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

THE OLIGOCENE

Paul F. Huddlestun

DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

BULLETIN 105

Cover photo: Seventy feet of Bridgeboro Limestone exposed at the the type locality in the southern-most pit of the Bridgeboro Lime and Stone Company, 6.5 miles west-southwest of the community of Bridgeboro, south of Georgia 112, Mitchell County.

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ABSTRACT

Lithostratigraphic units are described in terms of their stratigraphic associations. These include an eastern Gulf of Mexico stratigraphic association, a Gulf Trough stratigraphic association, a Florida Bank stratigraphic association, and an Atlantic continental shelf stratigraphic association. The faunal provinces and the stratigraphic associations appear to be directly related.

Four previously named Oligocene formations are recognized in this study: the typical Suwannee Limestone is largely restricted to the Florida Bank stratigraphic association but also occurs north of the Gulf Trough in the central Georgia Coastal Plain, the Cooper Formation is confined to the Atlantic continental shelf stratigraphic association, and the Marianna Limestone and Glendon Limestone of the Vicksburg Group are restricted to the eastern Gulf of Mexico continental shelf stratigraphic association. Of seven new formations, the Ochlockonee Formation, Wolf Pit Dolostone, Okapilco Limestone, and Bridgeboro Limestone are confined to the Gulf Trough stratigraphic association; the Ellaville Limestone and Suwannacoochee Dolostone are confined to the Florida Bank stratigraphic association; and the Lazaretto Creek Formation is restricted to the Atlantic continental shelf stratigraphic association. Of two new members, the Pridgen Limestone Member of the Ochlockonee Formation is confined to the northeastern part of the Gulf Trough and the Florala Limestone Member of the Bridgeboro Limestone occurs in both the eastern Gulf of Mexico and along the northern flank of the Gulf Trough. The Shellstone Creek beds, an informal unit, and undifferentiated Oligocene residuum, in part the Flint River formation of Cooke (1935), are restricted to the eastern Gulf of Mexico stratigraphic association. An undifferentiated calcareous sand and sandy limestone formation occurs only within the northeastern part of the Gulf Trough and on the shelf to the northwest. Its stratigraphic association is uncertain.

Four primary structural elements, the Florida Platform, South Georgia rift, Piedmont Slope, and Peninsular Arch have influenced the stratigraphic framework of the entire Georgia Coastal Plain since the inception of deposition in the Coastal Plain Province. Other smaller scale features, formerly considered to be structurally controlled (the Ocala Arch, Beaufort Arch, and Southeast Georgia Embayment), are considered here to be structures originating from differential sedimentation patterns. It is concluded, on the other hand, that the Chattahoochee Arch and Barwick Arch do not exist and the names should be abandoned, and that there is no evidence for, and no real evidence has ever been presented for, various faults postulated to be associated with the Gulf Trough (and Chattahoochee Embayment). The section on Oligocene paleogeographic elements is divided into discussions on the Florida Bank, the Suwannee Strait, and the Atlantic continental shelf. The Oligocene history of the Suwannee Current is discussed in relationship to these features.

Three marine faunal provinces (or associations) are recognized in the Georgia area during the Oligocene: a Gulf of Mexico continental shelf faunal province characteristic of the region north and west of the Gulf Trough, a Florida province characteristic of and largely restricted to the Florida Bank, and an Atlantic continental shelf faunal province. The Gulf Trough through most of the Lower Oligocene separated the Gulf of Mexico province from the Florida province. The chronology and regional correlation of Oligocene depositional events, eustatic sea level events, the evolving paleogeography, and the paleoenvironmental evolution of Georgia and northern Florida are discussed.

ACKNOWLEDGMENTS

Stratigraphic work that culminated in this report was initiated in 1964. During the past 16 years, many geologists on the staff of the Georgia Geologic 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 the project. Dr. W.H. McLemore, State Geologist of Georgia, has continued in the encouragement and support of the project to its completion. I wish to express thanks to Mr. C.W. Henry, former State Geologist of Florida, and Dr. Walter Schmidt, the State Geologist of Florida, for sharing the resources of the Florida Geological Survey. Special thanks are extended to Mr. Gerald S. Grainger of Southern Services, Inc. for providing access to cores of Georgia Power Company, and to the United States Gypsum Company for donating twelve cores from Thomas, Brooks, and Colquitt Counties to the Georgia Geological Survey. Ms. Muriel E. Hunter of Tallahassee, Florida, has been of special assistance to me in her wealth of knowledge on the Oligocene limestones and faunas of Florida and the Southeast. Dr. Lucy E. Edwards of the U.S. Geological Survey, Reston, Virginia, has provided biostratigraphic information on limestones in the Gulf Trough. Dr. Burt Carter of Georgia Southwestern College has provided stimulating discussions on the Oligocene stratigraphy and paleontology of southwestern Georgia. Jonathon Bryan of Florida State University has also provided stimulating input on the paleontology of the Oligocene of this region.

I also wish to extend my deepest thanks and gratitude to Mr. M.P. Crowell, Mr. D.M. Cannon, and Mr. H.D. Baker, drillers for the Georgia Geologic Survey, whose efforts in coring have contributed greatly to the satisfactory conclusion of this project.

INTRODUCTION

This report, concerning the Oligocene Series of the Coastal Plain of Georgia (Fig. 1), is a part of a succession of stratigraphic reevaluations of the Georgia Coastal Plain and follows the report covering the Miocene through Holocene (Huddlestun, 1988). The purposes of this report are (1) to describe, as well as the current data permits, the Oligocene lithostratigraphic units of Georgia, (2) to base the lithostratigraphic definitions on the modern codes of stratigraphic nomenclature (American Commission on Stratigraphic Nomenclature, 1961, 1970; International Subcommission on Stratigraphic Classification, 1976; North American Commission on Stratigraphic Nomenclature, 1983), (3) to relate these units to the known Oligocene lithostratigraphic and chronostratigraphic framework of the southeastern Coastal Plain, (4) to relate the described stratigraphic units to the paleogeographic features of the region, (5) to evaluate the various described or postulated structural elements of the region that would involve Oligocene strata, (6) to describe the physical relationships of the postulated structural elements with the Oligocene stratigraphic framework, and (7) to describe the chronology of events (sequence stratigraphy) that resulted in the regional stratigraphic framework.

To this end, seventeen lithostratigraphic units are described. These include one group, eleven formally defined formations (seven new formations and four previously named formations), two new members, one informal unit, and two undifferentiated units. Of the stratigraphic names applied to Oligocene stratigraphic units in Georgia prior to the 1970's, only the redefined Suwannee Limestone is still recognized as a valid formation. Oligocene formations that had been recognized in Georgia but which are no longer used include the Flint River formation of Cooke (1935), which has not been considered a valid lithostratigraphic unit for many years (MacNeil, 1947a, 1947b); the Byram Formation of Mississippi whose extension into Georgia was not lithostratigraphically valid (Pickering, 1970); and the Vicksburg Formation of Veatch and Stephenson (1911) which in Georgia is now recognized as both a group and a stage (the Vicksburg Group and Vicksburgian Stage).

In addition to the above lithostratigraphic units, various other geologic and paleophysiographic features that are involved in concepts of the Oligocene stratigraphic framework of Georgia are discussed and evaluated. These geologic and paleophysiographic features include the Gulf Trough and its relationship to the Chattahoochee Embayment, Apalachicola Embayment, Suwannee Channel, and Tallahassee Embayment; to the Suwannee Strait; to the Peninsular Arch; the Piedmont Slope; Florida Platform; Florida Bank; Ocala Arch; Beaufort Arch; Southeast Georgia Embayment; and various faults.

METHODS

The initial process of lithostratigraphic subdivision of the Oligocene section of Georgia and northern Florida was based on core examinations and descriptions. This effort did not stem from a systematic study of the Oligocene but resulted from logging and sampling of cores (for microfossil content) from Georgia, South Carolina, and Florida (Figs. 2-5) and as parts of different studies. Thirty four cores from the panhandle and northern Florida were examined, logged and sampled for foraminiferal content as part of a PhD dissertation (Huddlestun, 1984). Twenty nine cores were examined, logged, and sampled for foraminiferal content as a part of the study of the geologic section in the vicinity of the Savannah River in eastern Georgia (in part, Huddlestun, 1988). Twelve cores from Thomas, Brooks, and Colquitt Counties, Georgia, were examined and logged in an effort to understand the stratigraphic framework of the northwestern part of the Florida Platform in Georgia; five cores were logged and sampled for foraminiferal content for the Gulf Trough Project; and two cores were logged from the Suwannee River area in Florida to support field work along the Suwannee River and Withlacoochee River in 1976 to precisely determine the lithology of the Suwannee Limestone. Other cores were logged and sampled for foraminiferal content where the Oligocene occurs as erosional outliers, as residuum, or is absent. Two cores were logged and sampled for foraminiferal content from the Hawkinsville area (Pulaski County, Georgia) in preparation for Guidebook 12 of the Southeastern Section of the Geological Society of America (Huddlestun and others, 1974); one core (AMCOR 6002) was taken by the U.S. Geological Survey on the outer continental shelf of Georgia (Hathaway and others, 1976); eight discontinuous cores were taken by the U. S. Army Core of Engineers on the outer continental shelf of Georgia, one core was logged and sampled for foraminiferal content from Wayne County, Georgia (Pickering, 1974); and seven cores were logged where the Oligocene is absent and the Miocene Hawthorne Group directly overlies the Upper Eocene Group in southeastern Georgia and eastern Florida. A number of cores from Port Royal Sound in the Beaufort County area of South Carolina were examined. One core, from near Coosawhatchie, South Carolina, also was logged and sampled. In all of these South Carolina cores, the Oligocene is absent. All totaled, this reevaluation of the Oligocene stratigraphy of Georgia and northern Florida is based on over hundred logged cores, many of which also were sampled for foraminifera.

A regional correlation chart (Pl. 1) of the Oligocene formations was constructed on the basis of biostratigraphic correlation and stratigraphic position. Standard procedures were employed in constructing the chart.

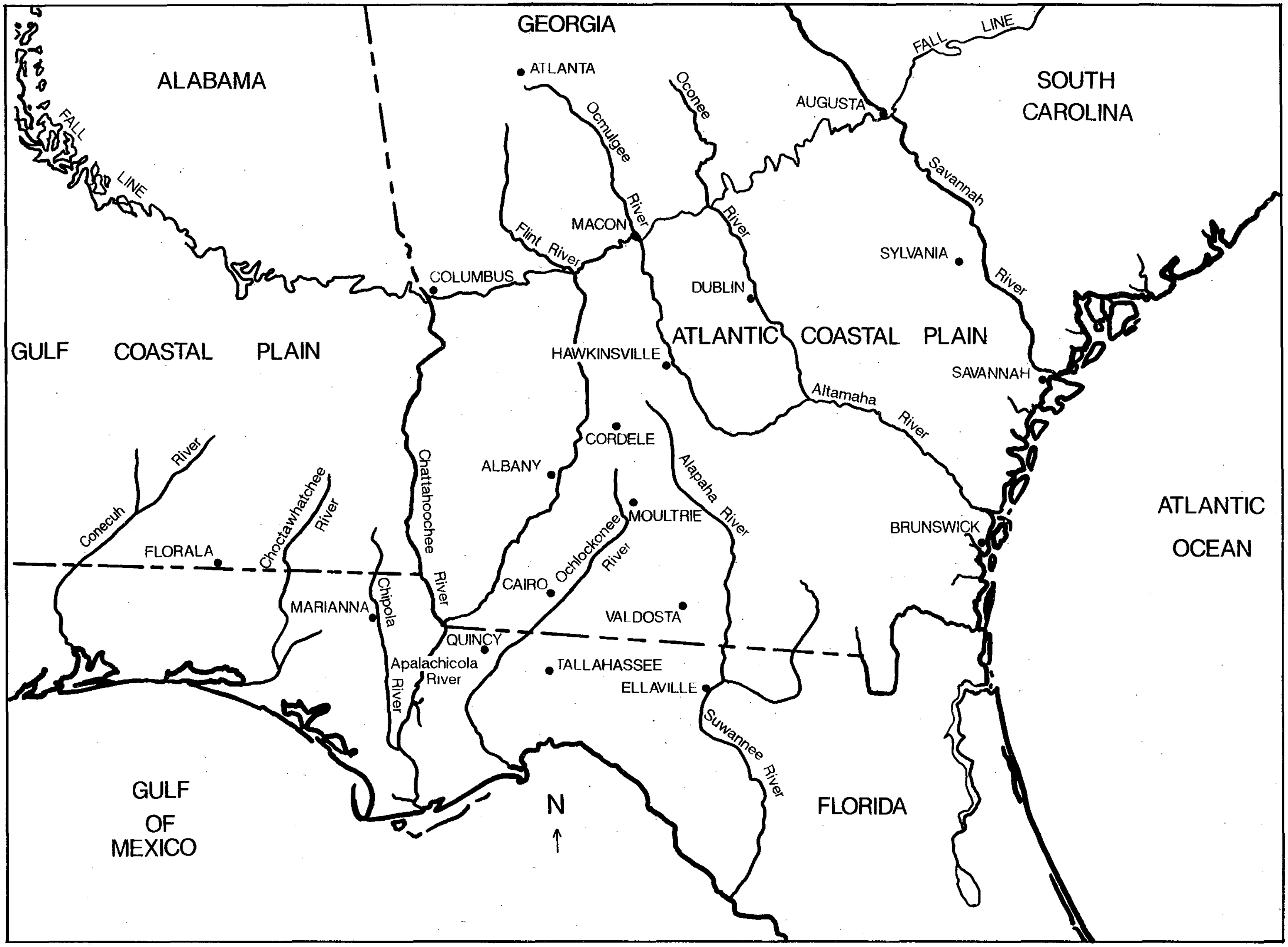

Figure 1. Location map of the study area.

Explanation of Symbols on Figure 2

TYPE LOCALITIES

A ... Ochlockonee Formation (upper part), Wolf Pit Dolostone, and Okapilco Limestone; Colquitt 5 (GGS-3199), ColquittCounty, Georgia.
B ... Ochlockonee Formation (lower part); Colquitt 9 (GGS-3535), Colquitt County, Georgia.
C ... Pridgen Limestone Member of the Ochlockonee Formation; Coffee 4 (GGS-3541), Coffee County, Georgia.
D ... Bridgeboro Limestone; Mitchell County, Georgia.

REFERENCE LOCALITIES
a ... Pridgen Limestone Member of the Ochlockonee Formation and Okapilco Limestone; Berrien 10 (GGS-3542), Berrien County, Georgia.
b ... Ellaville Limestone and Suwannacoochee Dolostone; Thomas 4 (GGS-3188), Thomas County, Georgia.
C ... Wolf Pit Dolostone, and Okapilco Limestone; Coffee 4, (GGS-3541), Coffee County, Georgia.

CORE SITES AND WELL SITES
A ... Colquitt 5 (GGS-3199); Colquitt County, Georgia
1 ... Colquitt 6 (GGS-3212); Colquitt County, Georgia
2 ... Colquitt 7 (GGS-3213) and Colquitt 10 (GGS-3544); Colquitt County, Georgia.
3 ... Colquitt 8 (GGS-3214); Colquitt County, Georgia.
B ... Colquitt 9 (GGS-3535); Colquitt County, Georgia.
4 ... Colquitt 10 (GGS-3196); Colquitt County, Georgia.
5 ... Colquitt 11 (GGS-3545); Colquitt County, Georgia.
b ... Thomas 4 (GGS-3188); Thomas County, Georgia.
6 ... Thomas 5 (GGS-3207); Thomas County, Georgia.
7 ... Thomas 6 (GGS-3215); Thomas County, Georgia.
8 ... Brooks 7 (GGS-3189) and Brooks 9 (GGS-3209); Brooks County, Georgia.
9 ... Brooks 8 (GGS-3208); Brooks County, Georgia.
10 ... Brooks 10 (GGS-3211); Brooks County, Georgia.
a ... Berrien 10 (GGS-3542); Berrien County, Georgia.
C .. .Coffee 4 (GGS-3541); Coffee County, Georgia.
11 ... Well Cuttings, GGS-468, GGS-508, GGS-509 Coffee County, Georgia.
12 ... Pulaski 3 (GGS-3111); Pulaski County, Georgia.
13 ... Pulaski 4 (GGS-3112); Pulaski County, Georgia.
14 ... Pulaski 5 (GGS-3511); (Arrowhead core); Pulaski County, Georgia.
15 ... Laurens 1 (GGS-3523); (Laurens County core); Laurens County, Georgia.
16 ... U.S. Geological Survey test well 5 (GGS-1063); Glynn County, Georgia.
17 ... AMCOR 6002; continental shelf.
18 ... TACTS core A; continental shelf
19 ... TACTS core B; continental shelf
20 ... TACTS core C; continental shelf
21 ... TACTS core D; continental shelf
22 ... TACTS core F; continental shelf
23 ... Wayne 2 (GGS-3512); Wayne County, Georgia.
24 ... Cumberland Island 1 (GGS-3426); Camden County, Georgia

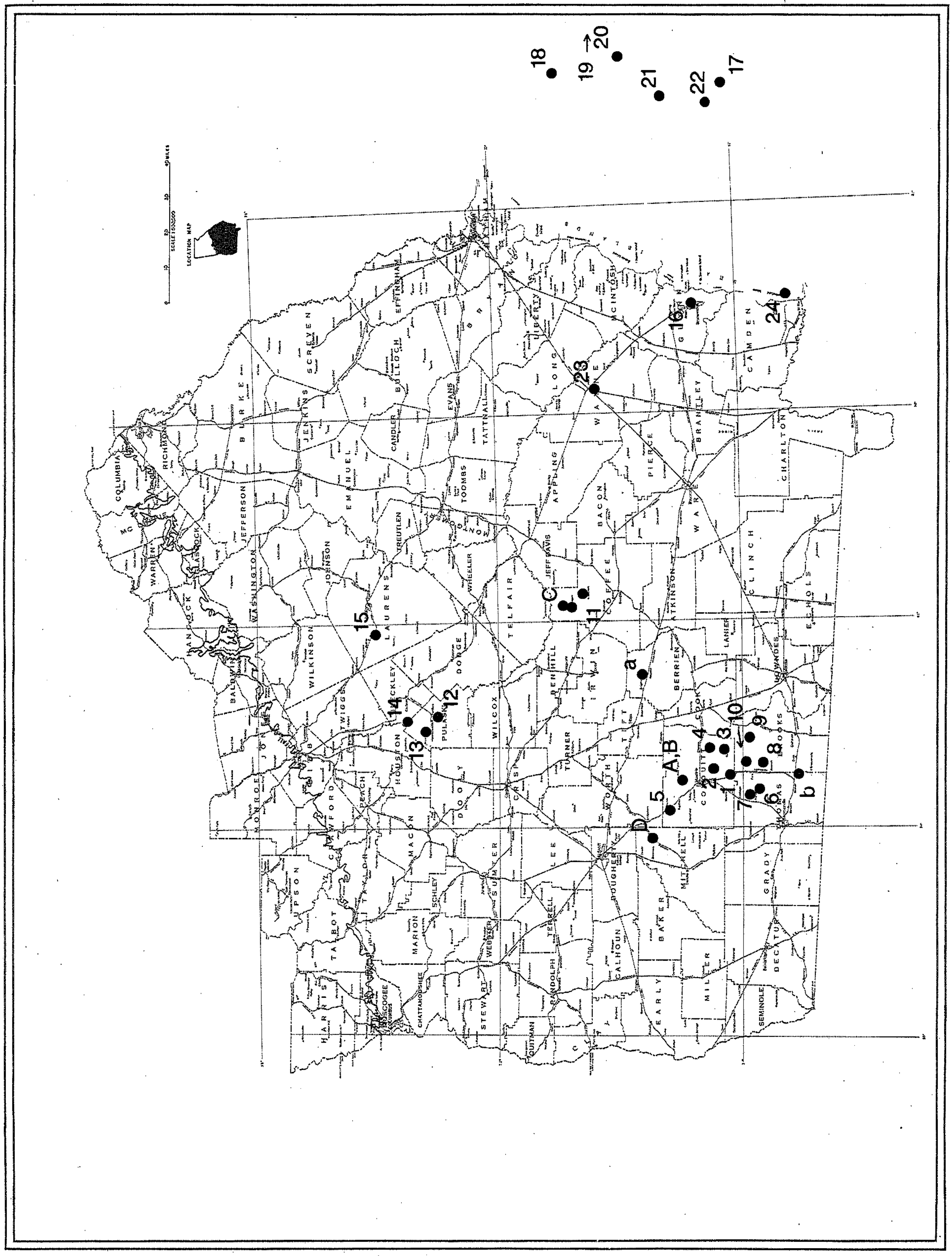

Figure 2. Location map of type localities, refererence localities, core sites, and well sites in Georgia and on the continental shelf of Georgia.

Explanation of Symbols on Figure 3

TYPE LOCALITY
E ... Lazaretto Creek Formation; Chatham 11 (GGS-1393), Chatham County, Georgia.

REFERENCE LOCALITIES
c ... Suwannee Limestone; Blue Springs, Screven County, Georgia.
d ... Lazaretto Creek Formation; Petit Chou 1 (GGS-1164), Petit Chou Island, Chatham County, Georgia.

CORE SITES AND WELL SITES
d ... Petit Chou 1 (GGS-1164); Chatham County, Georgia.
25 ... Screven 1 (GGS-1170); Screven County, Georgia.
26 ... Screven 8 (GGS-3198); Screven County, Georgia.
27... Georgia Power Company cores B3**, B21**, B22**;
28 ... Georgia Power Company core B38**, Screven County, Georgia.
29 ... Effingham 3 (GGS-2175); Effingham County, Georgia.
30 ... Effingham 6 (GGS-2179); Georgia Power Company core B40**; Effingham County, Georgia .
31 ... Effingham 9 (GGS-3107); Effingham 11 (GGS-3109); Effingham County, Georgia.
32 ... Effingham 10 (GGS-3108); Effingham County, Georgia.
33 ... Effingham 12 (GGS-3110); Effingham County, Georgia.
34 ... Effingham 13 (GGS-3140); Effingham County, Georgia.
35 ... Effingham 14 (GGS-3155); Effingham County, Georgia.
36 ... Georgia Power Company core B41**; Effingham County, Georgia.
37 ... Chatham 1 (GGS-1164); Chatham County, Georgia.
38 ... Chatham 3 (GGS-1341); Chatham County, Georgia.
39 ... Chatham 10 (GGS-1394); Chatham County, Georgia.
E ... Chatham 11 (GGS-1393); Chatham County, Georgia.
40 ... Chatham 12 (GGS-1411); Chatham County, Georgia.
41 ... Chatham 13 (GGS-1445); Chatham County, Georgia.
42 ... Chatham 14 (GGS-3139); Chatham County, Georgia.
43 ... Chatham 15 (GGS-3138); Chatham County, Georgia.
44 ... Chatham 17 (GGS-3554); Chatham County, Georgia.
45 ... Chatham 18 (GGS-3639); Chatham County, Georgia.
46 ... Chatham 19 (GGS-3640); Chatham County, Georgia.
47 ... Dawsons Landing; Jasper County, South Carolina.
48 .. Port Royal Sound; Beaufort County, South Carolina.

**Cores are no longer available

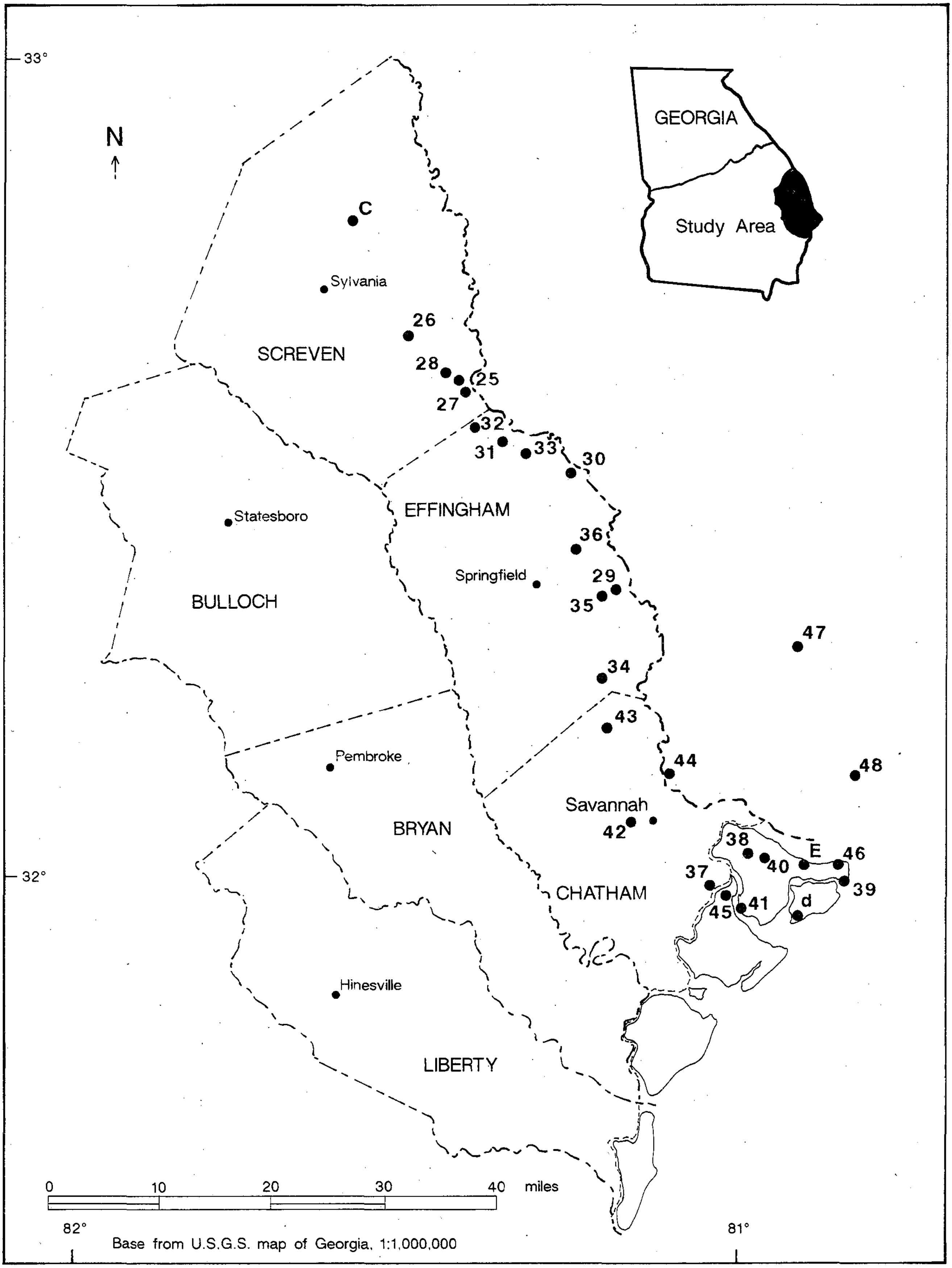

Figure 3. Location map of reference localities and core sites in the lower Savannah River area of Georgia and coastal South Carolina.

Explanation of Symbols on Figure 4

TYPE LOCALITY

F ... Ellaville Limestone and Suwannacoochee Dolostone; Ellaville, Suwannee County, Florida.

REFERENCE LOCALITIES

e ... Ellaville Limestone; Ellaville 1 (W-10657), Suwannee County, Florida.
f ... Suwannee Limestone; Suwannee River, Suwannee County, Florida.
g ... Ellaville Limestone, Suwannacoochee Dolostone, and Suwannee Limestone; Bass 1 (W-10480), Madison County, Florida

CORE SITES AND WELL SITES

e ... Ellaville 1 (W-10657); Suwannee County, Florida.
g ... Bass 1 (W-10480), Madison County, Florida.
49... Lake Talquin 1 (W-6890); Leon County, Florida.
50... Owenby 1 (W-7472); Gadsden County, Florida.
51... well cuttings, W-4 and W-6217; Gadsden County, Florida.
52... Gregory 1 (W-7528); Gadsden County, Florida.
53... Green 1 (W-6937); Leon County, Florida.
54... National Lead 1 (W-12360); Bradford County, Florida.
55... Dupont 1 (W-10488); Clay County, Florida.
56... Hawthorne 1 (W-11486); Alachua County, Florida.
57... Baywood 1 (W-8400); Putnam County, Florida.
58... Wall 2 (W-7458); Liberty County, Florida.

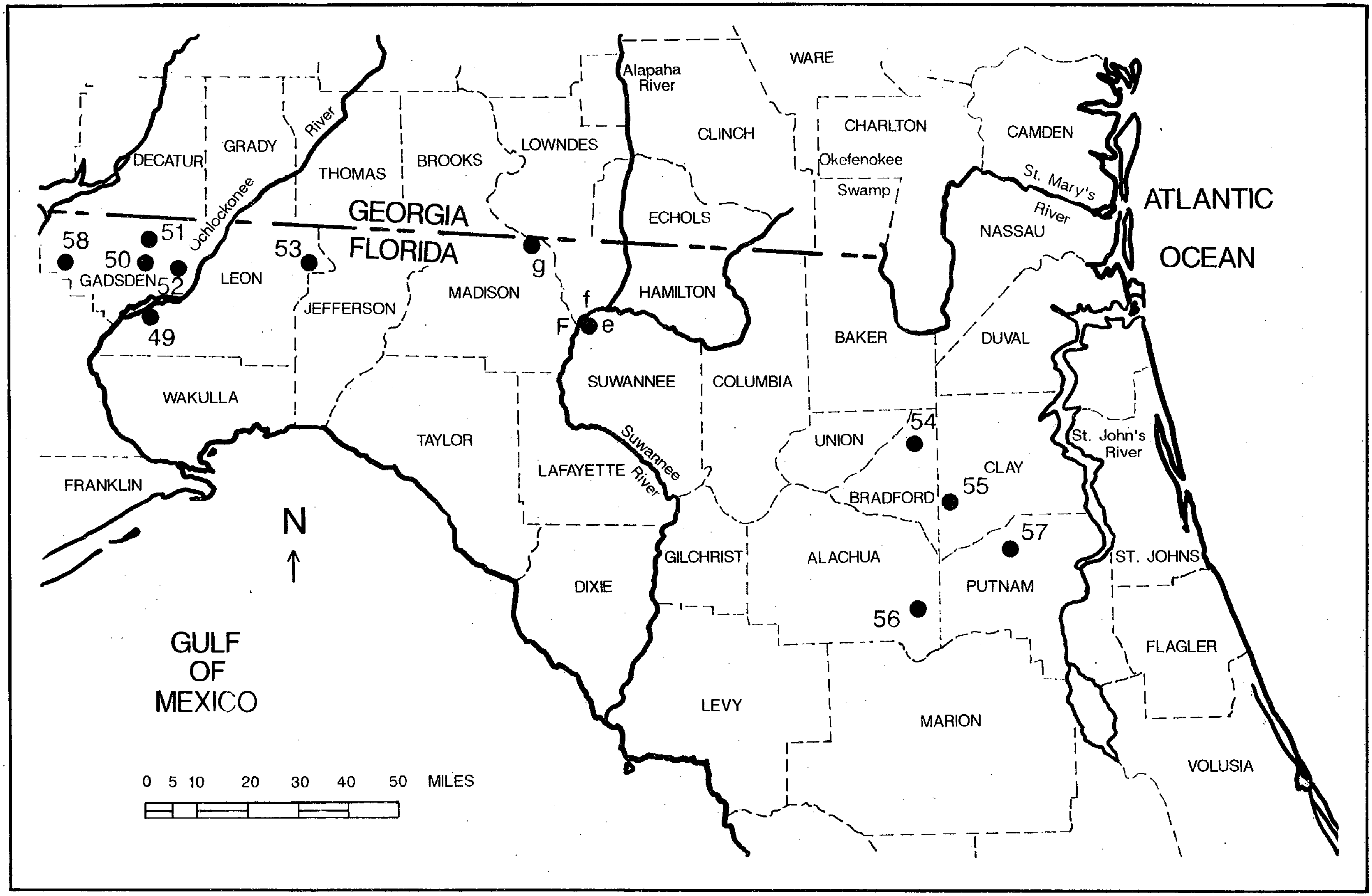

Figure 4. Location map of type localities, reference localities, cores sites, and well sites in peninsular Florida.

Explanation of Symbols on Figure 5

TYPE LOCALITIES

G ... Marianna Limestone; Marianna, Jackson County, Florida.
H ... Florala Limestone Member of the Bridgeboro Limestone; Florala, Covington County, Alabama.

REFERENCE LOCALITIES

h ... Florala Limestone Member of the Bridgeboro Limestone; Mathis 1 (W-8102), Walton County, Florida.
i ... Florala Limestone Limestone Member of the Bridgeboro Limestone; Brown 1 (W-8104), Walton County, Florida.
j ... Bridgeboro Limestone; Hunt 1 (W-10954), Washington County, Florida.
k ... BridgeboroLimestone; Limepit at Duncan Church, Washington County, Florida.

CORE SITES

h ... Mathis 1 (W-8102), Walton County, Florida.
i ... Brown 1 (W-8104), Walton County, Florida.
j ... Hunt 1 (W-10954), Washington County, Florida.
59... Oak Grove 1 (W-10833); Okaloosa County, Florida.
60 ... St. Regis 1 (W-8103); Walton County, Florida.
61 ... Shoal River 1 (W-8354); Walton County, Florida.
62 ... Eglin 1 (W-8351); Walton County, Florida.
63 ... La Londe 1 (W-8877); Walton County, Florida.
64 ... Holloway 1 (W-8356); Walton County, Florida.
65 ... Bunge 1 (W-8019); Walton County, Florida.
66 ... Bayview 1 (W-8478); Walton County, Florida.
67 ... Miller 1 (W-7973); Walton County, Florida.
68 ... Ryan 1 (W-8355); Walton County, Florida.
69 ... Sam 1 (W-8876); Walton County, Florida.
70 ... Bruce 1 (W-8592); Walton County, Florida.
71 ... Duncan Church 1 (W-11487); Washington County, Florida.
72 ... Alum Bluff 1 (W-6901); Liberty County, Florida.
73 ... Wall 1 (W-7457); Liberty County, Florida.

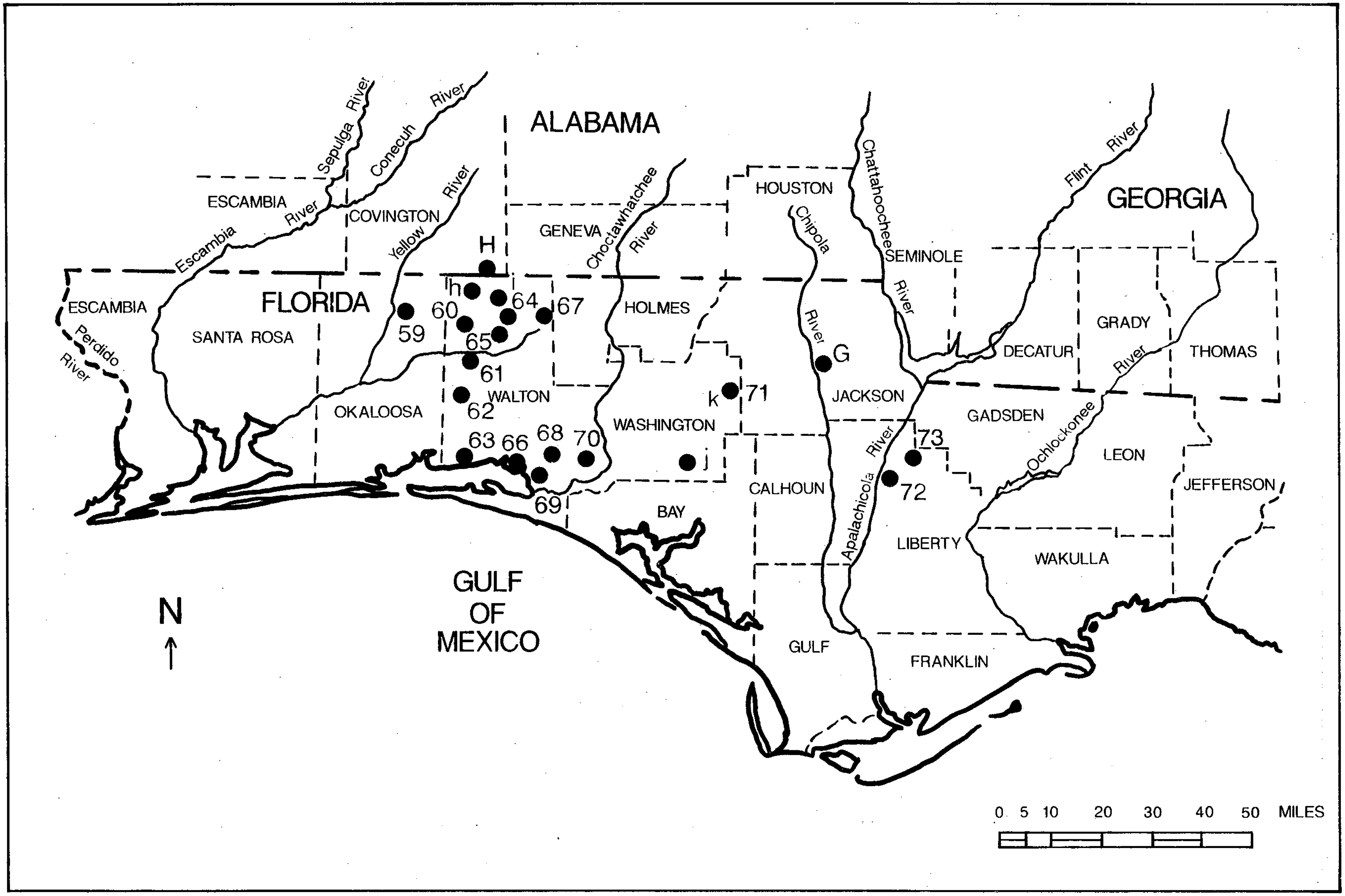

Figure 5. Location map of type localities, reference localities, and core sites in northwestern Florida and southern Alabama.

Although oil and gas exploratory well-cuttings were not studied for this report, I have relied heavily on the data and interpretations of Herrick (1961), Herrick and Vorhis (1963), Applin and Applin (1964), and McFadden and others (1986).

In the execution of the present study, stratigraphic sections were measured along the Suwannee River from Dowling Park, Suwannee County, Florida, almost to White Springs, Columbia and Hamilton Counties, Florida. In addition, the Withlacoochee River, a tributary of the Suwannee River, was traversed and numerous sections were measured northward from its confluence with the Suwannee River at Ellaville, to the Parachucla outcrop (Tampa Limestone of Fortson and Navarre, 1959), along the river in Brooks and Lowndes Counties, Georgia. Sections of Suwannee Limestone in the vicinity of Brooksville in Hernando County, Florida, a classical region for the study of the Suwannee Limestone (Mansfield, 1937; Yon and Hendry, 1972; Randazzo, 1972; Hunter, 1972), and exposures of the Suwannee Limestone (Jacksonboro limestone of Dall and Harris, 1892) in Screven County, Georgia, were also examined and sampled for foraminiferal content. The exposures of the Oligocene limestones and residuum in Pulaski and Houston Counties, Georgia, were examined. Various exposures of Oligocene limestone along the Pelham Escarpment and in caves near the Pelham Escarpment from the vicinity of Cordele, Crisp County, southwestward to Climax Cave in Decatur County, Georgia, were examined or measured. Many exposures of Oligocene residuum were examined in the Dougherty Plain area and northeastward through Randolph, Sumter, and Terrell Counties to Bleckley County; and in eastern Georgia in Screven and southern Burke Counties.

In the eastern Gulf Coastal Plain, Oligocene sections from Vicksburg, Mississippi, Wayne County, Mississippi; Washington, Jackson, Monroe, Conecuh, Covington, and Escambia Counties, Alabama; and Jackson and Washington Counties, Florida, were examined, measured, and sampled for foraminiferal content. Sections of the Oligocene Cooper Formation from various localities in Dorchester County, South Carolina, were also examined and sampled for foraminiferal content.

Paleontological correlation was based on both microfossils and macrofossils. The microfossils employed were primarily the foraminifera, both planktonic and benthic, but dinoflagellates aided biostratigraphic correlation within the Gulf Trough. The Oligocene planktonic foraminiferal zonation scheme of Stainforth and others (1975) was adopted in this study but the zonations of Bolli (1957) and Blow (1969) were also considered. The macrofossils employed in correlation were the mollusks (Dall, 1916; Mansfield, 1937, 1938; Dockery, 1982; MacNeil and Dockery, 1984) and echinoids (Cooke, 1942, 1959). Despite the Oligocene molluscan assemblage being vastly more diverse than the echinoid assemblage, the echinoids have been almost as important in correlation of Oligocene deposits as the mollusks due to their widespread distribution.

Standard field, laboratory, and paleontological procedures were followed throughout the investigations 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 degree of sand sorting are employed in this report.

OLIGOCENE CORRELATION PROBLEMS

Despite the common micro- and macro-fossiliferous Oligocene deposits in the southeastern United States, precise and detailed biostratigraphic and chrono-stratigraphic correlation between the eastern Gulf Coastal Plain in Mississippi (the type provincial Oligocene of eastern North America) and Alabama, eastward through the panhandle of Florida, the Gulf Trough, the Florida Platform in Georgia and Florida, to South Carolina and the continental shelf of Georgia has been difficult to achieve. The factors that contribute to this difficulty are both paleontological and stratigraphic-sedimentological in nature. The paleontological factors are as follows:

(1) Globally, the Oligocene planktonic foraminiferal faunas are characterized by low diversity and slow rates of evolution, and the Oligocene Epoch has relatively few planktonic foraminiferal zones. As a consequence, in Coastal Plain deposits, it has been possible only to distinguish readily between the Lower Oligocene (Vicksburgian) and the Upper Oligocene (Chickasawhayan) and, with considerable difficulty and some uncertainty, between the lower and upper Vicksburgian. In the Lower Oligocene Vicksburgian deposits, I have been able to satisfactorily differentiate between lower Vicksburgian and upper Vicksburgian planktonic foraminifera on the basis of the presence of *Globorotalia increbescens* and *Pseudohastigerina barbadoensis* or on the consistent absence of these species, on the abundance of *Globigerina eocana* and the *Globorotalia increbescen* plexus, and on the very gradually increasing presence of *Globigerina ampliapertura* through the Vicksburgian. The planktonic foraminiferal suite of the Chickasawhayan is noticeably different than the planktonic foraminiferal suite of the Vicksburgian, based on species presence and absence. The Chickasawhayan is not divisible at the present time based on planktonic foraminifera.

(2) Most of the Oligocene formations in Georgia

lack planktonic foraminifera, which are known to occur only in the Ochlockonee Formation and Okapilco Limestone within the Gulf Trough, the Lazaretto Creek Formation in eastern Georgia, and the Cooper Formation under the outer continental shelf of Georgia. I have not seen any planktonic foraminifera in Oligocene formations from the Florida Bank deposits in either Georgia or Florida. As a result, it is impossible to place most of the Oligocene formations of the region into a biostratigraphic or chronostratigraphic framework based solely on planktonic foraminifera.

(3) Although there have been numerous paleontological reports published on Oligocene fossil groups from the eastern Gulf Coastal Plain, there have been few paleontological investigations of the Oligocene of the Florida Platform, and no paleontological investigations on the Oligocene of the southern Atlantic Coastal Plain south of North Carolina. As a result, many of the conclusions in this report concerning faunal distributions in Oligocene deposits of the Florida-Georgia region are based on my own previously unpublished observations in conjunction with the information available in the literature. Based on the current literature alone, it is not possible to correlate regionally within the Oligocene at finer resolution than Epoch or Series.

(4) The distribution of Oligocene benthic foraminiferal species in the southeastern United States is primarily a function of paleoenvironment (also see Huddlestun, Hunter, and Carter [1988] and Dockery, [1988]). Superimposed on and directly related to the paleoenvironmental control on foraminiferal distribution is the presence and overlap of three faunal provinces (or subprovinces). Because of the absence of demonstrated Upper Oligocene (Chickasawhayan) deposits in Georgia, the local occurrences of deep-water Upper Oligocene deposits in South Carolina, and reported occurrences of Upper Oligocene deposits in peninsular Florida (Mansfield, 1937, 1938; Cooke, 1945), it is not clear to what degree temporal differences may have had an impact on Oligocene smaller benthic foraminiferal distributions across the region.

The Gulf of Mexico faunal province during the Early Oligocene encompassed not only the faunas of the typical eastern Gulf Coastal Plain deposits (Vicksburg Group) but also the Gulf Trough deposits (at this time little is known of the benthic foraminifera of the Bridgeboro Limestone). Within the Gulf of Mexico faunal province, two general types of benthic foraminiferal assemblages occur: a relatively shallow-water assemblage and a deeper water assemblage (compare with Hazel and others, 1980). The deeper water assemblage is characteristic of the Red Buff Clay and its calcareous stratigraphic equivalent in southwestern Alabama (Bumpnose Limestone of Hazel and others, 1980), the Marianna and Glendon Limestones in Alabama, and the Ochlockonee Formation in Georgia and Florida. The shallow-water assemblage is characteristic of the Mint Spring Formation and Glendon Limestone in western Mississippi, the Byram Formation, the Bucatunna Clay, the Okapilco Limestone, the Bumpnose and Marianna Limestones in Jackson County, Florida, and the Marianna and Glendon Limestones in Georgia. Apparently lithofacies, biofacies, and bathymetry were not strongly coupled during the Vicksburgian because the Marianna and Glendon Limestones of Georgia, and the Glendon Limestone in western Mississippi are characterized by shallow-water foraminiferal populations in contrast to the moderately deep water assemblages of the same formations in Alabama. As a result, at the present level of knowledge of benthic foraminiferal distributions in Vicksburgian deposits in the eastern Gulf Coastal Plain, detailed biostratigraphic correlation within the Vicksburgian based on benthic foraminifera is not yet attainable.

The Oligocene benthic foraminiferal suites of the Florida Bank can be characterized as a fauna that contains some typical benthic foraminiferal species of the eastern Gulf of Mexico continental shelf deposits (Vicksburg Group) in addition to some species that appear to be endemic to the Florida Bank. Therefore, the Oligocene (Vicksburgian) benthic foraminiferal fauna of the Florida Bank appears to consist of a mixture of eastern Gulf of Mexico continental shelf species and indigenous Florida Bank (Caribbean or Tethyan) species. All of the known indigenous species and the continental shelf foraminiferal species of the Florida Bank (compare with Horowitz, 1979) appear to be long ranging. In addition, no deeper water, Oligocene benthic foraminiferal faunas are known from the Florida Bank in Georgia or Florida. As a result, detailed biostratigraphic correlation between the Vicksburg Group of the eastern Gulf of Mexico continental shelf, and the shallow-water carbonates of the Florida Bank has not yet been attained. Little is currently known of the Oligocene benthic foraminiferal assemblages of the Atlantic faunal province. The deep-water foraminiferal fauna of the Upper Oligocene Cooper Formation in South Carolina (Ashley Member of Ward and Blackwelder, 1979) and continental shelf of Georgia cannot be directly related to the coeval shallow-water foraminiferal fauna of the Chickasawhay Formation or Paynes Hammock Sand (Poag, 1966) of the eastern Gulf Coastal Plain. The deep-water foraminiferal fauna of the Lower Oligocene component of the Cooper Formation on the continental shelf of Georgia (in the TACTS cores and in core AMCOR 6002) is also different (probably deeper water) from the coeval deep-water foraminiferal faunas of the correlative Red Bluff Clay, Marianna and Glendon Limestones of Alabama, and the Ochlockonee Formation of Florida and Georgia, thus permitting only general biostratigraphic correlation. Finally the shallow-water benthic foraminiferal fauna of the Lazaretto Creek Formation of eastern

Georgia has less diversity, greater faunal dominance, and has a generally different faunal make-up in terms of species proportions than correlative Vicksburgian assemblages of the eastern Gulf of Mexico continental shelf. The foraminiferal fauna of the Lazaretto Creek Formation has little in common with that of the Suwannee Limestone, even though the two formations appear to be gradational with each other over a short distance (see Pl. 4). The benthic foraminiferal faunas of the Atlantic province, therefore, can be correlated only approximately with Oligocene, Vicksburgian deposits of the Florida Platform (Florida province) and the eastern Gulf of Mexico continental shelf (Gulf of Mexico province).

(5) The macrofossils of the Oligocene appear to be of greater biostratigraphic value than the foraminifera in establishing regional correlation. However, as with the foraminifera, the macro-fossils are useful only at the stage level (Vicksburgian and Chickasawhayan) and have not yet been shown to be useful in correlation at much finer resolution. Based on the mollusks and echinoids, all of the unweathered Georgia Oligocene formations are shown to be compatible with the Vicksburgian and not with the Chickasawhayan.

The upper part of the Suwannee Limestone in the Brooksville area of peninsular Florida (Mansfield, 1937; Yon and Hendry, 1972) has been reported to contain a younger Oligocene molluscan assemblage and, therefore, was correlated with the Upper Oligocene Chickasawhay Formation (Mansfield, 1937, 1938; Cooke, 1945). Dall (1916), Mansfield (1937), and Cooke (1943) identified some of these younger Oligocene mollusks of the peninsular Florida Suwannee Limestone in chert residuum of southwestern Georgia and concluded that the residuum is correlative, therefore, with the upper Suwannee Limestone of peninsular Florida. Because these deposits in peninsular Florida and southwestern Georgia occur at the tops of some local geologic sections, the faunas were correlated with the Chickasawhay Formation. However, the Chickasawhay Formation of Mississippi is only sparsely macrofossiliferous and does not contain the characteristic upper Suwannee mollusks of Florida, which appear to be restricted largely to the Florida Bank (but some elements of the fauna have been identified from residuum as far west as central Alabama). I conclude, therefore, that macrofossil correlation of Chickasawhayan deposits between Mississippi, Alabama, and the Florida Platform of Florida and Georgia has not yet been established.

Correlation by lithology and stratigraphic position, coupled with biostratigraphic correlation, appears to be a reliable means of detailed correlation within the Vicksburg Group of the eastern Gulf Coastal Plain. The formations of the Vicksburg Group are restricted to the continental shelf of the eastern Gulf of Mexico and constitute a stratigraphic association. The Forest Hill Formation-Red Bluff Clay make up the lowest series of formations of the group. The Bumpnose Limestone of Alabama and western Florida (Moore, 1955; not the Bumpnose of Hazel and others, 1980) is also part of this series but is not a part of the Vicksburg Group because it is an Ocala-like limestone. The Mint Spring Formation-Marianna Limestone make up the overlying series of formations; the Glendon Limestone regionally and conformably overlies the Mint Spring Formation-Marianna Limestone; the Byram Formation overlies the Glendon Limestone, and the Bucatunna Clay is the uppermost formation of the Vicksburg Group (Pl. 1). Most of these formations can be traced and correlated from Mississippi to central Alabama and western Florida, with outliers of Marianna Limestone and Glendon Limestone in central Georgia north of the Gulf Trough. The northern flank of the Gulf Trough and the projected vicinity of the Peninsular Arch defines the eastern limit of the Vicksburg Group of the eastern Gulf Coastal Plain. The Vicksburg Group grades laterally southward, offshore, into the Florala Member of the Bridgeboro Limestone in southern Alabama and western Florida. None of the formations of the Vicksburg Group occur within, south, or east of the Gulf Trough.

Sea level regressions with the accompanying disconformities are postulated to constrain the four stratigraphic assemblages of the Vicksburgian in the eastern Gulf coastal Plain. These events are considered to be synchronous across the region and, therefore, the various deposits between the disconformities are considered also to be approximately synchronous.

A different association of formations is present on the Florida Bank east of the Gulf Trough. In ascending order, these formations include the Ellaville Limestone, Suwannacoochee Dolostone, and Suwannee Limestone. The upper part of what has been mapped as Ocala Limestone also may be of Early Oligocene age and correlative with the Red Bluff-Bumpnose (Hunter, 1976). There is some reason to believe that these formations are widespread on the platform and can be traced in outcrop or the shallow subsurface over wide areas of northwestern peninsular Florida and southwestern Georgia. The basal Ocala-like limestone, the Ellaville Limestone and the Suwannacoochee Dolostone appear to be the least extensive of the platform formations whereas the Suwannee Limestone can be traced intermittently from the vicinity of Brooksville in Hernando County, Florida, at least as far northeastward as the Savannah River in Georgia. Oligocene formations are absent in southeastern-most Georgia and the eastern part of the peninsula of Florida. As with the Vicksburg Group on the continental shelf to the northwest, correlation by lithology and stratigraphic position at this time appears to be a reliable means of detailed correlation of Oligocene formations on the platform, but biostratigraphic correlation has yet to be tied closely to physical correlation.

The Gulf Trough contains a separate suite (stratigraphic association) of lithostratigraphic units, distinct from that of the continental shelf to the west and north (Vicksburg Group), and distinct from that of the Florida Bank to the east and south. There are also pronounced differences in elevations of Oligocene formations within the Gulf Trough compared with the elevations of the correlative formations outside of the trough (see Pl. 2). Therefore, correlation by lithology is not possible; and correlation by stratigraphic position is unreliable between formations within the trough and those on either side of it, and between formations across the trough. Those Oligocene lithostratigraphic units restricted to the Gulf Trough include the Ochlockonee Formation, Wolf Pit Dolostone, and Okapilco Limestone. The Bridgeboro Limestone is restricted in occurrence to both northern and southern flanks of the trough and is not found more than approximately 20 or 30 miles (32 or 48 km) from the Gulf Trough in south Georgia. Biostratigraphic correlation remains the only reliable means of correlation between the Oligocene stratigraphic units within the trough and those outside it.

The Lazaretto Creek Formation of the Atlantic continental shelf stratigraphic association grades laterally westward into Suwannee Limestone (Pl. 3) and, therefore, is physically correlative with the Florida Bank formations. Correlation of the Lazaretto Creek Formation to the standard Vicksburg Group is achieved through its lateral gradation with the Suwannee Limestone. In this report, the Cooper Formation of South Carolina and the Atlantic continental shelf of Georgia is correlated with the standard provincial Oligocene section in the eastern Gulf Coastal Plain through planktonic foraminifera and not through physical correlation.

In summary, regional correlation of Oligocene deposits in southeastern North America is impeded by (1) lack of modern, rigorous, definitive biostratigraphic and paleontological studies across the region, (2) irregular and sparse occurrence of planktonic microfossils in Oligocene formations, (3) pronounced paleobathymetric changes within formations along the outcrop belt and, therefore, the weakened utility of benthic micro- and macrofossils in correlation, and (4) the presence of three faunal provinces (or subprovinces) with different and distinct micro- and macrofaunas.

LITHOSTRATIGRAPHY

EASTERN GULF OF MEXICO STRATIGRAPHIC ASSOCIATION

VICKSBURG GROUP

Definition

The Vicksburg Group is a lithologically heterogeneous suite of formations of the eastern Gulf Coastal Plain that range from noncalcareous, argillaceous sand to sandy clay and variably calcareous clay (Forest Hill Formation, Bucatunna Clay and Red Bluff Clay) to fossiliferous, calcareous, argillaceous sands (Mint Spring Formation and Byram Formation), to relatively pure, variably macrofossiliferous limestones (Marianna Limestone and Glendon Limestone). In contrast to 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]), it is not the similar lithologies or common lithologic features that serve to unite the above formations into one group. The Vicksburg Group deposits bear a common fauna and it is the common fauna that is the real basis of the group. In accord with the common Vicksburg fauna, Murray (1961 p. 394-395) proposed changing the sense of the name Vicksburg from lithostratigraphic unit (Vicksburg Group) to chronostratigraphic unit (Vicksburgian Stage):

> Since Vicksburg has no real lithologic unity in its present broad application and has been widely employed in essentially a time-rock (time-stratigraphic) sense, it is used herein as a provincial stage in the Atlantic and Gulf coastal region to include all beds which can be reasonably demonstrated as equivalent to the type Vicksburg and its characteristic divisions which are wholly or in part exposed in and around the city of Vicksburg, Warren County (Mississippi).

The name Vicksburg is still applied as a lithostratigraphic unit in Mississippi and Alabama where the formations of the original Vicksburg Group can be identified and traced. In Georgia, however, the Vicksburg Group consists only of outliers of Marianna Limestone and Glendon Limestone, and none of the formations of the Vicksburg Group are present in peninsular Florida where stratigraphically equivalent formations are present. The Vicksburgian fauna, upon which the Vicksburgian Stage is ultimately based, is present in Georgia and peninsular Florida. As a result, the Vicksburgian chronostratigraphic unit is more applicable in this region than the name Vicksburg Group. Because the Marianna and Glendon Limestones are present in Georgia, the sense of the Vicksburg Group is retained in Georgia in this report.

Type Area

The Vicksburg Group is named from the city of Vicksburg, Warren County, Mississippi (Conrad, 1848a, 1848b; Murray, 1961; Dockery, 1982; MacNeil and Dockery, 1984; Fisher and Ward, 1984), where the Forest Hill Formation, Mint Spring Formation, Glendon Limestone, and Byram Formation are exposed in and about the city of Vicksburg and in the bluffs overlooking the Mississippi River.

Lithology

The Vicksburg Group is lithologically heterogeneous in the type area in Mississippi and in Alabama. However, in Pulaski County, Georgia, the group consists only of relatively pure limestone of the Marianna Limestone and Glendon Limestone (see Pickering, 1970, p. 51).

Stratigraphic Relationships

The Vicksburg Group is restricted to the eastern Gulf Coastal Plain west and north of the Gulf Trough. In Georgia, the Vicksburg Group is restricted in known occurrence to the vicinity of Hawkinsville in Pulaski County (Fig. 2). It is possible, however, that Vicksburg Group limestones occur along a southwest-northeast band from the vicinity of Hawkinsville southwestward some distance. It also seems likely that at one time, the occurrence of the Vicksburg Group may have been continuous across the Dougherty Plain from Jackson County, Florida, northeastward to Pulaski County.

Age

Based on the occurrence of *Clypeaster rogersi, Paraster americanus, Chlamys anatipes, C. duncanensis,* and *Lepidocyclina mantelli* (Pickering, 1970; Glawe, 1974), the Vicksburgian sediments of Georgia are correlated with typical Vicksburgian sediments in Mississippi and Alabama. In the eastern Gulf Coastal Plain, the Vicksburg Group is correlated with the Rupelian Stage and is included in the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone of Stainforth and others (1975) (Pl. 1).

MARIANNA LIMESTONE

Definition

The Marianna Limestone was named by Matson and Clapp (1909, p. 52-59) for a Vicksburg-related limestone formation typically exposed in the vicinity of Marianna in Jackson County, Florida. In Georgia, the only known occurrence of Marianna Limestone is in a small area in and immediately south of Hawkinsville in Pulaski County. It is well-exposed along the Ocmulgee River on the south side of Hawkinsville and in river bluffs 1.2 miles (2 km) south of Hawkinsville. In the past, the limestone in these bluffs was referred to the Vicksburg Formation (Veatch and Stephenson, 1911, p. 322-323), Flint River formation (Cooke, 1943, p. 83), unit B of the Byram Formation (Pickering, 1970, p. 34-35), and Marianna Limestone (Huddlestun, and others, 1974; Glawe, 1974). In the Chattahoochee Embayment in southwestern Georgia, the Marianna Limestone of Sever and Herrick (1967) and the Marianna Limestone equivalent of Zimmerman (1977) are the Ochlockonee Formation of this report.

Type Section

Matson and Clapp (1909) did not specifically designate a type locality for the Marianna Limestone. However, they included measured sections from exposures "near the east edge of the town of Marianna" (Matson and Clapp, 1909, p. 57) that were considered by Mossom (1925, p. 71) and Cooke and Mossom (1929, p. 63, 65) to be the type locality. This site is on the right bank[1] of the Chipola River where, "roads leading to the old bridge and to the new bridge (built in 1927) have been cut through the rock" (Cooke and Mossom, 1929, p. 65). The type section or unit-stratotype of the Marianna Limestone, then, is that section of Marianna Limestone exposed in low bluffs along the west bank of the Chipola River near the U.S. 90 highway bridge on the east side of Marianna, Florida, in SE1/4, Sec. 3, T4N, R10W (Fig. 6).

Lithology

The Marianna Limestone in Pulaski County, Georgia, is lithologically typical for the formation and is essentially the "chimney rock" (Matson and Clapp, 1909, p. 58; Mossom, 1925, p. 44, 45, 73; Cooke, 1945, p. 76, 77) of the type area. The Marianna is finely granular with substantial interstitial "lime paste" or micrite and is chalky in appearance. The grain-size of the granular or arenitic material, which is of bioclastic origin, ranges from very fine to fine on the Wentworth scale. Fossils, particularly *Lepidocyclina*, some bryozoa, scattered *Clypeaster rogersi*, and mollusk molds supply the only coarse, bioclastic material. The limestone is variably macrofossiliferous, with some intervals being virtually nonmacrofossiliferous. In general, the Marianna Limestone in Pulaski County is poorly but variably fossiliferous.

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[1] The convention concerning "left bank" and "right bank" of a river is as follows: facing downstream, the "left bank" is that bank on the left side of the river, and the "right bank" is that bank on the right side of the river.

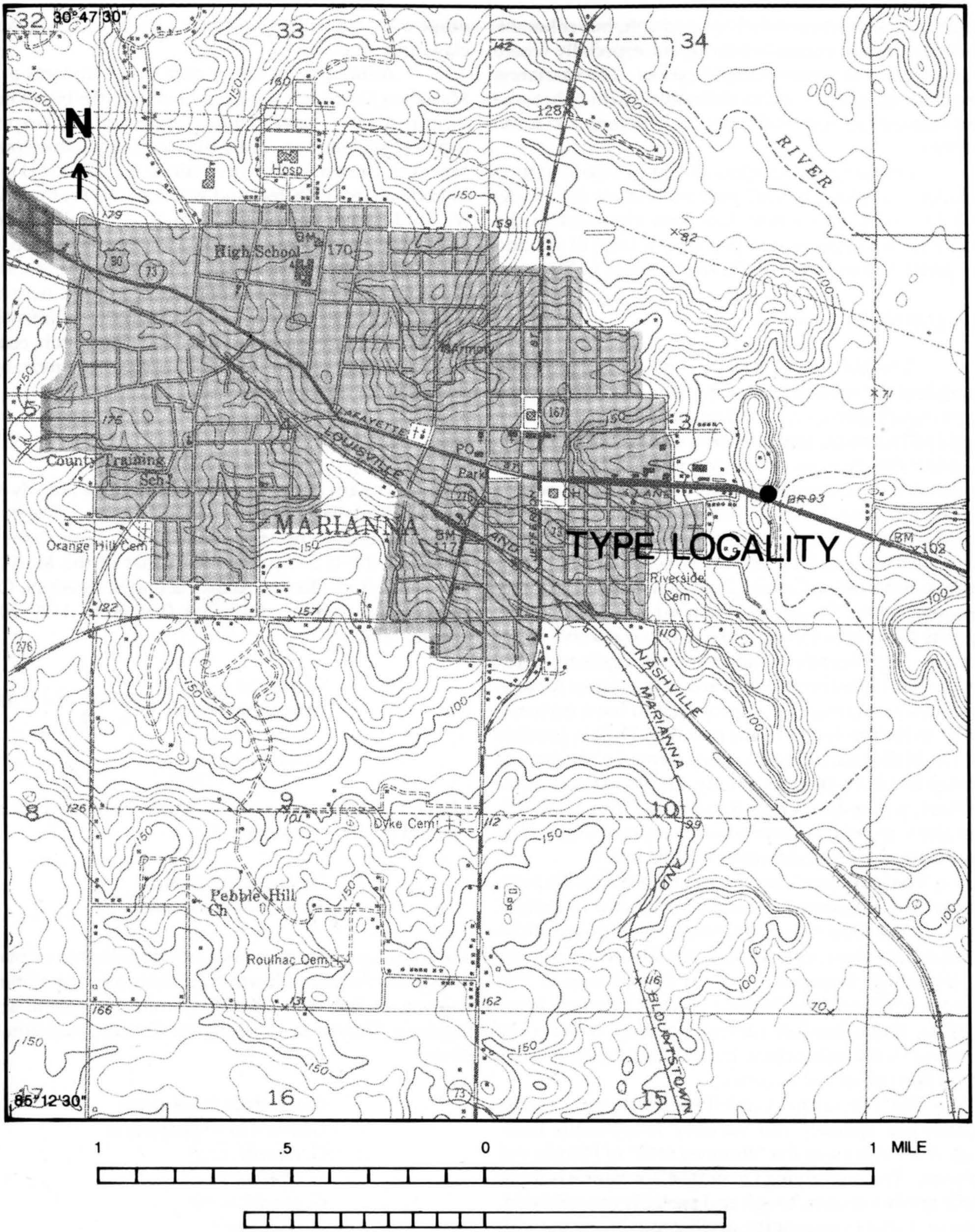

Figure 6. The type locality of the MariannaLimestone (U. S. Geological Survey, Marianna, Fla. 1:24,000 topographic quadrangle).

The limestone is unconsolidated and soft, but coherent. Minor induration occurs in thin layers, especially where there are concentrations of *Lepidocyclina*. The Marianna Limestone is massive and thick-bedded, with only some thin, vague stratification defined on differences in fossil content.

According to Pickering (1970, p. 51), the Marianna Limestone consists of 98.41 percent calcium carbonate. No other lithic component has been observed in the Marianna although there is probably a trace of silt and clay present (compare with Pickering, 1970, p. 51).

Stratigraphic relationships

The Marianna Limestone in Georgia probably occurs near the eastern limit of the formation because the Oligocene calcareous sand and sandy limestone is present roughly 45 miles (72 km) farther east in Wheeler County. No other occurrences of the Marianna Limestone are known between central Pulaski County and the type area in central Jackson County, Florida, a linear distance of approximately 150 miles (240 km). A projected outcrop belt of the Marianna Limestone between Pulaski County, Georgia, and Jackson County, Florida, would occur along the center of the Dougherty Plain where all Oligocene deposits have either been eroded or weathered to residuum. Significantly, residuum of Bridgeboro Limestone can be traced northwestward only as far as Albany. The Marianna Limestone is projected to have occurred farther to the northwest in the past (Fig. 7). It is possible that the Marianna Limestone once formed a continuous outcrop belt from Jackson County, Florida, at least as far northeast as the Ocmulgee River area. The Marianna Limestone in Pulaski County would represent an outlier or remnant of the once-continuous formation.

The Marianna Limestone paraconformably overlies the Upper Eocene Ocmulgee Formation in Pulaski County. In turn, the Marianna is conformably overlain by Glendon Limestone, or is disconformably overlain either by Hawthorne Group deposits or by residuum. The presence of Glendon Limestone on the Ocmulgee River suggests that Glendon Limestone may overlie the Marianna in the subsurface, but this superposition has not yet been observed in cores.

The Marianna Limestone is a soft, chalk-like,massive, sparsely but variably fossiliferous limestone. It is the same as the "chimney rock" of Florida and Alabama. The underlying Ocmulgee Formation is more lithologically variable, tough and partially consolidated, granular, variably glauconitic, argillaceous limestone with commonly occurring bryozoa. The overlying Glendon Limestone is distinguished from the Marianna in consisting of alternating layers of indurated limestone (ledges) and soft, unconsolidated limestone (reentrants). In Pulaski County the Glendon is almost nonmacrofossiliferous. All other overlying deposits consist mainly of weathered clays and sand.

Although the upper and lower contacts of the Marianna Limestone are present in the river bluffs in the vicinity of Hawkinsville, the entire section is not exposed in any single outcrop. The entire Marianna Limestone is, however, present in the core Pulaski 3 (GGS-3111) in the interval 75 feet to 96 feet and is 21 feet (6.5 m) thick (also see Huddlestun and others, 1974, p. 27). It disconformably overlies deposits of the Hawthorne Group, the Glendon being absent at the core site. The Marianna Limestone in Georgia was deposited on the inner continental shelf in an area devoid of siliciclastic sediments. It appears to grade landward into siliciclastic-rich, coastal deposits, and it appears to grade seaward into more open marine Bridgeboro Limestone.

Age

The age of the Marianna Limestone is Early Oligocene (Rupelian), middle Vicksburgian. The fauna documented from the Marianna Limestone at Hawkinsville is compatible with that of the Marianna Limestone from Florida, Alabama, and Mississippi. Critical species include the following (Pickering, 1970, 20-24; Glawe, 1972, p. 11):

Clypeaster rogersi
Paraster americana
Chlamys anatipes
C. duncanensis

Oligocene foraminifera reported from the Marianna Limestone at Hawkinsville include:

Lepidocyclina mantelli
Pararotalia byramensis

The Marianna Limestone in Georgia is barren of planktonic foraminifera. However, planktonic foraminifera I have identified from the Marianna Limestone at St. Stephens Quarry in Washington County, Alabama include:

Globorotalia increbescens
Globigerina ampliapertura
G. eocaena
G. officinalis
G. ouachitaensis
G. ciperoensis
Globorotaloides suteri
Pseudohastigerina barbadoensis
Chiloguembelina cubensis

This assemblage is consistent with the *Cassigerinella*

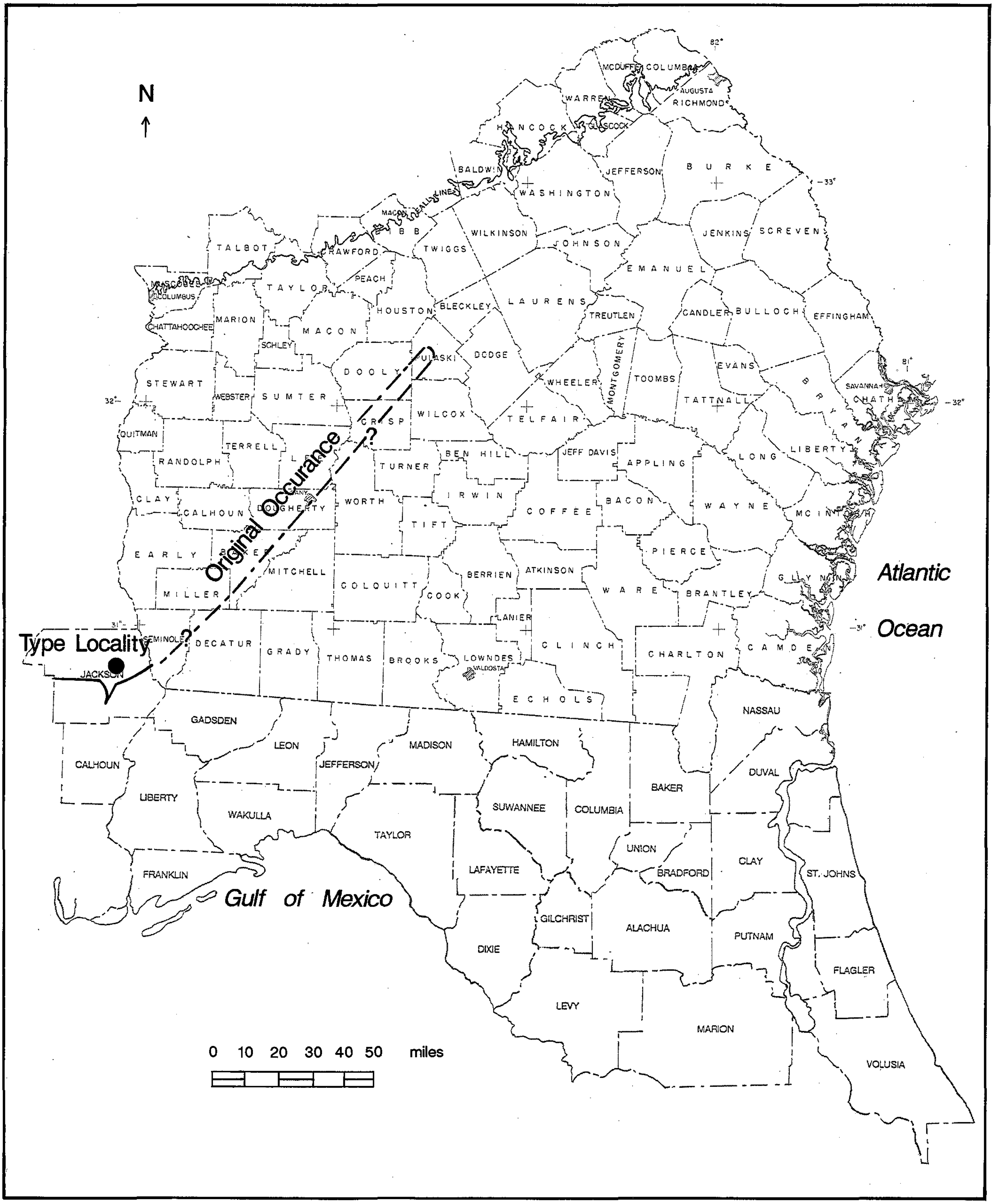

Figure 7. The areal distribution (outcrop and subcrop) of the Marianna Limestone in Georgia and northern Florida.

chipolensis-Pseudohastigerina micra Zone of Stainforth and others (1975),(Pl. 1) and with planktonic foraminiferal Zones P17-P19 of Blow (1969).

GLENDON LIMESTONE

Definition

The Glendon Limestone was named by Cooke (1918) for limestone of Vicksburgian age that overlies the Marianna Limestone in Alabama. In Georgia, the only known occurrence of the Glendon Limestone is in a bluff on the Ocmulgee River near Hawkinsville in Pulaski County. In the past, the Glendon Limestone at this site had been included in the Vicksburg formation (Veatch and Stephenson, 1911), undifferentiated Eocene and Oligocene (Brantly, 1916), Flint River formation (Cooke, 1943), unit A of the Byram Formation (Pickering, 1970) and Glendon Limestone (Huddlestun and others, 1974; Huddlestun, 1981).

The name Glendon was once applied extensively to limestones and residuum in southwestern Georgia. Cooke (1923) referred the chert-bearing deposits in the Bainbridge area to the Glendon Limestone on the basis of the postulated correlation of faunas of the Glendon Limestone of Alabama with that of the chert-bearing residuum of southwestern Georgia. Later, Cooke (1935) developed doubts, on paleontological grounds, concerning the identification and correlation of the residual deposits of southwestern Georgia with the Glendon Limestone. He postulated that the southwestern Georgia deposits contain a foraminiferal and coralline assemblage that was more similar to the Antigua Limestone of the British West Indies. Cooke (1935), therefore, abandoned the name Glendon in Georgia and assigned the chert-bearing residual deposits and associated limestones (Bridgeboro Limestone of this report) to the Flint River formation.

Type Section

The type locality and unit-stratotype of the Glendon Limestone is an abandoned and overgrown limestone quarry north of the abandoned Glendon flag station on the Southern Railroad between Jackson and Walker Springs in NE1/4, Sec. 2, T6N, R2E, Clarke County, Alabama.

Lithology

Near its type area in eastern Mississippi, the lithology of the Glendon Limestone has been discribed by Thomas (1948, p. 20-21) as follows:

> ... where the facies consists of 15 to 20 feet of hard, fossiliferous crystalline limestone (locally called "horsebone") with softer marl interbeds. In the Vicksburg area the beds correlated with the typical Glendon consists of 15 to 40 feet of hard, sandy, glauconitic fossiliferous limestone with softer marly interbeds and, locally, a thin bentonite bed. The lithology of the Glendon at Vicksburg differs from typical Glendon in being more sandy and less crystalline, with the absence of the 'horse bone' weathering effect.

