IC 25

GEORGIA

STATE DIVISION OF CONSERVATION

DEPARTMENT OF MINES, MINING AND GEOLOGY
GARLAND PEYTON, Director

THE GEOLOGICAL SURVEY
Information Circular 25

SUBSURFACE GEOLOGY OF THE GEORGIA COASTAL PLAIN

by

Stephen M. Herrick and Robert C. Vorhis
United States Geological Survey

Prepared cooperatively by the Geological Survey, United States
Department of the Interior, Washington, D. C.

ATLANTA

1963

CONTENTS

	Page
ABSTRACT	1
INTRODUCTION	1
Previous work	2
Mapping methods	7
Cooperation, administration, and acknowledgments	8
STRATIGRAPHY	9
Quaternary and Tertiary Systems	10
Recent to Miocene Series	10
Tertiary System	13
Oligocene Series	13
Eocene Series	18
Upper Eocene rocks	18
Middle Eocene rocks	25
Lower Eocene rocks	32
Paleocene Series	36
Cretaceous System	41
Upper Cretaceous Series	41
Post-Tuscaloosa deposits	41
Tuscaloosa Formation	47
Lower Cretaceous(?) Series	51
STRUCTURE	55
UNSOLVED PROBLEMS	66
REFERENCES	68
INDEX	74

ILLUSTRATIONS

		Page
Figure 1.	Map of Coastal Plain of Georgia showing location of logged wells and geologic sections	Inside Back Cover
2.	Thickness-distribution map of Recent to Miocene deposits	11
3.	Structural-contour map of the top of Oligocene deposits	12
4.	Thickness-distribution map of Oligocene deposits	14
5.	Distribution of Oligocene index fossil: Rotalia mexicana var.	15
6.	Structural-contour map of the top of upper Eocene deposits	20
7.	Thickness-distribution map of upper Eocene deposits	21
8.	Structural-contour map of the top of the middle Eocene deposits	26
9.	Thickness-distribution map of middle Eocene deposits	27
10.	Structural-contour map of the top of lower Eocene deposits and erosion surface	34
11.	Thickness-distribution map of lower Eocene deposits	35
12.	Structural-contour map of the top of Paleocene deposits	39
13.	Thickness-distribution map of Paleocene deposits	40
14.	Structural-contour map of the top of Upper Cretaceous post-Tuscaloosa deposits	42
15.	Thickness-distribution map of post-Tuscaloosa Cretaceous deposits	43
16.	Structural-contour map of the top of Tuscaloosa Formation	49
17.	Thickness-distribution map of Tuscaloosa Formation	50
18.	Structural-contour map of the top of Lower Cretaceous(?) deposits and erosion surface	52
19.	Thickness-distribution map of Lower Cretaceous(?) deposits	53
20.	Structural-contour map of the pre-Cretaceous surface	54
21.	Geologic section, Early County northeastward to Richmond County	58
22.	Geologic section, Seminole County northeastward to Richmond County	59
23.	Geologic section, Brooks County northeastward to Beaufort County, S. C.	60
24.	Geologic section, Early County easterly to McIntosh County	61
25.	Geologic section, Decatur County eastward to Echols County	62
26.	Geologic section, Clay County southeastward to Echols County	63
27.	Geologic section, Macon County southeastward to Glynn County	64
28.	Geologic section, Chattahoochee County southward to Decatur County	65

TABLES

		Page
Table 1.	Previous subsurface geologic maps of the Georgia Coastal Plain	3
2.	Previous geologic sections through the Coastal Plain of Georgia	6
3.	Explanation of symbols on maps	8
4.	Oligocene Foraminifera of Georgia	16
5.	Upper Eocene Foraminifera of Georgia	22
6.	Middle Eocene Foraminifera of Georgia	29
7.	Lower Eocene Foraminifera of Georgia	33
8.	Paleocene Foraminifera of Georgia	37
9.	Correlation of surface and subsurface units of post-Tuscaloosa Cretaceous age	41
10.	Foraminifera from the post-Tuscaloosa Cretaceous of Georgia	45
11.	Foraminifera from the marine facies of the Tuscaloosa Formation in Georgia	48
12.	Generalized dip of formational contacts in the Coastal Plain of Georgia	56

SUBSURFACE GEOLOGY OF THE GEORGIA COASTAL PLAIN

Stephen M. Herrick and Robert C. Vorhis

ABSTRACT

The subsurface geology of the Coastal Plain of Georgia has been restudied using data from 354 lithologic-paleontologic logs. Two contrasting areas of deposition are described: an updip area of clastics and a downdip area of limestones. Because faunas of the clastics are found to be different from those of the limestones, foraminiferal lists for each type are included as well as for each geologic unit.

In the Coastal Plain the sediments are wedge-shaped, being in general thinnest inland and thickest near the present shoreline. This wedge is modified in some of the units by the presence of depocenters where the thickness is greater than in surrounding areas. Locally, overlap is important in the northern part of the Coastal Plain with middle Eocene sediments overlapping those of the Paleocene and lower Eocene and being overlapped in turn by upper Eocene sediments.

An outgrowth of the study has been some reinterpretations as well as some reinforcing of the stratigraphy. The Charlton Formation is regarded by the authors as being late Miocene in age and is tentatively correlated with the Duplin Marl of the Carolinas and eastern Georgia. The Cooper Marl and the underlying Barnwell Formation of late Eocene age are the updip clastic equivalents of the upper member of the Ocala Limestone. The lower member of the Ocala Limestone is the part of the formation that crops out in Georgia, the upper member not extending far enough updip to crop out. The Lisbon and Tallahatta Formations of middle Eocene age extend through much of the subsurface of Georgia and are the updip equivalents of the Avon Park and Lake City Limestones of Florida. The lower Eocene clastic deposits correlate with the Wilcox Group of Alabama and their downdip limestone equivalent is the Oldsmar Limestone of Florida. The Paleocene deposits consist of the Clayton Formation, overlying, in southwest Georgia and in Chatham County, fossiliferous marls equivalent in age to the Tamesi (Velasco) of Mexico. The surface updip post-Tuscaloosa deposits correlate with their downdip marine equivalents of Navarro, Taylor, and Austin age.

