaha was taken from the Altamaha River in southern Georgia. Dall and Harris (1892, p. 82), the authors of the Altamaha lithostratigraphic unit, observed that "Between Rocky Hammock and Doctor Town, all the bluffs (which are mostly on the right bank of the river) are composed of the grit, sometimes extremely hard and flinty and at others more disposed to crumble." They added that "The Altamaha grit is well exposed in these bluffs, ... ". The stretch of river described by Dall and Harris (1892) extends from western Jeff Davis County to central Wayne County, a distance of about 80 miles (128 km). The only reference of Veatch and Stephenson (1911, p. 401) relevant to a type locality or type area of the Altamaha Formation was that "The name 'Altamaha grit' was applied by Dall in 1892, from typical exposures along Altamaha River." Evidently the original authors of the Altamaha Formation and subsequent authors did not conceive of a specific type locality for the formation, only a type area. The type area they thought of is that stretch of the Ocmulgee River and Altamaha River from Jeff Davis County (Rocky Hammock is now in Jeff Davis County, Jeff Davis County having been a part of Coffee County in 1892) to Wayne County.

Because a type section has not been designated for the Altamaha Formation by earlier authors, I am designating as lectostratotype (principal reference section) the exposures of the formation at Upper Sister Bluff on the Altamaha River (also see Veatch and Stephenson [1911, p. 359-360]). Upper Sister Bluff, the principal reference locality of the Altamaha Formation, is located on the south bank of the Altamaha River in Applin County, Georgia, where Georgia highways 121, 144, and 169 cross the river (Fig. 41). The lectostratotype includes the section exposed in the bluff and the series of road cuts along Ga. 121, 144, and 169 to the top of the hill 0.6 miles (1.0 km) south of the bluff. The lower part of the

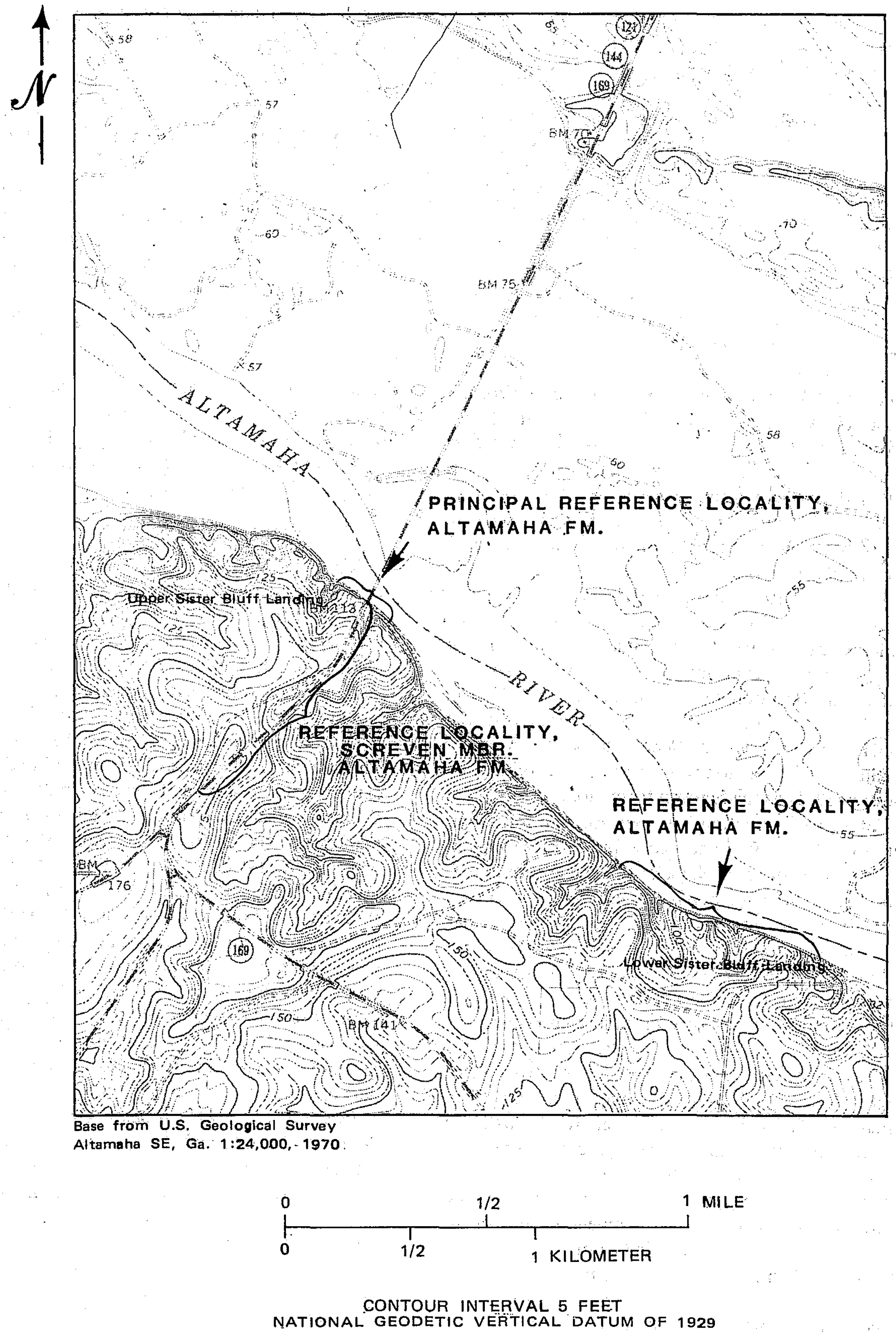


Figure 41. The principal reference locality of the Altamaha Formation.

lectostratotype (exposures in the bluff) extends for several hundred feet (about 100 m) along the face of the bluff under the highway bridge and is currently exposed from approximately 15 feet (4.6 m) above the river at mean-low-water to the top of the bluff at approximately 65 feet (20 m) above the river. The series of road cuts extends from the top of the bluff to the top of the hill at an elevation of approximately 140 feet (43 m) above the river.

Four other sections are herein designated reference localities and hypostratotypes of the Altamaha Formation. Lower Sister Bluff, a reference locality and hypostratotype, is approximately 1 mile (1.6 km) downriver from the lectostratotype at Upper Sister Bluff (Fig. 41; also see Veatch and Stephenson, 1911, p. 359-360, 410-411). This locality is significant because it exposes the best stratigraphic section on the Altamaha River and because the indurated phase of the Altamaha Formation is poorly developed at this site.

Lower Fort James Bluff (see Veatch and Stephenson, 1911, p. 411), herein designated a reference locality and hypostratotype, is located in northern Wayne County (Fig. 2). The Altamaha Formation is exposed at the boat landing and in the roadcut leading down to the landing at the bluff. This section is significant, because it is the easternmost good exposure of the Altamaha Formation, because the Screven lithology in the upper part of the Altamaha Formation is not well-developed at this site, and because the Altamaha Formation is overlain by Cypresshead Formation.

The bluff on the west side of the Oconee River, in a county park at the Georgia highway 46 crossing in northernmost Wheeler County, is herein designated a reference locality and hypostratotype of the Altamaha Formation (Fig. 2). This section shows the close stratigraphic relationship between the sandstone and the poorly sorted, pebbly, clayey sand phases of the formation.

Berryhill Bluff (see Veatch and Stephenson, 1911, p. 358-359) on the Oconee River in Treutlen County is designated herein as a reference locality and hypostratotype (Fig. 2). Berryhill Bluff is significant because it displays the thick, massive sandstone phase of the formation better than any other exposure.

Lithology

The Altamaha Formation consists of thin to thick bedded or crossbedded, well-sorted to very poorly sorted, variably feldspathic, sporadically pebbly or gravelly, argillaceous sand, sandstone, sandy clay, clay, and claystone. Calcite and dolomite, phosphate, the magnesian clays palygorskite and sepiolite are unknown in the formation.

Quartz sand is the dominant lithic component of the Altamaha Formation, but clay is also significant and dominates the lithology of the formation at some sites. The sand ranges in size from fine through very coarse, with coarser quartz ranging from granule to cobble size. The quartz gravel of the Altamaha is subangular to well-rounded, and is characteristically coarser than the gravel in the older Cretaceous and Lower Tertiary deposits in Georgia. Quartz cobbles up to 7 inches (18 cm) in diameter along the major axis have been observed in Washington County, Georgia, and Aiken County, South Carolina. Generally, the finer the upper limit of the sand-size present, the better the sorting; and conversely, the coarser the upper limit of the sand-size present, the poorer the sorting. Poorly sorted, clayey, gravelly sands are characteristic of the Altamaha Formation in the updip areas. Commonly, the coarser beds in the Altamaha are conspicuously feldspathic, and lath-shaped feldspar pebbles within the gravelly beds have been reported by Veatch and Stephenson (1911).

Generally, in the Altamaha Formation, the sand and clay occur in varying states of admixture, with lithologies ranging from argillaceous sand to sandy clay. Beds or lenses of relatively pure sand occur locally but are exceptional. Relatively pure clay or claystone, however, is commonly encountered only in the lower Miocene component of the Altamaha Formation.

The clay mineral suite of the Altamaha Formation is dominated by kaolinite whereas illite and smectite are generally minor constituents (Hetrick, pers. comm., 1986; Hetrick, *in* Huddlestun, 1985). In weathered outcrops, however, kaolinite is generally the only clay mineral present. Both smectite and illite are more significant elements of the clay mineral suite in those sections transitional between typical Altamaha Formation and typical Hawthorne Group.

Secondary silica is locally conspicuous in the Altamaha Formation. Most commonly, the silica occurs as thin veins of siliceous material that has a woodgrain-like texture. In addition, Veatch and Stephenson (1911) speculated that the cementing agent in the indurated phases of the formation is silica.

Bedding style is variable in the Altamaha Formation but typically consists either of rude, thick to very massive bedding or of vague and inconspicuous to very prominent cross-bedding on small to large scales. In the thick-bedded deposits, beds are typically less than 10 feet (3 m) thick, but massive sections of sandstone or clay up to 50 feet (15 m) thick have been observed in outcrops and cores. Generally, the sediments within bedding units are well-mixed and homogeneous. Clays in thick beds, however, are more commonly laminated. Cross-bedding is locally prominent and in the Screven Member cross-bedding is characteristic of the unit. Cross-bedding is generally associated with channel cut-and-fill structures of a wide range of sizes. The cut-and-fill structures generally are either filled with cross-bedded, gravelly, feldspathic sands with clay clasts, or with laminated to massive, blocky clays. The channel cut-and-fill structures are more commonly encountered in the upper part of the middle Miocene component of the Altamaha Formation, but they are also encountered in the lower part of the lower Miocene component of the formation.

The most characteristic lithologies of the Altamaha Formation are the thick-bedded and massive, structureless sandstones and claystones that produce extensive areas of flat rock outcrops and low bluffs (Dall and Harris, 1892, p. 81-82; Veatch and Stephenson, 1911, p. 403-405). Olson (1967) informally called these indurated phases of the Altamaha Formation the Ashburn formation, after exposures of the sandstone cropping out along Interstate 75 north of the town of Ashburn in Turner County, Georgia. The name Ashburn has not been adopted in this report because Ashburn is a junior synonym of the Altamaha Formation, the name has never been formalized, and the indurated phases (Ashburn) are known to be discontinuous in outcrop and cannot be mapped over any large area (also see Georgia Geological Survey, 1976). There is evidence, however, that the lower part of the middle Miocene Altamaha Formation is pervasively indurated in the subsurface, and that the sporadic distribution of outcropping indurated phases of the formation is due to weathering and leaching of the cementing material. At this time, there are few cores that penetrate the entire middle Miocene portion of the Altamaha Formation. In these cores, however (Coffee 3 and 4, GGS-3539, GGS-3541; Berrien 10, GGS-3542; Colquitt 3, GGS-3179; see Fig. 2), the lower part of the Altamaha Formation is consistently indurated. The typical outcropping, middle Miocene Altamaha Formation that occurs in the stratigraphic position of the indurated sediments, consists of weathered, thick-bedded to massive and structureless, sandy clay and argillaceous sand. These weathered sandy clays and argillaceous sands are closely related to the indurated sediments in outcrop. At many outcrop sites, small (as little as 1 x 0.5 foot [30 x 15 cm]) to large (greater than 3 x 1 feet [1 x 0.3 m]) pods of apparently unweathered sandstone are enclosed or surrounded by weathered sands and clays, indicating that the surrounding weathered sediments are weathering products of the indurated sediments (sandstones and claystones). It is likely, therefore, that the typical unweathered, unleached, lower part of the middle Miocene Altamaha Formation consists of argillaceous sandstone and sandy claystone, and that this is the typical unaltered lithology of the lower part of the unit.

A lower, indurated phase is not so readily apparent in the lower Miocene part of the Altamaha Formation. The indurated phases of the lower Miocene do appear to be encountered more in the lower part of the unit or, perhaps more accurately, at lower elevations in the outcrop area. Field studies, in addition to a few cores that penetrate much of the lower Miocene Altamaha Formation (Washington 8, GGS-1179; Washington 10, GGS-1182; Washington 17, GGS-1189; Screven 4, GGS-1007; see Fig. 2), indicate that the indurated phases are not as pervasive as in the middle Miocene, and they tend to be more interstratified with nonindurated sands and clays.

Whereas channel-fill lithologies (cross-bedded sands and gravels) are encountered in the upper part of the middle Miocene Altamaha, channel-fill lithologies occur more randomly throughout the lower Miocene Altamaha. Field observations also indicate that channel-fill lithologies are more closely associated with the indurated phases in the lower Miocene.

The above observations suggest that there are some systematic but subtle differences between the lower Miocene and middle Miocene components of the Altamaha Formation. Particular lithologies are not known to be restricted to either the lower or middle Miocene parts of the Altamaha Formation. However, thick beds of unweathered clay, finely sandy claystone, and claystone that are devoid of sand appear, at this time, to be more characteristic of the lower Miocene Altamaha. Indurated sediments in the middle Miocene Altamaha generally consist of variably argillaceous sandstones or, less commonly, sandy claystones.

The Altamaha Formation is essentially nonfossiliferous. Scattered oyster shell fragments have been reported from the formation at Collins in Tattnall County (Veatch and Stephenson, 1911, p. 406). I have seen evidence of a few burrows in Coffee, Emanuel, and Screven Counties. Small irregular burrows, approximately 1 mm in diameter and constructed of fine-grained sand cemented with siliceous material, are locally abundant in fine-grained sediments of the formation in the Altamaha River area. Presumably these are trace fossils, but they are unlike trace fossils found in other Coastal Plain deposits in Georgia. No other fossils or trace fossils are known from the Altamaha Formation.

Stratigraphic Relationships

The Altamaha Formation is the most widespread outcropping lithostratigraphic unit in Georgia (Fig. 42). Its eastern, or seaward, limit is the Orangeburg Escarpment-Trail Ridge trend in eastern Georgia. The Altamaha Formation grades laterally eastward into the Aquitanian Tiger Leap Member of the Parachucla Formation (Hawthorne Group) in the vicinity of the Orangeburg Escarpment in the Savannah River area (Pl. 2). In the Southeast Georgia Embayment region south of Bulloch County, the Altamaha Formation grades laterally eastward into the middle Miocene Ebenezer Member of the Coosawhatchie Formation of the Hawthorne Group in the vicinity of the Orangeburg Escarpment in the north and Trail Ridge in the south (Fig. 11). The updip limits of the Altamaha Formation in Georgia extend from northern Burke County in the east, westward through Jefferson, Washington, northern Laurens, and southeastern Twiggs Counties. Farther south, the updip limits of the Altamaha Formation are in the vicinity of the Ocmulgee River in the north, and the Pelham Escarpment in the south (Fig. 42). The southern limit of the Altamaha Formation approximates a line (or zone of facies change) that extends from Ware County in the east through Colquitt County in the west. East of the vicinity of Cook and Lowndes Counties, the Altamaha Formation appears to grade laterally southward into the Statenville Formation of the Hawthorne Group. West of the Little River, the Altamaha Formation appears to thin and pinch out in a southward direction in Colquitt County. The Altamaha Forma-

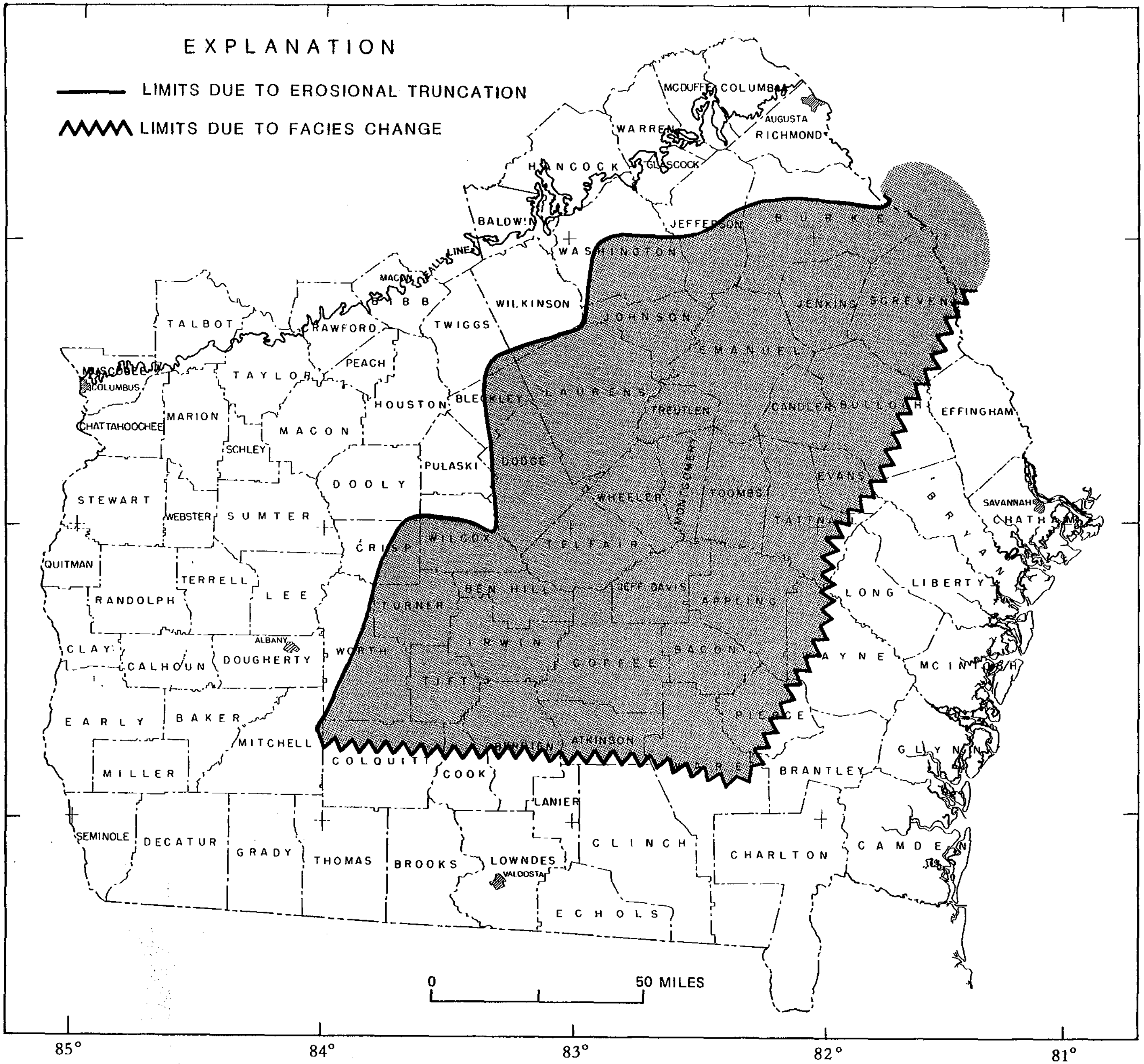


Figure 42. The areal distribution (outcrop and subcrop) of the Altamaha Formation in Georgia.

tion in most places is the only formation that crops out within the geographic confines outlined above.

More stratigraphic information can be gleaned from the Altamaha by recognizing lower and middle Miocene parts of the formation. Recognition of and discrimination between the lower and middle Miocene parts of the Altamaha Formation is based, at this time, mainly on physical correlation with datable marine deposits, and on stratigraphic position. Furthermore, as discussed above, the lower and middle Miocene Altamaha exhibit some lithologic distinctions, but the stratigraphic control is currently insufficient for one to be certain of regional systematic differences. The lower Miocene and middle Miocene components of the Altamaha Formation are not referred to here as lower and upper Altamaha Formation because the two components are not generally present together in the same area or at the same site. Rather, it appears that the lower Miocene Altamaha occurs in the inner part of the Coastal Plain and the middle Miocene Altamaha occurs only in the central and eastern part of the Coastal Plain. The updip limit of the middle Miocene Altamaha Formation, where it thins and pinches out, is in the same area where the underlying lower Miocene Altamaha grades seaward into the calcareous, fossiliferous Parachucla Formation in the subsurface (Fig. 11). As a result, at this time no areas or sections are known with certainty where middle Miocene Altamaha formation directly overlies lower Miocene Altamaha Formation in outcrop or subcrop.

The lower Miocene (Aquitanian) component of the Altamaha Formation can be traced from Screven and Burke Counties in the Savannah River area, westward through Jenkins, northern Emanuel, Jefferson, Washington, Johnson, and Laurens Counties. The stratigraphic position of the outcropping Altamaha Formation in Treutlen County is uncertain but could consist of both lower and middle Miocene components. In addition, the stratigraphic position of the Altamaha Formation southwest of the Ocmulgee River and northwest of the Gulf Trough is uncertain. It is noted, however, that claystone, a prominent lithology of the lower Miocene Altamaha Formation, is widespread in Turner County, Georgia (the type area of the Ashburn formation of Olson, 1967).

The lower Miocene Altamaha Formation grades laterally (or seaward) into calcareous, fossiliferous Parachucla Formation in the subsurface (Fig. 11; Pl. 2). The trend of the Altamaha-Parachucla facies change, in Georgia, extends in the east from southern Screven County westward through central Emanuel County, and thence westward through Treutlen and northwestern Wheeler County (Fig. 15). The Altamaha-Parachucla stratigraphic relationships are uncertain southwest of Wheeler County.

There is no evidence yet of an upper lower Miocene (Burdigalian) component of the Altamaha Formation. That is, the Marks Head Formation, or its stratigraphic equivalent, does not appear to grade updip (or landward) into Altamaha Formation. The absence of Marks Head-equivalent Altamaha Formation may account for a broad east-west belt, extending from Bulloch County westward through south-central Emanuel County, where the typical indurated phases and prominently cross-bedded feldspathic sands and gravels (Screven lithofacies) of the Altamaha Formation are absent, and only deeply weathered sands and clays are poorly exposed. Possibly this belt of poorly developed Altamaha deposits represents the outcrop belt of the Burdigalian, with the lower Miocene (Aquitanian) Altamaha Formation occurring in outcrop north of the belt and the middle Miocene (Serravallian) Altamaha Formation occurring in outcrop south of the belt. This belt does not extend into Treutlen County, suggesting that the updip limit of the Burdigalian deposits (Marks Head-equivalent) is overlapped by the middle Miocene Altamaha Formation and also that the Burdigalian occurs only in the subsurface of the central Georgia Coastal Plain. Moreover, this stratigraphic model suggests that the middle Miocene part of the Altamaha Formation could directly overlie the lower Miocene (Aquitanian) part of the Altamaha Formation in Treutlen County, thus accounting for the unusually thick Altamaha section in Treutlen County.

The updip limits of the middle Miocene part of the Altamaha formation can be traced, approximately, from southwestern Bulloch County in the east, westward through Candler County to southern Emanuel and northern Toombs Counties where the Altamaha Formation overlies the Meigs Member of the Coosawhatchie Formation in outcrop. The middle Miocene Altamaha Formation changes trend in Treutlen County to a more southwesterly direction, passing through Wheeler and Telfair Counties. The updip limits of the middle Miocene Altamaha are uncertain southwest of the Ocmulgee River in Georgia, but the middle Miocene Altamaha is known to occur in the Gulf Trough as far southwest as the vicinity of Norman Park in northeastern Colquitt County.

The Altamaha Formation disconformably overlies various formations in Georgia, including the Tobacco Road Sand of the Barnwell Group, Ocmulgee Formation, and several Oligocene limestone formations. The Altamaha Formation conformably overlies a basal tongue of the Tiger Leap Member of the Parachucla Formation in southern Screven County in the Savannah River area (Pl. 2), and Meigs Member of the Coosawhatchie Formation in the central southwestern Georgia Coastal Plain (Fig. 10).

The Altamaha Formation generally occurs at the top of the local geologic sections in Georgia. Overlying deposits, where present, include colluvium, undifferentiated surficial sands, undifferentiated alluvial deposits, and undifferentiated lacustrine and paludal deposits. In a narrow belt a few miles (a few km) wide west of Trail Ridge in Wayne and Pierce Counties, however, the Altamaha Formation is disconformably overlain by the upper Pliocene Cypresshead Formation (Pl. 3).

The average thickness of the Altamaha Formation in Georgia, based on scattered information, is between 100 and

200 feet (30 and 60 m). The formation is at least 125 feet (38 m) thick at and near the type locality. The Altamaha is approximately 150 feet (46 m) thick in northern Screven County, southern Emanuel, and northern Toombs Counties. It is 77 feet (23 m) thick in the core Coffee 3 (GGS-3539) in northern Coffee County; 112 feet (34 m) thick in the core Berrien 10 (GGS-3542) in northern Berrien County; 125 feet (38 m) thick in the core Colquitt 3 (GGS-3179) in northeastern Colquitt County; at least 123 feet (37 m) thick in the core Screven 4 (GGS-1007) in northwestern Screven County; and 171 feet (52 m) thick in the core Screven 8 (GGS-3198) in southeastern Screven County, where the Altamaha Formation is undergoing facies change into the Tiger Leap Member of the Parachucla Formation (Hawthorne Group) (Pl. 2). The Altamaha Formation is unusually thick in Treutlen County where the formation is exposed from the highest upland elevations (350 feet [107 m]) to bluffs at river level on the Oconee River at elevations of 130 feet (40 m). There is at least, then, 220 feet (67 m) of Altamaha Formation in Treutlen County. If the top of the Oligocene in Treutlen County varies from sea level to +100 feet (30 m) as indicated by Herrick and Vorhis (1963, p. 12), then the thickness of the Altamaha Formation in Treutlen County could be more than 250 feet (76 m). This compares well with the thickness of 283 feet (86 m) of Altamaha Formation (as interpreted in this report) in the well GGS-600 in northern Montgomery County (Herrick, 1961, p. 311-312).

The environment of deposition of the Altamaha Formation is interpreted to be fluvial to upper estuarine. None of the typical marine lithic components (i.e., phosphate, glauconite, calcite, limestone, dolomite, dolostone, magnesium-rich clays) are known to occur in the Altamaha Formation. Consistent with this, the clay mineral suite is dominated by kaolinite, the sands are generally feldspathic, and the sorting of the sediments is characteristically poor (a condition not normally found in deposits of open-marine origin).

No fossils are known with certainty from the Altamaha Formation. The oyster shell fragments reported by Veatch and Stephenson (1911) from Collins could have come from the underlying Meigs Member of the Coosawhatchie Formation. The burrow structures I have seen in the Altamaha in Coffee and Emanuel Counties could be root structures although they appear to be burrows. Only those burrow structures I have seen in Screven County and in exposures along the Altamaha River (e.g., at the principal reference locality) do I consider to be real burrows. However, it is not clear whether the organisms responsible for the burrows lived in a subaerial, fresh water, or brackish marine environment. Perhaps significantly, bioturbation structures which are characteristic of marine sediments, whether of coastal origin or open-marine origin, are also unknown in the Altamaha Formation.

Age

The Altamaha Formation being nonfossiliferous, its age must be inferred from physical correlation and stratigraphic position. In the type area along the Altamaha River, the Altamaha Formation grades laterally eastward into the marine, inner continental shelf, Coosawhatchie Formation (Pl. 3). Therefore, the type Altamaha Formation is roughly time-equivalent to the Coosawhatchie Formation and is probably middle Miocene (Serravallian) in age, equivalent to planktonic foraminiferal Zones N10 or N11 of Blow and Banner (1966) and Blow (1969) (Pl. 1). From northeastern Colquitt County to northern Toombs County, the Altamaha Formation grades downsection into sands and diatomaceous clays of the Meigs Member of the Coosawhatchie Formation. This unit has been dated as middle Miocene (Gremillion, 1965; Andrews and Abbott; 1985) and biostratigraphically equivalent to the Berryville Clay Member of the Coosawhatchie Formation of eastern Georgia (Andrews and Abbott, 1985; Abbott, pers. com., 1984).

In the Savannah River area, however, the Altamaha Formation grades laterally southeastward (seaward) in southern Screven County into the Tiger Leap Member of the Parachucla Formation (Hawthorne Group) of earliest Miocene (Aquitanian) age (Pl. 2). Therefore, in Screven and Burke Counties, the Altamaha Formation is early Aquitanian in age, and equivalent to planktonic foraminiferal Zone N4 of Blow (1969) (see Pl. 1). There may be other chronostratigraphic components of the Altamaha Formation, but their existence is unknown.

SCREVEN MEMBER OF THE ALTAMAHA FORMATION (new name)

Definition

The Screven Member of the Altamaha Formation is a new name proposed herein for prominently cross-bedded, feldspathic, gravelly sands. The Screven Member of this report is restricted to the upper part of the Altamaha Formation (middle Miocene) in the region south of the Altamaha and Ocmulgee Rivers in Georgia. The occurrence of Screven lithologies in the upper part of the middle Miocene Altamaha Formation north of the Altamaha and Ocmulgee Rivers is erratic, discontinuous, and for practical purposes, unmappable. Those Screven lithologies, therefore, are not included in the Screven Member in this report, but are referred to as Screven lithofacies[1]. Screven-type lithofacies

[1]The stratigraphic relationships of the Screven lithofacies to the rest of the Altamaha Formation in Georgia is analogous to the lithofacies relationships of the members of the upper Eocene Dry Branch Formation of the Barnwell Group (Huddlestun and Hetrick, 1979, 1986; Nystrom and Willoughby, 1982a). The Twigs Clay and Irwinton Sand Members of the Dry Branch Formation are mappable lithostratigraphic units in some areas, and are discontinuous, unmappable, but distinctive lithofacies in other areas. Similarly, the Screven Member of the Altamaha Formation is a distinctive, mappable lithostratigraphic unit in one area, and is a discontinuous, unmappable, but distinctive lithofacies in other areas.

also occurs in the lower Miocene component of the Altamaha Formation. Except locally, however, the stratigraphic position of the Screven lithofacies is not consistent in the lower Miocene as it is in the middle Miocene component of the Altamaha Formation, and the regional occurrence of the lithofacies in likewise discontinuous.