Hendy (1948, p. 28) described the Glendon Limestone in Wayne County, Mississippi as follows:

> Above the Marianna the section consists of 15 to 30 feet of hard, crystalline, glauconitic lime or marl. This rock, when fresh, has a light blue color and on weathering changes to creamy yellow, buff or tan. The basal part, about 6 feet thick, is very irregularly indurated and on weathering has a "horsebone" characteristic similar to that associated with the weathered limestone of the Glendon in the type area in western Alabama. The typical upper part is composed of ledges of crystalline lime which thicken and thin and often have concretionary like projections, the ledges being separated by soft marl partings. Locally in the upper part induration is very irregular but "horse bone" does not form on weathering. Overlying the highest, crystalline, limestone ledge are 1 to 3 feet of soft, light blue-gray, slightly argillaceous marl, which is lithologically similar to the partings between the limestone ledges below.
>
> There are no evident breaks in deposition within the section, although the basal "horse bone" limestone which is gradational with the section above has a distinct characteristic when weathered. No break exists between the highest limestone ledge and the soft lime which overlies it; however, this contact is very evident on drillers' and electrica logs. ... This section rests conformably and gradationally on the Marianna. An

interval 2 to 3 feet thick is present in which the soft Marianna lime becomes harder and denser, grading upward into a noncrystalline, chalky, hard lime and thence into "horse bone: at the base of the Byram. (= Glendon of this report)

and NacNeil and Dockery (1984, p. 20):

> The Glendon Limestone is a hard, ledge-forming limestone ...

The Glendon Limestone on the Ocmulgee River consists of alternating hard and soft layers (ledges and reentrants) of limestone. The limestone in the ledges is partially recrystallized and consists of approximately 94 percent calcium carbonate (Pickering, 1970, p. 51). The limestone in the reentrants is argillaceous, silty, consists of approximately 70 percent calcium carbonate, and contains conspicuous carbonaceous material. The Glendon Limestone on the Ocmulgee River differs from typical Glendon Limestone in being very sparsely macrofossiliferous, and it does not contain any significant number of *Lepidocyclina* as is characteristic of the formation in Alabama. The soft limestone, however, is abundantly microfossiliferous.

Stratigraphic Relationships

The Glendon Limestone is known to occur only in one outcrop in Georgia, the most-downstream bluff on the right bank of the Ocmulgee River approximately 1.25 miles (2.0 km) southeast of Hawkinsville, Pulaski County (Fig. 8)(Pickering, 1970, Pl. 1, locality 38). The Glendon is not present in the core Pulaski 3 (GGS-3111) 1.5 miles (2.4 km) from the exposure on the river. Therefore, in the Hawkinsville area, the occurrence of the formation must be spotty. The occurrence of the Glendon Limestone in Georgia probably is similar to that of the underlying Marianna Limestone (see discussion on p. 18). If so, the Glendon outcrop belt once may have been continuous from central Georgia to the Mississippi River. In this event, the Glendon Limestone would have been removed either by erosion or dissolution from part or all of eastern Alabama, the Florida panhandle, and southwestern Georgia. The Bridgeboro Limestone occurs in the stratigraphic position of the Glendon Limestone at Rockhouse Cave southeast of Cordele.

The Glendon Limestone is distinguished from the underlying Marianna Limestone in consisting of alternating layers of hard (ledges) and soft (reentrants) limestone. The Marianna, on the other hand, is typically massive to thickly and rudely bedded, and consists of unconsolidated but firm and coherent limestone (chimney rock).

There is roughly 10 feet (3 m) of Glendon Limestone exposed on the Ocmulgee River. The Glendon Limestone in Georgia was deposited in relatively shallow, offshore, normal and open-marine, continental shelf water in an environment almost free from siliciclastic sediments.

Along the Ocmulgee River, the Glendon Limestone overlies the Marianna Limestone with apparent conformity, but the contact can be seen only at very low water stages of the river (Pickering, 1970, Fig. 9). The Glendon is overlain by surficial sand in outcrop. If the Glendon Limestone is present elsewhere in the Hawkinsville-Cordele area, it would probably be overlain either by Oligocene residuum, by Hawthorne Group deposits, or by river terrace deposits.

Age

The Glendon Limestone is Early Oligocene, Vicksburgian (Rupelian) in age. The only fossils that have been identified from the Glendon Limestone on the Ocmulgee River are all very rare and include *Paraster americanus*, fragments of an echinoid that appears to be *Clypeaster rogersi, Lepidocyclina, and molds of the gastropod Xenophora* (Pickering, pers. com., 1983). As reported, the meager fauna of the Glendon Limestone is consistent with a Vicksburgian age (Pl. 1).

SHELLSTONE CREEK BEDS, new informal name

Definition

The Shellstone Creek beds consist of moderately weathered, chert-bearing, stratified, argillaceous, well-sorted, fine-grained sand. At this time, the Shellstone Creek beds have been positively identified only in a roadcut on the southern valley wall of Shellstone Creek in northern Bleckley County, Georgia (Fig. 9, site 1)(Pickering, 1970, Pl. 1, locality 2), and at two sites in the Oakey Woods Wildlife Management Area in eastern Houston County, approximately 7 airline miles (11 km) west of the Bleckley County exposure. Shellstone Creek beds are exposed at the top of a ravine (Fig. 9, site 2)(Locality 5 of Huddlestun and Hetrick, 1978, Fig. 6, p. 77), and the upper parts of the beds are exposed in another ravine at the highest elevations in the area (Fig. 9, site 3). At these sites, where undisturbed stratified sand is present, the Shellstone Creek beds have a Barnwell-type lithology and most nearly resemble stratified argillaceous sands of the Dry Branch Formation. In the past, these exposures have been mapped with or described as Ocala Limestone and Flint River formation (Cooke, 1939, 1943), Suwannee Limestone (MacNeil, 1947b), Flint River Formation (Pickering, 1970, pl. 1), Suwannee residuum

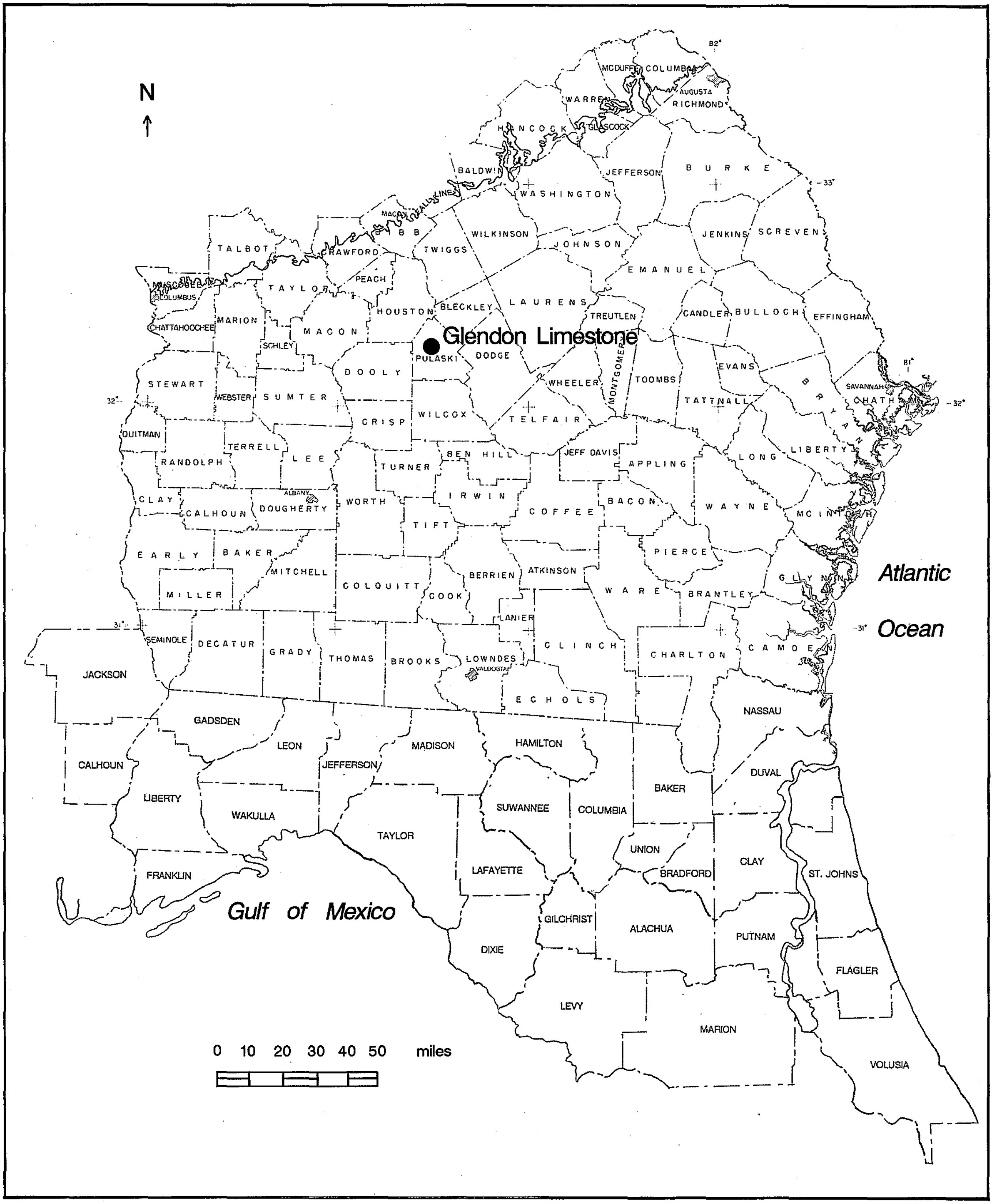

Figure 8. The known distribution of the Glendon Limestone in Georgia.

(Huddlestun and Hetrick, 1978, Fig. 6), and unnamed, thinly bedded, fine sand and clay unit (Huddlestun and Hetrick, 1978; p. 66).

The Shellstone Creek beds present a different stratigraphic problem from that of the Oligocene residuum. Based on the above three sections, if non-chert bearing (nonfossiliferous) Shellstone Creek beds occurred widely in the Fall Line Hills in central and eastern Georgia, lithostratigraphically they would be included in the Barnwell Group. And, if the Shellstone Creek beds that are barren of fossiliferous chert occurred farther north and directly overlie the Tobacco Road Sand, it could be difficult to differentiate the two sand units. However, neither stratified sands with Oligocene fossils nor residuum with Oligocene fossils have been identified at other Tobacco Road exposures in central and eastern Georgia. In the Fall Line Hills, typical Tobacco Road Sand either occurs at the top of the geologic section or is directly overlain by the Miocene Altamaha Formation. At some sites and in some areas in central and eastern Georgia, however, well-sorted, fine-grained sand reminiscent of the Shellstone Creek beds occur at the top of the Tobacco Road Sand sections. Because these fine-grained sands are weathered to some degree, lack chert, and are nonfossiliferous, specific age assignments have not been made on them and they have been included and mapped with the Tobacco Road Sand (e.g., Stop 4, beds 5 and 6 of the Tobacco Road Sand in Huddlestun and Hetrick, 1979, p. 51-52).

The Shellstone Creek beds are significant in that, previously in the Southeastern Coastal Plain, no Barnwell-type, stratified, siliciclastic deposits of Oligocene (and especially Vicksburgian) age have been reported. This occurrence adds to the accumulating evidence that the earliest Oligocene environment and depositional systems in the Southeast were very similar to those of the preceding Late Eocene, and that the Vicksburgian lithostratigraphic and distribution patterns are very similar to those of the underlying Jacksonian. It also suggests that Barnwell-type, Vicksburgian deposits once may have been much more widespread in the Fall Line Hills and near the Fall line than is the case now. Finally, it is possible that, locally, the uppermost beds of the Tobacco Road Sand of the Barnwell Group may be Vicksburgian in age.

Reference Sections

The locations of three exposures of the Shellstone Creek beds are given here for reference purposes. The roadcut at the intersection of Red Dog Road and Magnolia Road on the southern valley wall of the Shellstone Creek in Bleckley County is the main reference section of the Shellstone Creek beds (Fig. 8, site 1). Fossiliferous chert with rare Oligocene fossils occurs in the lower part of the section whereas the characteristic stratified sand occurs in the upper part of the section. The Shellstone Creek beds are overlain at this site by high terrace, gravelly sand deposits of the Ocmulgee River; but less than 1 mile (1.6 km) to the east on Red Dog Road, residuum with fossiliferous chert occurs at higher elevations than that at the road intersection. The exposure at the road intersection is located immediately east of the Ocmulgee River, approximately 3.5 miles (5.6 km) southeast of Westlake and 6.5 miles (10.4 km) north-west of Cochran (Fig. 8).

The other two reference sections are located in the Oakey Woods Wildlife Management Area in eastern Houston County, Georgia, west of the Ocmulgee River (Fig. 8, sites 2 and 3). The first section is in the top of a steep-head, about 100 feet (30 m) south of the dirt road, 0.5 mile (0.6 km) southeast of the Kathleen Observation Tower. This is Locality 5 of Huddlestun and Hetrick (1978, Fig. 6). The Shellstone Creek beds-Tobacco Road Sand contact is exposed at this site and most of the Shellstone Creek beds here consist of stratified to massive chert.

The other section is exposed in a ravine at the intersection of two dirt roads (Fig. 8, site 3). There is no chert exposed at this locality and the lithology of the sand most nearly resembles that of similarly stratified, argillaceous, fine sands of the Irwinton Sand Member of the Dry Branch Formation.

Lithology

In the area being described, the Shellstone Creek beds consist of a lower part with stratified, variably fossiliferous chert and interstratified chert and fine- to medium-grained sand. The upper part consists of weathered, thinly bedded, argillaceous, well-sorted, fine-grained sand.

Stratigraphic Relationships

The Shellstone Creek beds in northern Bleckley and eastern Houston Counties probably grade laterally southward (seaward) into the Marianna and Glendon Limestones because all are Vicksburgian in age. However, due at least in part to deep weathering and the nearby presence of deeply incised rivers, no other exposures of unweathered to only moderately weathered Oligocene sediments have yet been found between Shellstone Creek-Oakey Woods and Hawkinsville, where the Marianna and Glendon Limestones are exposed. Therefore I speculate that the zone of lithofacies change occurs in the vicinity of the east-west escarpment (cuesta) that occurs along the trend of Flat Creek-Big Indian Creek-South Shellstone Creek-Perry-Clinchfield (Ocala escarpment of Pickering, 1970, Pl. 1). Numerous Lower Tertiary stratigraphic units undergo a north to south

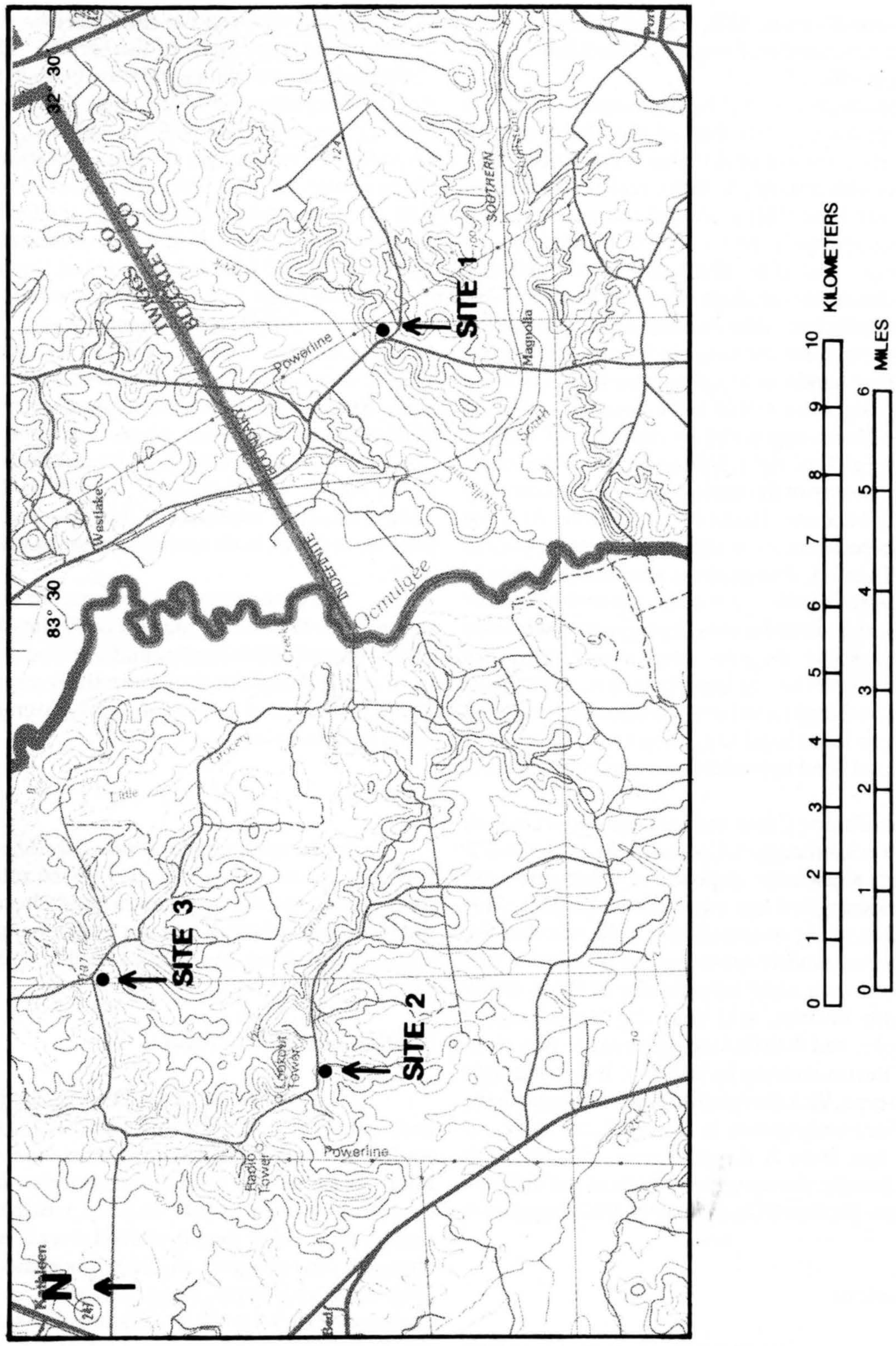

Figure 9. Reference locations for the Shellstone Creek Beds (U.S. Geological Survey, Hawkinsville, Georgia, 30 X 60 minute series [topographic]).

lithofacies change along this trend, including the lithofacies change of the underlying Tobacco Road Sand southward (seaward) into the Ocmulgee Formation. In addition, enigmatic sands that overlie the Ocmulgee Formation in the vicinity of Sugar Hill in southeasternmost Houston County may represent a paleo-barrier island phase of the Vicksburgian similar to one suggested by Huddlestun and Hetrick (1978, p. 65, 70-72) for the underlying Tobacco Road Sand-Ocmulgee Formation transition. If so, then the postulated Vicksburgian barrier island system would have migrated seaward by about 6 or 7 miles (10 or 11 km) from its Late Eocene position. There is no information concerning the stratigraphic relationships of the Shellstone Creek beds with Oligocene deposits farther east. Much of the massive and structureless, Oligocene residuum in southern Houston, Pulaski, and Bleckley Counties originally may have been an argillaceous, fossiliferous, calcareous phase of the Shellstone Creek beds.

The Shellstone Creek beds overlie the Tobacco Road Sand with sharp contact at Oakey Woods (Huddlestun and Hetrick, 1978, Fig. 6). There is no information from Bleckley County on the nature of the lower boundary, but the same stratigraphic relationship would be expected to be present there too. In eastern Houston County, the Shellstone Creek beds occur at the very top of the local section, but in Bleckley County the sand is overlain by Oligocene residuum that contains scattered layers of fossiliferous to nonfossiliferous chert.

In eastern Houston County, the Shellstone Creek beds are probably 40 feet (12 m) thick or less. At Shellstone Creek, the unit is less than 20 feet (6 m) thick but the composite thickness of the Shellstone Creek beds and residuum a few miles to the east (away from the Ocmulgee River) may be more than 70 feet (23 m).

The environment of deposition of the Shellstone Creek beds was coastal marine and appears to have been sound-lagoonal. The depositional environment of the Shellstone Creek beds was probably similar to that of the Barnwell, based on lithologic similarity to the underlying Barnwell Group,

Age

A *Clypeaster rogersi* found in the bedded chert from the lower part of the Shellstone Creek locality (B. Carter, pers. com., 1988), and a *Rhycholampas gouldii* found in chert from the stratigraphically higher residuum 1 mile (1.6 km) east of the Shellstone Creek locality indicates the age of the unit is Lower Oligocene, Vicksburgian. Based on stratigraphic position and the presence of the *C. rogersi*, the Shellstone Creek beds are probably correlative with the Marianna and Glendon exposures near Hawkinsville, 12.5 miles (20 km) to the south (Pl. 1)(compare with Pickering, 1970, Pl. 1).

UNDIFFERENTIATED RESIDUUM

Definition

The name Flint River formation was proposed by Cooke (1935, p. 1170-1171) for deposits exposed above the Ocala Limestone along the Flint River between Hales Landing and Red Bluff near Bainbridge in Decatur County, Georgia. The assortment of deposits exposed there included residuum; fossiliferous chert (with Oligocene fossils); Pleistocene fluvial deposits; and limestone. Because the chert contains Oligocene fossils, the "formation" was conceived to be of Oligocene age. The Flint River formation was subsequently mapped both as Flint River formation and Ocala Limestone by Cooke (1939, 1943), residuum and Suwannee Limestone by MacNeil (1947a), and Flint River formation and Neogene undifferentiated by Pickering (1970).

MacNeil (1944b, p. 35-37) abandoned the Flint River formation because he apparently considered it to be an inappropriate stratigraphic unit:

> The formation consists of fossiliferous chert, clay, sand, and gravel, intermingled and entirely without bedding. Recent mapping in southeastern Alabama by the writer has shown that the Flint River is not a single unit of deposition, but a mixture of the disarranged beds of Miocene formations. It was probably formed by the solution of rather pure Oligocene limestones during which partial silicification took place and higher beds of Tampa and Catahoula age were disarranged and incorporated with the limestone residuum by sink hole action.

Most workers have followed MacNeil (1946, 1947a, 1947b) in abandoning the name Flint River formation although Herrick and Counts (1968) and Pickering (1970) reintroduced the name.

I am in agreement with earlier authors that the Flint River formation is an invalid lithostratigraphic unit as proposed by Cooke (1935) and the name should not be used. However, the variably cherty, clayey residuum covers large areas of the Coastal Plain in Georgia (Fig. 9) and, although it consists of weathered deposits of Middle Eocene to Miocene age, the vast majority of the material appears to have been derived from Oligocene marine deposits. Therefore, this residual material cannot be ignored in a stratigraphic study because it gives stratigraphic information on the original distribution and physical nature of the component deposits. In the present study on the Oligocene stratigraphy of Georgia, the residual sediments described and discussed are only those that can be shown to be, or are believed to have been, derived from Oligocene marine deposits. This age relationship is based on the presence of associated cherts bearing Oligocene fossils, and on the direct physical correlation of chert-bearing residuum with residuum barren of fossiliferous chert that occurs nearby in a similar stratigraphic position and at similar elevations. It is admitted that due to the extreme disarrangement and dislocation of these sediments relative to the original deposits, the present physical relationship of the fossiliferous chert with the enclosing nonfossiliferous residual matrix is problematical; and the present fossiliferous chert may have a significantly different age from that of the enclosing, original undisturbed parent siliciclastic sediment (protolith). In addition, the time of generation of the residuum is much younger than the age of the unweathered parent deposits.

Lithology

Most of the Oligocene residuum consists of moderate reddish brown (10 R 4/6), variably sandy clay with associated blocks or inclusions of variably fossiliferous chert and local concentrations of ironstone. MacNeil (1944a, p. 4-5) gave an adequate description of these sediments:

> The Flint River formation, an assortment of varicolored chert, clay, sand, and gravel covers very large areas in Georgia and eastern Alabama. It is heterogeneous and entirely without bedding. It results from the solution of rather pure Oligocene limestones during which partial silicification took place to form large blocks of chert, and higher beds of Tampa and Catahoula age were disarranged and incorporated with or settled on the limestone residuum and chert by sink hole action. In regions where the Ocala has been dissolved, the Flint River is frequently incorporated with the residuum of the Ocala by the same process. In some areas the Ocala limestone also formed chert, and Ocala and Oligocene cherts are mixed together. Locally, however, the Ocala settled more uniformly and its residuum is recognizable as a zone of compacted sand and crumpled shale below the Flint River.

Although both Cooke (1935, 1943) and MacNeil (1944a, 1944b) included gravel in the concept of the Flint River formation, it is my observation that the Oligocene deposits of the southeastern United States are devoid of quartz gravel and quartz pebbles. The gravel identified by Cooke (1935, 1943) and MacNeil (1944a, 1944b) occurs in high terrace, fluvial deposits of the Chattahoochee and Flint Rivers across the entire southern part of the Dougherty Plain and is stratigraphically unrelated to the Oligocene or Eocene residual deposits.

MacNeil (1944a, 1944b) indicated that the sand and clay in the residuum were emplaced during the weathering of the Oligocene carbonate deposits from overlying Miocene deposits. If this is so, and I have seen nothing in the field that is inconsistent with this interpretation, then the sand component of the Oligocene residuum is largely an artifact of post-Oligocene weathering conditions and is not a reflection of the original lithology of the Oligocene sediments. It is possible, however, that much of the Oligocene clay residuum in Georgia was derived from the weathering and leaching of the Bucatunna Clay. The Bucatunna Clay originally may have occurred as far east as central Georgia.

Stratigraphic Relationships

The undifferentiated Oligocene residuum is known to occur in Georgia from the Chattahoochee River area in the west to the vicinity of the Oconee River (Laurens County) in the east (Fig.10). Oligocene residuum has not been identified in outcrop east of the vicinity of the Oconee River except along Brier Creek in northernmost Screven County, Georgia.

The undifferentiated Oligocene residuum generally occurs at the tops of the sections north of Baker County, Georgia. South of the vicinity of Baker County, the Oligocene residuum contains both Oligocene and Eocene cherts. North of the Dougherty Plain, the Oligocene residuum also directly overlies the Lisbon Formation and Factory Creek Formation of Huddlestun and others (in review). In Pulaski, Bleckley, and Laurens Counties, the Oligocene residuum overlies the Ocmulgee Formation and it is possible that in the far updip reaches of the deposit, the residuum directly overlies the Tobacco Road Sand. Also, in parts of Pulaski, Bleckley, and Laurens Counties, the undifferentiated Oligocene residuum is overlain by either Hawthorne Group deposits or Altamaha Formation.

In Burke County, Georgia, where the Tobacco Road Sand has been deeply weathered and resembles the typical Eocene-Oligocene residuum, it is possible that the Tobacco Road can be distinguished from Oligocene residuum because the sands of the Tobacco Road are coarser and poorly sorted. In southwestern Georgia, where the residuum may be a mixture of deeply weathered Eocene,

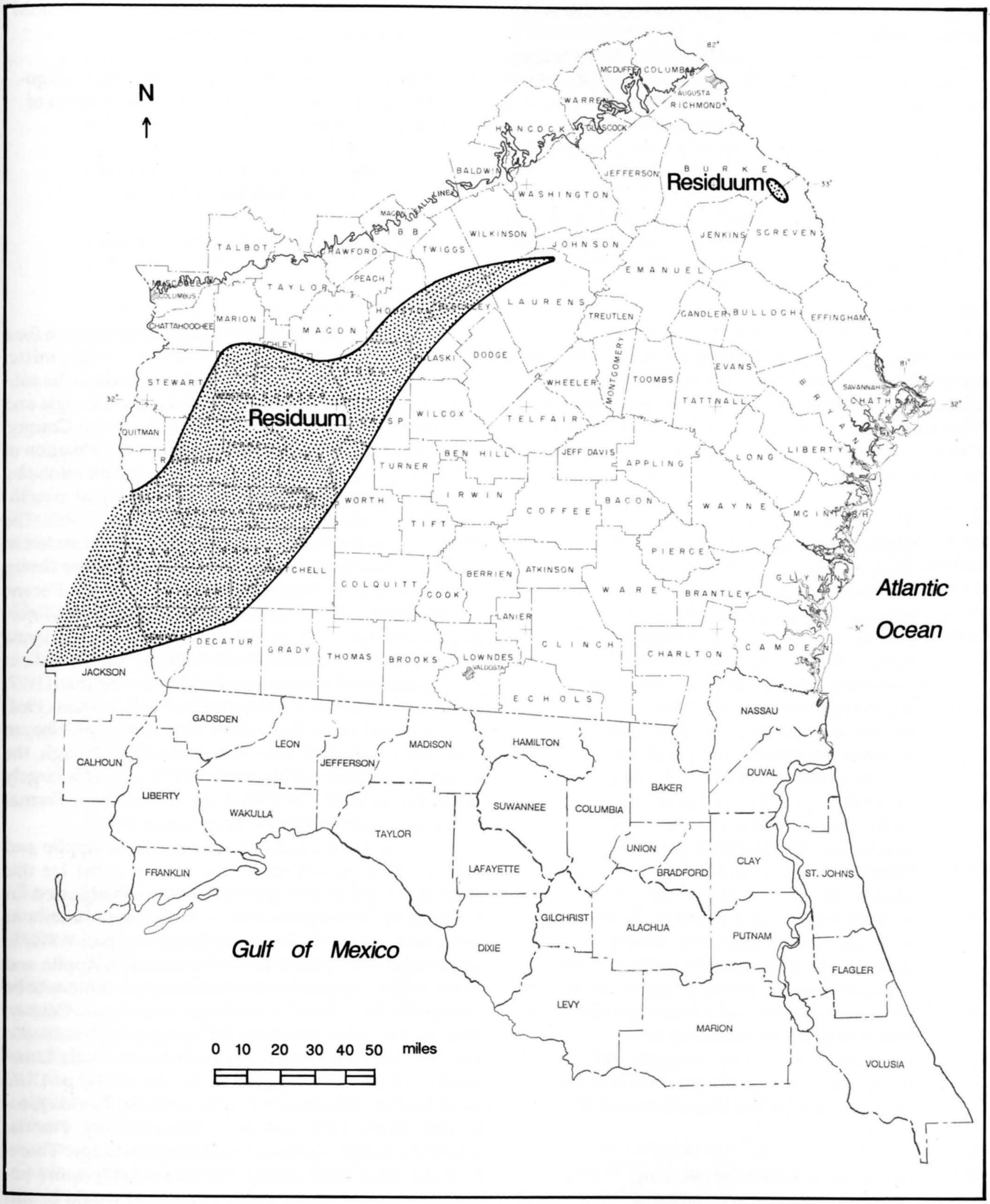

Figure 10. The areal distribution of undifferentiated Oligocene residuum in Georgia.

Oligocene, and Miocene sediments, the above distinction would not be true.

Deeply weathered and residual sediments of the Altamaha Formation can be distinguished from Eocene and Oligocene residuum in that the Altamaha is mottled (gray, maroon, and orange), contains no chert or fossils, is feldspathic, and the sand is generally medium to coarse and poorly sorted.

The thickness distribution of the Oligocene residuum is very irregular due to its residual nature. It appears to average approximately 50 feet (15 m) thick but locally it may be more than 100 feet (30 m) thick.

Age

Based on published faunal lists (Dall, 1916; Cooke, 1923, 1943; Mansfield, 1937, 1940), the undifferentiated Oligocene residuum includes both lower Oligocene, Vicksburgian (Rupelian) and Upper Oligocene, Chickasawhayan (Chattian) components. According to M.E. Hunter (written com., 1992), however:

> The residual clays overlying the pinnacled upper contact of the Bridgeboro Limestone at its type locality in Mitchell County, Georgia, contain silicified molluscan fossils that include such taxa as *Orthaulax hernandoensis*, *Ampullina flintensis* and other species. In addition to the Bridgeboro pit, a small fossil assemblage that includes these and a number of other fossil species also occurs locally above the Suwannee Limestone (post-Suwannee of Yon and Hendry, 1972) in parts of peninsular Florida and in the Oligocene residuum near the Flint River, and westward near the Florida state line as far west as Geneva, Alabama. I feel reasonably confidant in suggesting a correlation between these three areas. However, none of these taxa seems to have been reported from the type Chickasawhayan in Mississippi and I have found none of the typical Chickasawhayan fossils in the Florida/Georgia localities discussed above.
>
> I therefore question the old, long standing correlations (established by Cooke, 1923; 1935; 1943; and Mansfield, 1937; 1940) in which the three Florida/Georgia areas were correlated with the type Chickasawhayan of Mississippi.

Therefore the precise ages of this Florida Bank, Oligocene, molluscan fauna are not established in terms of the type provincial section in Mississippi.

GULF TROUGH STRATIGRAPHIC ASSOCIATION

OCHLOCKONEE FORMATION, new name

Definition

The Ochlockonee Formation is named here for a finely granular to lutitic, variably dolomitic, microfossiliferous limestone that is restricted to the subsurface in the Gulf Trough of southwestern Georgia and the eastern panhandle of Florida. In Gadsden County, Florida, the lower part of the Ochlockonee Formation of this report was included in the Tallahassee limestone by Applin and Applin (1944), and the upper part was included in the Gadsden limestone by Moore (1955). The Ochlockonee Formation has been variously included in the Ocala Limestone, Lisbon Formation, Claiborne Group (undifferentiated), and Oligocene and upper Eocene (undifferentiated) in Thomas and Colquitt Counties, Georgia, by Herrick (1961, p. 402, 128-133); in the Marianna Limestone by Sever and Herrick (1961, p. 402, 128-133); in the Marianna Limestone equivalent by Zimmerman (1977, p. 16), in the Ocala Limestone by Puri and Vernon (1964, p. 94-96), and in the Suwannee Limestone by Gelbaum and Howell (1982, p. 143-147). In the Gulf Trough, the Byram Formation of Zimmerman (1977, p. 17) is largely the upper dolostone section of the Ochlockonee Formation and probably Wolf Pit Dolostone.

The name Tallahassee limestone of Applin and Applin (1944) is not reintroduced as a name for this formation because no type well was ever designated for the proposed formation and the Tallahassee limestone as described and applied by Applin and Applin (1944) is stratigraphically inconsistent. For example, Applin and Applin (1944) considered the Tallahassee limestone to be middle Eocene (Claibornian) in age. In Jefferson County, Florida, and in Decatur County, Georgia, the Tallahassee limestone of their usage does underlie the Ocala Limestone. However, Applin and Applin (1944, p. 1736) identified the Tallahassee limestone in the Florida Geological Survey well W-4 in Gadsden County, Florida, where it is Early Oligocene (Vicksburgian) in age. Therefore, the name Tallahassee limestone would require unreasonable redefinition and revision, and would be different in content from the original intended use of the formation name.

The name Gadsden limestone was introduced by

Moore (1955, p. 43) for:

> ...those limestones of Jackson age that have no, or few, specimens of the larger Foraminifera such as *Lepidocyclina*, *Asterocyclina* or *Operculinoides*. The type section of the Gadsden limestone occurs in the Florida Geological Survey well W-4, from Quincy, Gadsden County, Florida, between the depths of 680 feet and, "tentatively", 900 feet. In the well W-4, the Gadsden limestone overlies the Tallahassee limestone of Applin and Applin (1944) at a depth of 910 feet although, "a clear-cut bottom for the Gadsden limestone could not be located in this well.

Moore (1955, p. 44) considered the Gadsden limestone to be Late Eocene in age, and correlative with the Ocala Limestone. He considered the Gadsden and Ocala Limestones in Jackson County, Florida, to be separated by a normal fault (Cypress fault) with the Gadsden limestone occurring on the downthrown side of the fault.

Puri and Vernon (1964, p. 95) rejected the name Gadsden limestone and the concept of the formation:

> Because the stratigraphic unit Crystal River Formation was established to include all calcareous sediments lying between the Williston Formation and the overlying Oligocene limestones (Puri, 1953), the downdip sediments are referred in this paper to the Crystal River Formation.

The Gadsden limestone of Moore (1955) was thereafter included in the Crystal River Formation because it was believed to be Late Eocene in age.

The Gadsden Limestone is not reintroduced in this report because it would take major revision and expansion of the original concept of the formation, and the revised and expanded formation would differ significantly in concept and content from the original definition of the formation. Both the Tallahassee limestone of Applin and Applin (1944) and the Gadsden limestone of Moore (1955) are subsumed under the Ochlockonee Formation of this report in Gadsden County, Florida. The Ochlockonee Formation is Early Oligocene whereas the Tallahassee limestone (lower part of the Ochlockonee Formation) in Gadsden County, Florida, was postulated to be Middle Eocene (Claibornian) by Applin and Applin (1944), and the Gadsden limestone (upper part of the Ochlockonee Formation) was postulated to be Upper Eocene (Jacksonian) by Moore (1955). Both the lower and upper parts of the Ochlockonee Formation in the W-4 are Oligocene.

One formal member of the Ochlockonee Formation is recognized in this report, the Pridgen Limestone Member of the Ochlockonee Formation. The Pridgen Limestone Member is restricted in occurrence to the Gulf Trough northeast of the Chattahoochee Embayment whereas typical Ochlockonee Formation is known to occur only in the Chattahoochee Embayment.

The modifying term of the Ochlockonee is "formation" rather than "limestone" because large parts of the Ochlockonee section at various sites in southwestern Georgia have been extensively dolomitized. In Florida and Colquitt County, Georgia, however, the Ochlockonee Formation appears to consist largely of limestone with extensive dolomitization only in the upper part of the formation.

Type Section

The name Ochlockonee is taken from the Ochlockonee River which lies 1 mile (1.6 km) southwest of the type locality. The type locality of the Ochlockonee Formation consists of two cores taken less than 200 feet (61 m) apart near the bank of a farm pond, approximately 3.1 miles (5.0 km) northwest of Moultrie, Colquitt County, Georgia (Fig. 11). The type section or unit-stratotype (composite holostratotype) of the upper part of the formation occurs from 606 feet to T.D. at 790 feet in the core Colquitt 5 (GGS-3199, U.S. Gypsum core 76-8)(Figs. 12 and 13). The unit-stratotype (holostratotype of the lower part of the formation) occurs from 790 feet to 976 feet in the core Colquitt 9 (GGS-3535) (Fig. 13). The upper boundary stratotype of the Ochlockonee Formation occurs at 606 feet in the core Colquitt 5 (GGS-3199) where the Ochlockonee is overlain with apparent conformity by the Wolf Pit Dolostone The lower boundary stratotype of the Ochlockonee Formation occurs at 976 feet in the core Colquitt 9 (GGS-3535) where the Ochlockonee Formation overlies, with apparent disconformity, undifferentiated Upper Eocene limestone. The two cores, the Colquitt 5 (GGS-3199) and the Colquitt 9 (GGS-3535) are stored at the Georgia Geologic Survey in Atlanta, Georgia.

Lithology

The Ochlockonee Formation is typically a light olive gray (5 Y 5/2) to yellowish gray (5 Y 7/2), hard and tough, variably recrystallized, massive-bedded to thinly bedded, bioturbated and burrowed, finely to very finely granular, even-textured, somewhat argillaceous limestone that is variably dolomitic and contains scattered

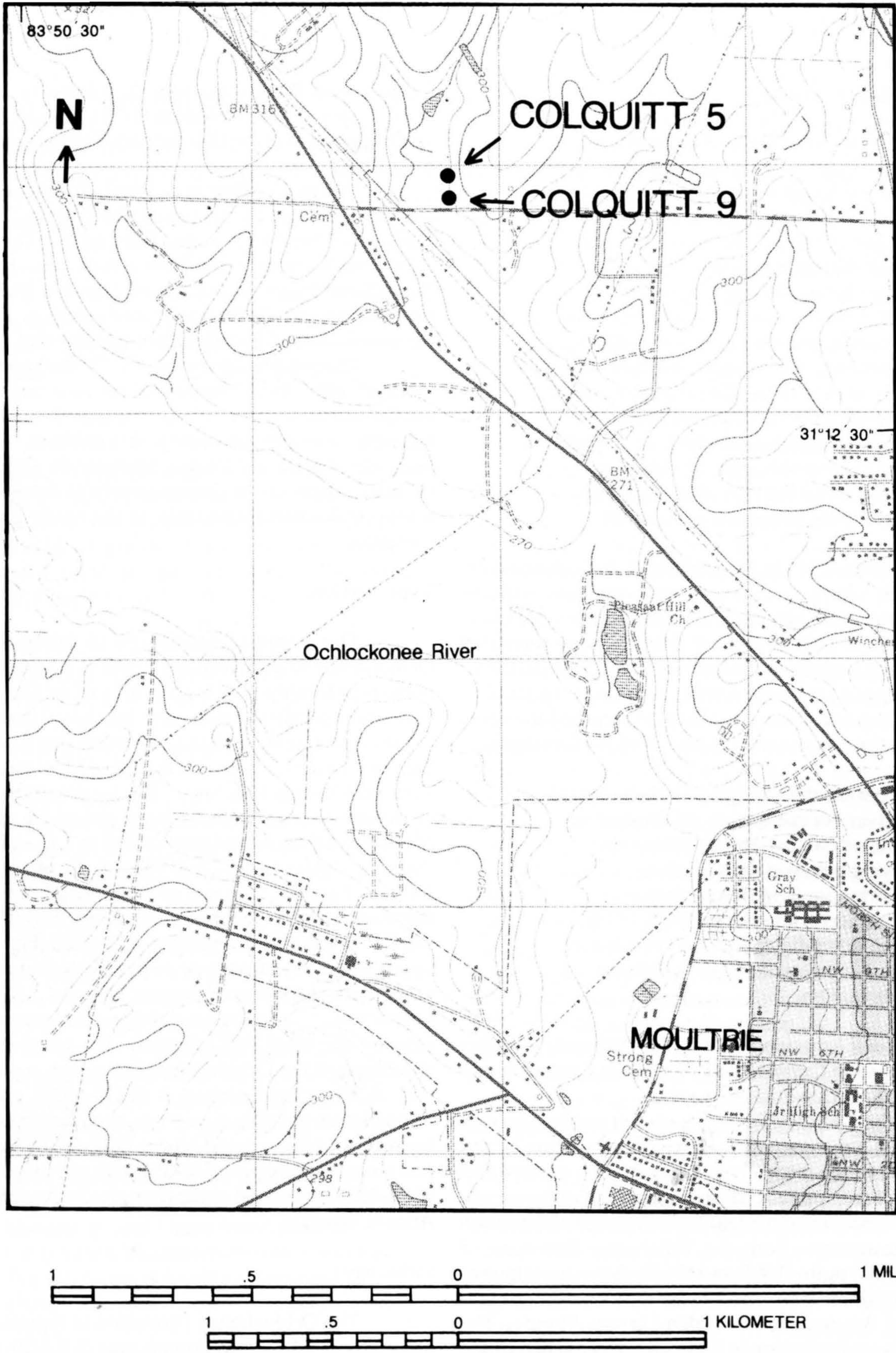

Figure 11. The type locality of the Ochlockonee Formation (Colquitt 5 and 9), Wolf Pit Dolostone (Colquitt 5), and Okapilco Limestone (Colquitt 5) (U.S. Geological Survey, Moultrie, Ga. 1:24,000 topographic quadrangle).

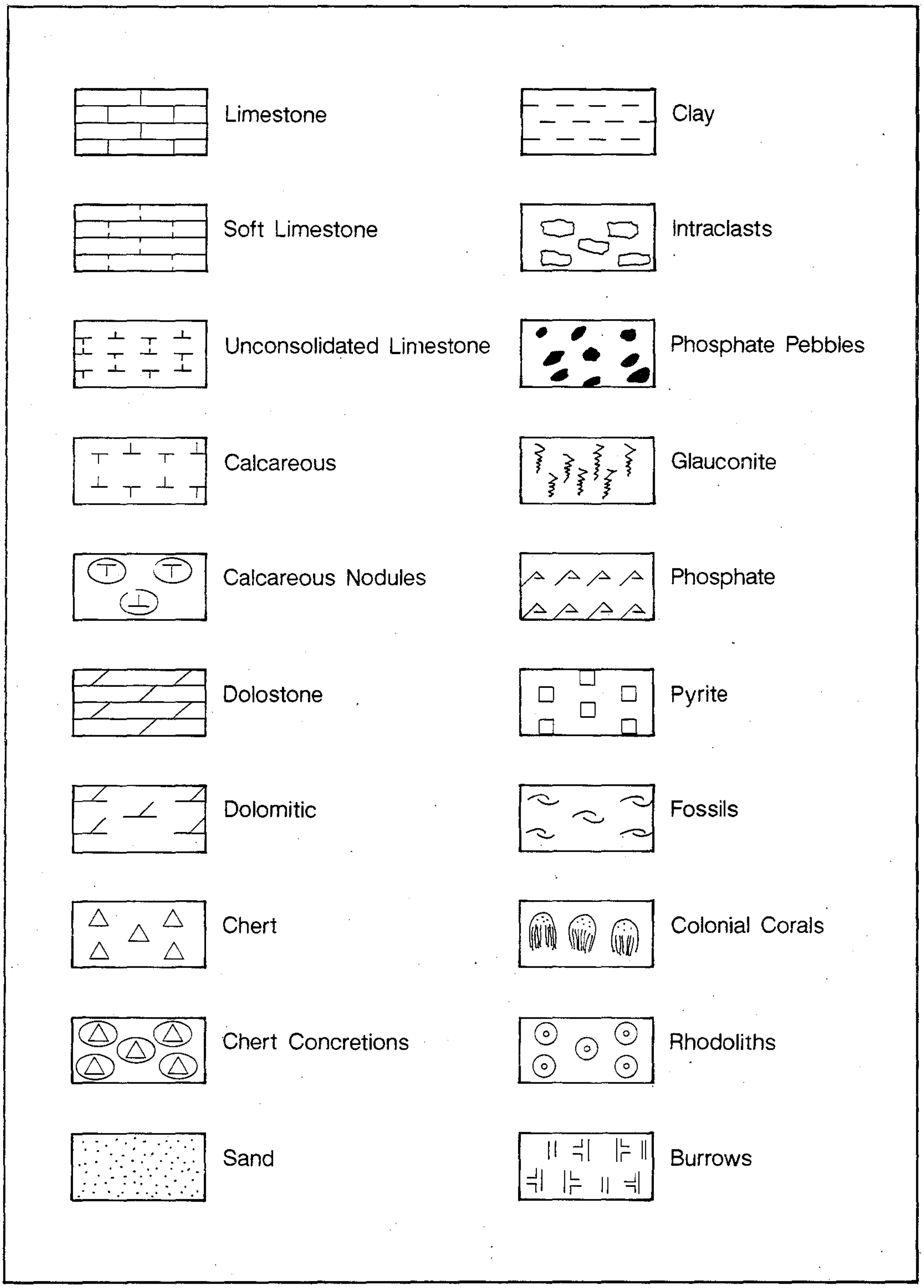

Figure 12. Lithology symbols.

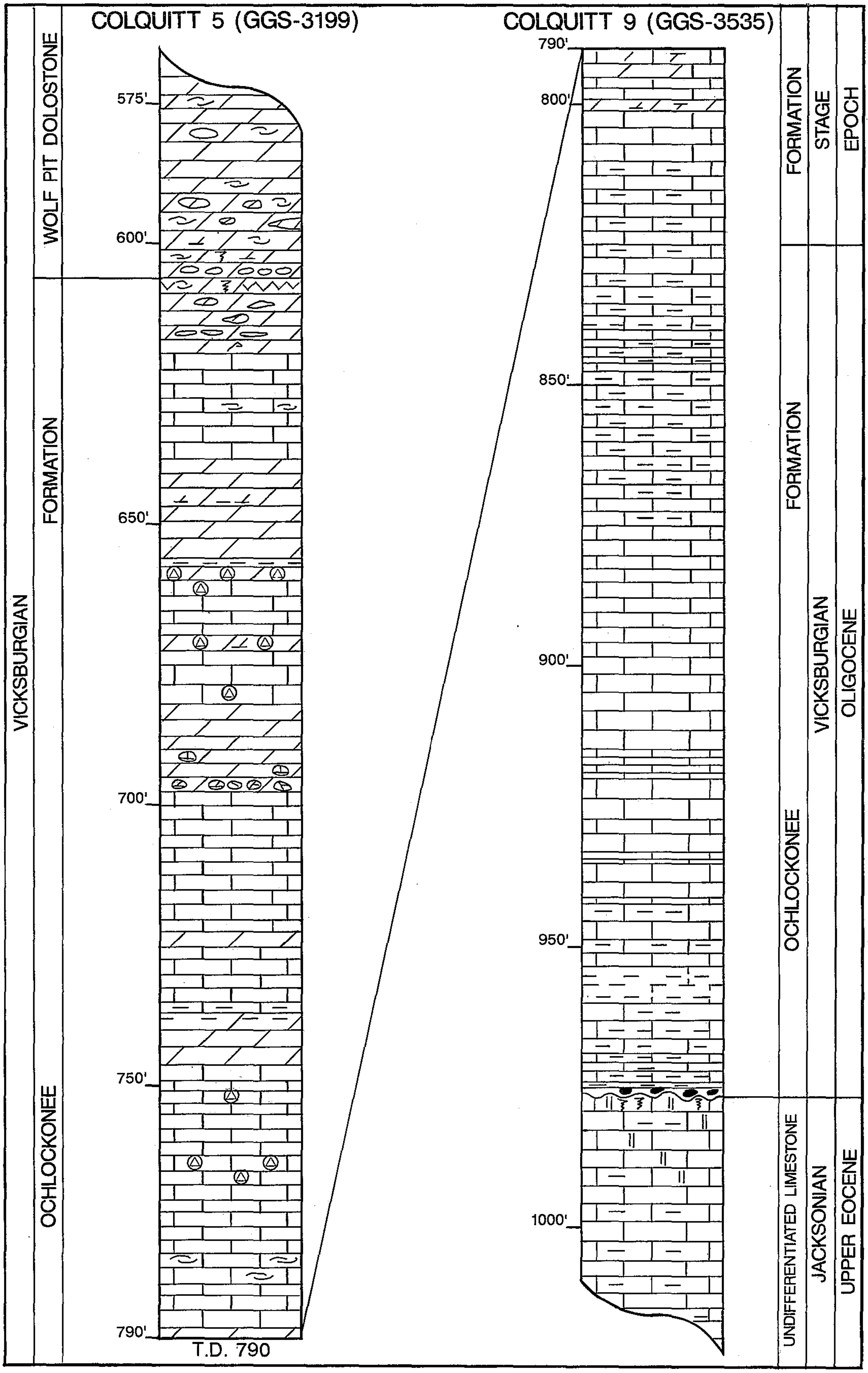

Figure 13. The measured holostratotype of the Ochlockonee Formation.

dolostone intervals. The dominant lithic component of the formation is limestone; subordinate lithic components include dolomite and dolostone, clay, chert, pyrite, phosphate, glauconite, microfossils, very minor and scattered mica and fine-grained sand, and scattered occurrences of gypsum.

The limestone (and all but the most intensely dolomitized intervals) is finely granular and the calcareous particles, where visible, are roughly equidimensional. The grain size of the calcareous particles ranges from medium sand to silt. In the coarser grained intervals, the calcareous grains appear to be suspended in a finer grained matrix. The textural variation within the sediment appears to result from incomplete mixing of fine, nondescript lutitic material and granular calcitic material. Typically, the calcareous sediment is bioturbated and burrowed; the sediment is incompletely mixed and displays color marbling. In some intervals, however, especially the fine-grained, chalky, nongranular intervals, the sediments show no evidence of bioturbation and are massive-bedded and devoid of sedimentary and biogenic structures. The thinly bedded to laminated sediments of the Ochlockonee Formation generally are argillaceous and have the appearance of calcareous shale. Rarely there are beds that consist of laminated or massive and structureless calcareous clay. The only other sedimentary structures that have been observed consist of rare occurrences of limestone and dolostone intraclasts.

Dolomitization has generally affected parts of any given section of the Ochlockonee Formation. Beds of dolostone or dolomitic limestone are most prevalent in the upper part of the formation and the Ochlockonee Formation generally grades up-section into dolostone. Dolostone and dolomite, on the other hand, are not known to occur in the lowest part of the formation. The Ochlockonee Formation has been extensively dolomitized in Grady and Decatur Counties, Georgia. Dolomite occurs both as scattered dolomite rhombs in limestone and as light yellowish brown (10R6/4-10R6/2) to olive gray to brownish black (5y4/1-5Y2/1-5YR2/1) sucrosic dolostone.

Chert concretions and, less commonly, calcite concretions occur at scattered intervals in the Ochlockonee Formation. Glauconite is typically rare and phosphate is known to occur only in the basal bed of the formation. Fine mica is present in some of the argillaceous beds of the Ochlockonee and fine- to very fine grained quartz sand also occurs rarely and in trace amounts. Minor finely disseminated pyrite commonly is present.

Except for some of the more argillaceous intervals, the Ochlockonee Formation is characteristically tough and indurated to some degree. The typical poor preservation of foraminifera indicates recrystallization of the limestone. However, it is only in the dolomitized intervals that recrystallization is generally evident.

The Ochlockonee Formation is not macrofossiliferous but microfossils, and especially foraminifera, are common and locally abundant. Due to induration and recrystallization, it is possible to concentrate microfossils only from scattered thin intervals. Where the limestone has been extensively recrystallized or indurated, the limestone (or dolostone) appears in hand specimens and under low magnification to be completely nonfossiliferous.

Stratigraphic Relationships

The Ochlockonee Formation is restricted to the Gulf Trough in Florida and Georgia (Fig. 14). Typical Ochlockonee Formation does not occur northeast of Colquitt County, but grades laterally northeastward into the argillaceous, more coarsely calcarenitic Pridgen Limestone Member. The Ochlockonee Formation is not known to occur northeast of Jeff Davis County, Georgia, and it is known to be present in the central part of the Chattahoochee Embayment in Florida. However, it possibly underlies all of the embayment to the south as far as the coastal area (Fig. 14).

In Georgia, the Ochlockonee Formation disconformably overlies undifferentiated Upper Eocene (Jacksonian) limestone and is overlain with apparent conformity by the Wolf Pit Dolostone, both of which are restricted in occurrence to the Gulf Trough. In the Chattahoochee Embayment in Florida, the Ochlockonee Formation does not appear to be overlain by the Wolf Pit Dolostone but rather by a correlative, undifferentiated limestone.

In contrast to the Ochlockonee Formation, the underlying Jacksonian limestone in the Gulf Trough consists of slightly glauconitic, fine-grained, more lithologically variable limestone. The Wolf Pit Dolostone is distinguished from the dolomitized Ochlockonee Formation in the more complete dolomitization of the section, commonly with the loss of all primary sedimentary structures. The overlying Oligocene limestones are more coarsely granular, porous, macrofossiliferous and, in the inner embayment and northeastern part of the Gulf Trough, are typically coral-rich (Okapilco Limestone). The stratigraphically correlative Bridgeboro Limestone on the flanks of the Gulf Trough is distinguished by an abundance of rhodoliths (hard, concentrically layered, irregularly rounded, calcitic balls formed by red algae [Bosellini and Ginsburg, 1971; Manker and Carter, 1987]) and is variably macrofossiliferous and fine- to coarse-grained with common bioclastic texture.

Because of poor stratigraphic control in the Chattahoochee Embayment in southwestern Georgia, little can be said of the thickness distribution of the Ochlockonee Formation based on direct measurements in cores and wells. However, in the cores Colquitt 5 and

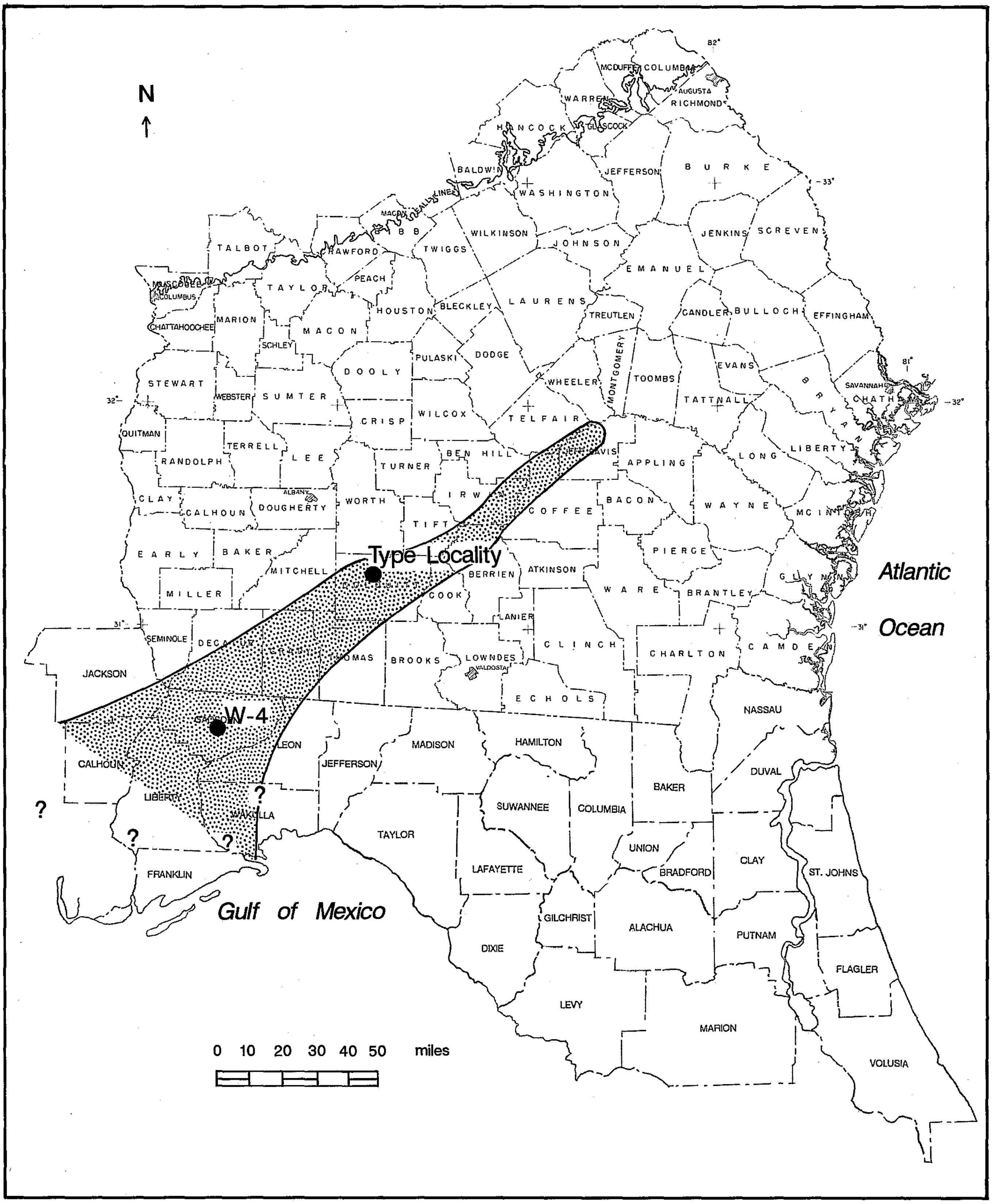

Figure 14. The areal distribution (subcrop) of the Ochlockonee Formation in Georgia and northern Florida.

Colquitt 11 (GGS-3199 and GGS-3535) in Colquitt County, Georgia, the composite thickness of the Ochlockonee Formation is 374 feet (114 m). Well data indicate that the Ochlockonee Formation thickens southwestward into the Chattahoochee Embayment; it is at least 705 feet (215 m) thick in the Florida Geological Survey well W-4, and may be more than 1200 feet (366 m) thick in the well W-6217 in Gadsden County, Florida.

The Ochlockonee Formation was deposited in a relatively deep-water channel whose water depth initially may have been much as 700 or 800 feet (213 or 249 m) in Georgia and significantly deeper in Florida. Deposition of the Ochlockonee was a trough-filling event and the carbonates deposited late in the depositional history of the formation were probably deposited in significantly shallower water. The low diversity of the benthic foraminiferal assemblages may suggest a somewhat restricted bottom environment, or may possibly be the result of selective destruction of foraminiferal tests during mild to severe recrystallization.

Age

The following benthic foraminifera have been identified from the Ochlockonee Formation:

Lenticulina vicksburgensis
Lenticulina spp.
Eponides byramensis
E. obesus
Siphonina advena
Baggina xenoula
Planulina cocoaensis
Cibicidoides cookei
C. pippeni
Anomalinoides bilateralis
Bulimina sculptilis
Uvigerina cf. jacksonensis
U. cf. cocoaensis
U. vicksburgensis
U. glabrans

This association is similar to that of the Lower Oligocene Red Bluff Clay and Marianna Limestone of southeastern Mississippi and southwestern Alabama and many of the species are not known to range below the Oligocene (compare with Bandy, 1949; Deboo, 1965). Moore (1955, p. 33) identified *Bolivina caelata* and *B. byramensis* from the Gadsden limestone (= upper part of the Ochlockonee Formation) in Jackson County, Florida. Neither species has been reported from deposits older than Oligocene. Therefore, the benthic foraminifera support an earliest Vicksburgian age for at least the lower, more microfossiliferous part of the formation.

The planktonic foraminifera identified from the Ochlockonee Formation include the following:

Globorotalia increbescens
Globigerina ampliapertura
G. eocaena

This association, in the absence of *Globorotalia cerroazulensis*, *Hantkenina* spp., and *Cribrohantkenina inflata* is indicative of an Early Oligocene (or possibly latest, Late Eocene) age, and would be included in the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone of Stainforth and others (1975), and in Zones P17-P19 of Blow (1969), (Pl. 1). In terms of the provincial chronostratigraphy, the preceding association is compatible only with the Vicksburgian. Therefore, the planktonic foraminifera support the age assigned to the Ochlockonee Formation based on the Early Oligocene (Vicksburgian) benthic foraminifera.

PRIDGEN LIMESTONE MEMBER OF THE OCHLOCKONEE FORMATION, new name

Definition

The Pridgen Limestone Member of the Ochlockonee Formation is named herein for a limestone subdivision of the Ochlockonee Formation that is restricted in occurrence to the northeastern, parallel sided part of the Gulf Trough. E. R. Applin (1960) briefly discussed this unit from the oil test well GGS-509 (Fig. 15) in Coffee County, Georgia. She did not assign a stratigraphic name to the Oligocene section in the well. Much of her discussion concerned the larger foraminifera *Miogypsina gunteri* and *Miogypsina antillea* and the beds that contain them in the test well. These beds, however, are included in the Lower Miocene Parachucla Formation of Aquitanian age (Huddlestun, 1988). Applin and Applin (1964) described a composite section from three more test wells (GGS-468, GGS-508, GGS-509) from this area in Coffee County (Pridgen prospect) in which they referred to the Pridgen Limestone Member of this report, the Wolf Pit Dolostone, the Okapilco Limestone, and the overlying Parachucla Formation as Oligocene Series undifferentiated. Gelbaum and Howell (1982, p. 143-147) referred to this unit as Suwannee Limestone, and McFadden and others (1986) referred to it as Oligocene undifferentiated.

The modifying term of the Pridgen Member is "limestone" rather than strictly "member" because the known lithology of the unit is overwhelmingly dominated by limestone. Dolostone or clay occurs only in

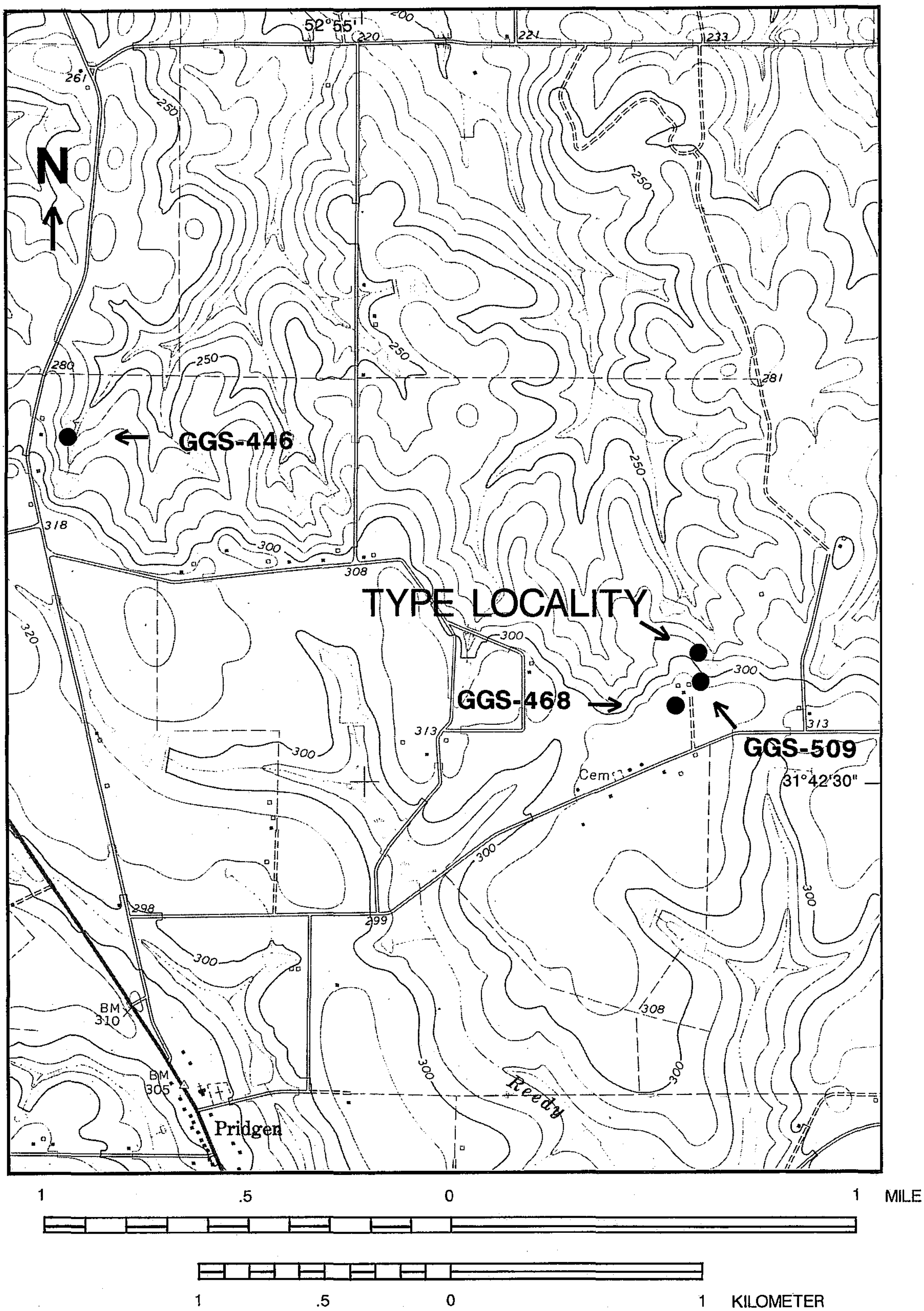

Figure 15. The type locality of the Pridgen Limestone Member of the Ochlockonee Formation, reference locality of the Okapilco Limestone and Wolf Pit Dolostone, and locations of oil test wells of the Pridgen Prospect of Applin (1960) (U.S. Geological Survey, Broxton North, Ga., 1:24,000 topographic quadrangle)

scattered beds or disseminated within the limestone.

Type Section

The name Pridgen is taken from the community of Pridgen in northern Coffee County, Georgia. The type locality of the Pridgen Limestone Member is the core site of the Coffee 4 (GGS-3541)(Fig. 15), located approximately 1.7 airline miles (2.7 km) northeast of the community of Pridgen). The type section or unit-stratotype (holostratotype) of the member occurs in the interval 700 feet to 992 feet in the core (Fig. 16). The upper boundary stratotype of the Pridgen Limestone Member occurs at approximately 700 feet where the Pridgen Limestone is conformably and gradationally overlain by the Wolf Pit Dolostone. The lower boundary stratotype of the Pridgen Limestone occurs at 992 feet in the core where an upper dolostone bed of the undifferentiated Upper Eocene limestone unit is gradationally overlain by the Pridgen Limestone Member. The type core is stored at the Georgia Geologic Survey in Atlanta, Georgia.

The core Berrien 10 (GGS-3542) is here designated a reference section and parastratotype of the Pridgen Limestone Member of the Ochlockonee Formation. The core site of the Berrien 10 (GGS-3542) is approximately 2.1 airline miles (3.4 km) northeast of the village of Enigma in northwestern Berrien County, Georgia (Fig. 2). The Pridgen Limestone Member occurs in the interval 721 feet (above which is a core gap) to 977 feet. The Pridgen Limestone grades downward into a five feet thick, calcareous clay bed in this core. The undifferentiated Upper Eocene limestone conformably underlies the clay bed, giving the appearance of continuous deposition across the stage boundary. The reference core is stored at the Georgia Geologic Survey in Atlanta, Georgia. At this time, undisturbed Pridgen Limestone can be examined in only the two cores, the Coffee 4 (GGS-3541) and the Berrien 10 (GGS-3542).

Lithology

Based on the lithology of the Pridgen Limestone Member of the cores Coffee 4 (GGS-3541) and Berrien 10 (GGS-3542), the unit consists of variably argillaceous, variably dolomitic limestone with scattered beds of dolostone and laminated clay. It is finely to coarsely granular, weakly fossiliferous limestone. The Pridgen Limestone is generally massive and structureless. However there are appreciable sections in the formation that are distinctly stratified. Scattered beds of dolostone are more common in the upper part of the formation and laminated clay is more common in the lower part. The dominant lithic component of the Pridgen Limestone Member is limestone; minor to trace components of the lithology include dolomite, dolostone, clay, carbonaceous material, pyrite, glauconite, phosphate, fossils, and rare and scattered very fine grained sand.

The Pridgen Limestone generally is hard, tough, and variably recrystallized. It is rarely soft and unconsolidated. Bedding typically is thick where the sediments are massive and devoid of biogenic and sedimentary structures. Less commonly the stratification is medium- to thin-bedded or laminated. Some bioturbated and burrowed intervals also are present. The texture of the sediment typically is finely to coarsely granular but beds of very fine grained, chalky limestone are not uncommon. The texture also ranges from even-textured to finely bioclastic and rough-textured. A consistent occurrence of carbonaceous material along bedding planes with some scattered sea grass impressions also appears to be characteristic of the member. The Pridgen Limestone is variably fossiliferous with both nonfossiliferous beds and beds containing commonly occurring larger and smaller foraminifera and less commonly occurring small macrofossils (especially bryozoa).

The lithology of the Pridgen Limestone Member is similar to that of the typical Ochlockonee Formation in that it is granular and calcarenitic, generally thick-bedded and massive, argillaceous, dolomitic, microfossiliferous, and not coarsely macrofossiliferous. The physical features that distinguish the Pridgen Limestone from typical Ochlockonee Formation are as follows: in general the Pridgen Limestone shows more stratification, is more coarsely textured with finely bioclastic intervals, more macrofossiliferous with a consistent occurrence of larger foraminifera (the characteristic "deep-water" foraminiferal fauna of the typical Ochlockonee Formation does not appear to be present in this unit), chalkier, more argillaceous with more discrete beds of clay, more carbonaceous, and less dolomitic.

Stratigraphic Relationships

The Pridgen Limestone Member of the Ochlockonee Formation is restricted to the Gulf Trough in Georgia, from the vicinity of Coffee County in the northeast to the vicinity of Tift County in the southwest (Fig. 17). The Pridgen Limestone grades laterally southwestward into typical Ochlockonee Formation in southwestern Tift or northeastern Colquitt Counties. Northeast of Coffee County, the Pridgen Limestone Member either grades laterally northeastward into undifferentiated calcareous sand and sandy limestone (based on well cuttings) or it pinches out. The upper part of the Pridgen Limestone Member occurs in the same stratigraphic position as the Suwannee Limestone on the flanks of the Gulf Trough to the south and the lower part occurs in the same stratigraphic position as the Bridgeboro Limestone on the flanks to the north. I assume, therefore, that the Pridgen grades laterally on the flanks of the trough into

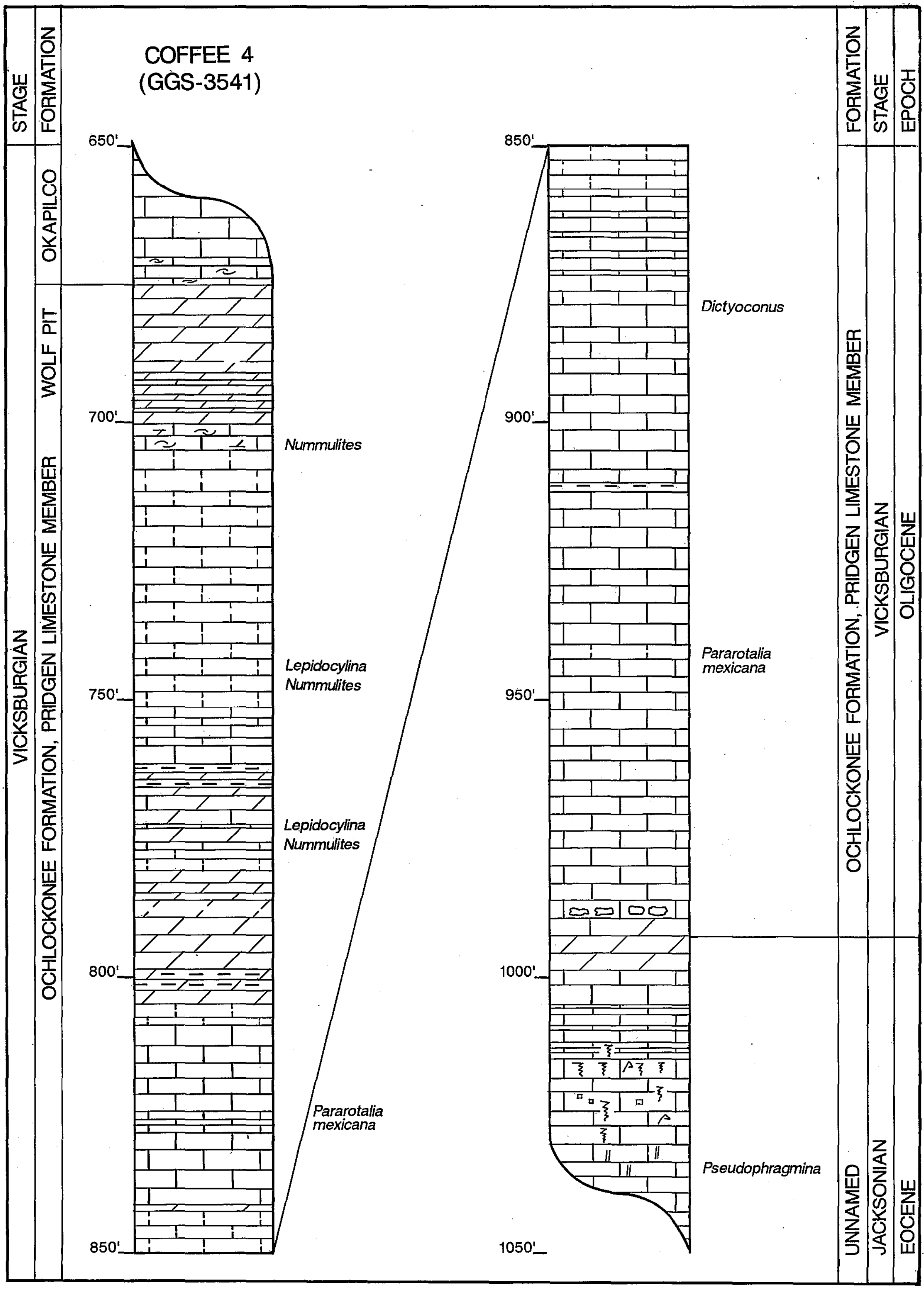

Figure 16. The measured holostratotype of the Pridgen Limestone Member of the Ochlockonee Formation, and parastratotype of the Wolf Pit Dolostone.