The geologic structure is outlined on maps showing the top of the Oligocene, upper Eocene, middle Eocene, lower Eocene, Paleocene, Cretaceous, Tuscaloosa Formation, Lower Cretaceous(?), and pre-Cretaceous. Other maps show the thickness and distribution of sediments of the Recent to Miocene, Oligocene, upper Eocene, middle Eocene, lower Eocene, Paleocene, post-Tuscaloosa Cretaceous, Tuscaloosa Formation, and Lower Cretaceous(?) sediments. Additional interpretation of the structure is shown on 8 geologic sections. The major structural basins in Georgia are the Atlantic Embayment in the southeast and the Gulf Trough in the southwest.

INTRODUCTION

The most important mineral resource of the Georgia Coastal Plain is its ground-water supply. In order to ascertain the magnitude and distribution of this supply in the sediments of the Coastal Plain, a good understanding of the geological framework that contains the ground water and directs its flow is needed. The purpose of this paper is to present the interpretation of the subsurface geology so that the ground-water hydrology of the 35,000 square miles that comprise the Coastal Plain of Georgia will be better understood. This report does not deal with ground water directly but is a basis for detailed ground-water studies in the Georgia Coastal Plain counties.

This report is based largely upon the records of wells reported by Herrick (1961) in a report frequently ferred to herein as "the well-log report." In that report the lithology and fauna from numerous samples e described in detail. For more information on individual wells the reader is referred to the well-log port.

Cuttings from water wells have been a source of much of the geologic knowledge of the Coastal Plain. However, the vast magnitude of the ground-water resource in Coastal Georgia has caused most wells to be drilled to relatively shallow depths, thereby limiting the data available on the geology of underlying formations and aquifers.

So far about a hundred wildcat oil-test wells have been drilled in the Coastal Plain of Georgia and these have been the other major source of data. However, many were drilled without adequate sampling and logging and with minimal geologic study so it is not misleading to say that the Georgia Coastal Plain is almost virgin material to the oil-driller's bit and that this area currently can be considered a relatively unexplored province. The approximately 100 oil tests give a well density of about 1 for each 350 square miles. Many of these wells are grouped so that the 34 oil tests logged by Herrick (1961) probably give a more representative figure for use in a ratio--namely, 1 geologically studied oil well for each 1,000 square miles of Coastal Plain. The 354 oil-test and water wells described in the well-log report give a ratio of one well for every 100 square miles of Coastal Plain. Ratios such as these indicate that much more geologic study of well samples will be needed for an adequate interpretation of Coastal Plain geology and that the present report still allows for much additional work. Although this is a preliminary study with great distances separating the wells studied, much new information has been added to the knowledge of the subsurface geology and areas where additional work is needed have been delineated.

This report summarizes paleontologic and stratigraphic work in the Coastal Plain of Georgia by the senior author done intermittently over several years. The maps are based almost solely on the logs prepared by him (Herrick, 1961). The maps, geologic sections, tables, and part of the text have been prepared by the junior author after some restudy of the well-log data. Differences to be found between the data as mapped herein and as published in the well-log report represent changes in interpretation.

The maps and sections (see fig. 1 inside back cover) are based on the published logs of 354 wells in the Coastal Plain of Georgia (Herrick, 1961). Because these logs have all been made by the senior author, they represent a uniform considered treatment, a balance often difficult to achieve when synthesizing data from many different sources. Therefore, with the wealth of new data, a completely fresh interpretation seemed needed. A major exception in this policy is the area along the Georgia-Florida line where the new maps were made to agree with the published literature: The thickness of the Miocene was reconciled with that for Florida by Vernon (1951); the top of the Ocala was reconciled with data given in Black and Brown (1951) and Meyer (1963); and the thickness of the Ocala tied to that given by Puri (1957).

Paul L. and Esther R. Applin kindly furnished picks on the top of the Lower Cretaceous(?) Series in the following wells: Colquitt 170, Early 121, and Echols 189; also from discussions with them revisions of the Lower Cretaceous(?) in the well-log report were made in Liberty 363, Mitchell 109, Seminole 187, and Wayne 52. Unpublished lithologic logs by the late Vaux Owen, Jr., furnished formational tops in the following wells: Sumter 281 and Sumter 296. Supplementary data on oil tests in Georgia were taken from Hurst (1960).

The foraminiferal names in the faunal lists of this report are mainly those as given in the well-log report. The authors are cognizant that many of the names are not in accordance with recent generic revisions. Examples include Epistomina caracolla which is now Hoglundina caracolla; Rotalia mexicana var. mecatepecensis, which has also been called Neorotalia mecatepecensis (E.R. Applin, 1960, p. B208) and Streblus mexicanus mecatepecensis (Cole and Applin, 1961, p. 127); many of the species of Cibicides that now would be put in Cibicidina; and many of the species of Discorbis that could be regrouped under Rosalina, Neoconorbina, and Rotorbinella. Nomenclatural changes such as these would be desirable mainly for those concerned with taxonomic usage. However, for the many who are concerned with checking their finds against the plates and descriptions as contained in paleontological publications, the use of the older established names seems highly desirable. Because the names as given are generally those found with the published plates, comparisons can be made far more readily than if the "up-to-date" names had been used.