Deposits referred to as Screven Member in this report have, in the past, been included with the Altamaha Formation (Veatch and Stephenson, 1911), Hawthorne Formation (Cooke, 1939, 1943; MacNeil, 1947a), Brandywine, Coharie, and Sunderland formations (Cooke, 1939, 1943, p. 106-107), "Duplin marl and Hawthorn formation" (MacNeil, 1947b), Citronelle Formation (Doering, 1960), Neogene undifferentiated and Pleistocene sands and gravels (Georgia Geological Survey, 1976). Although the Screven Member has been included in parts of all of these named units, it is not fully synonymous with any of them. The Screven Member of the Altamaha Formation was informally introduced as Screven formation by Huddlestun (1981).

Type Section

The name Screven is taken from the village of Screven in southwestern Wayne County, Georgia. The designated type locality of the Screven Member is a railroad cut of the Seaboard Coast Line in the eastern valley wall of Little Satilla River, approximately 2.5 miles (4. km) southwest of the village of Screven (Fig. 43). The type section, or unit-stratotype (holostratotype), is the exposure of the Screven Member in the railroad cut at the type locality. Both the Screven Member and the Cypresshead Formation are exposed in the railroad cut. The Screven-Cypresshead contact, the upper boundary stratotype of the Screven Member, is 12 feet (3.5 m) below the top of the land surface at the northeast end of the cut.

The roadcut along US 82, 0.3 mile (0.5 km) northwest of the type locality, is herein designated a reference locality and parastratotype of the Screven Member of the Altamaha Formation (Fig. 43). This locality is significant because it displays both the typical tough, resistant nature of the formation in outcrop, and the intense Leisegang banding that is characteristic of the member.

Upper Sister Bluff and the highway cuts above the bluff to the top of the hill are herein designated a reference locality and parastratotype of the Screven Member (Fig. 41). The Screven Member overlies undifferentiated Altamaha Formation at Upper Sister Bluff. The contact, at 60 feet (18 m) above mean-low-water of the Altamaha River, is designated the lower boundary stratotype of the member. The Screven Member is exposed at the top of the bluff near the level of the highway bridge and in roadcuts and ditches to the top of the hill approximately 0.6 mile (1.0 km) south of the bluff. This site is significant because the entire section characteristic of the upper Altamaha River region is exposed here. The site is also instructive in that the lower part of the Screven Member displays interstratification between typical Screven lithology and Altamaha lithology. This series of exposures is the thickest known section of the Screven Member.

Lithology

The Screven Member of the Altamaha Formation consists of a maze of fluvial channel, cut-and-fill structures, and typical Screven sediments are channel-fill deposits in the cut-and-fill structures. The Screven channel-fill deposits consist of planar and trough cross-bedded, variably micaceous and feldspathic, argillaceous, pebbly to gravelly sands with clay clasts, and scattered lenses of clay channel-fill. The sand phase of the Screven Member is the dominant and characteristic lithofacies of the member. Screven Member sands are typically poorly sorted and coarse-grained. As with the rest of the Altamaha Formation, the sorting of the sand component deteriorates as the upper limit of the sand-size increases. However, it is only in the southeastern-most occurrences of the Screven Member, in Pierce and Ware Counties, Georgia, that I have observed fine-to medium-grained, moderately well sorted sand in the Screven Member.

The sands of the Screven Member are variably pebbly and gravelly. Pebbles are commonly found distributed throughout layers of poorly sorted coarse-grained sand, whereas lenses or stringers of gravel are more scattered and localized in occurence. Feldspar content of the Screven is variable, but is most conspicuous in the coarse-grained, pebbly phases of the member. Most likely, however, the Screven was consistently more feldspathic than is now apparent due to differential weathering of the feldspar. Clay clasts of various sizes are also commonly found in the cross-bedded sands of the Screven Member, but occurrence of clasts and their size-distribution is not systematically related to the coarseness of the sand as are the occurrence and size-distribution of quartz and feldspar pebbles.

Bedding in the Screven Member predominantly consists of planar and trough cross bedding on a wide range of scales. Undulatory bedding is locally present, but I have not yet observed either horizontal, parallel bedding or thick, massive bedding in the sand phase of the Screven Member.

The Screven Member of the Altamaha Formation is typically argillaceous, and the clay occurs both interstitially and in lenses. The sands of the Screven Member are generally argillaceous, and it is the clayey nature of the sands that results in the characteristic toughness and resistance to physical weathering of the member, and in the abundance of Liesegang banding in the member. It is also the clayey nature of the Screven sands that distinguishes it from lithologically similar Pleistocene river terrace deposits, and from the far updip occurrences of the Cypresshead Formation, both of which are typically deficient in interstitial clay. Clay as a discrete lithologic entity occurs only in scattered lenses ranging in thickness from approximately 1 foot (0.3 m) to more than 6 feet (1.8 m). These clay lenses appear to be clay-filled channel structures. The clay within the cut-and-fill structures is generally massive, structureless and blocky,

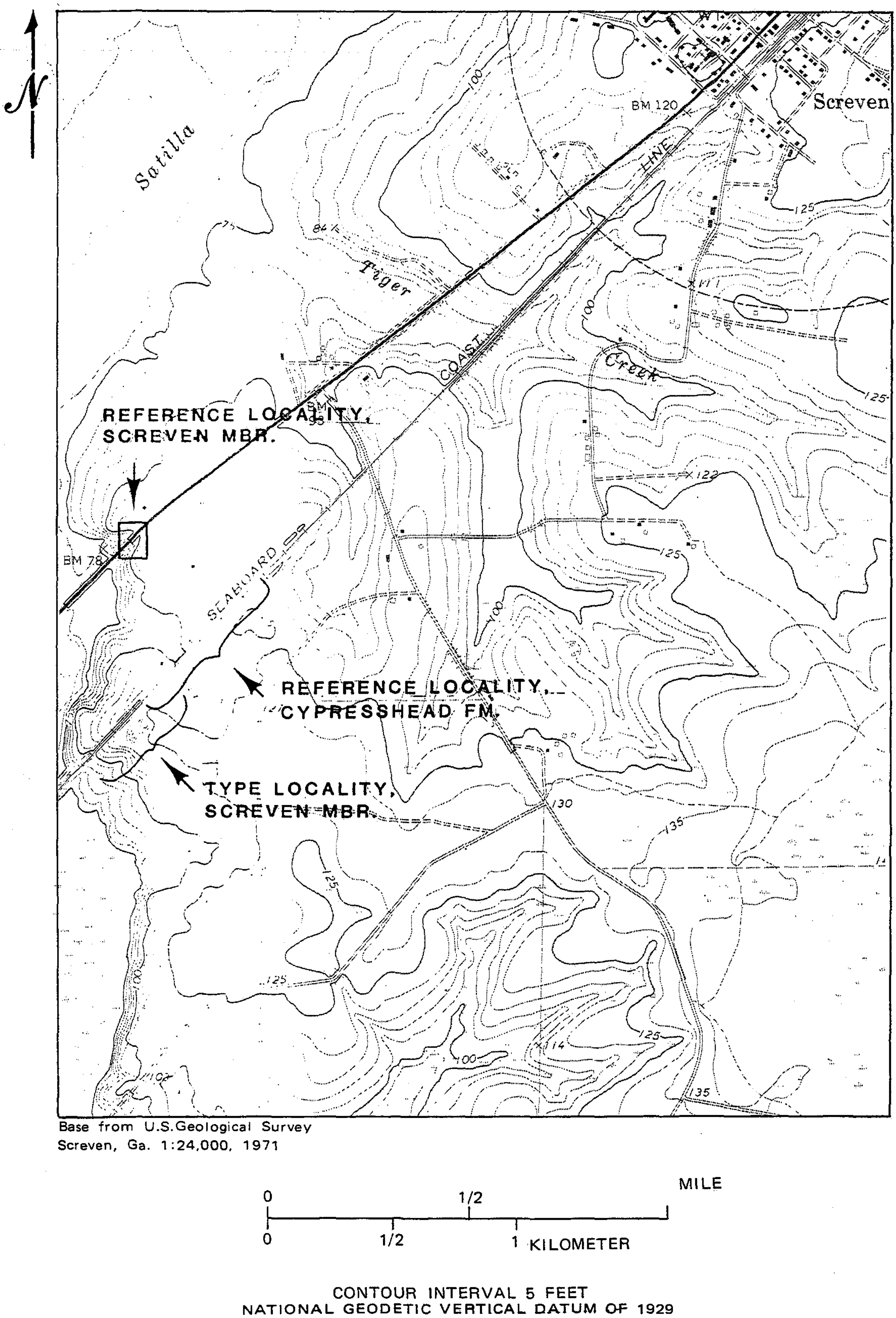


Figure 43. The type locality of the Screven Member of the Altamaha Formation.

color-mottled gray to dark gray and maroon. Scattered clay mineral data indicate that kaolinite is the dominant clay mineral of the Screven Member. Illite and smectite, if present, occur as minor or trace components of the clay mineral suite (Hetrick, pers. com., 1986).

Stratigraphic Relationships

The Screven Member of the Altamaha Formation, as defined in this report, is restricted largely to the region in Georgia south of the Altamaha and Ocmulgee Rivers, and west of Trail Ridge and the southernmost part of the Orangeburg escarpment (Fig. 44). The Screven Member is not known to occur west of the vicinity of the Gulf Trough in southwestern Georgia, and its southern limit approximates an east-west line from Ware County to southern Berrien County. Screven Member occurs north of the Altamaha River in a small area west of the Orangeburg escarpment in eastern Tattnall and eastern Evans Counties, and as far north as the vicinity of Daisy in Evans County. The Screven Member appears to grade laterally eastward into undifferentiated Altamaha Formation, or into the upper part of the Coosawhatchie Formation (Pl. 3). The Screven Member appears to grade southward into the upper part of the Statenville Formation.

Other areas where Screven lithofacies occurs at the top of the Altamaha Formation are southern and western Screven County, Georgia (lower Miocene Altamaha Formation), and northern Treutlen County (middle Miocene? Altamaha Formation). The Screven lithofacies appears to be scattered throughout the Altamaha Formation (lower Miocene) in northern Emanuel County. In Burke County, Georgia, and Aiken, Barnwell, and Allendale Counties, South Carolina, Screven lithofacies occurs only in the lower part or at the base of the Altamaha Formation (lower Miocene).

The Screven Member of the Altamaha Formation typically overlies the undifferentiated Altamaha Formation with sharp, "disconformable" contact (Figs. 10 and 11, Pl. 3). At some sites, however, the undifferentiated Altamaha Formation appears to grade upward into the Screven Member (e.g., at lower Fort James Bluff on the Altamaha River). The typical, sharp, "disconformable" lower contact of the Screven Member is interpreted in this report as the boundary between Altamaha flood plain or estuarine deposits, and the overlying fluvial channel-fill deposits. Because of the effect of channel scour preceding Screven deposition, no significant lapse in time is required to account for the "disconformable" relationships in this stratigraphic model.

The Screven Member generally occurs at the top of the local geologic section, being overlain only by undifferentiated surficial sands, undifferentiated alluvial deposits, or possibly undifferentiated lacustrine and paludal deposits. In a narrow belt west of the Orangeburg escarpment and Trail Ridge in Wayne and Pierce Counties, Georgia, however, the Screven Member of the Altamaha Formation is disconformably overlain by the upper Pliocene Cypresshead Formation.

The Screven Member of the Altamaha Formation is distinguished from the lithologically similar high river-terrace sand deposits in generally containing significantly more interstitial clay. The Screven Member is similarly distinguished from the overlying Cypresshead Formation (in Wayne and Pierce Counties) in containing significantly more interstitial clay. In addition, (1) bedding in the Cypresshead Formation is generally horizontal with only local occurrences of crossbedding, (2) the fine-grained, well-sorted sand with thin beds or laminae of clay so characteristic of the finer grained lithofacies of the Cypresshead Formation is unknown in the Screven Member, and (3) Cypresshead sediments are locally burrowed and bioturbated.

The Screven Member is distinguished from the rest of the Altamaha Formation in being prominently bedded and crossbedded, with channel cut-and-fill structures commonly being evident.

Limited outcrop and core information indicates that the Screven Member of the Altamaha Formation is generally less than 50 feet (15 m) thick. Twenty-four feet (7 m) of the Screven Member is exposed at the type locality and 21 feet (6.5 m) is exposed at the nearby reference locality along US 82. Approximately 41 feet (12.5 m) of the Screven Member is present in the core Coffee 3 (GGS-3539) in Coffee County, and 35 feet (11 m) is present in the core Berrien 10 (GGS-3542) in northern Berrien County. The thickest known occurrence of Screven Member is 78 feet (24 m) at the reference locality at Upper Sister Bluff on the Altamaha River in Appling County.

The environment of deposition of the Screven Member was fluvial. There is no evidence for marine or estuarine conditions in the Screven Member and, exept for one occurrence of small burrows in southern Screven County (near the eastern limit of the facies where it is undergoing facies change into the Parachucla Formation), fossils, trace fossils, and bioturbation structures are unknown in the member. Similarly, lithic components that are of marine origin in the southeastern United States (e.g., phosphate, glauconite, calcite, limestone, dolomite, dolostone, magnesium-rich clays), and even siliceous sediments, are unknown in the member. Channel cut-and-fill structures are characteristic of the Screven Member and locally the deposit appears to consist of a maze of sediment-filled channel structures. Consistent with the interpretation of a fluvial origin for the Screven Member, the unit is generally feldspathic and the sediments are poorly sorted.

Age

The Screven Member of the Altamaha Formation is barren of fossils and trace fossils. Therefore, constraints on the age of the member must be inferred from stratigraphic position and physical correlation. The Screven Member

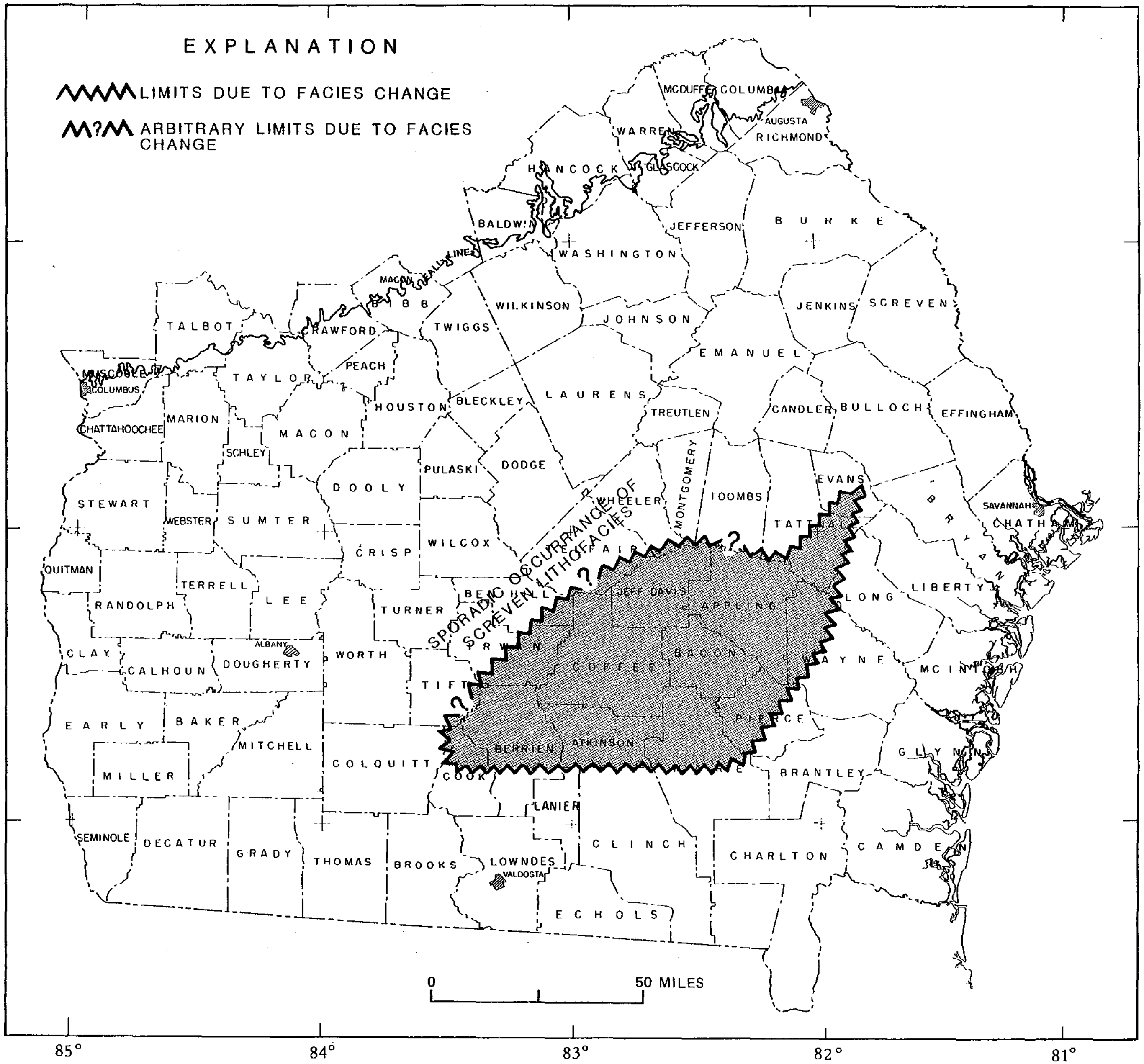


Figure 44. The areal distribution (outcrop and subcrop) of the Screven Member of the Altamaha Formation.

overlies with sharp contact, or gradationally at some sites, nonfossiliferous undifferentiated Altamaha Formation. The undifferentiated Altamaha Formation in turn gradationally overlies Meigs Member of the Coosawhatchie Formation (e.g., from northeastern Colquitt County in the southwest to Toombs County in the northeast). Undifferentiated Altamaha Formation also appears to overlie Coosawhatchie Formation in Pierce and western Wayne Counties (compare with Herrick, 1961, p. 322-324, 438-439; also compare with Pl. 3). Therefore, the Screven Member of the Altamaha Formation overlies fluvial to estuarine? deposits that grade downward into middle Miocene, inner continental shelf deposits. As a result, the Screven Member can be no older than middle Miocene. In its type area, the Screven Member is overlain disconformably by the upper Pliocene Cypresshead Formation, and the Screven Member must be as old as or older than late Pliocene.

In the Altamaha River area, the Screven Member of the Altamaha Formation appears to grade laterally southeastward (seaward) into undifferentiated Altamaha Formaton (see Pl. 3). At Lower Fort James approximately 3.5 miles (5.6 km) north of Madray Springs in Wayne County, Bluff, most of the 70 feet (21 m) of section that occurs between the top of the sandstone phase of the Altamaha Formation and the base of the Cypresshead Formation consists of undifferentiated Altamaha Formation. Only the upper 15 feet (4.6 m) of the Altamaha Formation at Lower Fort James Bluff is assignable to the Screven Member. In addition, no Screven Member has been identified southeast (seaward) of Lower Fort James Bluff in the Altamaha River area. It is, therefore, concluded that in the Altamaha River area, the Screven Member grades laterally southeastward (seaward) into undifferentiated Altamaha Formation, and undifferentiated Altamaha Formation grades southeastward into Coosawhatchie Formation (see Pl. 3). The Screven Member is likely, then, to be stratigraphically correlative with the Coosawhatchie Formation, and the best estimate of the age of the Screven Member is middle Miocene (Serravallian) (see Pl. 1).

In the Savannah River area, the Screven lithofacies in southern and western Screven County overlies Altamaha Formation of probable earliest Miocene (Aquitanian) age (see Pl. 1). Because no Hawthorne Group deposits of middle Miocene age are preserved in northern Effingham or southern Screven Counties (see Pl. 2), there is no evidence that the Screven lithofacies of Screven County once graded laterally into the Coosawhatchie Formation. Therefore, the best current estimate of the age of the Screven lithofacies in Screven County is early Miocene (Aquitanian). Similarly, the Screven lithofacies in the lower part of the Altamaha Formation in South Carolina is provisionally assigned to the lower Miocene (Aquitanian) because all of the Altamaha Formation in the Savannah River area appears to grade downdip (seaward) into the Tiger Leap Member of the Parachucla Formation (Pl. 2).

RAYSOR FORMATION

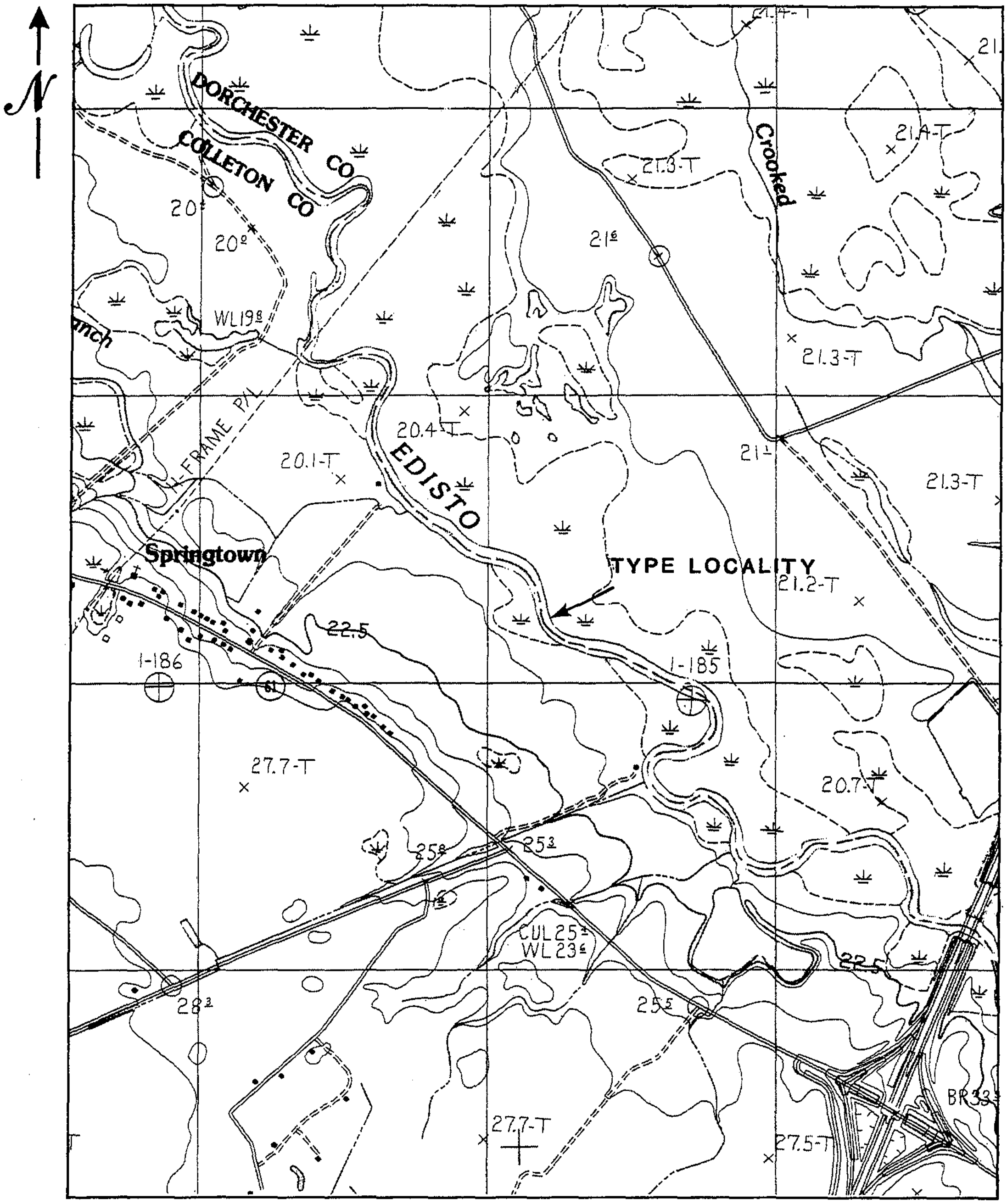
Definition

The Raysor Formation (Raysor Marl) was named by Cooke (1936, p. 115-117) "for deposits of upper Miocene age older than the Duplin marl in South Carolina." The name Raysor, however, was not generally adopted in South Carolina and, recently, Blackwelder and Ward (1979, p. 38-40) reintroduced the unit on a lithologic basis as the Raysor Formation. In the type area, these deposits consist of soft, variably shelly, slightly argillaceous, finely sandy, finely calcarenitic limestone (also see Sloan, 1908, p. 280-281; Cooke, 1936, p. 116). In Georgia, the Raysor Formation of this report includes deposits in Effingham County along the Savannah River that have been referred to the Edisto marl (Sloan, 1908, p. 273, 174), the Duplin formation (Veatch and Stephenson, 1911; Brantly, 1916; Cooke, 1943; MacNeil, 1947b; Georgia Geological Survey, 1976), and the Porters Landing facies of the Duplin formation (Woolsey, 1976) (part of which is Cypresshead Formation of this report). Raysor Formation along the Altamaha River in Wayne County near Doctortown in the past has been included in the Duplin formation (Veatch and Stephenson, 1911, p. 367-377; Cooke, 1943; MacNeil, 1947b; Herrick, 1976; Georgia Geological Survey, 1976). Those upper Pliocene deposits underlying the coastal area of Georgia that have been included in the Duplin Formation (Darby and Hoyt, 1964; Woolsey, 1976) are referred to, in this report, as unnamed Raysor-equivalent shelly sand. The calcareous upper Pliocene deposits in Effingham and Wayne Counties are assigned to the Raysor Formation because they are lithologically compatible with the Raysor Formation in its type area (an argillaceous, calcareous, variably shelly, finely sandy, finely calcarenitic limestone) (also see Blackwelder and Ward, 1979, p. 38-40) and differ significantly from the lithology of the Duplin deposits in its type area (shelly sand; see Blackwelder and Ward, 1979, p. 36-37).

Type Section

The name Raysor was taken from Raysor's bridge, a bridge that used to span the Edisto River between Dorchester and Colleton Counties, South Carolina (Cooke, 1936, p. 115). Cooke (1936) did not explicitly designate a type locality for the formation, but his comment, "near which the only know outcrops of the formation occur", can be construed as intent to designate a type locality. The exposures, therefore, along the west bank of the Edisto River, approximately 1,200 feet (0.37 km) downriver from the bridge (also see Sloan, 1908, p. 280-281), are interpreted as the type locality of the Raysor Formation, and the type section (unit-stratotype) is that section of the Raysor Formation exposed at the type locality in Colleton County, South Carolina (Fig. 45).

Blackwelder and Ward (1979, p. 39) were unable to locate



Base from U.S. Geological Survey
St. George SW, S.C. 1:24,000, 1982

0 1/2 1 MILE
0 1/2 1 KILOMETER

CONTOUR INTERVAL 1.5 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 45. The type locality of the Raysor Formation.

exposures along the Edisto River in the type area of the Raysor Formation and, therefore, concluded that the type locality was overgrown and inaccessible. As a result, they designated a neostratotype for the Raysor Formation near Givhans Ferry State Park on the east bank of the Edisto River, 1.2 airline miles (1.9 km [given as 1.1 km]) upriver from the South Carolina highway 61 bridge, near Muckenfuss Cemetery, in Dorchester County, South Carolina.

Raysor's bridge is no longer standing. However, there is doubt that the exposures cited by Sloan (1908) and Cooke (1936) are in fact near Raysor's bridge. According to Sloan (1908, p. 280) (whose measured section was adopted by Cooke, 1936), Raysor's bridge was located 8 miles S. 25° W. of the town of St. George. This position on the Edisto River is the approximate location of the community of Canadys and the US 15 highway crossing of the Edisto River. According to Cooke (1936, p. 116), however, Raysor's bridge was located 8 miles southwest of St. George (approximately 4 miles [6.4 km] upriver from the site of Raysor's bridge indicated by Sloan [1908]). There are old bridge pilings present in the Edisto River approximately S. 45° W. of St. George and, according to old maps, this is the site of the Raysor's bridge (see quadrangle map, U.S. Geol. Survey, St. George, South Carolina, 1918, 1:62,500). Raysor's bridge, however, may not be the same as the bridge alluded to by Sloan (1908) because the section ¼ mile downriver from the Raysor's bridge of Sloan (1908) exposed 34.25 feet (10.4 m) of sediments. Raysor's bridge is in the river floodplain and there could not have been more than 6 feet (1.8 m) of sediments exposed during low water stages of the river in historic times 1,200 feet downriver from the bridge. According to B.W. Blackwelder (pers. com., 1986), in the area in question there are only two sites along the Edisto River where old bridge pilings can be seen at low water: one is at the location given by Cooke (1936) and the other is at Canadys near the US 15 highway bridge. The location at Canadys is compatible with the location of Sloan (1908) because Canadys is located approximately S. 25° W. of St. George, and there are bluffs 30 feet (9.1 m) high overlooking the Edisto River in the vicinity of Canadys.

Lithology

The dominant lithic components of the Raysor Formation are calcite or calcareous material and quartz sand. In general, it appears that the Raysor Formation in Georgia is less calcareous, more sandy and limestone is less conspicuous than it is in the type area of the formation. Subordinate lithic components of the Raysor Formation include clay minerals, mica, phosphate, feldspar, heavy minerals, shells, rare fossil bones, and scattered carbonaceous material and lignitic flecks. The quartz sand is typically fine-grained and well-sorted. However, Veatch and Stephenson (1911) reported coarse sand in the Raysor Formation, and quartz and feldspar pebbles occur locally in basal sediments of the formation. Clay beds also occur locally in the Raysor Formation but volumetrically are not significant.

In Effingham County, Georgia, the Raysor Formation typically consists of massive, structureless, variably shelly and fossiliferous, argillaceous, generally fine-grained, well-sorted sand that lithologically ranges to a finely sandy, calcarenitic limestone. In the subsurface in Chatham County, there is an outlier of Raysor Formation in the core Chatham 1 (GGS-535) in the interval 49 feet to 52 feet that consists of richly foraminiferal, phosphatic, argillaceous, finely sandy, calcarenitic limestone.

The outcropping Raysor Formation in Wayne County consists of massive, structureless, variably shelly and fossiliferous, calcareous, argillaceous, fine- to medium-grained sand. The Raysor is more argillaceous and sandy in Wayne County, and limestone phases of the formation are not know to be present. In its updip extremities in Wayne County, the Raysor Formation at Bugs Bluff and Linden Bluff on the Altamaha River consists of noncalcareous, nonfossiliferous, massive to thin-bedded, finely sandy to silty (with scattered quartz pebbles), dark gray to black clay. At Buzzards Roost Bluff, 2 miles (3.2 km) above Doctortown, pebbly and shelly Raysor lithology occurs at the base of the black silty clay (Veatch and Stephenson, 1911, p. 376).