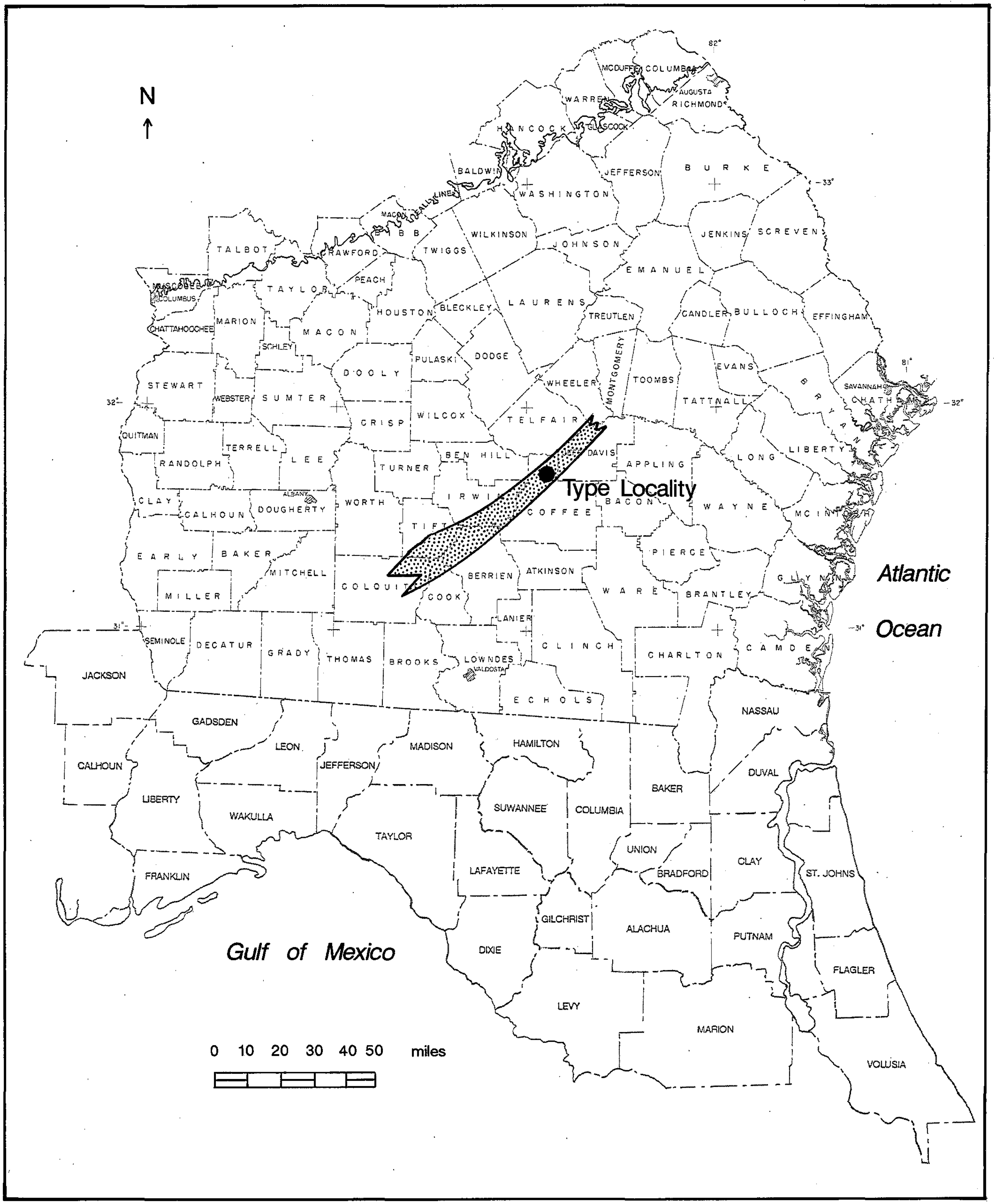

Figure 17. The areal distribution (subcrop) of the Pridgen Limestone Member of the Ochlockonee Formation.

the Bridgeboro and Suwannee Limestones. However, there is no stratigraphic information from the south flank of the trough and it is not known whether the Pridgen Limestone pinches out or grades into another formation.

The Pridgen Limestone Member either abruptly or gradationally overlies undifferentiated upper Eocene limestone, and is overlain conformably by the Wolf Pit Dolostone in the type core. The Pridgen Limestone Member of the Ochlockonee Formation is 317 feet (97 m) thick in the core Coffee 4 (GGS-3541) and is 256 feet (78 m) thick in the core Berrien 10 (GGS-3542).

Age

Based on physical correlation with the Ochlockonee Formation, the Pridgen Limestone Member is Early Oligocene, Vicksburgian (Rupelian) in age (Pl. 1). Compatible with this age, foraminifera that have been reported from this unit include the following:

Lepidocyclina undosa
Nummulites panamensis
Dictyoconus cookei
D. floridanus
Pararotalia mexicana

The known foraminiferal fauna of the Pridgen Limestone Member of the Ochlockonee Formation presents an anomaly and is difficult to reconcile with the stratigraphic model of the Gulf Trough as presented in this report. The Pridgen Limestone must have been deposited in relatively deep water below the photic zone (i.e., that part of the water column illuminated by sunlight). However, I have recovered no deep-water benthic foraminifera from the unit such as are found in typical Ochlockonee Formation. The small carbonaceous content of the unit, the presence of what appears to be sea grass impressions, the common occurrence of relatively shallow water smaller and larger foraminifera, especially *Dictyoconus cookei, D. floridanus, Lepidocyclina,* and *Nummulites* are all suggestive of a shallow to very shallow water marine environment. This would suggest that much shallow water material was able to reach the bottom of the eastern part of the Gulf Trough during deposition of the member. Also the presence of thinly bedded limestone indicates that from time to time, the bottom of the trough was not inhabited by a burrowing infauna. It is possible that the bottom conditions and water-mass conditions in the Gulf Trough at the time of deposition of the Pridgen Limestone deviated appreciably from normal marine conditions, consequently affecting the composition and distribution of the benthic fauna.

The occurrence of *Dictyoconus cookei* and *D. floridanus* in the lower part of the Pridgen Limestone in Coffee County is especially perplexing. Applin (1964) reported *D. cookei* and *D. floridanus* from the GGS-509 in Coffee County. *Dictyoconus cookei* is also present in the same stratigraphic interval in the Coffee 4 (GGS-3541) taken approximately 0.1 mile (0.06 km) from the GGS-509 (Fig. 14). Therefore, the occurrence of *Dictyoconus* in the lower part of the Pridgen Limestone in the Gulf Trough cannot be due to contamination. *Dictyoconus* was a common component of the Tethyan and Florida Bank faunal association through the Cretaceous to Middle Eocene and is characteristic of extremely shallow water, carbonate banks environments. It evidently flourished in water masses that deviated considerably from normal, open-ocean, marine water masses. The genus became extinct worldwide at the end of the Middle Eocene except somewhere in vicinity of the Florida Bank where it survived in refugia (compare with Stubbs, 1941, p. 14; and Cole, 1941, p. 15-16). I have neither seen nor know of any reports of *Dictyoconus* occurring in sediments between the top of the Claibornian Avon Park Formation (and the Inglis Formation of Vernon [1951] and Puri [1957]) on the Florida Bank and the late Vicksburgian Suwannee Limestone. Considering the open-marine environment that generally prevailed within the Suwannee Strait during this span of time (Middle Eocene through earliest Oligocene), the presence of the Florida Bank foraminiferal fauna in the strait would appear to be most unlikely.

The Florida Bank environment invaded the Suwannee Strait briefly only during the Suwannee-Byram stand of the sea and the only occurrence I know of *Dictyoconus* after the Avon Park and Inglis is in the Suwannee Limestone. Therefore I would expect that if *Dictyoconus* were found in Gulf Trough deposits, it would have been reworked from its very shallow habitat on the flanks of the trough and carried into deep water through submarine slump or down slope movement of shallow water sediments during the deposition of the Suwannee Limestone. Deposits within the Gulf Trough containing *Dictyoconus* then should be correlative with the Suwannee Limestone. However, the stratigraphic model constructed in this report would indicate that the lower part of the Ochlockonee Formation (and the Pridgen Limestone Member) is early Vicksburgian in age. If the lower part of the Pridgen Limestone contains *Dictyoconus* then it would have been derived from shelf deposits on the upper flanks of the trough during the early Vicksburgian. However, *Dictyoconus* is not known to occur in early Vicksburgian shelf or carbonate bank deposits in the Suwannee Strait or elsewhere.

If it is concluded that *Dictyoconus* was derived from the Suwannee Limestone on the upper flanks of the Gulf Trough, then the entire Pridgen Limestone is Suwannee-equivalent and correlative only with the Byram Formation of the Vicksburg Group. It would also appear that through physical correlation southwestward down the trough, that the lower part of the typical Ochlockonee

Formation in Colquitt County would also be correlative with the Suwannee Limestone and Byram Formation. This is an extreme interpretation and would indicate that the stratigraphic framework of the Gulf Trough and the Oligocene history of the Suwannee Current is more complex than described in the simple model proposed in this report.

A similar and possibly related example of an anomalous occurrence of the Florida Bank , Tethyan (Caribbean) foraminiferal fauna was reported by Applin and Applin (1964, p. 120-123) in the well GGS-55 located in northwestern Decatur County, Georgia. In this case, *Dictyoconus floridanus*, *Valvulina* sp., and *Valvulammina* sp. were identified at the top of the Middle Eocene (Avon Park Limestone of Applin and Applin, 1964). The top of the Middle Eocene in the nearby GGS-57 is 76 feet lower than that in the GGS-55 and contains no Florida Bank (Tethyan) , Claibornian foraminiferal fauna but rather a normal, Middle Eocene foraminiferal fauna. The sites of the GGS-55 and GGS-57 are on or near the northern flank of the Gulf Trough where no foraminifera peculiar to the Florida Bank (Tethyan) environment had been previously or subsequently reported. If the Middle Eocene Florida Bank (Tethyan) foraminifera reported from the GGS-55 are indeed in place, then perhaps there were many small and temporally changing sites of refugia in and south of the Suwannee Strait during the Middle Eocene (Claibornian), Late Eocene (Jacksonian) through Early Oligocene (Vicksburgian). Few of these sites are preserved in the stratigraphic record because they would have been small, localized, and bathymetrically high (very shallow water) and, consequently, were sites of nondeposition or were susceptible to subsequent erosion and destruction.

Finally, in regard to the anomalous occurrence of the *Dictyoconus cookei* and *D. floridanus* in the Pridgen Limestone in the Gulf Trough in Coffee County, there is a small area on the southern flank of the Gulf Trough in Coffee County where the Miocene directly overlies the Ocala Limestone and the Oligocene is absent. It is conceivable that this area of absent Oligocene was in extremely shallow water during the Oligocene and no Oligocene sediments were deposited there. If so, this Oligocene bathymetric high could have served as a local refugium for the Florida Bank, Tethyan (Caribbean) benthic foraminiferal fauna within the Suwannee Strait. As such it may have been the source of the *Dictyoconus* present nearby in the Gulf Trough.

WOLF PIT DOLOSTONE, new name

Definition

The Wolf Pit Dolostone is named here for a dolostone formation that is confined to the Gulf Trough in Georgia. It gradationally overlies the Ochlockonee Formation and is abruptly overlain by the Okapilco Limestone. The Wolf Pit Dolostone has been identified in two cores in the Gulf Trough: in the type core Colquitt 5 (GGS-3199) in Colquitt County, and in the Coffee 4 (GGS-3541) in Coffee County. It was not cored in the Berrien 10 (GGS-3542) because that stratigraphic interval was drilled and casing set without having taken cores or well-cuttings. The Wolf Pit Dolostone is lithologically similar to the Suwannacoochee Dolostone that occurs at higher elevations on the continental shelf south of the Gulf Trough. It is similarly interpreted to have been deposited during a low stand of the sea when the sea was confined to the Gulf Trough. This low stand of the sea was lower than that of the Suwannacoochee low stand and first exposed the floor of the trough to very shallow water conditions.

Type Section

The name Wolf Pit is taken from Wolf Pit Branch, a small tributary of the Ochlockonee river whose confluence with the river is 1.4 miles (2.5 km) northwest of the type locality. The type locality of the Wolf Pit Dolostone is the site of the core Colquitt 5 (GGS-3199), located adjacent to a small farm pond roughly 3.1 miles (5.0 km) northwest of the court house in Moultrie, Colquitt County, Georgia (Fig. 11). The type section, or unit-stratotype (holostratotype) of the Wolf Pit Dolostone occurs in the interval 535 to 606 feet (Fig. 13)(also see McFadden and others, 1986, p. 206). The interval 606 to 619 feet is broadly gradational with the underlying Ochlockonee Formation. The upper contact of the Wolf Pit Dolostone with the overlying Okapilco Limestone is abrupt and has the appearance of a disconformity.

The core Coffee 4 (GGS-3541) is designated here a reference locality and reference section (parastratotype) of the Wolf Pit Dolostone. The reference section of the Wolf Pit occurs in the interval 675 to 700 feet (Fig. 15)(also see McFadden and others, 1986, p. 168). The lower contact of the formation appears abruptly gradational with the underlying Pridgen Limestone Member of the Ochlockonee Formation. The upper contact appears to be abrupt with the overlying, poorly recovered Okapilco Limestone.

Lithology

The lithology of the Wolf Pit Dolostone is a sucrosic, tan to brown dolostone. There are few other lithic components of the formation. Minor calcitic intervals occur in both cores and the basal Wolf Pit in the type core is slightly glauconitic. There are zones of selenite (gypsum) in the dolostone in the upper part of the formation in the type core but none is apparent in the Coffee County core. Similarly, there is minor pyrite in the basal part of the formation in the type core and there is minor carbonaceous material in the basal part of the formation in the Coffee County core.

A dolostone section in the well GGS-962 (Sever and Herrick, 1967, p. 50, 51) in the interval 490 to 670 feet (called Byram Formation by Sever and Herrick, 1967) is tentatively assigned to the Wolf Pit Dolostone of this report. Sever and Herrick (1967) identified a green clay in residue of the dolostone and they thought the clay occurred within the dolomite rhombohedrons because no clay minerals were apparent in the untreated cuttings.

Most of the Wolf Pit Dolostone is sporadically fossiliferous above 602 feet in the type core with intervals that contain partially obliterated molds of *Lepidocyclina*, *Nummulites*, corals, bryozoans, and mollusks. Other intervals are nonfossiliferous but contain still visible remnants of bioturbation and burrows indicating the environment of deposition was intermediate to that of the overlying Okapilco Limestone and the underlying Ochlockonee Formation in the inner Chattahoochee Embayment. No fossils are apparent in the Coffee County core and Sever and Herrick (1967) reported the dolostone interval in the GGS-962 to be barren of fossils.

The texture of the dolostone ranges from finely to coarsely sucrosic and the color ranges from buff to tan to brown. The degree of consolidation ranges from friable to thoroughly recrystallized, hard, and dense. In much of the dolostone, however, there is appreciable secondary porosity. In the Coffee County core, the lower part of the Wolf Pit Dolostone is thinly bedded and has a shaley appearance but no clay material is apparent in the core. Also, there is some minor amount of carbonaceous material in the Coffee County core that is not apparent in the type core. However, the interval below 607 feet in the type core contains a trace of pyrite. The basal part of the Wolf Pit in both cores appears to have been most environmentally restricted with irregular mixed inclusions (intraclasts?) and calcite-filled veins or fractures between 603 and 606 feet in the type core, and "shaley" dolostone with carbonaceous material in the Coffee County core.

In general, the lithology and sequence of lithologies of the Wolf Pit Dolostone are very similar to that of the Suwannacoochee Dolostone, with which the Wolf Pit was initially correlated by myself. However, the stratigraphic positions and elevations of the two dolostone formations indicate noncorrelation.

Stratigraphic Relationships

The Wolf Pit Dolostone is confined to the Gulf Trough from at least Colquitt County in the southwest to Coffee County in the northeast (Fig. 18). It probably extends farther in each direction. The test well GGS-962 drilled in Cairo, Grady County, Georgia (Sever and Herrick, 1967, p. 50-53; McFadden and others, 1986, p. 241-243), contains a dolostone in the stratigraphic position of the Wolf Pit and is tentatively identified as the Wolf Pit Dolostone. The limestone section below 670 feet in the GGS-962 that Sever and Herrick (1967) called Marianna Limestone is the Ochlockonee Formation of this report, and the fauna listed from that unit in the test well is the typical Ochlockonee deep water foraminiferal fauna. The limestone at the top of the Oligocene section in the Cairo test well, between 471 and 490 feet, that Sever and Herrick (1967) called Suwannee Limestone, occurs in the stratigraphic position of the Okapilco Limestone. The lithology of this limestone, however, is not Suwannee lithology, and it also lacks the colonial corals that are characteristic of the Okapilco Limestone. It appears that the Okapilco Limestone grades laterally southwestward into a deeper water limestone where colonial corals did not flourish. This upper limestone of the Cairo test well is unusually thin and the underlying dolostone unusually thick, suggesting that dolomitization also occurred above the Wolf Pit Dolostone in the lower part of the overlying limestone formation. The southwestern limit of the Wolf Pit Dolostone is not known. Dolostone overlying the Ochlockonee Formation has not been reported in the W-4 well in Quincy, Gadsden County, Florida (Applin and Applin, 1944; Moore, 1955) or from Jackson County, Florida (Moore, 1955). The Florida Geological Survey core (W-6901) at Alum Bluff in Liberty County, Florida, did not penetrate to the projected depth of the Wolf Pit Dolostone (Pl. 2). The Wolf Pit Dolostone is 71 feet (22 m) thick in the type core Colquitt 5 (GGS-3199) and is 25 feet (7.6 m) thick in the reference core Coffee 4 (GGS-3541).

The Wolf Pit Dolostone seems to have been deposited during an unusually low stand of the sea that terminated the deposition of the Ochlockonee Formation in the Gulf Trough. During this low stand event, the flanks of the trough were probably subaerially exposed and the sea extended up the length of the Gulf Trough as a shallow, environmentally-restricted, long, narrow embayment. I envisage the dolomitization as being early diagenetic in origin, having occurred before the deposition of the overlying Okapilco Limestone.

Age

All known fossils in the Wolf Pit are very poorly preserved molds and casts in the dolostone and the age of the formation, therefore, cannot be paleontologically determined at this time. The age of the Wolf Pit Dolostone can be extrapolated through the ages of the overlying and underlying formations, and through physical correlation with Oligocene shelf deposits outside of the Gulf Trough. The overlying Okapilco Limestone contains a latest Vicksburgian, Bucatunna planktonic foraminiferal suite and is, therefore, correlated with the Bucatunna Clay of

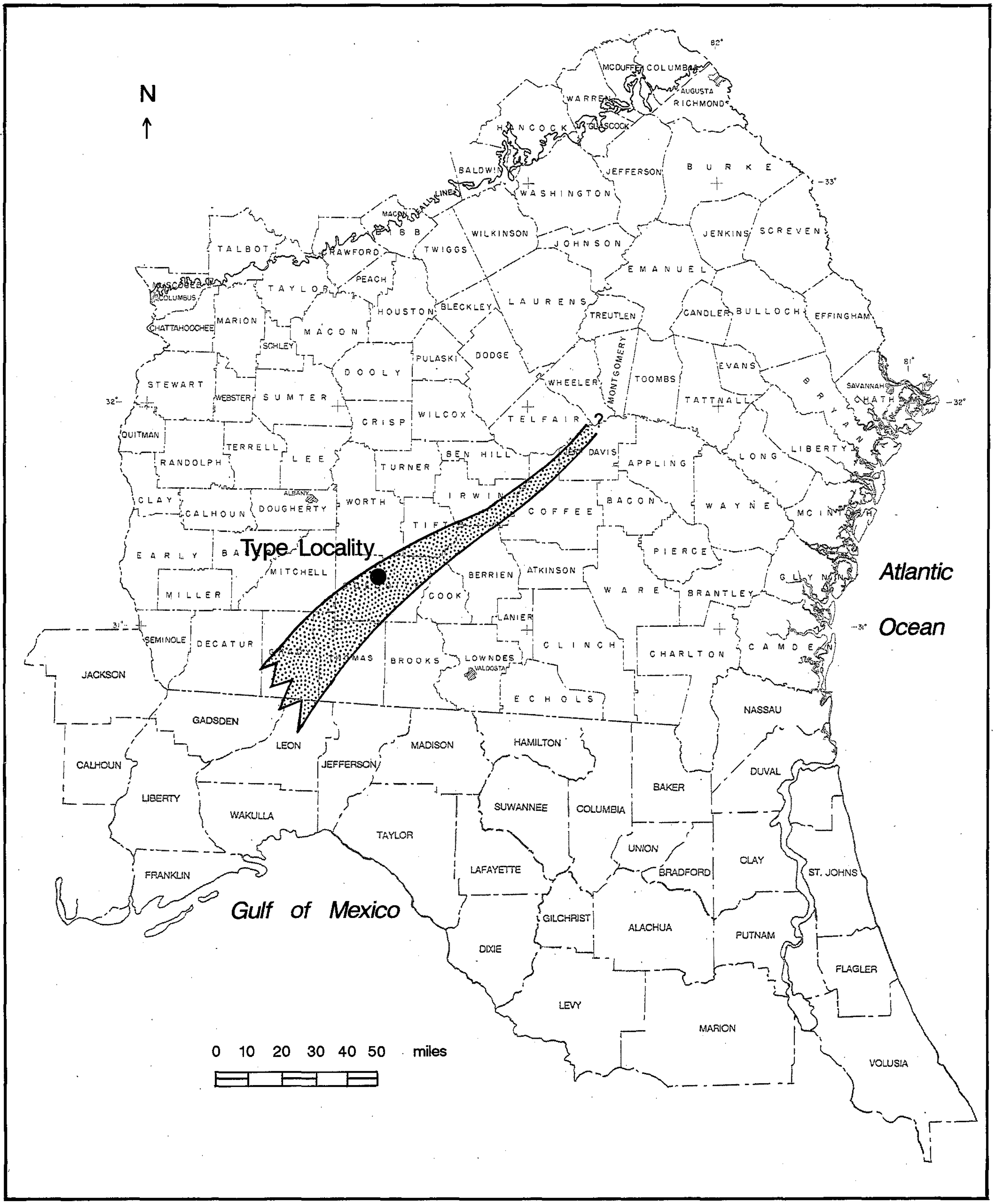

Figure 18. The areal distribution (subcrop) of the Wolf Pit Dolostone.

Mississippi and Alabama.

The youngest Oligocene formations in Georgia outside of the Gulf Trough are the Suwannee Limestone and, its lateral equivalent in the coastal area, the Lazaretto Creek Formation. The Suwannee Limestone is barren of planktonic foraminifera but the Lazaretto Creek Formation contains a small but consistent suite of planktonic foraminifera (see p. 82). These planktonic foraminifera indicate correlation of the Suwannee Limestone with the Byram Formation of Mississippi and not with the Bucatunna Clay of Mississippi and Alabama.

Based on biostratigraphy and stratigraphic position, the age of the Suwannee Limestone is consistent with correlation with the Byram Formation which underlies the Bucatunna Clay. Therefore, interpretation suggests that the Wolf Pit Dolostone was deposited during a severe low stand of the sea after Byram and Ochlockonee deposition, and prior to Bucatunna and Okapilco deposition. The age of the Wolf Pit Dolostone would then be, Early Oligocene, late Vicksburgian (late Rupelian) in age. It is suggested here that the Wolf Pit low stand is related to the planktonic foraminiferal zone boundary between the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone and the *Globigerina ampliapertura* Zone of Stainforth and others (1975)(Pl. 1).

OKAPILCO LIMESTONE, new name

Definition

The Okapilco Limestone is named here for a distinctive calcarenitic, colonial coral-bearing limestone formation at the top of the Oligocene section within and on the western flank of the Gulf Trough and interior of the Chattahoochee Embayment in Georgia. The Okapilco Limestone has been referred to the Suwannee Limestone (Zimmerman, 1977; Gelbaum and Howell, 1982) and the Byram Formation (Sever and Herrick, 1967) in the past.

Type Section

The name Okapilco is taken from Okapilco Creek, approximately 1.75 miles (2.8 km) east of the type locality. The type locality of the Okapilco Limestone is the core site of the Colquitt 5 (GGS-3199), approximately 3.5 miles (5.6 km) northwest of the court house at Moultrie, Colquitt County, Georgia (Fig. 11). The type section or unit-stratotype (holostratotype) of the formation occurs in the interval 396 feet to 535 feet in the core (Fig. 19). The upper boundary stratotype of the Okapilco Limestone occurs at 396 feet where the Okapilco Limestone is overlain disconformably by the Lower Miocene Parachucla Formation. The lower boundary stratotype of the formation occurs at 535 feet in the core where it overlies with apparent discomformity the Wolf Pit Dolostone. The site of the core Coffee 4 (GGS-3541) is here designated a reference locality and the core is a parastratotype of the Okapilco Limestone. The core site of the Coffee 4 (GGS-3541) is approximately 1.7 airline miles (2.7 km) northeast of the community of Pridgen in northern Coffee County, Georgia (Fig. 15). The reference section of the Okapilco Limestone is the interval 568 feet to 675 feet. In this core, the Okapilco Limestone is overlain disconformably by the Parachucla Formation. It overlies with apparent disconformity the Wolf Pit Dolostone.

The site of the core Berrien 10 (GGS-3542) is also designated a reference locality and the core is a parastratotype of the Okapilco Limestone. Core recovery in the Okapilco section in the Berrien 10 is only 34%. However, typical coralline limestone is present in the core and the core is, therefore, designated a reference section. The core site of the Berrien 10 (GGS-3542) is approximately 2.1 airline miles (3.4 km) northeast of the village of Enigma in northwestern Berrien County, Georgia (Fig. 2).

The reference section of the Okapilco Limestone is the interval 604 feet to 662 feet in the core. The member is overlain disconformably by the Parachucla formation and occurs above a core gap of 59 feet. The Pridgen Limestone Member of the Ochlockonee Formation is present below the core gap at 721 feet and the Wolf Pit Dolostone presumably occurs in the core gap between 662 feet and 721 feet in the core.

Lithology

The Okapilco Limestone consists of sporadically dolomitized limestone that is massive and structureless, varyingly indurated and recrystallized, sporadically chalky, moderate to coarsely but irregularly granular in texture, finely bioclastic, variably macrofossiliferous, and variably porous and dense. The three cores that penetrate this unit in the Gulf Trough contain common to abundant colonial corals or coral heads, suggesting that this limestone is coral-rich and locally may be a coralline limestone. Other fossils include scattered molds of mollusks, scattered occurrences of larger foraminifera (*Lepidocyclina* spp. and *Nummulites* sp.), and rare bryozoa and miliolid foraminifera. Locally the Okapilco Limestone is pyritic, and rarely it has abundant pyrite in the upper part.

The Okapilco Limestone is characterized by its uneven or irregular bioclastic texture, by its variable porosity and chalkiness, by locally common occurrence of pyrite, and in its tendency to be fossiliferous, and especially by the common occurrence or abundance of colonial corals.

Stratigraphic Relationships

The Okapilco Limestone is restricted to the Gulf

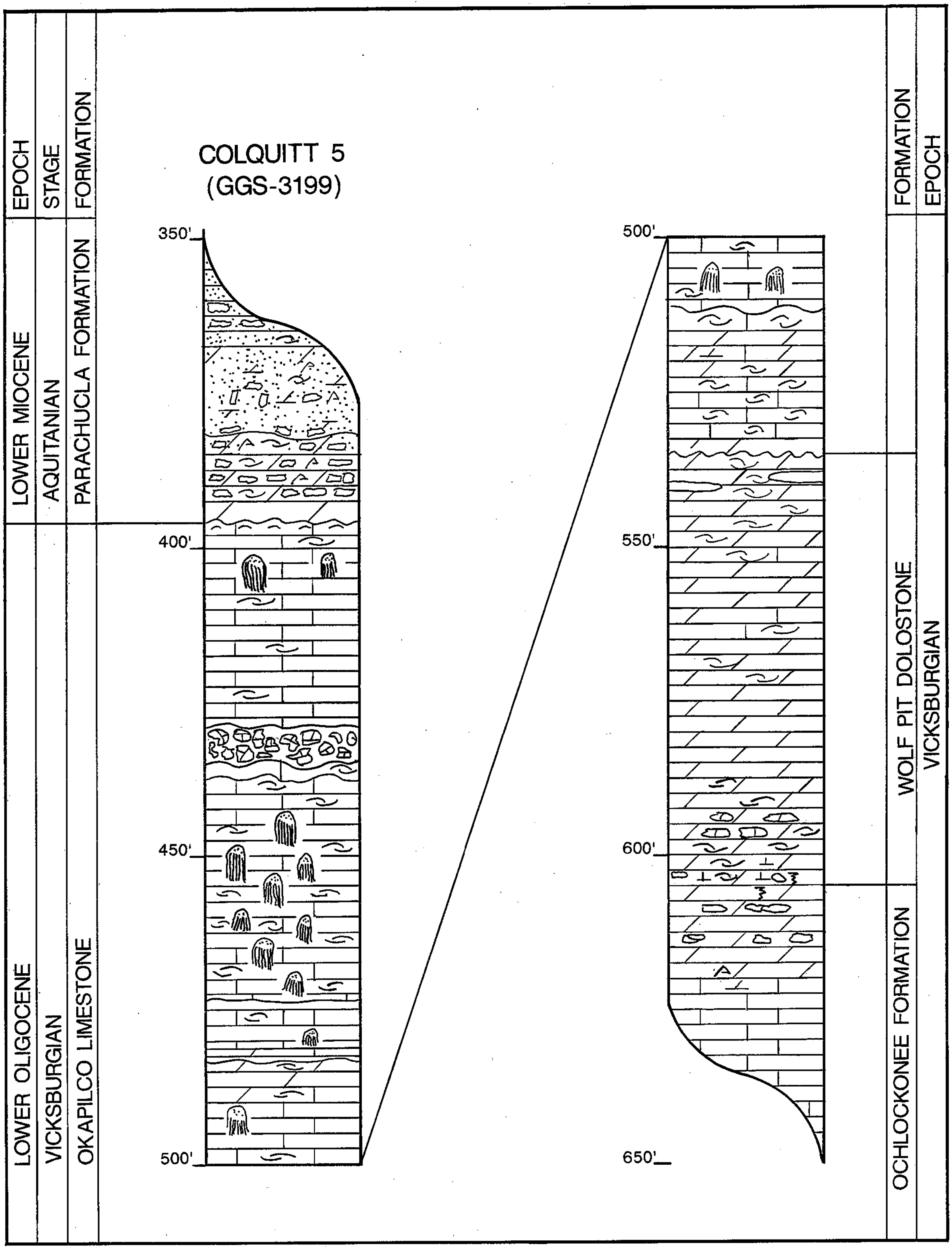

Figure 19. The measured holostratotype of the Okapilco Limestone and the Wolf Pit Dolostone.

Trough and to the interior of the Chattahoochee Embayment. It occurs from the vicinity of Coffee County in the northeast to at least central Colquitt County in the southwest (Fig. 20) but its southwestern limit is not known (see discussion on p. 42). Vaughan (1900) described a coralline limestone that contained twenty-five to thirty species of coral near Bainbridge, Georgia. Therefore, correlation of the above coralline limestone would appear to be a possibility. There are also massive coral heads near the top of the Bridgeboro Limestone at Climax Cave in Decatur County near Bainbridge, and scattered coral heads in the Bridgeboro Limestone at the type locality. The scattered occurrence of massive corals, therefore, is characteristic of the Bridgeboro Limestone. It is not likely, however, that the coral reef described by Vaughan (1900) is Okapilco Limestone because the limestone he described occurs at a low elevation along the Flint River (probably now submerged under Lake Seminole). It is evident from Plate 3 that the Flint River flows northwest of the Gulf Trough and, in Decatur County, Georgia, probably flows along the northwestern flank of the trough. Because the top of the Bridgeboro Limestone exposed in Climax Cave is roughly 6 miles (9.5 km) troughward of Vaughan's coral locality and occurs at a considerably higher elevation, it would appear that the coral locality of Vaughan (1900) occurs stratigraphically low in the Bridgeboro Limestone. On the other hand, it is possible that the corals at the top of the Oligocene section at Climax Cave (Bridgeboro Limestone) may represent the western feather edge of the Okapilco Limestone because of the proximity of the cave to the northwestern flank of the Gulf Trough. If so, the Wolf Pit Dolostone occurs in a disconformity at Climax Cave. Finally, the Okapilco Limestone is not recognizable in well-cuttings from its stratigraphic position in the Cairo test well (GGS-962) in Grady County, Georgia, and is not known to occur in the Chattahoochee Embayment in Gadsden County, Florida. The northeastern limit of the Okapilco Limestone is also unknown, but the undifferentiated calcareous sand and sandy limestone formation occurs in a similar stratigraphic position in the Gulf Trough in Toombs County, Georgia.

The Okapilco Limestone overlies the Wolf Pit Dolostone with apparent disconformity from Colquitt County to the vicinity of Coffee County. The Parachucla Formation of the Hawthorne Group disconformably overlies the Okapilco Limestone. The Okapilco Limestone is 210 feet (64 m) thick in the type core Colquitt 5 (GGS-3199), 138 feet (42 km) thick in the core Coffee 4 (GGS-3541), and is at least 58 feet (18 m) thick in the core Berrien 10 (GGS-3542).

Due to the deposition of approximately 320 feet (98 m) of Lower Oligocene limestones, the Gulf Trough was considerably shallower by the time the Okapilco Limestone was deposited. The common occurrence of coral-heads in the limestone suggests the sea floor of the trough was within the photic zone but the paucity of other macrofossils suggests an unsuitable environment for most larger benthic organisms.

Age

The Okapilco Limestone is correlated with the Bucatunna Clay of Mississippi and Alabama on the basis of planktonic foraminifera. The planktonic foraminifera identified from the Okapilco Limestone at the depth of 666 feet in the core Coffee 4 (GGS-3541) include the following:

Globigerina anguliofficinalis
G. ouachitaensis
G. eocaena
Globorotalia opima nana
Chiloguembelina cubensis

The absence of *Globorotalia increbescens*, *Globigerina ampliapertura*, and *Pseudohastigerina* spp. from this association is critical. These three planktonic foraminifera occur in the Byram Formation and lateral equivalents, and are consistently absent in the Bucatunna Clay, even in moderately rich assemblages. Therefore in this report the Okapilco Limestone is correlated with the Bucatunna Clay of Mississippi, Alabama and western Florida and is latest Vicksburgian in age. The consistent absence of *Globorotalia increbescens* and *Pseudohastigerina* spp. in the Bucatunna Clay and Okapilco Limestone suggests that these two formations occur above the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone and probably, therefore, occur within the *Globigerina ampliapertura* Zone (Pl. 1).

BRIDGEBORO LIMESTONE, new name

Definition

The name Bridgeboro Limestone was introduced informally by Huddlestun (1981) and was adopted by Manker and Carter (1987, p. 187) in their paleoecological study of the formation. The Bridgeboro Limestone is formally named here for a rhodolithic limestone that occurs on the flanks of the Gulf Trough in the central and southwestern Georgia Coastal Plain (Pl. 3). In the past, the Bridgeboro Limestone was included in part in the Flint River formation (Cooke, 1943, p. 81-83), Suwannee Limestone (Cooke, 1945; Owen, 1963, p. 19-21; Glawe, 1974, p. 16), and Vicksburg Group (Applin and Applin, 1964, p. 211). The Duncan Church beds of western Florida (Cole, 1934; Vernon, 1942; Cooke, 1945; Puri and Vernon, 1964) also are included in the Bridgeboro Limestone in this report.

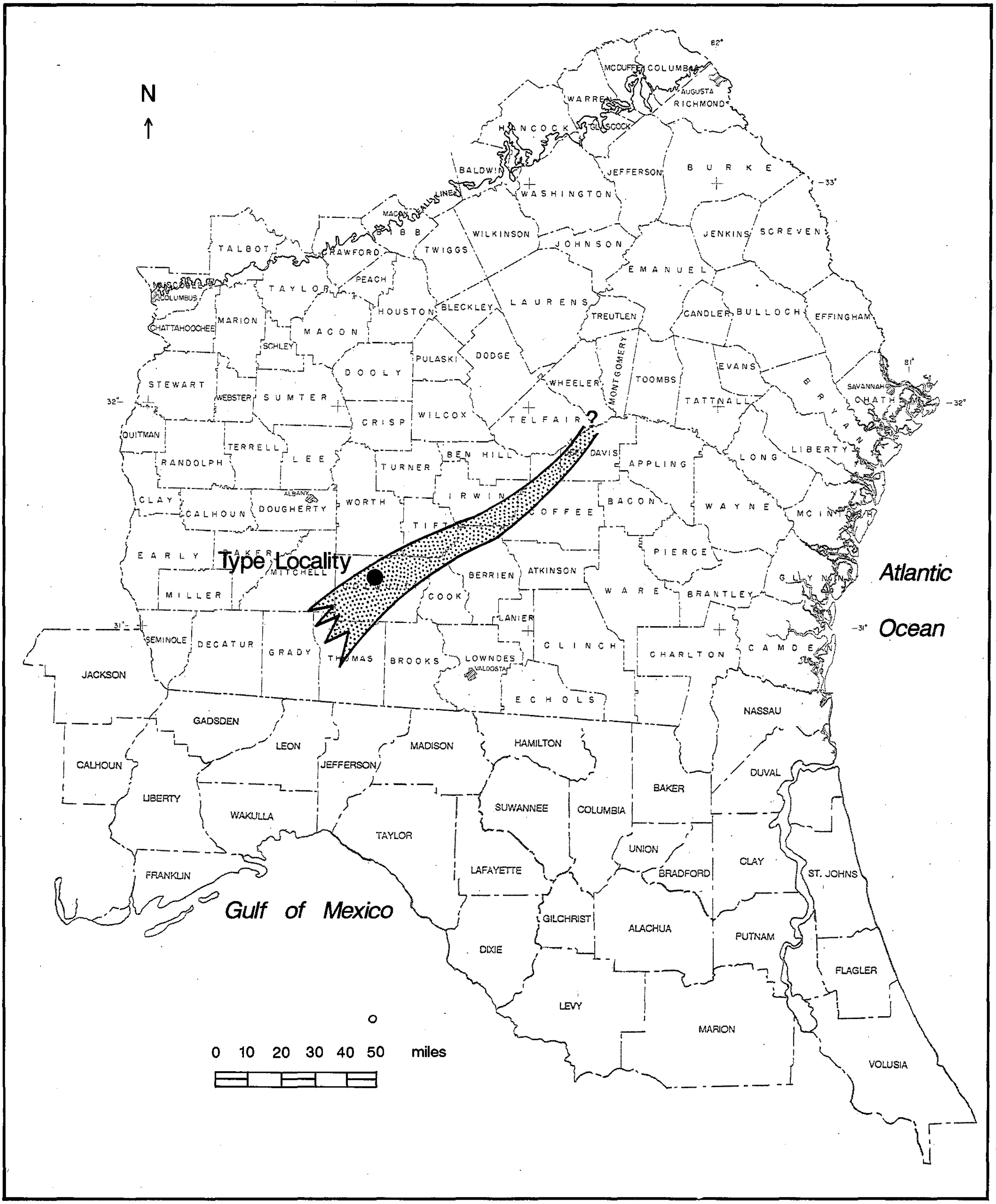

Figure 20. The areal distribution (subcrop) of the Okapilco Limestone.

Type Section

The name Bridgeboro is taken from the community of Bridgeboro in southwestern Worth County, Geogia. The type locality of the Bridgeboro Limestone is the southern-most pit of the Bridgeboro Lime and Stone Company, south of Georgia highway 112 in Mitchell County, Georgia, 6.5 miles (10.4 km) west-southwest of the community of Bridgeboro (Fig. 21). The section of Bridgeboro Limestone exposed in the pit is the type section or unit-stratotype (holostratotype) of the formation (Fig. 22). The lower contact is not exposed at the type locality, and the upper contact is a pinnacled solution surface with overlying clay residuum (Bucatunna Clay?) containing silicified Oligocene fossils.

In Florida, the lime pit at Duncan Church is designated a reference section, parastratotype, and lower boundary stratotype of the Bridgeboro Limestone. The lime pit at Duncan Church is located in NW1/4, SE. 1/4, Sec. 36, T4N, R14W in northeastern Washington County, Florida. Only the basal 10 feet (3 m) of the formation is exposed in the lime pit but the lower gradational and uneven contact with the Marianna Limestone is well-exposed. Similarly, the interval 8 feet to 40 feet in the Florida Geological Survey core Duncan Church 1 (W-11487) taken at a site near the lime pit is designated a parastratotype of the Bridgeboro Limestone. The section in the upper part of the core is very similar to that exposed in the pit. Finally, the Florida Geological Survey core Hunt 1 (W-10954) is designated a parastratotype of the Bridgeboro Limestone in Florida. This is the southernmost known occurrence of the formation. The site of the Hunt 1 (W-10954) is in the center of the NE1/4, Sec.16, T1N, R14W in south-central Washington County, Florida. The parastratotype section occurs in the interval 174 feet to T. D. at 226 feet. The Bridgeboro Limestone is overlain disconformably in this core by the basal Miocene Chattahoochee Formation at 174 feet, the younger Oligocene being absent at the site.

Lithology

The Bridgeboro Limestone is a rhodolithic limestone and it is the abundance of rhodoliths ("rounded nodules of clastic limestone" of Owen, 1963, p. 19) in a matrix of variably bioclastic calcarenite that distinguishes this formation. The abundance of rhodoliths varies from bed to bed. In some beds the rhodoliths are packed close together and impart a rubbly appearance to the bed. In other beds the rhodoliths do not dominate the lithology so completely, and the limestone takes on a more massive, uniform appearance. However, whether the rhodoliths are common or rare in a specific bed, they are always present in typical Bridgeboro deposits. The observed size of the rhodoliths range from less than 0.5 inch (1 cm) to as much as 5 inches 13 cm). Manker and Carter (1987, p. 182) described the rhodoliths and associated beds from the Bridgeboro Limestone at the type locality as follows:

> The 21 meters of exposed limestone is dominated by a densely packed mass of algal rhodoliths.... Field measurements show approximately 294 rhodoliths/m^2 in general, the number of rhodoliths remains nearly constant throughout most of the section; however, some variations have been noted. Three (1-3 m) thick zones of matrix-rich, algal-poor beds ($\geq$40 rhodoliths/m^2) occur within the quarry section. One of these zones corresponds to the upper 2 meters of the section and was sampled for paleoecologic analyses. The number of rhodoliths also varies laterally within the limits given above.
>
> Compared to the rhodoliths the encloing matrix is relatively soft, thereby facilitating the collection of algae for laboratory investigation. Throughout the exposed section, but most noticeably in the upper 15 meters, rhodoliths and enclosing carbonate sand matrix have in part been replaced by chert.
>
> Although silicification occurred in discrete beds 0.5-1.0 m thick, these chert beds are not continuous throughout the quarry. Lenses and pockets of a yellowish-green clay intercalated with the algal limestone occurs most in the upper 15 meters of the section. X-ray diffraction (XRD) analysis shows the clay to be smectite, which swells to 17 (Angstroms) upon glycol solvation (Bowman and Manker, 1982). ...

The matrix lithology of the Bridgeboro Limestone typically consists of a fairly uniform, even-textured, granular calcarenite. The calcarenite particles generally consist of very fine- to medium-grained bioclastic debris most of which is unidentifiable as to origin. Recognizable particles consist of fragments of bryozoa, foraminifera, echinoderms, rhodoliths, and rare calcitic mollusk fragments. Some scattered beds or lenses contain more coarsely bioclastic calcarenitic limestone in which the larger foraminifer *Lepidocyclina* is conspicuous. In some beds at the type locality of the Bridgeboro Limestone, the matrix lithology consists of a fine-grained calcarenite

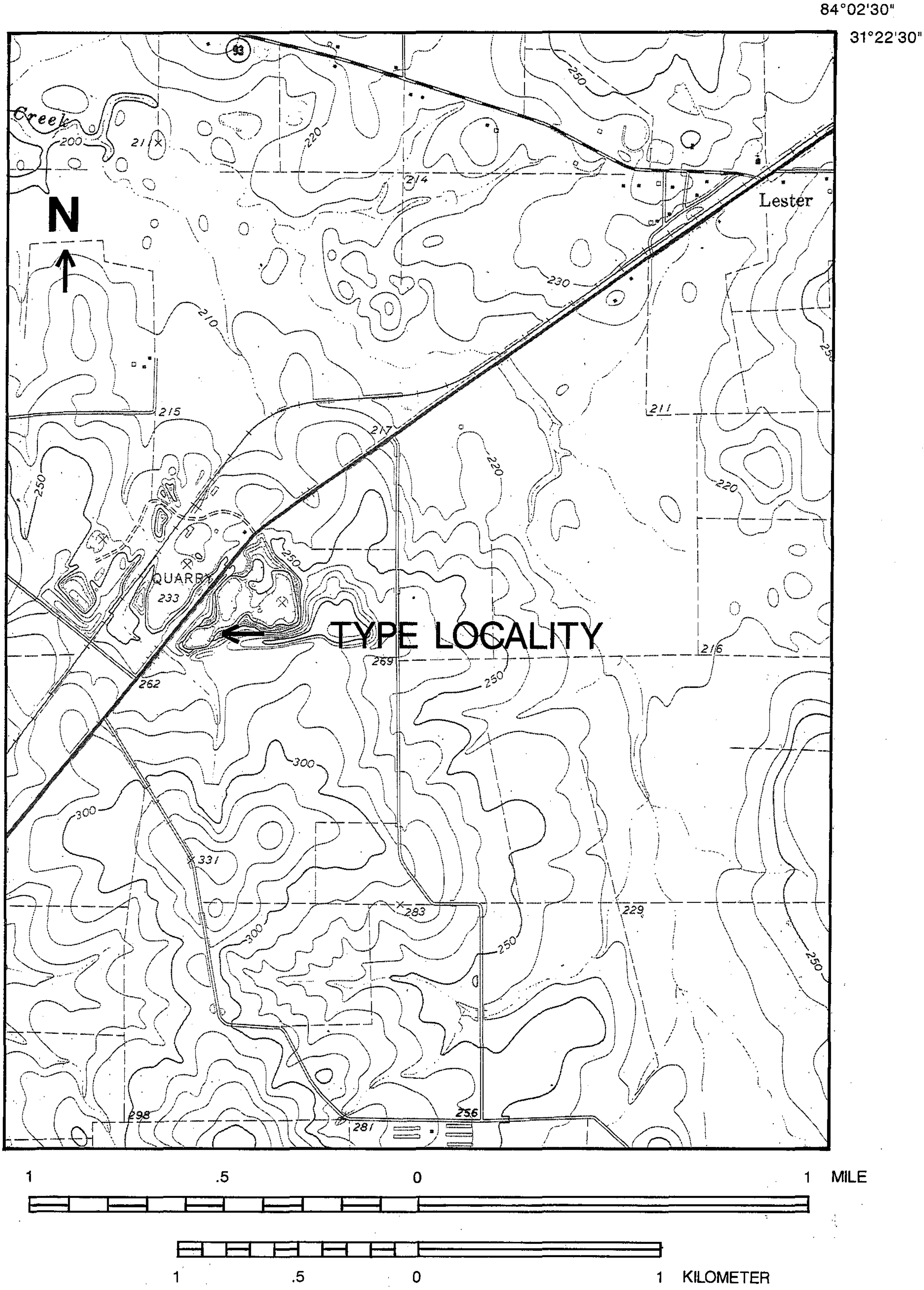

Figure 21. The type locality of the Bridgeboro Limestone (U. S. Geological Survey, Sale City, Ga. 1:24,000 topographic quadrangle).

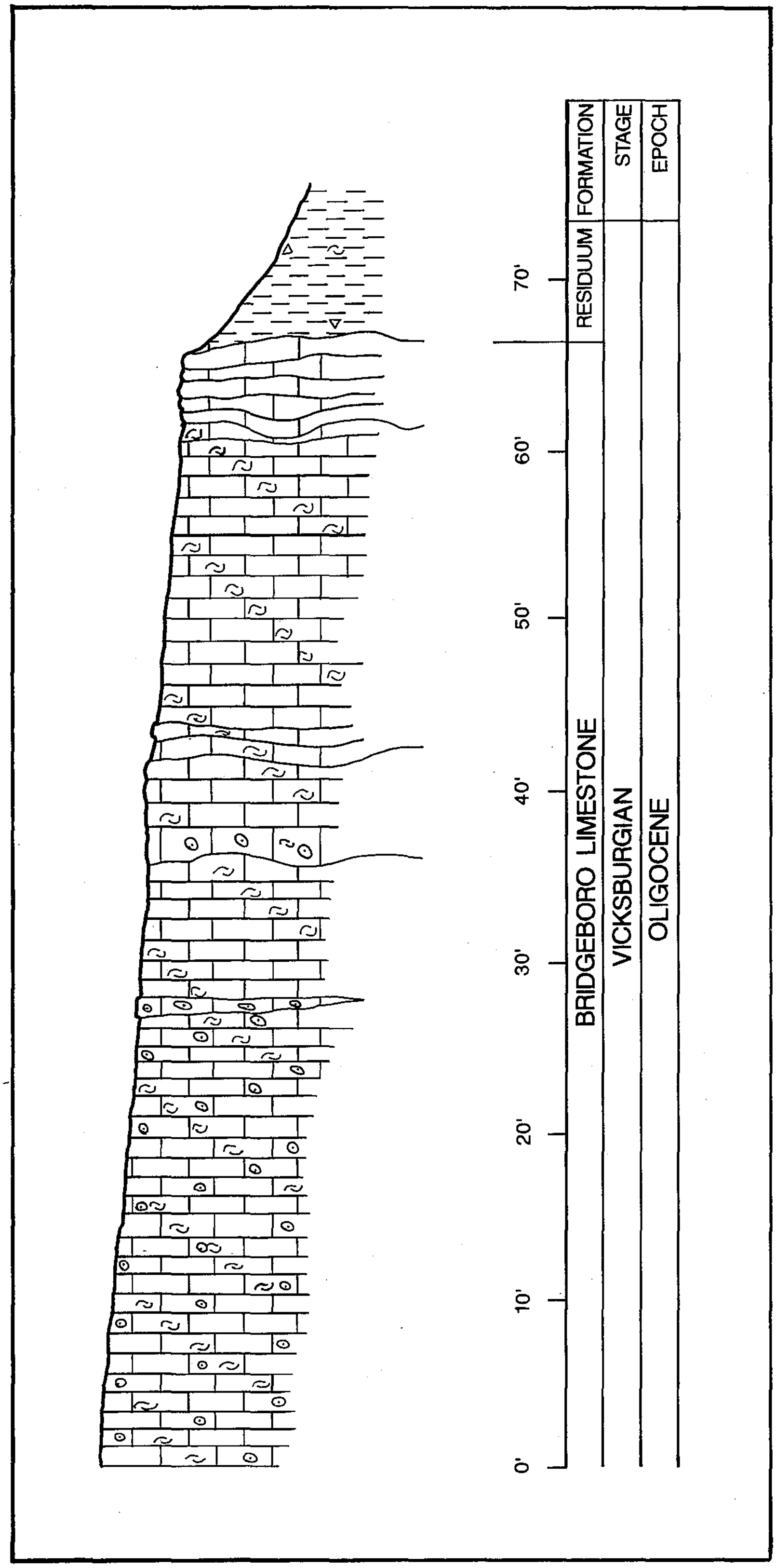

Figure 22. The measured holostratotype of the Bridgeboro Limestone.

which is lithologically similar to the Marianna Limestone.

Degree of consolidation of the calcarenite ranges from soft and unaltered to indurated. Most commonly, however, the matrix is only lightly to moderately recrystallized and is rather soft and easily eroded. Because of the typically soft nature of the calcarenite matrix and the hard, resistant rhodoliths, core recovery in the Bridgeboro Limestone is characteristically poor. Commonly the only sediments recovered are small rhodoliths and rhodolith fragments.

Other than rhodoliths and bioclastic debris, the Bridgeboro Limestone is only moderately fossiliferous. Macrofossils that do occur consist of mollusk molds and casts, *Chlamys anatipes, C. duncanensis* scattered occurrences of the echinoid *Clypeaster cotteaui*, bryozoa, and rare molds of colonial coral heads. The colonial coral heads are more commonly found near the top of the formation, where they get rather large and abundant. Other than rhodoliths, the only fossil that has been identified to date and that is moderately common in the formation is *Lepidocyclina*. At the type locality, *Lepidocyclina* ranges in abundance from common to rare and is spotty in distribution. Some zones or small lenses contain abundant *Lepidocyclina*. This sporadic distribution of *Lepidocyclina* appears to be typical of the Bridgeboro Limestone in the subsurface of Colquitt, Thomas, and Brooks Counties on the southern flank of the Chattahoochee Embayment. Some beds or intervals in the cores from that area consist of coquinoid *Lepidocyclina* limestone, and is lithologically reminiscent of the correlative Florala Limestone or the underlying Ocala Limestone. However, the *Lepidocyclina* in the Bridgeboro Limestone can be strikingly large, exceeding the diameter of the core (1-7/8 inches).

The Bridgeboro is a relatively pure limestone and there are few other subordinate lithic components of the formation. Irregularly occurring clasts and smeared out clasts of very fine grained sand and films of greenish waxy clay are present at the type locality but elsewhere, quartz sand and clay minerals are not apparent in the formation. Dolostone occurs at the base of the Bridgeboro Limestone on the shelf south of the Chattahoochee Embayment but dolostone or dolomite are not known to be present elsewhere. On the other hand, clay and chert occurrence near the top of the formation is common but results largely from weathering and solution.

Stratigraphic Relationships

The Bridgeboro Limestone occurs in two disconnected bands, one along the northern flank of the Gulf Trough and the other along the southern flank of the Gulf Trough (Fig. 23). These two separate occurrences of the formation are divided by the Gulf Trough. On the northern flank of the trough, the Bridgeboro Limestone grades laterally and troughward into the deeper water Florala Limestone Member, and the Florala Limestone grades troughward into the relatively deep water Ochlockonee Formation within the channel. Presumably the same facies relationships applies to the southern flank of the trough as well.

The northern band of Bridgeboro Limestone (on the northern flank of the Gulf Trough) extends from the vicinity of Dublin in Laurens County, in the northeast, southwestward to at least Decatur County, a distance of approximately 100 miles (160 km). The Bridgeboro Limestone has not yet been traced southwestward into Jackson County, Florida. However, it is exposed in a limestone pit in northeastern Washington County, south of Chipley, Florida (formerly Duncan Church beds) and is present in the Florida Geological Survey core Hunt 1 (W-10954) in southern Washington County, Florida.

The northern band of Bridgeboro Limestone appears to be no more than 20 to 30 miles (32 to 48 km) across at the most and it grades laterally northwestward into the Marianna? and Glendon Limestones in the Ocmulgee River area. Farther southwest, in Worth and Dougherty Counties, the outcrop belt of the Bridgeboro Limestone occurs in the Dougherty Plain where its former presence is indicated by the occurrence of rhodolith-bearing chert rubble and boulders. Presumably, the Bridgeboro Limestone graded laterally northwestward into the Marianna Limestone and Glendon Limestone on the Dougherty Plain, but it possibly could have graded directly into the siliciclastic Shellstone Creek beds. The Oligocene occurs today only as a residuum over the Dougherty Plain (Fig. 10). In western Florida and in Mitchell and Colquitt Counties, Georgia, the stratigraphic relationships indicate that the Bridgeboro Limestone grades both laterally westward and embaymentward into the stiller water Florala Limestone Member by elimination of rhodoliths.

The southern belt of Bridgeboro Limestone (on the southern flank of the Gulf Trough) occurs in Thomas, Brooks and Colquitt Counties. There is also some evidence that it may occur in Cook County (see McFadden and others, 1986, p. 233-234). The southern band is at least 13 miles (21 km) long, and may be more than 25 miles (40 km) long. It is not known to be more than approximately 10 miles (16 km) across. The southern band of Bridgeboro Limestone grades laterally southeastward into the Ellaville Limestone and Suwannacoochee Dolostone? in Thomas and Brooks Counties (Pl. 3). The regional stratigraphic relationships indicate that the Bridgeboro Limestone is a carbonate facies that is strongly influenced by the presence of the Suwannee Current.

There is no subsurface information on which to determine the formation underlying the Bridgeboro Limestone along the northern flank of the Gulf Trough. However, based on the stratigraphic cross-section between

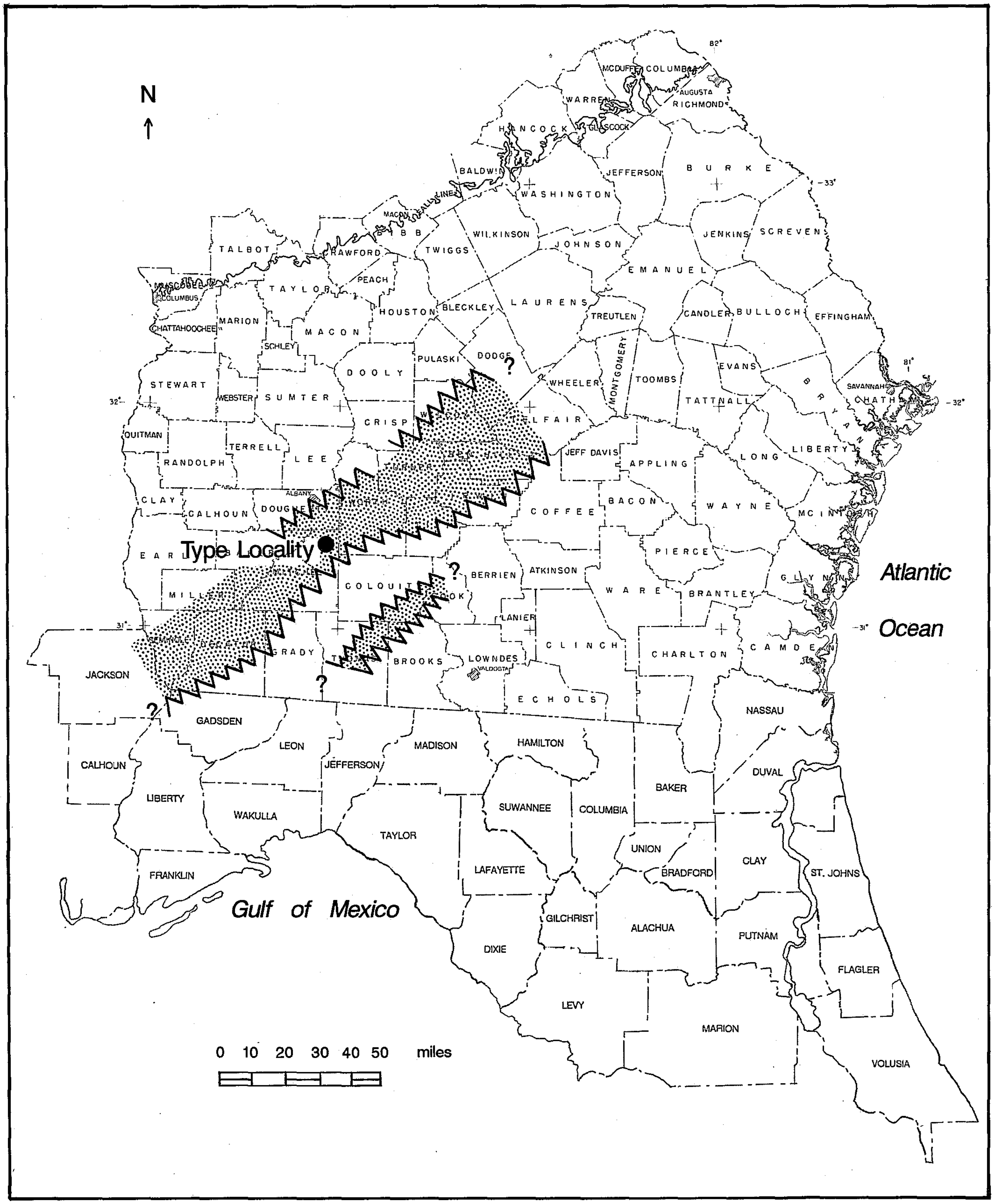

Figure 23. The areal distribution (outcrop and subcrop) of the Bridgeboro Limestone in Georgia.

Albany and Moultrie, Georgia (Pl. 3), it would appear that the Bridgeboro in its type area could be unusually thick and disconformably underlain by the Ocala Limestone, gradationally underlain by the Marianna Limestone (as at Duncan Church), or gradationally underlain by the Florala Limestone Member. In the type area of the formation, the upper contact relationships are ambiguous and the Bridgeboro Limestone occurs at the top of the local section or is overlain by residuum. At the type locality, the pinnacled top of the Bridgeboro Limestone appears to be overlain by residuum of the Bucatunna Clay, somewhat similar to that at the type locality of the Florala Limestone Member. At Climax Cave in Grady County, Georgia, the Bridgeboro occurs at the top of the Oligocene section and is disconformably overlain by the Lower Miocene Chattahoochee Formation (Huddlestun, 1988). At Rockhouse Cave near Cordele in Crisp County, on the other hand, the Bridgeboro Limestone is disconformably overlain by the Suwannee Limestone and a 6 inch (15 cm) thick bed of dark chert that occurs in the stratigraphic position of the Suwannacoochee Dolostone separates the two formations.

The Bridgeboro Limestone crops out in scattered areas along the northern belt. The southern belt of the formation occurs only in the shallow subsurface. The southern Bridgeboro Limestone disconformably, or with apparent gradation due to dolomitization, overlies the Ocala Limestone. It is overlain by the Suwannee Limestone but the nature of the contact is obscure due to poor core recovery in the Bridgeboro.

The Bridgeboro Limestone is distinguished from the adjacent and superjacent limestone formations in containing common to abundant rhodoliths. Although rhodoliths also occur in the Ocala Limestone, Ellaville Limestone and Suwannee Limestone, they are never common in those formations. Typical Bridgeboro Limestone is distinguished from the Florala Limestone Member in containing abundant, rounded rhodoliths and common to abundant *Lepidocyclina* whereas the Florala Limestone contains consistently abundant *Lepidocyclina* and scattered occurrences of abundant encrusting or anastomosing algae.

The Bridgeboro Limestone is at least 65 feet (20 m) thick at the type locality. Although the pinnacled and weathered top of the formation is exposed there, the lower contact is not, and the complete thickness of the formation at the type locality is not known. In ten cores scattered through the southern belt of the formation in southeastern Colquitt, northeastern Thomas, and northwestern Brooks Counties (Fig. 2). the Bridgeboro Limestone ranges from 25.5 feet (7.7 m) to 92.5 feet (28 m) thick, with an average thickness of approximately 55 feet (17 m).

The Bridgeboro Limestone was deposited on the flanks of the Gulf Trough in moderately deep water but still within the photic zone, and under relatively high energy conditions. The occurrence of the Bridgeboro Limestone in close proximity to the Gulf Trough indicates that the Suwannee Current also influenced the depositional environment in its vicinity (also see Huddlestun and others, in review). Manker and Carter (1987, p. 185-187) described the paleoecology of the Bridgeboro Limestone at the type locality as follows:

> Both *Archaeolithothamnium* and *Lithoporella* are warm water genera with the latter being more common on tropical reefs (Adey and Macintyre, 1973; Wray, 1977). *Archaeolithothamnium* prefers, but is not restricted to, lower light intensities, which imply a deeper water environment. *Lithoporella*, because of its dominance on reefs, may indicate shallower water with greater light intensity, although no precise information for this genus has been found.
>
> A consideration of the shape/sphericity and internal growth patterns of the rhodoliths gives some indication of depth. In a study of Recent rhodoliths, Bosellini and Ginsburg (1971) noted that those specimens that were spherical or compact displayed an internal laminar growth pattern. Those algae that were trapped in beds of turtle grass tended to be discoidal to flat and had a columnar growth pattern. The majority of the specimens collected during this study were compact and displayed a laminar growth pattern. This suggests that the rhodoliths grew under relatively high-energy conditions that moved them frequently, implying depths that are shallower than what might typically be expected for *Archaeolithothamnium*. The bladed to platy specimens observed in this investigation were found in association with pockets and lenses of swelling clays. They usually occurred at the bottom and in margins of the pockets, indicating that the algae had been trapped in a depression and rendered immobile. These depressions were subsequently filled with swelling clay.
>
> Since *Lithoporella*, which is a shallow water alga, tends to be more abundant at the top of the quarry section, a change in water depth with time may be inferred. A general shoaling, either due to

a sea-level change or the build-up of the algal facies probably occurred.

Because the biota can be characterized as a low-diversity community dominated by red algae..., it may have been subjected to a type of environmental stress that would have restricted or excluded a more diverse and abundant biota. However, the kinds of species that are present (including the red algae) suggest that such stress could not have resulted from abnormal salinity, sea -water chemistry, or turbidity. The paucity of fine-grained sediment supports a low-turbidity environment, and the nature of the faunal assemblage itself implies a warm, normal marine open-ocean setting. We suggest that the mechanism causing the low species diversity in this environment was the irregular and mobile substrate produced by the rhodoliths.

Most of the species... can be shown to have some specific adaptation for an irregular, mobile substrate. These adaptations include the ability to bore into or encrust upon the algae, and the ability to reside in interstices between rhodoliths. In addition, some species' mobility or large size relative to rhodoliths may have aided in their survival on the substrate. *Lithophaga nuda* survived in this environment by boring into the nodular algae. Its frequent occurrence in collections... along with the numerous borings observed in sectioned rhodoliths demonstrates its abundance.

Attachment or encrustation upon rhodoliths or other skeletal remains was another common survival strategy. The solitary coral *Trochocyathus*(?) attached to rhodoliths or dead tests of *Clypeaster cotteaui* and cheilostomes encrusted the tests of *Lepidocyclina* and rhodoliths. Sabellarid(?) worm tubes also encrusted the alga. Oysters displaying irregular attachment scars on their valves suggest that they also attached to the rhodoliths.

Chlamys duncanensis and *Chlamys anatipes* (scallops) probably relied upon their mobility and crevice-dwelling habit to cope with the shifting substratum, as do modern species of this genus (Kauffman, 1969; Stanley, 1970). *Lima* was probably byssally attached within crevices between rhodoliths. Modern species of *Lima* live interstitially in cobbly substrata (Kauffman, 1969; Stanley, 1970). *Lepidocyclina* may also have lived between the rhodoliths.

Borers and encrusters were often found in life position within the rhodolith-rich facies.... This was not true, however, for other species that were large and mobile, such as *Conus* sp. and other snails, echinoids, and bivalves; these species were more frequently in life position in rhodolith-poor carbonate sands, where they were more abundant than in rhodolith-dominated environments.... Therefore, their presence in the rhodolith facies may reflect post-mortem transport from a sandy environment. For example, autecological analysis of *Conus* (Kohn, 1959), *Rhyncholampas* (Mortensen, 1948a; Kier, 1962, 1975; Gladfelter, 1978), *Clypeaster* (Mortensen, 1948b, *Glycymeris*, *Pitar*, and *Phacoides* (Kauffman, 1969; Stanley, 1970), suggests that these organisms have preferences for sandy substrata. Modern species of *Brissus* also inhabit mixed sand and gravel substrata (Kier, 1984; Kier and Grant, 1965).

Age

The age of the Bridgeboro Limestone is Early Oligocene, Vicksburgian (Rupelian). All of the principal macrofossils of the formation are known to occur only in Vicksburgian formations in the type provincial Vicksburgian in Mississippi and Alabama.

The following macrofossils are present in the Bridgeboro Limestone at the type locality:

Clypeaster cotteaui
C. rogersi (?)
Rhyncholampas gouldii
Chlamys duncanensis
C. anatipes

In Mississippi, *Clypeaster cotteaui* is known to occur only in the Glendon Limestone (M. Hunter, pers. com., 1986) and *C. cotteaui* occurs in the Florala Limestone Member in

Alabama. *Clypeaster rogersi* has been reported from the Marianna Limestone, Mint Spring Formation, Glendon Limestone, and Byram Formation in Mississippi (MacNeil and Dockery, 1984, p. 19), and from the Marianna and Glendon Limestones in Alabama (Cooke, 1926). *Rhyncholampas gouldii* is reported from the Mint Spring Formation (Cooke, 1959; MacNeil and Dockery, 1984, p. 19) and Marianna Limestone (MacNeil and Dockery, 1984, p. 19) in Mississippi, but has not been reported from Alabama. *Chlamys anatipes* has been reported from the Forest Hill Formation, Mint Spring Formation, Marianna Limestone and Glendon Limestone in Mississippi (Glawe, 1974; Dockery, 1982), and from the Red Bluff Clay, Marianna Limestone, Glendon Limestone and Byram Formation in Alabama (Cooke, 1926; Glawe, 1974; Dockery, 1982). It is also found in the Bumpnose Limestone in Florida (MacNeil, 1944c, p. 1324; Moore, 1955, p. 38, 41; Glawe, 1974) and the Marianna Limestone in Georgia (Glawe, 1974). *Chlamys duncanensis* has been reported from the Glendon Limestone and Byram Formation in Mississippi and Alabama (Glawe, 1974; Dockery, 1982), from the Bridgeboro Limestone at Duncan Church (Mansfield, 1934; Glawe, 1974), Bucatunna-equivalent limestone at Natural Bridge in Walton County, Florida (Glawe, 1974), and from the Marianna Limestone in Georgia (Glawe, 1974). Because neither the lower Vicksburgian Red Bluff Clay nor the Bumpnose Limestone contain *Clypeaster rogersi* but, rather, an undescribed species of *Clypeaster*, and because the Bridgeboro Limestone is overlain by the Vicksburgian Suwannee Limestone on the southern flank of the Chattahoochee Embayment, it appears that the Bridgeboro Limestone is correlative with only the middle part of the Vicksburgian section of Mississippi and Alabama (i.e., to the Glendon and possibly Marianna Limestones). However, at Duncan Church the Bridgeboro Limestone gradationally overlies the Marianna Limestone. Finally, Bryan and Huddlestun (1990) produced evidence that the Bridgeboro Limestone at its type locality (which is the upper part of the formation) is correlative only with the Glendon Limestone of Mississippi and Alabama.

Based on the above discussion, the Bridgeboro Limestone occurs within the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone of Stainforth and others (1975), and within Zones P18-P19 of Blow (1969)(Pl. 1).

FLORALA LIMESTONE MEMBER OF THE BRIDGEBORO LIMESTONE, new name

Definition

The Florala Limestone was informally introduced by Bryan (1991) and is formally proposed here for a fossiliferous, *Lepidocyclina*-rich, nonrhodolothic, and sporadically algal-rich, subdivision of the Bridgeboro Limestone. In the type area, the Florala Limestone Member occurs seaward of the Vicksburg Group. Relative to the Vicksburg Group, the Florala Limestone appears to represent a farther offshore, possibly deeper, and a more still-water (but still within the photic zone) facies. When compared to typical Bridgeboro Limestone, the Florala Limestone again seems to represent an environment in which the water was probably deeper and more still than is indicated for the Bridgeboro. Because Florala lithology has been observed only on the northern flank of the Gulf Trough in Georgia, troughward of the typical Bridgeboro Limestone, it appears that in Georgia the Florala Limestone may have been deposited in deeper water than the Bridgeboro, below the main influence of the Suwannee Current but still within the photic zone. The lithology of the undivided Bridgeboro Limestone, then, appears to have been deposited under the direct influence of the Suwannee Current whereas the Florala Limestone Member and the formations of the Vicksburg Group were little effected or influenced by it.

The Florala Limestone Member in the central panhandle of Florida has been generally referred to the Suwannee Limestone (Cooke, 1945; Puri and Vernon (1964); Schmidt, 1984). MacNeil (1944c), however, correlated the Florala Member at its type locality with the Duncan Church beds of Washington County, Florida, which in this report are included in the undivided Bridgeboro Limestone.

Type Section

The name Florala is taken from the town of Florala, near the Alabama-Florida state line in southern Covington County, Alabama. The type locality of the Florala Limestone is here designated the lime pit of the Stovall Lime and Cattle Co., Inc. The Stovall lime pit is located approximately 7 miles (11 km) east of Florala, Alabama, on Alabama state highway 54 in Covington County. The pit is located in the SE1/4, Sec. 22, T1N, R20W, in the Hacoda, Alabama, 1:24,000 quadrangle map (Fig. 24). The section of Florala Limestone Member exposed at the type locality is the unit-stratotype (holostratotype) of the formation (Fig. 25).

The type section also contains the upper boundary stratotype of the member. The Bucatunna Clay disconformably overlies the Florala Limestone Member near the top of a hard ledge, approximately 50 feet (15 m) above the floor of the pit.

The following Florida Geological Survey cores are designated reference sections and parastratotypes of the Florala Limestone Member of the Bridgeboro Limestone: The core Mathis 1 (W-8102), taken approximately 6 miles (10 km) west-southwest of the type locality in NE, NW1/4, NW1/4, SW1/4, Sec. 36, T6N, T21W, Walton County, Florida is a refernce section and parastratotype.

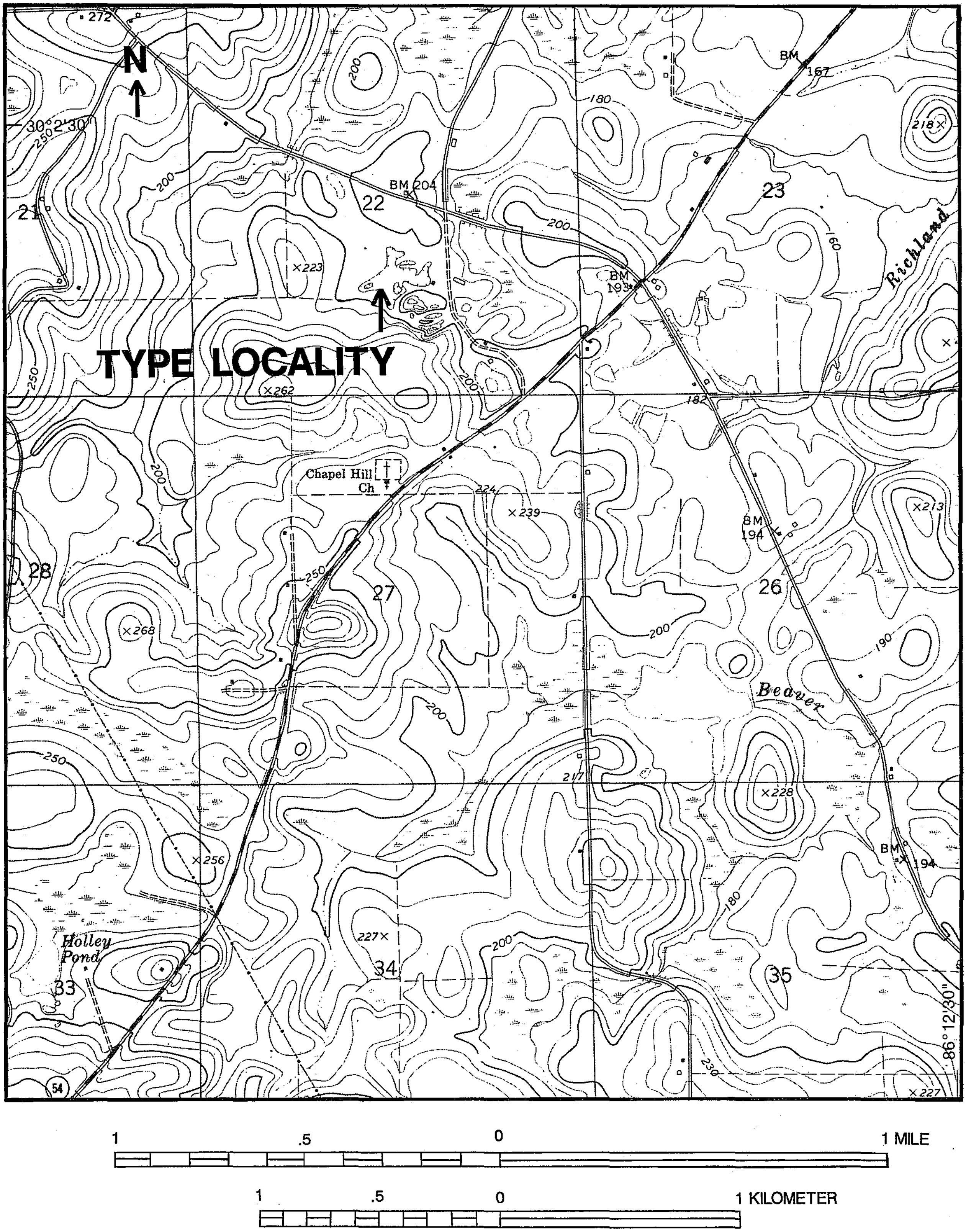

Figure 24. The type locality of the Florala Limestone Member of the Bridgeboro Limestone (U. S. Geological Survey, Hacoda, Ala. 1:24,000 topographic quadrangle.