Previous Work

The interpretations in this report represent a fresh look at the stratigraphy, paleontology, and structure of the Coastal Plain in Georgia. Although the previous work has not been used directly, it has been examined. Because the pertinent geologic literature on the area is synthesized by Murray (1961) and is summarized by LeGrand (1961), the authors believe that any extensive review of the literature is unnecessary in this report. The review of the literature on the Coastal Plain of Georgia is condensed into two tables: one listing published subsurface geologic maps; the other listing published geologic sections. Also, in the discussion of the stratigraphy, pertinent paleontologic papers are cited.

The subsurface maps in table 1 include those of the entire Georgia Coastal Plain as well as those of individual counties. To facilitate use of the table, the maps generally are listed by geologic age of the top or thickness of the unit mapped. Where titles mentioned base of a unit, this was altered to indicate the top of the next lower unit. The list is restricted to original contributions and does not include maps that are copied from previous publications.

The geologic sections pertaining to the Georgia Coastal Plain (see table 2) are listed by author. To

Table 1.--Previous subsurface geologic maps of the Georgia Coastal Plain

Mapped features of subsurface geology	Contour interval (except as noted) (feet)	Scale	Reference
Thickness of Recent, Pleistocene, and Pliocene	50	1:7,000,000	Toulmin, 1952, fig. 8
Base of Hawthorn Formation of Miocene age	100	1:1,800,000	Pettyman and Cave, 1923, pl. 3
Thickness of Miocene	100	1:7,000,000	Toulmin, 1952, fig. 7
Top of limestone of Miocene, Oligocene or late Eocene age	50	1:7,700,000	Warren, 1944, fig. 1
Top of Oligocene, Mitchell County	50	1:310,000	Owen, 1961, fig. 3
Thickness of Oligocene	100	1:7,000,000	Toulmin, 1952, fig. 6
Oligocene, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 1
Top of upper Eocene (Ocala Limestone)	200	1:7,000,000	Applin and Applin, 1944, fig. 14
Top of upper Eocene (Ocala Limestone)	100	1:2,800,000	Black and Brown, 1951, fig. 3
Upper Eocene, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 2
Thickness of upper Eocene	50	1:7,000,000	Applin and Applin, 1944, fig. 17
Thickness of upper Eocene	100	1:7,000,000	Toulmin, 1952, fig. 5
Thickness of upper Eocene and upper middle Eocene	500	1:7,000,000	Applin and Applin, 1944, fig. 18
Top of middle Eocene, southwest Georgia	50	1:1,000,000	Munyan, 1939
Thickness of middle Eocene	250	1:7,000,000	Toulmin, 1952, fig. 4
Top of middle Eocene, Dougherty County	50	1:621,000	Wait, 1963, fig. 9
Top of Middle Eocene, Lee and Sumter Counties	40	?	Owen, in press, fig. 13
Upper middle Eocene (Avon Park Limestone), subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 3
Lower part of upper middle Eocene (Tallahassee Limestone), subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 4
Lower middle Eocene (Cook Mountain age), subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 5
Top of lower middle Eocene	500	1:7,000,000	Applin and Applin, 1944, fig. 15
Thickness, lower middle Eocene through beds of Navarro age	500	1:7,000,000	Applin and Applin, 1944, fig. 19
Top of lower Eocene, Dougherty County	50	1:621,000	Wait, 1963, fig. 8
Top of lower Eocene, Lee and Sumter Counties	40	?	Owen, in press, fig. 12

Table 1.--Previous subsurface geologic maps of the Georgia Coastal Plain - continued

Mapped features of subsurface geology	Contour interval (except as noted) (feet)	Scale	Reference
Lower Eocene, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 6
Thickness of lower Eocene	250	1:7,000,000	Toulmin, 1952, fig. 3
Top of Paleocene, Dougherty County	100	1:621,000	Wait, 1963, fig. 7
Top of Paleocene, Lee and Sumter Counties	40	?	Owen, in press, fig. 11
Top of Paleocene (Clayton Limestone), Terrell County	100	1:414,000	Wait, 1960, p. 118
Paleocene, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 7
Thickness of Paleocene	250	1:7,000,000	Toulmin, 1952, fig. 2
Top of Cretaceous	500	1:5,000,000	Hull, 1962, fig. 1
Top of Cretaceous, western Georgia	100	1:500,000	Eargle, 1955, pl. 3
Top of Cretaceous, Dougherty County	100	1:621,000	Wait, 1963, fig. 6
Top of Cretaceous, Lee and Sumter Counties	50	?	Owen, in press, fig. 10
Cretaceous System, thickness and lithofacies	---	1:21,860,000	Sloss, Dapples and Krumbein 1960, map 123
Beds of Navarro age, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 8
Thickness of Upper Cretaceous	500	1:500,000	Hull, 1962, fig. 2
Thickness of post-Eutaw Cretaceous	500	1:7,000,000	Applin and Applin, 1944, fig. 20
Thickness of Upper Cretaceous (Gulf Series)	500	1:6,700,000	Applin, 1952, fig. 2.
Top of beds of Taylor age	500	1:7,000,000	Applin and Applin, 1944, fig. 16
Upper beds of Taylor age, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 9
Lower beds of Taylor age, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 10
Top of Ripley Formation, western Georgia	50	1:500,000	Eargle, 1955, pl. 3
Top of Cusseta Sand, western Georgia	50	1:500,000	Eargle, 1955, pl. 3
Subsurface extent of beds of Austin age	---	1:7,000,000	Applin and Applin, 1944, fig. 11
Top of Blufftown Formation, western Georgia	50	1:500,000	Eargle, 1955, pl. 3
Top of Eutaw Formation, western Georgia	50	1:500,000	Eargle, 1955, pl. 3