Stratigraphic Relationships

The Raysor Formation is known to occur in only two areas in Georgia and in a core in Chatham County (Chatham 1 [GGS-1164]). It is found in scattered outcrops in bluffs along the Savannah River in northern Effingham County, and in a few outcrops in bluffs along the Altamaha River in the vicinity of Doctortown in Wayne County (Figs. 46, 47). Based on limited core information, the deposits of the two areas are not known to be continuous with each other. The Raysor Formation in Effingham and Wayne Counties appears to cover small areas. Despite close core control in Effingham County, the Raysor Formation has not been found as little as 1 mile (1.6 km) from the Savannah River and it is concluded that the Raysor occurs only as outliers or erosional remnants in Georgia.

The western limit of the Raysor Formation in Georgia approximates the Orangeburg Escarpment. In Wayne County, the escarpment appears to approximate the Raysor shoreline.

The Raysor Formation disconformably overlies formations of the Hawthorne Group in Georgia. It overlies the Marks Head Formation in Effingham County, and the Coosawhatchie Formation in Wayne County. The Cypresshead Formation disconformably or paraconformably overlies the Raysor Formation in both Effingham and Wayne Counties.

Being predominantly calcareous and macrofossiliferous, the Raysor Formation is readily distinguished from the underlying characteristically noncalcareous and nonfossiliferous, phosphatic Marks Head Formation, and from the non-calcareous, nonfossiliferous, finely sandy clay and

Figure 46. The areal distribution (outcrop and subcrop) of the Raysor Formation in Georgia.

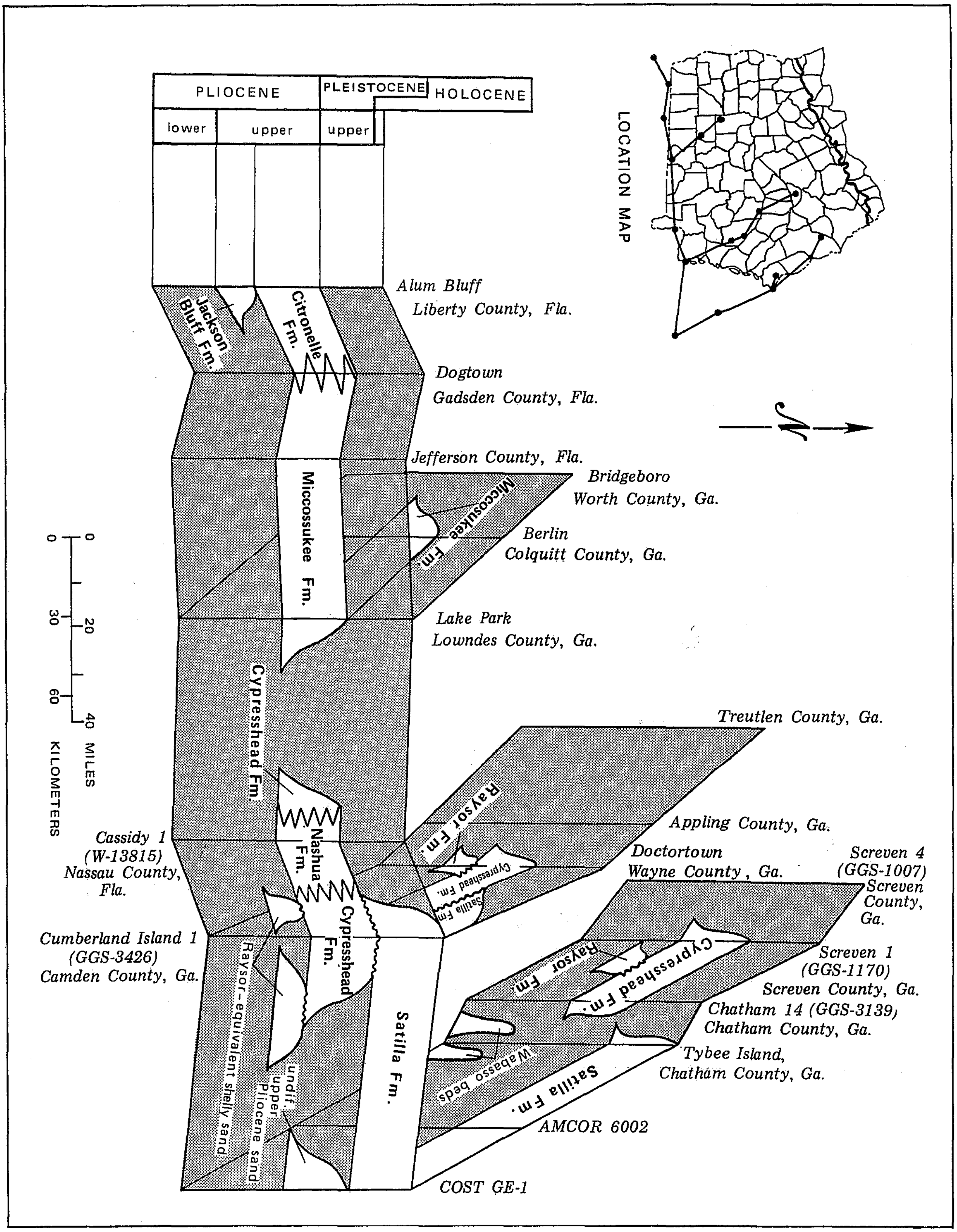


Figure 47. Fence diagram showing stratigraphic relationships of Pliocene, Pleistocene, and Holocene deposits in Georgia.

argillaceous fine sand of the Coosawhatchie Formation. The overlying Cypresshead Formation typically contains prominent horizontal- and crossbedding, and trace fossils including *Ophiomorpha nodosa*. Generally, however, the Cypresshead is noncalcareous, nonfossiliferous, and nonphosphatic. In a few places known where the Cypresshead Formation does contain carbonate based fossils, these deposits consist of channel-fill and are coarsely gravelly, prominently bedded, and the sand is poorly sorted.

In the bluffs along the Savannah River in Effingham County, the Raysor Formation is thin and variable in thickness, ranging from 2 to at least 10 feet (0.6 to 3 m) thick. The Raysor is locally absent, apparently due to solution of the calcium carbonate. In the bluffs along the Altamaha River in Wayne County, the thickness of the Raysor Formation is approximately 10 feet (3 m), although Brantly (1916, p. 32) reported 12 to 15 feet (3.6 to 4.6 m) in the same area.

The environment of deposition of the Raysor Formation in Georgia was open-marine to coastal, inner to possibly middle neritic continental shelf. The relatively high percentage to abundance of planktonic foraminifera in the Raysor Formation suggests shallow upwelling along the edge of the continental shelf and relatively strong currents on the continental shelf.

Age

The following planktonic foraminifera have been identified from the Raysor Formation in Georgia:

Globorotalia menardii (dextral)
G. puncticulata
G. crassula
Neogloboquadrina acostaensis
N. humerosa
Globigerina apertura
G. decoraperta
G. cf. *G. falconesis*
Globigerinoides ruber
G. quadrilobatus quadrilobatus
G. quadrilobatus sacculiferus
G. obliquus
G. conglobatus
G. cf. *G. conglobatus*
Globoquadrina altispira
Sphaeroidinellopsis seminulina
Globigerinella aequilateralis aequilateralis
G. aequilateralis praesiphonifera
Orbulina universa

This association is consistent with Zone PL3 of Berggren (1973) and is roughly equivalent to the concept of Zone N20 of Blow (1969). The Raysor Formation is, therefore, early late Pliocene (early Piacenzian) in age (see Pl. 1).

UNNAMED RAYSOR-EQUIVALENT SHELLY SAND

Definition

The unnamed Raysor-equivalent shelly sand of this report is a subsurface deposit and is restricted to the coastal area of Georgia. In the past, it has been referred to the Duplin formation (Darby and Hoyt, 1964; Woolsey, 1976), to Pliocene, middle Pliocene, or Duplin formation (Woolsey and Henry, 1974; Martinez, 1980; Foley, 1981), and to the Sapelo facies of the Duplin formation (Woolsey, 1976). Although the unnamed Raysor-equivalent shelly sand has largely the same lithology as the Duplin formation in its type area in North Carolina, there is a large gap in the occurrence of deposits of Duplin lithology and age (Zone PL3 of Berggren, 1973) from northern South Carolina to the vicinity of the Ogeechee River in coastal Georgia. The stratigraphically equivalent Raysor Formation is the only formation of that age known to occur in that area. In addition, Blackwelder and Ward (1979, p. 36) proposed the abandonment of the name Duplin in North Carolina and South Carolina, and assigned the shelly sand deposits, previously referred to the Duplin formation, to the Yorktown Formation. As a result, at this time there is question as to the lithostratigraphic validity of the name Duplin formation.

The unnamed Raysor-equivalent shelly sand is a distinctive and mappable lithostratigraphic unit of formational rank. It is not given a formal formation name in this report because there are currently no known outcrops of the unit, and no cores on which to base a type section.

Lithology

Shells, calcareous material, and quartz sand are the characteristic and dominant lithic components of the unnamed Raysor-equivalent shelly sand. Subordinate lithic components include clay, minor phosphate, feldspar, pyrite, mica, heavy minerals, lignitic plant material, and minor scattered limestone (Woolsey, 1976; Martinez, 1980; Foley, 1981). The unnamed Raysor-equivalent sand consists mainly of olive-gray to dark greenish-gray, massive to stratified, slightly argillaceous, variably calcareous and fossiliferous, very well sorted to poorly sorted, fine-to very coarse grained sand that is locally pebbly and gravelly. Dark greenish-gray, to medium to dark gray, to bluish-gray, thinly bedded, variably diatomaceous clay has been reported (Martinez, 1980) (which may be Cypresshead Formation). The unnamed shelly sand is characterized, in seismic profiles, by large-scale, seaward dipping reflectors (Woolsey and Henry, 1974; Woolsey, 1976; Foley, 1981).

Stratigraphic Relationships

The unnamed Raysor-equivalent shelly sand has the geometry of a "double wedge", thinning and pinching out both in landward and seaward directions (Figs. 47, 48). It

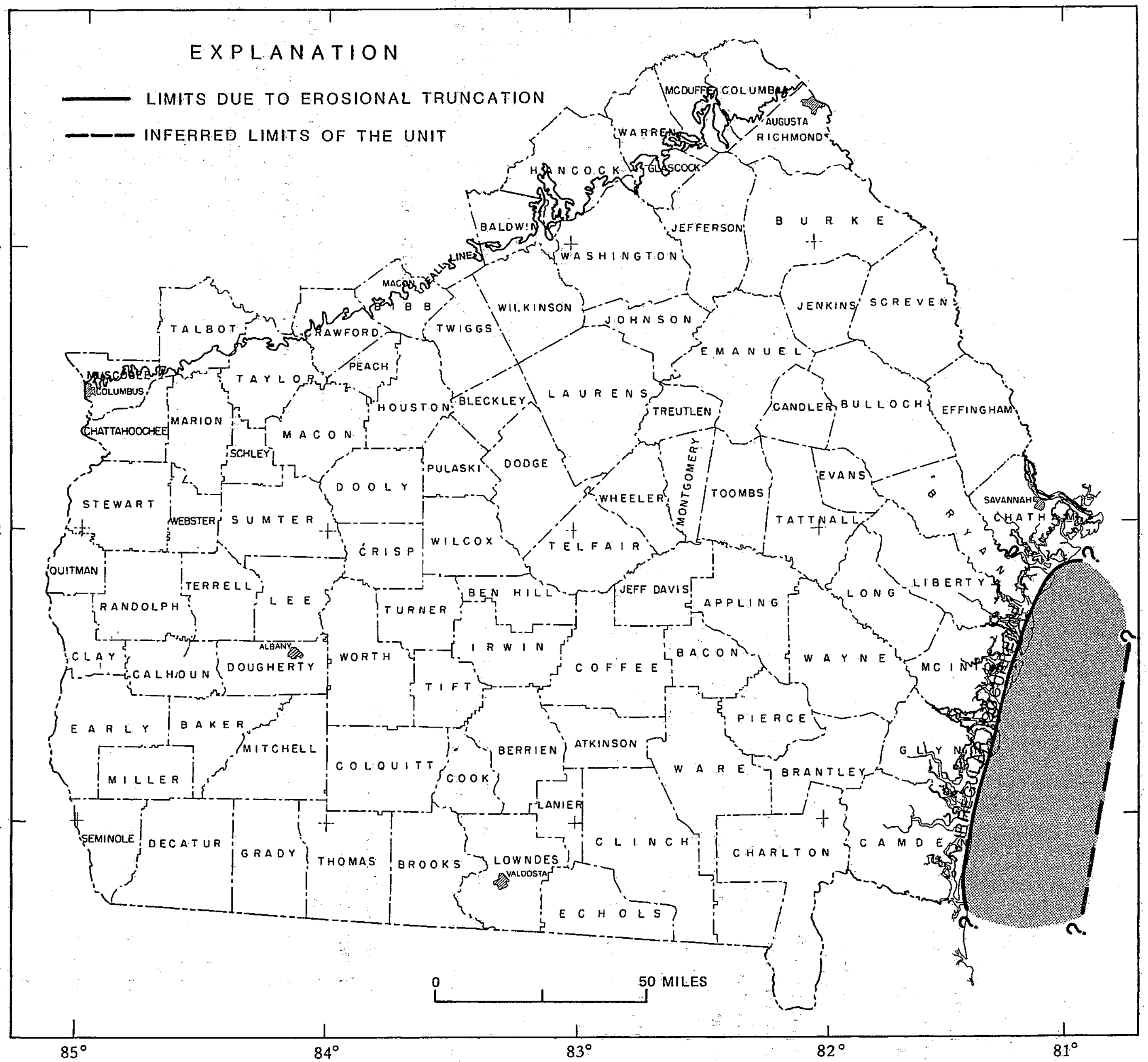


Figure 48. The areal distribution (subcrop) of the unnamed Raysor-equivalent shelly sand in Georgia.

reaches its greatest thickness immediately offshore of the islands, and it is not known to be present on the outer continental shelf of Georgia (compare with Hathaway and others, 1976; Poag and Hall, 1979). The unnamed Raysor-equivalent shelly sand also thins and pinches out in the northern coastal area of Georgia. It is present in coastal Bryan and Chatham Counties in the vicinity of the Ogeechee River only in scattered, thin outliers. Woolsey (1976) recorded the presence of the unnamed Raysor-equivalent sand (Duplin formation of Woolsey, 1976) under Amelia Island in northeastern Florida. The unit, or its stratigraphic equivalent, is not known to occur farther south.

The unnamed Raysor-equivalent shelly sand disconformably overlies the Coosawhatchie Formation of the Hawthorne Group. As yet, no cores have been recovered in which the unnamed Raysor-equivalent sand can be seen to overlie the lower Pliocene Wabasso beds. In the coastal area, the unnamed Raysor-equivalent sand is disconformably or paraconformably overlain by the Cypresshead Formation. Where the Cypresshead locally has been removed by erosion, and under the continental shelf, the unnamed Raysor-equivalent shelly sand is disconformably overlain by the Satilla Formation.

The unnamed Raysor-equivalent shelly sand is distinguished from the underlying Coosawhatchie Formation in consisting of calcareous, shelly, well-sorted to poorly sorted, fine- to very coarse-grained, locally pebbly and gravelly sand that is rarely phosphatic. In contrast, the Coosawhatchie Formation, north of the Atlamaha River, is a noncalcareous and nonfossiliferous, phosphatic, generally well-sorted, fine-grained sand that is locally coarse, pebbly, and poorly sorted only at the top of the formation. South of the Altamaha River, the Coosawhatchie Formation (Charlton Member and sediments lithologically intermediate from Ebenezer Member to Charlton Member) is lithologically heterogeneous and locally consists of phosphatic, well-sorted, fine-grained sand that is variably calcareous or dolomitic, variably phosphatic, sandy limestone, variably phosphatic, sandy dolostone, variably fossiliferous limestone and dolostone, and clay.

The unnamed Raysor-equivalent shelly sand is distinguished from the lower Pliocene Wabasso beds (Tybee facies of Woolsey, 1976) in that the Wabasso beds consist of massive, bioturbated, calcareous, generally nonmacrofossiliferous, phosphatic, well-sorted, fine-grained to silty sand.

What is known of the overlying Cypresshead Formation in the coastal area differs from the unnamed Raysor-equivalent shelly sand in consisting of noncalcareous, nonfossiliferous sand, and noncalcareous, diatomaceous, thinly bedded clay. Except in basal, channel cut-and-fill deposits, the overlying Satilla Formation differs in being lithologically more variable, more argillaceous, having better sorted sand, is more finely sandy, and is generally nonphosphatic.

Woolsey (1976) reported between 2 feet and 31 feet (0.6 to 9.5 m) of unnamed Raysor-equivalent shelly sand (referred to as Sapelo facies of the Duplin formation) from borings and ditch cuttings. However, the thickness distribution of the unnamed Raysor-equivalent sand interpreted from seismic profiles (Woolsey and Henry, 1974, Woolsey, 1976; Foley, 1981) indicates that, in the coastal area and inner continental shelf, it may reach thicknesses approaching 100 feet (31 m).

The environment of deposoition of the unnamed Raysor-equivalent sand was marine, inner to middle continental shelf.

Age

The following planktonic foraminifera have been identified from the unnamed Raysor-equivalent shelly sand in Georgia:

Globorotalia menardii (dextral)
G. puncticulata
G. crassula
Neogloboquadrina acostaensis
N. humerosa
Globigerina apertura
G. quinqueloba
G. cf. *G. falconesis*
Globigerinoides ruber (common)
G. quadrilobatus quadrilobatus
G. quadrilobatus sacculiferus
G. obliquus
G. conglobatus
G. cf. *G. conglobatus*
Globoquadrina altispira
C. cf. *G. venezuelana*
Sphaeroidinellopsis seminulina
Sphaeroidinella dehiscens
Globigerinella aequilateralis aequilateralis
G. aequilateralis praesiphonifera
Orbulina universa

This association is consistent with Zone PL3 or PL4 of Berggren (1973) and is roughly equivalent to the concept of Zone N20 of Blow (1969). The unnamed Raysor-equivalent shelly sand is, therefore, early late Pliocene (early Piacenzian) in age (Pl. 1). The unnamed shelly sand is correlative with the Yorktown and Raysor Formations of the Atlantic Coastal Plain, and with the Jackson Bluff Formation of the eastern Gulf Coastal Plain.

CYPRESSHEAD FORMATION (new name)

Definition

The Cypresshead Formation is named herein for a prominently thin- to thick-bedded and massive, planar- to cross-bedded, variably burrowed and bioturbated, fine-grained to pebbly, coarse-grained sand formation in the terrace region of eastern Georgia (Figs. 47, 56; Pl. 2, 3). It is the uppermost formation in the section between the Orangeburg Escarpment and the Pamlico terrace, and, except along the major streams, it is the only outcropping formation in that region. Its stratigraphic relationships and associations have not been clearly understood in the past. It was included in both the Okefenokee formation and Altamaha Formation by Veatch and Stephenson (1911, p. 427-428, 415-416). Cooke, (1943) and Hails and Hoyt (1969) included the Cypresshead Formation of this report in the Talbot, Penholoway, and Wicomico formations. The Cypresshead of this report was also mapped with parts of the Hawthorne, Sunderland, and Pamlico formations by Cooke (1939). In addition to having been mapped as various shoreline complexes, the Cypresshead was also mapped with both "Pleistocene-Pliocene sands and gravels" and "Neogene undifferentiated" by Georgia Geological Survey (1976). The Cypresshead Formation has been referred to as the Citronelle Formation in northeastern Florida (Cooke and Mossom, 1929); (Cooke, 1945; and Pirkle and others, 1963, 1965).

Although the Cypresshead Formation directly underlies the "Talbot," Penholoway, and "Wicomico" terraces, and portions of the Okefenokee, Waycross, Argyle, and Pamlico terraces, field and core evidence has not shown any direct stratigraphic relationships between the Cypresshead Formation and these terraces. Field and core evidence indicates, on the other hand, that the Cypresshead is an older formation that predates terrace construction. The terraces later were constructed on the Cypresshead Formation.

Type Section

The name Cypresshead is taken from Cypresshead Branch, a small tributary of Goose Creek near the type locality in Wayne County, Georgia. The type locality is a sand-pit in the southern valley wall of Goose Creek, 0.25 mile (0.4 km) southeast of the confluence of Cypresshead Branch and Goose Creek (Fig. 49). The sand-pit is adjacent to a county road, 0.7 mile (1.1 km) north of the intersection of the county road and highway Ga. 169, and 4.6 airline miles (7.5 km) north-northwest of the center of the town of Jesup, Wayne County. There is 39 feet (12 m) of section exposed at the type locality. The upper 23 feet (7 m) is Cypresshead Formation. The lower 16 feet (5 m) of the section is lithologically an intermediate lithofacies between the Altamaha and Coosawhatchie Formations and, in this report, is arbitrarily assigned to the Ebenezer Member of the Coosawhatchie Formation. The section of Cypresshead Formation exposed at the type locality is the type section, or unit-stratotype (holostratotype), of the formation. The disconformable contact between the Cypresshead Formation and the underlying Coosawhatchie Formation, 23 feet (7 m) below the top of the section at the type locality, is the lower boundary stratotype for the Cypresshead.

Four other sections are herein designated reference localities and parastratotypes of the Cypresshead Formation. Linden Bluff on the Altamaha River, a reference locality and parastratotype (Fig. 2), is 2.2 airline miles (3.5 km) northwest of the US-25-82-301 bridge over the Altamaha River in Wayne County (also see Veatch and Stephenson, 1911, p. 412, who referred the Cypresshead Formation at this site to the Altamaha Formation). This locality is significant for two reasons: 1) it represents a more consistently undulatory and cross-bedded, nonburrowed and nonbioturbated sand lithofacies, and 2) the Cypresshead Formation at this site is underlain by a dark-gray, thinly bedded, finely sandy clay that is interpreted in this report as representing the nearshore, updip feather-edge of the Raysor Formation (referred to by Veatch and Stephenson, 1911, p. 412, as Miocene ?).

The railroad cut of the Seaboard Coast Line Railroad (type locality of the Screven Member of the Altamaha Formation), approximately 2.5 miles (4 km) southwest of the village of Screven in Wayne County, is herein designated a reference locality and parastratotype of the Cypresshead Formation (Fig. 43). This locality is significant because typical bioturbated Cypresshead Formation, exposed in the upper 12 feet (3.6 m) of the cut, can be seen disconformably overlying the Screven Member of the Altamaha Formation.

The roadcut on US 301 at Trudie in Brantley County, in the southern valley wall of the Little Satilla River, is herein designated a reference locality and parastratotype of the Cypresshead Formation (Fig. 2). This locality is significant because the thinly interbedded fine-grained sand and clay lithofacies of the Cypresshead Formation is exposed in this cut. The lithology of the Cypresshead at this site is indistinguishable from the typical lithology of the correlative Miccosukee Formation of southwestern Georgia.

The exposure in the Seaboard Coast Line Railroad cut in the southern valley wall of Ebenezer Creek at Birds in Effingham County, Georgia, is herein designated a reference locality and parastratotype of the Cypresshead Formation (Fig. 2). Birds is located at the crossing of the railroad with highway Ga. 275, 0.85 mile (1.4 km) east of the junction of highways Ga. 21 and Ga. 275. The junction of Ga. 21 and Ga. 275 is 3.6 miles (5.8 km) north of Rincon in Effingham County. The railroad cut at Birds is significant because it is the best exposure of the Cypresshead Formation in Effingham County. The exposure is relatively thick, and 35 feet (1.5 m) of the formation is exposed. Most of the lithologic variation present in the formation in central and southern Effingham County can be observed at this site, and the sediments of the lower part of the formation in the cut are exceptionally well-preserved and unweathered. The lower contact of the formation is not exposed at this site, but the top of the Ebenezer Member of the Coosawhatchie Formation is present 1.5 miles (2.4 km) west of Birds in the bed and bank of Ebenezer Creek at an elevation 18 feet lower than the base of the exposure at Birds. The reference locality of the Cypresshead Formation at Birds is 4.4 miles (7 km) southwest of the type locality of the Ebenezer Member of the Coosawhatchie Formation at Ebenezer Landing on the Savannah River.

Lithology

The Cypresshead Formation is dominantly a quartz sand. In some downdip areas, clay beds are prominent or may even dominate the Cypresshead section. Other subordinate

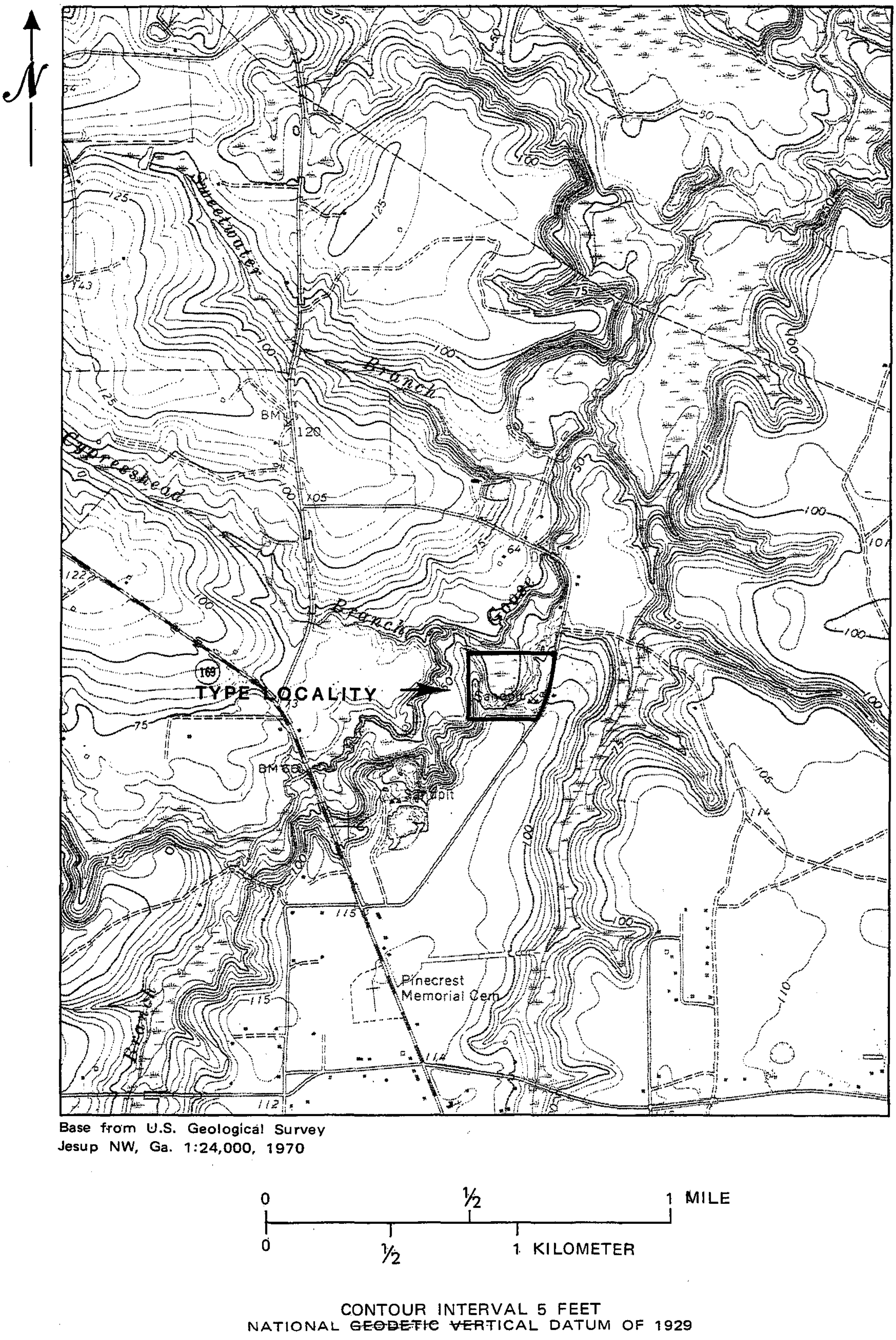


Figure 49. The type locality of the Cypresshead Formation.

lithic components include pebbles and gravel, heavy minerals, mica, trace fossils, and rarely, phosphatic pebbles, calcite, shells, calcareous microfossils, and siliceous microfossils.

The Cypresshead Formation is a coastal, beach/sound-type of deposit and, therefore, is lithologically variable over short distances. However, two gross lithofacies types can be distinguished in the formation in outcrop and in the shallow subsurface: one typically developed in the updip area and near the large rivers (Savannah and Altamaha Rivers), the other typically developed between the large rivers and in downdip areas.

The updip lithofacies is coarse-grained, and the sand-size ranges from fine to coarse and pebbly with scattered gravel stringers. Sorting ranges from well-sorted to poorly sorted in the coarser facies. Bedding is typically prominent with bed thickness ranging from thin to thick, and bedding definition ranging from vague to distinct. Cross-bedding is conspicuous in this lithofacies, and the scale is variable with the largest scale cross-bedding associated with the coarsest and most poorly sorted sands. *Ophiomorpha nodosa*, a trace fossil, is locally common in this lithofacies and is especially characteristic of the massive, structureless, medium to coarse sands. Similarly, there are scattered occurrences of bioturbated and burrowed beds. This coarse-grained sand lithofacies is reminiscent of the time-equivalent Citronelle Formation of western Florida.

The downdip lithofacies of the Cypresshead Formation consists of fine-grained sand and clay. This is the more distinctive lithology of the formation. It is characterized by thinly-bedded, fine-grained, well-sorted sand with thin layers, laminae, or partings of clay dispersed through the sand. The sand is typically weathered to a moderate reddish-brown (10 R 4/6) or orange, and the clay layers and laminae are white, producing a dramatic color contrast that highlights the bedding of the formation. In some scattered areas, the bulk of the formation consists of massive, argillaceous, fine-grained sand that is devoid of any primary sedimentary or biogenic structures. The sediment in this type of deposit is interpreted as being completely mixed and homogenized by burrowing organisms.

Intermediate lithologies consist of bioturbated, poorly mixed sediments. Also characteristic of this intermediate lithofacies is a discontinuous, gray, thinly layered, silty, diatomaceous clay. This gray diatomaceous clay occurs mainly in the subsurface but crops out along the Savannah River in the vicinity of Old Wood Landing, about 1.5 miles (2.4 km) downstream from Ebenezer Landing in Effingham County. The downdip lithofacies of the Cypresshead Formation lithologically resembles the time-equivalent Miccosukee Formation of southwestern Georgia and western Florida.

The Cypresshead Formation is rarely calcareous. Where calcite is present, it is generally, but not invariably, associated with macrofossils. Shell beds have been periodically uncovered in the Cypresshead Formation, but they generally are rare, and only have been seen near the base of the formation.

Stratigraphic Relationships

The Cypresshead Formation occurs at least as far north as the vicinity of Summerville in Dorchester County, South Carolina, and at least as far south as the vicinity of Orlando in Orange County, Florida. North of the Altamaha River in Georgia, the western limit of the Cypresshead Formation occurs at or a few miles west of the Orangeburg Escarpment. South of the Altamaha River, the Cypresshead occurs west of the escarpment in northern Wayne County, and immediately west of Trail Ridge farther south (Figs. 47, 50). The Cypresshead Formation underlies the coastal area of Georgia, except where it is absent on the crest of the Beaufort Arch (Fig. 2). It apparently pinches out offshore, or else grades laterally into an undifferentiated Pliocene sand on the continental shelf (Pls. 2, 3).