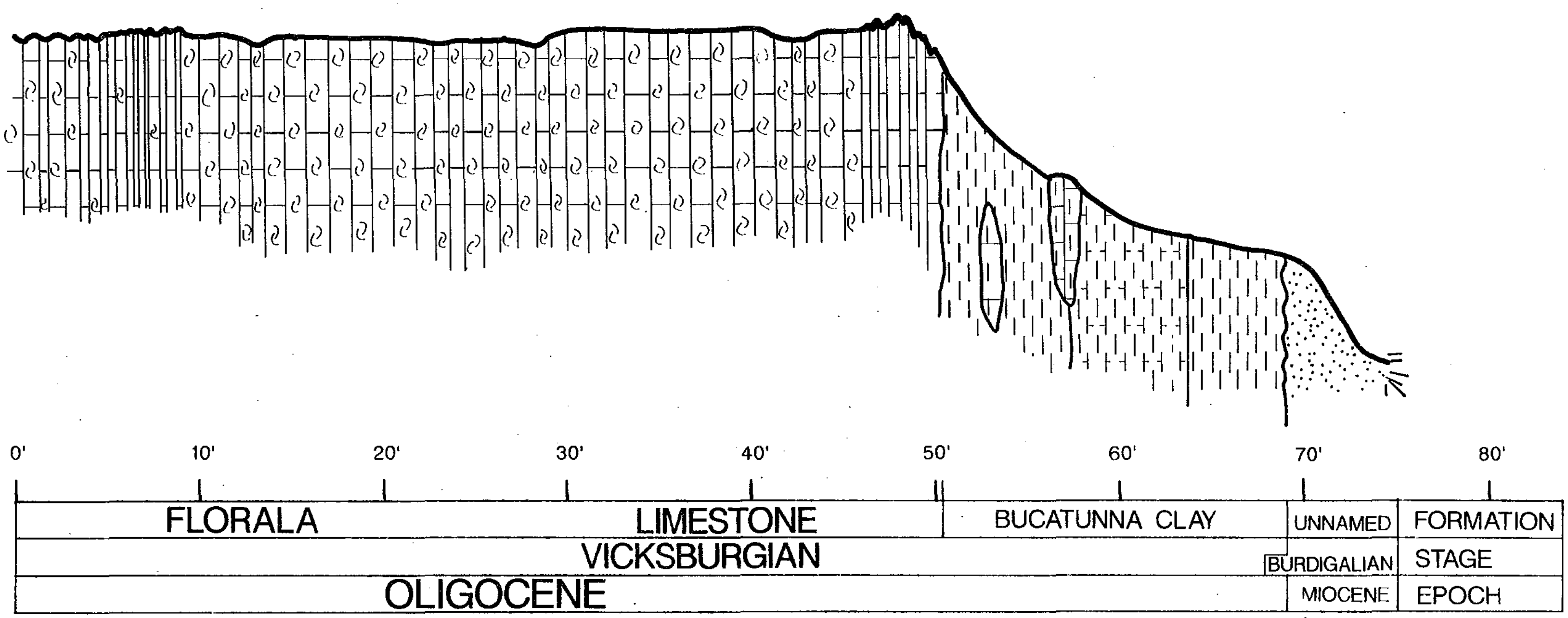

Figure 25. The measured holostratotype of the Florala Limestone Member of the Bridgeboro Limestone.

The parastratotype section of the Florala Limestone occurs in the interval 274 feet to total depth at 375 feet. The core Brown 1 (W-8104), was taken approximately 4 miles (6 km) south of the locality in NW1/4, NW1/4, NW1/4, Sec. 11, T5N, R20W, Walton County, Florida (Fig. 5). The parastratotype section of the Florala Limestone in the Brown 1 occurs in the interval 203 feet to 272 feet. The above cores are stored at the Florida Geological Survey in Tallahassee, Florida.

Lithology

The lithology of the Florala limestone Member of the Bridgeboro Limestone in its type area consists of relatively pure, coarsely fossiliferous, *Lepidocyclina*-rich, variably algal-rich limestone. However, farther south in the subsurface of Walton County, Florida, the Florala Limestone also contains lenses of sucrosic, tan to brown dolostone in varying stages of dolomitization that appear to be laterally continuous only over short distances. Encrusting algae are conspicuous and ubiquitous at the type locality but not in the reference cores. These algae appear to be related to the rhodoliths of the typical Bridgeboro Limestone but they are encrusting and flat, not spheroidal like the Bridgeboro rhodoliths, nor anastomosing as some algae in limestone in the Gulf Trough in Florida. Other than dolomite and dolostone, no other mineral components of the lithology have been observed.

The Florala Limestone Member is vaguely and rudely stratified, but the stratification may not be apparent except through the concentration of encrusting algae or the predominantly horizontal layering of the *Lepidocyclina* and other flat fossils. At the type locality, the limestone appears to be generally massive and structureless except for some thin intervals of up to 2 feet (0.6 m) thick of more coarsely fossiliferous, rubbly limestone. The rest of the limestone contains much micrite and chalky matrix calcite. The lower several feet exposed at the type locality contains more common encrusting algae than the overlying sections, producing distinct, thin- to medium-bedded stratification in the limestone. Where the encrusting algae is less concentrated, the stratification is much thicker and tends to be massive and structureless. In these intervals, flat or discoidal fossils vary from random in orientation to a moderate, horizontal orientation.

The limestone is generally partially consolidated but friable and soft, and there are intervals or lenses within the limestone that are also hard and recrystallized or completely unconsolidated and uncemented. The abundance of the encrusting algae probably contributes to the cementing of the calcitic and biogenic debris.

Although the Florala Limestone Member is richly fossiliferous, the faunal diversity is low, typical of all of the Oligocene limestones of the southeastern United States. The predominant biotic elements of the limestone include *Lepidocyclina* spp., encrusting algae, local concentrations of *Nummulites panamensis*, some bryozoa, and rare echinoids, scattered pectinids, molds of mollusks, and corals. The *Lepidocyclina* are variably sellaeform but some flat variants are also present. In some cores, the *Lepidocyclina* are principally flat.

The Florala Limestone Member is distinguished lithologically from typical Bridgeboro Limestone by the absence of rhodoliths and either the absence or scattered occurrences of abundant encrusting algae as opposed to rhodoliths of the undifferentiated Bridgeboro. Where encrusting algae are absent in the Florala Limestone Member, the formation can be identified as a *Lepidocyclina*-rich limestone of the Ocala type, though of lower faunal diversity. In addition, *Nummulites* is locally common to abundant or absent in the Florala Limestone but is not known to occur in the Bridgeboro Limestone

Stratigraphic Relationships

It is postulated here that the Florala Limestone Member represents deposition under far-offshore, relatively deep and still-water, photic zone conditions. The sediments are part of the carbonate continental shelf facies of the Vicksburgian of southern Alabama and western Florida, west of and on the northern flank of the Gulf Trough (Chattahoochee Embayment)(Fig. 26). In the vicinity of the Chattahoochee Embayment (Georgia Geologic Survey core Colquitt 11 GGS-3545), the Florala facies appears to occur along the northwestern flank of the embayment at intermediate depths as a relatively narrow band of subsurface deposits grading downsection and troughward into the Ochlockonee Formation.

The Florala Limestone Member is predominantly a subsurface formation but it is known to crop out in southeastern Covington County, Alabama. The Florala Limestone is known to underlie the central Florida panhandle, at least as far west as Walton County, Florida. It occurs as far east as the northern flank of the Gulf Trough within the upper part of the Oligocene sequence in the western part of the Chattahoochee Embayment as far north as Colquitt County, Georgia. However, the subsurface data in the western part of the Chattahoochee Embayment southwest of Colquitt County is sparse. The Florala Limestone member is not known to occur in Jackson County, Florida, where its stratigraphic position northwest of the embayment is occupied by the Vicksburg Group. The correlative stratigraphic interval within the northern flank of the embayment may occur in a very narrow band in the subsurface, between the Marianna/Glendon Limestones and the Ochlockonee Formation. The lithology of the Florala Limestone cannot be discriminated in the well-cutting descriptions of Moore (1955). West of the Chattahoochee Embayment in Walton County,

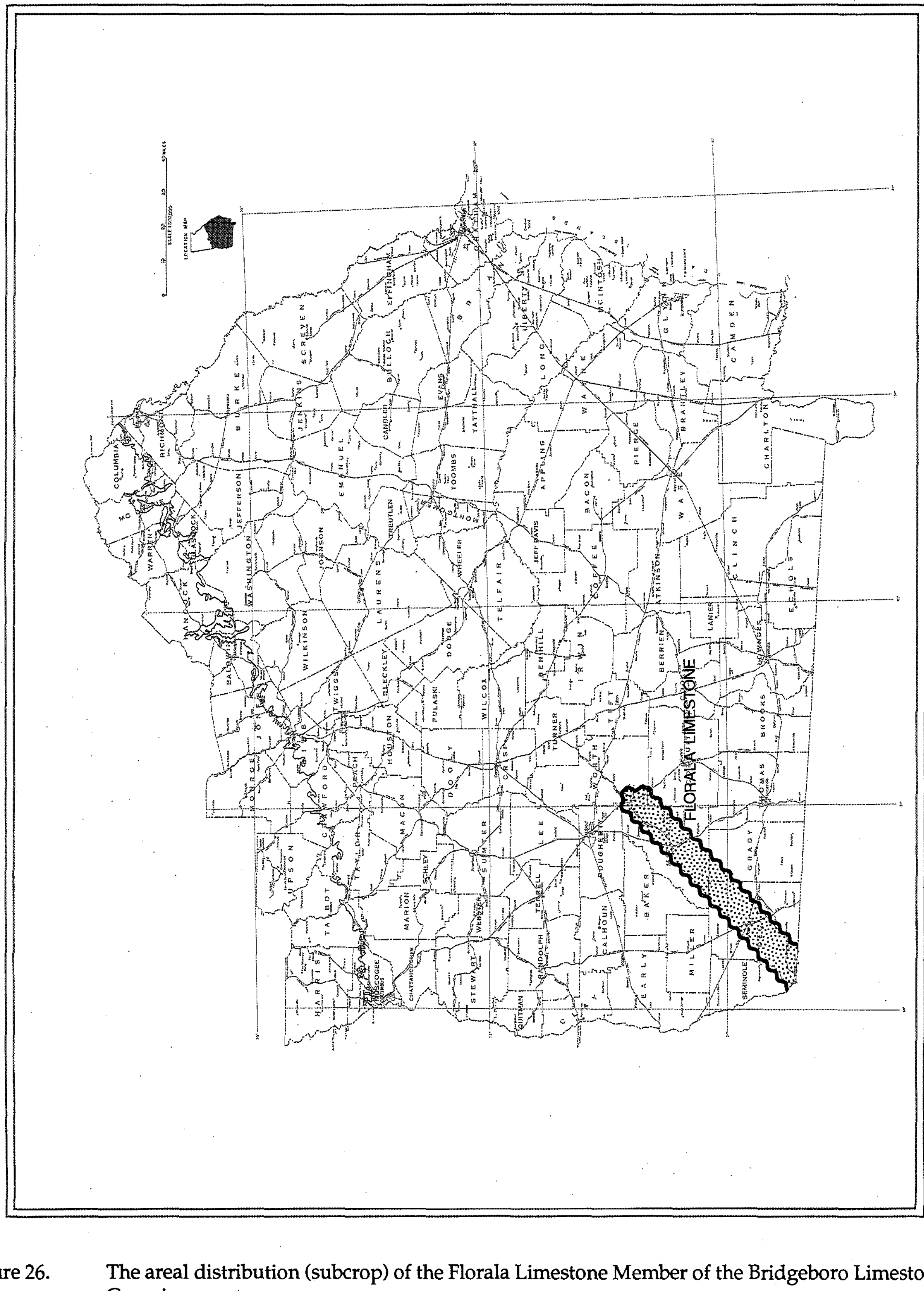

Figure 26. The areal distribution (subcrop) of the Florala Limestone Member of the Bridgeboro Limestone in Georgia.

Florida, the Florala Limestone Member occurs at least as far south as the coastal area of Florida.

In its type area in the vicinity of Florala, Alabama, the Florala Limestone Member appears to consist of the offshore, lateral, stratigraphic equivalents of the Marianna?, Glendon Limestones and possibly the Byam Formation. It is disconformably overlain by the Bucatunna Clay in its type area but farther south in the subsurface of western Florida, the Florala Limestone appears also to include the stratigraphic equivalent of the Bucatunna Clay. The discontinuities representing the low sea level stands between the various Vicksburg Group formations are not evident within the Florala Limestone except, possibly, as discontinuous beds or lenses of dolostone or dolomitized limestone within the Florala Limestone. The Florala Limestone Member appears to grade laterally eastward in the vicinity of the Chattahoochee Embayment into typical Bridgeboro Limestone. At Duncan Church the Bridgeboro Limestone gradationally overlies the Marianna Limestone.

The lithofacies interpretation of the Vicksburg Group, Bridgeboro Limestone, and Florala Limestone Member of the Bridgeboro adopted in this report is that the Florala Limestone is an offshore, deeper water but still relatively shallow water (within the photic zone) correlative of the Vicksburg Group and relatively still-water facies of the Bridgeboro Limestone. The Florala Limestone Member appears to grade laterally into typical Bridgeboro Limestone near the western margin of the Chattahoochee Embayment and in the vicinity of the Suwannee Current.

Along the western flank of the Chattahoochee Embayment (Gulf Trough), the Florala also appears to occur in a deeper water, trough-ward position to the Bridgeboro Limestone and, therefore, reflects a deeper water origin. The type locality of the Bridgeboro Limestone occurs in northeastern Mitchell County, Georgia, northwest of the Gulf Trough (Chattahoochee Embayment)(Fig. 2). The core Colquitt 11 (GGS-3545), taken near Doerun in northwestern Colquitt County between the Gulf Trough and Bridgeboro type locality, encountered only Florala Limestone Member that gradationally overlies the Ochlockonee Formation (Pl. 2). Typical Bridgeboro Limestone is absent in the Colquitt 11 (GGS-3545). On the western margin of the Chattahoochee Embayment, then, deposition of the Florala Limestone represents a later period of channel filling when the embayment floor had been raised through carbonate sedimentation into the photic zone.

The Florala Limestone Member of the Bridgeboro Limestone disconformably overlies the Ocala Limestone in the northern panhandle of Florida west of the Chattahoochee Embayment. In its type area, the Florala Limestone Member is disconformably overlain by the Bucatunna Clay. In all known occurrences of the Florala Limestone in the subsurface west of the Choctawhatchee River in the panhandle of Florida, the member is overlain disconformably by Bucatunna-equivalent limestone (as at Natural Bridge in northern Walton County, Florida) or Chickasawhay?-equivalent limestone. East of the Choctawhatchee River, the Florala Limestone Member is disconformably overlain by the Chattahoochee Formation. In the Colquitt 11 (GGS-3545) in northwestern Colquitt County, the Florala Limestone is gradationally overlain by the late Vicksburgian Suwannee Limestone (Pl. 3).

Age

The age of the Florala Limestone Member of the Bridgeboro Limestone is Early Oligocene, Vicksburgian. The Florala Limestone is a lithofacies of the Bridgeboro Limestone and is, therefore, considered to be the same age as the Bridgeboro (Pl. 1). Stratigraphic position supports this correlation. Along the southern flank of the Gulf Trough, the Bridgeboro Limestone is overlain by the Suwannee Limestone, considered here to be correlative with the Byram Formation. At Duncan Church in Washington County, Florida, the Bridgeboro Limestone conformably overlies the Marianna Limestone. In addition, Bryan and Huddlestun (1990) demonstrated a biostratigraphic correlation that is most compatible with the Glendon Limestone, thereby supporting physical correlation with the Glendon Limestone. However, the Bucatunna Clay disconformably overlies the Florala Limestone in its type area, and this leaves open the possibility that the Byram stratigraphic interval has not been satisfactorily distinguished paleontologically from the Glendon stratigraphic interval in an open shelf, fossiliferous limestone facies. Similarly, Plate 3 suggests that there may be a thick section of Oligocene limestone below the floors of the limestone pits near Bridgeboro in Mitchell County. This raises the possibility that a lower part of the Bridgeboro Limestone may also be a lithofacies of the Marianna Limestone.

There appear to be no lithologic discontinuities or breaks within the few completely cored Florala Limestone sections in western Florida. There is likewise no stratigraphic evidence that the Bumpnose Limestone may grade laterally seaward into the Florala.

Vicksburgian macrofossils identified at the type locality in the Florala Limestone include the following:

Chlamys anatipes
Pycnodonta vicksburgensis
Clypeaster cotteaui
C. rogersi
Brissus bridgeboroensis
Macropneustes mortoni
Lytechinus floridanus

the larger foraminifera *include:*

Lepidocyclina (Eulepidina) undosa
L. (Nephrolepidina) yurnaguensis
Nummulites panamensis
(Heller and Bryan, 1991)

The Florala Limestone contains the following planktonic foraminifera (at 290 feet, 294 feet, 305 feet, 317 feet, amd 374 feet) from the core Mathis 1 (W-8102) in Walton County, Florida:

Globorotalia increbescens
Globigerina ampliapertura
G. eocaena
G. ouachitaensis
Pseudohastigerina barbadoensis
Chiloguembelina cubensis

The association of planktonic foraminifera is compatible with the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone.

In view of the above discussion, the best age approximation that has been determined for the Florala Limestone is Glendon- to possibly Byram-equivalency.

FLORIDA BANK STRATIGRAPHIC ASSOCIATION

ELLAVILLE LIMESTONE, new name

Definition

The name Ellaville Limestone is proposed here for a subsurface limestone of southwestern Georgia that crops out along the Suwannee and lower Withlacoochee Rivers in Madison, Hamilton, and Suwannee Counties, Florida. In this area, and especially at Ellaville on the Suwannee River, the type locality of the formation (Fig. 27), the Ellaville Limestone has been assigned to various formations in the past. At the type locality, Matson and Clapp (1909) referred the limestone to the Hawthorne Formation whereas Cooke and Mossom (1929, p. 72-73, beds 1 and 2) referred it to the Glendon Limestone. Cooke and Mansfield (1936) discussed all the carbonates exposed along the Suwannee River between Ellaville and White Springs. They proposed the name Suwannee Limestone for the yellowish upper beds (beds 3 and 4 of Cooke and Mossom, 1929) and they called the lower limestone at Ellaville (beds 1 and 2 of Cooke and Mossom, 1929) "white limestone containing Vicksburg (Oligocene) fossils" (Ellaville Limestone of this report). They considered the Suwannee Limestone to disconformably overlie the "white limestone containing Vicksburg (Oligocene) fossils".

Cooke (1945) included the "white limestone" of Cooke and Mossom (1929) in the "Byram Limestone" and the overlying carbonates (including the Suwannacoochee Dolostone of this report) in the Suwannee Limestone. MacNeil (1944c) identified *Turritella martinensis* in this limestone at Ellaville and, as a result of his investigations, he correlated the limestone with the lowest Oligocene Forest Hill Sand and Red Bluff Clay of Mississippi. Puri and Vernon (1964, p. 110) included beds 1 and 2 of Cooke and Mossom (1929) in the Suwannee Limestone, and Hunter (1972) followed MacNeil (1944c) and informally included the "white limestone" in the Bumpnose Limestone on the basis of the occurrence of *T. martinensis*.

Type Section

The name Ellaville is taken from the community of Ellaville on the Suwannee River in Hamilton County, Florida. The type locality of the Ellaville Limestone is here designated the exposures of the limestone at Ellaville on the left bank of the Suwannee River in Suwannee County, Florida (Fig. 27). The section of the Ellaville Limestone exposed at the type locality is the unit-stratotype (holostratotype) of the formation (Fig. 28). The Ellaville Limestone of this report is the same as beds 1 and 2 at Ellaville of Cooke and Mossom (1929) and Puri and Vernon (1964). The type locality of the formation is near the center of Sec. 24 in T1S, RIIE, and the formation crops out discontinuously along the Suwannee River from the vicinity of Dowling Park, approximately 10 miles (16 km) south (downriver) fromEllaville, to 1 mile (1.6 km) northeast (upriver) from Ellaville. The type locality contains the upper boundary stratotype of the Ellaville Limestone. The Suwannacoochee Dolostone gradationally and conformably overlies the Ellaville Limestone approximately 8 feet (2.4 m) above mean low water of the Suwannee River. The lower boundary stratotype is not exposed at the type locality. In any event, the lower boundary is difficult to distinguish in outcrop along the river due to case hardening of the limestones and I have not been able to identify a satisfactory lower boundary stratotype in outcrop (Fig. 28).

The Florida Geological Survey core Ellaville 1 (W-10657) taken at the type locality is here designated a reference section and parastratotype of the Ellaville Limestone (Figs. 27 and 28), which occurs in the interval 25 feet to 39 feet in the core. The core site is at Ellaville in SW 1/4, NE1/4, Sec. 24, T1S, R11E. The lower boundary stratotype of the formation is at 39 feet in the core and the Ellaville Limestone overlies the *Ratularia vernoni* Zone of the "Ocala Limestone" abruptly and with apparent discontinuity. The Ellaville 1 (W-10657) is stored at the Florida Geological Survey in Tallahassee, Florida.

In Georgia, the core Thomas 4 (GGS-3188) [U.S. Gypsum core 76-1]) is herein designated a reference

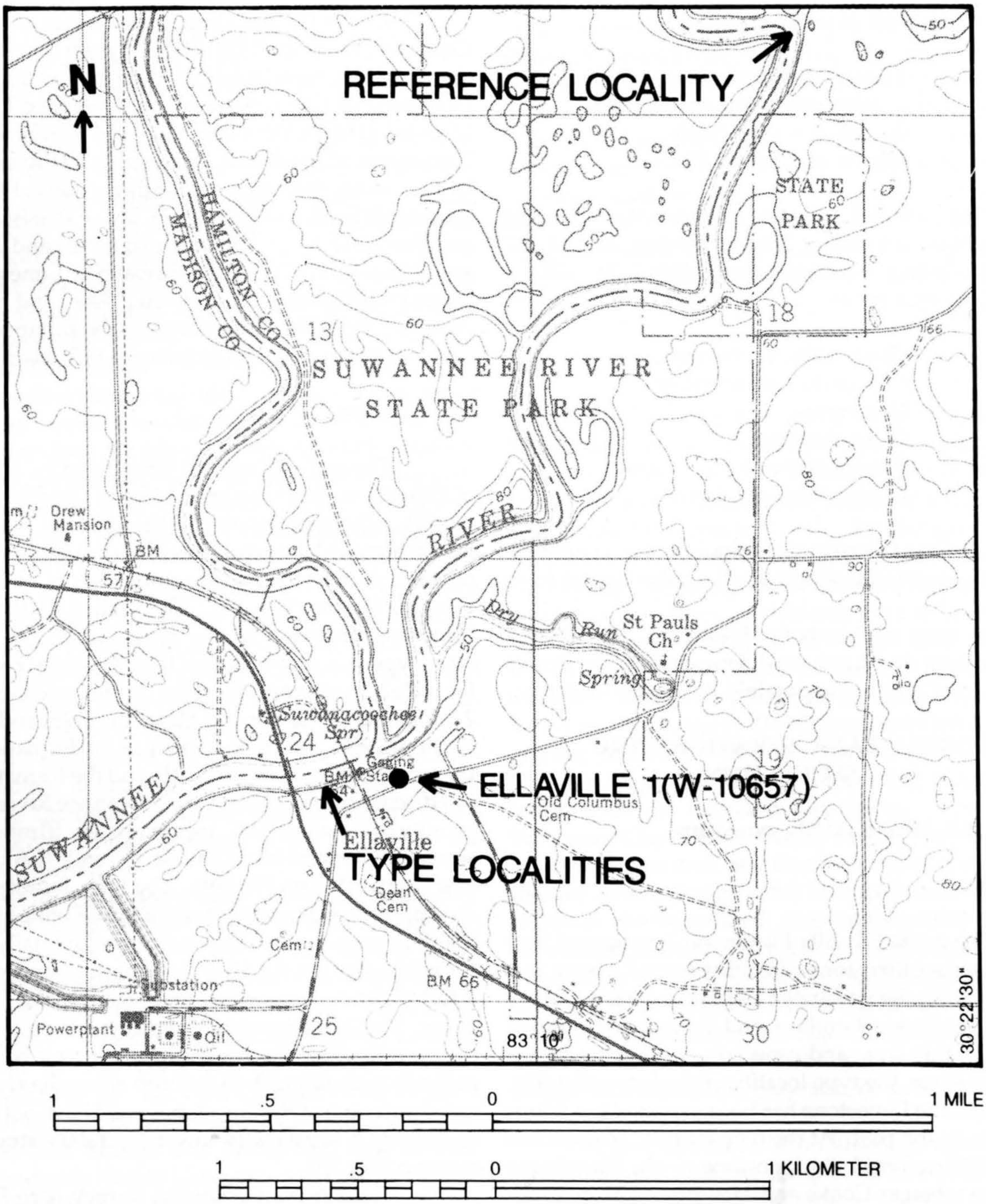

Figure 27. The type localities of the Ellaville Limestone and Suwannacoochee Dolostone, and the reference locality of the Suwannee Limestone (U.S. Geological Survey, Ellaville, Florida, 1:24,000 topographic quadrangle).

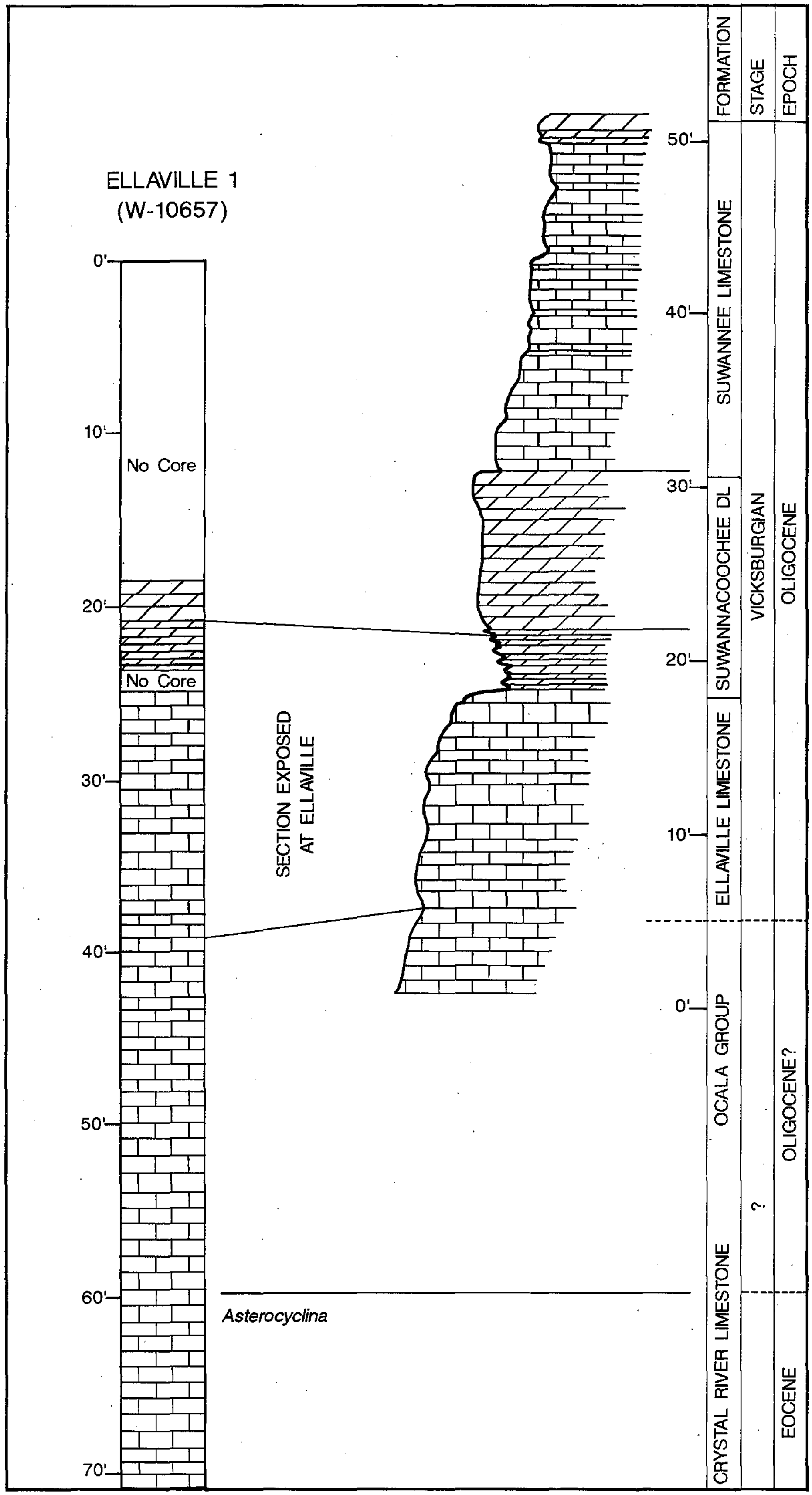

Figure 28. Composite stratigraphic section along the Suwannee River from Dowling Park to the confluence with the Alapaha River compared with the Florida Geological Survey core Ellaville 1 (W-10657).

section and parastratotype of the Ellaville Limestone. The core site of the Thomas 1 (GGS-3188) is on the side of an abandoned railroad grade, less than 0.1 mile (0.16 km) south of the crossing of Old Quitman Road and the railroad crossing, approximately 2.4 airline miles (3.8 km) northeast of the center of the village of Boston in Thomas County, Georgia (Fig. 2). The Ellaville Limestone occurs in the interval 273.5 feet to 311.5 feet in the core. The core Thomas 4 (GGS-3188) is stored at the Georgia Geologic Survey in Atlanta, Georgia.

Lithology

The Ellaville Limestone is a lithologically nondistinctive, sparsely but variably macrofossiliferous, calcarenitic, relatively pure, moderately indurated limestone. Dolomite and dolostone are the only significant minor lithic components of the formation and they occur rarely and sporadically. There are no known occurrences of clay, quartz sand, glauconite, phosphate, or gypsum in the formation.

The calcarenitic particles consist of bioclastic debris and range in size from medium sand-size to silt-size with some minor coarse, porous, well-washed, foraminiferal-pelletal arenite. The more finely granular limestone is also more chalky or micritic. Little of the granular calcarenitic material is identifiable as to origin: most is probably algal but foraminifera, especially miliolids, can be recognized with a hand lens even where the limestone appears well-cemented. The roundness of the particles ranges from well-rounded to angular and the coarser bioclastic particles are generally the more angular.

Macrofossils occur in stratified concentrations. They largely consist of mollusk molds and casts of small to moderate size. The most abundant mollusks are small species of *Turritella* that include *T. mississippiensis* and *T.* cf. *martinensis* (fide Dockery). In places, rhodoliths and corals are conspicuous, but they are never as abundant as in the correlative Bridgeboro Limestone. *Lepidocyclina* is generally present in any given section but is not common in the type area. In Georgia, however, the lower part of the Ellaville Limestone locally consists of a coarsely fossiliferous, *Lepidocyclina*-rich limestone that resembles the correlative Florala Limestone to the west of the Gulf Trough and the *Rotularia vernoni.* Zone of the Ocala Limestone in Florida. Bryozoa are generally associated with *Lepidocyclina*, but the bryozoa appear always to be a subordinate element of the fauna and lithology. *Lepidocyclina* commonly is distributed in vague layers, the intervening intervals generally consisting of calcarenitic limestone.

Sucrosic, tan to brown, hard and dense to soft and porous dolostone occurs locally within the Ellaville Limestone. In Georgia, dolomitization has occurred near the Ellaville-Ocala boundary and a variable and uncertain thickness of dolostone occurs in the lower part of the Ellaville.

The Ellaville Limestone typically is massive and structureless but there is some rude and vague organization of the sediments into layers. Stratification is most noticeable where there are varying abundances of macrofossils in different beds or strata in the section. The Ellaville is indurated and recrystallized to varying degrees. Unconsolidated limestone is not known to occur in the formation.

Stratigraphic Relationships

The Ellaville Limestone is known to occur in Thomas and Brooks Counties, Georgia, and in Madison, Hamilton, and Suwannee Counties, Florida (Fig. 28). It also probably underlies Lowndes County, Georgia, and Jefferson County, Florida. It thins and pinches out eastward in Georgia and Florida in the vicinity of the Peninsular Arch, and grades laterally northwestward into the Bridgeboro Limestone (Pls. 3 and 4). The southern limit of the formation is not known at this time.

The Ellaville Limestone overlies the Ocala Limestone with apparent disconformity. In Georgia, extensive dolomitization has occurred near the Ellaville-Ocala boundary and the contact relationships, therefore, are uncertain. I have been unable to distinguish a clear formational contact in outcrop along the Suwannee River in Florida but, in the parastratotype core Ellaville 1 (W-10657), the contact is distinct at 39 feet in the core and appears to be an abrupt change in limestone beds. The Ellaville Limestone is overlain conformably and gradationally in the type area and in Georgia by the Suwannacoochee Dolostone.

Farther down river from Ellaville, below the I-10 highway bridge on the left bank of the river in SE1/4, SW1/4, Sec. 35, T1S, R11E, fossiliferous limestone containing *the echinoid Wythella eldgridei* and a worm case, *Rotularia vernoni* (= *Spirulaea vernoni*) occurs at approximately 18 feet (5.5 m) below the top of the Ellaville Limestone (Fig. 27). Lithologically this limestone is not Ellaville Limestone and more closely resembles the Ocala Limestone. In the Ellaville 1 (W-10657), the top of the Upper Eocene Ocala Limestone occurs at a paraconformable lithology change at 59 feet, below which *Aequipecten spillmani, Amusium ocalanum*, typical *Nummulites wilcoxi*, and *Asterocyclina* are present. Hunter (1976 and pers. com., 1991) considers the *Rotularia vernoni* Zone of Puri (1957) to be earliest Oligocene in age and correlative with the Red Bluff Clay and Bumpnose Limestone of the eastern Gulf Coastal Plain. The lithology of the limestone containing *R. vernoni* on the Suwannee River is compatible with the lithology of the limestone that contains the Oligocene echinoid *Clypeaster cotteaui* at the Steinhatchee pit in Dixie County, Florida, formerly

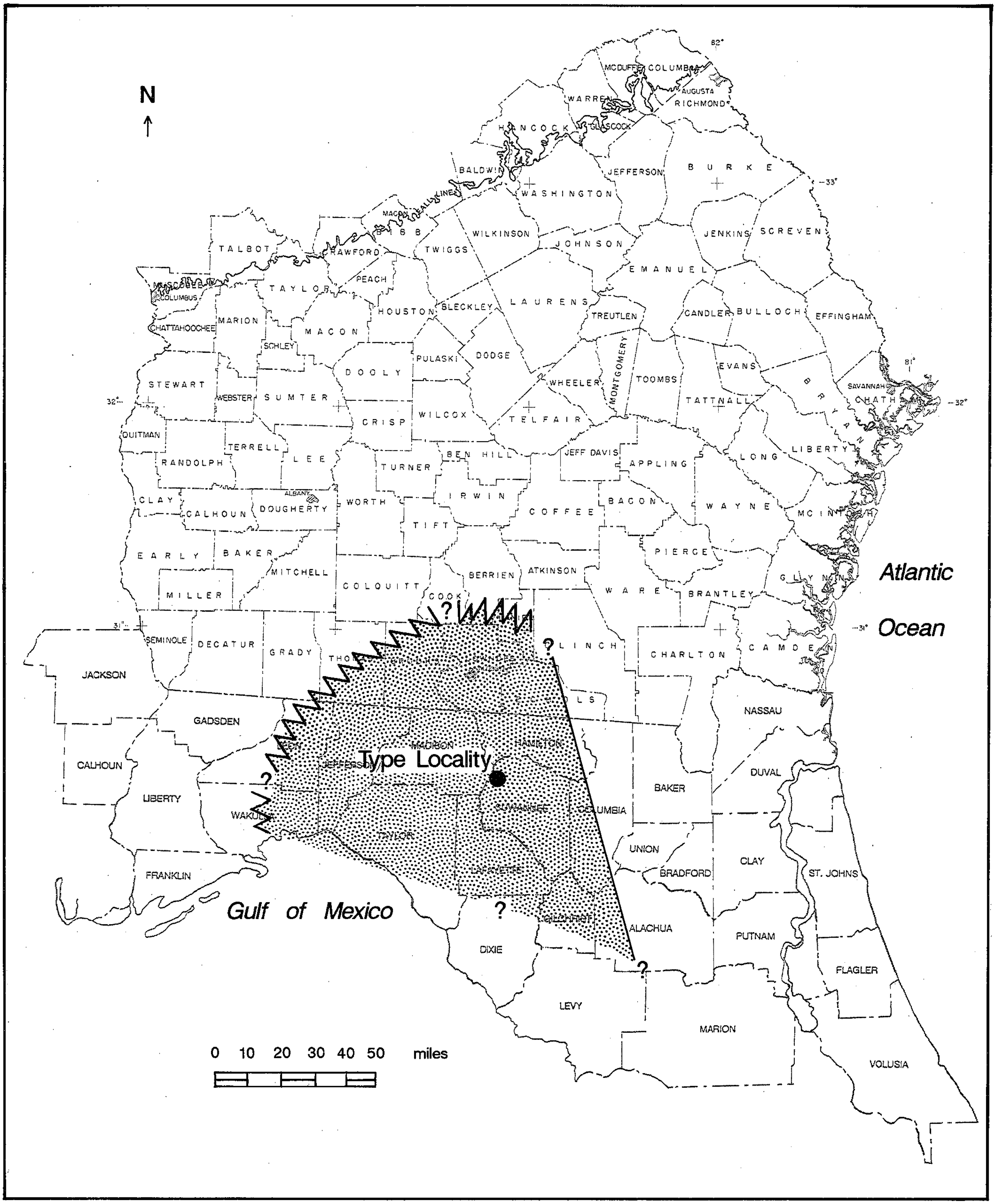

Figure 29. The areal distribution (outcrop and subcrop) of the Ellaville Limestone in Georgia and northern Florida.

included in the Ocala Limestone. *Clypeaster cotteaui* is known to occur only in the Glendon Limestone in Mississippi but it also occurs in the Florala Limestone in Albama and in the Bridgeboro Limestone in Georgia (considered to be Glendon-equivalent at the Bridgeboro type locality). I could find no fossils in the limestone containing *R. vernoni* on the Suwannee River that are clearly restricted to sediments of Eocene age such as *Amusium ocalanum, Aequipecten spillmani* and discocyclinid larger foraminifera. Therefore it is possible that what has been called the top of the Ocala Limestone on the Suwannee River may be an unnamed Oligocene limestone that is lithologically similar to the Ocala Limestone as is the Bumpnose Limestone. This particular limestone resembles the Bumpnose Limestone and other richly fossiliferous Oligocene limestones in the low species diversity of the fauna, but it is not Bumpnose Limestone in that it is not glauconitic, a characteristic of all occurrences of Bumpnose Limestone known to me. With the available paleontological evidence, this Ocala-like Oligocene limestone in northwestern Florida may range in age from earliest Vicksburgian through middle (Glendon-equivalent) Vicksburgian. Such a correlation would suggest that the Ellaville Limestone may grade southward into Ocala-like limestone. Put the other way, Ocala-like Oligocene limestone in peninsular Florida may grade northward into the Ellaville Limestone with a slight intertonguing relationship. This Ocala-like Oligocene limestone is not known to occur in Georgia.

The Ellaville Limestone lithologically is a nondescript and nondistinctive limestone. It is typically massive with only thick and rude stratification, and is variably macrofossiliferous although most beds are only poorly fossiliferous. In contrast, both the underlying *Rotularia vernoni* Zone and "Upper Eocene" Ocala Limestone are abundantly macrofossiliferous. The Ocala also contains a rich and diverse suite of macrofossils and larger foraminifer whereas most of the Ellaville typically contains relatively few larger foraminifera. The overlying Suwannacoochee Dolostone, on the other hand, is a gray to tan, poorly fossiliferous to nonfossiliferous, fine-grained, sucrosic dolostone. In contrast, the Suwannee Limestone has a granular, "mealy" texture that is rarely seen in the Ellaville. The Suwannee Limestone rarely contains larger foraminifera and is generally nonmacrofossiliferous but contains local concentrations of macrofossil molds and casts. The laterally correlative Bridgeboro Limestone is distinguished from the Ellaville Limestone in containing abundant rhodoliths and more common larger foraminifera.

Only about 8 feet (2.5 m) of the Ellaville Limestone is exposed during mean low water at the type locality on the Suwannee River. In the nearby reference core, Ellaville 1 (W-10657), the Ellaville Limestone is 14 feet (4.3 m) thick (Fig. 27). In the Florida Geological Survey core Bass 1 (W-10480) taken near the Georgia-Florida state line near the Withlacoochee River in Hamilton County, Florida, approximately 20 miles (32 km) north of Ellaville, the formation is 12 feet (3.6 m) thick (Pl. 3).

In Georgia, the Ellaville Limestone is 36.5 (11.1 m) thick in the reference core Thomas 4 (GGS-3188) near Boston in Thomas County; 18.5 feet (5.6 m) thick in the Brooks 7 (GGS-3189) in Brooks County near Pavo; and 22 feet (6.7 m) thick in the core Brooks 8 (GGS-3208) in northern Brooks County (Fig. 2, 3). The Ellaville Limestone is at least 13 feet (4.0 m) thick in the core Brooks 9 (GGS-3209), but the lower part of the formation has been dolomitized in that core and the true thickness of the formation is uncertain.

It would appear from limited data that the Ellaville Limestone averages between 10 feet (3.4 m) and 15 feet (4.6 m) thick in the type area. It thickens northwestward into Georgia to an average of approximately 25 feet (7.6 m) before it grades laterally northwestward into Bridgeboro Limestone.

The Ellaville Limestone was deposited in relatively shallow-water on the continental shelf in a bank-type environment. The absence of cross bedding and the poorly bedded nature of the limestone indicates low energy conditions, probably below wave base. The climate was subtropical to tropical, probably much like that of the Bahamas Islands of today.

Age

The age of the Ellaville limestone is Early Oligocene, Vicksburgian (P1.1). Macrofossils present in the Ellaville Limestone include:

Clypeaster rogersi (?)
Rhyncholampas gouldii
Turritella mississippiensis

In the type area of the Vicksburgian and Chickasawhayan in Mississippi and Alabama, all of the principal macrofossils of the Ellaville limestone are known to occur only in Vicksburgian formations. *Clypeaster rogersi* has been reported from the Marianna Limestone, Mint Spring Formation, Glendon Limestone, and Byram Formation in Mississippi (MacNeil and Dockery, 1984, p. 19), and from the Marianna and Glendon Limestones in Alabama (Cooke, 1926). *Rhyncholampas gouldii* has been reported from the Mint Spring Formation and Marianna Limestone in Mississippi (MacNeil and Dockery, 1984, p. 19), but has not been reported from Alabama. *Turritella mississippiensis* has been recorded only from the Byram Formation in Mississippi (MacNeil and Dockery, 1984, p. 50).

The earliest Vicksburgian Red Bluff Clay in Mississippi and Alabama, and the correlative Bumpnose

Limestone in Alabama and Florida do not contain *Clypeaster rogersi* but, rather, a smaller, undescribed and probably ancestral species. Therefore it is concluded that the typical Ellaville Limestone is younger than earliest Vicksburgian.

Because of the pervasive induration of the Ellaville Limestone, I have been unable to concentrate foraminifera from the formation. One can only identify a few smaller foraminifera, mainly miliolids, along fracture surfaces of the limestone. *Lepidocyclina mantelli* (= *L. supera*) is the only larger foraminifer that has been reported to date from the Ellaville Limestone (Cooke, 1945, p. 86) and it is known to range throughout the Oligocene of southeastern North America.

The Suwannee Limestone that overlies the Suwannacoochee Dolostone, which in turn overlies the Ellaville Limestone, is correlated with the Byram Formation of Mississippi. It is, therefore, concluded that the most likely age of the Ellaville Limestone is middle Vicksburgian, probably correlative with the Glendon Limestone (Pl. 1) as earlier proposed by Cooke and Mossom (1929).

SUWANNACOOCHEE DOLOSTONE, new name

Definition

The name Suwannacoochee Dolostone is proposed here for a lithologically distinctive and mappable dolostone formation in the area of the Suwannee and lower Withlacoochee Rivers in Madison, Hamilton, and Suwannee Counties, Florida, and in the subsurface of Thomas and Brooks Counties, Georgia. At Ellaville, Florida, the type locality of the formation (Fig. 26), the Suwannacoochee Dolostone has been included in the Hawthorne Formation (Matson and Clapp, 1909), Tampa Limestone (Dall, 1892; Cooke and Mossom, 1929), and Suwannee Limestone (beds 3 and 4 of Cooke and Mossom, 1929)(Cooke and Mansfield, 1936; Mansfield, 1937; Cooke, 1945; Puri and Vernon, 1964).

Cooke (1945, p. 98) did not recognize this unit as a dolostone (or dolomite) but his description of the Suwannacoochee at Ellaville is clear enough:

> Most of the rock is cream-colored or yellow hard, compact limestone without apparent bedding planes; the lower 4 feet is thin-bedded and somewhat conglomeratic.

Although this dolostone consistently has been included in the Suwannee Limestone in recent years, I am excluding it from that formation because the Suwannacoochee is a mappable and lithologically distinctive stratigraphic unit. In addition, the Suwannacoochee Dolostone does not appear to be a subdivision of the Suwannee Limestone but is more closely related to the pre-Suwannee Oligocene formations in the area. That is, the Suwannacoochee has approximately the same geographic distribution as the underlying Ellaville Limestone, and it appears to grade laterally into the upper part of the Bridgeboro Limestone in the same area where the Ellaville Limestone grades laterally into the lower part of the Bridgeboro (Pl. 3). The Suwannee Limestone overlies both the Suwannacoochee Dolostone and the Bridgeboro Limestone, and the thickness of the Suwannee is generally consistent over the entire area, suggesting that the Suwannacoochee is not a dolomitized lower phase of the Suwannee Limestone (Pls. 3 and 4).

Type Section

The name Suwannacoochee is taken from a spring near the right bank of the Suwannee River opposite Ellaville, Florida. The type locality of the Suwannacoochee Dolostone is designated here as the exposures of the formation at Ellaville on the left bank of the Suwannee River in Suwannee County, Florida (Fig. 26). This is also the type locality of the Ellaville Limestone. The section of Suwannacoochee Dolostone exposed at the type locality is the unit-stratotype (holostratotype) of the formation (Fig. 27). The type locality of the formation is near the center of Sec. 24 in T1S, R11E, and the formation crops out discontinuously along the Suwannee River from the vicinity of Dowling Park approximately 10 miles (16 km) south of Ellaville, to 1.5 miles (2.4 km) northeast (upriver) from Ellaville. It also crops out discontinuously for approximately 4 miles (6.4 km) along the Withlacoochee River above its confluence with the Suwannee River. The best exposures of the Suwannacoochee Dolostone occur in low bluffs on the right bank of the Suwannee River approximately 4 miles (6.4 km) south (downriver) from Ellaville in S 1/4, Sec. 34, T1S, R11E. The lower boundary stratotype is present at the type locality where the Suwannacoochee Dolostone conformably and gradationally overlies the Ellaville Limestone.

In Georgia, the core Thomas 4 (GGS-3188, U.S. Gypsum 76-1) is here designated a reference section and parastratotype of the Suwannacoochee Dolostone (Fig. 2). The site of the Thomas 4 (GGS-3188) is on the side of an abandoned railroad grade, less than 0.1 mile (0.16 km) south of the crossing of Old Quitman Road and the railroad right-of-way, approximately 2.4 airline miles (3.8 km) northeast of the center of the village of Boston in Thomas County, Georgia. The Suwannacoochee Dolostone occurs in the interval 217.5 feet to 273.5 feet in the core. This section has been chosen as a parastratotype because the lithology is typical for the formation, all the lithologic characteristics of the formation are present in this section, and the core recovery of more than 80% is exceptionally good.

Lithology

The Suwannacoochee Dolostone typically is a gray or buff to tan to brown, thin-bedded to massive and structureless, fine-grained dolostone. Where post-depositional dolomitization has been extensive, the formation consists of buff to brown, sucrosic dolostone and, except for the basal part, is massive and devoid of sedimentary and biogenic structures. However, where extensive recrystallization has not obliterated the original sedimentary fabric of the formation, the dolostone is characteristically gray, very fine grained, slightly argillaceous, thinly bedded to laminated, and with scattered layers containing intraformational breccia (intraclasts). A thin marker bed of dark gray to black, dolomitic clay or buff, clayey dolostone consistently occurs at the base of the Suwannacoochee Dolostone in Thomas and Brooks Counties, Georgia. This clay bed, however, is not present at the type locality or in the type area along the Suwannee and lower Withlacoochee Rivers in Florida. In its place there is a thinly bedded dolostone with scattered layers of intraformational breccia (bed 3 at Ellaville of Cooke and Mossom, 1929; Cooke, 1945; Puri and Vernon, 1964). Also, in the type area, the Suwannacoochee is not known to contain the gray, thinly layered dolostone that is characteristic of the formation in Georgia. Recrystallization has been more extensive in the type area than in Georgia.

Subordinate lithic components of the Suwannacoochee Dolostone include clay, rare occurrences of chert, and carbonaceous material in the lower part. The Suwannacoochee is an exceptionally hard and resistant dolostone and, as a result, where the formation occurs at river level, it forms a rubble of boulders and, in places, huge blocks of dolostone that form rapids in the rivers during low water stages.

The Suwannacoochee Dolostone is not typically fossiliferous. However, layers or bedding planes containing molds of very small mollusks (apparently a depauperate fauna), and thick intervals with rare, scattered, small mollusk molds and impressions are not uncommon. Cooke and Mossom (1929) reported echinoid molds (*Rhyncholampas gouldii*) in the upper, massive dolostone (bed 4) at the type locality.

Stratigraphic Relationships

The Suwannacoochee Dolostone is known to occur in Thomas and Brooks Counties, Georgia, and in Madison, Hamilton, and Suwannee Counties, Florida (Fig. 29) and is present in all wells and cores from this area. It also probably underlies Lowndes County, Georgia, and Jefferson County, Florida. In addition, there is some evidence that it occurs in Cook County, Georgia, and parts of Taylor County, Florida. The Suwannacoochee Dolostone either pinches out or wedges out eastward in Georgia and Florida in the vicinity of the Peninsular Arch, and it appears to grade laterally northwestward into the upper part of the Bridgeboro Limestone (Pls. 3 and 4). The southern extent of the formation is unknown at this time.

The Suwannacoochee Dolostone overlies the Ellaville Limestone conformably and with apparent gradation. It is overlain conformably and with apparent gradation by the Suwannee Limestone. The Suwannacoochee Dolostone is distinguished from all other formations in the area in being a dolostone with thin bedding and with scattered beds containing intraformational breccia.

In the type area along the Suwannee River, the thickness of the Suwannacoochee Dolostone ranges from 11 feet (3.4 m) to 15 feet (4.5 m). It is 15 feet (4.5 m) thick at the type locality and is 16.5 feet (5.0 m) thick in the Florida Geological Survey core Bass 1 (W-10480) in Madison County near the Withlacoochee River. In Thomas and Brooks Counties, Georgia, the Suwannacoochee Dolostone ranges in thickness from 9.5 feet (2.9 m) in the core Brooks 8 (GGS-3208) to 56 feet (17 m) in the reference core Thomas 4 (GGS-3188).

The scattered occurrence of unusually small mollusks, the presence of thin bedding and lamination, the presence of intraclast beds, and the presence of carbonaceous clay are all suggestive of a low-energy, biologically restricted, possibly intertidal or supratidal environment. The above characteristics, in addition to the decline in fossil content upward through the section from the Ocala Limestone through the Ellaville Limestone to the Suwannacoochee Dolostone, is suggestive of a progressive shoaling. Therefore it appears that the Suwannacoochee Dolostone was deposited in a relatively shallow water, low-energy environment (with periodic higher energy that resulted in the ripping up of bottom sediments). Being a shallow water shelf carbonate, the Suwannacoochee Dolostone, as with all shallow water shelf carbonates, was deposited in a tropical-subtropical climate.

Age

The age of the Suwannacoochee Dolostone is early Oligocene, Vicksburgian (Rupelian) (Pl.1). The Suwannacoochee is overlain and underlain, and grades laterally into Vicksburgian formations. Occurrence of *Rhyncholampas gouldii* in the Suwannacoochee is consistent with a Vicksburgian age. The Suwannacoochee Dolostone is gradationally overlain by the Suwannee Limestone that, on the basis of physical and biostratigraphic correlation, is correlated with the Byram Formation of Mississippi. The Suwannacoochee is abruptly but gradationally underlain by the Ellaville Limestone that is

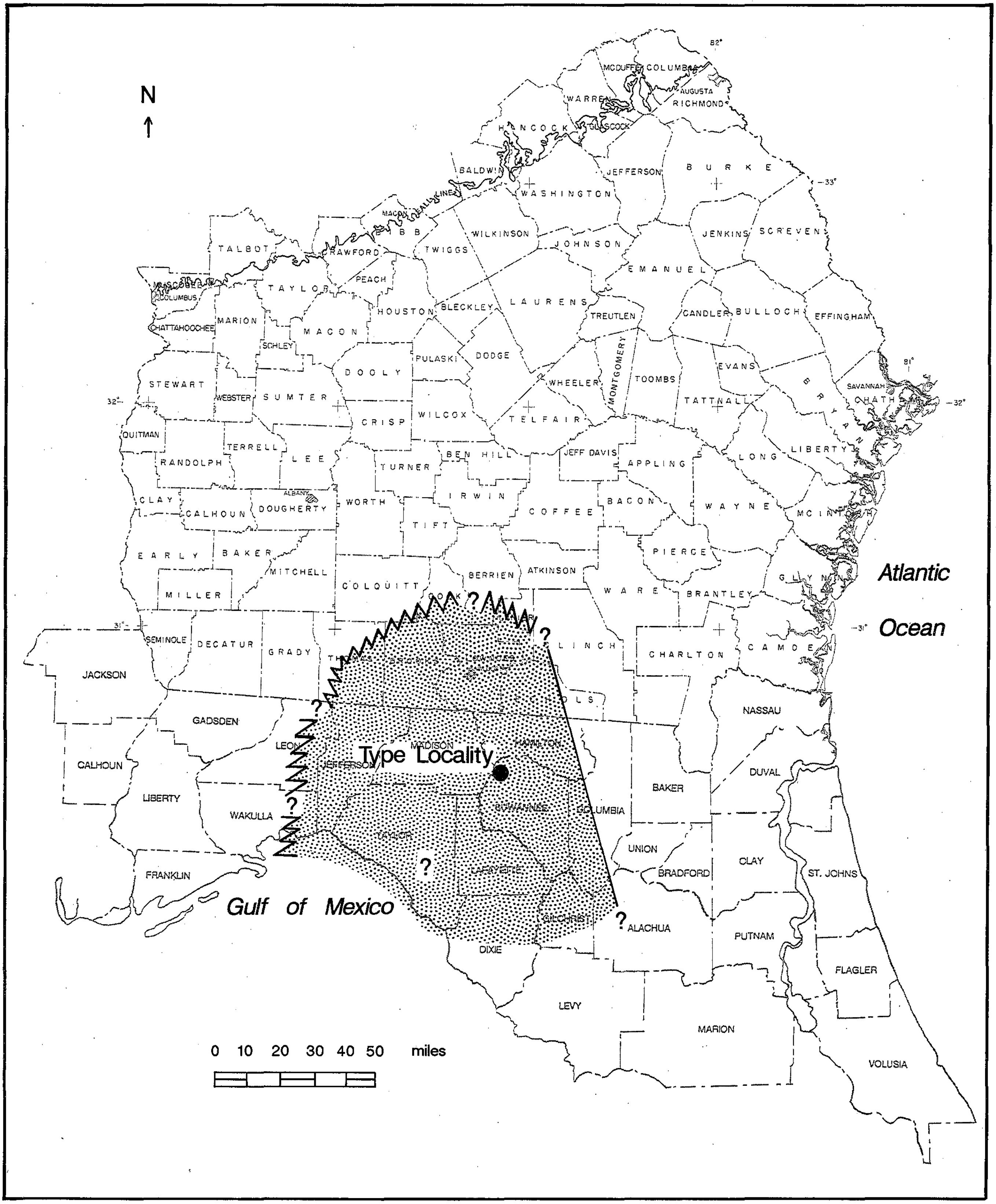

Figure 30. The areal distribution (outcrop and subcrop) of the Suwannacoochee Dolostone in Georgia and northern Florida.

roughly correlated with the Glendon Limestone. Therefore it would appear that the Suwannacoochee Dolostone was deposited during the low stand of the sea subsequent to the deposition of the Glendon but prior to the deposition of the Byram in Mississippi (Pl. 1).

SUWANNEE LIMESTONE, redefined and revised

Definition

The Suwannee Limestone is recognized and described here as a lithologically distinctive stratigraphic unit that occurs in Georgia from the Florida state line to the Savannah River. Like the earlier Upper Eocene Ocala Limestone, the Suwannee Limestone occurs on both sides of the Gulf Trough in Georgia and occurs east of the eastern termination of the trough. However, its occurrence north of the Gulf Trough is much more restricted than its occurrence south of the trough. The Suwannee lithostratigraphic unit was not deposited west of the vicinity of the Chattahoochee Embayment (contrary to past stratigraphic usage west of the Apalachicola River). In that area, either the Bridgeboro Limestone or the Florala Limestone Member of the Bridgeboro occurs in the Suwannee stratigraphic position or the Suwannee stratigraphic-equivalent is not present in western Florida (due either to nondeposition or removal prior to the deposition of the Bucatunna Clay and correlative limestones).

The name Suwannee Limestone was proposed by Cooke and Mansfield (1936, p. 71-72) for "...yellowish limestone typically exposed along the Suwannee River in Florida, from Ellaville,...., almost to White Springs,....".[2] In Florida this section along the Suwannee River had previously been referred to vaguely as the Hawthorne Formation (Matson and Clapp, 1909) and Tampa Limestone (Cooke and Mossom, 1929, p. 89-91). In Georgia, the Suwannee Limestone of this report had been included in the Jacksonboro limestone (Dall and Harris, 1892, p. 83-84), the Chattahoochee Formation (Veatch and Stephenson, 1911, p. 339, 341; Brantly, 1916, p. 25-28), and both the Flint River formation (p. 83-84) and Suwannee Limestone (p. 84-86) by Cooke (1943). On the other hand, in Georgia, both the Bridgeboro Limestone (Owen, 1963; Glawe, 1974) and the Ochlockonee Formation (Gelbaum and Howell, 1982) have been included in the Suwannee Limestone.

The lithostratigraphic definition of the Suwannee Limestone has never been clear. This results from (1) the original ambiguous lithostratigraphic definition of the formation by Cooke and Mansfield (1936, p. 71)

> The name "Suwannee Limestone" is proposed for yellowish limestone typically exposed along the Suwannee River in Florida, from Ellaville, where it unconformably overlies white limestone containing Vicksburg (Oligocene) fossils, almost to White Springs, near which it lies unconformably below the Miocene Hawthorn formation, ...

(2) from confusion resulting from the absence of the Suwannee Limestone (in the lithostratigraphic sense of this report) from the most commonly cited reference locality at Ellaville on the Suwannee River (compare with Cooke, 1945, p. 85-86; Puri and Vernon, 1964, p. 10); (3) from extension of the formation name, on the basis of stratigraphic position, to other Oligocene limestone lithostratigraphic units (Vernon, 1942, p. 59)[3];

> As used in this report the Suwannee limestone includes all limestone beds lying below definite Tampa formation and above definite Marianna limestone.

and (4), from identification of the "Suwannee Limestone" based on Oligocene fossils (Vernon, 1951, p. 175).

> As used in this report the Suwannee limestone includes all beds of Oligocene age in Citrus and Levy Counties.

Based on a survey of the literature, it is concluded that the Suwannee Limestone of previous usage has largely been a biostratigraphic "formation" that required identification of Oligocene or "Suwannee" fossils for formation recognition (compare with Mansfield, 1937, 1938; Cooke, 1945; Vernon, 1942, 1951; MacNeil, 1944c, 1946). Rarely has the Suwannee Limestone been treated primarily as a lithostratigraphic unit (compare with Cooke,

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[2]Cooke and Mansfield (1936) first described the formation, but their publication was in an abstract and contained little information. The first adequate description of the Suwannee Limestone in the type area appeared in Cooke (1945, p. 86-104). Within the period 1936-1945, however, the name Suwannee Limestone was adopted by many workers.

[3]However, "the light gray limestone underlying Holmes and Washington Counties that bears the Marianna fauna described by Cushman (1922a, 1923), and Cole and Ponton (1930) is mapped as Marianna in the report." (Vernon, 1942, p. 51) and, "As used in this report the term Tampa formation applies to all sediments lying above the Suwannee limestone and below the Alum Bluff group." (Vernon, 1942, p. 68).

1943, p. 84-86[4]; Puri and Vernon, 1964, p. 105-114, Fig. 13; Hendry and Sproul, 1966, p. 58-60; Yon and Hendry, 1972; Randazzo, 1972). Most commonly, based on my interpretation of the various texts, it appears that the Suwannee Limestone has been recognized more on the combination of fossil content and stratigraphic position than on any single criterion. The extent to which earlier authors based their recognition of the Suwannee Limestone on lithologic characteristics other than limestone is problematical because, in most texts, little weight had been given to discussion of the lithology of the formation.

The concept of the Suwannee Limestone of the present report is lithostratigraphic. Definition of the Suwannee lithostratigraphic unit is based on the lithology and stratigraphic relationships of the limestone cropping out along the Suwannee River as defined by Cooke and Mansfield (1936) and Cooke (1945). Based on my field knowledge of the limestones in the type area of the Suwannee Limestone, there is only one limestone formation that crops out along the Suwannee River from approximately 1.5 airline miles (2.4 km) northeast of Ellaville to the vicinity of White Springs. This limestone lithostratigraphic unit must serve as the central concept of the Suwannee Limestone of Cooke and Mansfield (1936) and Cooke (1945). Furthermore, the lithology of this limestone formation is broadly compatible with much of the limestone in northern Florida that has been called Suwannee Limestone on the basis of stratigraphic position and fossil content (Mansfield, 1937; MacNeil, 1944c, 1946; Cooke, 1945; Vernon, 1951; Puri and Vernon, 1964) and more recently on lithology (Hendry and Sproul, 1966; Yon, 1966, Yon and Hendry, 1972; Randazzo, 1972). Therefore, the lithostratigraphic concept of the Suwannee Limestone of this report is compatible with both the lithology of the Suwannee Limestone section cropping out along the Suwannee River in the type area of the formation, and with field identifications of the formation in northern Florida by most previous workers. In the type area of the Suwannee Limestone, and in most of northern Florida and Georgia, the Suwannee Limestone can be described as a very pale orange (10 YR 8/2), massive-bedded and structureless to rudely and thickly stratified, fine- to coarse-grained, even-textured and mealy- textured (granular), variably soft and hard limestone that generally contains no macrofossils but which is richly macrofossiliferous and bioclastic in some scattered stratigraphic intervals or lenses.

[4]Although Cooke's concept of the Suwannee Limestone was generally that of a biostratigraphic "formation", his treatment of the Suwannee Limestone in the **Geology of the Coastal Plain of Georgia** closely approximates the lithostratigraphic concept of the Suwannee Limestone of this report.

Type Section

The Suwannee Limestone was named for the Suwannee River in northern Florida. No specific type locality or type section was ever designated for the Suwannee Limestone. Rather, Cooke and Mansfield (1936, p. 71-72) only described a type area:

> ..yellowish limestone typically exposed along the Suwannee River in Florida, from Ellaville, ...almost to White Springs, ...

Later, Cooke (1943, p. 84) commented that:

> The type area is along the Suwannee River above the bridge of the Seaboard Railway at Ellaville, Fla.

However, Cooke (1945, p. 86) reverted to the original concept of the type Suwannee Limestone:

> The name 'Suwannee limestone' was proposed by Cooke and Mansfield (1936, p. 71) for yellowish limestone typically exposed along Suwannee River in Florida from Ellaville almost to White Springs.

From this, it is concluded that Cooke and Mansfield (1936) and Cooke (1943, 1945) did not intend to designate a specific type locality for the Suwannee Limestone, but only a type area. And, there has never been a formally designated type locality or type section for the formation.

The section exposed in the bluffs along the Suwannee River at Ellaville has been the most generally cited reference locality of the Suwannee Limestone (Cooke, 1945, p. 85-86; Puri and Vernon, 1964, p. 110; also see Cooke and Mossom, 1929, p. 72-73). Cooke (1945) included the lower part of this section, "beds 1 and 2", in the "Byram limestone" (Ellaville Limestone of this report) and the upper part of the section, "beds 3 and 4", in the Suwannee Limestone (Suwannacoochee Dolostone of this report). Puri and Vernon (1964), on the other hand, included the entire carbonate section exposed at Ellaville in the Suwannee Limestone.

It is my contention, however, that no Suwannee Limestone, in the strict sense of the name and the sense adhered to in this report, is exposed in the bluff at Ellaville. The Suwannacoochee Dolostone, "beds 3 and 4" of Cooke (1945), represents a distinct, mappable dolostone unit (see p. 67-70 of this report) that lithostratigraphically is not included in the Suwannee Limestone and has not been shown to be a lithofacies of the Suwannee Limestone. The Suwannacoochee Dolostone does appear, however, to grade laterally into the upper part of the Bridgeboro Limestone in Thomas and Brooks Counties, Georgia (Pls. 3 and 4). Similarly, the Ellaville Limestone that is exposed in the lower part of the bluff at Ellaville, beds 1 and 2 of Cooke (1945), has always been considered to be lithostratigraphically distinct from the Suwannee (except by Puri and Vernon, 1964).

The Suwannee Limestone is exposed less than 0.25 mile (0.4 km) downriver from the US 90 highway bridge at Ellaville and discontinuously for several miles farther downriver from Ellaville. This discontinuous occurrence results from structural undulation of the bed rock which alternately brings the top of the Ocala Limestone above river level and the Ellaville Limestone, Suwannacoochee Dolostone, and Suwannee Limestone down to river level. Upriver from Ellaville, the Suwannee Limestone again dips down to river level at approximately 1.5 airline miles (2.4 km) northeast of Ellaville, and from there to the vicinity of White Springs the Suwannee Limestone is the only formation that crops out in place along the river.

To clarify the lithostratigraphy and the formation concept of the Suwannee Limestone, it is the intent of this writer to formally propose a principal reference locality and lectostratotype of the formation. Lithologically, the most typical Suwannee Limestone exposed in the type area of Cooke and Mansfield (1936) and Cooke (1943, 1945) occurs along a short reach of the river in or adjacent to Suwannee River State Park in Hamilton and and Suwannee Counties, Florida; from approximately 1.5 airline miles (2.4 km) northeast of Ellaville in NE1/4, NW1/4, Sec. 18, T1S, R12E, upriver to S1/2, Sec. 5 and N1/2, Sec. 8, T1S, R12E. The best single outcrop along this reach of the river occurs in a sharp bend of the Suwannee River in SW1/4, SE1/4, Sec. 7, T1S, R12E where approximately 16 feet (4.9 km) of lithologically typical Suwannee Limestone is exposed. The low bluff at this bend in the river is proposed here as the principal reference locality of the Suwannee Limestone (Fig. 26) and the section exposed at the principal reference locality is here designated the lectostratotype of the formation (Fig. 30). Although it is possible to reach the lectostratotype over land, access is difficult and the nearest road is more than 0.5 mile (0.8 km) from the exposure. The lectostratotype is easily accessible by small boat, however, and there is an excellent boat ramp in Suwannee River State Park, 1.5 airline miles (2.4 km) downriver from the principal reference locality. As amended, the lectostratotype of the Suwannee limestone includes very pale orange (10 YR 8/2), massive-bedded and structureless to rudely and vaguely stratified and thick-bedded, mealy textured, soft to weakly indurated and friable, sparsely macrofossiliferous limestone that overlies the Suwannacoochee Dolostone.

The Florida Geological Survey core Bass 1 (W-10480) is here designated a reference locality and hypostratotype of the Suwannee Limestone. The core site of the Bass 1 (W-10480) is approximately 17 airline miles (27 km) northwest of the principal reference locality of the Suwannee Limestone, and is located less than 0.2 mile (0.32 km) south of the Georgia-Florida state line near the center of Sec. 206, T3N, R10E in Madison County, Florida (Fig. 2). The core site is approximately 0.5 mile (0.8 km) south of the Ga. 31 bridge crossing of the Withlacoochee River near the Georgia-Florida state line. The Suwannee Limestone occurs in the reference core from approximately 23 feet to 175 feet and is approximately 152.5 feet (46.5 m) thick. However, 16 feet (4.9 km) of Suwannee Limestone is exposed along the Withlacoochee River near the core site, indicating that the top of the Suwannee Limestone is at least as high as 90 feet above sea level in the vicinity of the core site. The elevation of the top of the Suwannee Limestone in the core Bass 1 (W-10480) is approximately 60 feet above sea level, indicating local topographic relief of at least 30 feet (9 m) on top of the formation. The Suwannee Limestone, therefore, is at least 182.5 feet (55.6 m) thick in the vicinity of the core Bass 1 (W-10480). The Bass 1 (W-10480) is stored at the Florida Geological Survey in Tallahassee, Florida.

Lithology

Typical Suwannee Limestone consists of very pale orange (10 YR 8/2), even-textured, and mealy (medium- to coarse-grained) limestone. The grains generally consist of roughly equidimensional, rounded, nondescript calcareous pellets that may be largely algal or fecal in origin (also see Randazzo, 1972), miliolid foraminifera, and fine, nondescript bioclastic debris. The grain-size of the pellets is variable, ranging from fine with much intragranular calcite "paste," to generally coarse and relatively well-sorted, with little calcite "paste." The Suwannee Limestone is soft to indurated and recrystallized, massive-bedded and structureless to rudely but distinctly bedded, and sparingly macrofossiliferous. Dolostone lenses or beds are generally rare in the Suwannee Limestone in Georgia except near its western limit (see Sever, 1966a, 1966b; Hendry and Sproul, 1966; Yon, 1966) in the vicinity of the Gulf Trough. In that area, dolomitization of the Suwannee Limestone appears to be extensive. Other than dolomite, subordinate lithic components of the Suwannee Limestone are minor and the carbonate is fairly pure (probably greater than 95%). Quartz sand or silt is not apparent in the formation and conspicuous interstitial clay is rare in the formation. On the other hand, clay is more conspicuous, but still minor, in the upper part of the Suwannee Limestone in the Brooksville, Florida area,

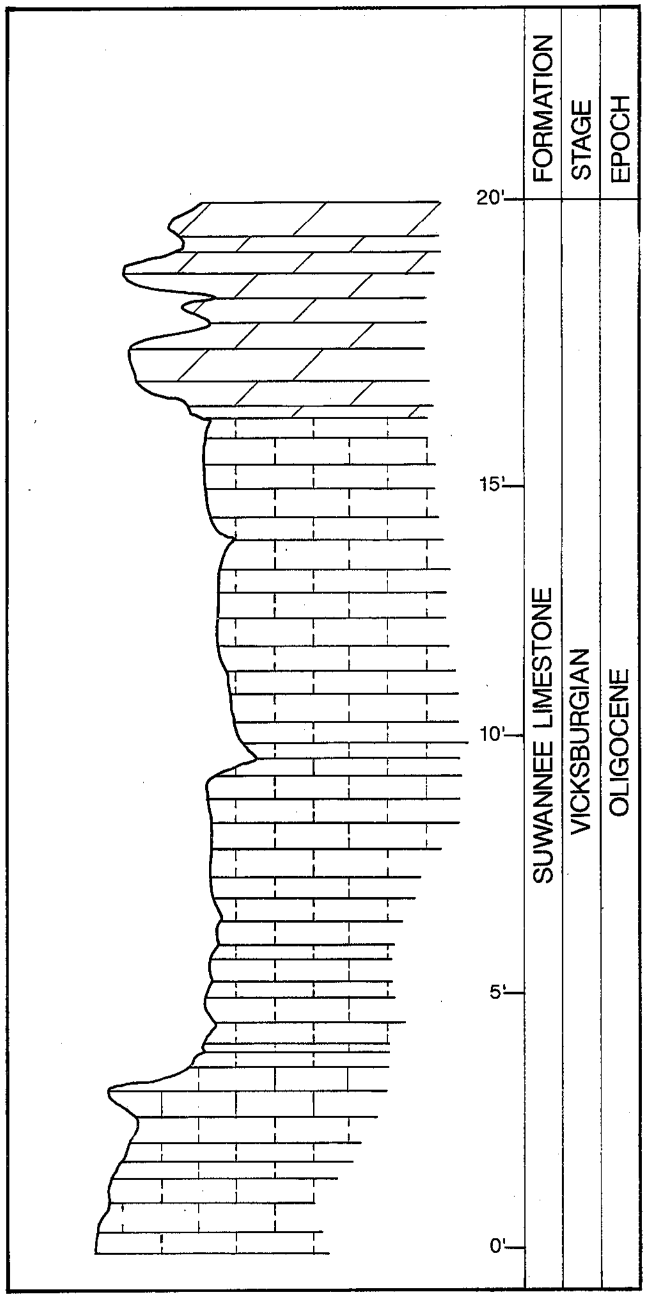

Figure 31. The measured lectostratotype of the Suwannee Limestone.

both interstitially and in irregular-shaped inclusions (also see Randazzo, 1972). Similarly, small lenses of chert occur rarely throughout the Suwannee Limestone but the occurrence of chert is commonplace only in the upper part of the formation where there are lenses of massive chert (silicified limestone) and chert concretions. In cores, small crystals of optically continuous selenite (gypsum) can be seen in places interstitial to the calcitic grains and pellets. Glauconite and phosphate are unknown in the Suwannee Limestone.

The granular quality of the Suwannee Limestone is more pronounced than in the underlying Bridgeboro Limestone, Suwannacoochee Dolostone, Ellaville Limestone, or Ocala Limestone in Georgia; or in the overlying Chattahoochee Formation. The Okapilco Limestone in the Gulf Trough is also characteristically granular in texture but it is also commonly well-washed with much less intragranular calcite. The granularity of the Suwannee Limestone commonly remains evident where the limestone has been entirely converted to chert, leaving only "ghosts" of the pellets and foraminifera within the translucent chert, or where the limestone has been completely recrystallized by calcite and is lacking in porosity.

Stratification in the Suwannee Limestone ranges from massive and devoid of sedimentary and biogenic structures, to vaguely stratified, to prominently stratified. Small-scale cross-bedding is present locally but is rare and never prominent. In all of the cores that contain Suwannee Limestone that I have examined, the formation appears to be devoid of sedimentary structures other than gradual alternation in grain-size and alternation in induration or consolidation. In outcrop along the Suwannee River in Florida and along the Withlacoochee River in Florida and Georgia, the Suwannee Limestone generally is prominently stratified, with stratification commonly being irregular, rude, and characteristically defined by alternation between hard and soft limestone (ledges and reentrants). Casual examination with a hand lens, however, indicates that the characteristic granular lithology of the Suwannee Limestone prevails throughout the sections, from hard bed to soft bed, suggesting that the prominent stratification seen in outcrop is a surficial phenomenon, perhaps related to ground-water geochemistry in the limestone exposures.

The Suwannee Limestone characteristically contains few macrofossils, and large sections (e.g., along the Suwannee River) may be entirely devoid of macrofossils or visible bioclastic debris. In other places the Suwannee may be moderately macrofossiliferous with scattered concentrations of *Rhyncholampas gouldii* or rich concentrations of molluscan molds (typically with low diversity). Although *Lepidocyclina* occurs in scattered beds in low or moderate abundance, I know of no abundant occurrences of larger foraminifera in the Suwannee Limestone in cores or outcrops.