Table 1.--Previous subsurface geologic maps of the Georgia Coastal Plain - continued

Mapped features of subsurface geology	Contour interval (except as noted)	Scale	Reference
Top of Tuscaloosa Formation, western Georgia	50	1:500,000	Eargle, 1955, pl. 3
Tuscaloosa Formation, subsurface extent	---	1:7,000,000	Applin and Applin, 1944, fig. 12
Top of Atkinson Formation (top of Eutaw)	500	1:2,500,000	Applin, 1961
Top of Atkinson Formation (top of Eutaw)	250	1:3,900,000	Applin and Applin, 1947, map 1
Thickness of upper and middle members of Atkinson Formation	100	1:3,900,000	Applin and Applin, 1947, map 3
Top of basal member of Atkinson Formation	250	1:3,900,000	Applin and Applin, 1947, map 2
Littoral facies of upper member of Atkinson Formation	---	1:3,900,000	Applin and Applin, 1947, map 4
Shallow-water marine facies, upper member of Atkinson Formation	---	1:3,900,000	Applin and Applin, 1947, map 5
Deeper-water marine facies, upper member of Atkinson Formation	---	1:3,900,000	Applin and Applin, 1947, map 6
Upper Cretaceous, thickness and lithofacies of Woodbine equivalent	200	1:10,900,000	Sloss, Dapples and Krumbein, 1960, map 130
Thickness of Lower Cretaceous(?)	500	1:6,700,000	Applin, 1952, fig. 3
Lower Cretaceous, thickness and lithofacies of Trinity equivalent	500	1:9,200,000	Sloss, Dapples and Krumbein, 1960, map 124; Fortgotson, 1963, fig. 4
Top of pre-Cretaceous	1,000	1:2,000,000	Woollard, 1955, fig. 6
Top of pre-Cretaceous, eastern Georgia	500	1:4,200,000	Bonini and Woollard, 1960, fig. 4
Top of crystalline rocks, western Georgia	50	1:500,000	Eargle, 1955, pl. 3
Top of pre-Mesozoic surface	1,000	1:5,000,000	P. L. Applin, 1951, fig. 2
Top of Precambrian and Paleozoic	2,500	1:2,500,000	P. L. Applin, 1961
Thickness of Cenozoic deposits	1,000	1:13,200,000	LeGrand, 1961, fig. 8
Thickness of Cenozoic sediments	500	1:7,000,000	Toulmin, 1952, fig. 1
Thickness of Cenozoic sediments	500	1:9,300,000	Toulmin, 1955, fig. 1
Isogamic map	200 gammas	1:6,336,000	Murray, 1961, fig . 2. 18
Bouguer gravity anomaly map	10 milligals	1:2,000,000	Woollard, 1955, fig. 1
Major structural features	---	1:13,200,000	LeGrand, 1961, fig. 3
Major tectonic features of eastern Gulf Coast	---	1:13,200,000	Braunstein, 1959, p. 12

Table 2.--Previous geologic selections through the Coastal Plain of Georgia

Well numbers as given in Herrick (1961)

Reference	Location of section	Vertical scale	Horizontal scale
Applin and Applin, 1944, fig. 22	Pierce 119 and Florida wells	1 in = 1,500 ft	1 in = 50 mi
Applin, 1951, fig. 3	Tennille, Laurens 51, Montgomery 190, Appling 148, Atkinson 107, Clinch 144, Clinch 481, Echols 169, and Florida wells	1 in = 3,400 ft	1 in = 54 mi
Applin and Applin, 1947, fig. 2	Early 121, Mitchell 109, Atkinson, 107, Pierce 119, Wayne 52	1 in = 1,000 ft	1 in = 20 mi
Bonini and Woollard, 1960, fig. 5	Section E-E' shows profile of pre-Cretaceous near Savannah River	1 in = 4,000 ft	1 in = 58 mi
Counts and Donsky, in press	Tattnall County through Savannah to Atlantic Ocean and fence diagram		
Eargle, 1955, fig. 16	Muscogee to Randolph Counties	1 in = 2,200 ft	1 in = 12 1/2 mi
Eargle, 1955, fig. 17	Crawford to Houston Counties	1 in = 1,600 ft	1 in = 8 mi
Herrick and Wait, 1955	Liberty 363, Chatham 381, Beaufort 385, and South Carolina well	1 in = 100 ft	?
Do	Screven 295 Effingham 211, Chatham 62, Chatham 386, Chatham 381	1 in = 100 ft	?
Herrick and Wait, 1956, fig. 1	Columbia 264, Burke 131, Screven 235, Effingham 211, Chatham 62, and Liberty 363	1 in = 860 ft	1 in = 33 1/3 mi
Hull, 1962, fig. 3	Atkinson 107, 3 wells in Clinch County, and an Echols County well	1 in = 1,4000 ft	1 in = 11 mi
LaMoreaux, 1946, fig. 8	Sections of outcrops in Twiggs, Wilkinson, and Washington Counties	1 in = 90 ft	1 in = 8.3 mi
LeGrand, 1956, fig. 3	Washington 94, Jefferson 133, and well in Burke County	1 in = 400 ft	
Owen, 1961, fig. 2	Calhoun 331; wells at Newton, Camilla, and Pelham; and Thomas 59	1 in = 280 ft	1 in = 5.7 mi
Owen, in press, fig. 7	Andersonville to Albany, northwestern Sumter County, Ellaville to Bronwood		
Richards, 1945, fig. 25	South Carolina wells, Pierce 119, Florida well		
Richards, 1948, fig. 3	Early 121, Mitchell 109, Atkinson 107, and Wayne 52	1 in = 2,400 ft	1 in = 32 mi
Southeastern Geol. Soc., 1949, Mesozoic Comm.	South Carolina well, Wayne 52, Camden 153, Florida wells	1 in = 200 ft	1 in = 10 mi
Do	Toombs 95, Appling 148, Atkinson 107, Clinch 144, Echols 166	1 in = 200 ft	1 in = 10 mi
Toulmin, 1952	Washington 94, Treutlen 127, Montgomery (Wilkes 1), Appling 148, Pierce 119, Camden 153, and Florida wells	1 in = 1,000 ft	1 in = 37 1/2 mi
Toulmin, 1955	Two lithologic sections	1 in = 1,725 ft	1 in = 66 mi
Wait, 1963, pl. 4	Webster, Dougherty, and Mitchell Counties	1 in = 133 ft	1 in = 2 2/3 mi
Wait, 1963, pl. 5	Fence diagram of Tertiary stratigraphy in Albany area	1 in = 133 ft	1 in = 1 mi
Wait, 1963, pl. 3	City of Morgan well, Dougherty 11, City of Albany well, and U.S. Marine Corps well	1 in = 133 ft	1 in = 0.75 mi