Generally the Cypresshead Formation disconformably overlies Coosawhatchie Formation in Georgia (Pls. 2 and 3). In northern Effingham County, however, the Cypresshead Formation disconformably overlies the Marks Head Formation and Parachucla Formation progressively in a northwestward direction (Pl. 2). The Cypresshead Formation overlies the Raysor Formation in only a few places, and with ambiguous contact. The Cypresshead disconformably overlies the Screven Member of the Altamaha Formation west of Trail Ridge and north of the vicinity of Waycross.

The Satilla Formation overlies the Cypresshead Formation in the coastal area of Georgia (Figs. 47, 58; Pls. 2 and 3). Because of poor core recovery in these deposits, the contact relationships between the Cypresshead and Satilla Formations are poorly defined, but the two formations are presumably disconformable. Elsewhere, only surficial sand, Quaternary fluvial deposits, paludal deposits, or residuum overlies the Cypresshead Formation.

The Cypresshead Formation is distinguished from the underlying formations of the Hawthorne Group in being prominently horizontal- and crossbedded, nonphosphatic, in containing little interstitial clay, and commonly containing burrows and bioturbation structures. In contrast, formations of the Hawthorne group are typically thick-bedded and massive, commonly phosphatic (except where they grade into the Altamaha Formation), argillaceous, and locally dolomitic, calcareous, and siliceous. Where the Cypresshead Formation overlies the Screven member of the Altamaha Formation, which is also prominently bedded, the sand of the Cypresshead generally is better sorted, there is little interstitial clay, and the sediments are commonly, but not always, burrowed and bioturbated to some extent. In contrast, the Screven Member has considerable amounts of interstitial clay, typically has poor sorting, Liesegang banding is commonly apparent, and burrows and bioturbation structures are absent. Where the Cypresshead Formation overlies the Raysor Formation, the Raysor is generally thick-bedded and massive, calcareous, and fossiliferous.

The Cypresshead Formation occurs at the top of the

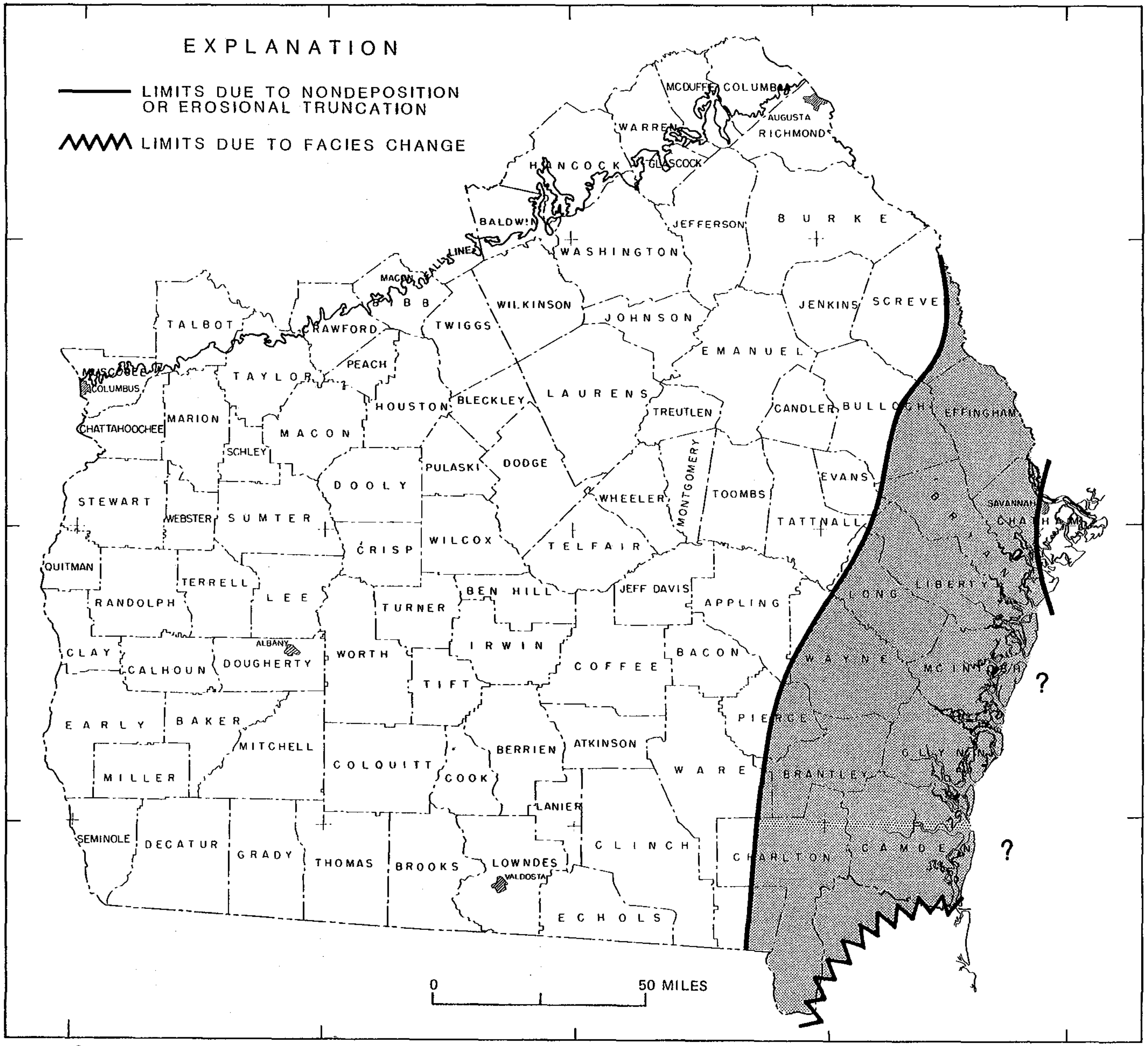


Figure 50. The areal distribution (outcrop and subcrop) of the Cypresshead Formation in Georgia.

stratigraphic section (excluding surficial sand deposits and barrier island sand deposits) west of the Pamlico terrace. However, on the Pamlico and lower terraces, the Satilla Formation overlies the Cypresshead Formation in most places. In this area, the Satilla can be distinguished in its better sorting and finer grain size of the sand, the local occurrence of massive clay beds, in the local presence of calcareous and fossiliferous sediments, and in being generally thick-bedded and massive (except in channel-fill deposits). Where the Satilla Formation locally is prominently bedded and crossbedded, it is distinguished from the Cypresshead Formation by its prevailingly finer grain-size and lack of pebbles, better sorting, and relatively smaller-scale sedimentary structures.

The Cypresshead Formation is 23 feet (7 m) thick at the type locality. The thickness of the formation in cores in the Savannah River area ranges from 25 feet to 62 feet (7.6 m to 19 m). Elsewhere, the maximum thickness of the formation appears to be between 60 and 70 feet (18 and 21 m). In the coastal area, where it is overlain by the Satilla Formation, the Cypresshead may be significantly thinner, even locally absent. As a result of the low topographic relief of the terrain in which the Cypresshead Formation occurs, the Cypresshead outcrop thickness ranges from a few feet (approximately 1 m) to as much as 30 or 40 feet (9 to 12 m) in sand pits, road cuts, railroad cuts, or in bluffs along major rivers.

The environment of deposition of the Cypresshead Formation was coastal marine. It is not clear, however, whether the Cypresshead Formation was deposited in a large sound/lagoon that was partially isolated from the open ocean, or whether it was deposited on the inner continental shelf seaward of the beach. The presence of locally abundant *Ophiomorpha nodosa* indicates that the associated sediments are of very shallow water, near sealevel origin; the presence of abundant *Ammonia beccarii* and *Elphidium* spp. at 61 feet in the core Effingham 13 (GGS-3140), near the base of the Cypresshead Formation, indicates brackish water conditions. On the other hand, the presence of sparse planktonic foraminiferal assemblages in the few scattered occurrences of calcareous, fossiliferous sediments in the Cypresshead suggests that near normal salinities must have prevailed some of the time. The lithology of the Cypresshead Formation, and the nature of the sedimentary structures, is more suggestive to me of deposition in very shallow water in a partially enclosed sound. If this model is correct, then associated barrier islands must have occurred in the present coastal area, or slightly offshore of the present coast. This model would require a very broad sound, at least 50 miles (80 km) wide.

Age

Because the Cypresshead Formation is largely nonfossiliferous, the age of the formation must be inferred from stratigraphic position, from physical correlation with fossiliferous formations, and from limited internal paleontological evidence. On the basis of stratigraphic position, the age of the Cypresshead Formation can be determined within broad limits. The Cypresshead overlies the Raysor Formation of early late Pliocene age along the Altamaha River in Wayne County with ambiguous contact, (either paraconformable or gradational) and it overlies the Raysor Formation along the Savannah River in Effingham County with a weathering contact of high relief. As a consequence, it is not clear whether the Raysor and Cypresshead Formations are disconformable, paraconformable, or conformable and gradational. The Satilla Formation of late Pleistocene age overlies the Cypresshead Formation in the coastal area. In addition, Pirkle and Czel (1983) reported a Pleistocene macrofossil assemblage from Trail Ridge sands in southern Charlton County. These Trail Ridge sands overlie the Cypresshead Formation. The highest marine terrace that the Cypresshead underlies is the Argyle terrace in northern Wayne County. Based on stratigraphic position, therefore, it is concluded that the Cypresshead Formation is no older than early late Pliocene (assuming conformity with the underlying Raysor Formation), is older than the late Pleistocene Satilla Formation, and is older than Trail Ridge and the Argyle terrace (both of which appear to be older than the Satilla Formation).

A small assemblage of planktonic foraminifera consisting only of juveniles was recovered from the interval 53.5 feet to 56 feet in the core Wayne 1 (Mineral Engineering Branch, Engineering Experiment Station, Georgia Institute of Technology and Georgia Department of Mines, Mining, and Geology, 1967, p. 93-95), approximately 5 miles (8 km) south of Jesup (Fig. 2). This assemblage includes the following species:

Globigerina apertura
Globigerina cf. *G. decoraperta*
Globigerina cf. *G. falconesis*
G. bulloides
G. rubescens
Neogloboquadrina cf. *N. dutertrei*
Globigerinoides ruber
G. obliquus

Globigerina apertura and *Globigerinoides obliquus* are not found in deposits younger than the Pliocene. Therefore, the Cypresshead Formation in this core can be no younger than Pliocene.

A small assemblage of benthic foraminifera was recovered from the basal Cypresshead Formation in the core Chatham 14 (GGS-3139) from northern Chatham County, Georgia (Fig. 3). The assemblage from the interval 39 feet to 45 feet includes the following species:

Buccella mansfieldi
Buliminella curta
B. elegantissima
Virgulinella gunteri
Florilus atlantica

The genus *Virgulinella* is not known to occur in deposits younger than the Jackson Bluff Formation (Raysor-equivalent) in western Florida and *Virgulinella* has not been previously reported from the southern Atlantic Coastal Plain Pliocene deposits.

Both the planktonic and benthic foraminifera from the Cypresshead Formation in Wayne and Chatham Counties, Georgia, indicate a Pliocene age for the formation.

In terms of macropaleontological evidence, no published accounts of shell beds can be assigned to the Cypresshead Formation except possibly a "marl" from the Satilla River 4 miles (6.4 km) south of Atkinson in Brantley County, described by Aldrich (1911) and commented on by Richards (1969). Very likely the deposits that contained *Chione cancellata,* along the St. Marys River, and that were assigned by Veatch and Stephenson (1911) and Cooke (1943) to the Charlton Formation, are in fact Cypresshead Formation or Nashua Formation as defined in this paper. This suggestion is based on fieldwork and studies of cores which indicate that the Charlton is a lithofacies of the middle Miocene Coosawhatchie Formation. The deposition of the Coosawhatchie Formation long predates the first occurrence of *C. cancellata*, a late Pliocene to Holocene species.

The Cypresshead Formation grades laterally southward, in the vicinity of the St. Marys River, into the Nashua Formation, a calcareous, shelly sand that underlies much of northeastern Florida east of Trail Ridge. A planktonic foraminiferal assemblage from the Nashua Formation at the depth of 65 feet in the Florida Geological Survey core Cassidy 1 (W-13815) includes the following species restricted to the Pliocene:

Globorotalia menardii miocenica
Globigerina aperatura
Globigerinoides obliquus

The presence of *G. menardii miocenica* is indicative of planktonic foraminiferal Zone PL5 of Berggren (1973) and of the middle part of Zone N21 of Blow (1969). The Nashua Formation in the core Cassidy 1 (W-13815) is, therefore, younger than the Raysor Formation and is time-equivalent to the Bear Bluff Formation of South Carolina.

The age of the Nashua Formation, at the type locality, is early Pleistocene, and the formation is, therefore, a multideposit formation (more than one sedimentational episode involved in the deposition of a formation). This circumstance raises the possibility that the correlative Cypresshead Formation may consequently also be a multideposit unit with a younger, as yet biostratigraphically undifferentiated component.

The best current estimate of the maximum age range of the Cypresshead Formation, based on stratigraphic position, internal paleontology, and physical correlation, is late Pliocene (early Piacenzian; Zone PL3 of Berggren [1973], or approximately Zone N20 of Blow [1969]), to early Pleistocene (Calabrian; Zone N22 of Blow [1969]). The most likely age of the Cypresshead Formation in Georgia is late Pliocene (Piacenzian; Zone PL5 of Berggren [1973], or Zone N21 of Blow [1969], [see Pl. 1]).

MICCOSUKEE FORMATION

Definition

The Miccosukee Formation was named by Hendry and Yon (1967) for a prominently bedded, fine- to coarse-grained sand that overlies the Hawthorne Group in Leon and Jefferson Counties, Florida, and occurs there at the top of the geologic section. The Miccosukee Formation farther north in Georgia is not known to differ in any way from the formation in Florida.

The Miccosukee Formation has been referred to the Lafayette formation (Matson and Clapp, 1909, p. 141-145), Altamaha Formation (Veatch and Stephenson, 1911, p. 421-423), Alum Bluff Formation (Sellards, 1917, p. 104-106), Hawthorne Formation (Cooke and Mossom, 1929, 123-125; Cooke, 1939; 1943, p. 91-92; 1945, p. 151, 153, 157), and Citronelle Formation (Doering, 1960). In addition, it was mapped as "Duplin marl and Hawthorn formation" by MacNeil (1947b). Sellards and Gunter (1909, p. 263-265; 1918, p. 49-51) gave an excellent account of the formation in Gadsden and Leon Counties, Florida, but did not refer it to any named unit.

Type Section

The name Miccosukee was taken from the community of Miccosukee in northeastern Leon County, Florida, and from Lake Miccosukee in eastern Leon and western Jefferson Counties, Florida (Hendry and Yon, 1967). The type locality is a roadcut, now completely overgrown, on highway US 19, approximately 3.1 miles (5 km) south of the Georgia-Florida state line in NW ¼, NW ¼, Sec. 31, T3N, R5E (Fig. 3). The type section (unit-stratotype) is that section of Miccosukee Formation that was exposed at the type locality. The Florida Bureau of Geological Survey core Green 1 (W-6937), taken about 0.75 mile (1.2 km) west of the community of Miccosukee in Leon County (Fig. 3), was designated a reference locality (Hendry and Yon, 1967, p. 253-254). The interval 2.5 feet to 62.5 feet in the core Green 1 (W-6937) (also see Hendry and Sproul, 1966, p. 151-125) is, therefore, a reference section and parastratotype of the Miccosukee Formation.

Lithology

The lithology of the Miccosukee Formation is dominated by sand, although in some areas, and in some parts of the section, clay is a significant or dominant component of the lithology. Other known subordinate lithic components include mica, heavy minerals, feldspar, and rarely, wad or MnO_2 dendrites. Limonite is locally present as a weathering product. The clay mineral components of the lithology consist of montmorillonite, kaolinite, and illite (Hendry and Yon, 1967).

Several lithology types or lithofacies can be identified in the Miccosukee Formation. The most characteristic lithology type is a thinly bedded to laminated, well-sorted, fine-to medium-grained sand with scattered layers or laminae of clay. Where the clay layers are absent, the sand generally remains distinctly and thinly layered, fine- to very fine-grained and well-sorted. Medium- and, rarely, coarse-grained sand beds are associated with the thinly layered, fine-grained sand lithologies. The clay layers typically range in thickness from 1 foot (30 cm) to 1/16 inch (1 mm). Thicker beds of clay are rare. Also associated with the clay beds are thin beds of intraclastic or intraformational clay breccia. Some beds or stratigraphic intervals in this lithofacies are bioturbated with incomplete mixing of the sediments. In outcrop, the Miccosukee Formation is moderately to deeply weathered, and the sands typically are orange to moderate reddish brown. The clay layers or laminae are white, and the resulting color contrast imparts a dramatic and characteristic appearance to the formation (identical to the analagous lithofacies of the equivalent Cypresshead Formation).

Pebbly to gravelly, coarse-grained sand lenses are present locally in the Miccosukee Formation and represent tidal channel scour-and-fill structures. These deposits are conspicuously cross-bedded, and the sorting commonly is poor. Gravel occurs in stringers. Lithologies intermediate to the thinly bedded, fine-grained sand lithofacies and the pebbly, cross-bedded sand also exist, indicating a wide spectrum of energy levels in the paleo-environment.

In some areas, the Miccosukee is dominated by other lithologies, including a massive-bedded, structureless sandy clay to clayey sand (e.g., in a large part of eastern Thomas County, Georgia); massive-bedded, structureless, well-sorted, fine- to coarse-grained sand; or vaguely bedded, well-sorted to moderately well sorted, fine- to coarse-grained sand.

The Miccosukee Formation is characteristically noncalcareous and nonfossiliferous. However, trace fossils such as burrows, bioturbation structures, and *Ophiomorpha nodosa* are locally conspicuous.

Stratigraphic Relationships

In Georgia, the Miccosukee Formation extends from the Pelham escarpment in the west, to the vicinity of the Alapaha River in the east (Fig. 51). The southern limit of the Miccosukee Formation is the Cody Escarpment in Florida (Puri and Vernon, 1964, p. 15, Fig. 5; Hendry and Sproul, 1966; Yon, 1966).

The northern limit of the Miccosukee Formation in Georgia approximates an east-west line trending from the vicinity of Pelham in Mitchell County in the west, through the vicinity of Berlin in Colquitt County, and to northern Lowndes County (Fig. 51). The Miccosukee Formation may exist north of this line but is not recognizable in outcrop because of deep and intense weathering.

The Miccosukee Formation disconformably overlies various formations of the Hawthorne Group: the Torreya Formation, the Meigs Member of the Coosawhatchie Formation in northwestern Thomas County, and the Statenville Formation in Echols County. In western Leon County, Florida, the Miccosukee Formation reportedly overlies the Jackson Bluff Formation (Hendry and Sproul, 1966; Hendry and Yon, 1967). The Miccosukee Formation occurs at the top of the local section in Georgia and Florida (Fig. 47), and is overlain only by various undifferentiated surficial deposits. However, it underlies various marine terraces in Georgia: the Argyle, the Claxton, the Pearson, and the Hazlehurst. Furthermore, it also occurs inland from the marine terrace belt.

The Miccosukee Formation is distinguished from the underlying deposits of the Hawthorne Group in consisting of locally burrowed and bioturbated fine-grained sand with thin beds or laminae of clay and with local occurrences of prominently cross-bedded medium- to coarse-grained, pebbly, channel-fill sands. In contrast, the underlying Hawthorne deposits are typically thick-bedded and massive, variably phosphatic, locally calcareous, dolomitic, and siliceous, and commonly contain magnesium-rich clays. The Miccosukee Formation is always weathered to some degree whereas Hawthorne deposits, due in part of high clay content and occurrence only at topographically low elevations, generally are unweathered to only mildly weathered. Where the Miccosukee Formation has been reported to overlie the Jackson Bluff Formation, the Jackson Bluff consists of a shelly, calcareous sand or, in Gadsden County, Florida, dark gray, sulphurous, finely sandy clay (aluminous clay of Dall and Stanley-Brown, 1894).

The Miccosukee Formation grades laterally westward, in central Gadsden County, Florida, into the Citronelle Formation (Fig. 47). However, the cross-bedded, pebbly and gravelly, coarse-grained sands in the cut-and-fill structures in the Miccosukee Formation represent Citronelle-type lithologies. These lithologies indicate that the west-east facies change from Citronelle Formation into Miccosukee Formation is not uniform and gradual, but irregular and locally discontinuous.

The apparent absence of the Miccosukee Formation east of the Alapaha River in Georgia may be a deception deriving from lack of exposures in the flat, featureless terrain. The alternative explanation is that the absence of the Miccosukee is the result of erosion after deposition. However, the Miccosukee Formation occurs in the same stratigraphic position and is lithologically the same as the Cypresshead Formation of eastern Georgia. The two formations are not continuous across northern Florida in the Suwannee River area, where the Statenville Formation is the uppermost formation in the section. The Miccosukee and Cypresshead Formations are also not known to be continuous across southern Georgia. Possibly, then, the Miccosukee was once continuous with the Cypresshead, and they were at that time one continuous formation. Later, this formation was partly eroded during the period of terrace construction west of the

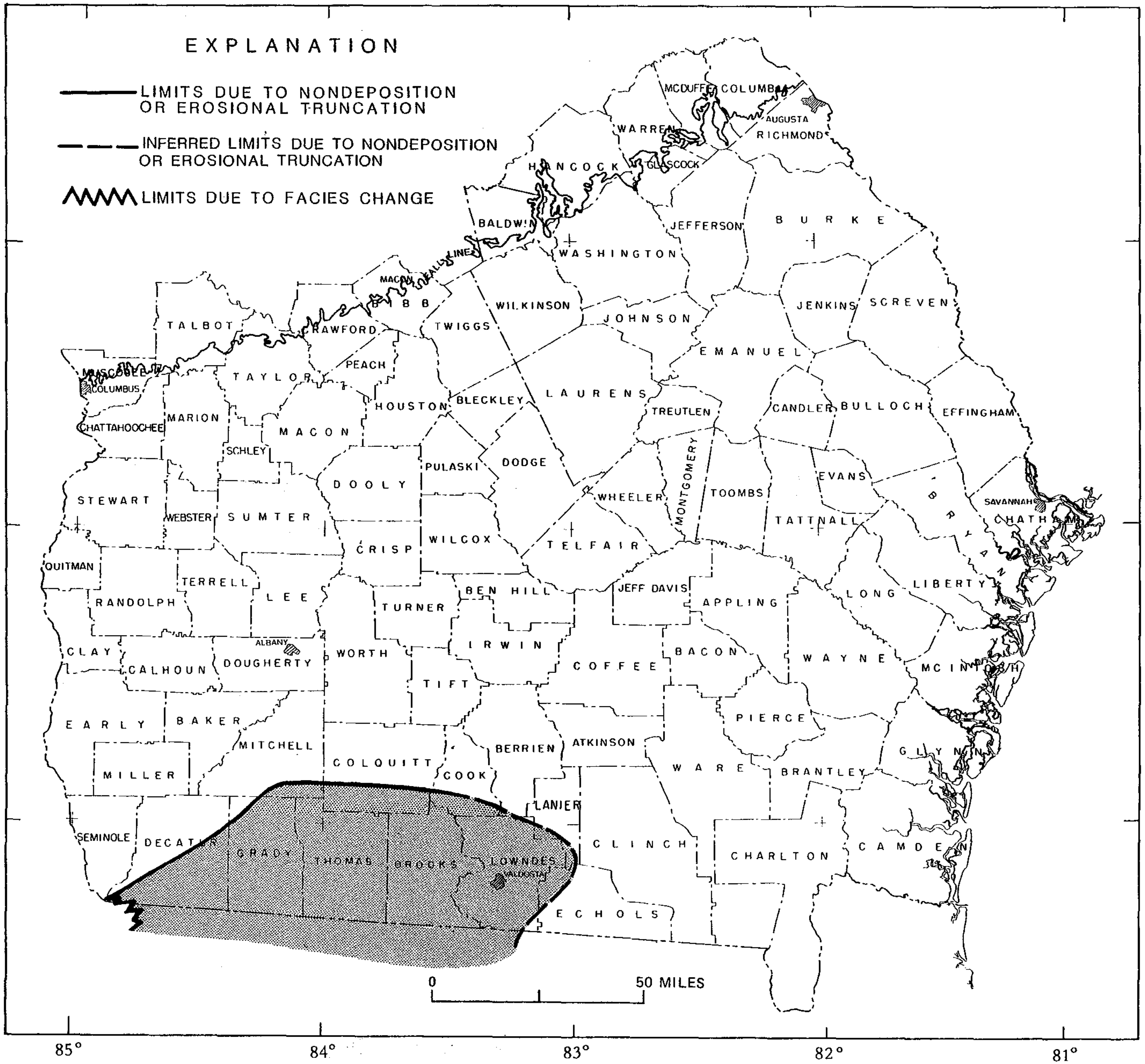


Figure 51. The areal distribution (outcrop and subcrop) of the Miccosukee Formation in Georgia.

Okefenokee Swamp, resulting in the present two formations. The basis for this suggestion is that the lowest elevations of the outcropping Miccosukee Formation in Lowndes County and westward (approximately 150 feet) are higher than the land elevations in the projected Miccosukee subcrop belt east of the Alapaha River. Because of the oblique methods employed to determine the ages of the two formations and, therefore, correlation, this author considers it more prudent to separate the units lithostratigraphically, tying each formation to a local stratotype.

Because of lack of core control in southwestern Georgia, the thickness distribution of the Miccosukee Formation there is not known. In Florida, however, where there is extensive well and core control (Hendry and Sproul, 1966; Yon, 1966), the Miccosukee Formation ranges from 43.5 feet to 83.5 feet (13 m to 25 m) thick. The average thickness of the formation, where it has not been dissected, appears to be between 50 and 60 feet (15 and 18 m).

Based on the scattered occurrences of burrows, bioturbated sediments, and *Ophiomorpha nodosa*, it is concluded that the environment of deposition of the Miccosukee Formation was coastal marine, probably bay-sound. This conclusion is consistent with the interpreted environments of deposition of the stratigraphically better known and lithologically comparable Cypresshead Formation and Tobacco Road Sand (Huddlestun and Hetrick, 1978, 1979, 1986).

Age

Because the Miccosukee Formation is nonfossiliferous, the age of the formation must be extrapolated from its stratigraphic position and physical correlation with adjacent deposits. Stratigraphic position of the Miccosukee Formation in Georgia is of little value in delimiting its age because it occurs at the top of the local stratigraphic section and overlies Hawthorne Group deposits of early and middle Miocene age. However, the Miccosukee Formation is reported to overlie the Jackson Bluff Formation of early late Pliocene age in western Leon County, Florida (Hendry and Sproul, 1966; Hendry and Yon, 1967).

The Miccosukee Formation grades westward, by coarsening of the sediments, into the Citronelle Formation in western Gadsden and Liberty Counties, Florida (also see Cooke and Mossom, 1929, p. 185, Pl. 2). In that area, the Citronelle Formation overlies the Jackson Bluff Formation with ambiguous stratigraphic relationships in the Florida Geological Survey cores Wall 1 and 2 (W-7457 and W-7458), and at Alum Bluff in Liberty County. Therefore, both the Citronelle and Miccosukee Formations are no older than early late Pliocene.

The Citronelle and Miccosukee Formations are overlain by the highest marine terraces, the Claxton, Pearson, and Hazlehurst terraces, and both formations occur inland of the highest marine terrace, the Hazlehurst terrace, in Florida and Georgia. Furthermore, the Miccosukee Formation occurs at elevations between 300 and 350 feet (91 and 107 m) in the vicinity of Pelham, in Mitchell County, Georgia, almost 100 feet (30 m) higher than the Hazlehurst terrace. Therefore, both the Miccosukee Formation and the equivalent Citronelle Formation (also see Carlston, 1950) are older than the highest and, presumably, oldest marine terrace.

The Citronelle Formation has historically been regarded as being of Pliocene age (Matson, 1916; Cooke and Mossom, 1929; Cooke, 1945), but Doering (1960) maintained that the Citronelle is of early Pleistocene (Calabrian) age. There is, however, no known paleontological or local correlation evidence in western Florida or southwestern Georgia to support a Pleistocene age for either the Citronelle or Miccosukee Formations. On the other hand, the stratigraphic evidence does not preclude a Pleistocene age for these formations.

Yon (1966, p. 55-57) identified the vertebrate fossil bed exposed on highway S-146 in northern Jefferson County, Florida (see also Olsen, 1963, p. 308-314; Olson, 1966, p. 19-24) as being Miccosukee Formation. On the basis of molars from the horse *Merychippus* sp. and the rhinoceros *Diceratherium* sp. from this locality, the bed containing the fossil mammal bones and, therefore, the Miccosukee Formation (or "Upper Miocene Clastics" of Yon, 1965) were assigned a late Miocene age (Yon, 1965, 1966; Hendry and Yon, 1967). It is now believed (Tedford and Hunter, 1984, p. 143-144; Fig. 4), however, that the fossils from this Jefferson County vertebrate bed (the Ashville local fauna) are of middle Miocene (late Barstovian) age, and are correlative with those found in the Statenville Formation (Statenville local fauna) at Statenville, Georgia.

Except for a central core of Torreya Formation that is still exposed, this roadcut is now overgrown and the bone-bearing bed can no longer be seen or evaluated in outcrop. However, based on my knowledge of the geology of northern Jefferson County, Florida, the following alternate interpretation of this important locality is offered. In contrast to the interpretation of Yon (1966, p. 103-104) only Torreya Formation is recognized in the upper part of the Florida Geological Survey core Ashville 1 (W-6561) taken at the vertebrate fossil locality. The Miccosukee Formation is, however, exposed at similar elevations in nearby roadcuts, indicating topographic relief on the Hawthorne Group/Miccosukee Formation disconformity. Beds A and B of Yon (1966, p. 60-61) and Olson (1966, p. 46-51) are lithologically consistent with the Torreya Formation that is still exposed. From published descriptions, Beds E and F appear to be Miccosukee Formation which is no longer exposed. The lithologic descriptions of Bed D and the critical bone-bearing Bed C do not clearly suggest either Torreya Formation or Miccosukee Formation. It is not likely that Bed C is Torreya Formation because of the presence of quartz pebbles, which are not known to occur in the Torreya Formation elsewhere. The indication that the vertebrates of Bed C are actually of middle Miocene age and correlative with those from Statenville (Tedford and Hunter, 1984) can not be ignored. This evidence strongly suggests that the coarse, pebbly, bone-bearing Bed C is actually a correlative of the Statenville Formation. The lithology of Bed C and the Statenville is somewhat dissimilar, although the coarse, pebbly sandy is characteristic of both. In addition, there is no known point at which the two units are known to merge, even though the distance now known to separate them is not great. It thus seems indavisable to refer Bed C to the Statenville Formation at this time, but it is here regarded as correlative to the Statenville Formation.