Stratigraphic Relationships

The Suwannee Limestone underlies most of the Coastal Plain of southeastern Georgia from the Florida state line in the south to the Savannah River in the northeast, and from the vicinity of the Pelham Escarment in Crisp County, Georgia, eastward to Screven County, Georgia (Fig. 31). The Suwannee Limestone is absent in the Gulf Trough, in the coastal area of Georgia south of the vicinity of Glynn County, and it is likewise absent farther to the south in eastern Florida. Its distribution pattern in Georgia appears to be a broad, northeast-southwest band parallel to the Gulf Trough.

Typical Suwannee Limestone overlies the Bridgeboro Limestone immediately east of the Gulf Trough in southwestern Georgia and north of the Gulf Trough in the central Georgia Coastal Plain. However, the Suwannee Limestone or its stratigraphic equivalent is absent at the Bridgeboro type locality where residuum of Bucatunna Clay (?) disconformably overlies the Bridgeboro Limestone. In most of Thomas and Brooks Counties, Georgia, the Suwannee overlies the Suwannacoochee Dolostone with apparent conformity. Elsewhere in Georgia, the Suwannee Limestone discoformably overlies the Ocala Limestone.

The Parachucla Formation of the Hawthorne Group generally overlies the Suwannee Limestone disconformably in Georgia. Only in a small area east of the Chattahoochee Embayment in southwestern Georgia, however, does the Chattahoochee Formation disconformably overlie the Suwannee Limestone (Huddlestun, 1988). In its updip-most occurrences in Crisp and Screven Counties, Georgia, the Suwannee Limestone is disconformably overlain by the Lower Miocene Altamaha Formation.

The Suwannee Limestone is distinguished from the underlying carbonates in consisting of very pale orange, granular, mealy textured, generally nonmacrofossiliferous limestone. The Bridgeboro Limestone characteristically contains abundant rhodoliths and scattered concentrations of *Lepidocyclina* (larger foraminfera). The Suwannacoochee Dolostone is charaterized as being a nonfossiliferous, either tan to brown sucrosic dolostone or light-gray, thinly bedded to laminated dolostone. The Ocala Limestone is characterized as being richly bioclastic with abundant and varied larger foraminifera, and other varied biogenic debris consisting of bryozoa, rhodoliths, echinoids, corals, molds of a varied suite of mollusks, and other nondescript biogenic debris in a variably indurated, chalky matrix. The overlying Parachucla Formation is variably sandy, argillaceous, dolomitic, calcareous, phosphatic, and macrofossiliferous. The Chattahoochee Formation cosists predominantly of finely sandy dolostone with varying amounts of clay or dolomitic clay beds.

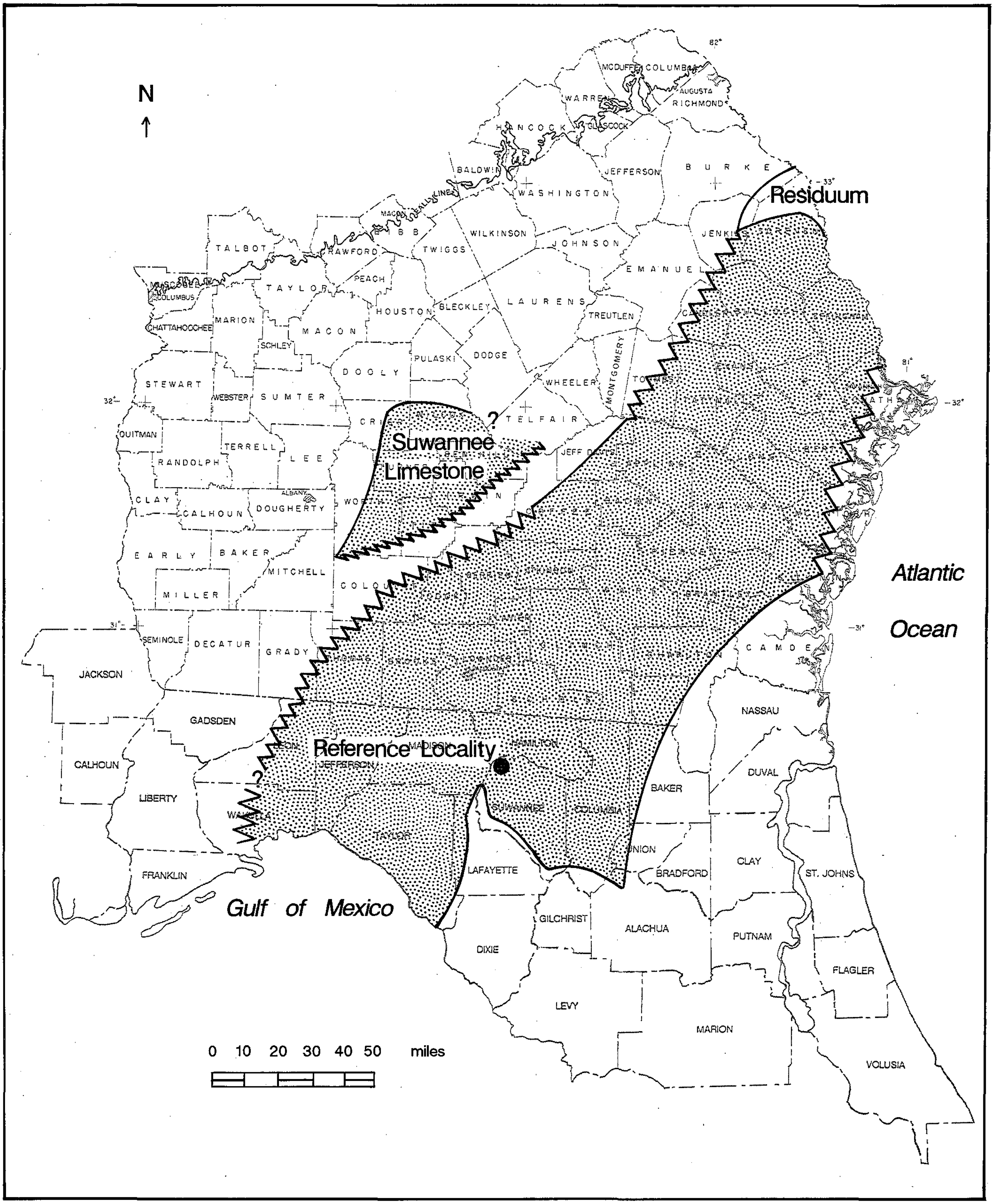

Figure 32. The areal distribution (outcrop and subcrop) of the Suwannee Limestone in Georgia and northern Florida.

In the northern coastal area of Georgia, the Suwannee Limestone grades laterally eastward into the Lazaretto Creek Formation, a variably sandy, calcarenitic limestone to calcareous sand/sandstone. Except on the flanks of the Gulf Trough, where it is thought that the Suwannee grades laterally into the upper part of the Ochlockonee Formation, the Suwannee Limestone is not known to grade laterally into any other formation in the region.

The Suwannee Limestone averages about 100 feet (30 m) thick over most of the central Coastal Plain of Georgia but appears to systematically thin northwestward and southeastward away from the Gulf Trough (Pl. 3). In the eastern part of the Coastal Plain in Georgia, it averages 50 feet (15 m) thick. Among 10 cores taken in Thomas, Brooks, and Colquitt Counties, Georgia (GGS-3213, GGS-3214, GGS-3215, GGS-3207, GGS-3211, GGS-3212, GGS-3208, GGS-3188, GGS-3189), the thickness of the Suwannee Limestone ranges between 104 feet and 152.5^+ feet (32 and 46^+ m), and averages approximately 120 feet (35 m). In the subsurface of the Savannah River area, the Suwannee Limestone ranges from 0 (locally), to approximately 50 feet (15 m) thick and averages approximately 40 feet (13 m) thick.

The Suwannee Limestone was deposited on the Florida Bank and on the continental shelf in eastern Georgia in an environment free of siliciclastic sediments. In general, it appears that the water depth in which the Suwannee Limestone was deposited was relatively shallow. The scattered presence of small-scale cross-bedding suggests periods of relatively high wave or current energy on the bank and shelf. The abundance of what appears to be small, rounded pellets (which contribute to the mealy texture of the Suwannee) and the scattered occurrence of selenite gypsum within the formation also argues for a shallow-water environment (in the photic zone if the pellets are of algal origin), probably no deeper than 50 feet (15 m) and probably considerably less.

The paleontological evidence is compatible with a shallow-water environment for the Suwannee Limstone with some evidence for the physical and chemical watermass conditions deviating from the stable, normal marine environment. The local abundance of the arenceous, carbonate banks foraminifera *Dictyoconus*, *Discorinopsis*, and *Valvulina*, three genera which do not occur with "normal" marine benthic faunas; the general abundance of miliolid foraminifera; the complete absence of planktonic foraminifera; the low diversity and high faunal dominance of the Mollusca in macrofossiliferous beds; and the scattered occurrences, and local abudance, of one species of echinoid, *Rhyncholampas gouldii* all suggest somewhat restricted marine conditions.

Age

Originally, Mansfield (1937) and Cooke (1943, 1945) paleontologically correlated the Suwannee Limestone with the Chickasawhay Formation of Mississippi and Alabama. According to Mansfield (1937, p. 50):

> A comparison of the fauna of the Suwannee Limestone with that of the Flint River formation (upper part of the Vicksburg), and other faunas similar to that of the Flint River formation, indicates that the fauna of the Suwannee Limestone as a whole lived during the latter part of the time represented by the Flint River formation and continued on up to the end of the Vicksburg epoch.[5]

and (1937, p. 62):

> Cooke correlates the Flint River formation (S.C., Ga., and Ala.) with the Chickasawhay marl member of Byram marl (Ala. and Miss.); ... The Flint River formation is correlated with the European Rupelian.

It is concluded in this report, however, that the age of the Suwannee Limestone is Early Oligocene, Vicksburgian (Rupelian)(Pl. 1). The principal macrofossils of the formation are known to occur only in the Vicksburg Group in the Vicksburgian type area in Mississippi and also in Alabama. None are presently known to

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[5]At that time, the Chickasawhay was considered to be a member of the Byram which was a formation of the Vicksburg Group. Therefore, the Chickasawhay was Vicksburgian in age by definition. The Flint River formation was believed to contain only a Chickasawhay fauna and, therefore, the Flint River was correlative with both the Chickasawhay Formation and Vicksburg Group. Subsequently Murray (1961) formally split the Chickasawhay Formation from the Vicksburg Group and assigned it spearate formation status and separate stage status (Chickasawhayan Stage). However, the surficial residuum of Georgia is now known to consist of residuum of fossiliferous chert with silicified fossils of numerous ages, from Late Eocene to Miocene. There are as yet no known fossils from the residuum and chert that contain specifically Chickasawhayan fossils.

occur in the Chickasawhay Formation.

Because the upper part of the Oligocene limestone section of peninsular Florida (post-Suwannee Limestone of Yon and Hendry, 1972) has always been referred to as Suwannee Limestone and contains a distinctive molluscan fauna, it has always been correlated with the Chickasawhay Formation (Mansfield, 1937). The lower, typical, less macrofossiliferous Suwannee Limestone (Vicksburgian) that crops out along the Suwannee River, therefore, has always been correlated with the Chickasawhay which, in the past, was also considered to be Vicksburgian.

As can be seen, there is ambiguity between the earlier stratigraphic terminology of the Oligocene and the modern terminology. If one reads the older terminology and correlations in the modern sense, they may appear to be consistent with modern usage but to do so will often lead to confusion and erroneous correlation.

The following macrofossils are present in the Suwannee Limestone in its type area:

Clypeaster rogersi (?)
Rhycholampas gouldii

Clypeaster rogersi has been reported from the Marianna Limestone, Mint Spring Formation, Glendon Limestone, and Byram Formation in Mississippi (MacNeil and Dockery, 1984, p. 19), and from the Marianna and Glendon Limestones in Alabama (Cooke, 1926). *Clypeaster rogersi* also occurs commonly in the Marianna Limestone at Hawkinsville in Pulaski County, Georgia (Pickering, 1970). *Rhyncholampas gouldii* has been reported from the Mint Spring Formation and Marianna Limestone in Mississippi (MacNeil and Dockery, 1984, p. 19), but has not been reported from Alabama. Neither *C. rogersi* nor *R. gouldii* have been reported from the Chickasawhay Formation or Paynes Hammock Sand of Mississippi and Alabama.

Chlamys anatipes has also been reported from chert derived from Suwannee Limestone in northern Screven County, Georgia (Cooke, 1943, p. 84). *Kuphus incrassatus*, believed to be the calcitic burrow-lining tube of the boring bivalve *Teredo*, commonly is found in the upper part of the Suwannee Limestone in outcrop along the Withlacoochee River in Lowndes County, Georgia, Madison and Suwannee Counties, Florida, and in cores from Brooks, Thomas, and Colquitt Counties, Georgia.

Chlamys anatipes has been reported from the Forest Hill Formation, Mint Spring Formation, Marianna Limestone, and Glendon Limestone in Mississippi (Glawe, 1974; Dockery, 1982), and from the Red Bluff Clay, Marianna Limestone, Glendon Limestone, and Byram Formation in Alabama (Cooke, 1926; Glawe, 1974, Dockery, 1982). It is also found in the Bumpnose Limestone in Florida (MacNeil, 1944c, p. 1324; Moore, 1955, p. 38, 41; Glawe, 1974) and the Marianna Limestone in Georgia (Glawe, 1974). *Chlamys anatipes* is also found in the Florala Limestone in Alabama, and in the Bridgeboro Limestone in Georgia. *Chlamys anatipes* has not yet been reported from the Chickasawhay Formation or Paynes Hammock Sand of Mississippi and Alabama.

Kuphus incrassatus has most commonly been reported from the Chickasawhay Formation of Mississippi and Alabama. *Kuphus incrassatus*, however, is also present in the Red Bluff-equivalent carbonate deposits in southwestern Alabama, and in the lower Miocene Chipola Formation of western Florida. Although the Chickasawhayan appears to represent a peak zone of *K. incrassatus*, its temporal range is more extensive than once thought and it can no longer be used for precise correlation.

On the other hand, the common occurrence of *K. incrassatus* at the top of the Suwannee Limestone section in southwestern Georgia and in the Withlacoochee River area of Georgia and Florida, may indicate that an unrecognized, overlying formation of younger Oligocene age may be present in that area. These sediments differ from typical Suwannee lithologies and reflect even shallower water conditions than that of typical Suwannee Limestone.

The few macrofossils of the Suwannee Limestone with reasonably established ranges are restricted to the Vicksburgian of the eastern Gulf Coastal Plain. It is, therefore, concluded in this report that the best estimation of the age of the Suwannee Limestone in its type area along the Suwannee River in Florida, and in Georgia, is Early Oligocene, Vicksburgian (Rupelian). Because other Vicksburgian formations underlie the Suwannee Limestone, because the Suwannee occurs at the top of the local Oligocene stratigraphic section, because the Okapilco Limestone in the Gulf Trough contains a younger, Bucatunna planktonic foraminiferal suite, and because the Suwannee grades laterally into the Lazaretto Creek Formation that contains the planktonic foraminiferal plexus of *Globorotalia increbescens-Globigerina ampliapertura* that most resembles that of the Byram Formation of Mississippi, the Suwannee Limestone is correlated in this report with the upper Vicksburgian, Byram Formation. On that basis, the Suwannee Limestone would be included in the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone of Stainforth and others (1975), and in Zone P19 of Blow (1969),(Pl. 1). For a listing of Suwannee smaller benthic foraminifera, see Horowitz (1979).

ATLANTIC CONTINENTAL SHELF STRATIGRAPHIC ASSOCIATION

LAZARETTO CREEK FORMATION (new name)

Definition

The name Lazaretto Creek Formation is proposed here for calcareous sand, sandstone and sandy limestone in the shallow subsurface of the northern coastal area of Georgia, from Glynn County in the south to Chatham County in the north. The Lazaretto Creek Formation was referred to as "undifferentiated Oligocene" in Chatham County by Furlow (1969, p. 14-15), and the name Lazaretto Creek Formation was informally applied by Huddlestun (1981) and Hetrick and others (1987).

Type Section

The name Lazaretto Creek is taken from the tidal creek, Lazaretto Creek, which separates McQueens Island from Tybee Island in the coastal area of Chatham County. The Lazaretto Creek Formation is a subsurface unit and the site of the Georgia Geologic Survey core Chatham 11 (GGS-1393) is here designated the type locality of the formation (Fig. 32). The location of the core site of Chatham 11 is approximately 1 airline mile (1.6 km) southeast of the US 80 bridge over Lazaretto Creek on Tybee Island, on the highway right-of-way of a county road 0.6 mile (1.0 km) south of the junction of the county road with US 80. The unit-stratotype (holostratotype) of the Lazaretto Creek Formation occurs in the interval 126 feet to 196 feet in the core Chatham 11 (GGS-1393) (Fig. 33). The core Chatham 11 (GGS-1393) is stored at the Georgia Geological Survey in Atlanta, Georgia.

The site of the core Petit Chou 1 (GGS-1164) is here designated a reference locality of the formation. The Petit Chou 1 was taken on the beach near the western end of Petit Chou Island (also known as Beach Hammock Island) in Chatham County (Fig. 3). The parastratotype section of the Lazaretto Creek Formation occurs in the interval 159 feet to 215 feet in the core Petit Chou 1 (GGS-1164). The core is stored at the Geology Department of the University of Georgia in Athens, Georgia.

Lithology

The lithology of the Lazaretto Creek Formation ranges from an unconsolidated, incoherent, calcareous quartz sand; to a soft, friable, very calcareous quartz sandstone; to a friable, moderately indurated to unconsolidated, sandy, fine- to medium-grained, calcarenitic limestone. Subordinate lithic components include clay minerals, phosphate in the form of small pellets or grains, and glauconite. The pelletal phosphate is the most conspicuous subordinate component of the lithology but is known to occur in only local and minor concentrations. Phosphate is most conspicuous in the more sandy phases of the formation. Both glauconite and clay are very inconspicuous in the Lazaretto Creek Formation and the clay is known to occur only interstitially and in low concentrations. The clay minerals that have been reported include smectite and kaolinite (Hetrick and others, 1987).

Macrofossils are rare and are known to consist only of mollusks. Where present, the macrofossils occur in concentrations of molds and casts in the sandstone or limestone.

In cores, the sediment has the appearance of being massive-bedded with no distinct primary sedimentary or biogenic structures. Stratification, where evident, is rude and ill-defined.

Stratigraphic Relationships

The Lazaretto Creek Formation is known to occur only in the northern coastal area of Georgia (Fig. 34). It grades laterally westward into the Suwannee Limestone but it pinches out southward and northward. There are no Oligocene deposits in the southern coastal area of Georgia and eastern Florida, nor in the lower Port Royal Sound area of South Carolina. It is not known whether the Lazaretto Creek Formation grades laterally eastward under the continental shelf into the Cooper Formation or if it pinches out under the inner continental shelf. Because the Lazaretto Creek Formation either grades laterally into relatively pure limestones or pinches out, and it overlies relatively pure carbonates (Ocala Limestone), the source of quartz sand for the formation is problematical. It must, however, have been derived from the north, possibly via southward flowing continental shelf currents flowing along the trend of the Beaufort Arch. There are no other Lower Tertiary quartz sand sources for the Lazaretto Creek Formation to the east, south, or west.

The Lazaretto Creek Formation generally overlies the Ocala Limestone disconformably. Where the Lazaretto Creek grades laterally into the Suwannee Limestone, it also locally overlies the Suwannee conformably and gradationally (Pl. 4). No lithologies are known that are transitional from Suwannee to Lazaretto Creek. The Lazaretto Creek is disconformably overlain by the Parachucla Formation.

The Lazaretto Creek Formation is distinguished from the Ocala Limestone, Suwannee Limestone and Cooper Formation in being consistently sandy and locally phosphatic. The Parachucla Formation differs from the Lazaretto Creek in being lithologically more variable, in being more argillaceous, and in consistently being more phosphatic. Over short intervals of core, however, the lithology of the Lazaretto Creek closely resembles the lithology of the Parachucla, and distinguishing the two formations may be difficult. However, there is generally a prominent disconformity between the two formations in which the uppermost Vicksburgian and Chickasawhayan are missing.

In Chatham County, the Lazaretto Creek Formtion ranges from 56 feet (17 m) thick in the Petit Chou 1 (GGS-1164) to 70 feet (21 m) thick in the Chatham

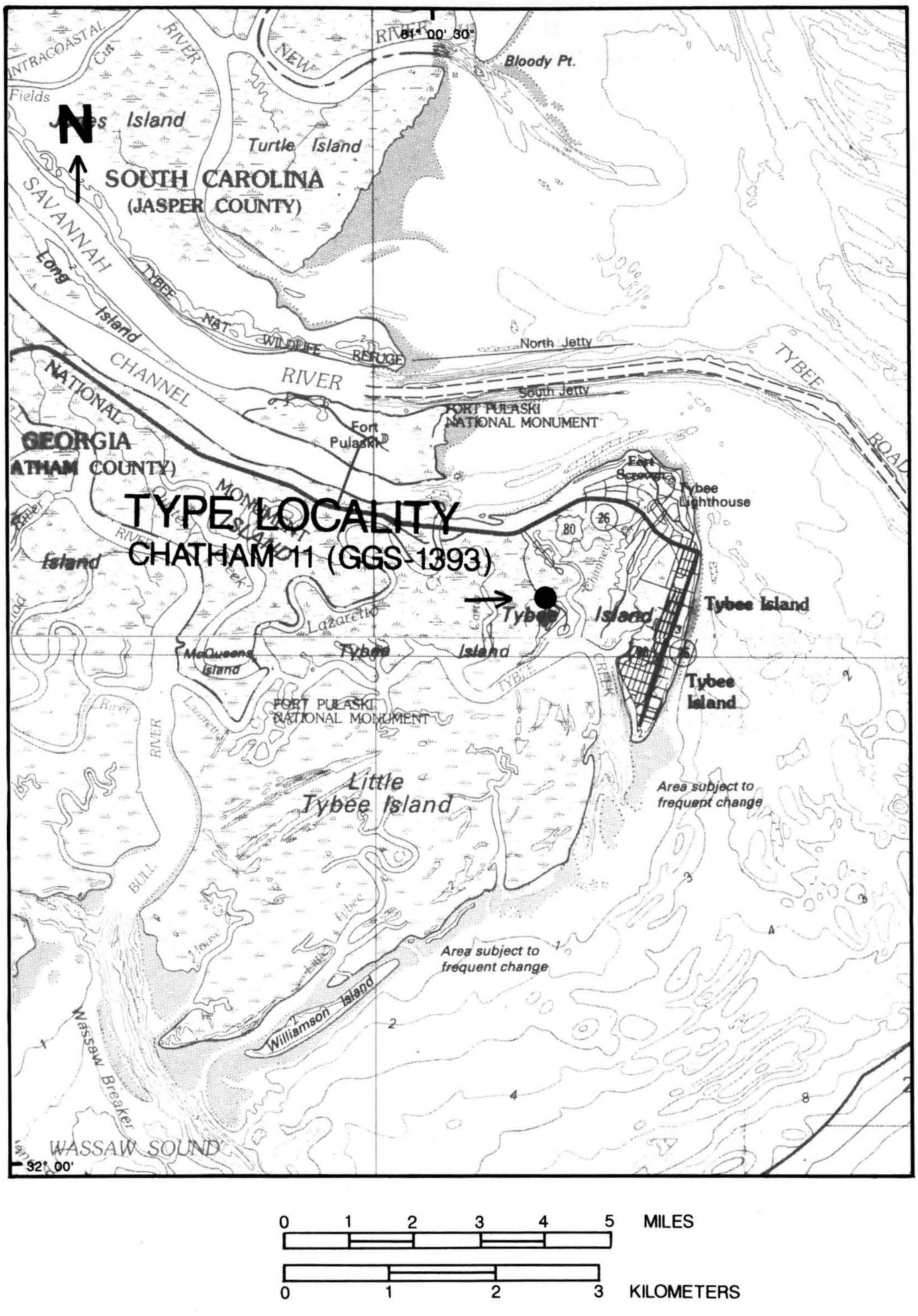

Figure 33. The type locality of the Lazaretto Creek Formation (U.S. Geological Survey, Beaufort, South Carolina-Georgia, 30 X 60 minute series, and Wassaw Sound, Georgia, 30 X 60 minute series [topographic-bathymetric quadrangles]).

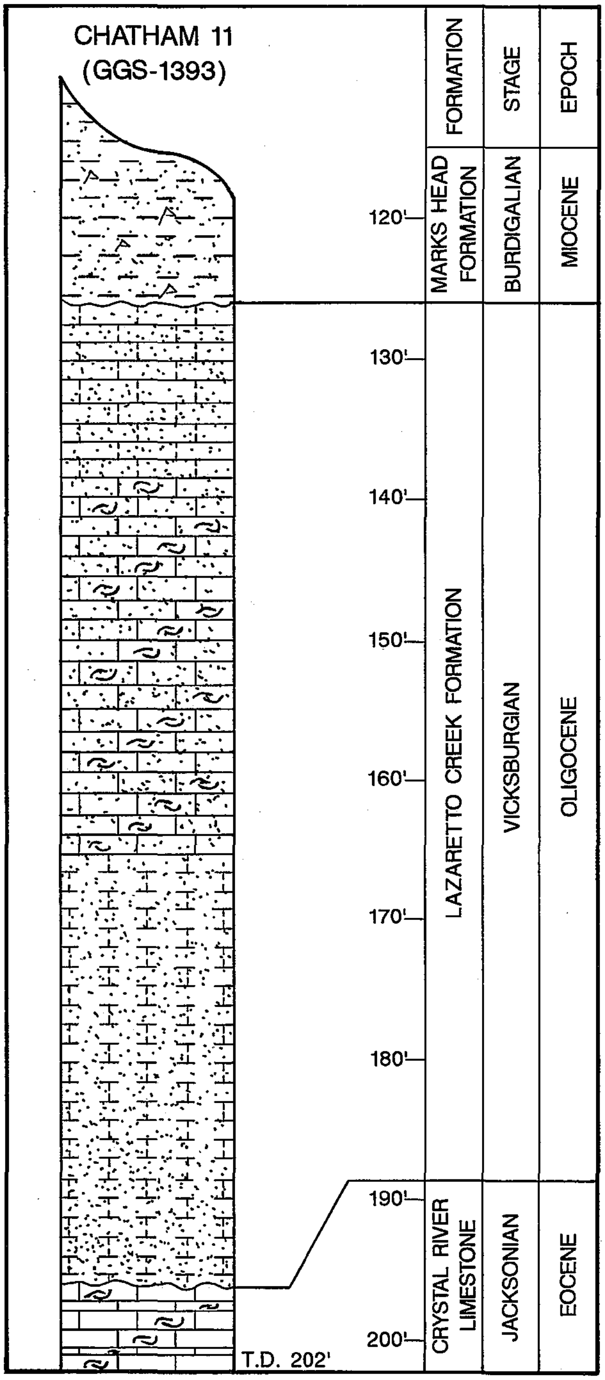

Figure 34. The measured holostratotype of the Lazaretto Creek Formation.

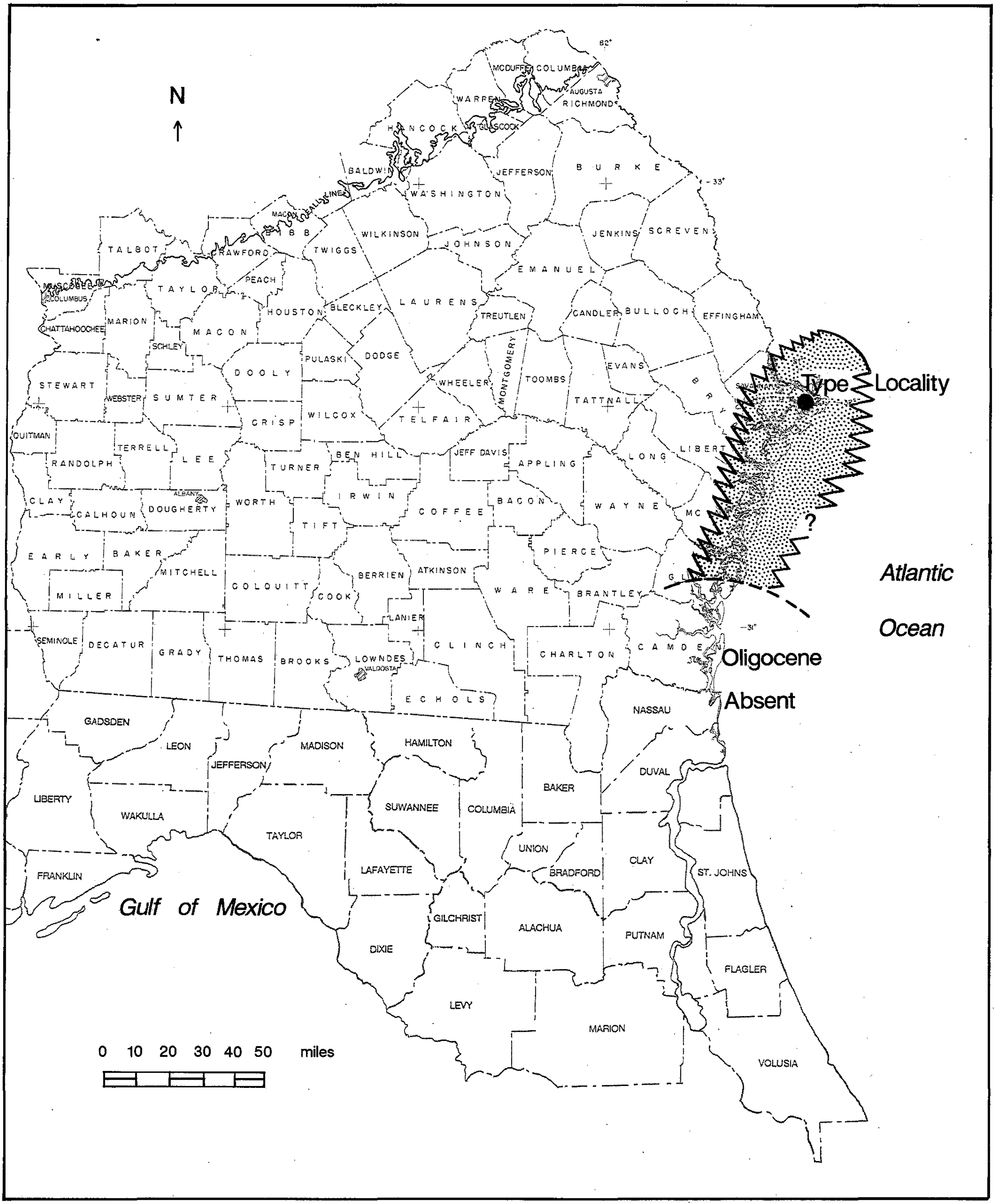

Figure 35. The areal distribution (subcrop) of the Lazaretto Creek Formation in Georgia.

11 (GGS-1393). It averages approximately 60 feet (18 m) in thickness in Chatham County. The thickness distribution of the Lazaretto Creek Formation in the coastal area south of Chatham County is unknown due to lack of core control. It is present in the U.S. Geological Survey test well 5 (GGS-1063) from Brunswick in Glynn County but its occurrence is not apparent from well log descriptions of Herrick (1961) in coastal Bryan, Liberty, McIntosh, and Chatham Counties.

The Lazaretto Creek Formation was deposited in relatively shallow water on the continental shelf. The foraminiferal assemblage of the Lazaretto Creek is suggestive of inner neritic conditions under approximately normal marine salinities. In general, the benthic foraminiferal fauna of the Lazaretto Creek is less diverse and shows higher species dominance than does the Suwannee foraminiferal fauna (for a listing of Suwannee foraminifera, see Horowitz, 1979). This suggests that the Lazaretto Creek Formation may have been deposited in shallower water than that of the Suwannee Limestone.

Age

The Lazaretto Creek Formation is interpreted to be late Vicksburgian, Rupelian, Early Oligocene in age. The Lazaretto Creek Formation contains a meager planktonic foraminiferal suite that consists of the following:

Globorotalia increbescens
Globigerina ampliapertura.
Globigerina eocaena

The occurrence of *G. increbescens* in the Lazaretto Creek indicates the formation is within the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone of Stainforth and others (1975). In addition, the presence of well developed and moderately common *G. ampliapertura* relative to *G. increbescens* is characteristic especially of the upper Vicksburgian Byram Formation in Mississippi. Therefore, because *G. increbescens* and *G. ampliapertura* are not present in the Bucatunna Clay or the Okapilco Limestone, both of which are of Vicksburgian age, the Lazaretto Creek Formation is correlated with the Byram Formation (Pl. 1). The presence of the above three species in the Lazaretto Creek formation could be construed to indicate a latest Eocene age for the Lazaretto Creek. However, the presence of the benthic foraminiferal species *Pararotalia byramensis* and *P. mexicana* requires an Oligocene age for the formation).

COOPER FORMATION

Definition

The Cooper Formation, part of which is Oligocene in age, is restricted to the continental shelf in the Georgia area, and consists of massive and structureless, generally unconsolidated, 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 by Tuomey (1848). Sloan (1908, p. 462-464) referred to the Cooper variably as "Ashley-Cooper marls," "Cooper River marl," "Cooper marl,", and "Ashley marl," and to the marl cropping out along the Ashley River as Ashley Marl. He believed the Ashley and Cooper marls to be lithologically similar enough to be combined under the name Ashley-Cooper marl. Sloan noted, however, that the "Ashley marl" tended to be more phosphatic than the "Cooper marl." In addition, (Sloan, 1908, p. 463) suggested that the marl along the Cooper River is of Eocene age whereas he suspected that the marl along the Ashley River might possibly be 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.

In the Georgia area, the Cooper Formation is present only under the continental shelf and ranges in age from Late Eocene (late Jacksonian) to Early Miocene (Aquitanian). The Miocene component of the Cooper Formation beneath the continental shelf of Georgia was described previously by Huddlestun (1988) and the description of the Cooper Formation in this report will be restricted to the Oligocene portion of the formation. In contrast to the Oligocene sections onshore in Georgia, both Lower and Upper Oligocene (Vicksburgian and Chickasawhayan) components of the Series are present in the TACTS cores and in the USGS core AMCOR 6002. In these cores, the lithologies of the Early Oligocene, Vicksburgian; Late Oligocene, Chickasawhayan; and the Miocene parts of the Cooper Formation differ somewhat as will be described below.

Type Section

The name Cooper is derived from the Cooper River north of Charleston in South Carolina. No specific type locality was ever designated for the Cooper Formation along the Cooper river, 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., 1991) and Ward and Blackwelder (1979, p. 14), the Cooper Formation along the Cooper River is poorly exposed and the sediments are poorly preserved. Ward and Blackwelder (1979, p. 14) proposed that the section of Cooper Formation exposed in the quarry of the Giant Portland Cement Company near Holly Hill, Dorchester County, South Carolina, be the lectostratotype of the formation and they changed the sense of the formation from Cooper Marl to Cooper Formation. In addition, they (1979, p. 14) designated the exposures of the Cooper Formation in the bluff at Givhans Ferry State Park on the left bank of the Edisto River in Dorchester County as a reference section (hypostratotype).

For reference purposes, the Oligocene component of the Cooper Formation under the continental shelf of Georgia occurs in the interval from approximately 289 feet to approximately 508 feet in the core AMCOR 6002 (Hathaway and others, 1976, p. 29-38)(Fig. 2).

Lithology

In the Georgia area, the Cooper Formation is known to occur only under the outer continental shelf in the TACTS cores and in the USGS core AMCOR 6002. The following lithologic descriptions are only for the Oligocene part of the formation in these cores. With the small amount of data available from these cores, the Oligocene Cooper Formation on the outer shelf of Georgia can tentatively be subdivided into three parts, based on a progressive subtle change in lithology through the Oligocene. These stratigraphic intervals include a lower Vicksburgian component, a locally occurring uppermost Vicksburgian component, and a Chickasawhayan component. Generally the Oligocene Cooper Formation consists of olive-gray, massive, structureless, even-textured, finely to very finely granular, finely macrofossiliferous (macrofossil debris), microfossiliferous, unconsolidated and soft to slightly recrystallized and crumbly, variably argillaceous limestone or "marl". Calcite or limestone is the predominant lithic component of the formation whereas clay minerals are variably minor to trace components of the lithology. The clay mineral suite of the Oligocene part of the Cooper Formation in the AMCOR 6002 is dominated by smectite with subordinate illite and kaolinite (J.H. Hetrick, pers. com., 1985). Other minor to trace components of the Cooper Formation include phosphate, glauconite, and silt or fine-grained quartz sand. Pyrite, heavy minerals, mica, and gypsum occur as trace components in some samples.

The lower, Vicksburgian component of the Cooper (*Cassigerinella chipolensis-Pseudohastigerina micra* Zone) is slightly phosphatic and glauconitic. It is largely a foraminiferal coquina to foraminiferal coquinoid "marl" but other bioclastic components are conspicuous. These consist of fine bioclastic debris that includes echinoid fragments, ostracodes, mollusk shell fragments, bryozoa, and barnacles.

Phosphate is present in most samples and occurs in the forms of vertebrate bone debris, shiny ovoid pellets, and more irregular, rough-surfaced, subrounded to rounded pellets that range in color from amber to tan through brown to black. All pelletal phosphate ranges from less than 1 mm to very fine sand size. Glauconite and pyrite more commonly occur as trace components but are not apparent in all samples.

Quartz sand is also present in most samples and, in one sample from the core nearest to the coast (A-237), constitutes somewhat less than one half of the bulk sample. The sand in A-237, however, is poorly sorted, well-rounded to subangular, and medium- to coarse-grained. In other samples, quartz sand occurs as fine- to very fine grained sand in minor to trace amounts.

The upper-most Vicksburgian, Bucatunna-Okapilco-equivalent (probable *Globigerina ampliapertura* Zone) was detected in two samples, F-329 and C-253. Although two samples (or even two sections) are inadequate to define any stratigraphic patterns, the lithologies of both of the samples differ significantly from that of the older Vicksburgian and these differences may reflect the evolving depositional environment of the outer shelf. In sample F-329, the sediment consists of an argillaceous, phosphatic limestone or "marl" with gypsum bloom and scattered fine to very fine quartz sand. The sediment is exceptionally phosphatic and the washed residue may be described as phosphatic, foraminiferal coquina. The phosphate consists of both pellets and vertebrate debris. In C-253, on the other hand, the sediment is not exceptionally phosphatic but the lithology is conspicuously dominated by foraminifera as in the Upper Oligocene.

The Upper Oligocene, Chickasawhayan is represented by five samples and represents a continuation of the evolving lithologies of the Cooper Formation. Of the five samples, however, three (C-223.5, C-204, and AMCOR 6002 sample 11.2) are represented by typical Cooper "marl" whereas sample B-300 is a clay and Sample D-322.5 is a medium to coarse sand.

Sample B-300 consists of a light olive gray (5Y5/2), massive and structureless, silty, calcareous, phosphatic, foraminiferal clay. The washed residue consists of a foraminiferal, phosphatic, fine- to very fine grained quartz sand. The phosphatic component is common and consists of vertebrate skeletal debris and pelletal phosphate that is subrounded to subangular, and amber to dark brown in color.

Sample D-322.5 consists of light olive gray (5Y5/2), massive and structureless, calcareous, phosphatic, clayey sand with phosphate pebbles. The washed residue consists of calcareous, phosphatic sand. The sand component is poorly sorted, very coarse (well-rounded) to very fine (angular); the largest sand grain size is roughly 1 mm. In the coarser fractions, the phosphate component consists of poorly sorted phosphate pellets and pebbles up to 1 cm in greatest dimension. The finer fraction consists of vertebrate skeletal debris, tan to brown to black pellets, and some shiny ovoidal pellets. The calcareous fraction consists mostly of foraminifera and nondescript calcitic particles. Foraminifera and echinoid spines are rare in the coarser fraction but are more common in the finer fractions. Glauconite, pelletal phosphate, and heavy minerals also are more common in the finer fractions.

With five samples, it is difficult to generalize on the lithostratigraphy of the Upper Oligocene component of the Cooper Formation in the TACTS area. However, three samples are compatible with the Cooper Formation whereas the other two samples are siliciclastic and phosphatic variants of the Cooper. In general, the Upper Oligocene is generally more siliciclastic-rich, phosphatic, and the foraminiferal sediment is coarser textured than the underlying Vicksburgian.

The difference between the foraminiferal coquina of the lower Vicksburgian Cooper compared with that of the upper Vicksburgian Cooper and the Chickasawhayan Cooper is that there is declining micrite and fine, broken macrofossil debris upward through the section. This trend culminated in the Upper Oligocene and Miocene. As a result, the Upper Oligocene Cooper is more coarsely granular in texture and conspicuously foraminiferal whereas the Vicksburgian Cooper is finer grained and tends to be more chalky when dry.

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 in South Carolina (Fig. 35, Pls. 4 and 5). The stratigraphic relationships of the Oligocene component of the Cooper Formation with the Georgia onshore Oligocene section are uncertain however. Because there are no Oligocene deposits present in the coastal area of Georgia south of the vicinity of Brunswick in Glynn County, I must conclude that both the Lower and Upper Oligocene parts of the Cooper Formation thin westward and pinch out under the inner continental shelf in that area (Pl. 5). In the northern coastal area of Georgia, north of the vicinity of Brunswick, the Upper Oligocene, Chickasawhayan component of the Cooper Formation likewise thins and pinches out under the inner continental shelf (Pl. 3). The Lower Oligocene, Vicksburgian component, on the other hand, appears to grade laterally westward into the Lazaretto Creek Formation under the inner continental shelf (Pl. 4). The southern limit of the Cooper Formation on the continental shelf is unknown at this time.

The Cooper Formation is distinguished from other limestone formations in eastern Georgia in consisting of light olive gray, finely equigranular, microfossiliferous, phosphatic, argillaceous limestone ("marl") whereas the other limestone formations in the area are non-argillaceous and more coarsely granular to bioclastic in texture. The Lazaretto Creek Formation is also sandy and locally phosphatic, and the Miocene Parachucla Formation in the coastal area is sandy, argillaceous, phosphatic, variably macrofossiliferous, and locally dolomitic. Under the outer continental shelf, the lower Aquitanian (lower Parachucla equivalent) component of the Cooper Formation is consistently more siliciclastic-rich and more phosphatic.

The thickness distribution of the Oligocene component of the Cooper Formation under the continental shelf is variable. It is approximately 186 feet (57 m) thick in AMCOR 6002, is at least 145 feet thick in TACTS core C, but is only approximately 30 feet thick in TACTS core A). The environment of deposition of the Oligocene component of the Cooper Formation is marine, outer neritic, continental shelf.

Age

All of the ages of the Oligocene deposits that have been identified at onshore sites in the southeastern United States, have also been identified in the Oligocene component of the offshore Cooper Formation. The oldest Oligocene interval is the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone of Stainforth and others (1975) or Zones P18 to P19 of Blow (1969). This planktonic foraminiferal zone has been identified in the interval 327 feet to 508 feet in the AMCOR 6002, 220 feet to 250 feet in TACTS core A, and 261 feet to T.D. at 336 feet in TACTS core C. The age assignment is based on the identifications of the following planktonic foraminifera:

Globorotalia increbescens
Globigerina ampliapertura
G. eocaena
G. angiporoides
G. officinalis
G. praebulloides
G. cf. *ciperoensis*
Globorotaloides suteri
Pseudohastigerina barbadoensis
Cassigerinella chipolensis
Chiloguembelina cubensis

This zone is present throughout most of the onshore Vicksburgian and includes the Bumpnose Limestone-Red Bluff Clay stratigraphic interval through the Suwannee-Byram stratigraphic interval (Pl. 1). The age of this portion of the Cooper Formation is, therefore, considered to be Early Oligocene, Vicksburgian (Rupelian).

The latest Vicksburgian, Bucatunna-equivalent has been identified in the interval of approximately 235 feet to 265 feet in the TACTS core C and approximately 325 feet to T. D. at 336 feet in TACTS core F. This correlation is based on the identifications of the following

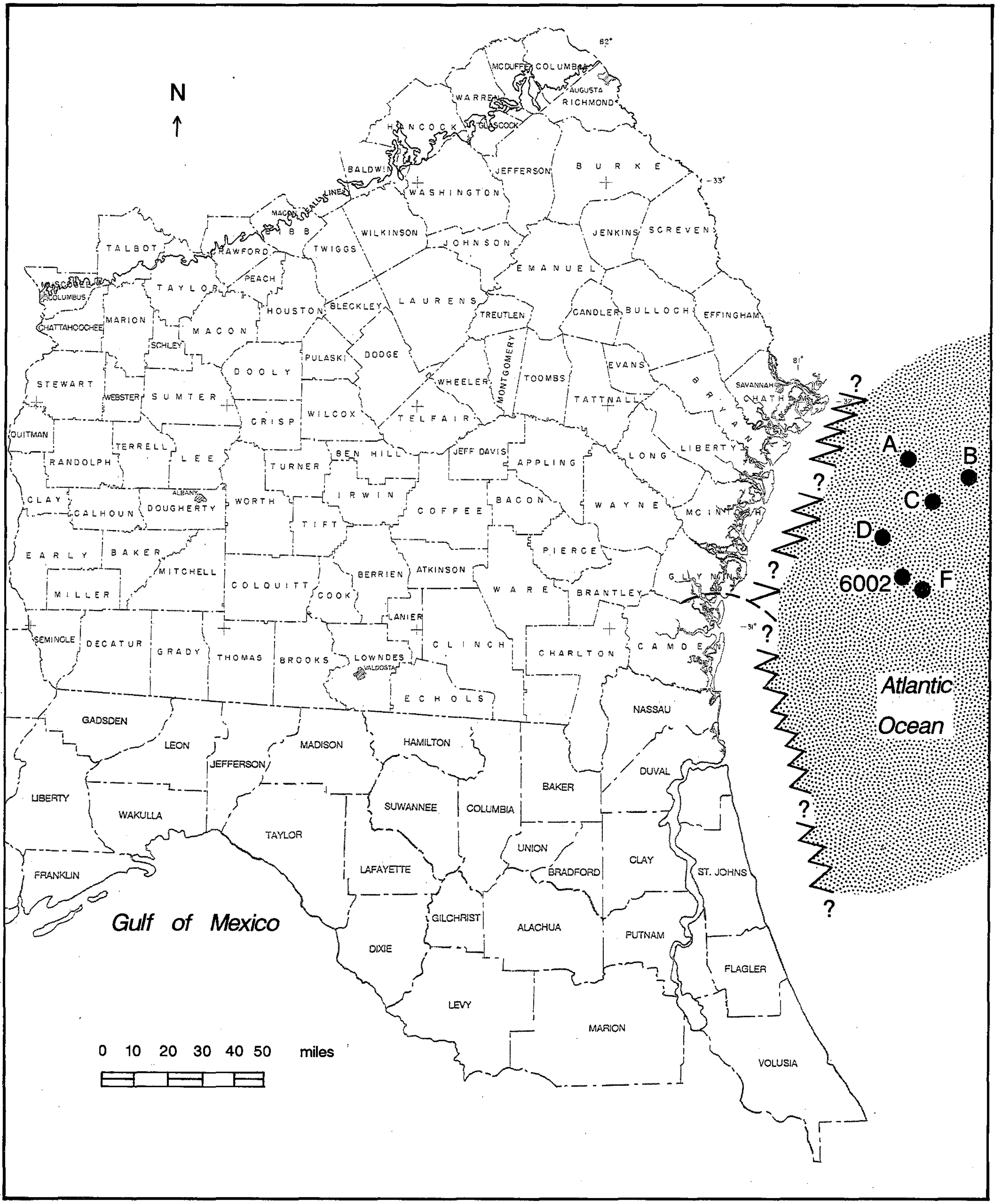

Figure 36. The areal distribution (subcrop) of the Cooper Formation beneath the continental shelf of Georgia.

planktonic foraminifera:

Globigerina eocaena
G. officinalis
G. praebulloides
G. anguliofficinalis
G. cf. *ciperoensis*
Chiloguembelina cubensis

The above correlation is based on the absence of *Globorotalia increbescens* and *Pseudohastigerina* spp. which became extinct near or at the top of the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone, and the absence of *Globigerina angulisuturalis* which evolved within the lower part of the *Globorotalia opima opima* Zone (Pl. 1). As a result, this stratigraphic interval is tentatively assigned to the *Globigerina ampliapertura* Zone of Bolli (1957), Stainforth and others (1975), and Zone P20 of Blow (1969).

The Upper Oligocene, Chickasawhayan interval has been identified in the interval 289 feet to 327 feet in the AMCOR 6002 (sample 11-2, 90-100 cm), approximately in the interval 295 feet to T.D. at 300 feet in the TACTS core B, approximately 193 feet to 235 feet in TACTS core C, approximately 310 feet to T.D. at 323 feet in TACTS core D, and approximately 319 feet to T.D. at 330 feet in TACTS core F. This age assignment is based on the following planktonic foraminifera:

Globigerina angulisuturalis
G. eocaena
G. praebulloides
G. ciperoensis
Cassigerinella chipolensis
Chiloguembelina cubensis

The above planktonic foraminiferal assemblage is consistent with Zones P21 or P22 of Blow (1969) and with the *Globorotalia opima opima* zone or *Globigerina ciperoensis* Zone of Bolli (1957) and Stainforth and others (1975). The assemblage of planktonic foraminifera is similar to that of the Chickasawhay and Paynes Hammock Formations of Alabama and Mississippi (Poag, 1966; 1972). As a result, this portion of the Cooper Formation is correlated with the Chicksawhay and Paynes Hammock Formations (Pl. 1).

STRATIGRAPHIC ASSOCIATION OF UNCERTAIN AFFINITIES

UNDIFFERENTIATED CALCAREOUS SAND AND SANDY LIMESTONE

Definition

This undifferentiated Oligocene unit is a subsurface formation that consists variably of sporadically phosphatic and cherty calcareous sand, sandy limestone, limestone, and "marl". It is restricted in occurrence to the northeastern part of the Gulf Trough area. (Fig. 36). The unit is poorly defined because 1) it is not known to crop out, 2) there are no cores from its area of occurrence, and 3) its lithology can be approximated at this time only through descriptions of well-cuttings (Herrick, 1961; McFadden and others, 1986). However, well-cuttings of Oligocene sediments from most sites in updip eastern Georgia, centered in the central Ohoopee River area, are consistently reported to be sandy and variably "marly", cherty and phosphatic. As a result, these Oligocene sediments can not be included in other named Oligocene limestone formations of Georgia and must, therefore, be described separately. The undifferentiated sand and sandy limestone does resemble the Lazaretto Creek Formation of the coastal area. However, Lazaretto Creek lithology is not apparent in the well logs of Herrick (1961). In addition, there is no consistent occurrence of phosphatic, sandy Oligocene sediments between the upper Gulf Trough area in Montgomery and Toombs Counties, Georgia, and the coastal subcrop area of the Lazaretto Creek in Georgia. Finally, it is not clear whether this undifferentiated calcareous sand consists of one formation or more than one formation.

Lithology

Based on well-cuttings descriptions, the lithology of the undifferentiated calcareous sand and sandy limestone consists variably of calcareous sand and sandy limestone with lesser amounts of relatively pure limestone, "marl", and calcareous clay. The quartz sand ranges from fine-grained to very coarse grained, and the sorting ranges from well-sorted to poorly sorted. Minor lithic components include phosphate, chert, glauconite, and rare claystone and mica. The deposits are generally but variably macro- and microfossiliferous.

Stratigraphic Relationships

The undifferentiated calcareous sand and sandy limestone is known to occur only in eastern Georgia in the northeastern part of the Gulf Trough and northwest of the trough (Fig. 36). Its known occurrence centers in Treutlen and Emanuel Counties but it is also found in Laurens, Wheeler, Montgomery, and Toombs Counties. There are scattered occurrences of the unit in northwestern Tattnall and western Candler Counties, and lithologically similar well-cuttings have been reported from Oligocene sediments at scattered sites from northern Bulloch County (McFadden and others, 1986).

The calcareous sand and sandy limestone unit appears to grade laterally southward and eastward into the Suwannee Limestone in the vicinity of the Gulf Trough.

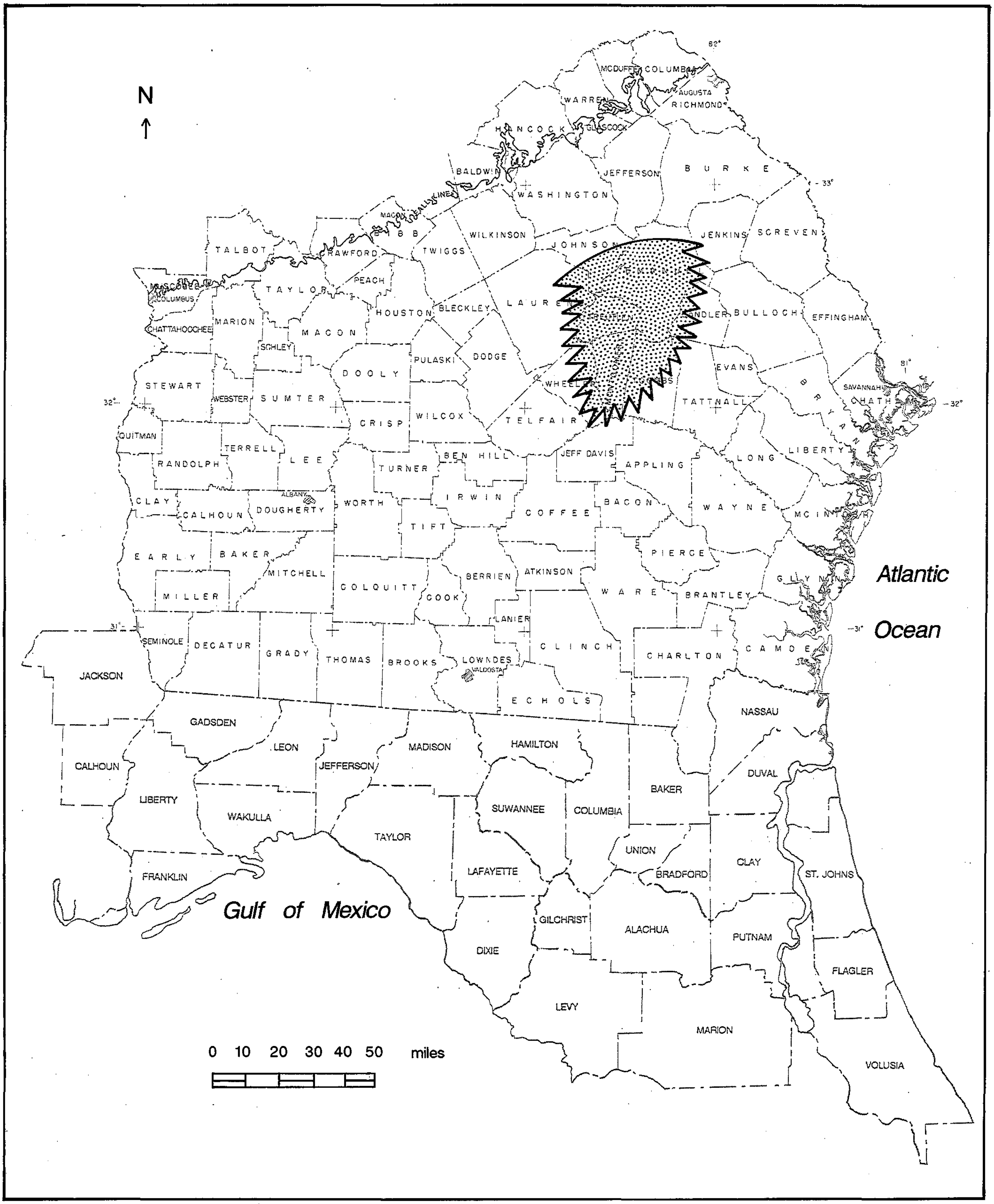

Figure 37. The areal distribution (subcrop) of the undifferentiated calcareous sand and sandy limestone.

The unit into which the calcareous sand and sandy limestone grades into southwestward in the Gulf Trough is not clear at this time. If the calcareous sand and sandy limestone unit grades laterally into the Suwannee Limestone, then it is seems likely that within the Gulf Trough, the unit would grade laterally into the upper part of the Pridgen Limestone Member of the Ochlockonee Formation. Because the calcareous sand and sandy limestone is unusually thick in the eastern end of the trough, it is also possible that the upper part of the deposit may grade laterally southwestward in the Gulf Trough into the Okapilco Limestone.

The thickness of this sandy unit, based on published thickness data of Herrick (1961), Herrick and Vorhis (1963), and McFadden and others (1986), ranges from approximately 30 feet (9.1 m) to 240 feet (73.2 m).

The environment of deposition of the undifferentiated calcareous and sandy limestone is marine, inner continental shelf. Considering the paucity of siliciclastics in Oligocene deposits in Georgia, Florida and South Carolina, the unusually large amount of siliciclastic material in this undifferentiated unit suggests a nearby river source.

Age

The undifferentiated calcareous sand and sandy limestone is assigned an Early Oligocene, Vicksburgian (Rupelian) age because its known microfauna consists of characteristically Oligocene species, and it grades laterally into the Suwannee Limestone which is considered to be Early Oligocene, late Vicksburgian in age. The undifferentiated calcareous sand and sandy limestone contains the following benthic foraminifera, which are compatible with a Vicksburgian age:

Pararotalia mexicana
P. byramensis
Asterigerina subacuta
Dictyoconus sp.
Baggina xenoula

Because this undifferentiated sandy unit is unusually thick in the Gulf Trough, it is possible that the unit is correlative with both the Ochlockonee Formation and Okapilco Limestone within the Gulf Trough.

DISCUSSION

PRIMARY STRUCTURAL ELEMENTS

Florida Platform

The Florida Platform[6] (Owens, 1960; Chen, 1965; Huddlestun 1988) (Florida Plateau of Vaughan, 1910; Cooke, 1945) (Fig. 38) is that segment of the Coastal Plain that consists of peninsular Florida and its continental shelves. Basement of the Florida Platform consists of Paleozoic sedimentary rocks called the Suwannee terrane (Dallmeyer, 1987), and plutonic igneous and metamorphic rocks that variously have been called African craton (Chowns and Williams, 1983), and African basement (Nelson and others, 1985a, 1985b). For simplicity in this report, the basement of the Florida Platform will be called African basement (Andress and others, 1969; Goldstein and others, 1969; Cook and others, 1979; Williams and Hatcher, 1982; Smith, 1982, 1983; Mueller and Porch, 1983; Chowns and Williams, 1983; Nelson and others, 1985a, 1985b; Dallmeyer, 1987).

A thick Coastal Plain sequence of flat lying to gently dipping, shallow-water, carbonate bank and assciated deposits of Late Jurassic? through Early Tetiary age overlies the African basement in peninsular Florida. The northern boundary of the Florida Platform is the Georgia Channel System, north of which these shallow-water, carbonate bank sediments were not dposited. African basement in this region is not restricted to the Florida Platform. The Florida panhandle and southern Alabama west and north of the Georgia Channel System, and much of the Georgia Channel System also are underlain by African Basement (Suwannee basin of Arden, 1974).

South Georgia Rift

Overlying the African basement in western Florida and Georgia is a thick sequence of Triassic-Jurasic(?) red beds of fluvial, probably braided stream origin (Chowns and Williams, 1983) that has been asigned to undifferentiated Newark Group (Huddlestun and others, 1988). These red beds were deposited in a large Triassic graben called the South Georgia rift by Daniel and others, 1983 (also see Chowns and Williams, 1983; Popenoe and Zietz, 1977; Popenoe, 1987; Gohn and others, 1978; Chowns, 1979)(Fig. 39).

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[6]The Florida Platform probably should be considered as continuous with the Bahamas Platform as described by Owens (1960). Sheridan and others (1981) indicate that the deeper Mesozoic strata are continuous from Florida to the Bahamas Platfrom: but the Florida-Bahamas Platform is bisected by the Northern Strait of Florida, a sedimentary constructional feature closely related in origin to the Georgia Channel System.

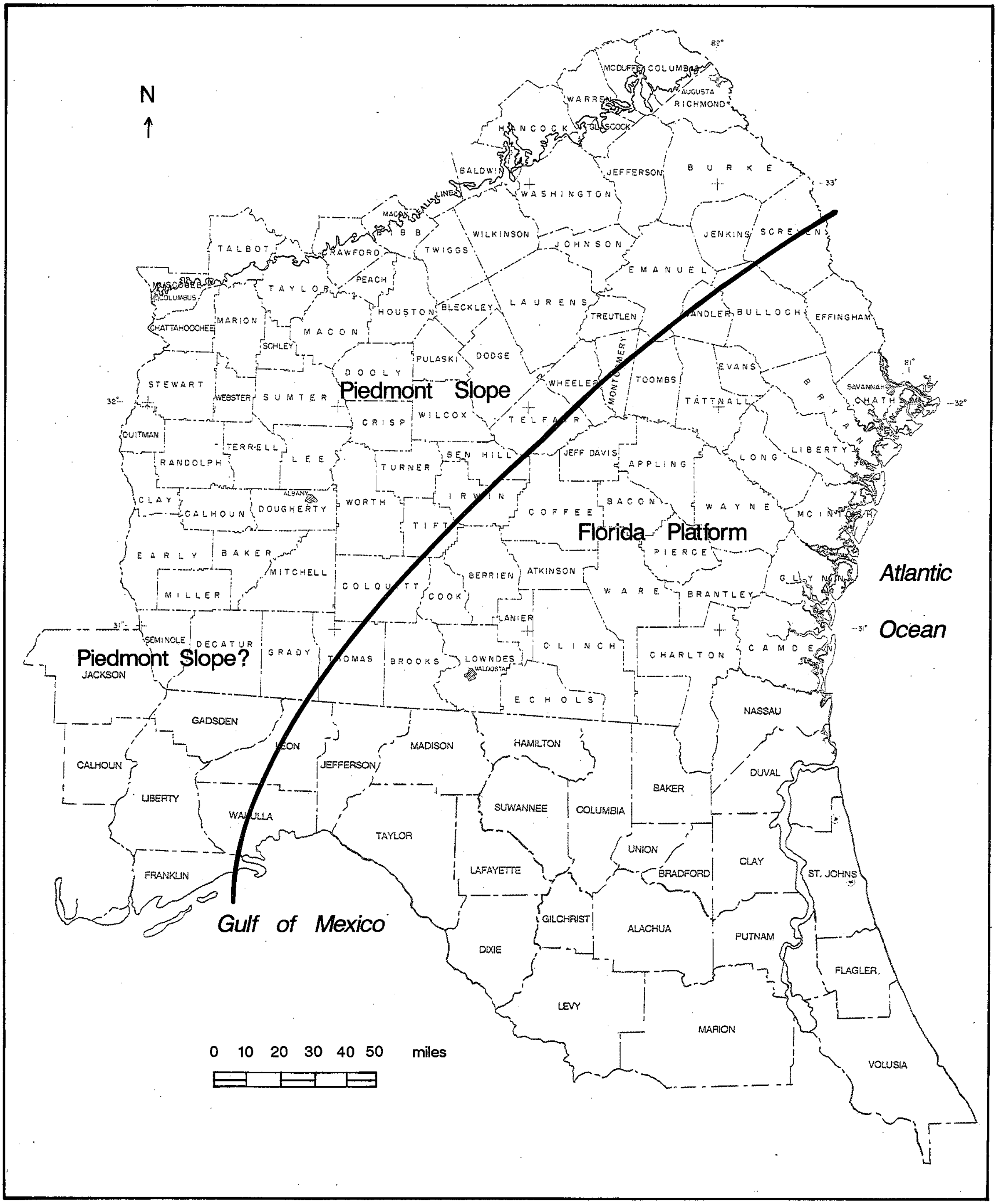

Figure 38. Proposed shallow structural elements controlled by basement structure in the Coastal Plain of Georgia and northern Florida.

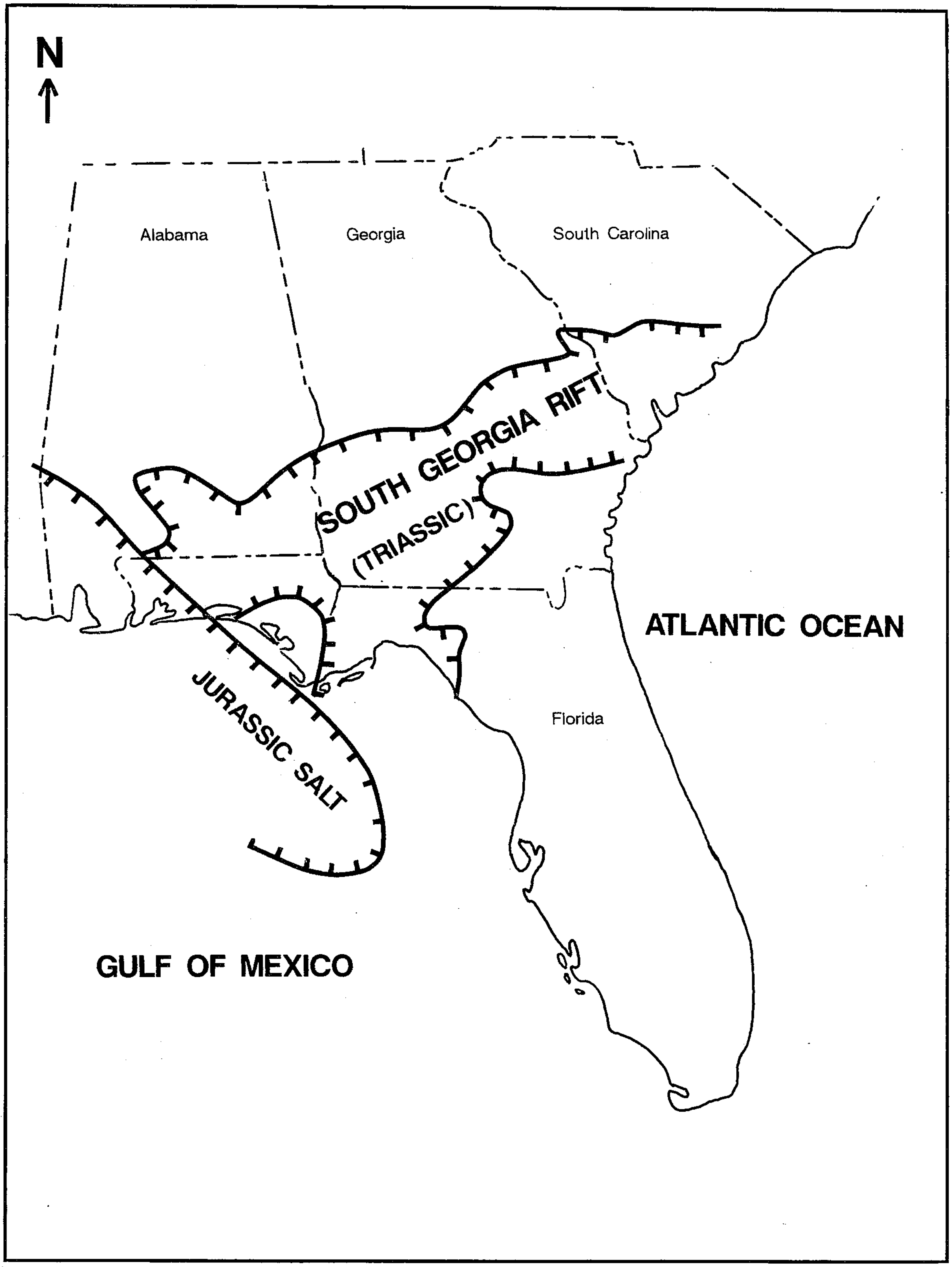

Figure 39. The South Georgia rift from Daniel and others (1988).

This Triassic basin has also been referred to as the Main rift zone (Daniels and others, 1983), the South Carolina-Georgia basin (Gohn and others, 1978), and the Tallahassee Graben (Opdyke and others, 1987). Two smaller grabens, the Riddleville basin and the Dunbarton basin, are associated with and north of the South Georgia rift. These Triassic grabens are similar to those farther north in the eastern United States except the South Georgia rift and Riddleville basin are oriented in a more east-northeast direction than the northern Triassic grabens.

The origin of the Suwannee Strait and the Georgia Channel System are best sought in the South Georgia rift of Daniels and others (1983). The South Georgia rift may also be continuous with a similar Triassic-Jurassic(?) basin referred to as the Apalachicola basin (Klitgord and others, 1984) in the northeastern Gulf of Mexico. If the South Georgia rift remained mildly and intermittently active (subsiding) during the middle and Late Cretceous, then the presence and orientation of the fault-block basins would be sufficient to make them progenitors of the Suwannee Strait during the Late Crtaceous. In this model, the origin of the coastal Apalachicola Embayment is the underlying Triassic-Jurassic(?) Apalachicola basin and the origin of the Suwannee Strait and Georgia Channel Sytem is the underlying South Georgia rift. Once the water depth in the Suwannee Strait had become sufficient to permit large scale movement of water from the Gulf of Mexico into the Atlantic Ocean, the Suwannee Current and the Georgia Channel System were established.

Piedmont slope

The Piedmont Slope (Cramer and Arden, 1980, Fig. 3; Huddlestun, 1988, p. 13) 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 crystalline basement (Fig. 38). The Piedmont Slope extends from the Fall line in the north to a poorly defined area in the south where a reduction in the dip of the basement occurs (compare with Maher, 1965, pl. 6; 1971, pl. 13). The slope change appears to be irregular but generally occurs along a trend from the southwestern corner of Georgia (the vicinity of Seminole and Decatur Counties), northeastward through Screven County (Pl. 2; compare with Herrick and Vorhis, 1963, Figs. 3, 6, 10, 14, 16, 18). However, the slope change cannot be readily identified in Applin and Applin, 1967, pls. 4D, 4E, 6C). The Georgia Channel System occurs at the toe of the Piedmont Slope.

The stratigraphic and structural relationship between the Piedmont Slope and the Florida Platform is ambiguous because the postulated boundary between the slope and platform approximates the trend of the Georgia Channel System and is, therefore, obscured by the overlying sedimentary constructional feature. The relationship of the Piedmont Slope to basement type and province is also not as apparent as that of the Florida Platform to African basement. However, the Piedmont Slope appears to be underlain by North American basement and the Paleozoic accreted terranes of Nelson and others (1985a, 1985b), and possibly by portions of disturbed or overthrust African basement (Dallmeyer, 1987). It may be that the major distinction between the Florida Platform and Piedmont Slope is that the basement of the platform is relatively "homogeneous" whereas that of the slope is heterogeneous, and the boundary is a zone and not a line.

Peninsular Arch

The Peninsular Arch has in the past been considered to be a north-northwest--south-southeast trending arch or structural high that influenced only Cretaceous deposits in Florida (Applin, 1951; Toulmin, 1955; Puri and Vernon, 1964; Maher, 1965; Banks, 1976). In this report, the Peninsular Arch can be recognized in Georgia as far north as Ben Hill and Irwin Counties (Fig. 40)(compare with Maher, 1965, pl. 7). In Georgia the Peninsular Arch appears to have influenced the structural attitudes of deposits as late as the Claibornian (Huddlestun and others, in review) but in Florida its influence on deposits younger than the Cretaceous is not apparent (Applin and Applin, 1967; Maher, 1965, 1971). Additionally, the Peninsular Arch appears to have influenced depositional patterns in the region as young as the Oligocene because no pre-Suwannee deposits occur east of the arch and all Oligocene deposits are absent along the crest of the arch in northern Florida.

The Peninsular Arch is a subtle structural feature in Georgia. The Georgia Channel System has overprinted much of the arch in southern Georgia so that its presence is difficult to detect. However, it can be identified as an arch on Plate 7 of Maher (1965) and in Figure 41, a stratigraphic cross section normal to the Peninsular Arch and paralleling the Gulf Trough. However, the Peninsular Arch appears to be more than simply a structural arch. Its influence on the Oligocene stratigraphy in the area suggests that it may also serve as a structural hinge between the Gulf of Mexico and Atlantic Coastal Plain. The extent of the Peninsular Arch thus appears to be greater and it appears to have persisted longer than previously thought.

There is evidence that the Peninsular Arch influenced the configuration of the latest Cretaceous-Early Paleocene Suwannee Channel and the later Gulf Trough. I suggest here that the Suwannee Saddle of Applin and Applin (1967) is a direct consequence of the Peninsular Arch; i.e., the Suwannee Saddle is a constriction that occurs where the channel crosses the arch (Fig. 40). As

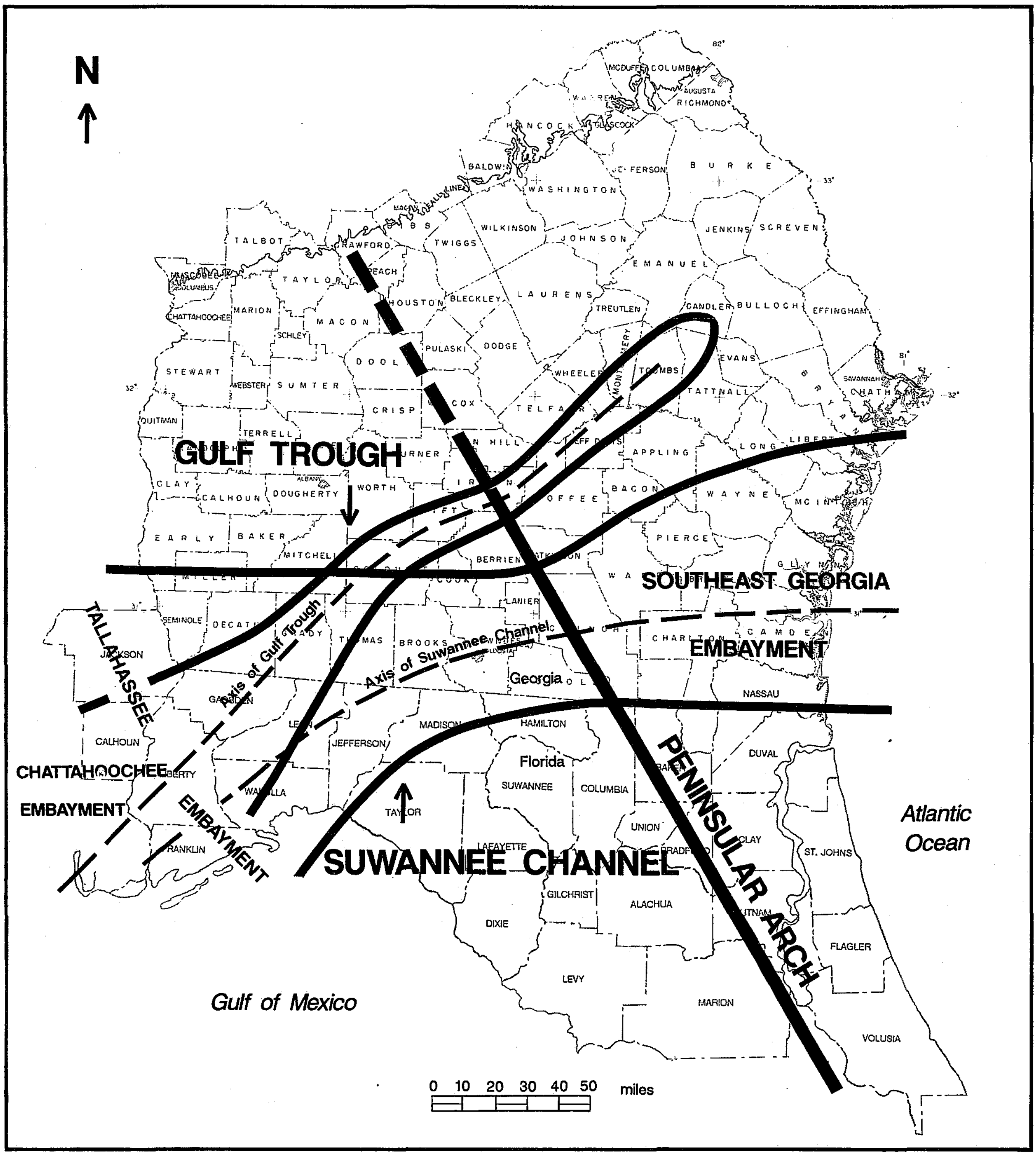

Figure 40. The Peninsular Arch and related features in Georgia and northern Florida.