describe the location of the geologic section, the county name and the Georgia Geological Survey number of the well are given: e.g., Atkinson 107. Under this number are filed in the sample library maintained by the Georgia Department of Mines, Mining and Geology, the cuttings of the wells which are available for further study by geologists and paleontologists. The numbers also are the same as those used in the well-log report by Herrick (1961).

One paper which the authors have used extensively is that by Paul and Esther Applin (1944), on the "Regional subsurface stratigraphy and structure of Florida and southern Georgia." Because the Applins' paper has been so remarkably useful, the authors have chosen to model this present paper more or less along similar lines.

Mapping Methods

The data presented are separated by horizontal distances measured in miles but the vertical measurements are in feet. Furthermore, errors in sampling and in interpretation of the samples can have too much influence in locating contour lines if the data are contoured mechanically. Therefore, the maps were prepared with the contours drawn to show the major structure thereby eliminating many of the minor features that strict mechanical contouring would show. At this stage in the investigation of the subsurface, the major features are not yet fully understood so adding minor ones would tend to obscure rather than aid interpretation.

The contoured maps have been superimposed to try and make the maps consistent one with another. Because of the wide spacing of many of the wells and lack of wells elsewhere the maps can be drawn with remarkably differing interpretation. Therefore, these maps are presented as the current interpretation of the authors and with the realization that they will need to be modified considerably as new data become available and as other interpretations are found to be more valid.

In order to make the maps more readily comparable, the contour interval on most of the maps is 100 feet. The tops of the lower Eocene down to the Tuscaloosa (of Late Cretaceous age) are contoured at an interval of 200 feet. The top of the Lower Cretaceous(?) and the pre-Cretaceous were contoured at 500-foot intervals. The thickness-distribution map for the Lower Cretaceous(?) was prepared with a contour interval of 400 feet.

Because of the many maps included in this study, the symbols used are listed and described in table 3 rather than having essentially the same explanation repeated on each map.

Table 3.--Explanation of symbols on maps

——— Structure-contour maps ———

———	Structure contour
10	Altitude of top of unit mapped
10^{+}	Top of unit above this altitude
10_{+}	Top of unit below this altitude
E	Altitudes based on estimated value for land surface
e	Altitude based on estimated thickness
	Datum is mean sea level
	Contour interval is 100 feet for maps of the top of the Oligocene, upper Eocene, and middle Eocene; 200 Feet for top of the lower Eocene, Paleocene, post-Tuscaloosa Cretaceous, and Tuscaloosa Formation; and 500 feet for top of the Lower Cretaceous (?) and pre-Cretaceous.

——— Thickness-distribution maps ———

———	Line of equal thickness
100	Logged thickness
100^{+}_{+}	Plus sign is used to indicate that the figure is a minimum value and that additional thickness is probable; the location of the plus indicating whether the additional thickness is above or below, or as in the case here, with two plus signs, the unit is likely to have additional thickness both above and below the 100 feet that were logged as being part of the geologic unit
e	Thickness estimated
0	Absent
	Contour interval is 100 feet for all maps except the Lower Cretaceous(?); for it the contour interval is 400 feet.

Cooperation, Administration, and Acknowledgments

The availability of material for a report such as this is evidence of the willing and splendid cooperation received from the water well drillers of Georgia, and the oil industry, who made the well cuttings available for study and who furnished the drillers logs and the electric logs.

The work was done under a cooperative program for ground-water investigations conducted by the U.S. Geological Survey and the Georgia Department of Mines, Mining, and Geology, Garland Peyton, Director, and under the supervision of J. T. Callahan, former district geologist, and H. B. Counts, current district engineer, U. S. Geological Survey.

Paul L. and Esther R. Applin, geologists with the U. S. Geological Survey, have both discussed phases of the work with the authors and the report has benefited from their helpfulness.

W. Storrs Cole, Professor of Geology at Cornell University, through his correspondence with the authors, discussed several aspects of the stratigraphy and paleontology thereby making available some of his vast experience on "larger" Foraminifera.

The illustrations have been drafted by Willis G. Hester.