The Miccosukee Formation occurs in the same stratigraphic position, with similar stratigraphic associations, and is lithologically almost identical to the Cypresshead Formation of the Atlantic coastal area. Presumably, therefore, the two formations are precisely time-equivalent and correlative. The Miccosukee Formation is also correlative, at least in part, to the Nashua Formation of northeastern Florida. The type Nashua Formation is early Pleistocene in age and is a multideposit unit. As a consequence, the possibility exists that the Miccosukee Formation is also a multideposit formation, and a part of the formation may be as young as early Pleistocene.

Based on the above discussion, the best current estimate of the age range of the Miccosukee Formation is from early late Pliocene (early Piacenzian; equivalent to Zone PL3 of Berggren [1973]), to early Pleistocene (Calabrian; equivalent to Zone N22 of Blow, [1969]), (see Pl. 1). However, it appears more likely to me that the Miccosukee Formation, like the Cypresshead Formation, is late Pliocene (Piacenzian) in age and is equivalent to Zone PL5 of Berggren (1973).

UNDIFFERENTIATED UPPER PLIOCENE SAND OF THE CONTINENTAL SHELF

Definition

This upper Pliocene deposit underlies the outer continental shelf of Georgia (Fig. 47). Based on paleontological correlation, it appears to be, in part, the offshore equivalent of the Cypresshead Formation. Its precise distribution, facies variations, and thickness distribution are not well-defined at this time due to insufficient core control. However, limited information indicates that the deposit may be widespread on the outer shelf (Poag and Hall, 1979).

Lithology

In the COST GE-1 test well, according to Rhodehamel (1979), the lithology of this deposit consists of loose, water-worn, brecciated shell hash; loose, clear to frosted, angular to subrounded, fine to very coarse to granule-size quartz sand; loose, white to gray oolite pellets; gray oomicrite; biomicrite; sparite; calcareous mud; brown to green glauconite; brown phosphate pellets; and sedimentary and volcanic rock fragments.

In the core AMCOR 6004 taken in approximately 570 feet (174 m) of water on the upper continental slope 63 miles (102 km) southeast of Charleston, South Carolina, and approximately 90 miles (145 km) east of Savannah, the lithology of the correlative deposit consists of massive and structureless, unconsolidated, macrofossiliferous, calcareous, sandy, olive-colored, foraminiferal clay (also see Hathaway and others, 1976).

Thickness

This unit is approximately 124 feet (38 m) thick in the COST GE-1 test well. Poag and Hall (1979, p. 49) noted that the interval is thinner in the wells J-1 and J-2 on the southern rim of the Southeast Georgia Embayment on the continental shelf. This unit is absent in the U.S. Geological Survey core AMCOR 6002 taken on the continental shelf 46 miles (74 km) east of Brunswick. Its correlative is 62 feet (19 m) thick in the core AMCOR 6004 (Hathaway and others, 1976).

Age

This deposit is late Pliocene, Piacenzian in age, and contains planktonic foraminiferal Zone PL5 of Berggren (1973) or Zone N21 of Blow (1969) (Pl. 1). The age assignment is based on the occurrence of the following species of planktonic foraminifera (Poag and Hall, 1979):

Globoratalia menardii miocenica
G. menardii exilis
Globorotaloides planispira
Sphaeroidinella dehiscens
Globigerinoides obliquus
G. conglobatus
Globigerina apertura
G. incisa
G. decoraperta
Neogloboquadrina dutertrei

NASHUA FORMATION (reintroduced)

Definition

The Nashua Marl of Matson and Clapp (1909, p. 128-133) is herein reintroduced as the Nashua Formation. Typically, the Nashua is a variably calcareous, shelly sand and a finely sandy shell coquina that occurs in outcrop in the St. Johns River Valley in northeastern Florida. The Nashua Formation is significant to the understanding of the late Cenozoic stratigraphy of Georgia in that its northern limit is in the vicinity of St. Marys River; therefore, it probably occurs in Georgia (see Fig. 47; Pl. 2). The Nashua Formation is critical for delimiting the age of the correlative Cypresshead Formation in eastern Georgia, and it is useful in defining the age range of the correlative Miccosukee Formation of southwestern Georgia.

The name Nashua Marl was abandoned by Cooke and Mossom (1929) in favor of the name Caloosahatchee marl, a south Florida unit presumably biostratigraphically equivalent to and continuous with the Nashua of northeastern Florida. Because of a lack of stratigraphic investigations in the area, neither the name Nashua nor Caloosahatchee has been applied to any deposit in northeastern Florida in recent years. The name Caloosahatchee is not adopted in this report because it is not clear that the Caloosahatchee marl of former usage is a mappable lithostratigraphic unit of formation rank, nor is there evidence that these shelly, fossiliferous deposits are continuous in the subsurface. The Caloosahatchee (in the strict sense) has always been recognized first on its fossil content and, therefore, its age, and second on its fossiliferous "marl" lithology (Dall, 1892; Matson and Clapp, 1909; Sellards, 1919; Cooke and Mossom, 1929; Cooke, 1945; Dubar, 1958). Because beds have been removed from the upper and lower parts of the Caloosahatchee marl of Dall (1892) on paleontological grounds (i.e., Fort Thompson Formation of Sellards [1919], "unit A" and Pinecrest beds of Olsson and Petit [1964]), the lithostratigraphic ranking of the Caloosahatchie has been rendered ambiguous, and it is questionable whether it is a mappable unit with a lithology that serves to distinguish it from underlying and overlying units. As a result, the Nashua Formation, a lithologically characteristic and mappable formation in northeastern Florida, is reintroduced in this report.

Type Section

The type locality of the Nashua Formation, by original designation (Marson and Clapp, 1909, p. 130), is "one-fourth mile south of Nashua, Putnam County", Florida (Fig. 46). Mansfield (1924 p. 28) noted that the type locality is on the "river bank." There are, however, low bluffs with scattered, poorly exposed outcrops along the St. Johns River for approximately 2 miles (3.2 km) on the east side of the river at Nashua. Cooke and Mossom (1929, p. 160) were unable to find the specific site of the type locality designated by Matson and Clapp (1909); therefore, the precise location of the type locality of the Nashua Formation is not clear. According to the information supplied by the above authors, however, the type locality must be on the east bank of the St. Johns River, in Sec. 28 (possibly Sec. 41), T11S, R26E, approximately 3 miles (4.8 km) southwest of the community of Satsuma, and approximately 10 miles (16 km) south of the town of Palatka, Florida (Fig. 52).

The type section (unit-stratotype) of the Nashua Formation is that section of Nashua exposed at the type locality. The exposures of the Nashua Formation in the bluffs at the type locality are all low. No more than about 3 feet (1 m) of section is currently exposed, and neither lower nor upper contacts can be seen.

Lithology

The Nashua Formation is a variably calcareous, shelly sand to finely sandy coquina. Limited information indicates that all other lithic components are minor. Known subordinate lithic components include calcite, aragonitic and calcitic shells, clay, mica, heavy minerals, and minor phosphate.

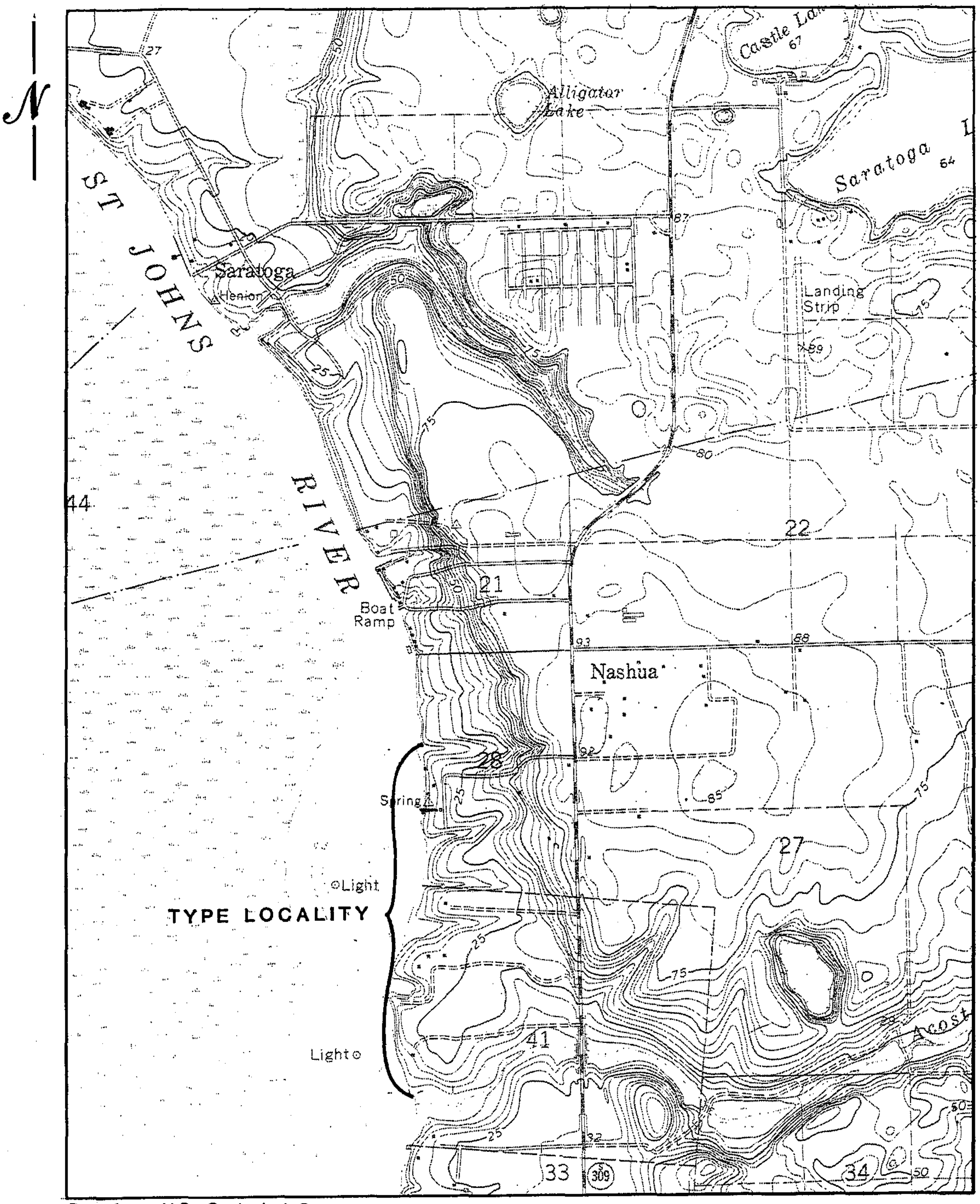
Quartz sand is the dominant lithic component of the formation and ranges in grain-size from medium to fine. In its area of facies change with the Cypresshead Formation, quartz sand constitutes the bulk of the formation with only minor occurrences of shells and shell debris. In the type area, the lithology alternates between relatively unfossiliferous sand and sandy coquina (shell marl). The alternation of sand and "shell marl" reported by Matson and Clapp (1909) suggests indistinct organization of the deposit into thick beds. The sediments within the beds are massive and devoid of primary sedimentary or biogenic structures.

Stratigraphic Relationships

The Nashua Formation underlies the St. Johns River area at least as far south as the vicinity of Deland in Volusia County, Florida, and its northern limit is the vicinity of the St. Marys River between Florida and Georgia (Fig. 53). The western limit of the Nashua in northeastern Florida appears to be the vicinity of Trail Ridge. Its eastern limit is unknown at this time. From its stratigraphic position and elevations, and from additional paleontological support, the Nashua Formation apparently grades westward into the Cypresshead Formation in the vicinity of Trail Ridge, and northward into the Cypresshead Formation in the vicinity of the St. Marys River (Fig. 47; Pl. 1).

The Nashua Formation disconformably overlies the Coosawhatchie Formation in northeasternmost Florida. In its area of occurrence, it is the uppermost formation in the geologic section, being overlain only by undifferentiated surficial sand deposits. To the east, in the coastal area, it may be locally overlain by the Satilla Formation.

The Nashua Formation is distinguished from the underlying Coosawhatchie Formation in consisting of buff to cream colored, massive, thick-bedded, variably shelly and calcareous sand whereas the Coosawhatchie Formation is phosphatic, nonfossiliferous and, in northeastern Florida, is locally dolomitic but generally lacks carbonate. Where the Nashua Formation overlies the Charlton Member of the Coosawhatchie Formation, the Charlton Member consists of variably fossiliferous (moldic) dolostone or limestone and clay. Quartz sand in typical Charlton Member occurs in minor amounts but is the principal lithic component in the Nashua. The aragonite and calcite of the fossil shells in the Nashua are generally in a good state of preservation (locally or at some stratigraphic intervals the shells are chalky and poorly preserved) whereas only the calcitic shells in the Charlton are locally well-preserved. The Nashua Formation is not known to overlie the unnamed Raysor-equivalent shelly sand. Because both units are shelly calcareous sand deposits, the Nashua Formation could be mistaken lithologically for the unnamed Raysor-equivalent sand. The un-



Base from U.S. Geological Survey
Satsuma, Fla. 1:24,000, 1968

0 1/2 1 MILE
0 1/2 1 KILOMETER

CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 52. The type locality of the Nashua Formation.

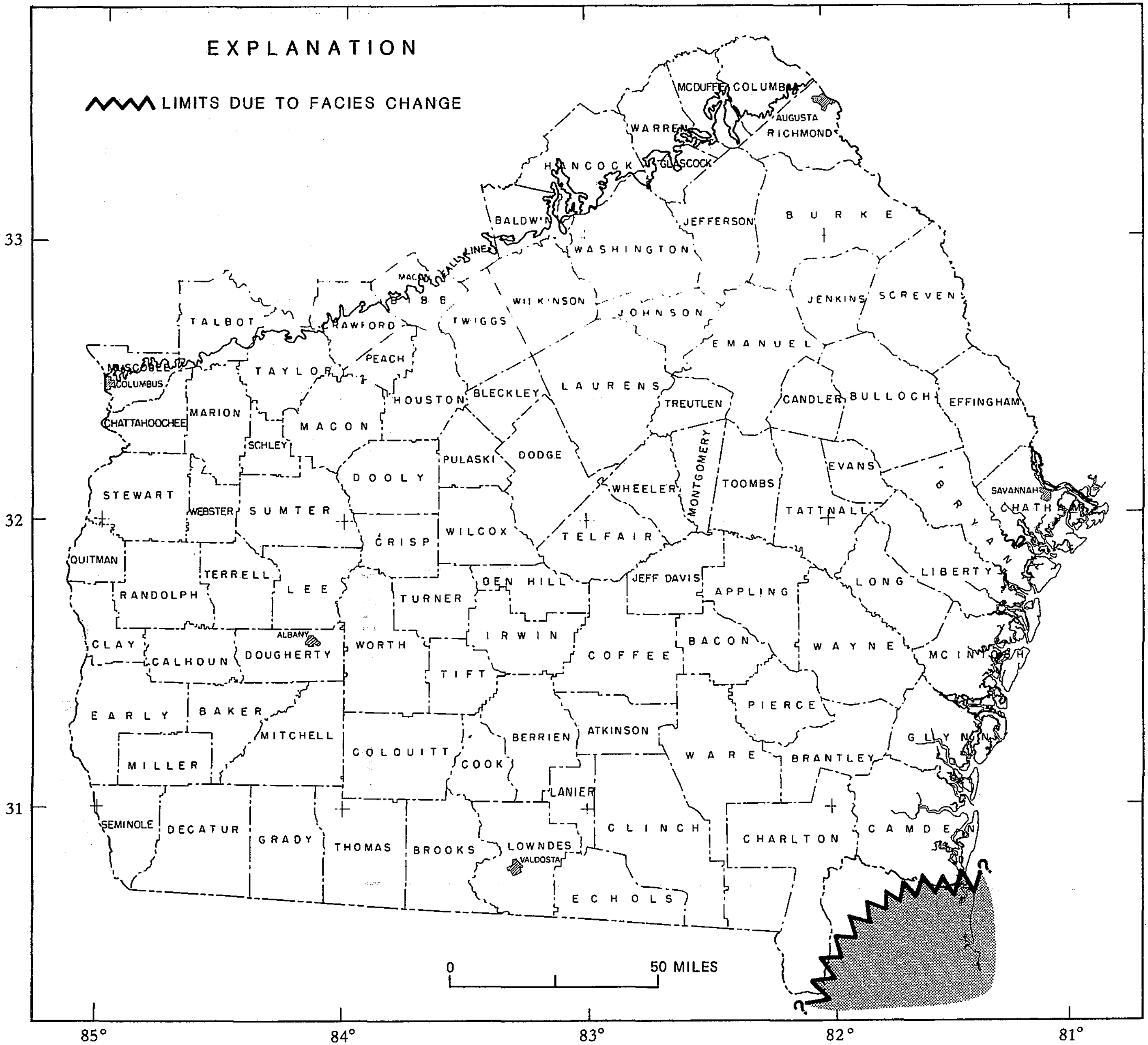


Figure 53. The areal distribution (subcrop) of the Nashua Formation in Georgia.

named Raysor-equivalent sand, however, typically is olive-gray in color, the sand generally more poorly sorted, and it contains a minor amount of phosphate.

The Nashua Formation is distinguished from the stratigraphically equivalent Cypresshead Formation in that the Cypresshead typically is prominently horizontal- and cross-bedded and, in Florida, is not known to be calcareous and fossiliferous.

The Nashua Formation is distinguished from the calcareous, fossiliferous phases of the Satilla Formation in that the Satilla generally is less calcareous and more argillaceous.

There is virtually no information on the thickness distribution of the Nashua Formation. Matson and Clapp (1909) reported 15 feet (4.5 m) of the formation at the type locality, but observed that the formation was seldom more than 6 to 8 feet (1.8 to 2.4 m) thick (presumably in outcrop). The Nashua in a well at Deland was reported to have a thickness of 32 feet (10 m).

Based on similarity in stratigraphic position and elevation to the Cypresshead Formation, total thicknesses ranging from 40 to 60 feet (12 and 18 m) would be expected for the Nashua Formation.

The environment of deposition of the Nashua Formation was open-marine, shallow-water, inner neritic continental shelf. The Nashua Formation is an offshore facies of the coastal marine Cypresshead Formation.

Age

The molluscan fauna of the Nashua Formation and its age implications have been discussed at some length in the literature (Matson and Clapp, 1909, p. 128-133; Mansfield, 1918, p. 111-123; 1924, p. 29-35; Cooke and Mossom, 1929, p. 156-160; Cooke, 1945, p. 225-226). The above authors consistently correlated the Nashua Formation with the Waccamaw Formation of the Carolinas and with the Caloosahatchee marl of southern Florida. Both the Waccamaw Formation and Caloosahatchee marl had been thought to be of Pliocene age. However, Dubar (1958) first assigned a Pleistocene age to the Caloosahatchee, and this age assessment was supported independently by Bender (1973) on helium-uranium dating of corals. Similarly, Akers (1972) assigned a Pleistocene age to the Waccamaw Formation on the evidence of planktonic foraminifera. My identification of both *Globorotalia truncatulinoides* and *G. tosaensis* in samples from the Waccamaw Formation in the vicinity of Myrtle Beach, South Carolina, and Calabash, North Carolina, substantiates the early Pleistocene (Calabrian) age for the Waccamaw Formation.

A sparse suite of planktonic foraminifera has been identified from the Nashua Formation near the type locality at a marina at Nashua in Sec. 21, T11S, R26E. The planktonic foraminifera include the following species:

Globigerina falconensis
G. rubescens
Globigerinoides ruber
G. quadrilobatus
Neogloboquadrina cf. *dutretrei* (juveniles)
Pulleniatina obliquiloculata (juveniles)
Orbulina universa

Pulleniatina obliquiloculata is very rare to absent even in richly microfossiliferous sediments from Coastal Plain deposits of late Pliocene age, but is commonly present even in poorly microfossiliferous sediments of the Waccamaw Formation. The presence of *Globigerina rubescens*, however, is not conspicuous in Coastal Plain deposits of late Pleistocene age. The planktonic foraminiferal suite from the Nashua Formation at Nashua, Florida, is, therefore, consistent with that of the early Pleistocene Waccamaw Formation and is probably early Pleistocene (Calabrian) in age (see Pl. 1).

The following planktonic foraminifera were identified from a sample at 65 feet in the Florida Geological Survey core Cassidy 1 (W-13815) in Nassau County, Florida:

Globorotalia menardii miocenica s.s.
G. puncticulata
Globigerina apertura
G. decoraperta
G. bulloides
G. cf. *falconensis*
Globigerinoides obliquus
G. ruber
G. quadrilobatus
Neogloboquadrina dutertrei
Globigerinella aequilateralis
Sphaeroidinella? (juveniles)

Based on the presence of *G. menardii miocenica, G. apertura*, and *G. obliquus*, none of which occur in the Pleistocene, this assemblage is late Pliocene in age. It is characteristic of Zones PL5 of Berggren (1973) or N21 of Blow (1969) (Pl. 1). The Nashua Formation in this core, which is a shelly, calcareous sand consistent with Nashua lithology, is older than the type Nashua Formation and the Waccamaw Formation of the Carolinas, and is correlative with the Bear Bluff Formation of the Carolinas.

A similar suite was identified from the Nashua Formation in the interval 169 to 171.5 feet in the Florida Geological Survey core Baywood 1 (W-8400) in Putnam County, Florida. These species include the following:

Globigerina decoraperta
G. rubescens
G. falconensis
Globigerinoides obliquus
G. ruber
G. quadrilobatus
Neogloboquadrina dutertrei (juveniles)
Sphaeroidinella? (juveniles)

On the basis of the evidence presented here, the Nashua Formation is probably a multideposit formation (i.e., it was deposited during more than one episode of sedimentation). The evidence in northeastern Florida supports an age range for the Nashua from late Pliocene (Piacenzian; Zone PL5 of Berggren, [1973], or N21 of Blow [1969], to early Pleistocene (Calabrian; Zone N22 of Blow [1969]).

SATILLA FORMATION (reintroduced, redefined, and revised)

Definition

The Satilla Formation of Veatch and Stephenson (1911, p. 434-440) is heren reintroduced as a lithostratigraphic unit of formation rank. The concept of the Satilla Formation of Veatch and Stephenson (1911) consisted of two types of deposits: coastal marine ("coastal terrace") deposits and the presumed equivalent river terrace deposits of Pleistocene age. The reintroduced Satilla Formation is restricted here to include only coastal marine deposits, and it is expanded also to include Holocene coastal marine deposits. The river terrace deposits of the Satilla Formation of Veatch and Stephenson (1911) are excluded from the Satilla Formation of this report because they are lithologically different and distinct from the coastal marine deposits and are not mappable between river valleys. Similarly, the Holocene coastal marine deposits are included in the Satilla Formation of this report because they are lithologically indistinguishable from the late Pleistocene deposits, and the entire suite of deposits constitute a mappable lithostratigraphic unit.

Cooke (1943, p. 111) suppressed the name Satilla Formation in favor of the Pamlico Formation of North Carolina. The present author proposes abandonment of the name Pamlico Formation in Georgia because the name Pamlico is associated with the specific marine terrace as well as with certain Pleistocene deposits in North Carolina (Stephenson, 1912). The use of the name for two widely occurring but different geological phenomena is confusing and is undesirable. Because the formation in question (Satilla) also includes deposits which underlie younger terraces, including the Holocene, the use of the same name for both a formation and a specific terrace is all the more confusing. Because (1) the name Pamlico terrace is deeply entrenched in the literature, (2) the Pamlico Formation has not been in general use in Georgia or in South Carolina in recent years (Georgia Geological Survey, 1976; Dubar, 1971; Dubar and others, 1974), and (3) the lithostratigraphic name Satilla (Veatch and Stephenson, 1911) has priority over the name Pamlico (Stephenson, 1912), I consider it preferable to retain the name Pamlico for the marine terrace and to propose abandonment of that name for the lithostratigraphic unit.

The Satilla Formation is a heterogenous unit that consists of variably fossiliferous, shelly sands and clays of offshore, inner continental shelf origin; prominently bedded to nonbedded barrier island deposits (excluding the undifferentiated soft, incoherent, massive, structureless sands of probably aeolian origin that cap the barrier islands and emergent barrier islands)[1]; and marsh deposits.

The Satilla Formation of this report includes the Pamlico Formation of Cooke (1943); the Pamlico, Princess Anne, and Silver Bluff formations of Hails and Hoyt (1969); and the Pamlico, Princess Anne, Silver Bluff, and Holocene shoreline complexes of Mann (Georgia Geological Survey, 1976).

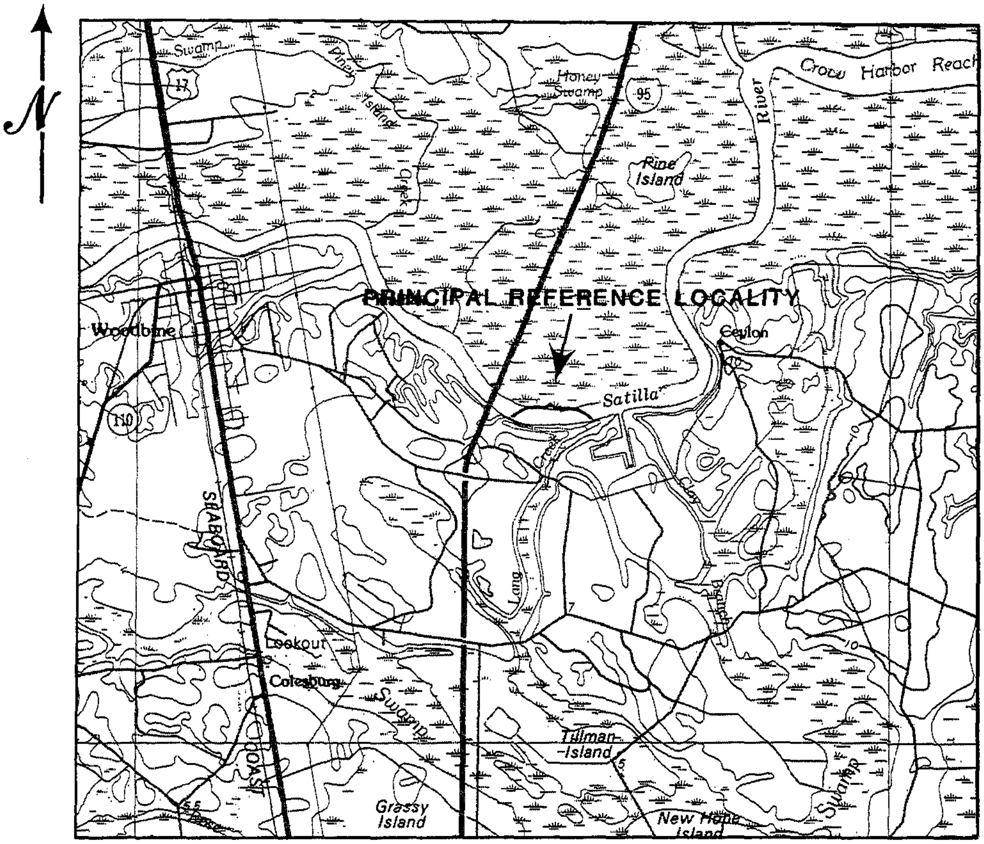
Type Section

Veatch and Stephenson (1911, p. 434) did not specifically designate a type locality for the Satilla Formation. The type locality is inferred from their comment, "These deposits are typically developed along either side of the Satilla River in Camden and Charlton Counties." Most of the exposed deposits along the stretch of the Satilla River in Camden and Charlton Counties consist of undifferentiated Quaternary alluvial deposits that are a part of the original concept of the Satilla Formation of Veatch and Stephenson (1911). The only exposed section of Satilla Formation of this report (coastal marine deposits of Veatch and Stephenson [1911]) on the Satilla River is at Satilla Bluff. Satilla Bluff, therefore, is designated herein the principal reference locality of the Satilla Formation, and the section at Satilla Bluff is the principal reference section (lectostratotype) of the formation. At Satilla Bluff, the Satilla Formation consists of orange to yellow, massive-bedded, structureless, argillaceous, well-sorted, fine- to medium-grained sand. Neither the upper nor lower boundaries of the formation are exposed at Satilla Bluff.

Satilla Bluff is in Camden County, Georgia, approximately 3 miles (5 km) east-southeast (downriver) of the village of Woodbine (Fig. 54). The Interstate-95 bridge over the Satilla River is at the western end of Satilla Bluff.

The best and most instructive exposures of the Satilla Formation in the type area are at Roses and Bells Bluffs along Bells River, a tidal distributary of the St. Marys River, and at Reids Bluff on the lower St. Marys River (Fig. 2). These bluffs are all in Nassau County, Florida, across the St. Marys River from St. Marys, Georgia. Roses and Bells Bluffs, which form one continuous bluff, and Reids Bluff are here designated reference localities of the Satilla Formaation. Roses Bluff and Reids Bluff are parastratotypes of the formation (see Veatch and Stephenson, 1911, p. 436, 440; also see Sellards, 1910; Scott, 1976), and Bells Bluff is designated herein a hypostratotype. Another useful reference locality and hypostratotype in the type area of the formation is Elliots Bluff at Crooked River State Park on

[1]In this report, emergent barrier islands are ancient barrier islands that stand out topographically as ridges due to relative lowering of sea level and withdrawal of the sea.



Base from U.S. Geological Survey
Fernandina Beach, Fla.-Ga. 1:100,000, 1981

0 1 2 3 MILES

0 1 2 3 KILOMETERS

CONTOUR INTERVAL 2 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 54. The principal reference locality of the Satilla Formation.

Crooked River in Camden County, Georgia, 8 miles (13 km) north of St. Marys.

Roses, Bells, and Elliotts Bluffs occur in the cores or centers of Pamlico barrier islands. Reids Bluff occurs near the landward margin of the Pleistocene barrier island whose core is exposed at Roses and Bells Bluffs. Satilla Bluff occurs in the back-barrier tract, immediately behind a Pamlico barrier island. It is expected, therefore, that each of the reference localities would expose sediments of differing character and lithology.

Lithology

The Satilla Formation is a lithologically heterogeneous unit and consists variably of sand and clay. Sand appears to be the dominant lithic component, at least in the barrier island lithofacies, and is most conspicuous at the type locality and reference localities. Other subordinate lithic components include calcite, shells and other fossils, heavy minerals, mica, humate, scattered carbonaceous material, and, locally, fossil vertebrate remains.