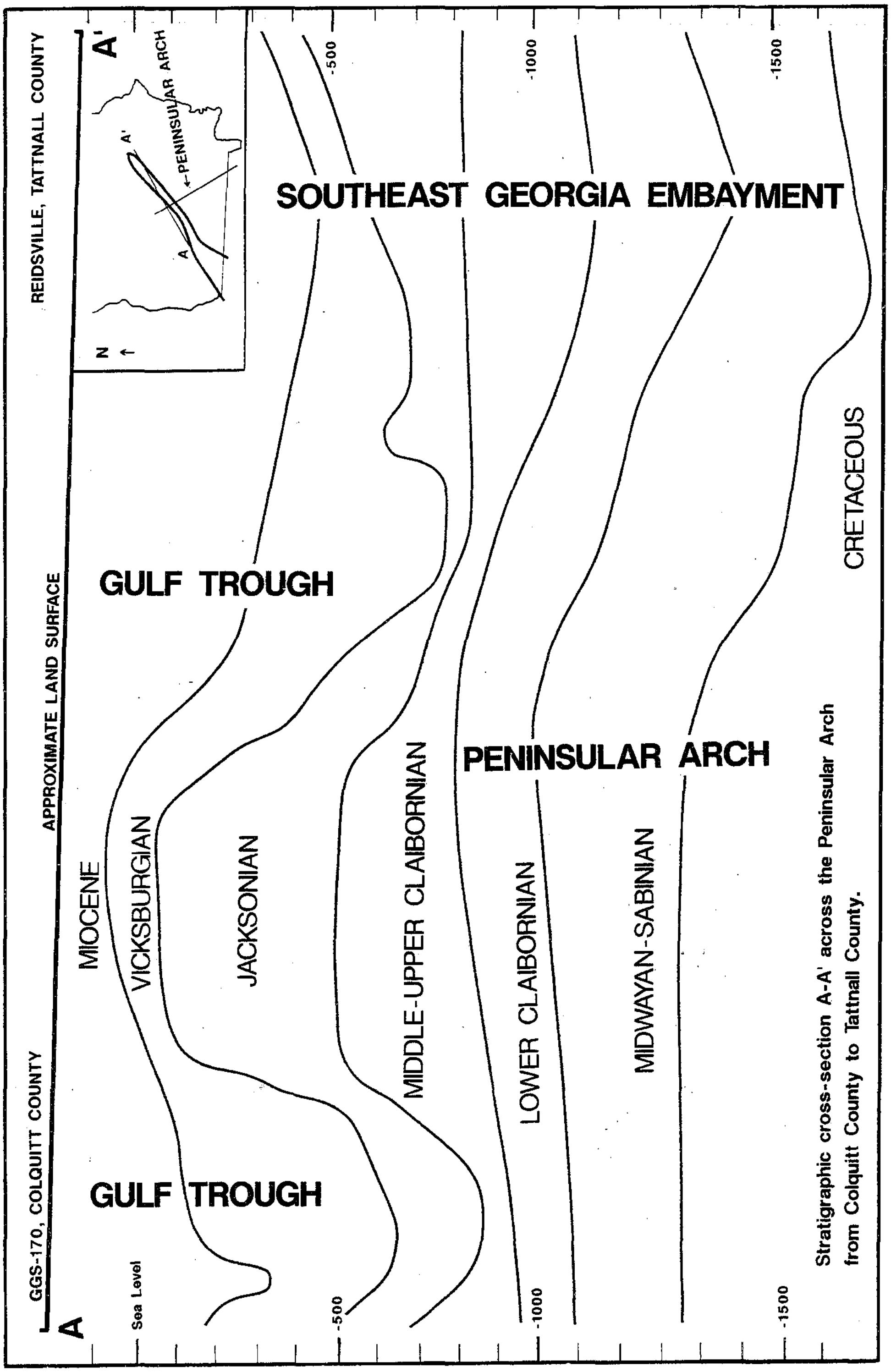

Figure 41. Stratigraphic cross-section across the Peninsular Arch and paralleling the trend of the Gulf Trough from Dougherty County to Emanual County.

such, the Peninsular Arch divided the Tallahassee Embayment to the west from the Southeast Georgia Embayment to the east (Fig. 40). It is not known whether the floor of the Suwannee Saddle was shallower than the rest of the channel during the occupation of the channel by the Suwannee Current. If future studies indicate that it was, then the Peninsular Arch also could have formed a sill that acted as a blockage to the Suwannee Current during the terminal Midwayan low stand of the sea.

The Peninsular Arch also may have influenced the position of the Gulf Trough. The only feasible explanation for the dog-leg in the Gulf Trough in Colquitt, Tift, Cook, Berrien, and Irwin Counties, Georgia (Fig. 41), is that the floor of the Suwannee Strait was bathymetrically high along the axis of the Peninsular Arch during the Claibornian. This shallowing caused the Suwannee Current to veer slightly seaward into deeper water offshore of the shoal. This model can explain both bends in the trough, the western bend in Colquitt County where the shoaling began, and the eastern bend in Irwin County. Where the shoaling ended, the current appears to have resumed its northeastward flow. This may have been due to the Suwannee Current being dragged northeastward by the northward flowing water-masses of the paleo-Florida Current and paleo-Antilles Current merging off of Georgia to form the paleo-Gulf Stream (compare with Popenoe and others, 1987, Fig. 6).

CONSTRUCTIONAL FEATURES OF SEDIMENTARY ORIGIN

Georgia Channel System

As defined by Huddlestun and others (in manuscript), the Apalachicola Embayment, Chattahoochee Embayment, Tallahassee Embayment, Gulf Trough, and Suwannee Channel, are components of a system of sedimentary constructional features called the Georgia Channel System (Fig. 42). The Georgia Channel System was formed largely through nondeposition or diminished deposition under the axis of the Suwannee Current (see p. 110-112-), a Late Cretaceous through Early Tertiary component of the western North Atlantic Ocean current system (Huddlestun and others, in manuscript). It is postulated here that the Suwannee Current and Georgia Channel System must have dominated or at least strongly influenced the sedimentary patterns, stratigraphy, and faunas of most of the Coastal Plain of Georgia from the Late Cretaceous (upper Tayloran or Navarroan to the Middle Miocene (lower Serravallian).

The Georgia Channel System is divided into two spatially and temporally separate but analogous channels. There is an older, Late Cretaceous (Tayloran-Navarroan) through Middle Eocene channel which consists of the Suwannee Channel with a southwestward flaring component called the Tallahassee Embayment and an eastern component called the Southeast Georgia Embayment (Fig. 43)(Huddlestun and others, in manuscript). Second, there is a younger Middle Eocene to Middle Miocene component that is called the Gulf Trough and which has a southwestward flaring component called the Chattahoochee Embayment (Fig. 44)(Huddlestun and others, in manuscript). The combined southwestward flaring Tallahassee and Chattahoochee Embayments are referred to collectively as the Apalachicola Embayment (Fig. 42-44). The presence of the two spatially and temporally distinct channels is postulated to have resulted from a reduction and change in flow direction of the Suwannee Current during the Late Paleocene (early Sabinian). This usage differs from, but is compatible with, previous usage.

The distinction made here between the Chattahoochee Embayment and Gulf Trough is that proposed by Huddlestun and others (in manuscript). The Chattahoochee Embayment is the flaring southwestern part of the Gulf Trough (Fig. 44), which gradually narrows and shallows to the northeast. The Gulf Trough constitutes the entire channel, including the Chattahoochee Embayment, from at least the coastal area (and probably across the entire continental shelf of eastern panhandle Florida), northeastward to the vicinity of Candler County, Georgia. East of the Chattahoochee Embayment in Colquitt County, Georgia, the Gulf Trough is a roughly parallel sided, relatively narrow feature. In addition, the stratigraphy of the Chattahoochee Embayment differs somewhat from that of the Gulf Trough northeast of the embayment. For the Oligocene, typical Ochlockonee Formation is confined to the Chattahoochee Embayment whereas the Pridgen Limestone Member of the Ochlockonee is present only in the parallel sided Gulf Trough to the northeast. The Wolf Pit Dolostone and Okapilco Limestone are largely confined to the parallel-sided northeastern part of the trough and the interior of the Chattahoochee Embayment in Colquitt County and, perhaps as far southwest as Grady County. These formations are not known to be present farther southwest in the Chattahoochee Embayment.

This imperfect distinction between the Chattahoochee Embayment, Apalachicola Embayment, and Gulf Trough is at variance with past distinctions between the features. The Apalachicola Embayment generally has been believed to be an ancient, Jurassic to Miocene, westward to southwestward flaring, structurally subsiding feature that is largely confined to Florida (Murray, 1961; Schmidt, 1984). However, the southwestward flaring Suwannee Channel and Gulf Trough were pointed out by Huddlestun and others (in manuscript) to be temporally and, to a lesser extent, spatially distinct features. Therefore, Huddlestun and others (in manuscript) assigned two different names for these embayments in the

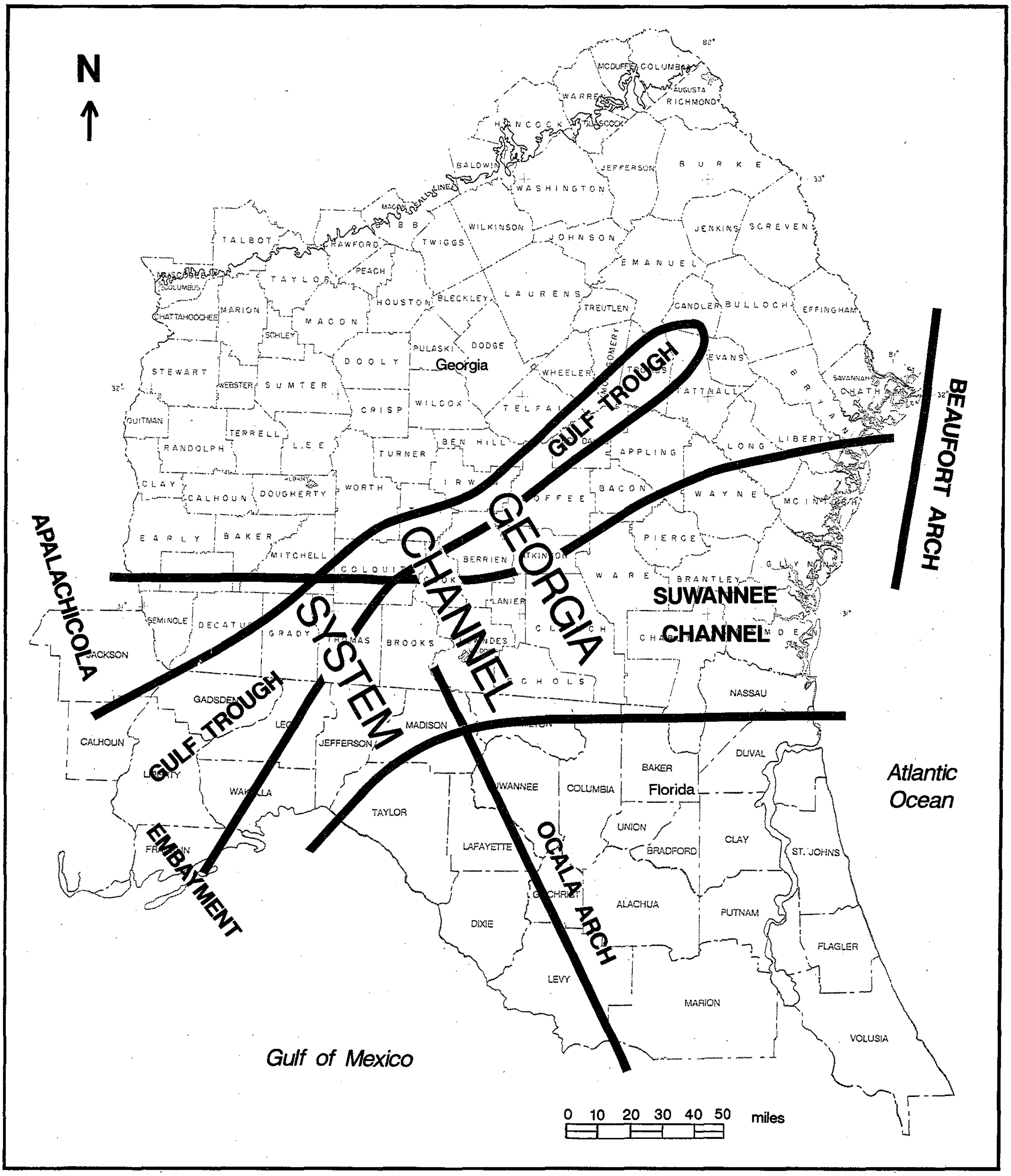

Figure 42. Constructional features of sedimentary origin.

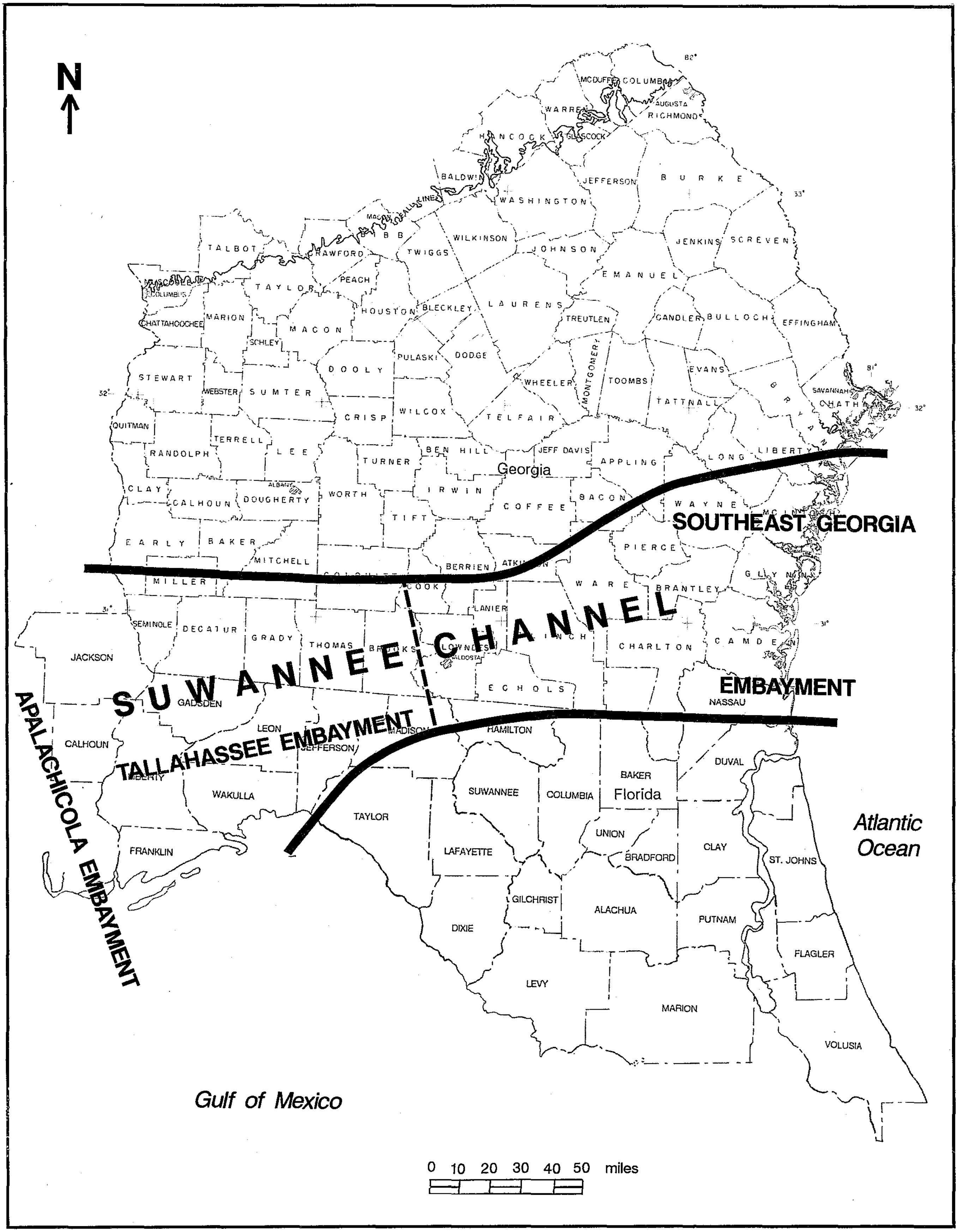

Figure 43. Reconstruction of the Suwannee Channel, Tallahassee Embayment, and Southeast Georgia Embayment in Georgia and northern Florida.

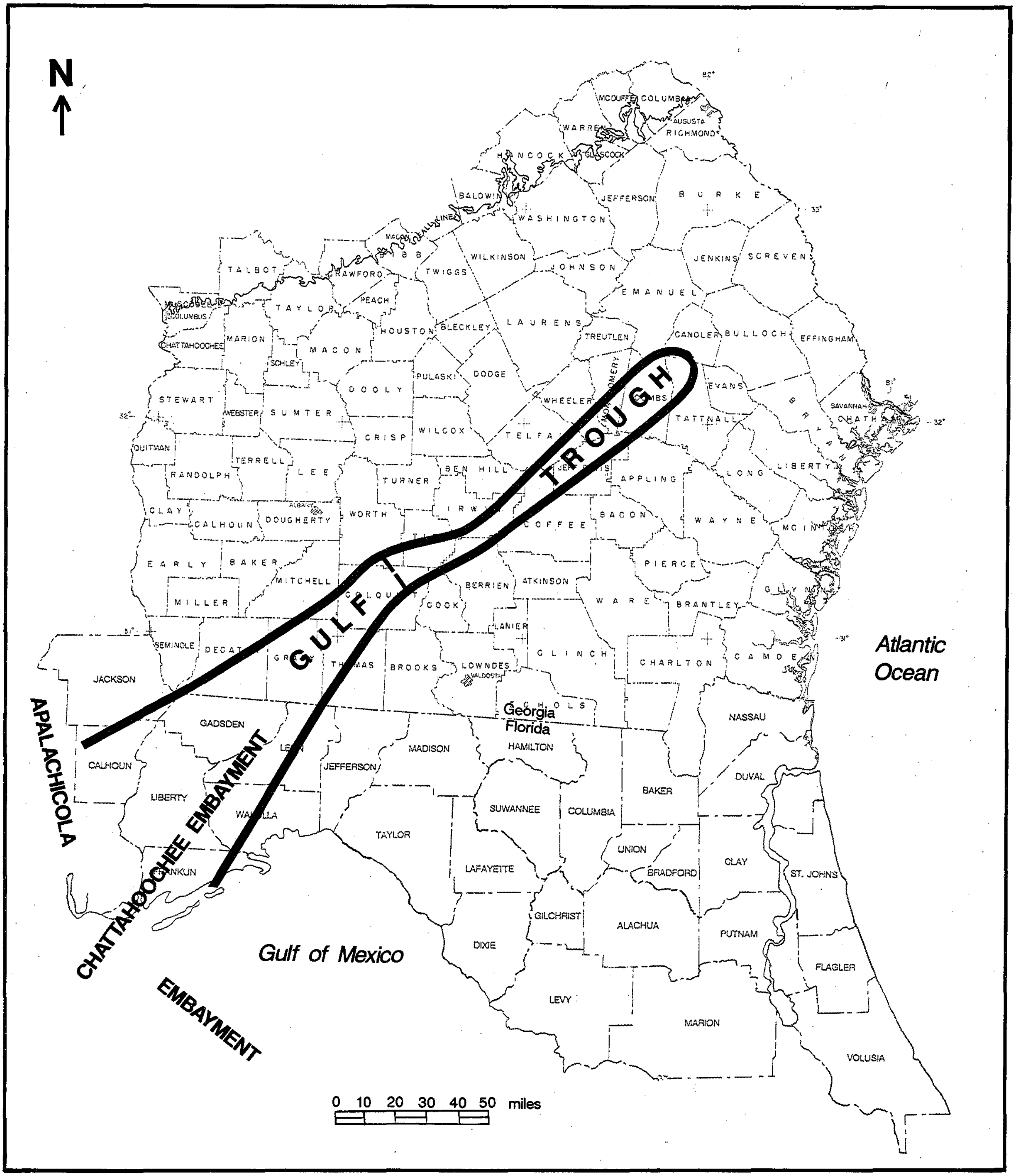

Figure 44. Reconstruction of the Gulf Trough and Chattahoochee Embayment in Georgia and northern Florida.

interest of precision in communication. Huddlestun and others (in manuscript) also concluded that there may be some utility in retaining the concept of the Apalachicola Embayment as the collective southwestward flaring feature of the channel system.

In Georgia, the entire channel system has been variously called the Suwannee Strait (Rainwater, 1956; Manker and Carter, 1987), Suwannee Channel (Chen, 1965; McKinney, 1984), or Gulf Trough (Herrick and Vorhis, 1963; Sever and others, 1967; Gelbaum, 1978; Gelbaum and Howell, 1982) whereas in Florida the system has generally been referred to as the Apalachicola Embayment, Suwannee Strait, or Suwannee Channel (see Huddlestun and others [in review] for a discussion of the usage of the terms). However, Huddlestun and others (in manuscript found that there are no valid distinctions in the channel system on either side of the Florida-Georgia state line.

The general morphologies of the Gulf Trough and Suwannee Channel differ somewhat. The Gulf Trough (Fig. 44) flares southwestward southwest of Tift County (Chattahoochee Embayment) and, other than two minor bends in the channel, it remains relatively straight, narrow and parallel sided until it shoals and merges with the continental shelf in eastern Georgia. The Suwannee Channel has a different morphology. The Tallahassee Embayment (Fig. 43) flares to the west and is narrowest where it crosses the Peninsular Arch in the Lowndes-Echols County area in Georgia. The Southeast Georgia Embayment opens eastward from there.

Based on data presented here, the time span of the Suwannee Channel was Late Cretaceous (late Tayloran) through Middle Eocene (Claibornian) with channel-infilling occurring from Late Paleocene (Sabinian) through Middle Eocene (Claibornian)(also see Hull, 1962). The time span of the Gulf Trough was from the middle to late Middle Eocene (Claibornian) to Middle Miocene (early Serravallian) with channel-infilling occurring from the Oligocene (Vicksburgian) into the Middle Miocene (Serravallian)(see Plates 2, 3, 5)(Huddlestun and others, 1988).

The Gulf Trough originated with the northwestward migration of the carbonate depositional province on the Florida Bank to the southern margin of the Suwannee Current during the middle Claibornian (Huddlestun and others, in manuscript). This expansion of the carbonate province resulted from a decrease in siliciclastic input to the continental shelf from the continent. Because current velocities would decline on either side of the Suwannee Current, skeletal sediment accumulation and upbuilding of the carbonate shelf bottom would occur away from the current. In contrast, there was reduced sedimentation or nondeposition under the current (resulting in relatively deep water conditions). Once the channel margins were constructed in this manner, the current was locked in place and could not migrate laterally.

The Gulf Trough reached its greatest development and depth near the end of the Eocene when topographic relief in the vicinity of the trough may have been as much as 600 feet in southwestern Georgia (Huddlestun and others, in manuscript). Diminished volume of the Suwannee Current and diminished current velocity at the end of the Eocene raised the base level of sedimentational equilibrium on the floor of the Gulf Trough. Thus channel-infilling was initiated at the end of the Eocene and beginning of the Oligocene (Fig. 45).

Southeast Georgia Embayment

The Southeast Georgia Embayment was considered by Huddlestun and others (in manuscript) to have originated as the eastward flaring component of the Suwannee Channel (Fig. 43)(compare with Pinet and Popenoe, 1985). That is, it originated through nondeposition on the continental shelf under the massive Suwannee Current. Therefore, they concluded that the latest Cretaceous and Tertiary Southeast Georgia Embayment was not so much a result of basement tectonics and differential subsidence, but of sedimentary processes. This is consistent with the observation of Maher (1965) where he considered the Southeast Georgia Embayment to be a passive structure. Subsequent to the massive reduction in the Suwannee Current after the Midwayan, the Suwannee Channel and its eastern component, the Southeast Georgia Embayment, became a depocenter on the continental shelf. By the end of the Middle Eocene, much of the onshore part of the Suwannee Channel had been filled with sediment. As a result, Upper Eocene and Oligocene deposits in eastern Georgia do not reflect the presence of the Southeast Georgia Embayment and they are uniformly and relatively thin across the region. The Miocene "depocenter" in the Southeast Georgia Embayment was ascribed by Huddlestun and others (in manuscript) to deep entrenchment of the paleo-Altamaha River system during the Late Oligocene low stands of the sea.

Beaufort Arch

The Beaufort Arch (Heron and Johnson, 1966, p. 54; Huddlestun, 1988, p. 15) is a low, broad, structural high trending south-southwestward from Beaufort County, South Carolina, onto the continental shelf off Georgia (Fig. 41). The Beaufort Arch is present on-shore 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. 56, Fig. 3; Foley, 1981, p. 48-49, Fig. 20).

Huddlestun (1988) thought that the Beaufort Arch

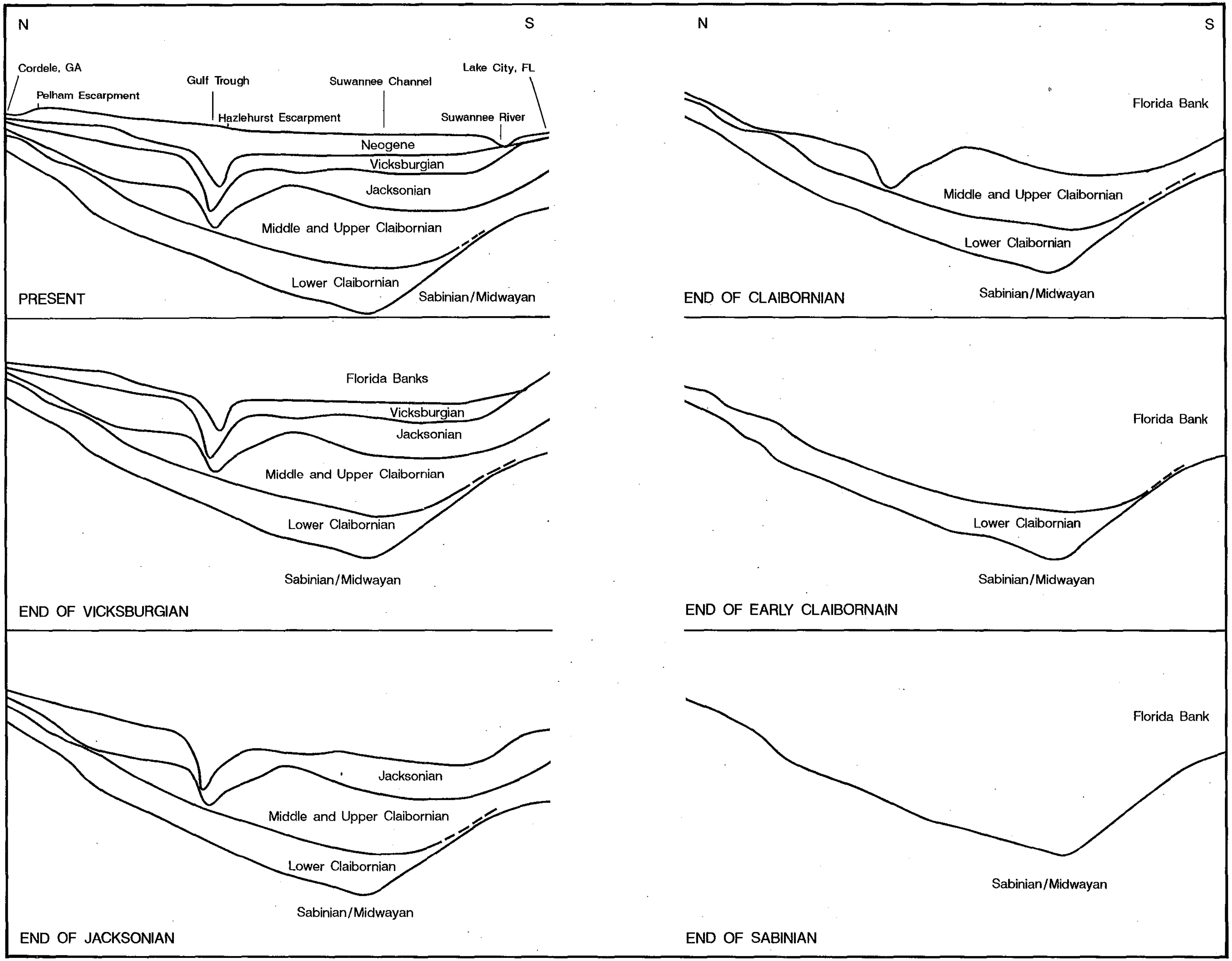

Figure 45. Schematic north-south cross-section illustrating the infilling andsequential northward migration of the Florida Bank and the subsequent termination of the bank.

did not exist prior to Miocene time and, therefore, was a Neogene structural element. However, subsequent work (Huddlestun and others, in manuscript) has shown that the Beaufort Arch can be traced on structural contours on the top of the Eocene but not on the tops of any older horizons in the area. In addition, the only known occurrences of the shallow-water, sandy Lazaretto Creek Formation of Vicksburgian age are on, and in the vicinity of, the Beaufort Arch in Chatham and Glynn Counties, Georgia. This suggests that the Beaufort Arch influenced sedimentation patterns during the Early Oligocene. Because the Beaufort Arch cannot be recognized prior to the Upper Eocene, it is concluded that the arch may have formed as a result of differential carbonate shelf sedimentation. That is, the Beaufort Arch represents a linear area where Late Eocene sedimentation rates were relatively high compared with the surrounding continental shelf. Therefore it is concluded that the Beaufort Arch is not a structural feature related to basement tectonics but is probably associated with differential sedimentary processes on the continental shelf during the Late Eocene.

Ocala Arch

The Ocala Arch (Fig. 42) is a structural high that in Florida is also reffered to as the Florida Platform (pers. com., T. Scott, 1992). For discussion, see Huddlestun, 1988, p. 13-15). Huddlestun (1988) reasoned that if tectonic uplift occurred on the arch, it must have been minor, and that the major structural movement associated with the "arch" was subsidence on the flanks of the Peninsular Arch. Winston (1976) also denied the uplift model of the Ocala Arch and he described the structure as a "blister dome". Winston (1976, p. 993) observed that the:

> ...direction of thickening in all formations is southwestward, and the rate of thickening in all units except the Lake City is fairly constant. In the Lake City, the rate of thickening increases abruptly.... beneath the crest of the Ocala feature, then return to normal farther southwest....

Winston (1976) interpreted the arching of the Ocala feature to be the result of the initial uniform dip to the southwest and an abrupt thickening of the Lake City Formation. The "arch" was formed later by subsidence and tilting of the continental margin to the east or northeast. As such, the Ocala Arch is not a true structural arch; it has the geometric appearance of an arch in the upper part of the geologic section but not in the lower part of the geologic section or basement (see Winston, 1976, Figs. 3 and 4). In addition, the Ocala Arch cannot be separated from the Peninsular Arch on Plate 8 of Maher (1965).

The trend of the Ocala Arch can be traced by the outcrop pattern of Oligocene and older formations in northwestern peninsular Florida. On this basis, the Ocala Arch can be identified as far northwest as the lower Withlacoochee River in southern Brooks and Lowndes Counties, Georgia. The occurrence of karst terrain in southern Lowndes and Brooks Counties also results from the presence of the Ocala Arch.

HYPOTHETICAL STRUCTURES

Chattahoochee Arch

For a comprehensive survey of the history of the name Chattahoochee Arch (also referred to as Chattahoochee uplift and Chattahoochee anticline), see Patterson and Herrick (1971). The conclusions of Patterson and Herrick (1971, p. 13-14) concerning the Chattahoochee Arch are as follows:

> So many different ideas on the location and extent of the Chattahoochee Anticline have been published... without supporting evidence that anyone who reviews them has difficulaty indistinguishing the imagined from reality. Accordingly, interpretations of this feature, presented without evidence, should be considered as no more than hypothetical. Sufficient geologic evidence is now available to conclude that the original proposal of the existence of this anticline by Veatch and Stephenson (1911), and the redifinition by Sever (1965) should be considered invalid.

In the present study, I must conclude that the opinion of Patterson and Herrick (1971) is correct and that the Chattahoochee Arch (or uplift or anticline) exists neither as a real nor apparent structural feature. The concept of the Chattahoochee Arch is rejected here based on three lines of evidence. First, if the Chattahoochee Arch were a true positive element (i.e., defined either by uplift along the crest of the structure or by subsidence in adjacent areas), it should stand out prominently on structural contour maps on deeper stratigraphic horizons. No such significant structural relief can be observed on the top of the pre-Upper Cretaceous, base of the Austinian, top of the Tayloran, top of the Cretaceous, top of the Paleocene-Lower Eocene, top of the Middle Eocene, or top of the Upper Eocene in the eastern panhandle of Florida or southwestern Georgia (Applin and Applin, 1967, pls. 2, 4. 6; Chen, 1965, Figs. 7, 8, 10-12; Herrick and Vorhis, 1963, Fig. 10, 14, 16; Miller, 1986; Huddlestun and others, in manuscript). Therefore, there is no stratigraphic evidence for the existence of the arch.

A second line of reasoning involves regional strike. The structural strike of various Upper Cretaceousand Tertiary horizons and the outcrop pattern of Tertiary strata in the vicinity of the postulated Chattahoochee Arch in the Florida panhandle is approximately west-northwest—east-southeast to east-west (Applin and Applin, 1967, Pls. 2, 4, 6; Chen, 1965, Figs. 1, 8, 10-12; PennWell Publishing Co., 1982; Huddlestun, 1984, Figs. 6-9; Huddlestun and others, in manuscript; also compare with Applin and Applin, 1944; Herrick and Vorhis, 1963; American Association of Petroleum Geologists, 1975). In contrast, the strikes of the various postulated axes of the Chattahoochee Arch vary from approximately north-south to southwest-northeast (see Patterson and Herrick, 1971, Fig. 1). If there were a structural arch in the vicinity of the postulated Chattahoochee Arch, the resulting deflection in the regional strike of formations and stratigraphic horizons should be evident in local occurrences of north-south or southwest-northeast strikes. No such trends are evident, and no such strikes have been reported.

Structural strikes of stratigraphic horizons or formations in Alabama (Cooke, 1926, pl. 1; PennWell Publishing Co., 1982), and Georgia (Herrick and Vorhis, 1963; Chen, 1965; Huddlestun and others, in manuscript), also suggest that there is a smooth, general rotation of structural dips around the southeastern corner of the continent in eastern Alabama and western Georgia. The southeastern corner of the continent is thus characterized by a gradual swing of structural contours on stratigraphic horizons from west-northwest—east-southeast in Alabama and western Florida (eastern Gulf Coastal Plain) to southwest-northeast in Georgia (Atlantic Coastal Plain). This gradual rotation of the structural contours is interrupted in the upper part of the geologic section (Middle Eocene-Middle Miocene) by the presence of the Gulf Trough in the eastern panhandle of Florida and southwestern Georgia. Were it not for the presence of the Gulf Trough, the structural contours on stratigraphic horizons in the upper part of the section would probably trend east-west across the panhandle of Florida (compare with the Oligocene outcrop belt in American Association of Petroleum Geologists, 1975).

A third line of reasoning results from the older formations occurring at relatively high elevations in the Holmes-Washington-Jackson Counties area of Florida. When considering only the structural attitudes of formations in Florida and ignoring those in Alabama and Georgia, the structurally high occurrences of those formations in Florida give the appearance of an "arch" or "uplift." The appearance of an arch in Florida is inferred by the occurrence of the Gulf Coast Basin (or Gulf of Mexico sedimentary basin, or Gulf geosyncline of Murray, 1961), a tectonically subsiding sedimentary basin to the west, and the Gulf Trough which is not a tectonically subsiding basin, to the east. It is the juxtaposition of the Gulf Coast Basin and the Gulf Trough that gives the illusion of the presence of an arch in the area between.

In summary, I strongly urge that the use of the names Chattahoochee Arch, Chattahoochee uplift, and Chattahoochee anticline be discontinued. No data have been presented by any author that supports the existence of the Chattahoochee Arch, and all of the published data relevant to the Chattahoochee Arch are incompatible with the presence of an arch, anticline, or uplift at the site of the postulated structure.

Barwick Arch

The Barwick Arch was named by Sever (1966a, p. 7-8, Figs. 2-6) for a southwest-northeast trending structural high on top of the Suwannee Limestone in Thomas County, Georgia. He described the structure as follows:

> Contours drawn on the top of the Suwannee Limestone of Oligocene age and the Tampa Limestone of early Miocene age...show that these rocks in northwestern Thomas County are downfolded along a northeast-plunging structure called the Miegs basin... In central Thomas County the rocks have been upfolded along a northeast trending arch named the Barwick Arch. These folds are separated by the Ochlockonee fault which has a displacement of about 200 feet in northern Thomas County... Rocks on the southeast side of the fault are upthrown with the amount of displacement increasing to the northeast.

However, Patterson and Herrick (1971, p. 13) concluded:

> The elevations of the top of the Suwannee that were determined at many well sites and outcrops do not differ greatly from those illustrated by Sever (1966a, Fig. 1: 1966b, Fig. 2). We therefore agree with Sever to the extent that the top of the Suwannee is high in the vicinity of his "Barwick Arch"..., which is a short distance east of the proposed fault ....
>
> The "high" in the top of the Suwannee Limestone along the so-called Barwick Arch of Sever (1966a, Fig. 1; 1966b, Fig. 2) does not prove the existence of this anticline, and it too should be questioned. One of the reasons for

> questioning this arch is that water wells in this vicinity do not penetrate through Oligocene rocks, and there is little information to prove or disprove the existence of such a feature. With the evidence now available, we cannot rule out the possibility that the apparent reversal of the regional dip from the arch into the Gulf Trough is an initial dip resulting from deposition on the east side of a strait or a submarine valley. The apparent dips in this vicinity also may have been modified significantly by carbonate solution, inasmuch as structure contour maps on the top of the Oligocene in areas south of the arch (Hendry and Sproul, 1966, Fig. 16; Yon, 1966, Fig,. 10) show a buried karst topography having high areas of the same magnitude as that illustrated by Sever for Barwick Arch.

So, the original basis for postulating the existence of the Barwick Arch was the supposed topographically high (and presumable structurally high) occurrence of Suwannee Limestone and Chattahoochee Formation ("Tampa Limestone") along a southwest-northeast trend that passes near the community of Barwick in Thomas County, Georgia (Sever, 1966a, Figs. 2 and 3). Based on cores in the same area, I have not been able to reproduce the structurally high upper contact of the Suwannee Limestone (Pl. 3) and, based on cores and well-cuttings, only a broad, low "undulation" is recognizable on top of the Suwannee Limestone south of the Gulf Trough in southwestern Georgia (Huddlestun and others, in manuscript). In addition, structural contours on stratigraphic horizons older than the Middle Eocene show no indication of an arch in the postulated position of the Barwick Arch (see Herrick and Vorhis, 1963; Applin and Applin, 1967; Huddlestun and others, in manuscript). Because older reports based on deep but sparse control, and newer reports with more stratigraphic control than that of Sever (1966a) do not show any evidence for the existence of the Barwick Arch, it is concluded that the Barwick Arch of Sever (1966a) does not exist as a structural arch (a feature resulting from tectonic processes).

A low, broad undulation on the top of the Oligocene does occur parallel to and south of the Gulf Trough, roughly in the position of the Barwick Arch, and may have resulted from one of two causes. The high occurrence of the Suwannee Limestone (and adjacent formations) may result from the interruption of the normal regional dip to the southeast by the depression of stratigraphic horizons within the Gulf Trough (see Pl. 3). Therefore the Barwick Arch, or the low, broad undulation south of the channel, is an artifact of the Gulf Trough much as is the Chattahoochee "arch" in western Florida.

Alternatively, this low, broad undulation could be the result of increased sedimentation rates on the southern flank of the Gulf Trough. The sea floor would stand bathymetrically high where there was greater organic production and, therefore, greater rates of sedimentation (much as a bioherm). In support of this model, it is in the vicinity of the community of Pavo (near Barwick) in eastern Thomas County that the relatively thick Bridgeboro Limestone grades laterally southeastward into the Ellaville Limestone and Suwannacoochee Dolostone (Pl. 3) both of which are restricted to and characteristic of the Florida Platform.

The results of current investigations support the conclusion of Patterson and Herrick (1971) that the Barwick Arch does not exist. I therefore also recommend that the name Barwick Arch be abandoned because, with increased and improved data and stratigraphic control, the presence of the arch as a structural (tectonic) feature has not been verified and its presence as a sedimentary constructional feature, if real, is trivial.

Faults

A number of faults have been proposed to account for lithostratigraphic and thickness anomalies in the vicinity of the Gulf Trough (see Patterson and Herrick, 1971). All of these proposed faults can be interpreted as involving Oligocene stratigraphy or sedimentation patterns. Consequently, they should be discussed in this report. Those postulated faults that can be construed to bound the Gulf Trough (or Chattahoochee Embayment) include two parallel, unnamed faults with downthrown southeastern sides (Callahan, 1964, p. 33); "linears" or faults which bound the South Georgia Trough, or graben (Gulf Trough), of Tanner (1966, p. 84, 85, 87) (in part the Bainbridge-Chattahoochee-Blountstown fault as interpreted by Patterson and Herrick, 1971); the Cypress fault of Moore (1955, p. 26-29) which marks the western flank of the Chattahoochee Embayment in Jackson County, Florida; and the Ochlockonee fault of Sever (1966a, p. 7-8, 1966b) which bounds the southeastern flank of the Gulf Trough in Thomas County, Georgia. Concerning these faults, Patterson and Herrick (1971, p. 13) concluded:

> ...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, 1986). Similarly, no data has been submitted that supports the existence of the Big Satilla fault of Gelbaum and Howell (1982, p. 149).

There is no evidence for fault displacement of the top of the Cretaceous in the vicinity of the Gulf Trough in Georgia (Huddlestun and others, in manuscript; also compare with Herrick and Vorhis, 1963; Applin and Applin, 1967) or in the vicinity of the Chattahoochee Embayment in Florida (see Chen, 1965, Fig. 8; Applin and Applin, 1967, Pl. 6C). Therefore, it is concluded in the present report that all of the above faults are hypothetical and have not been shown to exist.

PALEOGEOGRAPHIC ELEMENTS

Florida Bank

For a substantial period of the history of the Coastal Plain Province, the physiographic expression of the Florida Platform was that of a marine, shallow-water, carbonate bank analogous to the present Bahamas Banks (Fig. 45, 46). The surface of the platform did not become a shallow water bank until near the end of the Tayloran (Campanian) or beginning of the Navarroan (Maastrichtian) when the Lawson Formation, the first of the carbonate bank formations, was deposited on the deeper water Pine Key Formation. Prior to the deposition of the Lawson Formation, the physiographic expression of the Florida Platform during the Late Jurassic, Early Cretaceous, and early Late Cretaceous was a peninsula, island, or archipelago of moderate to low topographic relief (Levy Hills of Banks, 1976a). This land area was surrounded by a shallow shelf upon which siliciclastic sediments were deposited in the north and upon which shallow water carbonates and evaporites were deposited in the south (see Applin and Applin, 1965, 1967; Babcock, 1969). The Florida Bank probably persisted as a physiographic feature from the latest Cretaceous into the Early Miocene. During the Miocene, siliciclastic shelf sediments, eroded from the rejuvenated Appalachian Mountain system, spread southward across the shelf from the Georgia area into the Florida area. Before the end of the Middle Miocene, siliciclastic sedimentation sutured the former Florida Bank onto the continental mainland as the Florida peninsula and filled the Gulf Trough and made the former bank continuous with the continental shelf.

The northern bank-edge of the Florida Bank is defined by the northernmost occurrence of Florida Bank carbonate formations. These include in ascending order: the Upper Cretaceous Lawson Formation, the Paleocene to possibly Lower Eocene? Cedar Keys Formation, the Upper Paleocene? to Lower Eocene? Oldsmar Formation, the Middle Eocene Avon Park Formation (including the Lake City formation of Applin and Applin, 1944), the Oligocene Suwannacoochee Dolostone, and the Oligocene Suwannee Limestone. The northern bank-edge occurred on the southern flank of the Suwannee Channel during the latest Cretaceous through Middle Eocene. The Florida Bank environment prevailed briefly north of the trough during deposition of the late Vicksburgian Suwannee Limestone (Fig. 46). Although there were bathymetric highs and lows on the floor of the Suwannee Strait and former Florida Bank during the Late Eocene, the Florida Bank environment ceased to exist at that time in onshore Georgia and Florida. Despite the Gulf Trough having been initiated during the Middle Eocene, the northern bank-edge of the Florida Bank remained on the southern flank of the Suwannee Channel during that time.

The site of the Suwannee Channel remained a site of relatively deep water during the Middle Eocene and the channel does not appear to have been filled in until the end of the Middle Eocene. Although the Suwannee Strait continued to exist through the Late Eocene, carbonate shelf conditions prevailed during that time from the nearshore, inner neritic shelf and coastal area (where they interfingered with the coastal, siliciclastic Barnwell Group), across the Florida Platform almost to the shelf edge. This great expanse of shelf carbonates (Ocala Limestone) was bisected by the Gulf Trough in which deep-water limestones were deposited (Fig. 47).

During the Late Eocene, then, the Florida Bank does not appear to have existed as a discrete paleogeographic province on the present peninsula of Florida. It is probable that bank-type conditions continued to prevail on the Florida Platform under the present western peninsular Florida continental shelf of the Gulf of Mexico because the younger, Oligocene Suwannee Limestone contains a few taxa common to relict Florida Bank (Tethyan or Caribbean) foraminiferal fauna (with special reference to *Dictyoconus cookei*, *D. floridana*, *Valvulimmina* spp., *Valvulina* spp., and *Discorinopsis* spp.) that is characteristic of Middle Eocene and older sediments of the Florida Bank. This Tethyan (Caribbean) fauna must have existed in refugia somewhere nearby during the Late Eocene, as discussed earlier, because there seems to be no record of it in the world after the Middle Eocene (also see Cole and Applin, 1964). Therefore, as such the Suwannee Strait must have continued to exist, but the site of the strait, in the strict sense, would have been farther west than the earlier strait.

At the end of the Eocene and during the Early Oligocene, there were a series of sea level drops and low stands punctuated by progressively lower high stands (Pl. 1). During the early Vicksburgian, water depths on the Florida Platform remained sufficiently great so that carbonate shelf conditions continued to prevail across most of the shelf as during the Late Eocene. However, with the abrupt fall in sea level (that resulted in the deposition of the Suwannacoochee Dolostone), Florida

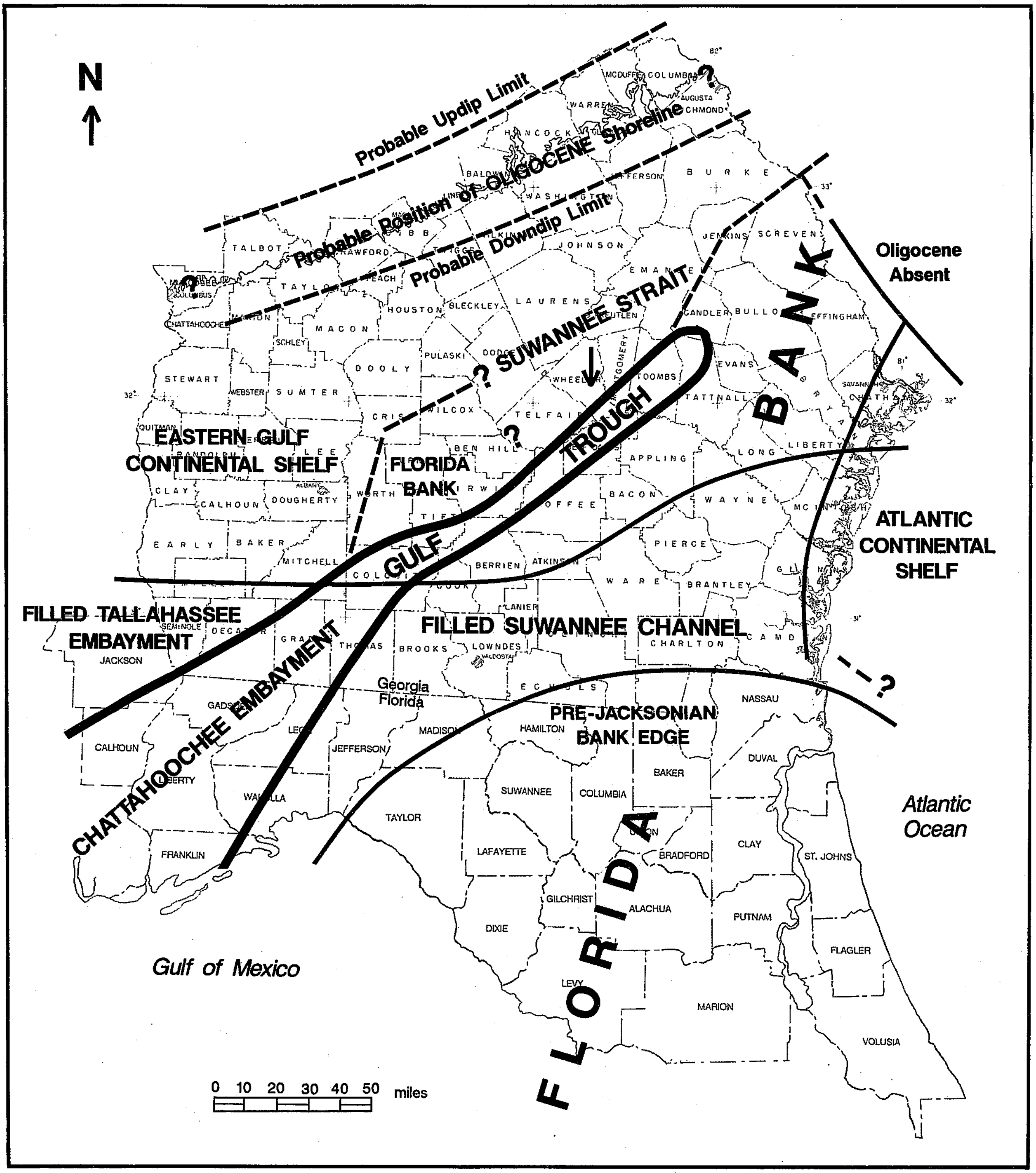

Figure 46. Early Oligocene paleogeographic elements of Georgia and northern Florida.

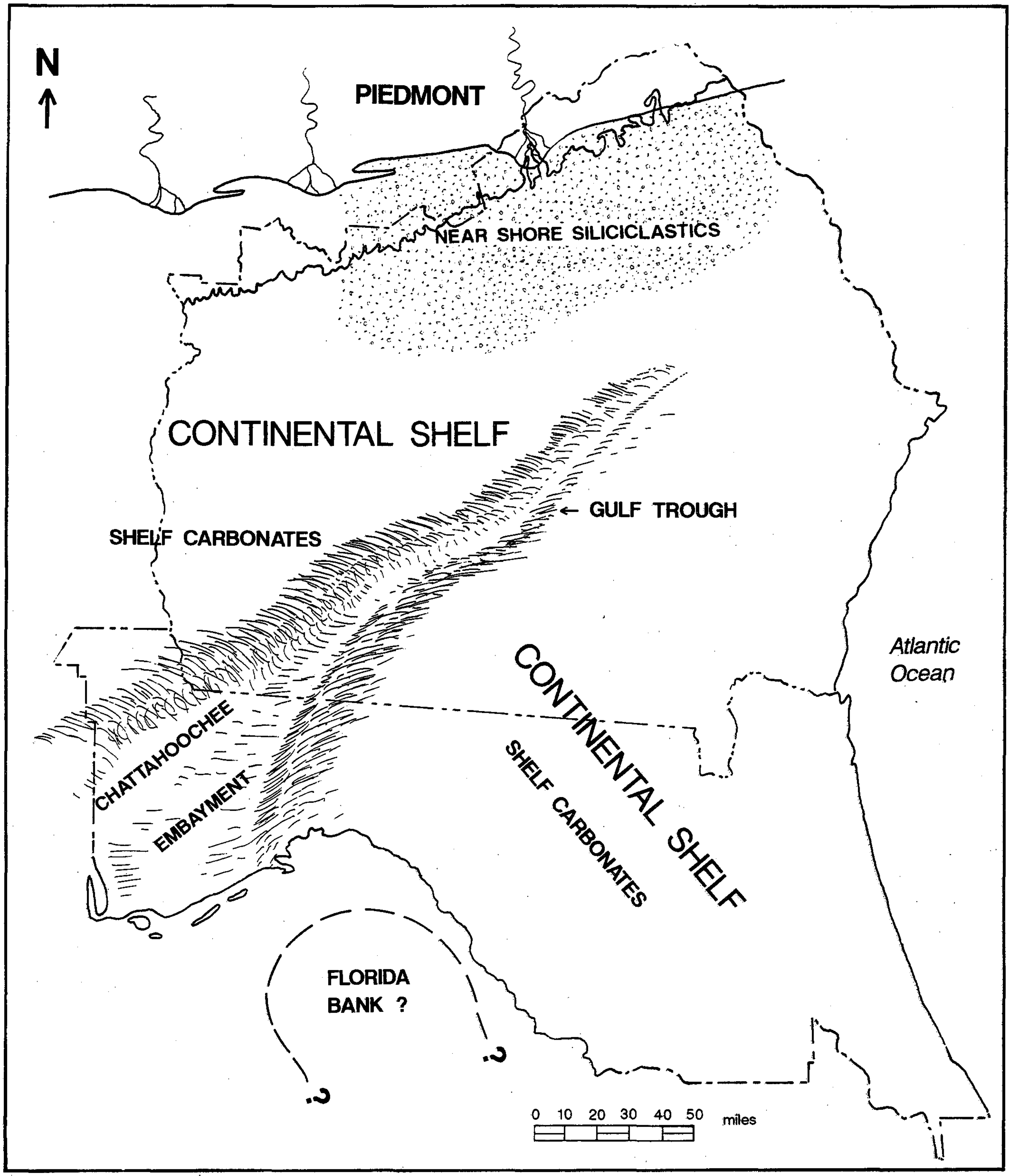

Figure 47. Late Eocene paleogeographic reconstruction of the Coastal Plain area of Georgia and northern Florida.

Bank conditions became reestablished across the entire continental shelf of Georgia (excluding the Gulf Trough). Additional distinctions between the Florida Bank of the Oligocene and the earlier Cretaceous-through-Middle-Eocene Florida Bank exists. Whereas the earlier bank was topographically discontinuous and faunally isolated from the continental shelf region north of the Suwannee Channel, during the Oligocene the Florida Bank bathymetrically and faunally was continuous with the continental shelf around the eastern end of the Gulf Trough in eastern Georgia. This permitted some degree of faunal interchange between the continental shelf region and the Florida Bank. The most widespread Oligocene bank limestone formation (Suwannee Limestone) is a modified bank formation, being environmentally, lithologically, and faunally intermediate between the earlier Cretaceous-and-Early-Tertiary carbonate bank formations and the continental shelf carbonate units (Ocala Limestone and Ellaville Limestone). This indicates that there was only a partial return to the earlier carbonate bank environment during the Oligocene.

The Florida Bank as a shallow water carbonate bank probably ceased to exist in Georgia after Vicksburgian time but a bank type of environment probably persisted somewhere else on the continental shelf of Florida throughout the Oligocene. Although Upper Oligocene (Chickasawhayan) deposits are not present in Georgia, even within the Gulf Trough. Their presence has not been conclusively demonstrated in peninsular Florida. The vestiges of a Florida Bank (Tethyan) foraminiferal fauna in the Early Miocene, Aquitanian Chattahoochee Formation in Florida and Georgia (e.g., *Discorinopsis* sp.) requires the persistence of the Oligocene fauna in refugia during the later Oligocene. However, during the Late Oligocene, the former bank was continuous with the mainland and the bank had been grafted onto the continental mainland as a peninsula (Fig. 48).

Based on the occurrence of Arikareean land mammals in peninsular Florida (Tedford and Hunter, 1984), it is clear that terrestrial conditions had certainly become established on the Florida Platform by the Early Miocene (Aquitanian), and the former bank may have become physiographically a part of the continental mainland at least during low sea level stands of the Oligocene and Miocene. It is possible that parts of the Florida Bank continued to exist during the earliest Miocene (Aquitanian). Islands analogous to the Bahamas Islands of today would occur on the topographically highest parts of the bank and carbonates were deposited in the topographic (or bathymetric) lows (Tampa Limestone Member of the Arcadia Formation (Scott, 1988) and associated shallow water carbonates). However, the Florida Bank as such certainly ceased to exist in the late Early Miocene (Burdigalian) when siliciclastics (Hawthorne Group) from the Piedmont finally inundated and buried the shallow-water, carbonate sediments of the Florida Bank.

Suwannee Strait

The name Suwannee Strait has often been used synonymously with Apalachicola Embayment, Suwannee Channel, and Gulf Trough. However, as defined by Huddlestun and others (in manuscript) and as applied in this report, the Apalachicola Embayment, Chattahoochee Embayment, Gulf Trough, Tallahassee Embayment, and Suwannee Channel are sediment filled channel structures and they are defined on their channel morphology and their sediment fill. The term "strait," however, is a geographic descriptive term that is defined as a narrow marine passage connecting two larger bodies of water. The word "strait," therefore, is not a morphological or sedimentary descriptive term and can not be applied to the above sedimentary constructional features (channel structures).

In the introduction of the name "Suwannee Strait," Dall (1892, p. 111, 120-122) described the Suwannee Strait as, "a passage between Florida and the mainland" (p. 121) and noted that the strait was now completely sediment filled. Dall (1892) was unaware of the existence of the Suwannee Channel and Gulf Trough and gave no evidence or clear idea of the existence of the channel system as presently understood. Therefore, in this report the name Suwannee Strait is used in the paleogeographic sense of Dall (1892) as that constricted marine seaway connecting the Gulf of Mexico with the Atlantic Ocean across the eastern panhandle of Florida and southern Georgia (Figs. 49, 50). Typically a strait occurs between two shoals or land masses. The later may have been the case during early Eaglefordian to Austinian (Cenomanian to Santonian), during the Miocene history of the strait, and during the Early Pleistocene high stands of the sea (that produced the high marine terraces in Georgia) between the continental shoreline and the Brooksville Ridge in Florida. However, during much of the history of the Suwannee Strait, the strait was flanked on the north by the continental mainland and on the south by the shallow water expanse of the Florida Bank.

During the history of the Suwannee Strait, the northern margin of the strait remained in the coastal area of the continental mainland of North America whereas the southern margin shifted through time (Fig. 46). During the early part of the Late Cretaceous (Eaglefordian to Austinian), the southern margin of the strait was an island or archipelago on the Peninsular Arch in northeastern Florida (see Applin and Applin, 1967; Babcock, 1969) and has been referred to as the Levy Ranges by Banks (1976a). Later in the Cretaceous (upper Tayloran or Navarroan [upper Campanian or Maastrichtian])

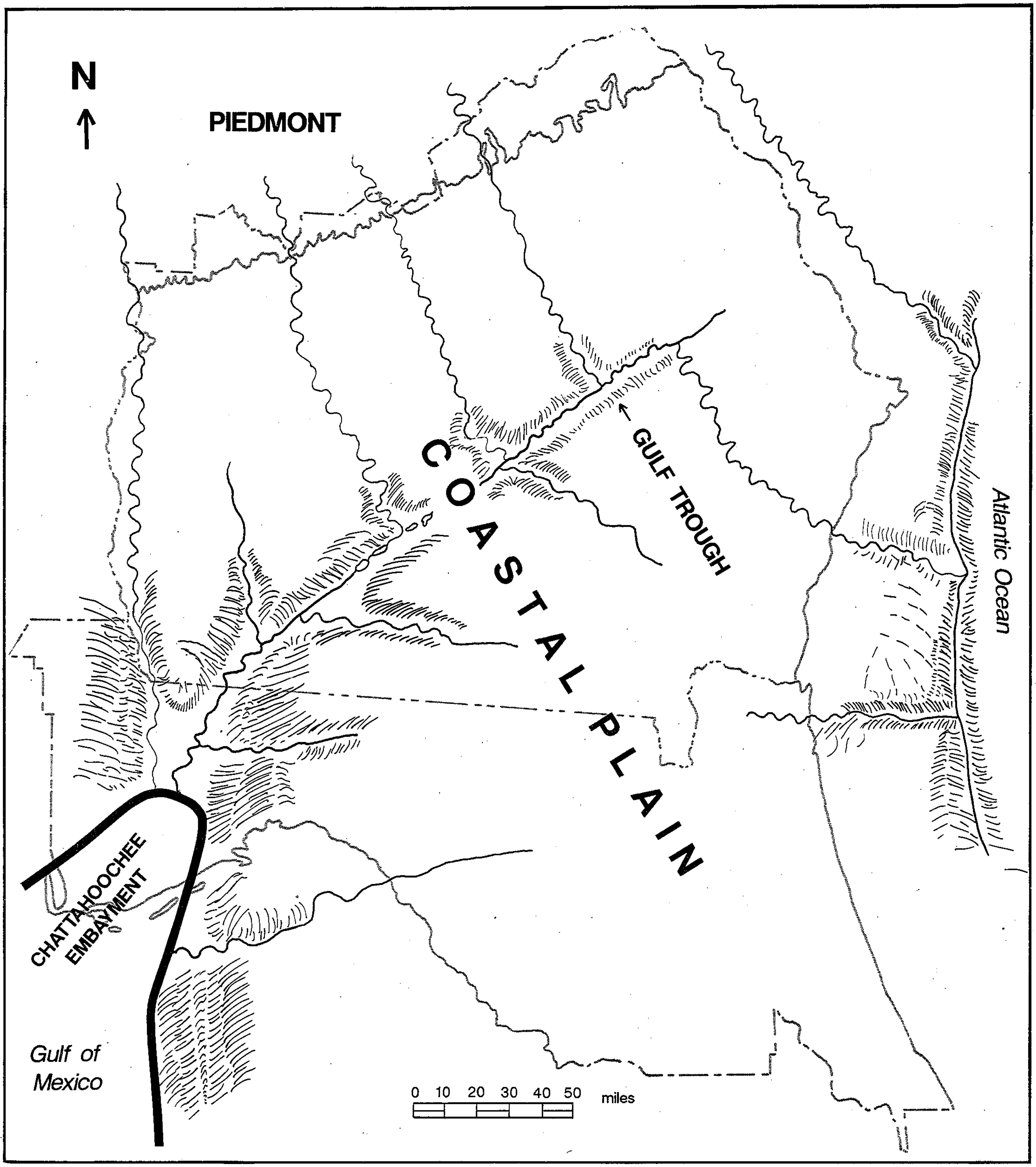

Figure 48. Latest Oligocene paleogeographic reconstruction of the Coastal Plain of Georgia and northern Florida.

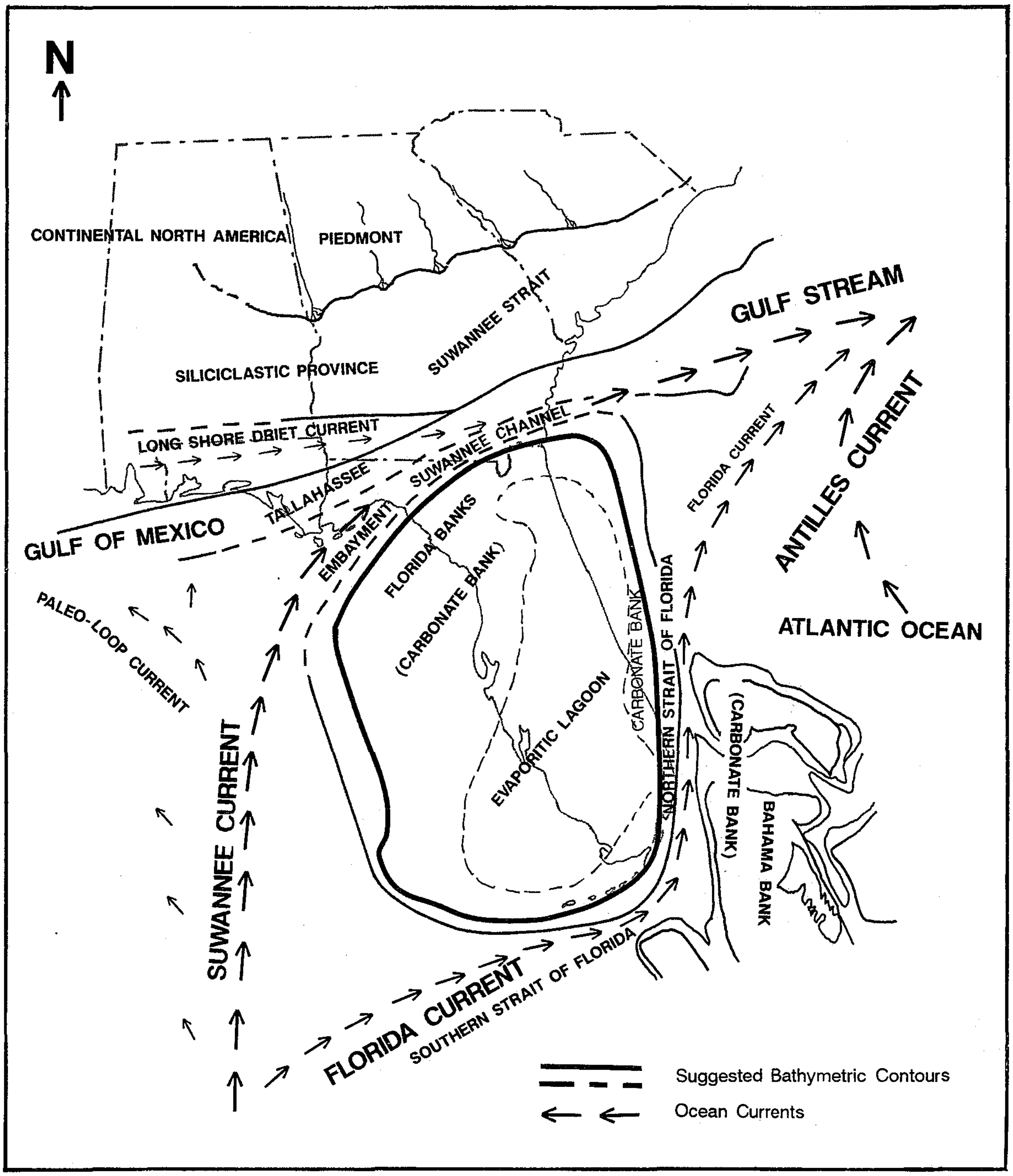

Figure 49. Proposed paleogeography and paleoceanographic current distributions of the Florida and Suwannee Strait Region during the Midwayan highstand of the sea.

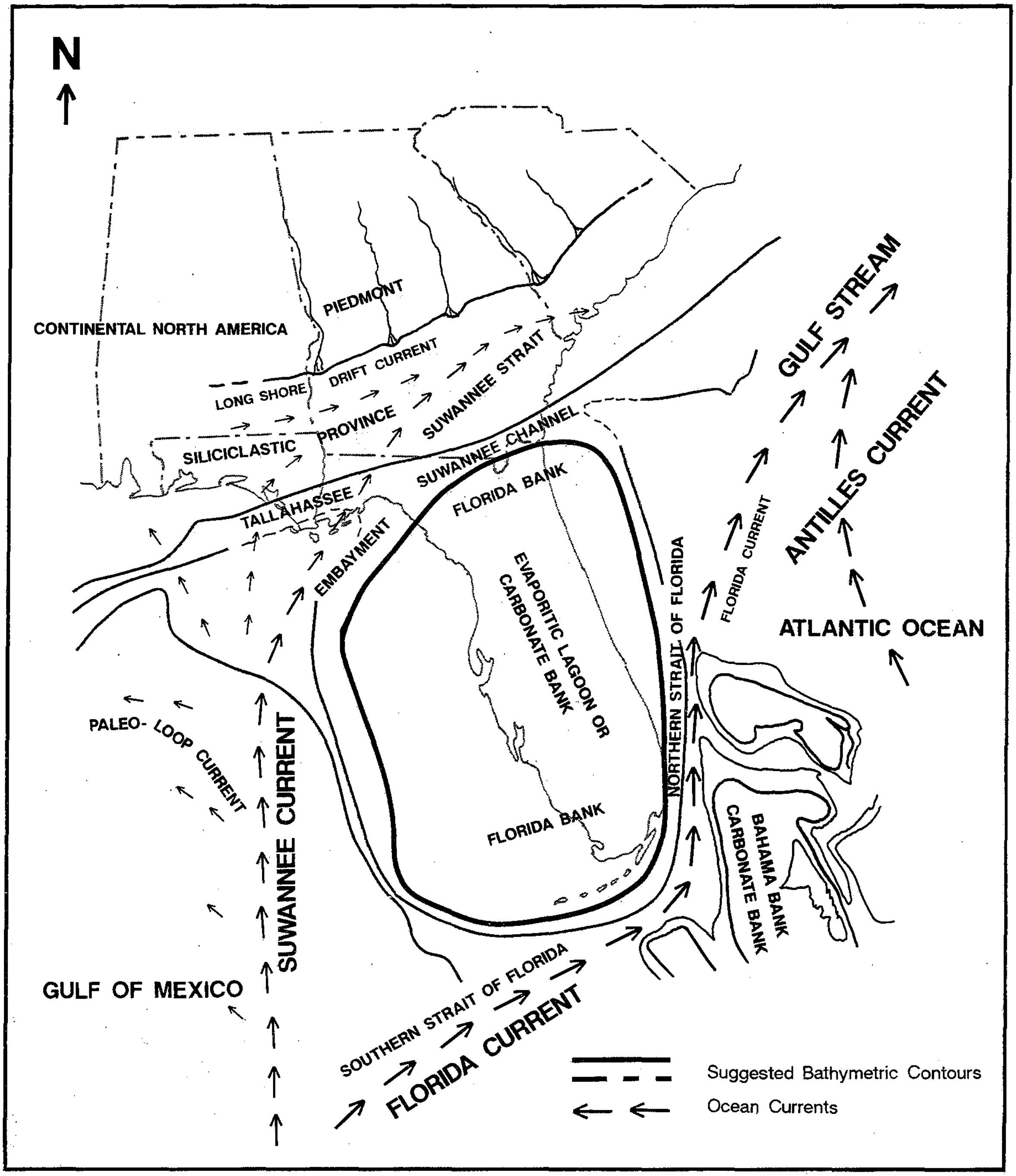

Figure 50. Proposed paleogeography and paleoceanographic current distribution of the Florida and Suwannee Strait region during the Sabinian high stands of the sea.

through Middle Eocene, the southern margin of the Suwannee Strait was the southern margin of the Suwannee Channel and northern bank-edge of the Florida Bank.

During the Late Eocene, most of the Suwannee Strait area and much of the former Florida Bank was combined to form an areally extensive carbonate shelf bisected by the deeper-water Gulf Trough (Figs. 47, 51). However, the site of the former Florida Bank still remained a site of shallower water deposition in peninsular Florida (Carter, 1990). In addition, the proposed refugia of the Tethyan (Caribbean) foraminiferal fauna suggests that a small portion of the Florida Bank continued to exist on the continental shelf off the present coast of the northwestern peninsula of Florida. Therefore, a strait probably still existed in the region during the Late Eocene.

When the Florida Bank became reestablished in peninsular Florida during the late Vicksburgian, due to relative lowering of sea level, the Suwannee Strait as it had existed earlier was not reestablished. In the central Coastal Plain of Georgia, the Florida Bank Suwannee Limestone extended approximately 40 miles (64 km) north of the Gulf Trough and probably extended into the coastal marine area during that time. Therefore, most of the continental shelf that had been the Suwannee Strait briefly became Florida Bank (Fig. 45). During that period of time (deposition of Suwannee Limestone) and later during the Oligocene, the only feature that could be equated with the Suwannee Strait would have been specifically the Gulf Trough. In other words, during these periods of time, the Suwannee Strait would have been confined to the Gulf Trough.

During low sea level stands in the Late Oligocene to the early part of the Middle Miocene, the Suwannee Strait region was a part of the continental mainland to the north and land areas on the former Florida Bank to the south. Thus, a paleo-Florida Peninsula came into existence (Fig. 48). During the Early and early Middle Miocene high stands of the sea, the Suwannee Strait continued to exist as a shallow water seaway in the unfilled Gulf Trough between the continental mainland to the north and a landmass, island, or archipelago in peninsular Florida to the south. After prograding fluvial deposits (Altamaha Formation) filled in and buried the Gulf Trough during the early Middle Miocene, the Suwannee Strait no longer existed, except briefly during the Early Pleistocene.

Atlantic Continental Shelf

This is a vaguely defined belt that roughly parallels the trend of the continental shelf in southern South Carolina and northern coastal Georgia. Oligocene sediments of varying lithologies and depositional environments are present in this area and, locally or regionally, Oligocene sediments are also absent (Fig. 32, 35, 46). Deeper water sediments are present onshore in southern South Carolina and on the continental shelf of Georgia (Cooper Formation). Shallow-water, sandy sediments are present in the northern coastal area of Georgia but correlative sediments are absent in the Port Royal Sound area of South Carolina and in southeastern Georgia and eastern Florida south of Glynn County, Georgia. The stratigraphic variability of the Atlantic coastal and continental shelf area during the Oligocene suggests an environmentally distinct region from that of the continental shelf of the eastern Gulf Coastal Plain, Florida Bank, or Suwannee Strait.

SUWANNEE CURRENT

The Suwannee Current was identified by Huddlestun and others (in manuscript) as a gradient current that was generated by the hydrostatic head between the Gulf of Mexico and the Atlantic ocean. During its entire existence, the Suwannee Current served along with the Florida Current as the major currents passing from the Gulf of Mexico into the Atlantic Ocean (Figs. 49-51). The Suwannee and Florida Currents can be viewed as sibling currents. The Florida Current appears to have come into existence first, probably during the Cenomanian, and is the surviving current. The Suwannee Current seems to have come into existence somewhat later during the Late Cretaceous and is a northward continuation of the paleo-Caribbean Current in the eastern Gulf of Mexico. After passing through the Yucatan Strait, the paleo-Caribbean Current separated into two currents, an eastward flowing current (paleo-Florida Current) that passed through the Straits of Florida into the Atlantic Ocean, and a northward flowing current (Suwannee Current) that flowed into the Atlantic Ocean through the Suwannee Strait. The northern outlet of the Gulf of Mexico, the Suwannee Strait, is thought to be the natural outlet from the Gulf of Mexico for the Caribbean Current because of both the inertia of the moving water mass and the Coriolis effect. However, the northern outlet was more vulnerable to tectonism on the margin of the North American continent, to eustatic falls in sea level, and to sedimentation which ultimately filled the outlet. It was the combination of the last two factors that terminated the Suwannee Current during the Oligocene, leaving the Florida Current as the only current exiting the Gulf of Mexico into the Atlantic Ocean.