STRATIGRAPHY

At least four structural-depositional features characterize the Coastal Plain of Georgia in its overall aspects. The first obvious feature is that the Coastal Plain is composed of a wedge-shaped block of stratified sediments that rests upon a pre-Cretaceous basement complex ranging from Triassic(?) to Paleozoic to Precambrian in age. In Mitchell County, Triassic(?) rocks overlying the basement complex were encountered at depth whereas black shale of Paleozoic age was penetrated at depths of 3,782 feet and 6,950 feet in Echols and Early Counties, respectively (Applin, 1951, p. 25). Depth to the underlying crystalline basement varies according to the position on the dip. Crystalline rocks of Precambrian age were encountered in updip areas, such as Richmond and Washington Counties, at 162 and 871 feet; in middip areas such rocks were penetrated at depths of 1,685 and 2,532 feet in Houston and Laurens Counties; and in downdip parts of the Coastal Plain in southeastern and southern Georgia at 4,075, 4,250, 4,674 (Applin, 1951, p. 21), and 4,125 feet (Applin, 1951, p. 27), in Appling, Liberty, Camden, and Echols Counties. In extreme southeastern Seminole County, 7,620 feet of sediments were penetrated in the deepest known embayment area in the Coastal Plain of Georgia, but even so the depth was not great enough to encounter pre-Cretaceous rock.

The second outstanding feature is that most of the Coastal-Plain sediments are composed of two contrasting but stratigraphically equivalent types of sedimentary deposits, a fact first noted by the Applins (1944, p. 1679). In updip parts of the Coastal Plain the deposits are distinctly clastic by nature and, in their overall aspect, resemble those of the western Gulf Coastal Plain. Downdip, the lithology gradually grades into limestone. The limestones of downdip areas are lithologically and faunally similar to their stratigraphic equivalents in peninsular Florida. In Glynn County, for example, this limestone facies includes all geologic formations beginning with the early Miocene down to and including the strata of Navarro (Late Cretaceous) age. Beginning with the beds of Taylor age, the remainder of the sediments belonging to the Upper Cretaceous as well as those of the still older Lower Cretaceous(?) are of the clastic type in Georgia. Still farther south, as for example the Everglades area of Florida, these clastics of Cretaceous age grade laterally to limestones. Accompanying the facies change in downdip parts of the Coastal Plain is a corresponding change in foraminiferal microfaunas. As pointed out by the Applins (1944, p. 1680), the Foraminifera of the clastics are similar to those of the western Gulf Coast whereas those of the limestone facies are similar to those of Cuba, the West Indies, and Mexico. A good example of this is the foraminiferal fauna characterizing the Paleocene in Georgia, a microfauna that shows rather close relationship to that of the West Indies and Mexico.

The third outstanding feature of the Coastal Plain in Georgia is what Murray has called "depocenters" (1961, p. 5, 89). These are areas of maximum deposition. An example of such a depocenter is the east-west trending belt of greatest thickness of the post-Tuscaloosa in the central part of the Coastal Plain. (See fig. 15.) Murray (1961, p. 281) attributes these depocenters to: (1) major variations in locale or rate of sedimentary accumulations, whatever their cause, and (2) regional warpings related to epeirogenic and isostatic adjustments.

The fourth structural-depositional feature of the Coastal Plain in Georgia requiring mention is formational overlap. From Lower Cretaceous(?) through upper Eocene time this was taking place in Coastal-Plain Georgia. The best example of this phenomenon is that of the upper Eocene which overlaps middle Eocene and Upper Cretaceous deposits in east-central Georgia, finally coming to rest directly upon Precambrian rocks in the Piedmont.

In this report a brief description of the subsurface stratigraphic section starts with the Miocene and ends with the Lower Cretaceous(?), the stratigraphic units being taken up in descending order. The veneer of post-Miocene strata is thin except for coastal Georgia and other more localized areas and is of such minor importance in the subsurface that it is omitted from this report.

Quaternary and Tertiary Systems

RECENT TO MIOCENE SERIES

Deposits of Recent to Miocene age have been identified throughout about three-fifths of the Coastal Plain of Georgia in more than 300 wells. (See fig. 2.) The uppermost unit is composed mainly of sand and is restricted in general to the coastal counties of southeast Georgia. The sand of post-Miocene age, is not discussed further in this report for it is of little importance in the subsurface, is remarkably barren of microfossils, and is the subject of another paper currently being prepared by the senior author.

The Miocene sediments compose the major portion of the deposits as mapped in figure 2 and the northern limit as shown is the general boundary of the occurrence of Miocene sediments. This inner limit of the outcrop trends from the southwest corner of Decatur County northeastward through the counties of Grady, Mitchell, Crisp, Bleckley, to Laurens County and thence southeasterly to the Savannah River along the southeast corner of Burke County.

Lithologically the upper and middle members of the Miocene in Georgia are composed of clastics, while the lower member consists of a series of limestones. The clastics are continuous throughout the entire area covered by this unit. If they grade downdip into limestones, such rocks have not yet been found anywhere in the subsurface of Georgia. It is possible, however, that such a downdip limestone facies does exist somewhere off the coast of Georgia. In the six coastal counties and eastern Wayne County the upper unit of the Miocene consists of dark-brownish-green, granular, rather loosely consolidated, abundantly micaceous, locally phosphatic and fossiliferous clays which rest either on beds of dolomitic limestone also of Miocene age as in Chatham County, or directly upon the underlying clays of the Hawthorn Formation, as for example in Glynn County. This upper member rapidly pinches out up the dip, coming to the surface as isolated outcrops along the major river valleys. Examples are exposures along the south bank of the Savannah River, particularly at Ebenezer Landing, Effingham County, along the south bank of the Altamaha River at Doctortown, Wayne County, and along the St. Mary's River south and southwest of Folkston, Charlton County. These strata represent the Charlton Formation (Veatch and Stephenson 1911, p. 392); they are tentatively correlated by the authors with the Duplin Marl of late Miocene age in the Carolinas and eastern Georgia, whereas the U. S. Geological Survey considers them to be of Pliocene age.