The sand generally is fine- to medium-grained and well-sorted. Coarser grained sand, where present, generally is more poorly sorted. Bedding in the dominantly sand lithofacies includes well-stratified sands with well-defined horizontal-bedding and various kinds of cross-bedding; vaguely bedded sands; and massive-bedded sand devoid of primary sedimentary structures. Bioturbated argillaceous sand is present in the more marine, inner shelf phases of the formation. Locally, as at Reids Bluff, channel cut-and-fill structures are conspicuous. Humate-cemented sandstone is also locally prominent, with large boulders of humate sandstone littering the bases of bluffs.

The Satilla Formation exhibits two types of clay deposits: variably bedded, variably calcareous and fossiliferous, silty to sandy clay of inner continental shelf origin; and massive-bedded, blocky to hackly clay of marsh origin with local concentrations of the oyster *Crassostrea virginica*. Based on limited core and outcrop control, it would appear that much of the Pamlico terrace complex is underlain by marsh-type clay in the area south of the Altamaha River (Logan, 1968). Clay containing *Crassostrea virginica* is exposed at Reids Bluff and at Orange Bluff on the St. Marys River in Nassau County, Florida. No stratigraphic information is available for the area north of the Altamaha River.

The Satilla Formation is variably calcareous and fossiliferous. It is least calcareous and fossiliferous in the western or landward part of its belt of occurrence, and in the upper part of the barrier island sequences. It is most commonly calcareous and fossiliferous at low elevations and in the subsurface in the coastal area. Fossiliferous, calcareous, shelly, argillaceous sand and bioturbated, argillaceous sand occur typically at the base of and seaward of the barrier island sequences. As at Roses and Bells Bluffs, sands overlying the bioturbated and shelly sands may be replete with *Ophiomorpha nodosa* (see Scott, 1976).

The Satilla Formation is distinguished from the Cypresshead Formation in the following ways: (1) The sands of the Satilla Formation are finer-grained with little coarse-grained sand and gravel (except in the vicinity of the Altamaha River). The sands of the Cypresshead Formation, on the other hand, are typically coarser, ranging from fine- to coarse-grained and pebbly. (2) Satilla Formation sands are typically well-sorted; poorly sorted sands are more characteristic of the coarser phases of the Cypresshead. (3) The Satilla Formation is consistently calcareous and fossiliferous in the coastal area and more variably calcareous and fossiliferous inland. The Cypresshead Formation is rarely calcareous and fossiliferous. (4) The Satilla Formation contains blocky, massive, locally fossiliferous clays of marsh origin. There are no known massive, blocky clays of marsh origin in the Cypresshead Formation, but there are thick beds of thinly bedded to laminated, conspicuously diatomaceous clay in the Cypresshead. In addition, (5) the thinly bedded, fine-grained sand lithofacies with thin clay partings is characteristic of the Cypresshead Formation and is not known to occur in the Satilla Formation.

Stratigraphic Relationships

The Satilla Formation is restricted to the lower marine terrace region in eastern Georgia and extends northward into South Carolina, and southward into Florida (Fig. 55). The western limit of the formation approximates the landward margin of the Pamlico terrace, and its eastern limit is in the offshore area. Woolsey and Henry (1974), Woolsey (1976), and Foley (1981) indicate that the "Holocene/Pleistocene" deposits of the coastal area of Georgia (Satilla Formation), characterized by prominent cut-and-fill structures and discordant reflectors on seismic cross-sections, are continuous on the inner continental shelf and extend many miles offshore. Similarly, the lithology of sediments on the continental shelf described by Pilkey and others (1981) is consistent with Satilla Formation.

The lower boundary of the Satilla Formation is not known to be exposed in outcrop. In Chatham County, Georgia, the Satilla Formation is known to disconformably overlie the Raysor Formation, and more generally, the Coosawhatchie Formation. In northern Chatham County, the Satilla Formation presumably overlies the Cypresshead Formation locally, but this relationship has not yet been observed in cores. The Satilla Formation disconformably overlies the Charlton Member of the Coosawhatchie Formation at Orange Bluff on the St. Marys River in Nassau County, Florida. In the Altamaha River area, Scott (1976) reported various kinds of deposits to underlie the Satilla Formation of this report: "granular silt and clay" (probably Ebenezer Member of the Coosawhatchie Formation), "arkosic sands" (Cypresshead Formation?), and "limestone and marl" (Charlton Member, Raysor Formation, or Cypresshead Formation?).

The Satilla Formation occurs at the top of the geologic

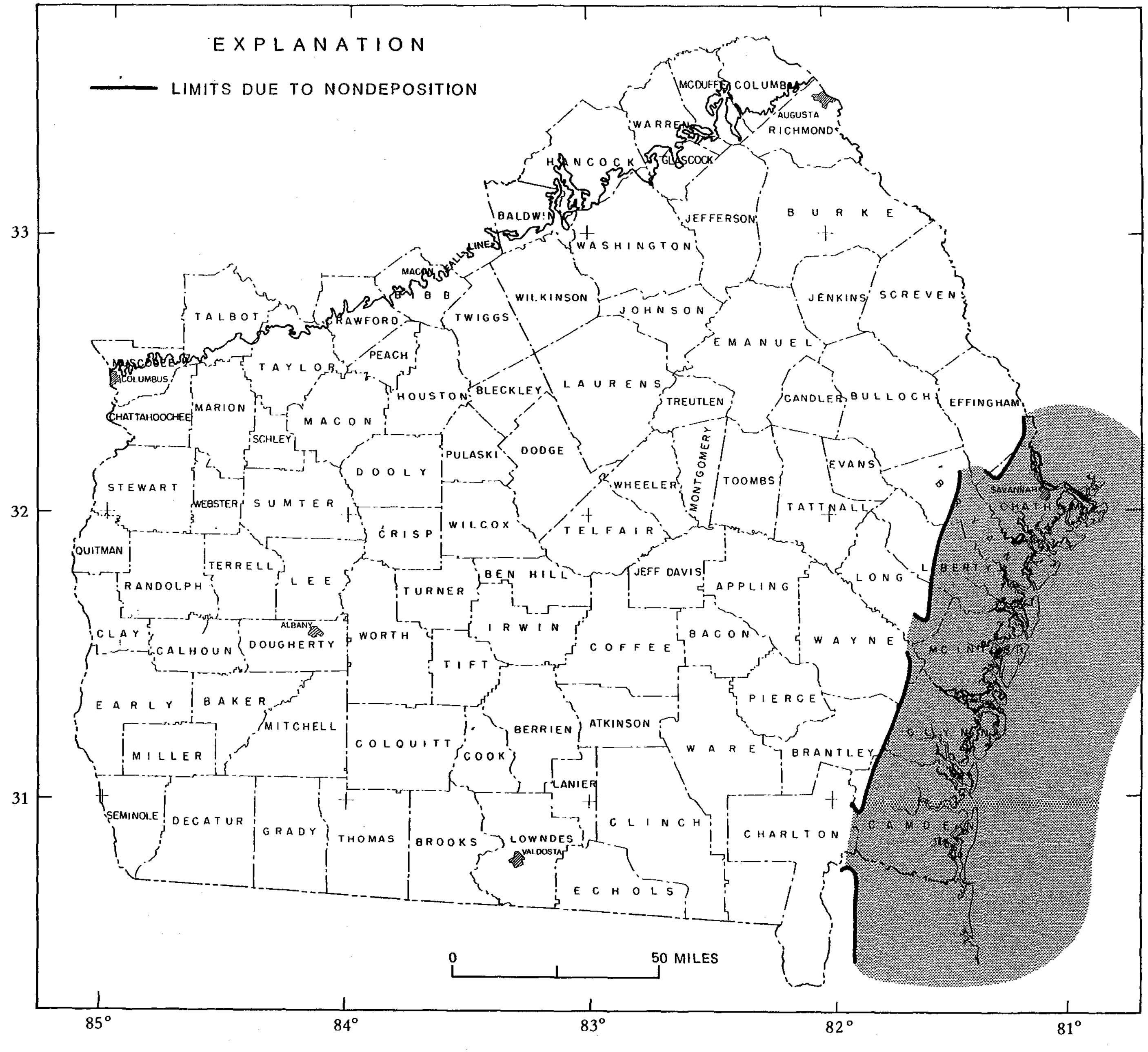


Figure 55. The areal distribution (outcrop and subcrop) of the Satilla Formation in Georgia.

section in the coastal area (Fig. 47) and is overlain only by undifferentiated surficial sand and undifferentiated alluvial deposits.

The Satilla Formation directly underlies the Pamlico and lower (or younger) marine terraces. Because the lithofacies distribution of the Satilla Formation appears to be related to the terrace landforms (i.e., barrier island and back-barrier features), the deposition of the Satilla appears to be related to the construction of the terraces (see Scott, 1976; Hails and Hoyt, 1969). However, based on examination of numerous cores, it appears to me that the lithofacies patterns described by Scott (1976) and Hails and Hoyt (1969) for the successive construction of the terraces is an oversimplification. They do not hold for the "Talbot" and higher terraces where the lithofacies patterns of the Cypresshead Formation show no relationship to the overlying terrace morphology.

The thickness distribution of the Satilla Formation in Georgia can not be established at this time because of inadequate core control. Approximately 10 feet (3 m) of Satilla Formation is exposed at the type locality, and approximately 40 feet (12 m) is exposed at Roses Bluff (also see Veatch and Stephenson, 1911, p. 435). Based on 16 cores taken in Chatham County, the Satilla Formation there ranges in thickness from 0 to 88 feet (0-27 m). The occurrence of the Satilla Formation west of Savannah (i.e., in the Pamlico back-barrier tract) appears to be discontinuous. Veatch and Stephenson (1911, p. 437-438) reported numerous occurrences of Satilla Formation in outcrop and auger holes. However, only Cypresshead Formation is present in the cores Chatham 14 (GGS-3139) and Chatham 15 (GGS-3138) (Fig. 5), indicating that the Satilla Formation in the Pamlico back-barrier tract is thin and discontinuous and that the upper surface of the Cypresshead Formation has considerable topographic relief. The Satilla Formation abruptly thickens eastward east of the Pamlico barrier island at Savannah (Pl. 2). In eastern Chatham County, on the Holocene, Silver Bluff, and Princess Anne terraces, the thickness of the Satilla Formation ranges from 49 feet (15 m) to 88 feet (27 m), and the Cypresshead Formation is absent. The large range in observed thickness (39 feet [12 m]) indicates considerable topographic relief on the pre-Satilla erosion surface.

In Glynn and McIntosh Counties, Georgia, Logan (1968) referred to the Satilla Formation of this report variously as Pamlico, Princess Anne, Silver Bluff, Holocene, and Talbot. As I interpreted the Satilla Formation in that area, it ranges from 17.5 feet (5 m) to 75 feet (23 m), and averages approximately 36 feet (11 m).

The Satilla Formation is a coastal marine unit that consists of marsh and sound deposits, barrier island deposits, and nearshore, continental shelf deposits.

Age

The Satilla Formation is of late Pleistocene and Holocene age. The molluscan faunas that have been reported from the formation (Veatch and Stephenson, 1911, p. 436; Richards, 1936, 1954; Logan, 1968) are not currently differentiable from the modern living fauna. Therefore, there is no indication that any part of the Satilla Formation may be as old as middle or early Pleistocene.

The basal beds of the Satilla Formation in Chatham County contain a small suite of planktonic foraminifera. However, there is considerable reworking of older Pliocene foraminifera from the Wabasso beds or Raysor Formation into the basal Satilla. The clearly reworked older foraminifera include *Globigerina nepenthes* and *Globigerinoides obliquus*. Commonly, but not invariably, there are preservation differences that allow discrimination between *in situ* populations and reworked populations. The Pleistocene planktonic foraminifera from the Satilla Formation in Chatham County include the following species:

Globorotalia menardii (sinistral)
G. inflata
Neogloboquadrina dutertrei
Globigerina falconensis
G. cf. *bulloides*
Globigerinoides ruber
G. quarilobatus
Globigerinella aequilateralis praesiphonifera
Globigerinita glutinata

The planktonic foraminifera are compatible with a Pleistocene age for the Satilla Formation.

UNDIFFERENTIATED ALLUVIAL DEPOSITS

Definition

The undifferentiated alluvial deposits consist of both modern flood plain deposits and river terrace deposits. These deposits occur throughout the drainage systems of the Coastal Plain, from the largest rivers to small creeks. However, the general lithologic composition of the alluvial deposits does not vary significantly between streams of different sizes, from stream valley to stream valley, or between river systems. Consequently the lithologies of the alluvial deposits cannot be differentiated from each other. They are, however, lithologically distinct from the underlying deposits and locally are mappable.

These deposits have generally been recognized and mapped in the past as undifferentiated river alluvium and terrace deposits (Cooke, 1943; Georgia Geological Survey, 1976). Veatch and Stephenson (1911), on the other hand, referred these deposits to the Satilla Formation and Okefenokee formation, distinguishing between coastal marine and alluvial phases of the formations.

Roberts (1958) presented the most modern treatment of the alluvial deposits and river terraces of Georgia. He recognized four river terraces above the modern flood plain of the Chattahoochee River and found no evidence of warping or tilting of the river terraces in the Coastal Plain.

Lithology

The undifferentiated alluvial deposits of Georgia consist predominantly of sand with minor clay. Other subordinate lithic components include gravel, mica, heavy minerals, and scattered carbonaceous or woody material. My observations on the lithologic distributions of the Quaternary alluvial deposits in the Coastal Plain, and those of Roberts (1958) for the Chattahoochee River in particular, indicate that the modern flood plain deposits are generally fine-grained, and the higher, older terrace deposits are coarser and more gravelly. The modern flood plain deposits typically consist of variably argillaceous fine-grained sand with scattered beds of finely sandy clay. Locally, as in point bars, the sand is clean, loose, and well-sorted, and ranges in size from fine to coarse (also see Teas, 1921). Bedding is seldom apparent in outcrop, and stratification is generally vague. In the smaller streams, lithology is more directly related to the valley configuration and to the immediately surrounding source area. The lithology of these deposits is, therefore, somewhat more variable in sand-size, clay content, and organic content. The basal beds of the modern flood plain deposits are more commonly coarser grained, and locally are gravelly and crossbedded.

According to Roberts (1958, p. 29-30), alluvial deposits of the Chattahoochee River flood plain and the 10- to 20-foot terrace range from clay to sandy clay, to fine-, medium- and coarse-grained sand with pea gravel and coarse gravel. Generally the sorting is poor. He observed (p. 30), that "The sands and clays are poorly cemented, friable masses with various sizes of pebbles disseminated throughout. Layers of quartz gravel are common but are not a dominant constituent."

The lithology of the alluvium of the 30- to 50-foot terrace is similar to that of the lower terraces (Roberts, 1958, p. 30). However, in the higher terraces along the Chattahoochee River, the lithology is coarser and gravel is more prevalent (Roberts, 1958, p. 30, 32). Cross-bedding is more conspicuous in the higher river deposits and the sediments are more poorly sorted.

In the central Georgia Coastal Plain, the high river terrace deposits that are present in the vicinity of the larger streams (i.e., the Ocmulgee, Oconee, and Altamaha Rivers) are lithologically reminiscent of the adjacent Screven lithofacies of the Altamaha Formation, a Miocene unit of similar fluvial origin. The Screven Member and other coarser phases of the Altamaha Formation can be distinguished from the high river terrace deposits of more recent origin in being consistently more argillaceous than the latter. Generally the clay component of the high river terrace deposits occurs in discrete clay lenses or beds, whereas the clay component of the Altamaha Formation is more commonly contained in both discrete lenses or beds, and interstitially between the sand and gravel particles.

Where high river terrace sands and gravels overlie lithologically similar pebbly to gravelly, cross-bedded sands of the lower Claibornian (Tallahatta Formation of some authors), the high terrace deposits can be distinguished in containing much coarser gravel and cobbles. I know of no occurrences in the Georgia Coastal Plain of gravel coarser than approximately 2 inches (5 cm) in diameter from deposits older than the Miocene. Quartz gravel of cobble-size is found only in Miocene or younger deposits in the Georgia Coastal Plain.

Thickness

The thickness distribution of alluvial deposits in Georgia is variable, and, there have been no data published on the thickness of these deposits in most of Georgia. In the Chattahoochee River area, however, Roberts (1958, p. 29) reported thicknesses ranging from 20 to 50 feet (6 to 14 m).

Age

With one exception (Voorhies, 1974a), no fossils have been reported from alluvial and river terrace deposits in the Coastal Plain of Georgia. Therefore the age of the alluvial terrace deposits must be extrapolated mainly from physical relationships (i.e., vertical stacking of the river terraces and relationship of this stacking to that of the marine terraces; direct association of river and marine terraces in the coastal area; and observations on lack of warping or tilting of the river terraces in the Coastal Plain). Veatch and Stephenson (1911) and Roberts (1958) identified a series of river terraces and related them to marine terraces. Veatch and Stephenson (1911) recognized only two terraces, the Okefenokee and Satilla; Roberts (1958) recognized four. Although Roberts (1958) correlated the river terraces with named marine terraces, the correlation of specific river terraces to specific marine terraces is speculative and doubtful at this time.

A significant clue to the age of the river terraces is the observation of Roberts (1958) that none of the river terraces is warped. The gradient on their surfaces appears to be no more than the original constructional gradient of the flood plain at the time of terrace construction. This observation is also compatible with my observations that none of the marine terraces or scarps are warped, a fact which argues for crustal stability in the region since the construction of the river and marine terraces. Because the youngest formations underlying the highest marine terraces (i.e., the Raysor, Jackson Bluff, Miccosukee, and Cypresshead Formations) are warped and tilted, and because these formations are late Pliocene to possibly earliest Pleistocene in age, it would seem that all of the fluvial terraces, up to elevations of 170 to 190 feet (52 to 58 m) above the present flood plain, are Pleistocene in age.

This correlation is inconsistent with the dating of the high terrace of the Flint River at Reynolds in Taylor County, Georgia, by Voorhies (1974a, p. 109-114). Voorhies (1974a) identified worn teeth of the small horse *Nannippus minor* from poorly sorted sand and gravel of the 100- to 130-foot terrace of Carver and Waters (1984). Voorhies (1974, p. 112) suggested an Hemphillian age for this deposit, based on the small size and relatively complex enamel patterns of the teeth. The Hemphillian mammal age extends from 9.0 million years to approximately 4.8 million years before the present (Tedford and Hunter, 1984) and is, therefore, late Miocene to early Pliocene in age. This age is older than any of the marine Plio-Pleistocene formations that underlie the marine terraces, and it is incompatible with warping of these formations and with lack of warping on the marine and fluvial terraces (Roberts, 1958; Carver and Waters, 1984). The question of the ages of the river terraces, and their correlation with marine terraces, is unresolved at this time.

UNDIFFERENTIATED LACUSTRINE AND PALUDAL DEPOSITS

Definition

Undifferentiated lacustrine and paludal deposits consist of lake, sink hole, Carolina bay, and swamp deposits. By nature, these types of deposits are restricted to small and isolated basins of deposition. The lacustrine and paludal deposits are lithologically distinctive and can be distinguished from both the undifferentiated alluvial deposits and the undifferentiated surficial sands. As with these other types of deposits, however, the lithologies of the lacustrine and paludal deposits in any one isolated basin are not systematically distinguishable from those of other basins in the region. Lithologies may vary, however, between specific deposits, depending on the local or regional topography and the nature of the nearby sediment source.

Lithology

In general,the lacustrine and paludal deposits have a significantly higher organic content, a higher clay and silt content, and a lower sand content than the alluvial and surficial sand deposits. In some deposits, the organic content is so high that the deposit is mined as peat (Fortson, 1961).

Thickness

Lacustrine and paludal deposits are typically thin, except possibly for sinkhole-fill. Reported thicknesses of these deposits from various lake and Carolina bay basins (Fortson, 1961) and from the Okefenokee Swamp (Cohen, 1973) indicate that the lacustrine and paludal deposits in Georgia range up to 30 feet (9 m) in lake basins with average thicknesses ranging from 10 to 15 feet (3 to 4.5 m). The greatest thickness of these deposits reported in the Okefenokee Swamp is approximately 12.5 feet (3.8 m) (Cohen, 1973).

Age

Because most of the lakes, swamps, and Carolina bays in Georgia are located on marine or fluvial terraces, all of which are believed to be Pleistocene in age, the age of th overlying lacustrine and paludal deposits must also be Plei tocene or Holocene in age. Similarly, because most of th topographic relief in the Coastal Plain of Georgia is believe to result from incision of the streams during Pleistocen time, most sinkholes must have formed only since the deve opment of the present topography (i.e., during the Plei tocene).

UNDIFFERENTIATED SURFICIAL SAND

Definition

The undifferentiated surficial sand of this report includ loose, generally structureless and massive, pale gray to bu to white sands that mantle the Georgia Coastal Plain i many areas. Sands of this type appear to be dominantly windblown origin and include aeolian drift sand, shee washed sand (also see Newell and others, 1980), barri island and river dune sand, sands that mantle emerge barrier islands and other linear sand ridges in the coast area (including Trail Ridge), and sands of probable ped genic origin in the region of low to nonexistent topograph relief in the lower Coastal Plain. The undifferentiated sur cial sands occur at the top of the local geologic sections, a underlie, or are a part of, the local soil profiles. The surficial sands do not occur in a consistent stratigraph context due to their heterogeneous origins, and they al occur at various elevations where there is considerab topographic relief. The undifferentiated surficial sands a all lithologically similar and cannot be easily differentiat on casual inspection. However, the fact that they do n occur in a consistent stratigraphic context precludes treati these sands in a formal lithostratigraphic sense. If mappe the undifferentiated surficial sands would more close resemble a soil unit than a lithostratigraphic unit. The surficial sands occur in Georgia from the Chattahooch River to the Savannah River, and from the Fall Line to t Florida state line.

Lithology

The undifferentiated surficial sand characteristically co sists of massive-bedded and structureless, well- to mode ately well-sorted, soft and incoherent, fine- to mediu grained, and rarely coarse-grained sand. The color of t sand is typically pale: white, light gray, buff, and less co monly yellow and orange. Humate is a common compone of the undifferentiated surficial sand in the coastal are Where humate is present, the sand may be tan to brown color and partially consolidated. Other known subordina components of the lithology include heavy minerals an rarely, clay.

Stratification can be observed at some sites, althou characteristically it is absent. Where present, stratificati consists of vague, thin to thick bedding, more commo distinguished on the basis of differences in sand-size of the adjacent layers. Within the beds that can be discerned, the sand is massive and structureless.

Thickness

The undifferentiated surficial sand is variable in thickness, ranging from absence, to as much as 50 feet (15 m) on Trail Ridge in Georgia. According to Newell and others (1980), the sand is at least 30 feet (9 m) thick in the Augusta area and mostly consists of colluvium. Sand dunes on the present barrier islands attain an average elevation of between 20 and 30 feet, suggesting a thickness of dune sand of at least 20 to 30 feet (6 and 9 m). Sand dunes on the north end of Cumberland Island reach elevations, and presumably thicknesses of greater than 40 feet (12 m). Elsewhere on the present barrier islands, the undifferentiated surficial sand (mainly aeolian drift sand) ranges from 0 feet to more than 6 feet (2 m) thick.

Because of insufficient exposures, thickness of the surficial sand on the emergent barrier islands is interpreted from topographic relief. Based on measured thicknesses seen in road cuts and small and pits, at least 5 feet (1.5 m) of this undifferentiated surficial sand is present on emergent barrier islands of the Princess Anne, Pamlico, Talbot, and Penholoway terraces. More than 10 feet (3 m) of surifical sand is exposed in a partially excavated Okefenokee Swamp drainage cut on Trail Ridge in Charlton County. Based on topographic relief of the emergent barrier islands and sand ridges (difference between the elevations of the back-barrier tracts and the summit elevations of the ridges), the thicknesses to be expected for the surficial sands range from 0 feet to 25 feet (7.5 m), with an average thickness between 15 and 20 feet (4.5 to 7.5 m). To repeat, however, these thicknesses have not been encountered in the field, nor have they been seen in the few cores taken on the sand ridges. On the same basis, the projected thickness of the Trail Ridge sand deposits range from 0 feet at pinchout, to as much as 50 feet (15 m) in Georgia.

My experience suggests that elsewhere in the Coastal Plain of Georgia, the undifferentiated surficial sand typically ranges in thickness from a few inches (less than 10 cm) to not more than 10 feet (3 m). Thicknesses greater than 10 feet (3 m) are exceptional and local.

Age

The age of the undifferentiated surficial sand cannot be older than the formation or terrace surface that it blankets, nor can it be older than the present topography. Therefore, in the marine terrace region, the surficial sands are all of Pleistocene age, and are probably all late Pleistocene to Holocene due to their prevailing aeolian nature.

Inland of the coastal marine terrace region, the undifferentiated surficial sand cannot be older than the present topography. There is evidence that the topographic relief of the Coastal Plain during the Hazlehurst stand of sea level was substantially less than it is today. Scattered erosional outliers of an earlier, flat to gently undulating terrain are present in the Coastal Plain of Georgia. The upland elevations of these outliers in the Fall Line region of eastern Georgia range around 500 feet (152 m) above present sea level. At the time of the Hazlehurst stand of sea level (approximately 275 feet [84 m] above present sea level), this older surface would have been no more than 225 feet (69 m) above the contemporary sea level, and less than 225 feet (69 m) above local base levels in the vicinity of the Fall Line. Therefore the maximum possible topographic relief in the vicinity of the Fall Line during the Hazlehurst stand of sea level would probably have been less than 200 feet (61 m) compared with the present 300 to 350 feet (91 to 107 m) maximum topographic relief. Consequently, a substantial proportion of the present topographic relief in the Coastal Plain of Georgia must have developed only during the Pleistocene, and most, if not all, of the undifferentiated surficial sand must be Pleistocene in age. Because of the prevailing aeolian nature of the sands, they are periodically rejuvenated or recycled, and are, therefore, probably late Pleistocene to Holocene in age.

MARINE TERRACES

Definition

Marine terraces, which are geomorphic features and not stratigraphic units, are included in this report on the lithostratigraphy of the Georgia Coastal Plain for two reasons: (1) recognition of the terraces offers penetrating insight into the geologic history and stratigraphic processes of the region, and, more important, (2) the concept of the marine terraces has significantly influenced the regional stratigraphic concepts of earlier workers (i.e., the two have traditionally been intimately related). According to the models of Cooke (1930a, 1930b, 1931, 1936, 1943, 1945), Hails and Hoyt (1969a, 1969b), and Georgia Geological Survey (1976), formations or deposits underlying the various terraces have borne the same name as the respective marine terraces. However, to be stratigraphically consistent, one must draw a clear and consistent distinction between the lithostratigraphic framework of the Georgia Coastal Plain, and the Plio-Pleistocene geomorphic framework. In this report, Coastal Plain lithostratigraphy and terrace morphology and sequence are separated.

No unique or discrete lithostratigraphic units are related genetically to any specific terrace surface. Conversely, no single marine terrace contains a discrete, unqiue lithostratigraphic unit that was deposited only during the construction of that particular marine terrace. Therefore, the concepts of the Silver Bluff, Princess Anne, Pamlico, Talbot, Penholoway, Wicomico, Sunderland, Coharie, and Brandywine formations (Cooke, 1943; Hails and Hoyt, 1969a, 1969b) are invalid, and these names should be abandoned in the lithostratigraphic sense.

Convincing evidence exists, however, that the Satilla Formation was deposited during the construction of the Pamlico, Princess Anne, and Silver Bluff-Holocene terraces and that it is, therefore, genetically related to those terrace construction events. The occurrence of back-barrier deposits (marsh clays) and barrier islands deposits within the Satilla Formation shows a direct spatial relationship to the occurrence of Pamlico, Princess Anne, Silver Bluff, and Holocene barrier island/back-barrier geomorphic features. On the other hand, the sediments of Satilla Formation under any one terrace cannot be lithologically discriminated from those Satilla sediments underlying any of the other marine terraces. Therefore, the Satilla Formation appears to be a multi-deposit formation consisting of lithologically undifferentiable components of late Pleistocene to Holocene age. The lower terraces, however, are not invariably underlain by the Satilla Formation. In the Savannah River area, portions of the back-barrier tract of the Pamlico terrace are directly underlain by the older Cypresshead Formation, with no Satilla Formation, apparently, having been deposited.

The higher and, presumably, older terraces present a different situation. The lithostratigraphic unit directly underlying the "Talbot", Penholoway and "Wicomico", and parts of the Okefenokee, Waycross (new name), and Argyle (new name) terraces is the Cypresshead Formation of late Pliocene to possibly early Pleistocene age. Although spatial relationships are evident between the lithofacies of the Satilla Formation and the location of the geomorphic features of the overlying marine terraces, no spatial relationship is discernible between the locations of the various geomorphic features of the "Talbot", Penholoway, "Wicomico", Okefenokee, and Waycross terraces, and the underlying lithologies or lithofacies distributions of the Cypresshead Formation. No evidence has been found to indicate that Cypresshead deposition is related to any of the marine terrace construction events, and the Cypresshead Formation is most likely older than any of the marine terraces (see discussion of age of Cypresshead Formation). The only existing deposits that appear to be directly related to the construction of the "Talbot", Penholoway, "Wicomico", Okefenokee and Waycross terraces are undifferentiated surficial sand deposits that cap the various emergent barrier islands and sand ridges. The surficial sands are thicker on these features but cannot be lithologically differentiated from surficial sand elsewhere in the region.

The terraces and shorelines described by Cooke (1925, 1930a, 1930b, 1931, 1936, 1943, 1945), MacNeil (1950), and Hails and Hoyt (1969a) are adopted here with modifications and a few additions. Twelve marine terraces are recognized and described in this study. In order of increasing elevation, they are the Holocene-Silver Bluff, Princess Anne, Pamlico, "Talbot", Penholoway, "Wicomico", Okefenokee, Waycross, Argyle, Claxton, Pearson (new name), and Hazlehurst (Fig. 56). I have recognized four types of marine terraces in this study: (1) geomorphically simple terraces consisting of gently inclined, featureless, flat surfaces bounded by two low, presumably wave-cut scarps; (2) geomorphically complex terraces — referred to in this report as terrace complexes — consisting of barrier islands or emergent barrier islands, barrier island-like sand ridges, and back-barrier tracts; (3) a few terraces — referred to in this report as composite marine terraces — having distinct and separated components of both simple marine terraces and marine terrace complexes; and (4) massive beach ridge systems lacking any back-barrier tracts.

The scarps that bound the geomorphically simple marine terraces are low, presumably wave-cut scarps that represent changes in elevation of approximately 10 to 15 feet (3 to 4.5 m) over a distance of approximately 1 to 2 miles (1.6 to 3.2 km). The landward bounding scarp of any terrace was presumably formed as a wave-cut coastal feature during the construction of that terrace. For the terrace complexes, however, the bounding scarps are the seaward faces of emergent barrier islands or barrier island-like sand ridges. These are not wave-cut features but constructional features.

The use of the word "shoreline" in describing terraces features is an oversimplification. For terrace complexes with barrier islands, barrier island-like sand ridges, beach ridge systems, back-barrier marshes, sounds, and lagoons, there are also complex and sinuous shorelines. For these terraces, the concept of "shoreline" has little meaning.