The Suwannee Current is envisioned as having occupied that water mass within the upper part of the water column of the marine channels (Suwannee Channel and Gulf Trough) during the Oligocene high stands of the sea (Huddlestun and others, in manuscript). During these high stands, it is thought that the current was not entirely

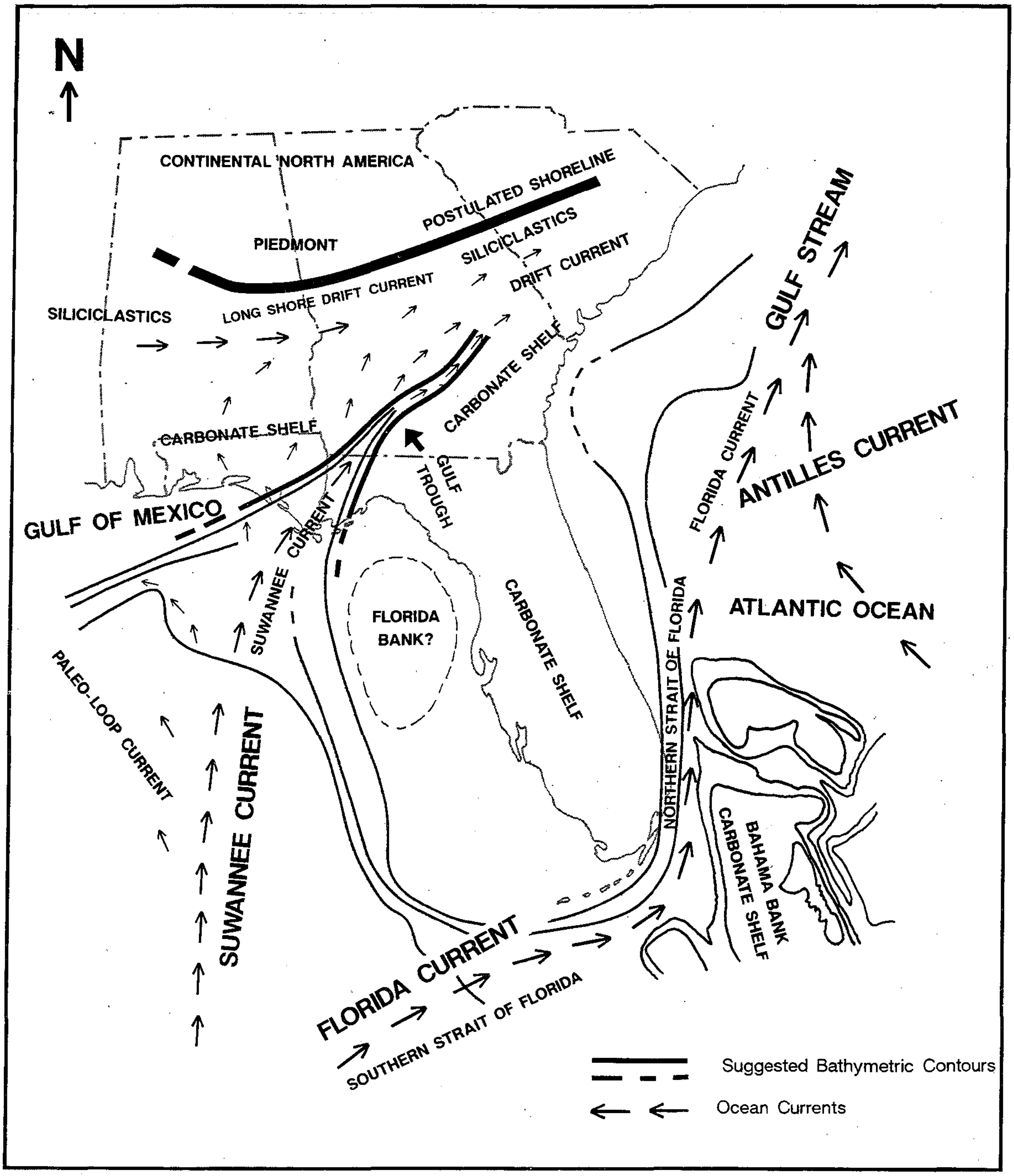

Figure 51. Proposed paleogeography and current distribution of the Florida and Suwannee strait region during the late Jacksonian.

confined to its channel but that the margins of the current also extended some distance beyond the channel proper and may have had some latitude for lateral movement (Fig. 52). During the low stands of the sea, however, the Suwannee Current is envisioned as having been lowered into the channel, confined to the channel or locked in place, thus frequently resulting in nondeposition within the channel or, during more drastic sea level low stands, scouring the floor of the channel (Fig. 51).

OLIGOCENE FAUNAL PROVINCES

Three faunal provinces (or subprovinces) were present in the southeastern Coastal Plain during the Oligocene (Fig. 53). Although the Oligocene faunas characteristic of each province have not yet been so identified in the literature, they are recognized in this report and briefly described. For discussion purposes, the three faunal provinces are referred to as the Gulf of Mexico faunal province, the Atlantic faunal province, and the Florida faunal province. The Gulf of Mexico and the Atlantic faunal provinces were physically connected throughout the Late Cretaceous and Early Tertiary, but were probably faunally distinct because of currents, differing water-masses, and differing substrate on the continental shelf. The Gulf of Mexico and the Atlantic faunal provinces were probably subdivisions of a larger western North Atlantic continental shelf faunal province. The Florida faunal province, on the other hand, was isolated from the other two provinces and appears to have been a subdivision of the Caribbean (or Tethyan) faunal province.

The most thoroughly described of these faunas is that of the continental shelf of the eastern Gulf of Mexico (Gulf of Mexico faunal province) or Gulf Coastal Plain (For Oligocene faunas, see Cushman, 1922a, 1922b, 1923, 1929, 1935; Cushman and McGlamery, 1938, 1939, 1942; Cushman and Todd, 1946, 1948; Cole and Ponton, 1930; Bandy, 1949; Todd, 1952; Poag, 1966; Hazel and others, 1980; Mansfield, 1938, 1940; Dockery, 1982; MacNeil and Dockery, 1984; Cooke, 1942, 1959). The Oligocene foraminiferal fauna of the Gulf of Mexico faunal province in Georgia includes the faunas of the Gulf Trough (and Chattahoochee Embayment)(Bridgeboro Limestone and Ochlockonee Formation) and the Oligocene continental shelf region to the north and west of the Gulf Trough (Marianna and Glendon Limestones).

The Oligocene fauna of the Florida faunal province has not been as well documented as that of the eastern Gulf Coastal Plain (Cole, 1941; Applin and Applin, 1944; Horowitz, 1979; Mansfield, 1937; Hunter, 1972; and Cooke, 1942, 1959) and, therefore, it has not been seen to be faunally distinct. Earlier investigations on the older faunas of the Florida Bank (Applin and Applin, 1944; Applin and Jordan, 1945; Cole and Applin, 1964, Palmer, 1953) indicated that the Middle Eocene Florida Platform fauna was dramatically different from that of the contemporaneous faunas of the continental shelf region in Alabama but was strongly affiliated with the Caribbean (Tethyan) fauna. Palmer (1953) observed that the Avon Park and Inglis mollusks were closely related to the Tethyan faunal province of the Caribbean region and of the eastern hemisphere but unrelated to those of the continental shelf of North America. Evidently the deeper water conditions on the Florida Platform during the Late Eocene terminated most of the Tethyan faunal elements of the Florida faunal province. However, the marine environment in which the Tethyan fauna flourished was partially reestablished during the Oligocene; and, briefly, the remaining faunal elements that had survived the Late Eocene submergence again flourished on the Florida Bank. An additional factor also subdued the faunal differences between the Oligocene continental shelf and Florida Bank. The Florida Bank was continuous with the Atlantic continental shelf in eastern Georgia; and, in the middle Savannah River area, the Florida Bank fauna is the only foraminiferal fauna present (excluding the endemic foraminiferal fauna of the Lazaretto Creek Formation in Chatham County).

The Gulf of Mexico foraminiferal fauna is characterized by *Pararotalia mexicana*. This species is especially abundant in the Chickasawhayan deposits of Mississippi and Alabama. However, it is also present, but rare, in the Vicksburgian Mint Spring and Byram Formations in the eastern Gulf Coastal Plain. In Georgia, *P. mexicana* occurs throughout the Oligocene section. *Pararotalia mexicana* also occurs south of the Gulf Trough in Georgia, but it is less common there, and very rare in Florida (compare with Herrick and Vorhis, 1963, Fig. 5). *Dictyoconus cookei*, on the other hand, is especially characteristic of the Florida faunal province during the Oligocene. It is also found within and on the northern flanks of the Gulf Trough in the central Georgia Coastal Plain, and in the Savannah River region northeast of the trend of the Gulf Trough. Elsewhere it is absent in Oligocene continental shelf deposits.

Among the mollusks, the *Pecten perplanus* stock, *Chlamys anatipes* and *C. duncanensis* are characteristic of Gulf of Mexico faunal province. *Cardium suwanneense*, *Cerithium hernandoensis*, *C. hernandoensis blackwaterensis and Orthaulax hernandoensiss* are characteristic of the Florida faunal province. Curiously, the Oligocene echinoids do not appear to show any substantial tendencies toward province preference (Carter, 1987).

The Atlantic faunal province is less well defined than the other two because of lack of study. The characteristic Atlantic Oligocene foraminiferal suites occur only in the shallow-water Lazaretto Creek Formation in the present coastal area of Georgia, and in the deeper water Cooper Formation in South Carolina and the continental

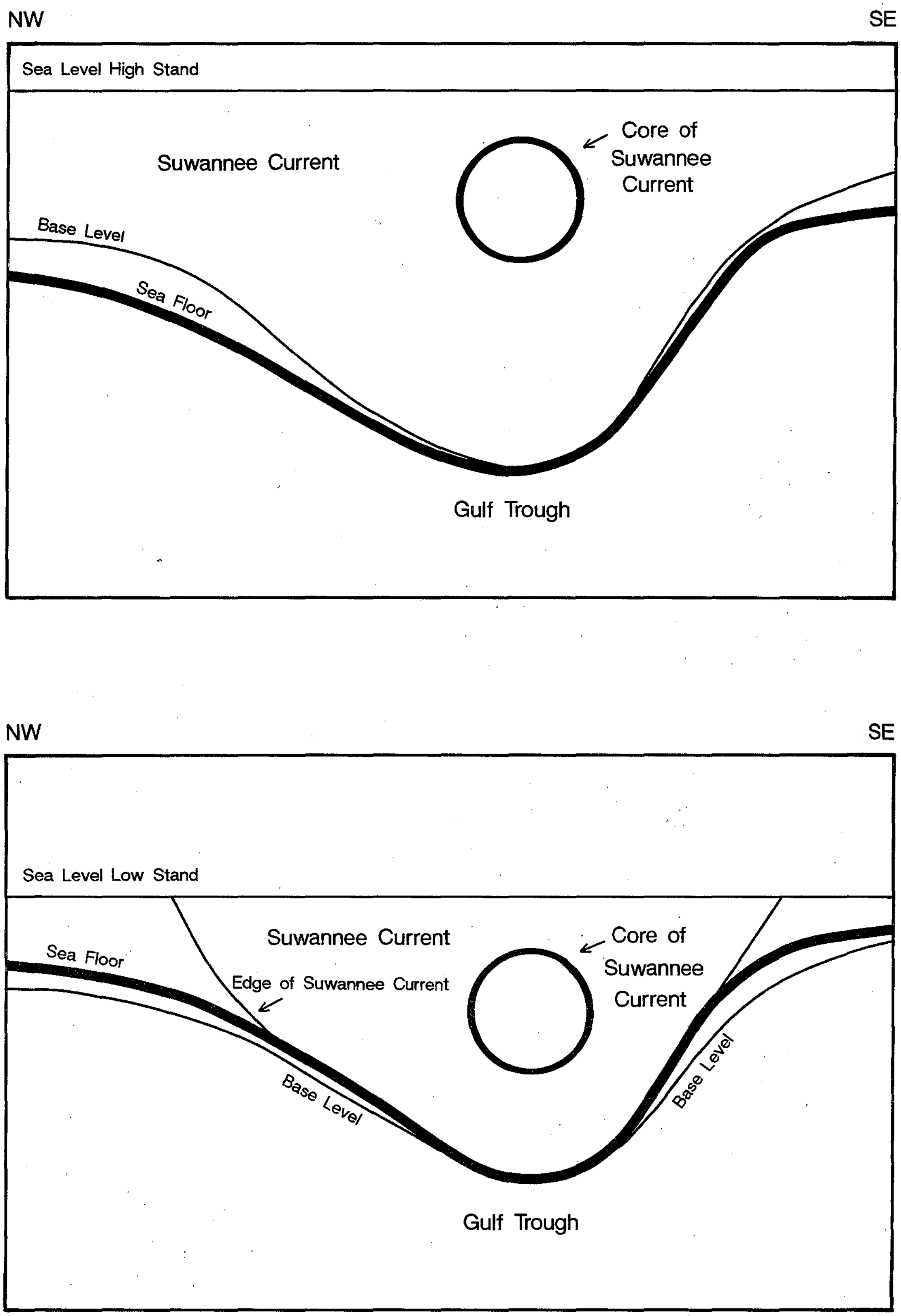

Figure 52. Hypothetical cross-section of the Suwannee Current in the Gulf Trough during the Oligocene high stands and low stands of the sea.

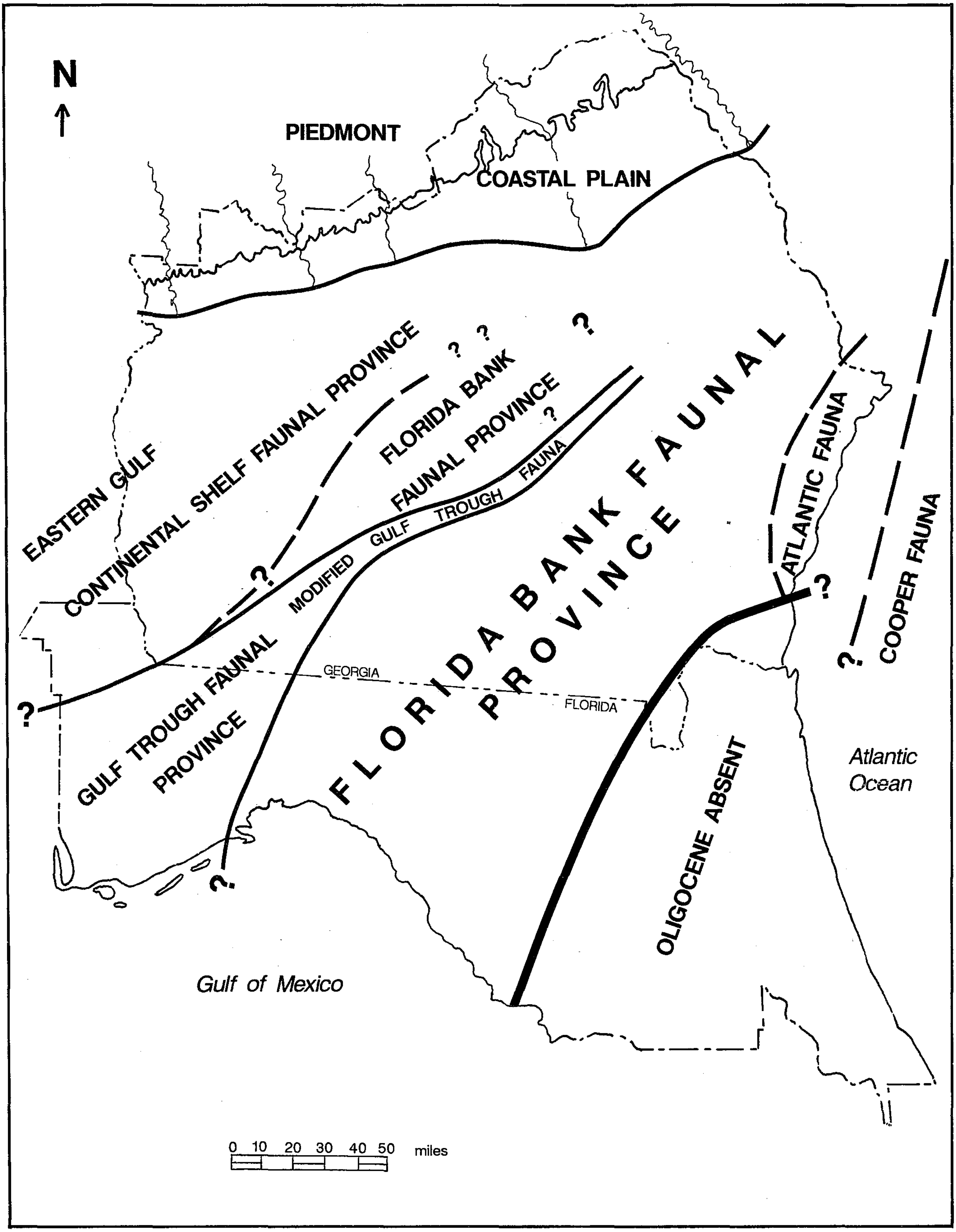

Figure 53. Distribution of Oligocene faunas in the Coastal Plain of Georgia and northern Florida during the deposition of the Suwannee Limestone.

shelf of Georgia. The foraminiferal fauna of the Cooper is relatively deep water (probably outer neritic), but it is distinct from that of the broadly contemporaneous deep-water assemblages in the Ochlockonee Formation in the Gulf Trough in Georgia, and in the Marianna Limestone and Red Bluff Clay in south-western Alabama.

EOCENE / OLIGOCENE BOUNDARY

Two events described here are associated with the Eocene/Oligocene boundary in the southeastern United State and it is not clear which of these two events represents the cosmopolitan Eocene/Oligocene boundary. The first event is a change in the planktonic and benthic foraminiferal fauna that can be traced from Mississippi eastward to Georgia. In terms of planktonic foraminiferal zonation, it marks the zonal boundary between the Late Eocene *Globorotalia cerroazulensis* Zone (*G. cerroazulensis cocoaensis*) and the Early Oligocene *Cassigerinella chipolensis- Pseudohastigerina micra* Zone of Stainforth and others (1975). This boundary is interpreted as representing the standard Eocene/Oligocene boundary in condensed sections. There may also be an associated macrofossil change associated with this event but I have yet to locate a section in which the faunal change occurs with certainty in outcrop or in cores. The only areas that I know of that may contain deposition across this stratigraphic interval is in eastern Mississippi, and the tongue of Shubuta Clay in southwestern Alabama. In Alabama, whatever change in the macro- and microbenthos that may have occurred across that interval would be more deeply influenced by the change in the environment from carbonate shelf bottom to clay mud bottom. Elsewhere, there is no apparent lithologic change across this boundary where I have observed the overlying section.

The second event is a stratigraphic and benthic foraminiferal boundary. The stratigraphic boundary in question is the conventional top of the Eocene lithostratigraphic units in the southeast and, therefore, is arbitrarily defined as the Eocene-Oligocene boundary in this report. In eastern Mississippi this boundary represents the Shubuta Clay/Red Bluff Clay formation boundary; in eastern Alabama and Jackson County, Florida, it represents the Ocala Limestone/Bumpnose Limestone contact. These formation contacts represent the conventional boundary between the Jacksonian Stage and the Vicksburgian Stage. They also represent the conventional change between the relatively deep water, late Jacksonian foraminiferal suites in eastern Mississippi and western Alabama, and the progressively shallower water Vicksburgian foraminiferal suites of the same area. The second event is thought to represent the eustatic low stand event (TA4.4) of Haq and others (1987). However, it should be pointed out that the first event could also have resulted in a shallowing from the typical Shubuta high-stand of the sea. The fauna is compatible with the interpretation that there was a lowering of sea level with the first event in that there appears to be lower faunal diversity in the Shubuta Clay and Ocmulgee Formation above the event. However, it is not clear whether the sea level fall that appears to have initiated the first event continued into the second event, or whether there were two very closely spaced falls in sea level, the second being the greater and correlated with TA4.4. Whichever the case, the two events described here that are associated with the terminal Eocene event in the southeast may appear as one event in condensed sections.

It is stressed that there are no clear, regional lithostratigraphic changes associated with the lower boundary. At the Red Bluff type locality at Hiwannee, Mississippi, the underlying Shubuta Clay is of characterisitic Shubuta lithology although its planktonic foraminiferal composition is that of the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone. A similar situation prevails in the central Georgia Coastal Plain where all of the Ocmulgee Formation in the near vicinity of Hawkinsville, Pulaski County, Georgia, is correlated with the Shubuta section at Hiwannee, Mississippi. That is, all of the Ocmulgee Formation exposed at and in the subsurface near Hawkinsville represents Ocmulgee Formation of the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone. Virtually identical Ocmulgee Formation is exposed northwest of Hawkinsville (Stop 5 of Huddlestun and others, 1974) that contains a typical benthic and planktonic foraminiferal suite of the *Globorotalia cerroazulensis* Zone. In the near vicinity of Hawkinsville, however, no Ocmulgee Formation has yet been identified that contains a *G. cerroazulensis cocoaensis* Zone planktonic foraminiferal suite.

Eastward from eastern Mississippi through western Alabama, the hiatus between the top of the Jacksonian and the overlying Vicksburgian contains progressively more missing section. The upper section of Shubuta Clay at St. Stephens Quarry and Little Stave Creek appears to contain the boundary "zone" of the *G. cerroazulensis* Zone and *Cassigerinella chipolensis-Pseudohastigerina micra* Zone; but this zone as well as the Shubuta Clay thins progressively eastward. In the vicinity of Claiborne Bluff on the Alabama River, the Vicksburgian directly overlies Late Eocene carbonates that are lithologically transitional between the Shubuta Clay and the Ocala Limestone and which contain a planktonic foraminiferal suite of the C. cerroazulensis cocoaensis Zone. This stratigraphic sequence also prevails along the Conecuh and Sepulga Rivers in Covington and Conecuh Counties, Alabama (Huddlestun and Toulmin, 1965; Huddlestun, 1965), and in Jackson County, Florida, where the lower Vicksburgian Bumpnose Limestone disconformably overlies Ocala Limestone containing a *G. cerroazulensis cocoaensis* Zone planktonic foraminiferal fauna.

The stratigraphy is more complex in the Hawkinsville, Georgia, area, where the occurrence of the *C. chipolensis-P. micra* Zone of the Ocmulgee Formation is the only known occurrence of that zone within the Ocmulgee Formation. All other known planktonic foraminiferal suites from the Ocmulgee Formation are compatible with the *G. cerroazulensis cocoaensis* Zone and not with the *C. chipolensis-P. micra* Zone.

In summary, two events are recognized to be related to the Eocene\Oligocene boundary in the moderately extended (thickened) sections in the southeastern United States. The first and older appears to be largely a biostratigraphic event that contains the planktonic foraminiferal zone boundary between the *G. cerroazulensis cocoaensis* Zone and the *C. chipolensis-P. micra* Zone. Some benthic foraminiferal changes are also noted as occurring with this event, and other faunal changes may also to occur with it.

Planktonic foraminifera that do occur above this first biostratigraphic event include the following:

Globorotalia cerroazulensis cocoaensis
Hantkenina alabamensis
Cribrohantkenina inflata

Common benthic foraminifera that are not known to occur above this biostratigraphic event include the following:

Bulimina jacksonensis
Uvigerina cocoaensis (in outcrop)

Bulimina sculptilis is a common benthic foraminifer that consistently occurs above this event but is not known to occur below it.

The second, younger event is a lithostratigraphic boundary, a stage boundary, and a biostratigraphic (benthic foraminiferal) boundary. Common benthic foraminifera that are not known to occur above the second biostratigraphic event include the following:

Planulina cooperensis
Uvigerina jacksonensis
Marginulina cocoaensis

Common benthic foraminifera that are not known to occur below the second biostratigraphic event include the following:

Lenticulina vicksburgensis
Uvigerina vicksburgensis
Planulina vicksburgensis
Bolivina caelata
Cibicides cookei

It is not the function of this report to fully address the problem of the Eocene\Oligocene boundary in the southeastern United States. Therefore, the conventional Eocene\Oligocene boundary of the region that occurs at the Shubuta/Red Bluff contact is that which is arbitrarily adopted here (Pl. 1).

CORRELATION OF OLIGOCENE STRATIGRAPHIC UNITS, SEQUENCE STRATIGRAPHY, AND PALEOGEOGRAPHY ACROSS GEORGIA AND NORTHERN FLORIDA

Introduction

Near the end of the Eocene, the shoreline of Georgia lay directly on crystalline rocks of the Piedmont north of the present Fall line. Both because the lithology of the Upper Eocene deposits along the Fall line become progressively more marine in character westward in Georgia, and due to the presence of outliers of Barnwell Group on the Piedmont near Sparta in Hancock County and at the Fall line at Rich Hill in Crawford County, it is suggested that the shoreline at the end of the Eocene may have trended obliquely to the present Fall line, being oriented more east-west. As a result, in western Georgia the shoreline at the end of the Eocene may have been as far north as the vicinity of Pine Mountain in Meriwether and Harris Counties (Fig. 51).

Because the uppermost Eocene deposits (Ocala Limestone) contain a rich and diverse biota, it is inferred from the present study that they were deposited within the photic zone in water depths probably not much greater than 200 feet (61 m) and possibly less (also see Cheetham, 1963, p. 31-33). Haq and others (1987) have estimated a eustatic sea level drop of about 165 feet (50 m) at the end of the Eocene. A sea level drop of roughly 165 feet (50 m) would have caused a significant seaward retreat of the shoreline and left much of the continental shelf covered by very shallow water. The Suwannee Current during this low-stand would have been entirely confined to the Gulf Trough.

This scenario is supported by the common occurrence of dolomitization near the top of the Ocala Limestone south of the Gulf Trough and the less common occurrence of intraclastic or brecciated dolostone at the top of the Ocala Limestone in cores from southernmost Georgia. Within the Gulf Trough, either dolomitization occurs at the top of the Eocene or there is a sharp disconformity at the top of the Eocene below a basal Ochlockonee phosphatic zone. The disconformity at the top of the Eocene section within the Gulf Trough is consistent with the Suwannee Current having been lowered into and confined to the trough at the end of the Eocene, resulting in a lowered baselevel and and nondeposition or scour within the trough. Dolomitization at the Eocene-Oligocene boundary within the Gulf Trough may be explained by the influx of chemically abnormal sea-water flowing into the trough as density currents from the very shallow water expanse of continental shelf adjacent to the Gulf Trough.

The position of the shoreline and the paleogeography of the Georgia Coastal Plain during the terminal Eocene, low stand of the sea can only be approximated in this report (Fig. 54). There is no record of any coastal marine deposits known to be associated with this eustatic low stand of the sea, and the apparent absence of the Bumpnose-Red Bluff sequence in Georgia combines to eliminate any possibility at this time of precisely identifying either of these geographic features.

The beginning of the Oligocene Epoch as recognized in this report commenced with the rise in sea level after the abrupt eustatic fall in the sea that is interpreted to be TA4.4 of Haq and others (1987). Baum and Vail (1988, Mancini and Tew, and Tew and Mancini (1992) have argued that the Eocene/Oligocene boundary in the eastern Gulf coastal Plain is a condensed section produced by a high stand of the sea rather than an erosional or nondepositional disconformity. They place the Lower Oligocene Forest Hill Formation and Red Bluff Clay within their Upper Eocene TE3 sequence. Dockery (1990) and Coleman and Galloway (1990) have presented evidence that the Eocene/Oligocene boundary does indeed represent an unconformity. My observations are compatible with those of Dockery (1990) and Coleman and Galloway, 1990).

After this terminal Eocene low stand of the sea, there was a succession of four progressively lower high stands of the sea during the Vicksburgian. These high stands were punctuated by progressively more severe but brief low stands of the sea that were unrecorded by Haq and others (1987) (Pl. 1). With the low stand of the sea at the close of the Vicksburgian Stage (probably TA4.5 of Haq and others, 1987), it is likely that even the floor of the Gulf Trough was subaerially exposed. It is interpreted here that the progressively falling sea level, with progressively more severe low stands of the sea during the Oligocene, culminated in the reduction and final termination of the Suwannee Current and initial filling of the Gulf Trough. Although there is evidence that the Suwannee Current was severely diminished as a gravity current at the end of the Eocene, there also is evidence that the Suwannee Current, in a progressively diminishing state, continued to occupy the Gulf Trough during the high stands of the sea through the duration of the Vicksburgian.

Oligocene deposits appear to be slightly regressive in relation to the Upper Eocene deposits in Alabama and in Georgia. However, no Oligocene sediments have yet been identified in the near vicinity of the Fall line in Georgia. The known updip limits of Oligocene deposits in Georgia, most of which consists of residuum in outcrop, occur between 20 and 30 miles (32 to 48 km) south of the Fall line and along a line from the Screven-Burke Counties line on Brier Creek in the east, through northern Emanual County, northern Laurens County, to southern Twiggs and Houston Counties in the west (Fig. 10). This Oligocene residuum is overlapped by fluvial deposits of the earliest Miocene, Aquitanian, Altamaha Formation (Huddlestun, 1988) from western Screven County in the east to the vicinity of the Oconee River in the west. In that area, the updip limits of the Oligocene occur in the subsurface. Farther updip, the Altamaha Formation directly overlies the Upper Eocene, Barnwell Group in outcrop. In eastern Georgia, the Oligocene outcrop belt occurs only in northern and eastern Screven County (Figs. 10 and 32).

In central Georgia from northern Laurens County to Houston and Pulaski County (also see Pickering, 1970), however, either the Altamaha Formation or Hawthorne Group deposits directly overlie deeply weathered Oligocene deposits or residuum. North of this there is no information because both the Altamaha and Oligocene have been removed by late Tertiary or Quaternary erosion.

In western Georgia, the northern limit of Oligocene residuum extends southwestward through Sumter to northern Randolph Counties (Fig. 10). Residuum that may include Oligocene material occurs as far north in western Georgia as the vicinity of Preston in Webster County and Buena Vista in Marion County (Georgia Geological Survey, 1976).

Except for the coastal area during the Oligocene, most of the Suwannee Strait region remained within the carbonate deposition province. In contrast to the preceding Late Eocene, however, the Gulf Trough during the Oligocene exerted a profound influence on the carbonate sediment distribution patterns in the Suwannee Strait region. The Vicksburg Group and its offshore stratigraphic equivalent, the Florala Limestone Member of the Bridgeboro Limestone, are restricted to the continental shelf region north and west of the Gulf Trough. A different suite of formations, typically exposed along the Suwannee River in Florida, is restricted to the shallow shelf region south of the trough. The Gulf Trough, on the other hand, contains a unique suite of formations that initially were of relatively deep water origin. However, as the Gulf Trough filled with sediment and sea level concurrently dropped late in the Vicksburgian, the younger formations were deposited in progressively shallower water. A rhodolithic limestone, the Bridgeboro Limestone, occurs on both flanks of the Gulf Trough in southwestern Georgia, but is more prominently developed on

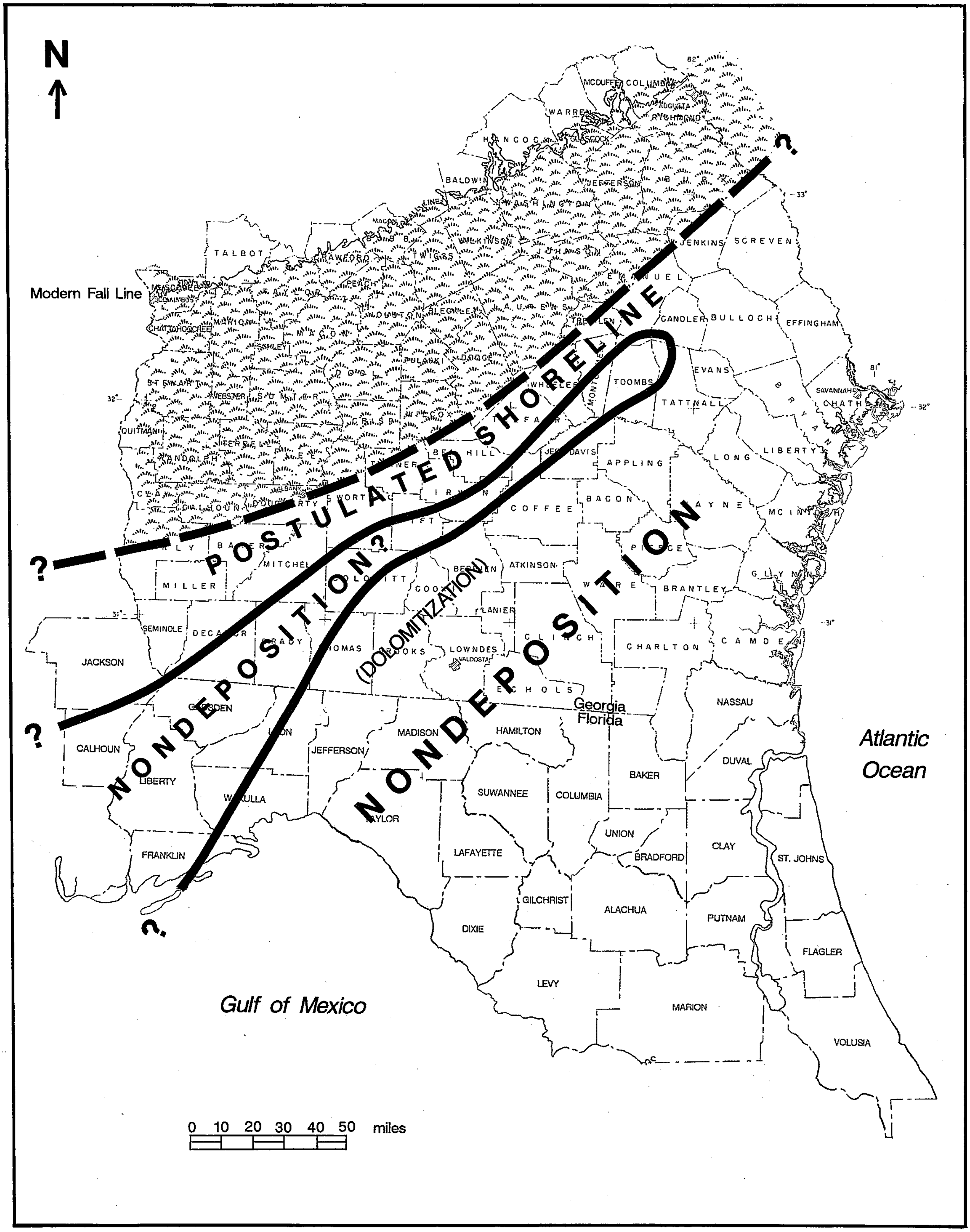

Figure 54. Paleogeographic reconstruction of Georgia and northern Florida during the terminal Eocene low stand of the sea.

the north side of the trough.

Because all of the nearshore Oligocene sediments consist of limestones, clayey residuum with silicified limestone, or fine-grained siliciclastics (clay and fine-grained sand), it is suggested that the Piedmont rivers during the Oligocene were near geomorphic base-level and were not undergoing incision into fresh country rock. The lithology of the updip Oligocene deposits is compatible with only mild erosion of saprolite (i.e., minor influx of siliciclastic sediments). According to this model, then, at the beginning of the Oligocene much of the Georgia Coastal Plain was part of the continental shelf (Fig. 54), and either there was no coastal plain at that time or it consisted at the most of a narrow, marshy, swampy plain between the topographically subdued Piedmont to the north and the open ocean to the south.

As with the underlying Upper Eocene, there are no discernable systematic lithologic differences between the Oligocene formations on the site of the Middle Eocene and older Florida Bank and the same formations on the site of the former Suwannee Channel. Therefore there were only minor bathymetric or other environmental differences between the sites of the former Suwannee Channel and the Florida Bank region to the south.

The diminishing of the Suwannee Current after the Eocene is indicated from two other lines of reasoning. (1) During the Middle and Late Eocene, deposits within the Gulf Trough were thin compared with correlative deposits outside of the trough. In contrast, the Oligocene is very thick within the Gulf Trough compared with the thickness of the Oligocene outside of the trough. (2) The deposits within the Gulf Trough consist of thick accumulations of finely granular, foraminiferal limestone and minor dolostone. In the vicinity of the Florida state line, the Oligocene fill in the trough is approximately 1000 feet (305 m) but thins rapidly northeastward in the trough (Pl. 2). From Colquitt County to Jeff Davis County the Oligocene channel fill averages about 400 to 500 feet (122 to 152 m) but in Toombs County it has thinned to less than 400 feet (122 m). The main part of the Oligocene channel-fill, the Ochlockonee Formation, ranges from near 300 feet (91 m) in Coffee County, thins to a little more than 250 feet (76 m) in the vicinity of the Peninsular Arch in Berrien County, thickens to almost 400 feet (122 m) in Colquitt County, and then thickens to almost 900 feet (274 m) near the Florida-Georgia state line. The Ochlockonee Formation may be as thick as 1200 feet (366 m) in Gadsden County, Florida. Evidently the Gulf Trough served as a basin that was rapidly filled with deep-water, fine-grained carbonates during the Early Oligocene. If the Suwannee Current had not weakened significantly but remained a strong current as during the latest Eocene, the accumulation of deep-water carbonates during the Early Oligocene would have been impeded.

Depositional history

In this report, the Oligocene Series is divided into five depositional sequences or phases that were deposited during eustatic high stands of the sea (Pl. 1). These high stand deposits are separated from each other either by disconformities or by dolostones postulated to have been deposited during low sea level events. The depositional sequences (or stratigraphic intervals) include from oldest to youngest:

Disconformity or paraconformity on top of Ocala

1) Bumpnose-Red Bluff-Forest Hill depositional sequence

Post-Bumpnose-Red Bluff hiatus-Paraconformity

2) Ellaville-Marianna-Mint Spring-Glendon depositional sequence

Disconformity or gradation - Suwannacoochee low stand of the sea

3) Suwannee-Byram depositional sequence

Disconformity or gradation - Wolf Pit low stand of the sea

4) Okapilco-Bucatunna depositional sequence

Disconformity - post-Vicksburgian low stand of the sea

5) Chickasawhay depositional sequence

Disconformity - post-Chickasawhay low stand(s) of the sea

The following discussion will be based on correlation of all other formations with these standard, provincial Vicksburgian and Chickasawhayan formations. It is noted here, however, that the interpretations by Dockery (1982), MacNeil and Dockery (1984), and Dockery (pers. com., 1992) of the contract relationships of the Marianna/Glendon Limestones through the rest of the younger Vicksburgian in Mississippi is diametrically opposed to those interpretations of the correlative sections presented in this report. That is, in the Mississippi Vicksburgian section, the Marianna/Glendon contact is perceived to be disconformable whereas the Glendon/Byram and Byram/Bucatunna contacts are perceived as being gradational and conformable. We have no explanation for these differences in interpretations at this time.

Bumpnose-Red Bluff-Forest Hill depositional sequence

There are no known deposits outside of the Gulf Trough in Georgia that are thought to be correlative with the Red Bluff Clay of Mississippi and Alabama or the Bumpnose Limestone of Alabama and Florida. The Ocala-like (but glauconitic) Bumpnose Limestone has not been found in Georgia. Georgia deposits that are closest in age to the Red Bluff, outside of the Gulf Trough, are the Ocmulgee Formation in the vicinity of Hawkinsville (which is interpreted to be youngest Jacksonian but within the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone) and the overlying, middle Vicksburgian Marianna Limestone. The apparent absence of the Bumpnose-Red Bluff stratigraphic interval on the continental shelf in Georgia is problematic. Although it is interpreted that the basal Oligocene, Red Bluff stratigraphic interval is off-lap of the latest Eocene, Shubuta high stand of the sea in the southeastern United States, the Marianna/Glendon depositional sequence commonly is interpreted to be off-lap of the Red Bluff depositional sequence. However, the Marianna and Glendon Limestones are both present in central Georgia where the Bumpnose or Red Bluff-equivalent is absent.

One possible interpretation is that the Marianna-Glendon depositional sequence is on-lap to that of the Red Bluff. That is, the Bumpnose-Red Bluff high stand of the sea neither equaled that of the previous Shubuta high stand nor that of the subsequent Ellaville-Glendon high stand. This is a valid interpretation across Mississippi as far east as St. Stephens Quarry in southwestern Alabama, where the open marine, continental shelf Mint Spring Formation or Marianna Limestone overlies the coastal marine or deltaic Forest Hill Sand or the relatively near-shore Red Bluff Clay with apparent disconformity.

However, farther east in Alabama, the correlative Bumpnose-Red Bluff carbonates contain an apparently deeper water and more diverse benthic foraminiferal fauna than that of the overlying Marianna or Glendon Limestones. This is consistent with the occurrence of a 15 feet (4.6 m) thick bed of *Lepidocyclina*-rich dolostone in the Bumpnose, stratigraphically between the underlying Ocala Limestone and the overlying Marianna Limestone in the interval 133 feet to 150 feet in the Florida Geological Survey core Duncan Church 1 (W-11487) from Washington County, Florida. The Red Bluff-Bumpnose is also consistently thin in outcrop across Alabama, averaging roughly 15 feet (4.6 m) in thickness. This is consistent with the thickness of the dolostone interval in the Duncan Church core. The underlying Upper Eocene deposits and overlying Marianna Limestone are considerably thicker than the Red Bluff-Bumpnose depositional sequence in Alabama and Florida (Huddlestun, 1965; Huddlestun and Toulmin, 1965; Huddlestun, 1966).

It is noted here that there was a siliciclastic pulse of sedimentation associated with this depositional sequence. It is not likely that the Forest Hill Sand represents strictly an off-lap, nearer shore sedimentary event because as far east as the Gulf Trough, all deposits of the Bumpnose-Red Bluff-Forest Hill depositional sequence are more sandy, argillaceous, or glauconitic than that of the underlying and overlying deposits. It is, therefore, interpreted here that the siliciclastic sedimentary pulse is real, and that the Mint Spring Formation and the lower glauconitic part of the Marianna Limestone in western Alabama represents the middle Vicksburgian fading of this event.

As a result of the above discussion, the working model in this report is that the Bumpnose-Red Bluff-Forest Hill depositional sequence is off-lap of the underlying Upper Eocene deposits (also see Dockery, 1990), and the middle Vicksburgian Ellaville-Marianna-Glendon deposition sequence is off-lap of the Forest Hill-Red Bluff-Bumpnose depositional sequence. This is consistent with the lithology of the Bumpnose Limestone resembling more the lithology of the underlying Ocala Limestone and the offshore, Vicksburgian Florala Limestone than that of the overlying Marianna Limestone.

Georgia is relatively more tectonically stable than the eastern Gulf Coastal Plain and has experienced less subsidence and contains fewer stratigraphic intervals in the geologic column than that of western Florida, Alabama, and Mississippi (see Huddlestun and others, 1988, Huddlestun and others, in manuscript). It is suggested, therefore, that the continental shelf of Georgia during the Bumpnose-Red Bluff-Forest Hill depositional sequence may have been a surface of sedimentary bypass, that the shelf bottom occurred within the zone of base-level oscillation and the shelf floor was often swept by currents (Fig. 55). The working model of this report is that the Suwannee Current was severely reduced after the terminal Eocene event and was again reduced after the Forest Hill-Red Bluff-Bumpnose depositional sequence. The current velocities on the shallower Georgia continental shelf during the period in question may have been sufficient to impede sedimentation on the shelf. However, with the subsequent decline in the Suwannee Current, the currents on the Georgia continental shelf were insufficient to impede sedimentation. This is consistent with the absence of planktonic foraminifera in the Marianna and Glendon Limestones in Georgia in contrast to their abundance in the same formations in western Florida and Alabama.

The depositional situation was probably different within the Gulf Trough and deeper water Florida Platform farther south. The lower part of the Ochlockonee Formation in the Gulf Trough is the most argillaceous part of the formation and contains a foraminiferal fauna that is largely compatible with that of the deeper water facies of the calcareous "Red Bluff" in southwestern Alabama. The continued occurrence, however, of the Jacksonian *Uvigerina cocoaensis* in the lower Ochlockonee

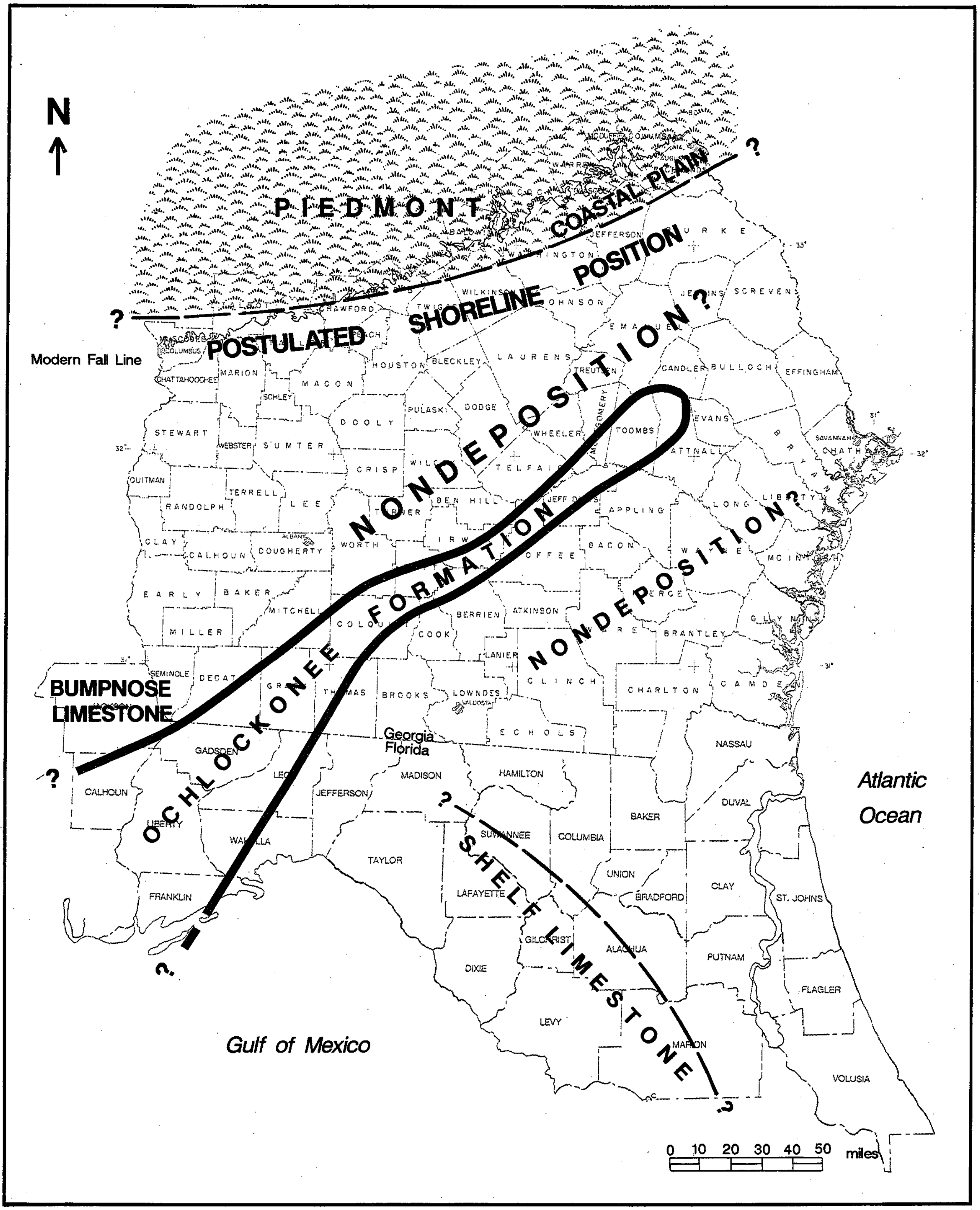

Figure 55. Paleogeographic reconstruction of Georgia and northern Florida during the Bumpnose-Red Bluff-Forest Hill depositional sequence.

Formation appears anomalous until it is noted that the lower part of the Ochlockonee Formation represents an unusually deep water Coastal Plain deposit, even deeper water than that of the Shubuta Clay in Mississippi and Alabama. In addition, the outer neritic Vicksburgian under the outer continental shelf of Georgia (cores AMCOR 6002 and TACTS cores A-D, F) contains this species in addition to other typical deep-water Vicksburgian benthic foraminifera and a planktonic foraminiferal suite of the *Cassigerinella chipolensis-Pseudohastigerina micra* Zone. It is concluded here that the benthic foraminifer *U. cocoaensis* did not become extinct after the Jacksonian, but only during the late Jacksonian were water depths on the continental shelf sufficiently deep for this species to briefly colonize much of the shelf floor of the southeastern North American continental margin. After Jacksonian time, the species withdrew toward the outer shelf where deeper water conditions prevailed. The geographic range of this species on the continental shelf during the Oligocene was possibly more restricted because of progressively shallower water conditions on the continental shelf and a consequent narrowing of the shelf.

Similarly, it is likely that the basal Oligocene, Bumpnose-Red Bluff-Forest Hill depositional sequence is present farther south on the Florida Platform. Because the limestone lithology of this interval is elsewhere similar to that of the underlying Ocala, the Bumpnosee-Red Bluff-Forest Hill depositional sequence of peninsular Florida may not have been differentiated lithostratigraphically from that of the underlying Ocala Limestone (see Banks, 1976b; Hunter, 1976).

It would appear that with the first high stand of the sea during the Oligocene (Bumpnose-Red Bluff-Forest Hill depositional sequence), the water depth in the Gulf Trough may have been sufficiently deep to still accommodate a gradient current in the Gulf Trough. However, as with the earlier reduction in the Suwannee Current at the end of the Midwayan (Huddlestun and others, in manuscript), the reduction of the Suwannee Current at the end of the Eocene was a one way event. When the inertia of the augmented Florida Current became established during the low stand of the sea at the end of the Eocene, additional water was not quickly diverted through the Suwannee Strait with the following high stand of the sea. Evidently the Suwannee Current had been so reduced by the terminal Eocene low stand of the sea that it could no longer exist as a strong gradient current.

Once sea level had risen during the earliest Oligocene and the Suwannee Current was no longer confined by the flanks of the Gulf Trough, the current appears to have risen out of the confines of the marine channel, and spread out as a shallow, broad current (Fig. 56a and 56b). Thick deposits of relatively deep water, argillaceous, foraminiferal carbonates appear to have been deposited in the Gulf Trough at this time. It is not clear to what extent the Suwannee Current may have existed as a small gradient current or was in part a drift current. There does not appear to have been a reduction in hydrostatic head between the Gulf of Mexico and Atlantic Ocean at the end of the Eocene because any change in head would also have had a similar impact on the Florida Current. However, there is no evidence of a reduction of the Florida Current on the Blake Plateau at the end of the Eocene (Popenoe, pers. com., 1991). Therefore it is concluded that during the early and middle Vicksburgian (Red Bluff through Glendon deposition), the Suwannee Current continued to flow across the Suwannee Strait area as a further reduced gradient or drift current.

Post-Bumpnose-Red Bluff hiatus

A eustatic low stand of the sea is postulated to separate the Red Bluff depositional sequence from that of the overlying Marianna-Glendon. At numerous localities in Alabama and northwestern Florida, the Marianna Limestone overlies the Bumpnose Limestone or Red Bluff-equivalent carbonates with a marked discontinuity and lithologic change. Because there are no known Red Bluff-equivalent deposits outside of the Gulf Trough in Georgia, the position of the strand line in the Suwannee Strait area during this low stand of the sea can only be conjectural (Fig. 57). It is possible that the low stand of the sea that terminated the Red Bluff-Bumpnose depositional sequence may have been as low as that of the preceding terminal Eocene low stand. If so, the strand line of this low stand probably would have occurred somewhere between Hawkinsville, Georgia, and the northern flank of the Gulf Trough.

It is expected that the Suwannee Current would have been strictly confined to the Gulf Trough again at this low stand of the sea and one would expect to find a physical discontinuity within the lower part of the Ochlockonee Formation within the trough. However, there is no indication of a sedimentation break within the lower part of the Ochlockonee Formation within the deeper parts of the Gulf Trough.

On the other hand, on the northern margin of the trough in northwestern Colquitt County in the Georgia Geologic Survey core Colquitt 11 (GGS-3545), there is a marked disconformity at 490 feet that may represent the low stand of the sea between the Bumpnose-Red Bluff-Forest Hill depositional sequence and the Ellaville-Glendon-Marianna-Mint Spring depositional sequence (see McFadden and others, 1986, p. 333-223). Typical dolomitized Ochlockonee Formation occurs above this discontinuity and the basal few feet of the unit is phosphatic and glauconitic. The lithology of the underlying limestone is not typical Ochlockonee and is chalky and

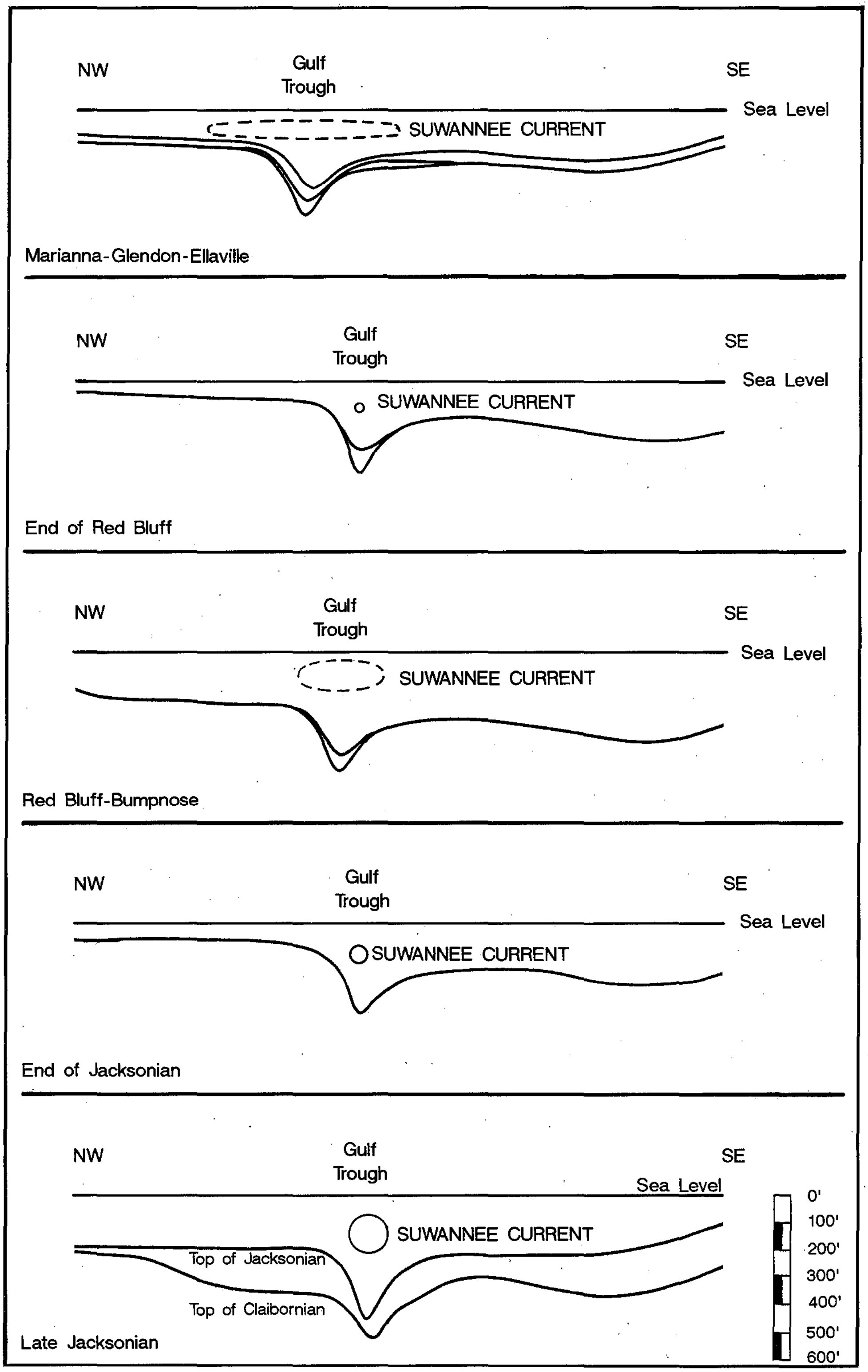

Figure 56a. Model of sequential diminishing and termination of the Suwannee Current in the Gulf Trough from the latest Eocene through the Oligocene.

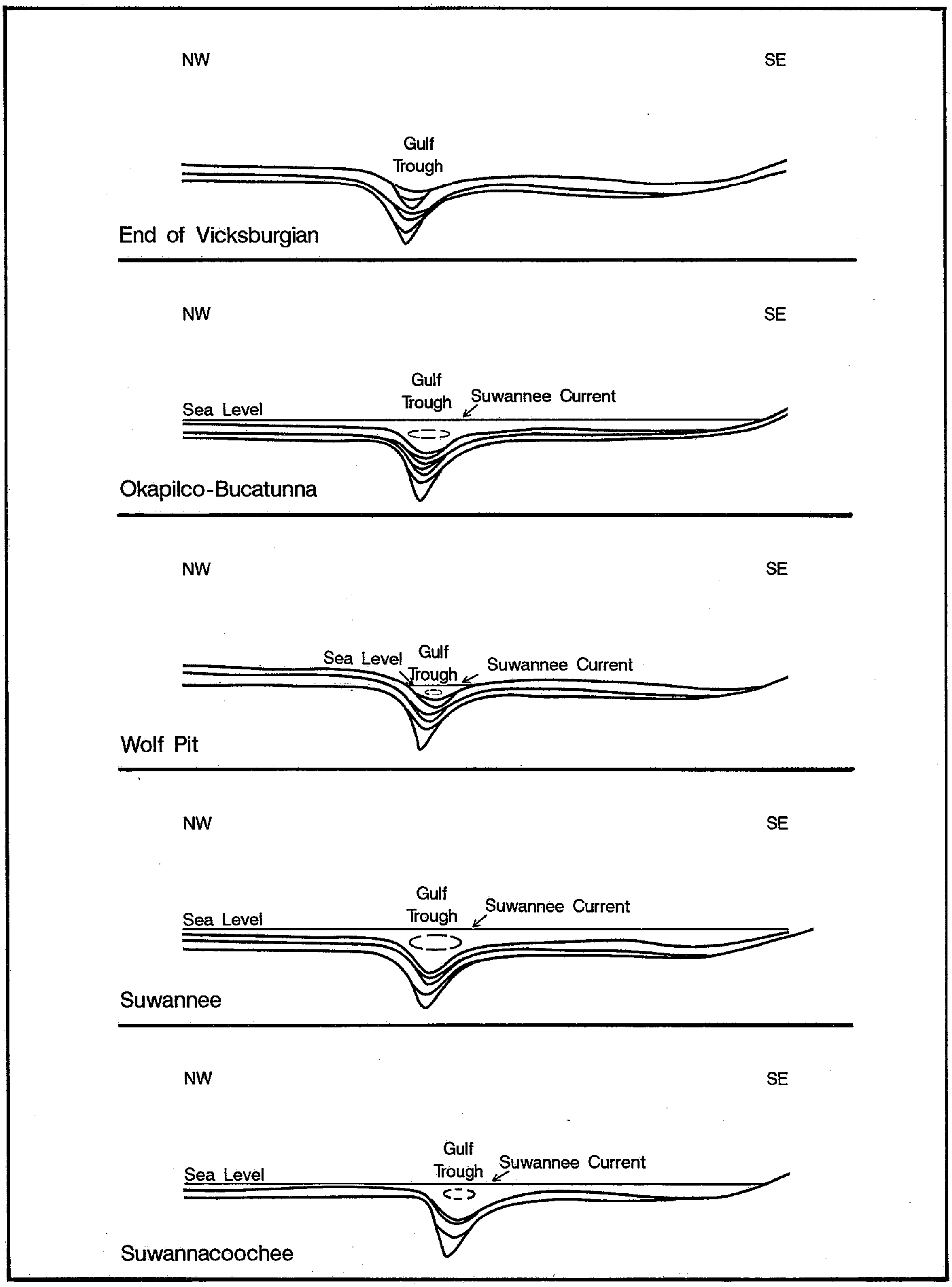

Figure 56b. Model of sequential diminishing and termination of the Suwannee Current in the Gulf Trough from the latest Eocene though the Oligocene.

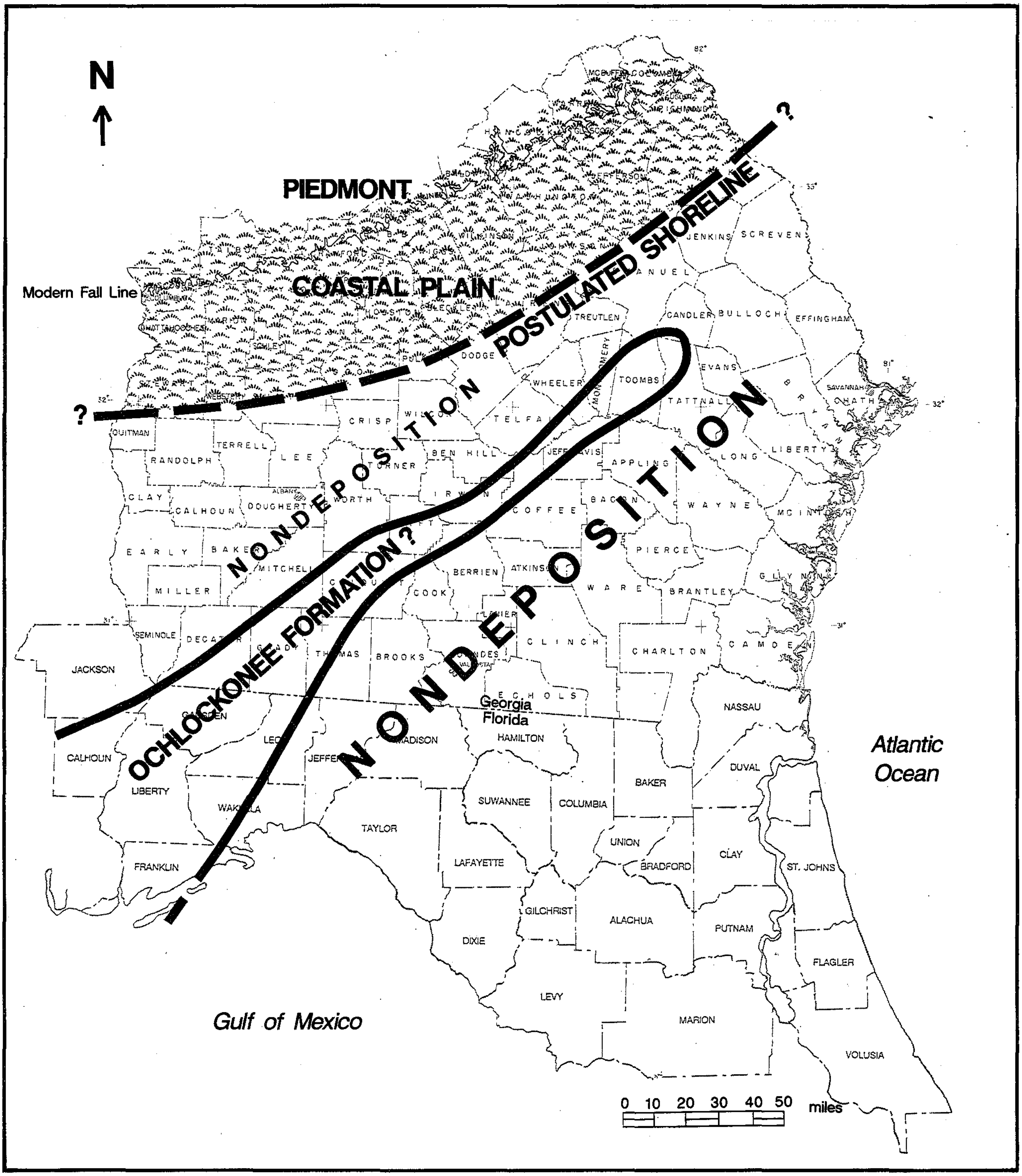

Figure 57. Paleogeographic reconstruction of Georgia and northern Florida during the post-Bumpnose-Red Bluff hiatus.

cherty. It does, however, contain a typical Ochlockonee foraminiferal fauna in its lower part. It is interpreted here that the lower cherty, chalky phase of the Oligocene channel fill at this site is Red Bluff-equivalent, and the overlying dolomitized Ochlockonee Formation and Florala Limestone represent the Ellaville-Glendon-Marianna-Mint Spring depositional sequence (Pl. 3).

Based on the preceding discussion, during the Red Bluff-Marianna low stand of the sea the Suwannee Current was so diminished that, when confined to the Gulf Trough, it was too feeble to influence bottom conditions in the deepest parts of the trough. However, the Suwannee Current remained substantial enough that in shallower water environments along the margins of the Gulf Trough, it impeded sedimentation when it was confined to the marine channel).

Ellaville-Glendon-Marianna-Mint Spring depositional sequence

During the subsequent high stand of the sea (Fig. 58), the middle Vicksburgian Florala Limestone Member of the Bridgeboro Limestone, Marianna Limestone, and Glendon Limestone were deposited north of the Gulf Trough and the Ellaville Limestone south of the Gulf Trough. The Bridgeboro Limestone was deposited along the flanks of the Gulf Trough in the influence of the Suwannee Current whereas the Florala Limestone Member was deposited mainly seaward of the Vicksburg Group and beyond the direct influence of the Suwannee Current in the Gulf Trough. These formations are included in the same depositional cycle because the Marianna and Glendon are conformable in Alabama and Georgia, because the Ellaville Limestone has generally been correlated with the Glendon Limestone (Cooke and Mossom, 1929), and because the Florala Limestone Member grades laterally into typical Bridgeboro Limestone.

The Marianna and Glendon Limestones in Georgia occur along the right bank of the Ocmulgee River below Hawkinsville, Pulaski County, Georgia (also see Pickering, 1970; Huddlestun and others, 1974; Glawe, 1974; this document, p. 16, 18-20, 21). These exposures are considered to be outliers, and the formations are thought not to be physically continuous in the subsurface due to subsequent erosion and dissolution of limestones in the Dougherty Plain area northeast of Jackson County, Florida. In addition, it is not likely that the Marianna and Glendon Limestones had been deposited appreciably farther north than the vicinity of Hawkinsville. In northernmost Bleckly County, Georgia, north of Hawkinsville, the Shellstone Creek beds, a series of thinly stratified, argillaceous fine sands of Barnwell Group appearance but with silicified Oligocene macrofossils (*Clypeaster rogersi* and *Rhyncholampas gouldii*) occur in the stratigraphic position of the Marianna and Glendon Limestones at Hawkinsville.

The Marianna and Glendon Limestones at Hawkinsville appear to be conformable and gradational, and the benthic foraminiferal faunas do not appear to reflect any substantial differences in the temporal or bathymetric aspects of the two formations. It is for these reasons that the Marianna and Glendon Limestones are postulated to have been deposited during a single eustatic high stand of the sea. Their differing lithologies are a reflection of a temporally abrupt change in the continental shelf water mass conditions from a relatively long term, stable water mass (reflected in the deposition of the Marianna Limestone), to periodically changing to a periodically varying water mass oscillating with respect to its oceanographic conditions (reflected in the deposition of the Glendon Limestone). That is, periodic changes resulted in the typical ledge and re-entrant characteristic of the Glendon Limestone. This quality is also present in the Bridgeboro Limestone at its type locality but on a larger scale (Fig. 24). Because the basal Vicksburgian, Red Bluff-equivalent carbonates and Bumpnose Limestone also exhibit this ledge and re-entrant characteristic, similar shelf water-mass conditions may have existed during the deposition of both the older Bumpnose Limestone and the younger Glendon Limestone.

The Marianna and Glendon Limestones do not occur south and east of the Hawkinsville exposures. Near Cochran in Bleckley County and as far south as Abbeville in Wilcox County, Georgia, the Bridgeboro Limestone occurs in the stratigraphic position of the Marianna and Glendon Limestones (Pl. 1). The Bridgeboro Limestone in the Ocmulgee River area appears to be laterally continuous with the Bridgeboro Limestone in its type area in that there are numerous exposures of the Bridgeboro Limestone between the type area and the Ocmulgee River.

Between Decatur County, Georgia, and Washington County, Georgia, there is a gap in the known occurrence of the Bridgeboro Limestone. It is observed that the Bridgeboro Limestone is not known to occur in Jackson County, Florida (one cannot interpret Bridgeboro lithology in Moore, 1955), but at Duncan Church in Washington County, Florida, the Bridgeboro Limestone gradationally overlies the Marianna Limestone.

The Marianna Limestone is not known to occur between the vicinity of Hawkinsville, Georgia, and Jackson County, Florida. Presumably the absence of the Marianna from this area is due to subsequent erosion or dissolution.

South of the Gulf Trough in Georgia and the northern peninsula of Florida, the type section of the Ellaville Limestone is correlated with the Glendon Limestone. As has been described earlier in this report, the *Rotularia vernoni* Zone is present on the Suwannee River and appears conformable with the overlying Ellaville

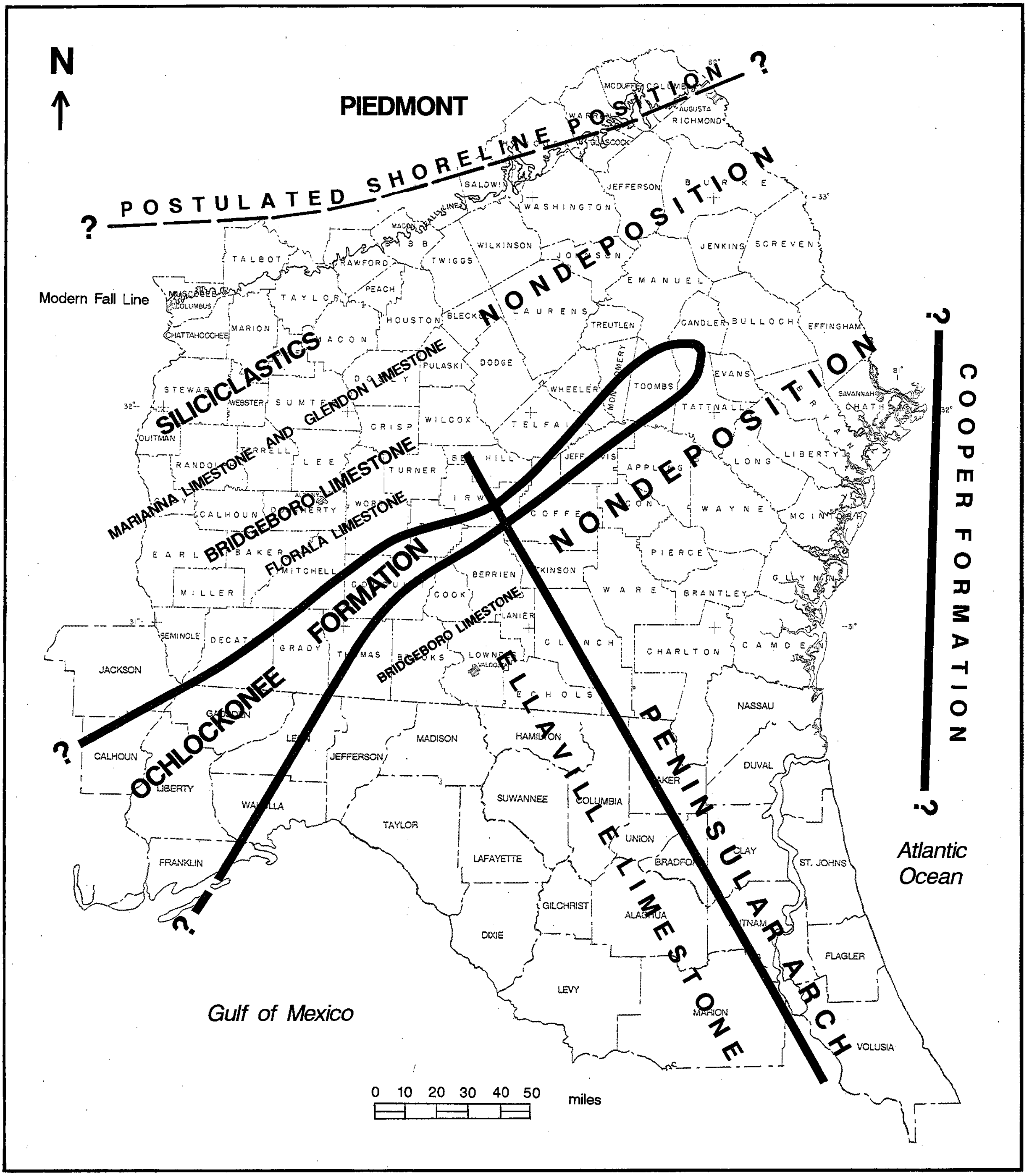

Figure 58. Paleogeographic reconstruction of Georgia and northern Florida during the Ellaville-Glendon-Marianna-Mint Spring depositional sequence.

Limestone. It is also noted that at 39 feet in the Florida Geological Survey core Ellaville 1 (W-10657), taken at Ellaville, the Ellaville Limestone disconformably? overlies limestone of Ocala appearance that contains abundant *Lepidocyclina* sp. and *Nummulites* sp., similar to the exposures down river. If the *Rotularia vernoni* Zone is lowest Oligocene, Red Bluff-equivalent, then the Marianna stratigraphic position probably occurs in a disconformity or in a condensed section at Ellaville. There may be considerable topographic relief on the top of the Eocene or basal Oligocene (Red Bluff-equivalent) in that area.

The Marianna-Glendon stratigraphic positions are postulated to occur within the Ochlockonee Formation within the Gulf Trough. However, as yet there is no biostratigraphic data from the Ochlockonee Formation that explicitly indicates correlation with any part of the Vicksburgian Stage other than lower or middle Vicksburgian, Red Bluff through Glendon. In addition, there is no evidence of a physical discontinuity or hiatus within the middle and lower parts of the Ochlockonee Formation along the axis of the Gulf Trough. However, as discussed above (p. 120, 122, 126), there is evidence for a disconformity within the Ochlockonee Formation on the northern margin of the Gulf Trough that appears to occur in the stratigraphic position of Marianna/Red Bluff disconformity. The lithology of the formation above this disconformity is typical dolomitized Ochlockonee. This dolomitic Ochlockonee interval also grades up-section into limestone that is indistinguishable from the Florala Limestone, again supporting correlation with the Glendon Limestone.

In Georgia and peninsular Florida, all of the lower and middle Vicksburgian (Red Bluff through Glendon stratigraphic intervals) are restricted to the region west of the vicinity of the Peninsular Arch (Fig. 58)(Huddlestun and others, in manuscript). No Oligocene of this age is known to occur in eastern Georgia or northeastern Florida although it is possible that the lower part of the undifferentiated calcareous sand/sandy limestone formation within the northeastern extremity of the Gulf Trough in Georgia may represent lower or middle Vicksburgian deposits. On the other hand, the lower or middle Vicksburgian does occur offshore on the outer continental shelf of Georgia in the relatively deep-water Cooper Formation (p. 83-84).

The presence of middle Vicksburgian (Glendon/Marianna-equivalent), relict Barnwell-type (coastal marine), nearshore deposits in the vicinity of the Ocmulgee River in Houston and Bleckley Counties in central Georgia (Fig. 9) indicates not only a similar depositional environment but also a similar spatial distribution (and shoreline position) to the Late Eocene. As during the Late Eocene, the positions of the shorelines during the early and middle Vicksburgian must be inferred indirectly because there seems to be no surviving Vicksburgian shoreline deposits in Georgia. If the shoreline during the early and middle Vicksburgian (earliest Oligocene) did occur near the Fall line (Figs. 54, 57), a band of nearshore to coastal marine Oligocene sediments at least 20 to 30 miles (32 to 48 km) across must have been removed by erosion in Georgia prior to the Miocene.

Evidence concerning the nature of the Suwannee Current during the middle Vicksburgian can be gleaned from the Bridgeboro Limestone. Modern rhodolith accumulations occur near shelf breaks with strong currents. In the case of the Bridgeboro Limestone, the current energy is presumed to be the Suwannee Current flowing from the Gulf of Mexico into the Atlantic Ocean. There are other hypothetical sources of current energy to produce the rounded rhodoliths, but the continued existence of a current above the Gulf Trough, the proximity of the Bridgeboro Limestone to the Gulf Trough, and the occurrence of the limestone only on the flanks of the trough point to the Suwannee Current as the source of energy. It is hypothesized here that the older formations in the vicinity of the Gulf Trough are non-rhodolithic because the Suwannee Current previous to the Oligocene had been a strongly-focused current and the bottom environment that was in contact with the current was below the photic zone. Other formations were deposited too far from the current for rhodoliths to flourish.