The Hawthorn Formation, the middle unit of the Miocene Series, consists of pale to dark-green (mottled at the surface), phosphatic (at depth), very sandy, locally fossiliferous and cherty, micaceous clays that are interbedded with scattered tongues of fine to coarse-grained, arkosic, phosphatic sand; both the clays and sands gradually thicken and become fossiliferous in a downdip direction. Beneath these clastics but to some extent interfingering with them is a series of limestones considered to be Tampa equivalent of early Miocene age. These limestones are white to cream, sandy, phosphatic, locally cherty, and sparingly fossiliferous. In southwest Georgia, particularly in Mitchell and Colquitt Counties as well as along the Georgia-Florida border from Decatur County eastward through Camden County, these basal Miocene limestones have been locally altered, becoming light to dark-brown, recrystallized, saccharoidal, sandy, phosphatic, dolomitic limestones. In areas where dolomitization has not taken place the lower Miocene limestones are distinguished from the underlying but older limestones of Oligocene age through the presence of quartz grains and phosphatic pebbles, and by the fossils where present.

The Recent to Miocene thickens gradually from a few feet in its updip outcrop area to over 600 feet in two depocenters (see fig. 2). One of these depocenters is long and linear extending diagonally across Grady County in a northeasterly direction as far as northeastern Toombs and northwestern Tattnall Counties. The other area of greatest thickening appears to center in Brantley, Pierce, and Glynn Counties.

Some of the publications in which Miocene microfossils are described and illustrated include several articles by Cole (1931 and 1941) and Cushman (1918 and 1930). Fossils that are diagnostic of the subsurface Miocene of Georgia include molluscan shells, occasional vertebrate remains such as fish teeth, vertebrae(?), etc.; ostracods; and the Foraminifera *Archaias floridanus* (Conrad) and *Rotalia beccarii* (Linné) var. Small Foraminifera* were noted in two recently drilled test holes in updip Chatham County, Ga., and Beaufort County, S. C. Subsequent analysis of this microfauna by the senior author indicated these Foraminifera to be late Miocene (Duplin) in age.

---

*M. J. McCollum U. S. Geological Survey geologist in Savannah, Ga., first called the authors' attention to the presence of these fossils in these test holes. This microfauna is being studied and processed for future publication by the senior author.