Whether the terrace geomorphologies are simple, complex, or composite depends on the adequacy of the sand supply to the coastal paleo-environment. Where the coastal environment was sand-starved, as along the northwestern peninsula of Florida during the Pleiscocene and Holocene, terraces of simple geomorphology were constructed. Where there was an abundance of sand in the coastal environment, beach ridge masses were constructed without sizable back-barrier tracts, as along the coast of eastern Florida. Where there was a moderate supply of sand to the coastal environment, as in eastern Georgia during the construction of the Penholoway and younger terraces, a complex coastal geomorphology was generated with barrier islands, various kinds of sand ridge systems, and back-barrier tracts with marsh, lagoon, or open sound. The type of development on any given terrace, therefore, is regionally variable and varies from area to area. For example, the Pamlico terrace has only simple morphology in northwestern peninsular Florida, has complex morphology in Georgia, and is characterized by sand-choked beach ridge systems in northeastern Florida. In addition, evaluation of the terraces in South Carolina, Georgia, and Florida suggests that both the sources and directions of sand transport have fluctuated in the region throughout the Quaternary, producing an even more complicated marine terrace system. As a result of the variations of the factors controlling coastal construction processes, each of the well preserved marine terraces has a set of characteristics that locally serve to distinguish it geomorphologically from all the other terraces.

Uniform elevations of scarps and terrace surfaces are characteristic of those terraces of simple geomorphology. They have been produced mainly by the eroding capabilities of waves, tides, and currents (destructional processes) at elevations near sea level. In South Carolina, Georgia, and northern Florida, the elevations of all the marine terraces of simple geomorphology do not vary significantly (e.g., the average elevation of the Okefenokee terrace from the Cape Fear River in North Carolina, to northern Florida is invariably between 110 and 120 feet [33 and 37 m] above sea level). As a result, contrary to the conclusions of MacNeil (1950), Hoyt (1969), and Winker and Howard (1977), none of the marine terraces in this region appear to have been tectonically tilted or warped. As a corollary, moreover, this region apparently has been tectonically stable and quiescent during the period of construction of all of the marine terraces.

In contrast to the marine terraces of simple morphology, the elevations on the marine terraces of complex geomorphology are variable. For example, the elevations on the Penholoway terrace in Georgia range from approximately 55 feet (17 m) to 100 feet (30 m) above sea level, a range of roughly 45 feet (14 m). This elevation differential, in light of the apparent tectonic stability, must be a reflection of topographic features formed during the construction of the terrace. Clearly, an investigator must approach the tasks of marine terrace recognition, correlation, and terminology with caution because of the large elevation differentials that are possible. Indeed, the highest elevations on one terrace complex may be higher than the lower elevations of an adjacent, higher, and older terrace complex.

Other factors affect terrace study, and these demand caution on the part of the investigator in recognizing and correlating marine terraces. First, the development of the emergent barrier islands, barrier island-like sand ridges, and back-barrier tracts is variable. The shoreline positions of some barrier islands have clearly been reoccupied during subsequent high stands of sea level (e.g., the shoreline of the present Holocene barrier islands, which were emergent Silver Bluff barrier islands during the Wisconsin low sea level stand, reoccupied the shoreline position of the Silver Bluff barrier islands). Similarly, back-barrier tracts have also been reoccupied during subsequent high stands of sea level (e.g., the Holocene marsh has reoccupied the Silver Bluff marsh, the Princess Ann marsh may have reoccupied the Pamlico marsh and back-barrier tract, and the Okefenokee back-barrier tract [sound?] had reoccupied the Waycross back-barrier tract [sound?]).

Second, in some instances, previously existing terraces have been obliterated by later terrace construction events. For example, the "Wicomico" back-barrier tract north of the Altamaha River has been deeply embayed by the Penholoway back-barrier, and south of the Altamaha River there is no existing "Wicomico" terrace between the vicinity of Jesup in Wayne County, and the vicinity of Folkston in Charlton County.

Third, the development of the back-barrier tracts is extremely variable in Georgia. The average breadth of the Holocene back-barrier (marsh) in Georgia is between 5 and 10 miles (8 and 16 km) whereas the average breadth of the Pamlico back-barrier is between 15 and 20 miles (24 and 32 km). On the other hand, in some instances no back-barrier is developed (e.g., where the "Talbot" barrier islands are constructed against the seaward faces of the Penholoway emergent barrier islands north of the Altamaha River).

There is also the possibility, although the evidence in Georgia is not clear on this point, that some terraces may have been constructed during multiple, closely spaced sea level stands. Given the present average tidal range along the coast of Georgia of approximately 7 feet (2 m), recurring sea level stands within a range of less than 15 feet (4.5 m) would be difficult to recognize, except possibly in the vicinity of large rivers where there is an abundant clastic source with active and rapid outbuilding of the coast.

There are three groups of terraces in Georgia, based on geomorphological distinction. They are referred to in this report as the lower, middle, and upper terraces. The lower terraces consist of the Holocene-Silver Bluff, Princess Anne, and Pamlico terrace complexes (Fig. 56). These terraces are characterized by numerous short, stubby barrier islands; by back-barrier marshes; and by widespread sedimentation associated with coastal construction (Satilla Formation). The lower terraces are the only terraces where active regional sedimentation has occurred during construction.

The middle terraces include the "Talbot," Penholoway, and "Wicomico" terrace complexes, and the Okefenokee and Waycross composite terraces (Fig. 56). These terraces are characterized by strong barrier island development with large, long, prominent barrier islands, barrier island-like ridges, and beach ridge systems in Georgia. The Okefenokee and Waycross terraces are exceptional in that they are the only composite terraces in Georgia. North of the Altamaha River, the Okefenokee and Waycross terraces are morphologically simple. South of the Altamaha River, they consist of a broad back-barrier tract that is morphologically simple, and of extensive sand ridge development (Trail Ridge, Waycross Ridge, and Lake City Ridge). Trail Ridge in Georgia must have been initially constructed during the Waycross terrace construction event, based on the elevation of the ridge and the occurrence of Waycross back-barrier tract west of the ridge in Georgia and Florida. After the withdrawal of the sea following the Waycross terrace construction, the coastal area was reinundated with the Okefenokee sea level stand. Both Trail Ridge and the expansive back-barrier tract between Trail Ridge and the mainland (site of present Okefenokee Swamp) were reoccupied by the sea.

Trail Ridge (Cooke, 1925; MacNeil, 1950; Pirkle, 1972) is the most prominent barrier island-like ridge in the state. Unlike the younger, lower barrier islands and barrier island-like ridges, it progressively becomes higher and more massive to the south, suggesting that the source of sand may

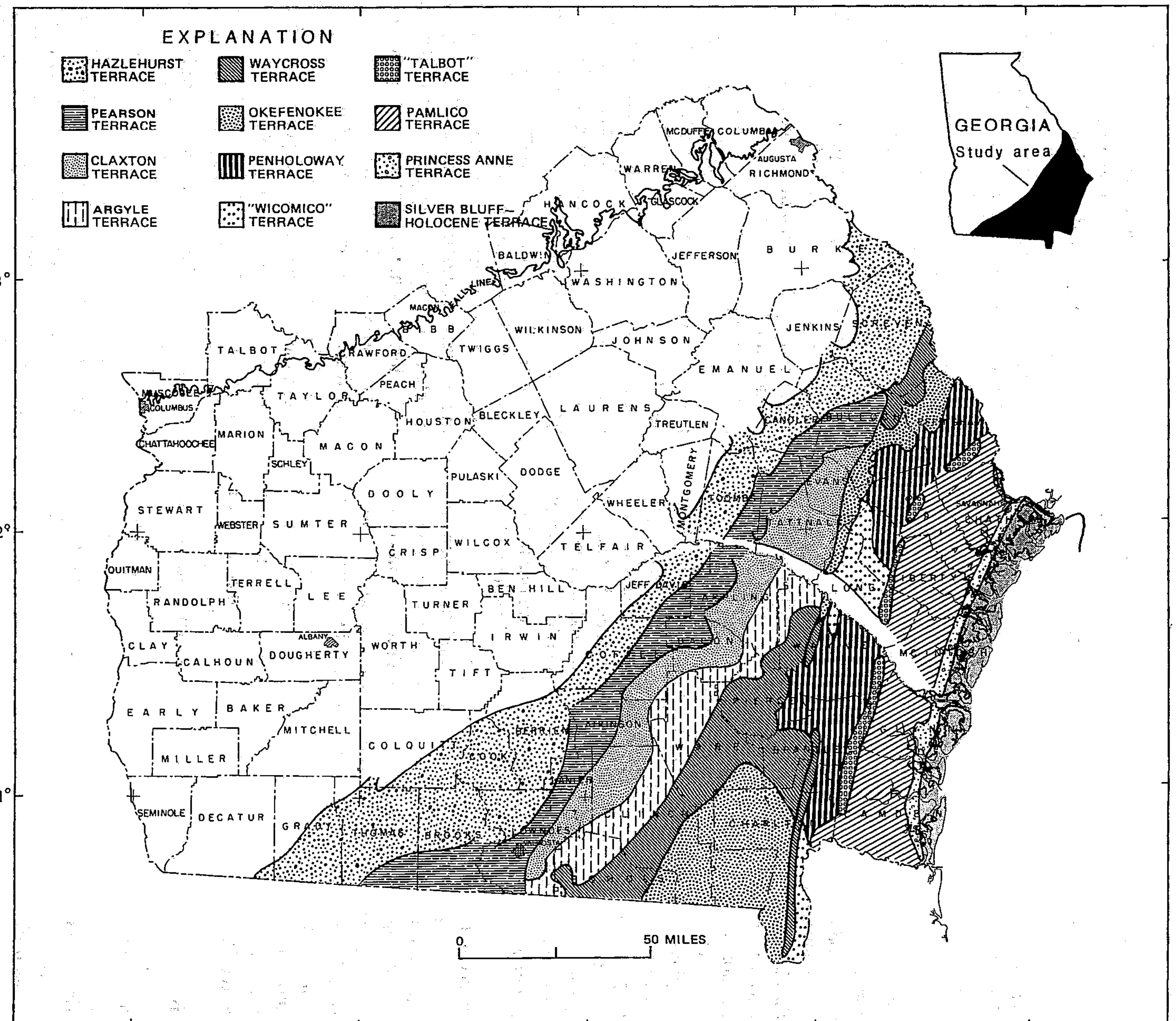


Figure 56. Generalized map of the marine terraces and the dissected marine terrace region of Georgia.

have been from the south. In contrast, all of the lower barrier systems in Georgia are more strongly developed near the major rivers, and become more weakly developed between the major rivers, suggesting that their sources of sand were the major rivers.

The upper terraces consist of the Argyle, Claxton, Pearson, and Hazlehurst (Fig. 56). These marine terraces are characterized, in Georgia, both by the absence of emergent barrier islands, barrier island-like ridges, back-barrier tracts, and associated deposits, and also by the simplicity of their morphology. The Argyle and Claxton terraces have relatively large expanses of undissected terrain, but the Pearson and Hazlehurst terraces are deeply dissected in most areas, with only a few remnants of undissected terrace still preserved.

The major terraces are separated by regular elevation intervals of approximately 25 feet (7.6 m) (i.e., the sea level stands that resulted in the construction of the major terraces were separated by intervals of approximately 25 feet [7.5 m]). In ascending order of age or elevation, these sea level stands and the resulting terraces are the following: Pamlico (25 feet [7.6 m]), "Talbot"(50 feet [15 m]), Penholoway (75 feet [22.5 m]), Okefenokee (125 feet [37.5 m]), Waycross (150 feet [46 m]), Argyle (175 feet [53 m]), Claxton (200 feet [61 m]), Pearson (225 feet [68.5 m]), and Hazlehurst (275 feet [84 m]). The only exceptions to this progression are the "Wicomico" sea level stand at between 90 and 95 feet (27.5 and 29 m), and the absence of evidence for a sea level stand at approximately 250 feet (76 m) above sea level. The Silver Bluff and Princess Anne appear to represent minor sea level stands in that these terraces are poorly developed or absent in marine terrace regions outside of the Sea Island district.

Discussion

Holocene-Silver Bluff terrace complex

The Holocene and the Silver Bluff (Cooke, 1945, p. 248; MacNeil, 1950) represent two different and distinct coastal construction events but are combined in this study because the Silver Bluff terrace was largely reoccupied by the Holocene transgression and its terracing event. The Silver Bluff marsh was reoccupied by the Holocene marsh, and the Holocene barrier islands are merely a continuation of the Silver Bluff barrier islands. The two terrace construction events, therefore, have merged, producing one marine terrace. The Holocene component of the terrace includes the present day barrier islands that have been constructed against the seaward faces of the Silver Bluff barrier islands, except in the vicinity of the Savannah and Altamaha Rivers where the Holocene marsh and barrier islands have been constructed seaward of the Silver Bluff barrier islands. The Holocene barrier islands are characterized by prominent modern dune development, in contrast to the subdued topography on the Silver Bluff barrier islands that are devoid of sand dunes. Only the greater topographic relief on the Holocene, because of continuing dune construction, serves to distinguish the Holocene component from the topographically more subdued Silver Bluff. In addition, the Silver Bluff marsh stands slightly higher than the Holocene marsh and generally is inundated only during the highest tides.

Holocene and Silver Bluff barrier islands are equally developed along the coast of Georgia with little or no distinction in styles of construction between those barrier islands adjacent to the major rivers and those distant from the major rivers.

The summit elevations of the Holocene barrier islands range from near sea level to approximately 45 feet (14 m) at the crests of the highest sand dunes. The average summit elevations of the Holocene islands typically are between 10 and 20 feet (3 to 6 m). The width of the Holocene marsh typically ranges from 3 to 6 miles (5 to 9.5 km). The elevation of the back-barrier tract is sea level to approximately 7 feet (2 m) above sea level.

Sea level during the Silver Bluff construction event stood at approximately 6 feet (1.8 m) above present sea level. The summit elevations of the Silver Bluff barrier islands typically range from 10 to 20 feet (3 to 6 m) with some localized elevations being in excess of 40 feet (12 m). Elevations on the Holocene-Silver Bluff terrace complex range from near sea level to 45 feet (14 m), a relief of more than 45 feet (14 m), including sub-sea level elevations of tidal channels.

The Holocene-Silver Bluff terrace complex is directly underlain by the Satilla Formation.

Princess Anne terrace complex

The Princess Anne (Hails and Hoyt, 1969) terrace complex bears the same relationship to the Pamlico terrace that the Holocene bears to the Silver Bluff (i.e., the Princess Anne marsh largely reoccupied the Pamlico marsh, and Princess Anne barrier islands, in most instances, were constructed against the seaward faces of the older Pamlico barrier islands). Princess Anne back-barrier tracts (marshes), as distinct from those of the reoccupied Pamlico back-barrier tracts, are very poorly developed or lacking in Georgia.

The emergent Princess Anne barrier islands are almost equally developed along the coastal area of Georgia with only slightly more prominent development near the major streams.

Sea level during the Princess Anne terrace construction event stood at approximately 13 feet (4.0 m). The summit elevations of the Princess Anne barrier islands range from approximately 15 to 25 feet (4.5 to 7.6 m) whereas the elevations of the suspected back-barrier tracts, where developed, range from approximately 10 to 20 feet (3 to 6 m) above sea level. Elevations on the Princess Anne terrace complex, therefore, range from approximately 10 to 25 feet (3 to 7.6 m), a range of 15 feet (4.5 m).

The Princess Anne terrace complex is directly underlain by the Satilla Formation.

Pamlico terrace complex

The Pamlico terrace complex of this report, or Pamlico terrace, was originally described as the Pamlico formation and Pamlico terrace in North Carolina (Stephenson, 1912, p. 286-290). Cooke (1930a, 1930b, 1931, 1936, 1943, 1945) applied the name Pamlico both to a marine terrace that was constructed when sea level stood at approximately 25 feet (7.6 m) above present sea level, and to a formation. Pamlico as a marine terrace name is retained in this report because of its widespread acceptance and continued usage in the sense of a marine terrace or shoreline complex (Hails and Hoyt, 1969; Mann, 1974; Georgia Geological Survey, 1976) and because it was originally also described as a terrace (Stephenson, 1912, p. 287).

The Pamlico terrace complex is morphologically similar to the Holocene-Silver Bluff terrace complex (i.e., it is characterized by numerous short, stubby, emergent barrier islands; by well developed back-barrier tracts; and by active sedimentation associated with coastal construction). There are two significant differences, however, between the Pamlico and the Holocene-Silver Bluff in Georgia. The Pamlico emergent barrier islands are prominently developed only adjacent to the major streams (Savannah and Altamaha Rivers) and are very poorly developed or nonexistent as barrier islands in the reaches away from the large rivers. Also, the back-barrier tract is extraordinarily wide compared to the Holocene-Silver Bluff back-barrier. The Pamlico back-barrier tract varies from 10 to 20 miles (16 to 32 km) across, compared with an average of 3 to 6 miles (5 to 9.6 km) for the Holocene-Silver Bluff.

Sea level during the Pamlico terrace construction event stood at approximately 25 feet (7.6 m). The summit elevations of the emergent Pamlico barrier islands range from approximately 25 to 35 feet (7.6 m to 10.5 m), with local summit elevations exceeding 40 feet (12 m). The elevations of the Pamlico back-barrier tract range approximately from 15 to 25 feet (4.5 to 7.6 m). The topographic relief on the Pamlico terrace complex, therefore, is at least 25 feet (7.6 m).

Large expanses of the Pamlico back-barrier tract are at elevations between 15 to 25 feet (4.5 and 7.6 m) above present sea level. In view of the projected Pamlico sea level stand of approximately 25 feet (7.6 m) above present sea level, large expanses of the Pamlico back-barrier were apparently below sea level and may have existed as open sound rather than marsh as maintained by Hails and Hoyt (1969), Mann (1974), and Georgia Geological Survey (1976). However, marsh-type clay deposits are present in the Pamlico back-barrier tract (also see Logan, 1968; Scott, 1976). Consequently, the Pamlico marshes probably existed either as tracts within the sound or as marsh fringing the sound. In appearance, the Pamlico coastal geomorphology in Georgia would have departed significantly from that of the modern Georgia coast.

In most places, the Satilla Formation directly underlies both the Pamlico terrace surface and the undifferentiated surficial sands that mantle the emergent Pamlico barrier islands on the terrace. The Satilla Formation appears to have been deposited during the construction of the terrace. However, in the Savannah River area in northern Chatham County, the Cypresshead Formation directly underlies portions of the Pamlico back-barrier surface and the undifferentiated surficial sands that form the Pamlico sand ridge near the Savannah airport. At least in that area, no appreciable sedimentation appears to have accompanied the construction of the Pamlico terrace.

"Talbot" terrace complex

The "Talbot" terrace of this report was originally described as the Talbot formation in Maryland (Shattuck, 1901, 1906). Cooke (1931, 1930a, 1930b,) also applied the name Talbot to a marine terrace that was believed to have been constructed when sea level stood at 42 feet (12.8 m) above present sea level, but he also referred the deposits underlying the "Talbot" terrace to the Talbot formation (Cooke, 1936, 1943, 1945). Talbot as a terrace name is considered to be inappropriate in this report because the name Talbot was originally applied to a formation. However, because there are no good reference areas on which to base a new terrace name for this particular terrace in Georgia, the name "Talbot" terrace will be retained in this report.

The concept of the "Talbot" terrace (Cooke, 1931) is modified from that of previous usage. Whereas, in the past, the sea level stand during the construction of the "Talbot" terrace was postulated to be near 42 feet (12.8 m) above present sea level (Cooke, 1931, 1936, 1943, 1945; Hails and Hoyt, 1969), there is no definitive evidence in Georgia, northern Florida, or South Carolina for a scarp or sea level stand at that elevation.

In areas where barrier islands are not developed and the marine terraces are of simple morphology, such as along the present coast of the Gulf of Mexico in the northwestern peninsula of Florida, a scarp consistently occurs at the elevation of approximately 50 feet (15 m), and no other scarp occurs between it and the Pamlico scarp at 25 feet (7.6 m). Similarly, only one gently sloping terrace surface occurs between the scarp at 50 feet (15 m) and the Pamlico scarp. This marine terrace surface, between 25 and 50 feet (7.6 and 15 m) above present sea level, incorporates most of the "Talbot" terrace of Cooke (1931). For that reason, the scarp at approximately 50 feet (15 m) is assigned to the "Talbot". The elevations of the emergent "Talbot" barrier islands and "Talbot" back-barrier tract in eastern Georgia are compatible with this higher elevation for the "Talbot" sea level stand. Therefore, as defined in this study, the "Talbot" is that terrace complex, in Georgia, constructed when sea level stood at approximately 50 feet (15 m).

The "Talbot" barrier complex in Georgia is mainly represented by emergent barrier islands and beach ridge complexes (Fig. 56). Generally, the "Talbot" barrier islands were constructed against the seaward faces of the adjacent Penholoway barrier islands, analogous to the Holocene barrier islands constructed against the Silver Bluff barrier islands, and the Princess Anne barrier islands against the Pamlico barrier islands. Only between Brantley County and the St. Marys River are the emergent "Talbot" barrier islands separated from the emergent Penholoway barrier islands by what appears to have been a "Talbot" back-barrier tract (now the valley and flood plain of the Satilla River). The only surviving tract of "Talbot" back-barrier in Georgia occurs in Wayne County.

South of the Altamaha River in Georgia, the "Talbot" barrier islands are prominent and equally developed, showing little if any difference in construction from the vicinity of the Altamaha River to reaches far from the river. On the other hand, north of the Altamaha River, the "Talbot" barrier islands are prominent only near the Savannah, Ogeechee, and Altamaha Rivers.

The summit elevations on the emergent "Talbot" barrier islands in Georgia range from 55 feet to 75 feet (17 m to 23 m), a relief of 20 feet (6 m). The elevation of the "Talbot" back-barrier tract ranges from 45 to 50 feet (13.5 to 15 m). The total relief on the "Talbot" terrace complex in Georgia is approximately 30 feet (9 m).

The Cypresshead Formation directly underlies both the "Talbot" terrace surface and the undifferentiated surficial sands that mantle the emergent "Talbot" barrier islands.

Penholoway terrace complex

The name Penholoway was originally applied to a marine terrace (Cooke, 1925). Subsequently, the deposits underlying the Penholoway terrace were also called the Penholoway formation (Cooke, 1936, 1943, 1945; Connell, 1969). The lithostratigraphic context of the Penholoway is abandoned in this report, however, and the name is used in its original sense as a marine terrace.

The Penholoway terrace complex in Georgia is characterized by prominent emergent barrier islands, sand ridge systems of uncertain origin, and extremely variable development of back-barrier tracts. The morphological variability and complexity of the Penholoway terrace complex in Georgia may have resulted from the terrace's being constructed during more than one marine occupation of the terrace.

In its type area in Wayne and Brantley Counties, the Penholoway terrace complex consists of a narrow but prominent emergent barrier island and a very broad back-barrier tract that is up to 15 miles (24 km) wide. The terrace narrows to the south, and the emergent barrier islands change form to become massive and stubby sand ridges. Some of the ridges have the appearance of intrasound beach ridge systems. The Penholoway back-barrier tract pinches out near Folkston. South of Folkston, in Florida, the Penholoway terrace consists only of an emergent barrier island component that apparently was constructed against the seaward face of a "Wicomico" barrier island.

North of the Altamaha River, the Penholoway barrier islands are strongly developed only near the major rivers. In addition, the back-barrier tracts of the Penholoway deeply embay the back-barrier tracts of the "Wicomico" terrace and the Okefenokee terrace.

Sea level during the Penholoway terrace construction event stood at approximately 70 to 75 feet (21 to 23 m). The summit elevations of the emergent Penholoway barrier islands or sand ridges range from approximately 75 to 95 feet (23 to 29 m), but elevations as high as 100 feet (30 m) occur in the Folkston area. The elevations of the Penholoway back-barrier tracts typically range from 55 to 70 feet (17 to 21 m) but also range upward to elevations as high as 75 to 80 feet (23 ro 24 m) in those areas where the Penholoway embays the "Wicomico". The total relief on the Penholoway terrace complex is approximately 45 feet (14 m).

The Penholoway terrace and the undifferentiated surficial sands that mantle the emergent barrier islands are directly underlain by the Cypresshead Formation.

"Wicomico" terrace

The "Wicomico" terrace of this report was originally described as the Wicomico formation in Maryland (Shattuck, 1901, 1906). Cooke (1930a, 1930b, 1931) later applied the name Wicomico to a marine terrace that was believed to have been constructed when sea level stood at approximately 100 feet (30 m) above present sea level. However, he also referred the deposits underlying the Wicomico terrace to the Wicomico formation (Cooke, 1936, 1943, 1945). Wicomico as a terrace name is considered to be inappropriate in this report because the name Wicomico was originally applied to a formation. However, because there are no good reference areas on which to base a new terrace name for this particular terrace in Georgia, the name "Wicomico" terrace will be retained in this report.

The "Wicomico" terrace is very poorly developed in Georgia and appears to have been largely consumed by erosion prior to or during the construction of the Penholoway terrace complex. As a result, only remnants of the "Wicomico" terrace are preserved in Georgia. These include a back-barrier tract betwen the St. Marys River and Trail Ridge in southern Charlton County, possibly the sand ridge (emergent barrier island?) on which Jesup is built in Wayne County, some deeply embayed back-barrier remnants north of the Altamaha River in Long and Liberty Counties, and possibly a small barrier island/back-barrier set near Springfield in Effingham County. Moreover, some of the Penholoway barrier islands may be, in part, reoccupied "Wicomico" barrier islands.

In contrast to the interpretation of Cooke (1931, 1936, 1943, 1945) and of others (MacNeil [1950]; Hails and Hoyt [1969]), sea level during the "Wicomico" terrace construction event is here postulated to have stood at approximately 90 to 95 feet (27 to 29 m) rather than 100 feet (30 m) above present sea level. This conclusion is consistent with (1) the scattered back-barrier tracts at 80 to 95 feet (24 to 29 m) in Georgia, (2) the elevations of the well-developed "Wicomico" back-barrier tracts of 80 to 90 feet (24 to 27 m) in South Carolina, and (3) the elevation of approximately 90 to 95 feet (27 to 29 m) of a prominent scarp along the Gulf of Mexico in northwestern peninsular Florida.

In South Carolina and perhaps in northeastern Florida, the summit elevations of the "Wicomico" barrier islands range from approximately 95 to 105 feet (29 to 32 m). The elevations of the "Wicomico" back-barrier tracts typically range in elevation from approximately 80 to 95 feet (24 to 29 m). The relief on the "Wicomico" terrace complex, therefore, appears to be approximately 25 feet (7.5 m).

The "Wicomico" terrace in Georgia is directly underlain by the Cypresshead Formation.

Okefenokee terrace (redefined)

The name Okefenokee terrace was first used by Veatch and Stephenson (1911), expanded on by Cooke (1925), and abandoned by Cooke (1931). MacNeil (1950) reintroduced the concept of the Okefenokee in a geomorphologic sense when he recognized an Okefenokee "shoreline" at an elevation of 150 feet (46 m). By implication, the Okefenokee terrace (not referred to as such by MacNeil, 1950) occupied the terrain between the scarp at 150 feet (36 m) and the presumed shoreline at 100 feet (30 m). There is also, however, a low scarp at 125 feet (38 m), not recognized by MacNeil (1950), that bounds the Okefenokee Swamp on the west. As a result, this author proposes a modification of the scheme introduced by MacNeil (1950). The terrain bounded by the scarp at 150 feet (46 m) and by the "Wicomico" terrace (sea level stand at approximately 90 to 95 feet) is divided into two terraces in this report. The upper of the two terraces is herein referred to as the Waycross terrace. It is bounded on the landward (western) side by a low scarp at approximately 150 feet (46 m) (Okefenokee shoreline of MacNeil, 1950). The lower of the two terraces is herein referred to as the Okefenokee terrace because the greater part of that terrace in Georgia is occupied by the Okefenokee Swamp. The Okefenokee terrace is bounded on the landward (western) side by a low scarp at approximately 125 feet (38 m).

The Okefenokee terrace is a composite terrace in Georgia. In the northern area, between the vicinity of Jesup and the Savannah River, it has simple terrace morphology, but in the southern area, in the Okefenokee basin, it has both simple and complex morphology. In the northern area, the Okefenokee terrace is restricted to the region east of the Orangeburg Escarpment (Fig. 56). In the southern area, it is found only west of Trail Ridge and south of the Satilla River. In this southern area, the Okefenokee terrace consists of a very wide back-barrier tract up to 30 miles (50 km) across that is now mainly occupied by the Okefenokee Swamp (Fig. 58). The Okefenokee terrace is bounded on the east by the eastern flanks of Trail Ridge, and on the north by a complex of anomalous sand ridges included in the Waycross Ridge. Trail Ridge and the associated Waycross Ridge are older features that were reoccupied during the Okefenokee stand of sea level. Trail Ridge may have been added to during the construction of the Okefenokee terrace, but the only sand ridges in Georgia that appear to have been constructed during the formation of the Okefenokee terrace are an obscure set of ridges paralleling and immediately south of Waycross Ridge. There is no development of barrier islands or sand ridges in the northern segment of the Okefenokee terrace in Georgia. There is no evidence that the Okefenokee terrace was ever present between the Okefenokee Swamp in Charlton County and the vicinity of Jesup in Wayne County (Fig. 56).

Sea level during the Okefenokee terrace construction event stood at approximately 125 feet (38 m). The typical elevations on the Okefenokee terrace range from 110 feet to 120 feet (33.5 m to 36.5 m). On the obscure associated sand ridges, summit elevations range from 120 to 130 feet (36.5 to 40 m), whereas on Trail Ridge, summit elevations range from approximately 135 feet to 175 feet (41 m to 53 m).

Between the Canoochee and Savannah Rivers, there are some remnants of extremely flat terrain with elevations between 95 and 105 feet (29 and 32 m). In this report, this terrain is included in the Okefenokee terrace because it is continuous in several places with surfaces of typical Okefenokee elevations. The total relief on the Okefenokee terrace complex, therefore, is approximately 80 feet (24 m).

In its northern segments, the Okefenokee terrace in Georgia is directly underlain by the Cypresshead Formation. The eastern part of the southern segment (i.e., the eastern part of the Okefenokee swamp), is directly underlain by swamp deposits or the Cypresshead Formation. The southwestern part of the southern segment is directly underlain by the Statenville Formation of the Hawthorne Group.

Waycross terrace (new name)

The Waycross terrace is a new terrace name proposed herein for that marine terrace that is bounded on the landward side by a low scarp at approximately 150 feet (46 m), and on the seaward side by the scarp at approximately 125 feet 38 m). Typical elevations on the Waycross terrace range from 130 to 140 feet (40 m to 43 m). The name Waycross is taken from the town of Waycross in Ware County, Georgia, that is built on the Waycross terrace.