The abundance of rhodoliths in the Bridgeboro Limestone is taken, then, to indicate the presence of a current flowing from the Gulf of Mexico into the Atlantic Ocean during middle Vicksburgian time. Based on the width of the Bridgeboro Limestone subcrop belt, both south and north of the Gulf Trough, the current spread out from roughly 15 miles (24 km) across in the Colquitt County area during the Late Eocene, to very roughly 45 miles (72 km) across in the same area during the Early Oligocene (Fig. 56a and 56b)(also see Huddlestun and others, in manuscript). The fact that the current affected only shallow water in the strait allowed the Gulf Trough to continue to rapidly fill with finely granular, foraminiferal (mainly smaller benthic foraminifera), argillaceous, relatively deep-water calcareous sediments. This resulted from the raising of sedimentational base level within the Gulf Trough above the bottom the trough, permitting net accumulation of sediments.

The shoaling and spreading out of the Suwannee Current after the Eocene is problematic. It could be interpreted as the transformation of the Suwannee Current from a gravity current to a drift current, or as a diminishing of the hydrostatic head between the Gulf of Mexico and Atlantic Ocean as discussed earlier.

Suwannacoochee low stand of the sea

Following the deposition of the middle Vicksburgian Glendon, Bridgeboro, and Ellaville Limestones, during the Late Oligocene, there occurred the first of a series of brief but drastic sea level drops that culminated in the subaerial exposure of most of the continental shelf of southeastern North America (compare with Fisher and Ward, 1984)(Fig. 59). In most areas of the eastern Gulf Coastal Plain, this low stand of the sea is represented by the disconformity between the Glendon Limestone and Byram Formation, between the Glendon Limestone and Bucatunna Clay where the Byram is absent (as at St. Stephens Quarry in Washington County, Alabama), or between the Marianna Limestone and Bucatunna Clay where both the Glendon and Byram are locally absent (see Dockery, 1982, p. 21; MacNeil and Dockery, 1984, p. 22).

South of the Gulf Trough in south Georgia and northwestern peninsular Florida, this stratigraphic interval is occupied by the Suwannacoochee Dolostone. The lowering of the sea associated with the deposition of the Suwannacoochee Dolostone had a profound sedimentary influence on the entire continental shelf perhaps as far south as central Florida. During this apparently brief period, the entire continental shelf of Georgia and northern Florida was under extremely shallow water, perhaps with near sea level conditions. Considering the vast areal extent of this shallow water shelf, the chemistry of the sea water must have deviated considerably from that of normal sea waters. In addition, the common occurrence of rip-up clasts in the dolostone indicates periodic and widespread high energy (storm?) conditions whereas the presence of a sparse, low-diversity, depauperate fauna suggests environmentally extreme conditions. In Georgia, there are occurrences of thinly bedded to laminated, very fine grained, gray dolostone that may be of primary originin the lower part of the Suwannacoochee . In addition, the presence of laminated dolostone indicates the absence of an infauna which further supports a biologically restrictive environment for the Suwannacoochee Dolostone.

The prevailing dolomitization of the Suwannacoochee is thought to be penecontemporaneous with deposition. The dolomitization is postulated to have resulted from the sea water that reacted with the fine-grained, calcitic material being deposited on the shelf in a tropical to subtropical climate. It is suggested that the sea water on the shelf could have become somewhat hypersaline. This chemically abnormal sea water also could have been swept off the shelf as drift currents by the easterly trade winds and the denser water could flow into the deeper Gulf Trough as gravity currents. Such a scenario could account for the dolomitization in a persistent stratigraphic interval in the upper part of the Ochlockonee Formation.

The shelf north of the Gulf Trough may have been bathymetrically higher than the shelf south of the trough. No Suwannacoochee Dolostone is known to occur north of the Gulf Trough. However, a thin, six inch bed of chert occurs in the Suwannacoochee stratigraphic position at the top of the Bridgeboro Limestone and below the overlying Suwannee Limestone in Rockhouse Cave in Crisp County, Georgia, approximately 40 miles (64 km) north of the Gulf Trough. Both stratigraphic position and the fact that the Suwannacoochee Dolostone commonly contains minor amounts of chert suggests stratigraphic relationship between the chert bed in Rockhouse Cave and the Suwannacoochee. The origin of the chert is problematic and is not considered to have been primary. It may represent nondeposition and replacement of the top of the Bridgeboro Limestone during the Suwannacoochee low stand of the sea. Similarly, it is possible that the present patchy distribution of the Glendon Limestone in the vicinity of Hawkinsville, Georgia, may be the result of subaerial exposure and dissolution of the Glendon in that area. Thus the Suwannacoochee shore line probably occurred somewhere between Hawkinsville and Cordele (Fig. 59). If the silicification is subaerial in origin, the shoreline would then have been between Cordele and the Gulf Trough (south of Cordele).

The water depth within the Gulf Trough during the Suwannacoocheelow stand of the sea is projected to have been less than 300 feet (91 m) in Colquitt County but may have been as much as 400 feet (122 m) in Berrien and Coffee Counties and, therefore, the trough remained in relatively deep water (compare with Pl. 3). The general paleoenvironment within the Gulf Trough appears not to have been substantially altered during the Suwannacoochee event because, except for minor dolomitization, the general lithology of the Ochlockonee Formation within this stratigraphic interval was not altered. i.e., it remained finely granular and bioturbated.

Because the general lithology of the Ochlockonee Formation within the Gulf Trough remained essentially constant across this interval, it is suggested that the Suwannee Current continued to flow through the Gulf Trough during the Suwannacoochee low stand of the sea. The current may have maintained its strength but was strictly confined to the trough (Fig. 52, 56b, 59).

Suwannee-Byram depositional sequence

The high stand of the sea subsequent to the Suwannacoochee low stand resulted in the deposition of the Byram Formation in Mississippi and the deposition of the Suwannee Limestone in Georgia and peninsular Florida (Fig. 60).

During this phase, the deposition of the Byram Formation signaled the end of carbonate deposition in the nearshore area of the eastern Gulf Coastal Plain. As yet I have not identified the Byram stratigraphic interval in southwestern Alabama. Those deposits that

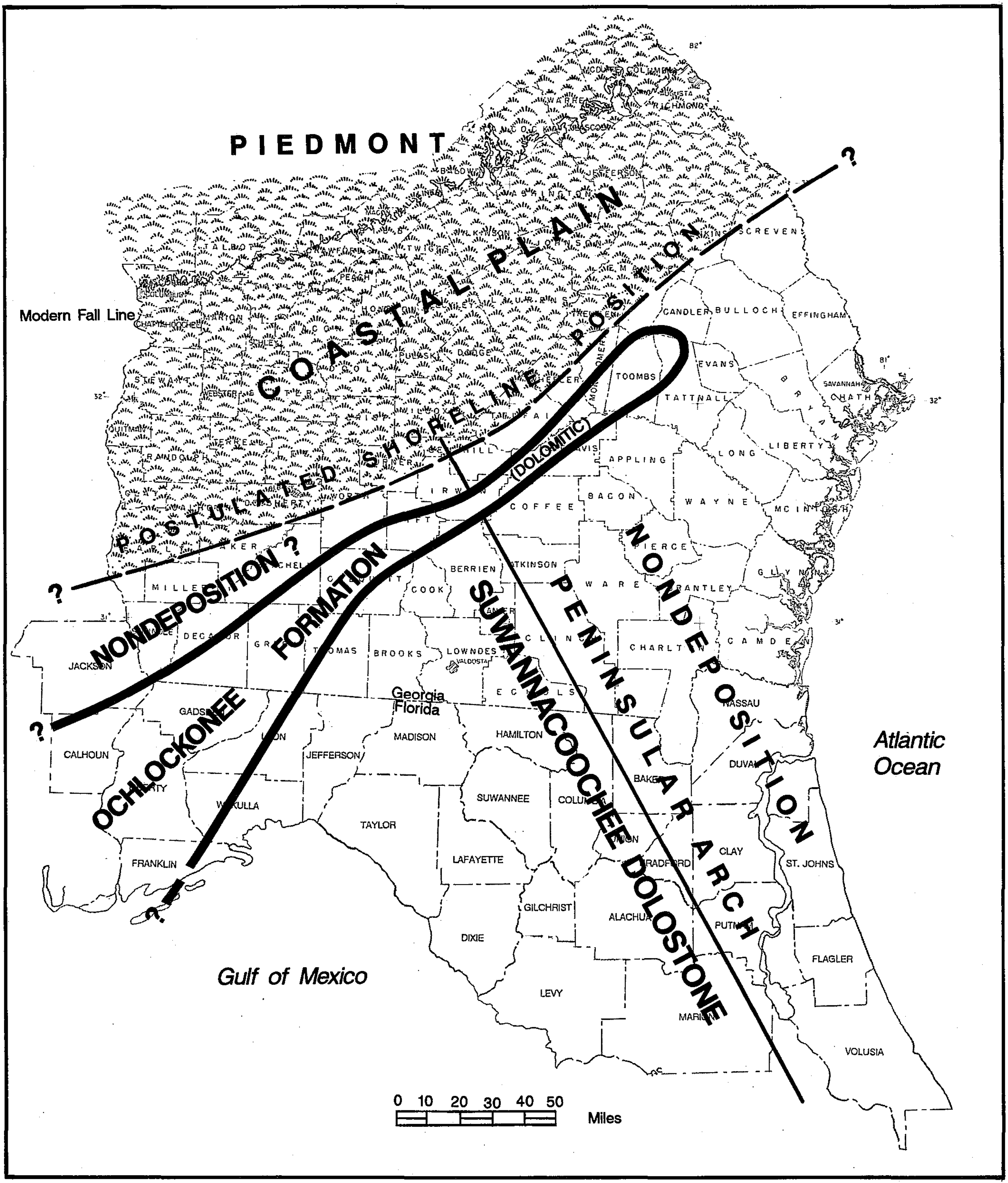

Figure 59. Paleogeographic reconstruction of Georgia and northern Florida during the Suwannacoochee low stand of the sea.

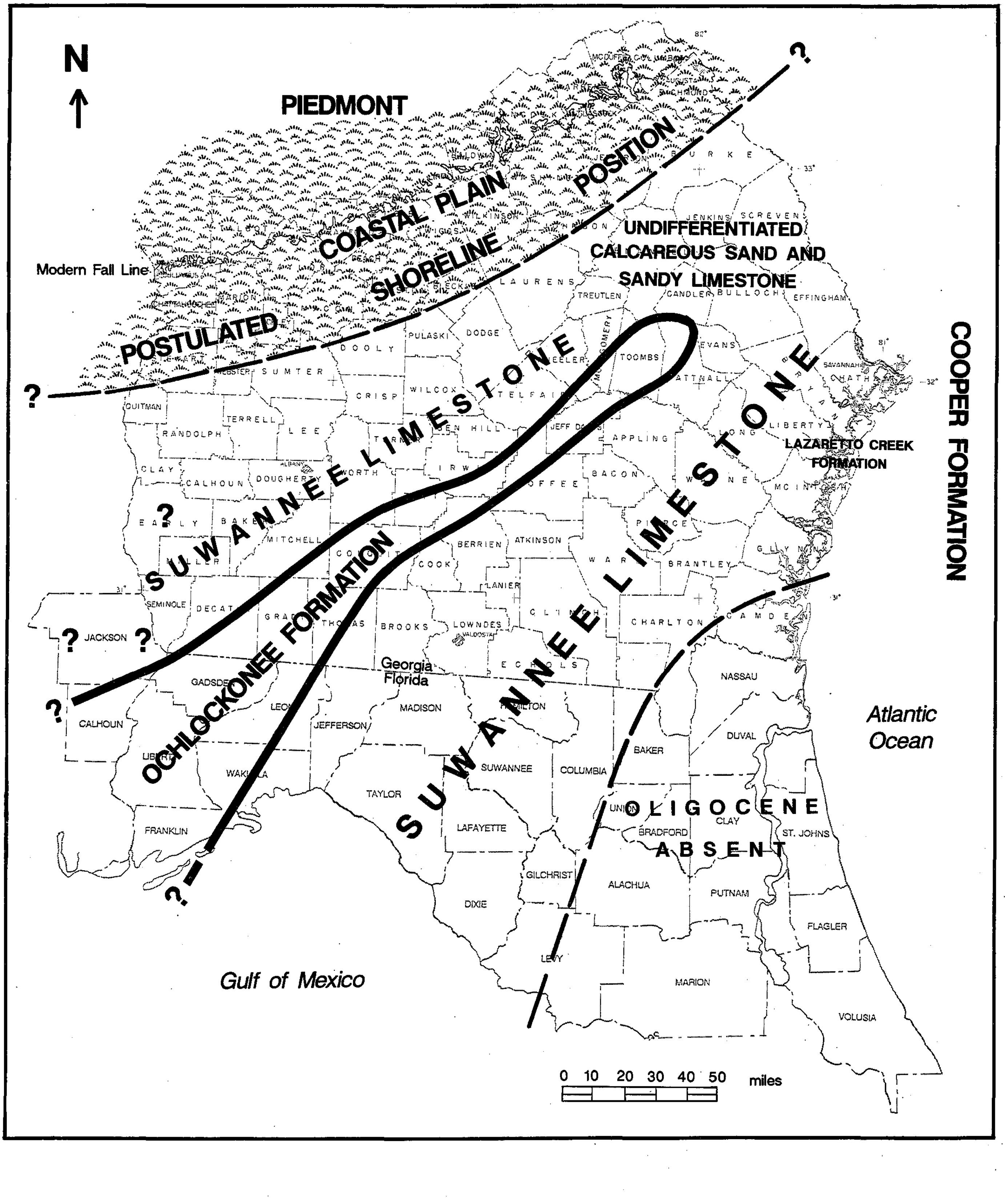

Figure 60. Paleogeographic reconstruction of Georgia and northern Florida during the Suwannee-Byram depositional sequence.

have been correlated with the Byram, e.g., the thin bed of "marl" overlying the Glendon Limestone at St. Stephens Quarry, are correlated with the Bucatunna Clay on the basis of the planktonic foraminiferal fauna. The uppermost part of the Florala Limestone in its type area may be correlative with the Byram Formation and the Byram stratigraphic interval is thought to occur in the Florala Limestone throughout western Florida.

The Suwannee high stand of the sea did not attain the same high level as the previous high stands but conformed to the order of progressively lower high stands of the sea through the rest of the Early Oligocene. The Suwannee shore line must have been considerably north of that of the Suwannacoochee. However, there is no evidence of limestone or chert that contains the typical Suwannee "mealy" lithology in the updip, Hawkinsville-Cochran area in Georgia. In that area the youngest identifiable Oligocene is Glendon Limestone and the correlative silicified Bridgeboro Limestone. In eastern Georgia, on the other hand, silicified Suwannee Limestone occurs as far north as the vicinity of the Burke-Screven Counties line along Beaverdam Creek (Figs. 10 and 32). It appears likely that the Suwannee Limestone and its coastal deposits were removed by erosion or dissolution subsequent to deposition in the updip area. It is also noted that fossiliferous chert that occurs at the top of the section farther north in Burke County contains an Late Eocene fauna and not an Oligocene fauna. The Miocene Altamaha Formation is known to disconformably overlie the Upper Eocene in Burke County. Therefore, if any Suwannee Limestone had once had been present in Burke County, Georgia, either its silicified remnants have not yet been identified or it was subsequently removed by erosion or dissolution before the Miocene.

The depth of water on the continental shelf south of the Gulf Trough in Georgia and Florida was substantially less than it had been during preceding high stands of the sea and is thought to have been less than 50 feet (15 m). As a result, the peculiar Tethyan (Caribbean) benthic foraminiferal fauna characteristic of the earlier shallow water Florida Bank, characterized especially by *Dictyoconus* (having survived the Late Eocene and earliest Oligocene inundations somewhere in refugia) became reestablished on the shelf south of the Gulf Trough. The presence of the Suwannee Limestone north of the Gulf Trough in central Georgia and east of the Gulf Trough in eastern Georgia (Fig. 60), indicates that the Tethyan (Caribbean) Florida Bank foraminiferal fauna briefly expanded its range. Previously it had been restricted to the Florida Bank.

The uppermost part of the Suwannee Limestone in outcrop (especially along the Withlacoochee River in Brooks and Lowndes Counties, Georgia) differs from typical Suwannee Limestone in that it is more stratified and contains conspicuous intraclast beds (intraformational rip-up breccia). The latter is characteristic of shallow water, high energy conditions and is suggestive of a pronounced sea level drop during the final phase of Suwannee Limestone deposition. Because the Suwannee Limestone is at the top of the Oligocene section in all of Georgia outside of the Gulf Trough, the effects and positioning of the subsequent eustatic fall in sea level that terminated Suwannee deposition cannot be observed in outcrop. However, additional Oligocene sediments are present within the Gulf Trough including sediments deposited during the subsequent low stand and following high stand of the sea.

Within the Gulf Trough in Georgia, the upper part of the Ochlockonee Formation is correlated with the Suwannee Limestone and Byram Formation. The upper part of the Ochlockonee Formation is lithologically the same as that below the dolomitized zone in the upper Ochlockonee but it is generally more lithified and less argillaceous than the lower parts of the formation.

Although no foraminifera have been extracted from the upper part of the Ochlockonee Formation, the typical lithology would indicate conditions similar to the older part of the Ochlockonee. Therefore, it is concluded that the Suwannee Current was still active within the Gulf Trough during the Suwannee-Byram high stand of the sea (Fig. 56b).

The Gulf Trough continued as a very constricted but still relatively deep water conduit for the Suwannee Current during the Suwannee high stand of the sea. During this brief period, the deep-water Ochlockonee Formation continued to be deposited within the Gulf Trough but the remnant of the Suwannee Current must have been entirely confined to the Gulf Trough. The Suwannee Limestone on either side of the Gulf Trough is barren of planktonic microfossils and has a low diversity, shallow water benthic macro- and microfauna. The depth of water on the shelf south of the Gulf Trough during this period was insufficient to sustain any large, directed current or eddies thereof.

The model adopted here for the paleogeography of the Georgia coastal area and continental shelf during the Suwannee-Byram depositional sequence is as follows (Fig. 60): in central Georgia, the Suwannee shoreline probably occurred somewhere in the vicinity of Hawkinsville or immediately south of Hawkinsville. In eastern Georgia, the Suwannee coastal area probably occurred in Burke County. It is possible that during deposition of the Suwannee Limestone, limestone depositionalso occurred in the shoreline but it is also possible there may have been a narrow, sandy coastal area. During the Suwannee high stand of the sea, and only during this high stand, it appears that a modified Florida Bank faunal province may have extended all the way from the earlier Florida Bank in the Florida peninsular area in the south, northward to the coastal area of North America in Georgia (Figs. 48, 49). During this brief, diminished high stand of the sea, there would have been a mingling of eastern Gulf Coastal Plain, southern Atlantic Coastal Plain, and Florida Bank faunas in the coastal waters.

In the vicinity of the modern Oconee River, however, the nearshore, subsurface, undifferentiated calcareous sand and sandy limestone suggests that the paleo-Oconee River flowed near its modern course and was a considerable local source of siliciclastics during the Oligocene. Physical correlation indicates that at least the upper part of this sandy sequence is correlative with the Suwannee Limestone and, therefore, presents a siliciclastic, coastal marine phase of the Suwannee Limestone. The abrupt appearance of siliciclastics in this part of the Vicksburgian is compatible with the Atlantic Coastal Plain suite of formations where the Lazaretto Creek Formation indicates a siliciclastic source from the north, and with the eastern Gulf Coastal Plain Vicksburgian where the Byram Formation presents an abrupt influx of siliciclastic sediments. The earlier Glendon depositional phase represents the greatest westward expansion of carbonate deposition during the Tertiary of the southeastern United States. The sudden but minor increase in siliciclastic deposition during the Byram-Suwannee depositional sequence is interpreted as representing a second pulse of siliciclastic deposition during the Oligocene. The sandy phase of late Vicksburgian deposition has not yet been identified in the Vicksburgian residuum west of the vicinity of the Ocmulgee River, nor east of the vicinity of the Ogeechee River.

Wolf Pit low stand of the sea

The second in the series of sudden, drastic but brief sea level falls followed the deposition of the Byram Formation in Mississippi and the Suwannee Limestone in Georgia and Florida (Fig. 61). This low stand of the sea was more severe than the preceding low stands and the Gulf Trough briefly became a vast, shallow water embayment projecting obliquely into the Coastal Plain of southeastern North America (Fig. 61). The Wolf Pit low stand of the sea also represents the termination of Oligocene sedimentation in Georgia outside of the of the Gulf Trough and outer continental shelf.

This fall in sea level was even more severe than that of the Suwannacoochee low stand and resulted in the deposition of the Wolf Pit Dolostone within the Gulf Trough and the probable subaerial exposure of the continental shelf outside of the Gulf Trough in Georgia and Florida. Within the Gulf Trough, the Suwannee-equivalent Ochlockonee Formation is gradationally and conformably overlain by the Wolf Pit Dolostone. The Wolf Pit is lithologically similar to the Suwannacoochee Dolostone but it occurs in a stratigraphically higher position and at much lower elevations than the Suwannacoochee and, therefore, is not considered to be correlative with the Suwannacoochee (Pl . 3). The Wolf Pit Dolostone is considered to represent the low stand of the sea following the deposition of the Suwannee Limestone on the continental shelf adjacent to the Gulf Trough. In Coffee County, the Wolf Pit Dolostone appears to have been deposited in a very shallow water, restricted environment, probably near sea level similar to the Suwannacoochee Dolostone. The Wolf Pit in the type core in Colquitt County appears to have been deposited largely as fossiliferous and bioturbated limestone that was penecontemporaneously or subsequently dolomitized. The Gulf Trough (Chattahoochee Embayment) is broader in Colquitt County than in Coffee County so the Wolf Pit Dolostone may have been deposited in more open marine conditions and in deeper water in Colquitt County than in Coffee County.

The depth of sea water within the Gulf Trough must have been inadequate to pass any more than a trickle of water through it and, if the eastern end of the trough was higher in elevation than the western end, it is likely that the eastern end of the trough was also exposed subaerially. Therefore there would have been no water passage during the Wolf Pit event. If the eastern end of the trough was subaerially exposed during the Wolf Pit event, the Gulf Trough would have been a long, narrow, linear embayment like a vast estuary. The shelf on either side of the trough would have been subaerially exposed, and the former Florida Bank was a peninsula for the first time (Fig. 61) since the early Late Cretaceous. The Suwannee Current, therefore, must have been finally terminated during this low stand of the sea (Fig. 56b). The outer, southwestern part of the Chattahoochee Embayment probably was the site of either shallow water limestone deposition, or of nondeposition, depending on the degree of up-welling of the dying Suwannee Current against the continental margin of North America.

During the Wolf Pit low stand of the sea, the emergent continental shelf outside of the Gulf Trough must have been covered with land, swamp, or marsh vegetation because of no established terrestrial drainage patterns (Fig. 61). Shallow water marine conditions prevailing within the Gulf Trough indicate that the shoreline during this event must have occurred deep within the trough along the northern and southern flanks. It is conjectured here that the thinning of the Byram Formation in eastern Mississippi (Johnson, 1982) and its absence in outcrop in southwestern Alabama is the result of subaerial erosion during the severe low stand of the sea following the deposition of the Byram Formation.

Okapilco-Bucatunna depositional sequence

With the subsequent rise in sea level following

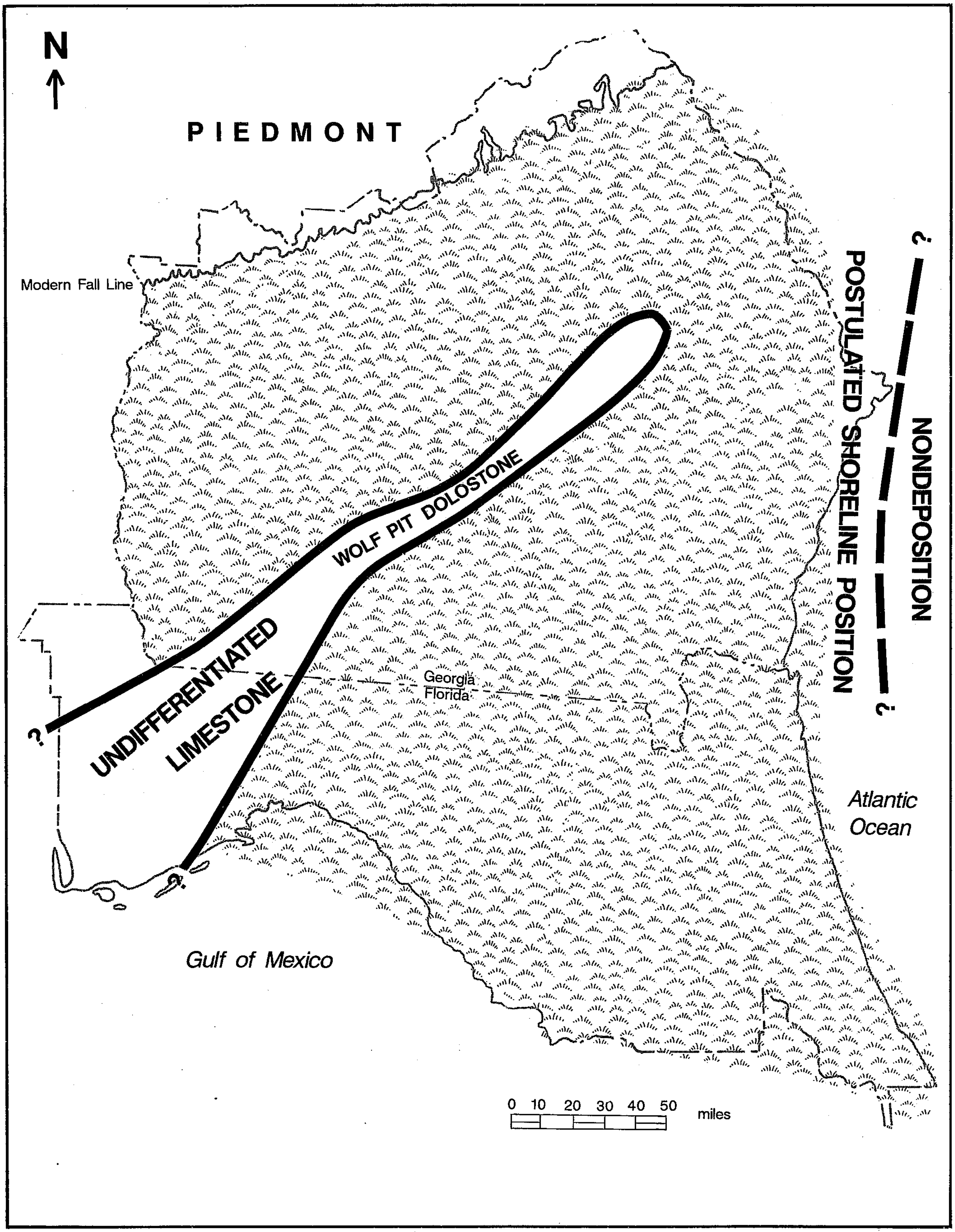

Figure 61. Paleogeographic reconstruction of Georgia and northern Florida during the Wolf Pit low stand of the sea.

the Wolf Pit low stand of the sea, a normal marine environment became reestablished within the Gulf Trough. In the eastern Gulf Coastal Plain, the post-Byram (post-Suwannee) high stand of the sea is represented by the deposition of the Bucatunna Clay in nearshore areas in Mississippi and Alabama, and in offshore areas by the upper part of the Florala Limestone in the western panhandle of Florida. In Georgia this sedimentary interval is represented by the Okapilco Limestone within the Gulf Trough (Fig. 62). The Okapilco Limestone is a relatively shallow-water deposit that contains abundant colonial corals and therefore, must have been deposited well within the photic zone.

The deposition of the granular, commonly fine grained, bioturbated carbonates of the Middle Eocene through most of the Early Oligocene did not resume during the Okapilco high stand in the Gulf Trough. Rather, a more coarsely granular limestone that was replete with colonial corals was deposited. The biota of this limestone is of low diversity. In addition, although the benthic foraminifera indicate that open marine conditions again prevailed in the trough, the diversity of the population is low and is indicative of only moderate water depths, consistent with the premise that the Gulf Trough had been largely filled by the end of the Vicksburgian.

It is unlikely that the Okapilco shoreline was far from the flanks of the Gulf Trough (Fig. 62). Rather, it appears likely that the shore line in Georgia for the Okapilco-Bucatunna high stand lay near the upper flanks of the trough.

Farther southwest in the Chattahoochee Embayment in Florida, limestone deposited during this high-stand resembles the Bridgeboro Limestone, though with anastomosing algae rather than rhodoliths. It is concluded, therefore, the Suwannee Current is rejuvinated and substantial current energy was expended by the Suwannee Current as it encroached on the continental shelf of Florida. That the Gulf Trough still served as a conduit for the Current is indicated by the presence of a substantial suite of planktonic foraminifera in the Okapilco Limestone in Coffee County, Georgia. The current, although feeble, must have been strong enough for open-marine water-mass conditions to prevail as far northeast as Coffee County. A directed ocean current, therefore, became reestablished in the Gulf Trough after the Suwannee Current had ceased during the Wolf Pit low stand of the sea. A feeble current reentering the Gulf Trough is not surprising in that the descendent of the Suwannee Current, the modern Loop Current, still exists in the eastern Gulf of Mexico and if the proper geologic and geographic conditions were to become reestablished in Georgia and northern Florida in the geologic future, there could be a rebirth of the Suwannee Current.

If the sea were restricted largely to the Gulf Trough in Georgia during the Okapilco high stand of the sea, then the terrane outside of the trough in Georgia and northern Florida would have remained near or above sea level and probably had the appearance of vast coastal, freshwater swamp. If, on the other hand, the sea was not confined to the trough, then the shelf outside of the trough would have been under extremely shallow water. Such deposits that may have been deposited (Bucatunna Clay? or dolostone) could have been removed by erosion prior to the Miocene. There is evidence that Bucatunna Clay may have been deposited in deeper water along the gently sloping northern flank of the Gulf Trough in Georgia because the weathered clay overlying the Bridgeboro Limestone at the type locality of the Bridgeboro lithologically resembles the Bucatunna Clay and contains silicified Oligocene mollusks.

Post-Vicksburgian-pre-Chickasawhayan low stand of the sea

There is no known marine record in Georgia for the subsequent Oligocene. At all known sites outside of the trough, the Suwannee Limestone is the youngest known unweathered formation that occurs at the tops of the local sections. The youngest unweathered Oligocene deposits in Georgia occur only within the Gulf Trough. All subsequent information on the Oligocene history of the Gulf Trough has been lost during weathering and erosion events prior to the Miocene. A core taken by the Florida Geological Survey from the Florida panhandle in Walton County (Mathis 1; W-8102) near the town of Florala in Alabama, however, contains a richly foraminiferal, late Vicksburgian and Chickasawhayan succession that can be employed to interpret the later Oligocene geologic history of Georgia and of the Gulf Trough (Fig. 63). In the Mathis 1 (W-8102), the section from 327 feet to T.D. at 375 feet consists of densely packed, subcoquinoid, *Lepidocyclina*-rich Florala Limestone. Above 327 feet the limestone is unconsolidated and less densely packed with *Lepidocyclina* but contains a rich and diverse suite of planktonic and benthic foraminifera. The core above 287 feet also consists of hard, indurated, coarsely fossiliferous, *Lepidocyclina*-rich limestone.

The top of the *Lepidocyclina*-rich Florala Limestone occurs at 274 feet and is a useful stratigraphic marker in the panhandle of Florida. The limestone from 274 feet to 251 feet is the limestone unit exposed at Natural Bridge in northern Walton County, Florida (Cooke and Mossom, 1929; Cooke, 1945; Puri and Vernon, 1964) and is a calcareous subdivision of the Bucatunna Clay. This limestone is generally slightly argillaceous, finely granular with scattered *Lepidocyclina*, *Nummulites*, and *Pecten poulsoni byramensis*. A thin feather-edge of calcareous Bucatunna Clay occurs from 252 feet to 245.5 feet in the core Mathis 1 and is overlain 1.5 feet of argillaceous

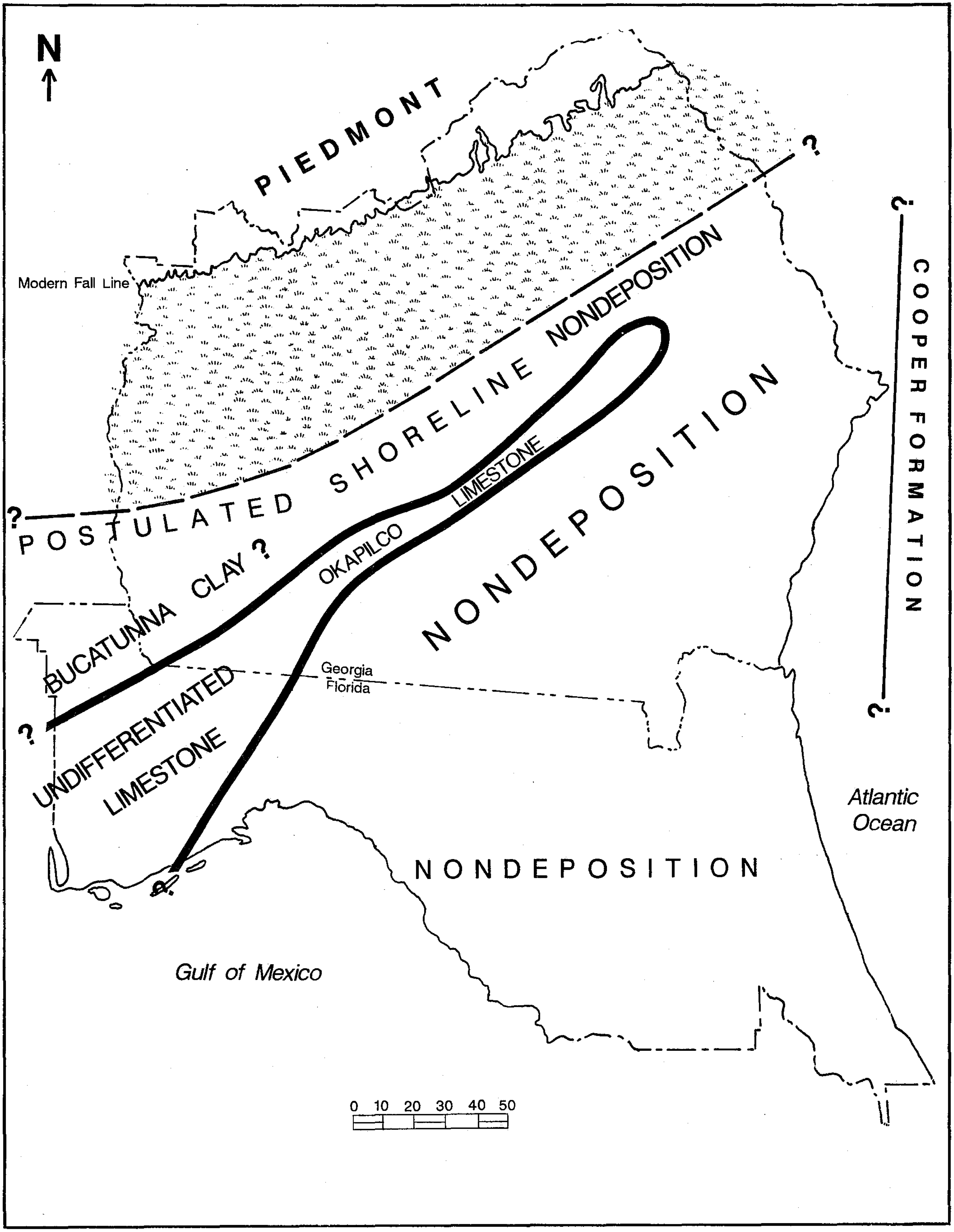

Figure 62. Paleogeographic reconstruction of Georgia and northern Florida during the Okapilco-Bucatunna depositional sequence.

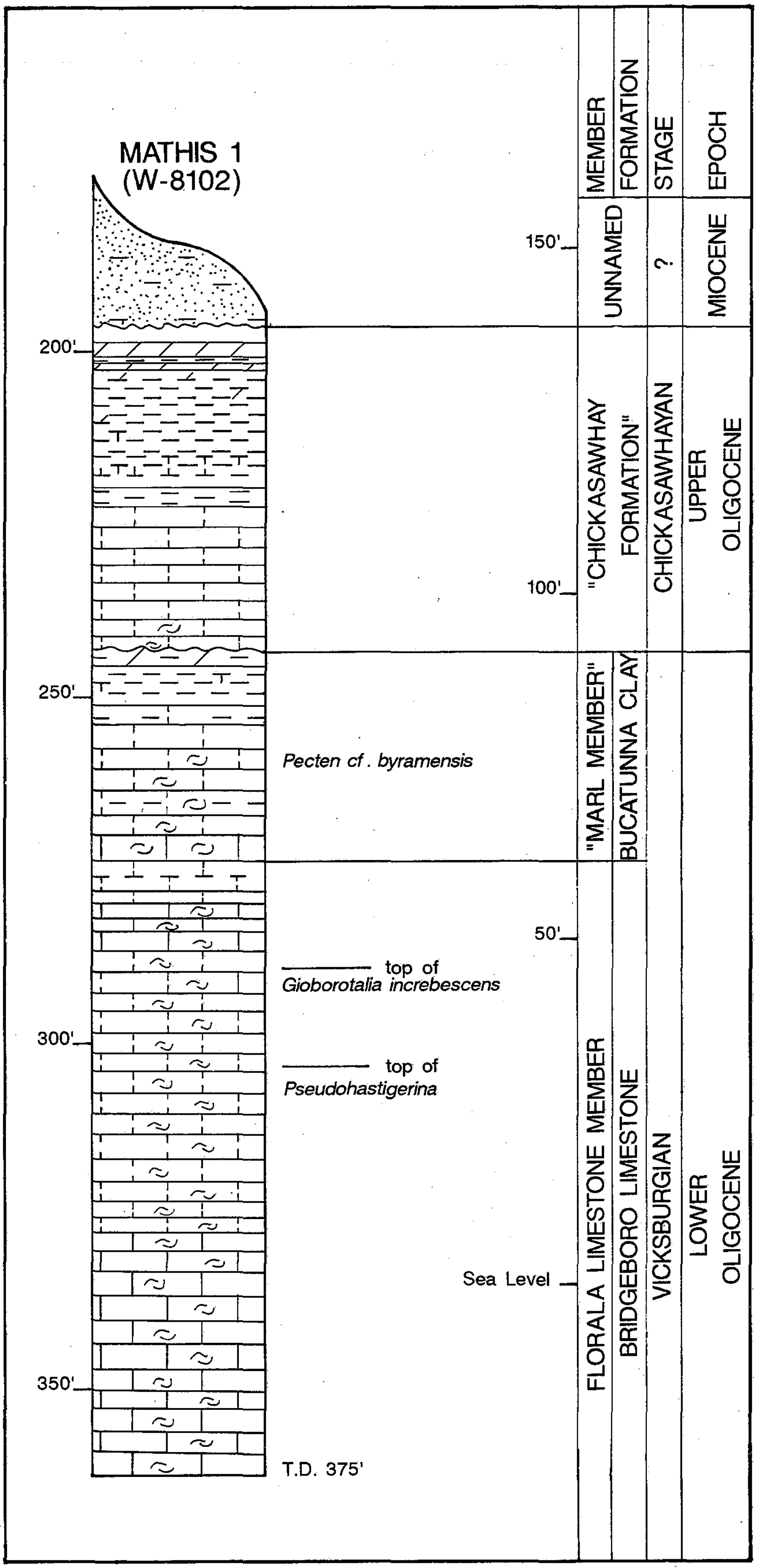

Figure 63. The Oligocene geologic section exposed in the Florida Geological Survey core Mathis 1 (W-8102)

dolostone. The dolostone is interpreted to represent a eustatic low stand of the sea.

The Chickasawhay Formation abruptly overlies the dolostone at 244 feet. Above 244 feet the Chickasawhay section consists of unconsolidated, slightly argillaceous and micaceous, granular limestone that grades upward into calcareous clay at 218 feet. The upper part of this clay bed is dolomitic and the clay in turn is overlain abruptly by dolostone at 201 feet. The dolostone is disconformably overlain by Lower Miocene sands at 192 feet (Also see Huddlestun, 1984, Fig. 21).

This section is interpreted as follows: Based on planktonic foraminifera the section from the top of the Florala Limestone at 274 feet to T.D. at 375 feet is correlated with the Byram Formation or Glendon Limestone. The local top of *Pseudohastigerina micra* occurs at 304 feet and that of *Globorotalia increbescens-Globigerina ampliapertura* at 290 feet. The changing benthic foraminiferal population above 317 feet indicates a progressive shoaling of the sea. The discontinuity at 274 feet is interpreted as representing the Wolf Pit low stand of the sea and is correlative with the Bucatunna/Byram disconformity (and the Wolf Pit Dolostone. The lack of dolomitization and other disconformity characteristics indicates that the continental shelf near Florala at this time in the Oligocene was in sufficiently deep water relative to the Suwannee Strait region to the east to mask the drastic effects of the Wolf Pit low stand.

The benthic foraminifera below 300 feet in the Mathis 1 (W-8102) are indicative of much deeper water than the benthic foraminifera from the type locality of the Byram Formation. The deeper water benthic foraminiferal populations below 300 feet in the core Mathis 1 are more similar to the benthic foraminifera of the Red Bluff Clay, Marianna Limestone, and Glendon Limestone of southwestern Alabama (St. Stephens Quarry and Little Stave Creek). However, the benthic foraminifera at 276 feet, near the top of the Florala Limestone in the core, indicate considerably shallower water, yet deeper still than that at the type locality of the Byram or of the Glendon at Vicksburg, Mississippi.

It is interpreted here that the close correlation between the top of the *Lepidocyclina*-rich Florala Limestone and the local extinctions of *Pseudohastigerina* at 304 feet and *Globorotalia increbescens* and *Globigerina ampliapertura* at 290 feet is significant. It is suggested here that the Wolf Pit low stand event not only approximates the base of the Bucatunna but also the boundary between the *Globigerina ampliapertura* and the *Cassigerinella chipolensis-Pseudohastigerina micra* Zones. It is also suggested that the subsequent consistent absence of the *Globorotalia increbescens* end-member of the plexus represents the extinction of that end-member, and the surviving end-member, *G. ampliapertura*, must have adopted a deeper-water habit because it too is consistently absent in the youngest, relatively planktonic foraminiferal rich, Vicksburgian deposits of the southeastern United States.

The Bucatunna Clay occurs in the interval 274 feet to 244 feet in the Mathis 1 (W-8102) and the interval 251 feet to 245.5 feet is represented by typical but calcareous Bucatunna Clay. The benthic foraminiferal suite within this interval is interpreted as originating in a significantly shallower water environment than that of the underlying *Lepidocyclina*-rich Florala Limestone, but still deeper water than the foraminiferal suites from outcropping Bucatunna Clay. It is concluded, therefore, that as was the case in the Suwannee Strait region, the Okapilco-Bucatunna high stand of sea in the eastern Gulf Coastal Plain was considerably lower than that of the previous Oligocene high stands of the sea.

Based on the occurrence of dolostone gradationally overlying the Bucatunna Clay at 245.5 feet in the core Mathis 1 (W-8102) and in turn being overlain with a sharp contact by coarsely fossiliferous limestone, it is concluded that the post-Vicksburgian (post Okapilco-Bucatunna) low stand of the sea (TA4.5 of Haq and others, 1987) was considerably lower than the previous Wolf Pit low stand. The continental shelf in the Florala area was exposed to very shallow water conditions that resulted in penecontemporaneous or subsequent dolomitization of the sea floor sediments. If this interpretation is correct, then the low stand of the sea (TA4.5) following the deposition of the Okapilco Limestone in the Gulf Trough was even lower than that of the Wolf Pit low stand. This post-Vicksburgian low stand would have not only exposed the Suwannee Strait region to subaerial erosion but also would probably have left the floor of the Gulf Trough subaerially exposed as well (Fig. 64). If there were topographic relief on the floor or the trough, i.e., highs and lows, then it is likely that the Gulf Trough could have contained a series of lakes and large, interconnecting streams. Through-flowing rivers could have become established at that time.

The only other evidence that I am aware of concerning the post-Vicksburgian low stand of the sea is the occurrence of the Waynesboro Sand of eastern Mississippi (Johnson, 1982). The Waynseboro Sand appears to be associated with the regressive stage of the Bucatunna Clay. Johnson (1982) reported that the Waynesboro Sand not only appears to grade latterally into the Bucatunna Clay but locally also disconformably overlies the Byram Formation, the Glendon Limestone, and the Marianna Limestone.

Chickasawhay depositional sequence

The Chickasawhay Formation abruptly overlies the dolostone at the top of the Bucatunna Clay at 244 feet in the Mathis 1 (W-8102) core. Evidently the Chickasawhay Formation was deposited in the depositional cycle that

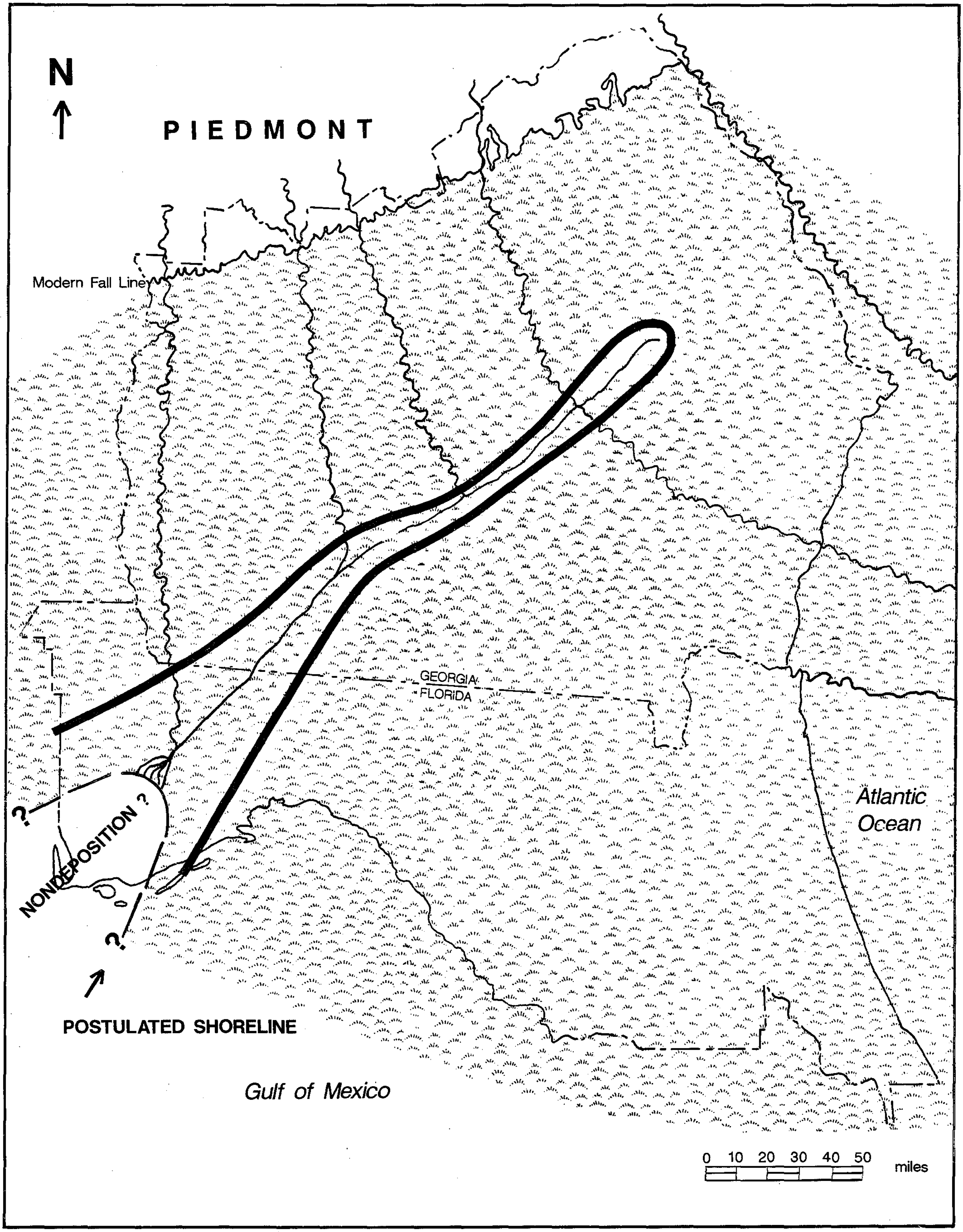

Figure 64. Paleogeographic reconstruction of Georgia and northern Florida during the post-Vicksburgian-pre-Chickasawhayan low stand of the sea.

followed after some lag of time the low stand of the sea that terminated the Vicksburgian (TA4.5). The appearance of the planktonic fauna suggests a relatively long period of time had lapsed between the time of Bucatunna deposition and the time of Chickasawhay deposition.

The benthic foraminiferal fauna of the Chickasawhay Formation is indicative of even shallower water conditions than the underlying Bucatunna section both in the Mathis 1 core and in outcrop in Mississippi and Alabama. To the east in Georgia then, if the high stand of the Chickasawhayan sea was noticeably lower than that of the earlier Okapilco-Bucatunna high stand, then much of the continental shelf south of the Gulf Trough must have remained subaerially exposed during the Chickasawhayan. The Gulf Trough would have existed as a narrow, shallow, linear embayment of the sea, a large estuary, or a river valley with a large estuary at its southwestern end (Fig. 65). Most of the Georgia Coastal Plain would have been subaerially exposed and there probably occurred an incipient Florida peninsula to the south. In addition, it is likely that the terrane south of the Gulf Trough in Georgia and Florida remained a low elevation, fresh water plain reminiscent of the modern Everglades of Florida.

This scenario would explain the absence of known Chickasawhayan deposits throughout Georgia outside of the lower Chattahoochee Embayment. The reports of shelly residuum of Chickasawhayan age on the Dougherty Plain stems from correlations by earlier workers from the 1930's and 1940's and since then has not been supported by field work. The stratigraphic cross-sections on Pl. 3 are not consistent with the presence of any Chickasawhayan deposits outside of the Gulf Trough in Georgia.

The Chickasawhayan, Upper Oligocene occurs only as deep water, outer neritic deposits in adjacent South Carolina, under the outer continental shelf of Georgia (Ashley Member of the Cooper Formation), and possibly within the Chattahoochee Embayment in Florida. The interpretation of the Late Oligocene geology in the Suwannee Strait region, therefore, is problematic. There are two principle contributing factors to the problem of what happened during the later Oligocene. (1) My observations of high stands and low stands of the sea during the Oligocene are generally consistent with the eustatic sea level curves of Haq and others (1987). However, I recognize more high amplitude eustatic sea level fluctuations during the Early Oligocene than reported by Haq and others (1987). This is more consistent with the sea level fluctuation proposed by Baum and Vail (1988) and Mancini and Tew (1990, 1991). (2) There is as yet no consensus on correlation between the cosmopolitan stage boundaries of the Oligocene and planktonic foraminifera zones. For example, Haq and others (1987) place the *Globigerina ampliapertura* Zone within the middle part of the Rupelian and place their TA4.5/TA4.4 boundary at the top of the *G. ampliapertura* Zone. The lower part of the *Globorotalia opima opima* Zone, of which the Chickasawhayan provincial stage is part, is partially in their Chattian Stage (Pl. 1). This is consistent with the appearance of the stratigraphic relationships between the upper part of the Vicksburgian and Chickasawhayan Stages in the southeast. That is, there appears to be no greater disconformity between the Chickasawhay Formation and Bucatunna clay than there is between the Bucatunna Clay and Byram Formation. On the other hand, there is considerably more faunal evolution between the planktonic foraminifera of the Chickasawhayan and Bucatunna, than between the Bucatunna and the Red Bluff, which bespeaks a greater time interval between the Chickasawhay and Bucatunna than between the Bucatunna and Red Bluff (PL. 1).

Hardenbol and Berggren (1978) included the *G. ampliapertura* Zone in the Chattian and, therefore, all of the *Globorotalia opima opima* Zone is within their Chattian. That interpretation is more compatible with the constitution of the Chickasawhayan planktonic foraminiferal suite than that of the Vicksburgian.

Post-Chickasawhay low stand(s) of the sea

The eustatic low stand of the sea following the deposition of the Chickasawhay Formation and Paynes Hammock Sand appears to have been unusually low relative to all of the Tertiary low stands of the sea that preceded it (Fig. 48). The post-Chickasawhay Formation low stand would appear to be that of TB1.1 of Haq and others (1987).

No preserved Oligocene deposits subsequent to the Chickasawhay and equivalent deposits are known from outcrop or cores from the Coastal Plain of Alabama, Georgia, Florida, South Carolina, or the continental shelf of Georgia and South Carolina. Based on the amplitudes of the eustatic sea level fluctuation of Haq and others (1987), it is most likely that the Coastal Plain of this region was subaerially exposed. This also includes the floor of the Gulf Trough and, as a consequence, there must have been at least a practical Florida peninsula during the Late Oligocene. During this period of subaerial exposure of the Georgia and Florida Coastal Plain, the entire Suwannee Strait region must have been a vast, low-elevation karst plain. The Gulf Trough would have been a large valley-like feature that may have contained a series of lakes of varying size with poor drainage between the lakes or was a large river valley. During the high stands of the sea during the latest Oligocene, it is possible that the trough could have been a vast estuary that either contained salt marshes or a continuous, brackish arm of the sea. The deposits associated with these environments, if they ever existed, must have been eroded and removed during the subsequent low stands. They may also have been removed during the earliest Miocene, Aquitanian re-

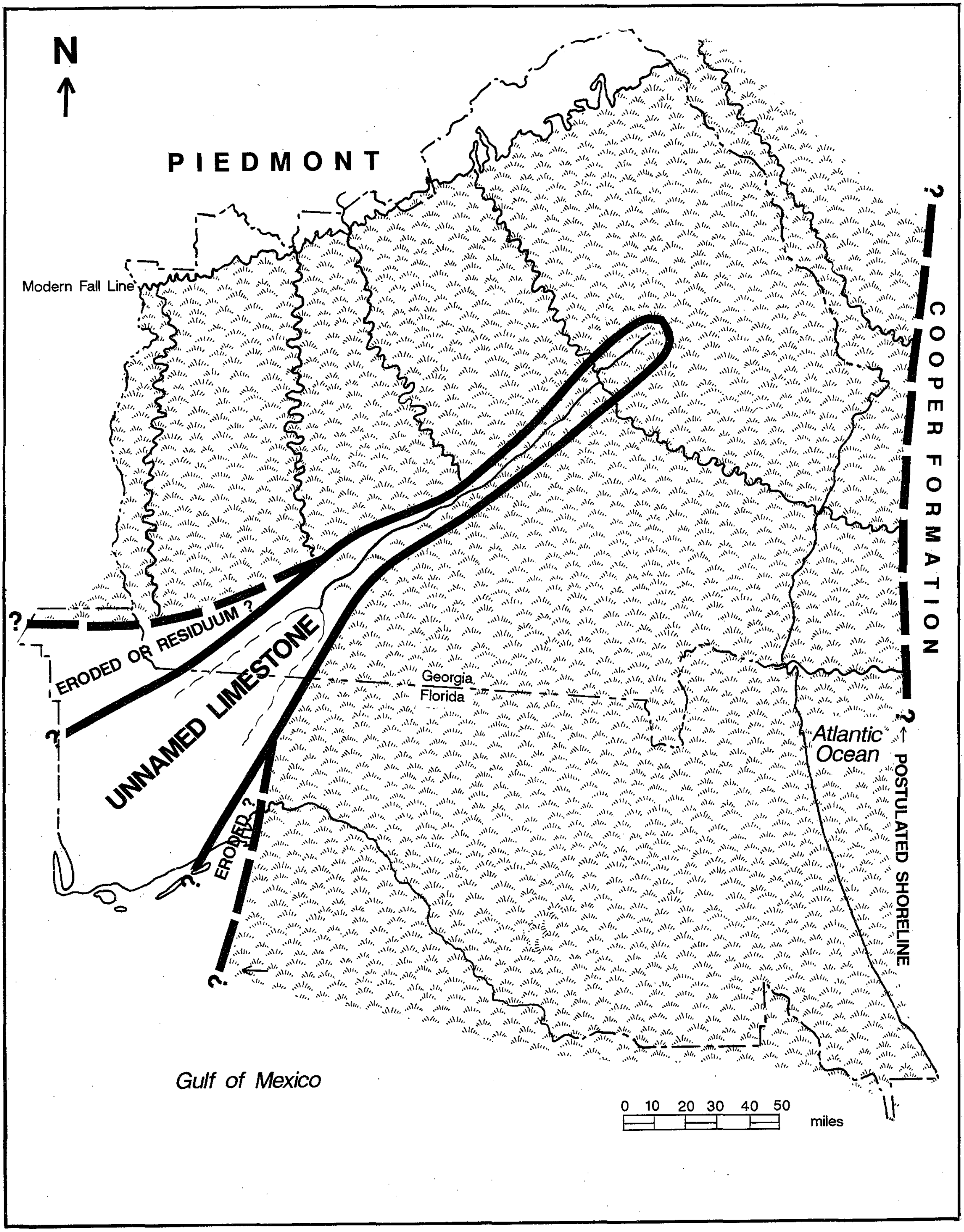

Figure 65. Paleogeographic reconstruction of Georgia and northern Florida during the Chickasawhayan depositional sequence.

entrance of the sea into the trough.

Based on the species constitution of the basal Miocene planktonic foraminiferal fauna (see Huddlestun, 1988), there is even more faunal evolution between the Chickasawhayan and Aquitanian, than between the Vicksburgian and Chickasawhayan. This suggests either a greater span of time between the former than the latter or more intense extinction/evolution between the Chickasawhayan and Aquitanian. On the basis of the above discussion, I suggest that the TB1.1/TA4.5 cycle boundary of Haq and others (1987) occurs not at the base of the Chattian but in the early part of the Chattian, that the *Globorotalia opima opima*/*Globigerina ampliapertura* Zones boundary approximates the Chickasawhayan/Vicksburgian Stages boundary and the Chattian/Rupelian Stages boundary (Pl. 1).

According to this model, the extreme low stand of the sea, TB1.1, was not a sudden event as indicated by Vail and others (1977) and Haq and others (1987). Rather, it was preceded by a series of progressively lower low stands of the sea punctuated by progressively lower high stands of the sea. The culmination of these falling sea levels was the extreme low stand at the beginning of depositional cycle TB1.1. Haq and others (1987) show a progressive rise in eustatic sea level following the TB1.1 low stand. These subsequent high stands, TB1.2 and TB1.3 consist of cycles of progressively higher high stands of the sea punctuated by progressively higher low stands of the sea.

Because the Gulf Trough extends more than three quarters of the way across the Coastal Plain of Georgia, it must have intercepted a number of large, Piedmont-draining rivers during the Oligocene low stands (and also during the Miocene low stands) of the sea. These rivers would have included the paleo-Chattahoochee, paleo-Flint, paleo-Ocmulgee, and paleo-Oconee rivers. Even if the Gulf Trough intercepted only one major river of the size of one of the above rivers, the Gulf Trough would have become an over-sized river valley during the subsequent Oligocene low stands of the sea and, at most, a large estuary during the Late Oligocene high stands of the sea. As a result it is postulated here that during the low stands of the sea of the Late and post-Vicksburgian Oligocene (and during the subsequent Miocene low stands), the Gulf Trough served as a large river valley system (Figs. 48, 64). Southwest of Coffee County, Georgia, the river system flowed southwestward into the Gulf of Mexico via the remnant of the Chattahoochee Embayment. The modern Ochlockonee River that flows southwestward along the southern margin of the Gulf Trough in Georgia and Florida may be the descendent of this Late Oligocene-Miocene river.

The floor of the Gulf Trough on the top of the Oligocene is topographically high in Coffee County, and it is interpreted that the Coffee County area (within the Gulf Trough) was a drainage divide. To the southwest of Coffee County it is speculated, the Late Oligocene Gulf Trough river (paleo-Ochlockonee River) drained southwestward through the Gulf Trough into the Gulf of Mexico via the remnant of the Chattahoochee Embayment. To the northeast of Coffee County, the Gulf Trough is thought to have been occupied by a large lake or inland swamp at this time. The paleo-Oconee River flowed into the basin from the north and tributary streams flowed into it from the northeast and southwest along the axis of the Gulf Trough (Fig. 48). This segment of the Gulf Trough drained into the Atlantic Ocean through the large river valley of the paleo-Altamaha River. It is unlikely that the Ocmulgee River was captured by the Oconee River during the Late Oligocene or Early Miocene because the Early Miocene marine transgressions (high stands of the sea) submerged the modern lower Ocmulgee/Oconee Rivers area. Subsequently, the fluvial Middle Miocene Altamaha Formation (of probable braided stream origin) blankets the area. Such a depositional environment on an active flood plain does not seem an appropriate place for stream capture by large streams. Yet curiously, and probably not coincidentally, the northeastward bend of the Ocmulgee River occurs east of the topographic high within the top along the buried Gulf Trough.

No siliciclastics are known to occur in any of the marine Chattahoochee Embayment Oligocene deposits in Florida (Huddlestun, 1984; Schmidt, 1984). It is concluded, therefore, that the paleo-Ochlockonee River had no siliciclastic bed load during the Oligocene. It is also concluded that there is no evidence for substantial tectonic uplift in the Piedmont during the Late Oligocene and the rejuvenation of the Piedmont appears to have occurred suddenly and with relatively rapid uplift at the beginning of the Miocene.

A linear depression (or series of depressions) formed within the Gulf Trough during the Oligocene (Fig. 48, Pl.2). The depression (or depressions) appears to have developed on the top of the Oligocene and is filled with gray to dark gray, fine- to medium-grained sand and clay that is barren of carbonates and is thought to be of earliest Miocene age (Parachucla Formation). The depression (or depressions) extends from eastern Irwin County southwestward to Mitchell County and ranges from 100 feet (30 m) to almost 300 feet (91 m) thick. It has the appearance of a narrow river valley within the Gulf Trough but it cannot yet be traced southwest of Mitchell County or northeast of Irwin County. Because the inner part of the Chattahoochee Embayment southwest of Mitchell County appears to have been emergent during the Late Oligocene, I think that if the depression were a river valley, it would extend into Florida. Because it does not, I suggest that the linear depression is either of karst origin or is related to differential sedimentation within the Gulf Trough during the Vicksburgian. If this model is accurate, it seems likely that the depression(s) would have been lacustrine during the Late Oligocene low stands of the sea but received no siliciclastics from the surrounding karst terrane. The initial sand and clay fill of the depressions would then represent the oldest sediments eroded from the rising Piedmont at the very beginning of the Miocene.

When the sea again reentered the Gulf Trough near the beginning of the Miocene, the southwestern part of the Gulf Trough in the Chattahoochee Embayment in Florida remained in very shallow, brackish water, whereas the northeastern part of the trough was in somewhat deeper water under inner continental shelf conditions. The marine influences in the Gulf Trough in Georgia during the Miocene were derived from the Atlantic Ocean rather than the Gulf of Mexico.

ENVIRONMENTAL EVOLUTION DURING THE OLIGOCENE

The environmental evolution of the onshore Oligocene, and especially that of the eastern Gulf Coastal Plain, appears to be different from that of the outer continental shelf of Georgia. In the eastern Gulf Coastal Plain, the Oligocene can be characterized by a progressive westward expansion of the of the carbonate lithosome. The middle Vicksburgian, limestone (Glendon Limestone) was being deposited at Vicksburg on the Mississippi River. Only subsequent to the deposition of the Glendon was there a progressive shallowing of the shelf and a seaward (southward) and eastward expansion of the siliciclastic lithosome. The greatest expansion of the Oligocene siliciclastic lithosome occurred during the deposition of the Bucatunna Clay. Subsequently, during the Chickasawhayan, the shelf deposits westward into Mississippi were a mixture of carbonates and siliciclastics.

On the outer continental shelf and perhaps onshore in eastern Georgia, another sort of environmental evolution appears to have occurred. The Upper Eocene carbonates onshore and offshore are devoid of phosphate and any significant amounts of siliciclastics except in the coastal environment (Barnwell Group). However, the Vicksburgian is characterized by the sudden appearance but minor occurrence of both phosphate and siliciclastics. The amount of phosphate and siliciclastics appear to increase incrementally from the early Vicksburgian through the subsequent Chickasawhayan, and into the lower Aquitanian.

The above observations are interpreted as indicating differing evolving conditions in the Gulf Coastal Plain and the Atlantic Coastal Plain. The beginning of phosphate generation in the Atlantic Coastal Plain began near the beginning of the Oligocene and increased incrementally through the Oligocene. In that area, the Oligocene can be viewed as transitional from the Eocene to the Miocene. In the eastern Gulf Coastal Plain, however, the evolving Oligocene environment of deposition does not appear to be transitional to the Miocene but appears to be mainly offlap of the Eocene with a number of pulses of siliciclastic deposition (Forest Hill-Red Bluff, Byram, and Bucatunna).

MIOCENE/OLIGOCENE BOUNDARY

Southeastern North America is a poor place to study the Oligocene/Miocene boundary. The Upper Oligocene is poorly represented in the region, with the only deposits of known Late Oligocene age being assigned to the Chickasawhayan. However, the precise correlation of the Chickasawhayan with the standard planktonic microfossil zonations has yet to be accomplished. In terms of planktonic foraminiferal zonation, the best approximation at this time is correlation with the *Globorotalia opima opima* Zone. Because the Chickasawhayan in Mississippi and Alabama represents mainly an inner neritic, continental shelf environment, the Chickasawhayan deposits do not contain rich planktonic foraminiferal suites and *Globorotalia opima* is represented by small to large *G. opima nana* (also see Poag, 1966, 1968?).

In the Ashley Member of the Cooper Formation in South Carolina which represents an outer neritic, continental shelf environment, and in the Cooper under the outer continental shelf of Georgia, the Chickasawhayan planktonic foraminiferal suite is still not diverse and *Globorotalia opima nana* is poorly represented. The consistent presence of *Globigerina angulisuturalis*, however, in Chickasawhayan deposits across the southeast indicates that the Chickasawhayan is post-*Globigerina ampliapertura* Zone.

The significant evolutionary advancement in the planktonic foraminiferal suite of the basal Miocene, Aquitanian, lower Parachucla Formation in Georgia (Huddlestun, 1988) over that of the Chickasawhayan suggests a significant time gap between the Chickasawhayan and the Aquitanian. Based on the relative changes in the planktonic foraminiferal faunas, the Chickasawhayan/Aquitanian hiatus would appear to be greater than that of the Vicksburgian/Chickasawhayan hiatus.

In most areas in Mississippi, Alabama, Florida, and Georgia, the Chickasawhayan is not directly overlain by the Aquitanian. Where it may be (Mississippi and Alabama), the Aquitanian is nonfossiliferous in terms of calcareous fossils. In the panhandle of Florida, the Chickasawhayan is commonly overlain by the Aquitanian Chattahoochee Formation or by the upper Burdigalian (upper Lower Miocene)(Huddlestun, 1984). In Georgia, and much of peninsular Florida, the Aquitanian directly overlies upper Vicksburgian, Byram- or Bucatunna-equivalent deposits. On the outer continental shelf of

Georgia, both the Chickasawhayan and lower Aquitanian contain unusually sparse planktonic foraminiferal faunas. Perhaps the best area to study the nature of the Oligocene/Miocene boundary in outcrop or shallow cores in the southeastern United States is in the Cooper Formation in the vicinity of Charleston, South Carolina. In that area, middle to outer neritic Aquitanian (Cooper Formation) directly overlies middle to outer neritic Chickasawhayan (Ashley Member of the Cooper Formation). Sediments of latest Oligocene age may be present in that area. It is also possible that there is a more extended Upper Oligocene and Lower Miocene section in the subsurface of southern Florida.

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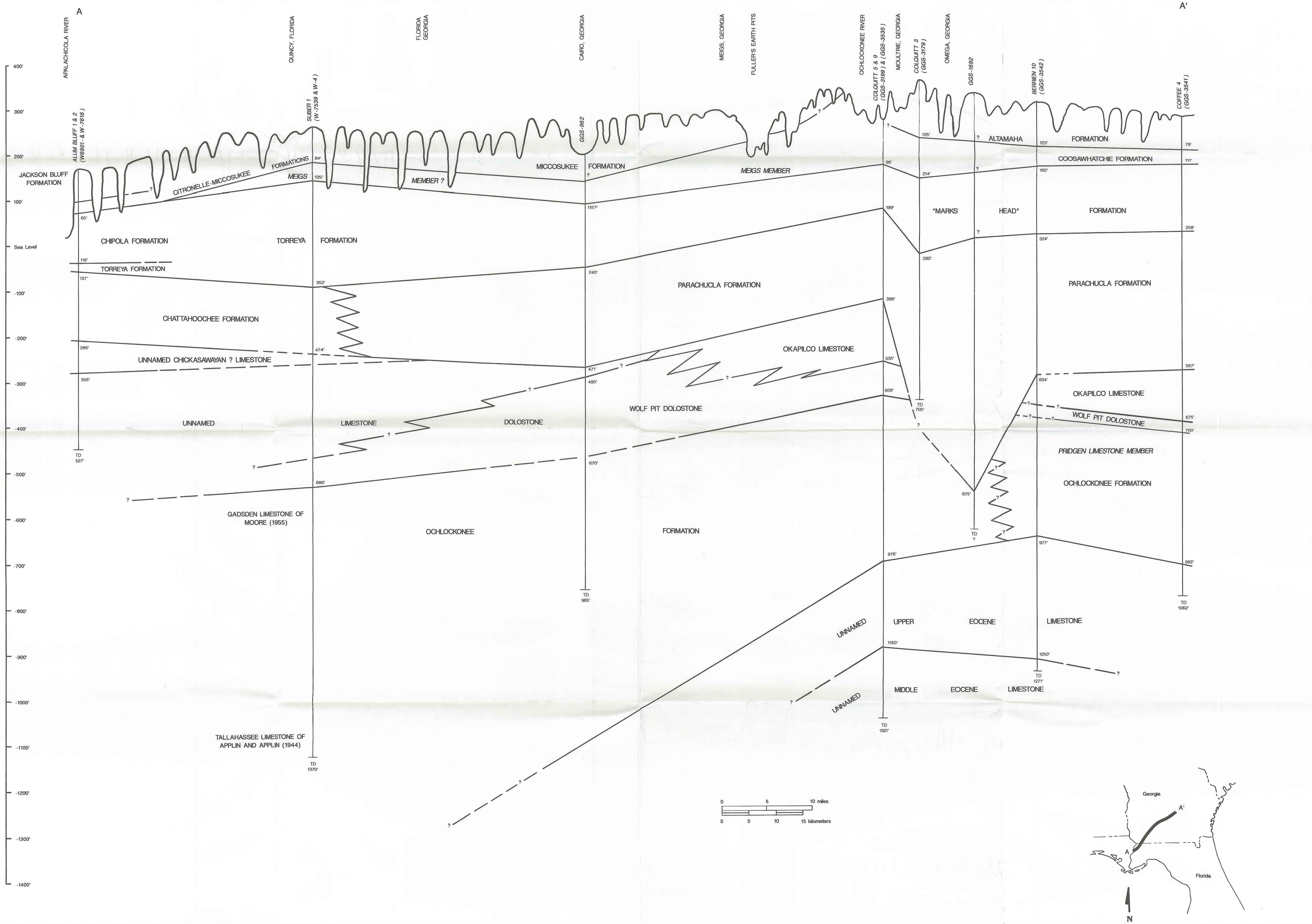
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

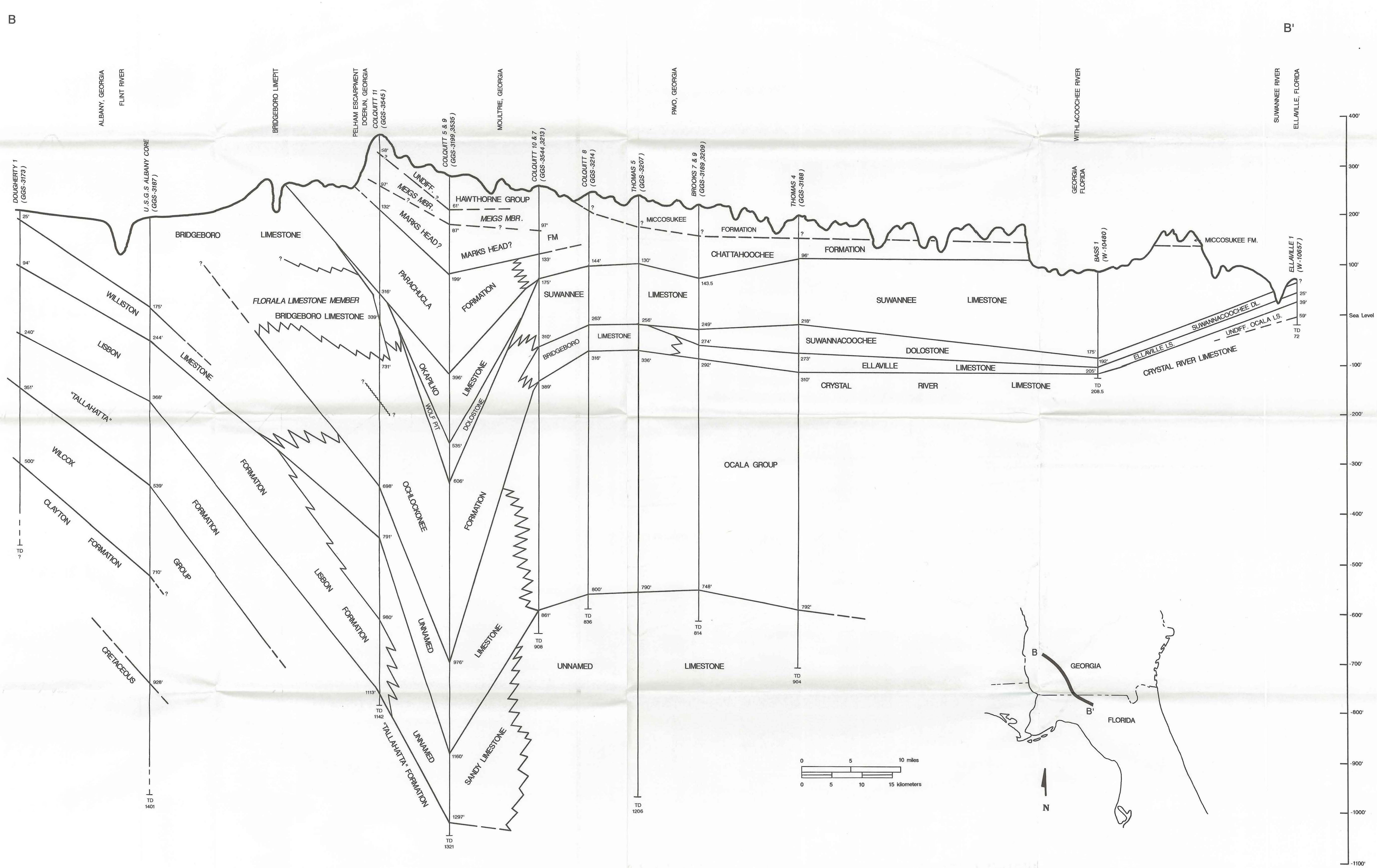
CORRELATION CHART

BULLETIN 105
PLATE 1

STRATIGRAPHIC CROSS-SECTION ALONG THE AXIS OF THE GULF TROUGH FROM THE CORE COFFEE 4 (GGS-3541) IN NORTHERN COFFEE COUNTY, GEORGIA, TO THE CORE ALUM BLUFF 1 (W-6901) IN LIBERTY COUNTY, FLORIDA



STRATIGRAPHIC CROSS-SECTION FROM DOUGHERTY COUNTY, GEORGIA TO ELLAVILLE, HAMILTON COUNTY, FLORIDA



STRATIGRAPHIC CROSS-SECTION NEAR THE SAVANNAH RIVER FROM SCREVEN COUNTY, GEORGIA, TO THE INNER CONTINENTAL SHELF

EAST-WEST STRATIGRAPHIC CROSS-SECTION FROM DUNCAN CHURCH, FLORIDA, TO AMCOR 6002 ON THE OUTER CONTINENTAL SHELF

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