The Waycross terrace of this report is the upper part of the Okefenokee terrace of Cooke (1925), and the scarp at 150 feet (46 m) is the Okefenokee shoreline of MacNeil (1950).

The Waycross terrace is a composite terrace in Georgia (i.e., it occurs with both simple terrace morphology and complex terrace morphology). Like the Okefenokee terrace, the Waycross terrace occurs in two different areas in Georgia; the southern segment includes Trail Ridge, Waycross

Ridge, and Lake City Ridge and a large expanse west of the Okefenokee terrace (Fig. 56). The northern segment occurs east of the Orangeburg Escarpment in Bulloch, Effingham, and Screven Counties, Georgia. The northern segment and the western part of the southern segment of the Waycross terrace are morphologically simple. However, Trail Ridge marks the eastern limit of the Waycross terrace in Brantley and Wayne Counties. South of Brantley County, Trail Ridge is separated from the rest of the Waycross terrace by the Okefenokee terrace, a large embayment in the Waycross terrace (Fig. 56).

Trail Ridge is the highest and most massive barrier island-like sand ridge in Georgia (also see Cooke, 1925; MacNeil, 1950; Pirkle, 1972). Its summit elevations, in Georgia, range from 135 feet to 175 feet (41 to 53 m). Farther south in Florida, the summit of Trail Ridge reaches elevations of 250 feet (76 m). In the past, Trail Ridge had been placed in the Sunderland terrace (Cooke, 1943; 1945), and in the "Wicomico" terrace (Hails and Hoyt, 1969; Mann, 1974; Georgia Geological Survey, 1976), and associated with the scarp at 150 feet (46 m) (MacNeil, 1950). Trail Ridge is considered to be a part of the Waycross terrace of this report because (1) the summit elevations of Trail Ridge (140 feet to 175 feet [43 m to 53 m]) in Georgia are compatible with elevations expected of the Waycross terrace and (2) Trail Ridge in Brantley and Wayne Counties occurs adjacent to and east (seaward) of the Waycross terrace surface, the standard configuration for a barrier island, back-barrier system (Fig. 56). In addition, the Okefenokee terrace lies east (seaward) of Trail Ridge in northern Wayne County, thus bracketing the terrace relationships of Trail Ridge.

Further evidence that Trail Ridge is not a part of the "Wicomico" terrace is the occurrence of "Wicomico" back-barrier east (seaward) of Trail Ridge in southern Charlton County, between Trail Ridge and the St. Marys River (Fig. 56). In addition, the Waycross Ridge, which must have been constructed during construction of the Waycross terrace because it lies directly on the Waycross surface and shows no geographic relationship to older or younger terraces, is a spur of Trail Ridge and has similar summit elevations (135 to 150 feet [41 to 46 m]). Furthermore, Trail Ridge and its spurs, the Waycross Ridge in Georgia and the Lake City Ridge in Florida, must have been reoccupied at least one time during the Pleistocene sea level fluctuations in the region. Trail Ridge, it appears, was reoccupied during the Okefenokee stand of sea level. Since both "Wicomico" and Penholoway back-barrier tracts abut Trail Ridge on the east, the ridge evidently served locally as a shoreline during construction of these terraces.

Additional evidence that Trail Ridge is part of the Waycross comes from Pirkle and Czel (1983), who reported macrofossils from elevations of 132 feet to 161 feet (41 m to 49 m) above sea level in cores from the southern part of Trail Ridge in Georgia. This finding is largely compatible with a seal level stand at approximately 150 feet (46 m). Fossil occurrences up to 11 feet (3.3 m) above the Waycross sea level stand could be attributed to extreme, but not unusual, tidal ranges or storms. Finally, it is possible, but less likely, that Trail Ridge construction could have been initiated to the south in Florida, where the summit elevations on the ridge reach 250 feet (76 m), during an earlier and higher stand of sea level. If the construction was initiated in Florida, the Trail Ridge was possibly not just reoccupied during successive high stands of sea level, but may also have been constructed through increments during these various high stands of the sea.

The Statenville Formation of the Hawthorne Group directly underlies the Waycross terrace in Georgia near the Florida state line, and the Screven Member of the Altamaha Formation or the Cypresshead Formation directly underlies the terrace surface north of the vicinity of Waycross. Trail Ridge in Georgia is constructed on the Cypresshead Formation. The Cypresshead Formation also directly underlies the Waycross terrace surface (or the undifferentiated surficial sands that mantle its surface) in its northern segment in Bulloch, Effingham, and Screven Counties.

Argyle terrace (new name)

The Argyle terrace is a new terrace name proposed herein for that marine terrace that is bounded on the landward side by the low scarp at approximately 170 to 175 feet (52 to 53 m) above sea level, and on the seaward side by the low scarp at approximately 150 feet (46 m). Typical elevations on the Argyle terrace range from approximately 155 to 165 feet (47 to 50 m). The Argyle terrace and all of the higher terraces in Georgia are morphologically simple (i.e., they are gently inclined surfaces bounded by low, presumably wave-cut scarps, and they do not have associated emergent barrier islands, sand ridges, or back-barrier tracts). The name Argyle is taken from the community of Argyle in northern Clinch County, Georgia, where the Argyle terrace is typically developed and upon which the village of Argyle is located.

The Sunderland terrace of Cooke (1930a, 1930b, 1931) includes the Argyle, Waycross, and Okefenokee terraces of this report, and the Argyle terrace approximates the upper part of the Sunderland terrace. Sunderland as a terrace name is considered to be inappropriate in this report because the name Sunderland was originally applied to the Sunderland formation, a lithostratigraphic unit, in Maryland (Shattuck, 1901, 1906).

The scarp that bounds the Argyle terrace on the west is easily traceable only in the expanse of undissected terrain west of the Okefenokee Swamp in Georgia, between the Alapaha and Satilla Rivers. North of the Satilla River, the Argyle terrace and scarp at 170 to 175 feet (52 to 53 m) are traceable with difficulty due to the dissection of the terrace surface by incision and erosion by the Satilla River system.

The Argyle terrace occurs only as far north as the Altamaha River in Georgia (Fig. 56). Farther north, the Argyle terrace elevations occur only in the face of the Orangeburg

Escarpment (i.e., the terraces in front, or east, of the Orangeburg Escarpment are lower in elevation and younger than the Argyle terrace, and the marine terraces behind, or west or, the Orangeburg Escarpment are higher in elevation and older than the Argyle) (see Fig. 57). The Argyle terrace re-emerges on the east side of the Orangeburg Escarpment farther north in South Carolina.

Near the Florida state line in Echols and Lowndes Counties, the Argyle terrace is directly underlain by the Statenville Formation of the Hawthorne Group, or by the Miccosukee Formation. From the vicinity of the Satilla River to the Altamaha River, the Argyle terrace is directly underlain by the Screven Member of the Altamaha Formation. In northern Wayne County, however, the Argyle terrace is directly underlain by the updip feather-edge of the Cypresshead Formation.

Claxton terrace (reintroduced)

The Claxton terrace of Cooke (1925, p. 29) is reintroduced in this report and is that marine terrace bounded on the shoreward (west) side by the low scarp at approximately 200 feet (61 m) and bounded on the seaward (east) side by the low scarp at approximately 170 to 175 feet (52 to 53 m). Typical elevations on the Claxton terrace range from 180 to 190 feet (55 to 58 m).

The surface of the Claxton terrace is more dissected than that of the lower, younger terraces. South of the Altamaha River, well-preserved and undissected Claxton terrace is still present in eastern Lowndes, Lanier, Clinch, Atkinson, Bacon, and Appling Counties. North of the Altamaha River, it is present in Tattnall and Evans Counties, the type area of the Claxton terrace of Cooke (1925).

The Claxton terrace occurs as a band from Lowndes County in the southwest, to Evans County in the northeast (Fig. 56). The Claxton terrace is not present in Georgia north of the Canoochee River, but it re-emerges on the east side of the Orangeburg Escarpment farther north in South Carolina.

The Claxton terrace is directly underlain by the Miccosukee Formation in Lowndes County, and by the Altamaha Formation north of the vicinity of the Satilla River. No information on the underlying formations is available between Lowndes County and the Satilla River.

Pearson terrace (new name)

The Pearson terrace is a new terrace name proposed herein for that marine terrace that is bounded on the landward side by the low scarp at approximately 225 feet (68 m), and on the seaward side by the low scarp at approximately 200 feet (61 m). Like the other upper terraces, the Pearson is morphologically simple. Typical elevations on the Pearson terrace range from 205 to 220 feet (62.5 to 67 m). The name Pearson is taken from the town of Pearson in Atkinson County, Georgia, which is located on the somewhat dissected seaward scarp bounding the Pearson terrace.

The Coharie terrace of Cooke (1930a,1930b,1931) (also called the Coharie formation [Cooke, 1936, 1943,1945], was postulated to occur between the shorelines at 170 feet and 215 feet. However, with modern 1:24,000-scale map coverage and contour intervals of 5 feet (1.5 m), no scarp at 215 feet (65.5 m) can be recognized. At that elevation, the terrace surface is flat or gently inclined. On the other hand, Stephenson (1912) originally defined the inner edge of the Coharie formation as occurring at elevations between 220 and 235 feet (67 and 71.5 m), a determination that is consistent with my observations for the inner margin of the Pearson terrace in Georgia and South Carolina. As a result of the above modifications, the Coharie terrace of Cooke (1930a, 1930b, 1931) is divided into two parts in this report, a lower Claxton terrace and an upper Pearson terrace. Coharie as a terrace name is considered inappropriate because the name Coharie was originally applied to the Coharie formation, a lithostratigraphic unit, in North Carolina, (Stephenson, 1912, p. 29).

The scarp, at approximately 225 feet (68 m), is considerably more dissected and ambiguous than the lower scarps. Only in northwestern Atkinson County is the low scarp still preserved and well developed. Elsewhere, its earlier existence is inferred from the relatively abrupt and systematic increase in interfluve summit elevations from approximately 200 feet (67 m) to 230-240 feet (70 to 73 m).

Relatively large expanses of undissected Pearson terrace surface still exist only in western Atkinson, northwestern Clinch, and northeastern Lanier Counties, between the Satilla and the Alapaha Rivers. Smaller remnants of the terrace occur in Appling, Tattnall, and Evans Counties. Elsewhere, this terrace is deeply dissected and can be traced only with difficulty by comparing interfluve summit elevations.

The Pearson terrace extends from southeastern Thomas County in the southwest, where it is very deeply dissected, to Bulloch County in the northeast, where it is also very deeply dissected (Fig. 56). The Pearson terrace, like the other upper terraces, occurs only west of the Orangeburg Escarpment, Trail Ridge, and the Okefenokee Swamp in Georgia. It emerges on the east side of the Orangeburg Escarpment in South Carolina.

The Pearson terrace is directly underlain by the Miccosukee Formation in Lowndes, Brooks, and Thomas Counties, and is underlain by the Altamaha Formation north of the Satilla River. No information is available on the underlying formations between Lowndes County and the vicinity of the Satilla River.

Hazlehurst terrace, (reintroduced)

The Hazlehurst terrace of Cooke (1925, p. 29) is reintroduced in this report for that marine terrace bounded on the shoreward side (west) by a generally dissected scarp at approximately 275 feet (84 m), and on the seaward side (east) by the low scarp at approximately 225 feet (68 m). The

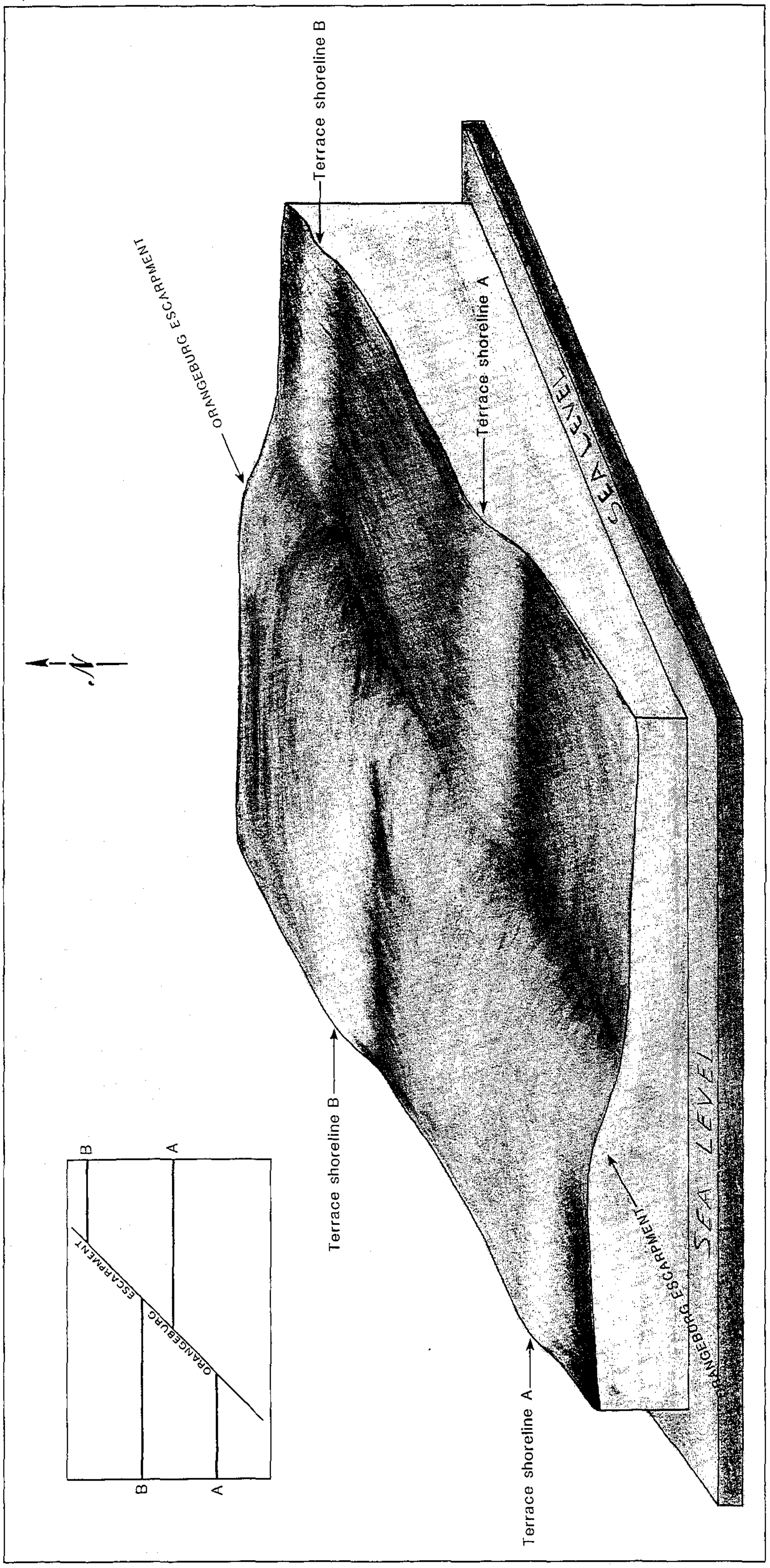


Figure 57. Block diagram showing relationships of marine terraces to the Orangeburg escarpment in Georgia.

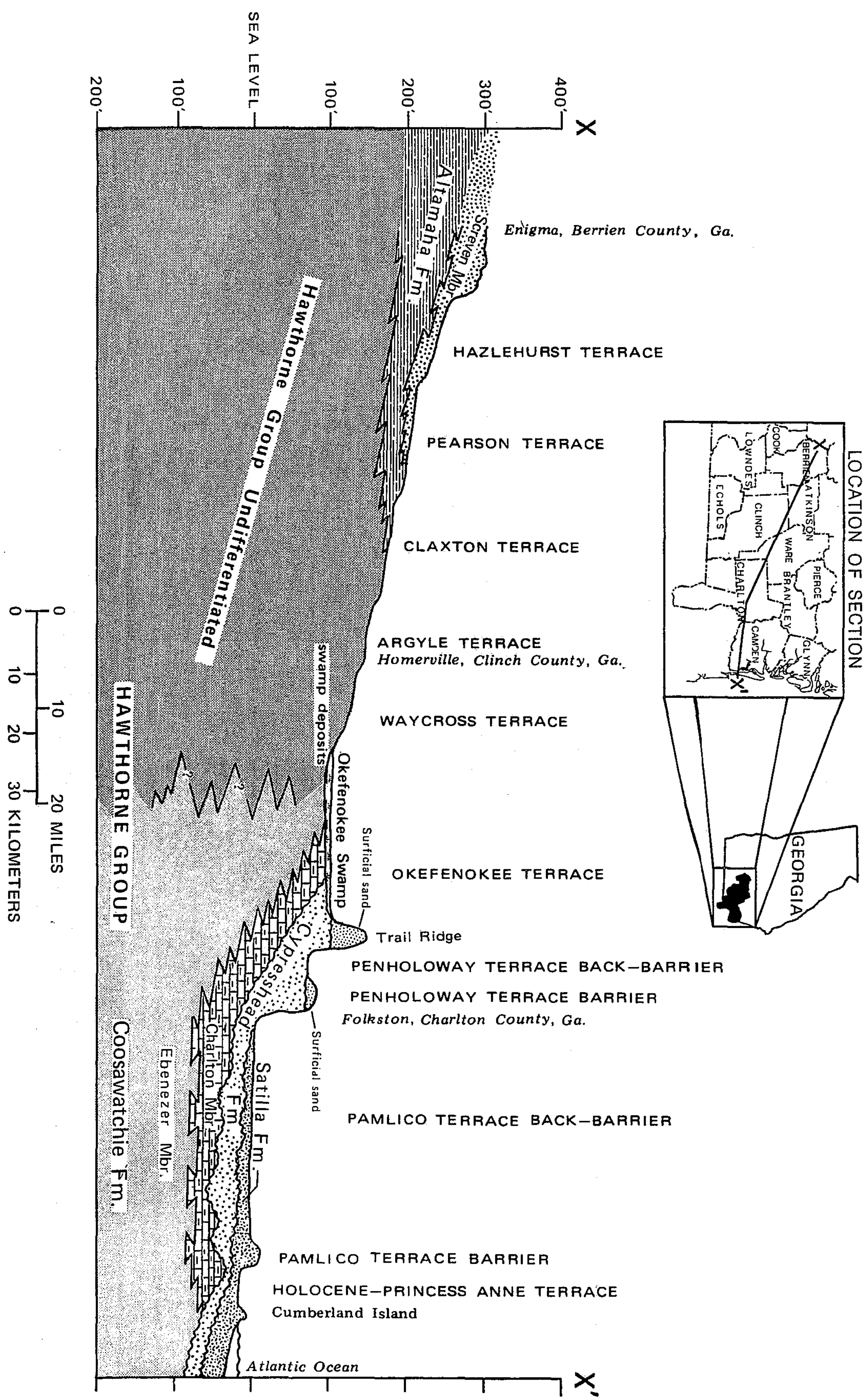


Figure 58. Schematic stratigraphic cross-section of the marine terraces from northern Berrien County to Cumberland Island.

remnants of the Hazlehurst terrace suggests that originally it was morphologically simple. Typical elevations on the Hazlehurst terrace range from 230 feet to 260 feet (70 m to 79 m).

The name Hazlehurst terrace was abandoned by Cooke (1930a, 1930b, 1931) in favor of the name Brandywine terrace. The Brandywine was originally described as a formation (Clark, 1915), and the name Brandywine was applied accordingly in South Carolina, Georgia, and Florida by Cooke (1936, 1943, 1945). The proper use of the name Brandywine, therefore, is as a lithostratigraphic unit and not as a terrace as proposed by Cooke (1930a, 1930b, 1931). The name Brandywine formation is not valid in Georgia because the terrace of that name is underlain by either Miccosukee Formation or by Altamaha Formation. Furthermore, the name Brandywine formation is no longer applied in its type area in Maryland. The name Hazlehurst, on the other hand, was defined as a marine terrace independent of any underlying deposits and is, for that reason, reintroduced herein. The Hazlehurst terrace of this report is largely the same as the Hazlehurst terrace of Cooke (1925, p. 29), with only minor modifications.

The scarp that defines the landward limit of the Hazlehurst terrace can be observed only in northern Berrien County. Elsewhere the former presence of this scarp is inferred from the relatively abrupt increase in interfluve summit elevations from approximately 260 or 270 feet 979 or 82 m), to elevations in excess of 290 feet (88 m).

The Hazlehurst terrace is deeply dissected in most areas of its occurrence, and in many places is virtually unrecognizable as a terrace. Only in northwestern Atkinson, eastern Berrien, western Brooks, southern Emanuel, and northern Tattnall Counties are there existing remnants of the undissected Hazlehurst terrace surface. In other places, the recognition of the former presence of the terrace surface is based on the elevations of the highest interfluve summits.

The Hazlehurst terrace, or deeply dissected remnants of the former terrace surface, extends from southeastern Decatur County in the southwest, northeastward through Jeff Davis County to Burke County (Fig. 51).

The Hazlehurst terrace is directly underlain by the Altamaha Formation from Screven and Burke Counties in the northeast, to Cook County in the southwest. Farther southwest it is underlain by the Miccosukee Formation in southern Colquitt, Lowndes, Brooks, Thomas, Grady, and Decatur Counties, Georgia.

Age of the marine terraces

Marine terraces are geomorphic features. In themselves, they cannot be dated, but the ages of the terraces can be inferred from the ages of associated datable deposits or from the real or interpreted ages of the underlying, unassociated deposits. In addition, I have found that relative ages inferred from regional tilting of the underlying deposits, and absence of tilting or warping of the terraces, are consistent with the age interpretations of the marine terraces based on ages of the underlying deposits.

Only the lowest marine terraces—the Holocene, Silver Bluff, Princess Anne, and Pamlico terraces—can be dated by the age of the associated Satilla Formation. The spatial relationships of the Satilla lithofacies appear to conform to terrace geomorphology (i.e., blocky, massive clays with scattered bioherms of *Crassostrea virginica* [marsh-type deposits] are largely confined to the back-barrier tracts of the terraces, and barrier island-type deposits are largely confined to the barrier island-type sand ridges of the terraces). Consequently, it is assumed that the Satilla Formation was deposited during the associated terrace construction events. The fauna of the Satilla Formation is not known to differ in any way from the modern, living fauna. As a consequence, the ages of the Pamlico, Princess Anne, and Silver Bluff terraces are assumed in this report to be late Pleistocene. The age of the Holocene terrace, which is currently being constructed, is, of course, Holocene.

Pirkle and Czel (1983) reported Pleistocene fossil associations from the Trail Ridge sand deposit in Georgia. The fossils came from elevations of 132 feet (40 m) to 161 feet (49 m) above sea level in cores taken on Trail Ridge. According to Pirkle and Czel (1983, p. 32), this assemblage contained no extinct species and it is, therefore, interpreted in this report as being Pleistocene, and possibly late Pleistocene, in age. The elevations of the fossil associations are consistent with the Trail Ridge being assigned to the Waycross terrace (approximately 125 feet [38 m] to 150 feet [46 m] with a sea level stand at approximately 150 feet [46 m] above sea level). The Waycross terrace, therefore, is interpreted as also being Pleistocene, and possibly late Pleistocene, in age.

No sediments of any kind are known to be associated with the marine terraces above the Waycross terrace in Georgia. However, the Cypresshead Formation, in addition to underlying the "Talbot", Penholoway, "Wicomico", Okefenokee, and Waycross terraces in Georgia, also underlies a small portion of the Argyle terrace in northern Wayne County, Georgia. The Cypresshead Formation is late Pliocene to possibly early Pleistocene in age. Therefore, the Argyle terrace would be no older than late Pliocene to possibly early Pleistocene in Georgia.

In southwestern Georgia, the Argyle, Claxton, Pearson, and Hazlehurst terraces are underlain by the Miccosukee Formation. The dissected scarp (shoreline) that bounds the Hazlehurst terrace on the north and west, is also cut into the Miccosukee Formation (i.e., the Miccosukee Formation both underlies the Hazlehurst terrace and occurs inland from the terrace and at higher elevations) (compare Figs. 51 and 56). The Hazlehurst terrace, which is the highest and oldest currently recognized terrace, is therefore younger than the Miccosukee Formation. The Miccosukee Formation is believed to be late Pliocene to possibly early Pleistocene in age, and the Hazlehurst terrace is interpreted as being no older than that.

The Miccosukee Formation appears to have been structurally tilted since it was deposited. In the vicinity of Pelham, Mitchell County, Georgia, the northernmost known occurrence of the formation, the Miccosukee occurs as high as approximately 350 feet (107 m) above sea level. Based on the known thickness distribution of the Miccosukee Formation, its base is probably not much higher than 300 feet (107 m) above sea level at Pelham. At Tallahassee, Florida, the base of the Miccosukee Formation is approximately 150 feet (46 m) above sea level, and the base of the correlative Citronelle Formation at Alum Bluff in Liberty County, Florida, is approximately at 70 feet (21 m) above sea level. Between Pelham, Georgia, and Alum Bluff in Florida, the elevation range of the base of the Miccosukee Formation-Citronelle Formation is roughly 230 feet (70 m). However, the Miccosukee Formation is interpreted as being of coastal marine origin, and the burrows (*Ophiomorpha nodosa*) of the intertidal shrimp *Callianassa major* are locally abundant in both the Miccosukee and Citronelle Formations. A water depth on the continental shelf of 230 feet (70 m) for deposition of the Miccosukee Formation is out of the question. For these reasons, therefore, the Miccosukee Formation has evidently been structurally tilted since it was deposited.

Similarly, it is concluded that the correlative Cypresshead Formation of eastern Georgia has been structurally tilted since it was deposited. Based on the presence of cross-bedded gravels, bioturbation, local abundance of *Ophiomorpha nodosa*, and rarely occurring fossiliferous beds, the Cypresshead Formation is interpreted as being of coastal marine origin. The base of the Cypresshead Formation occurs at least as high as 100 feet (30 m) above sea level in Screven County in the Savannah River area, and at elevations at least as low as 32 feet (10 m) below sea level in Chatham County, a range of roughly 130 feet (40 m). A water depth on the continental shelf for deposition of the Cypresshead Formation of 130 feet (40 m) is out of the question. For these reasons, the Cypresshead Formation has evidently been structurally tilted since it was deposited.

None of the marine terraces in Georgia and northern Florida have been structurally tilted or warped. Therefore, the tilting event took place after the deposition of the Miccosukee and Cypresshead Formations of late Pliocene to possibly early Pleistocene age, and prior to the construction of the marine terraces. Because the tilting event is likely to have taken some time, all of the marine terraces in Georgia, South Carolina, and northern Florida are interpreted here as being of Pleistocene age.

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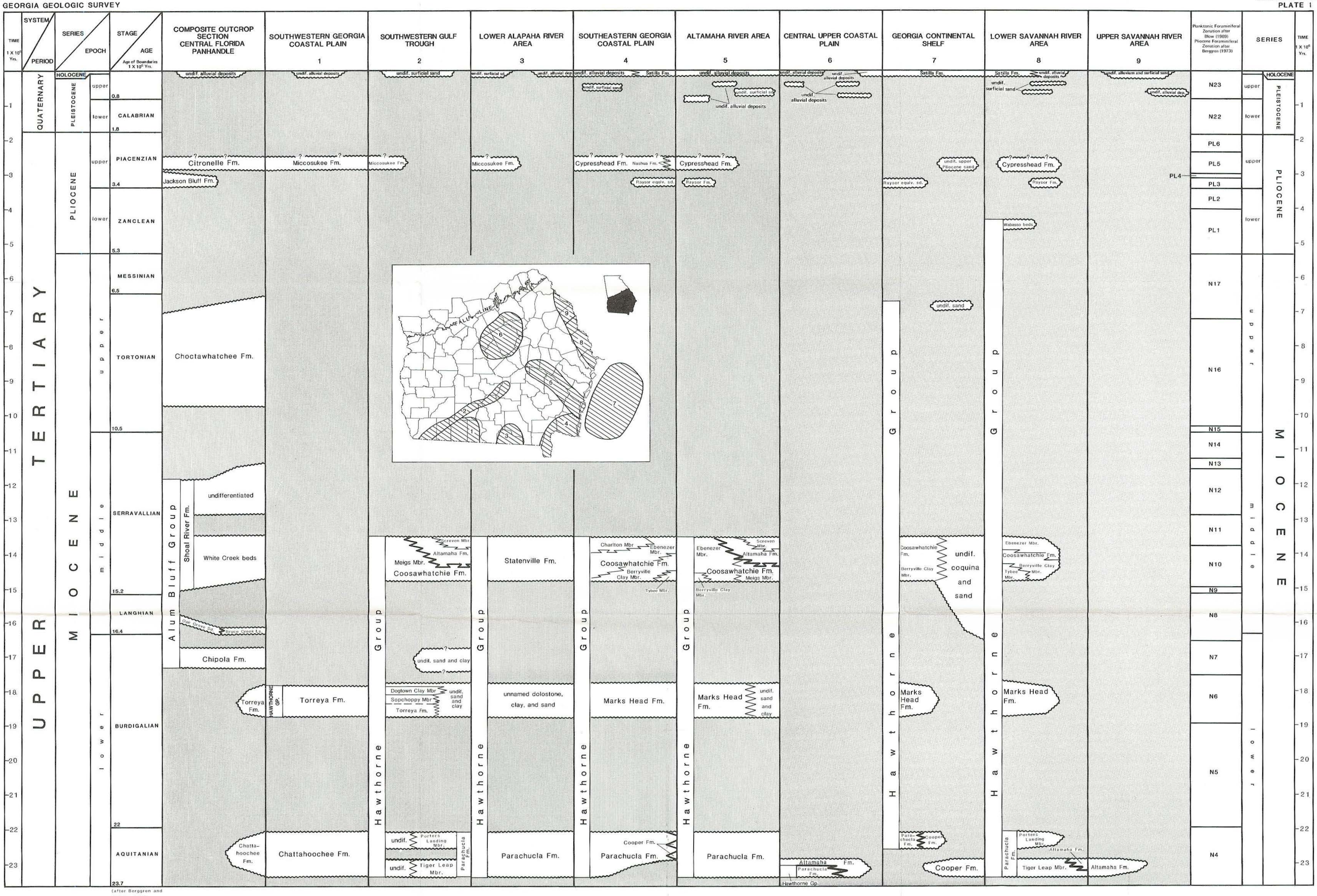

CORRELATION CHART OF MIOCENE TO HOLOCENE STRATIGRAPHIC UNITS OF GEORGIA AND WESTERN FLORIDA

STRATIGRAPHIC CROSS-SECTION NEAR THE SAVANNAH RIVER FROM SCREVEN COUNTY TO AMCOR 6002 ON THE CONTINENTAL SHELF

STRATIGRAPHIC CROSS-SECTION FROM UPPER SISTER BLUFF ON THE ALTAMAHA RIVER TO AMCOR 6002 ON THE CONTINENTAL SHELF