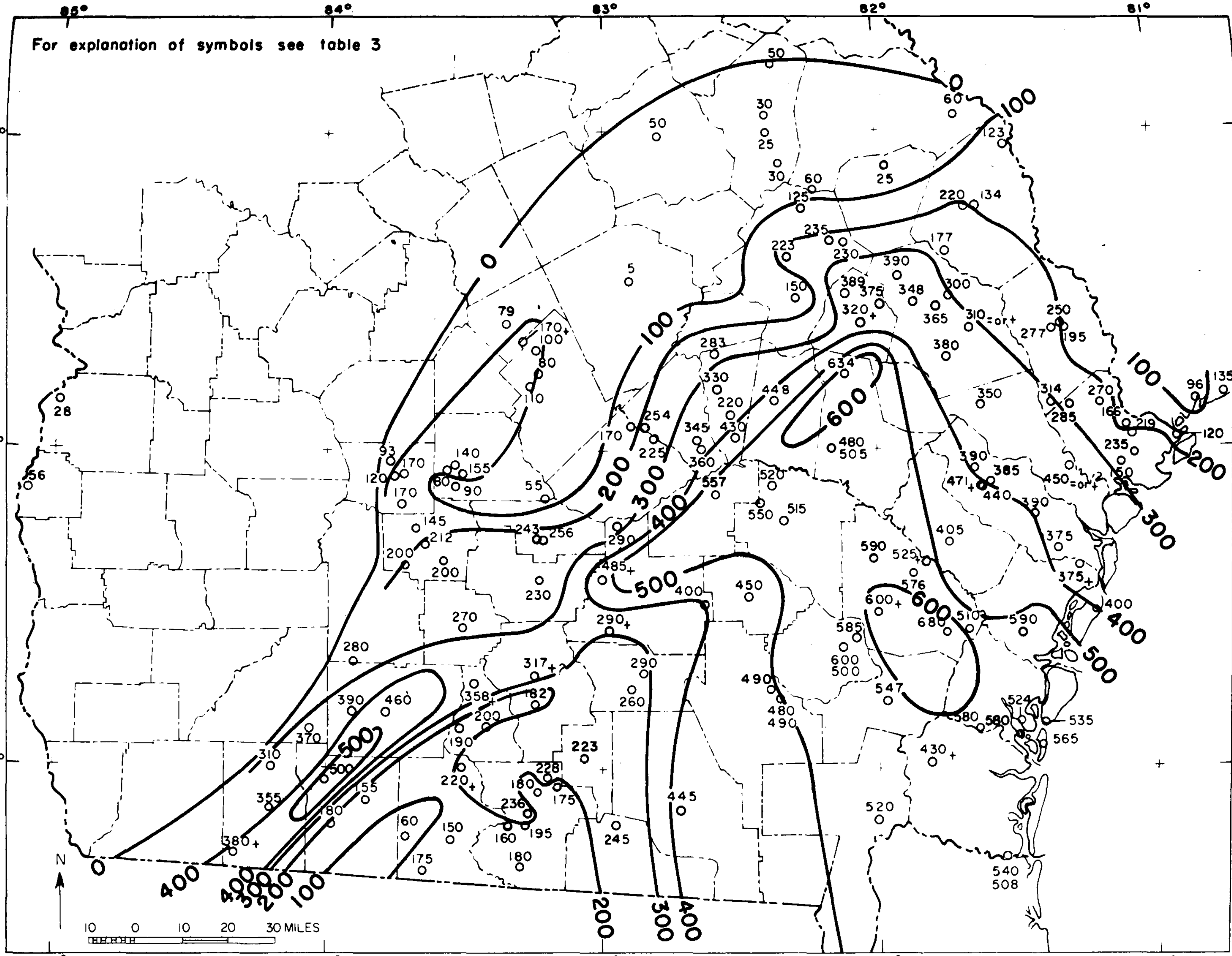

Figure 2.—Thickness-distribution map of Recent to Miocene deposits.

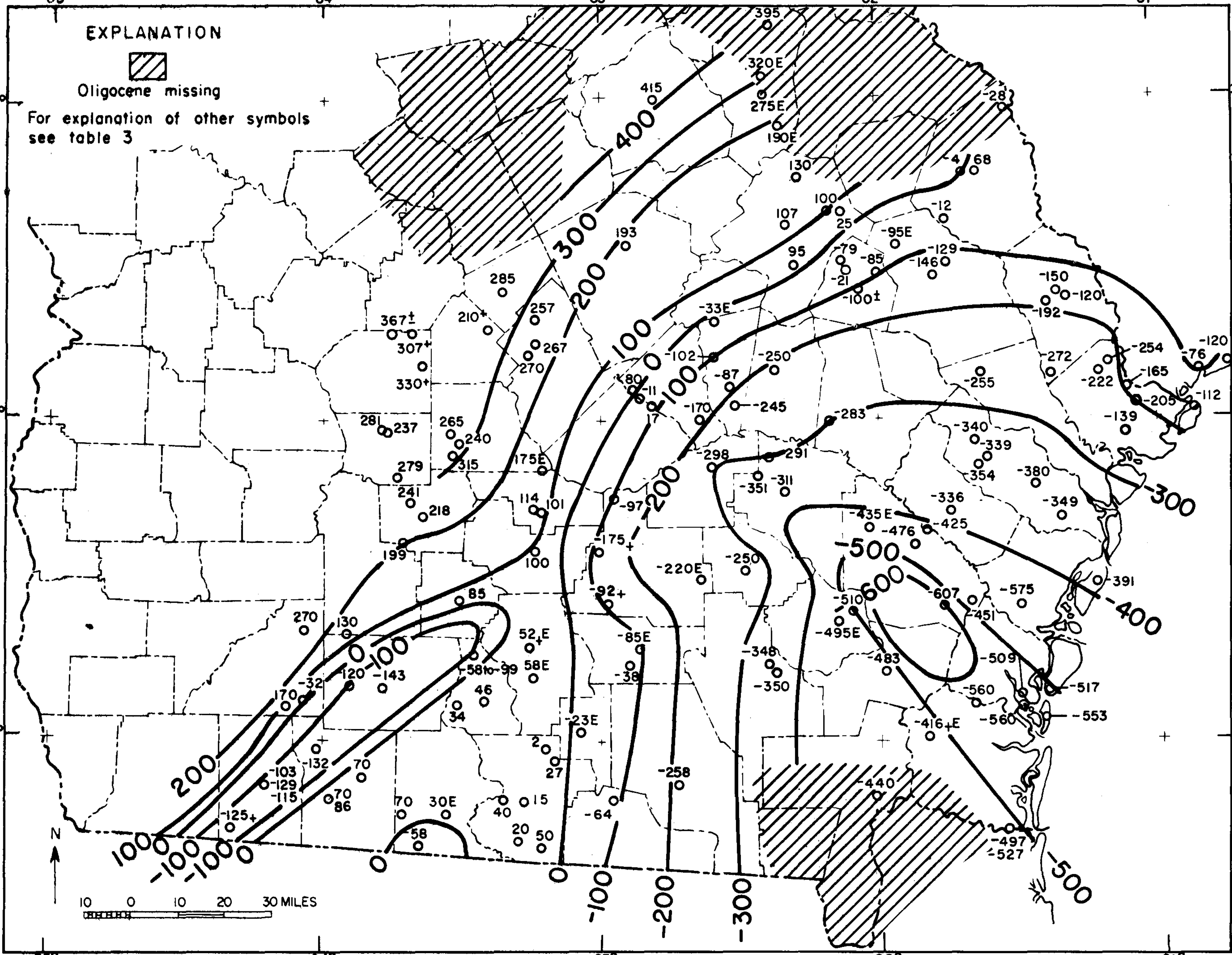

Figure 3.—Structural-contour map of the top of Oligocene deposits.

Tertiary System

OLIGOCENE SERIES

Beds of Oligocene age have been identified in over 300 wells in the subsurface of the Coastal Plain of Georgia. In subsurface areal extent the Oligocene Series approximates that of the overlying Miocene. (See fig. 3.) These strata occupy a position intermediate between the upper Eocene below and the Miocene Series above. As yet, however, the authors have been unable to correlate these beds of definite Oligocene age with the two outcropping formations of Oligocene age that have been mapped in Georgia: the Flint River Formation (Cooke, 1943, pl. 1) and the Suwannee Limestone (MacNeil, 1947). Until such time as a study of the outcrop and the subsurface is successfully completed it seems preferable to refer to the subsurface deposits as Oligocene Series or Oligocene undifferentiated.

The Oligocene Series increase in thickness from a few feet in updip areas to an average of 100 feet over most of the central part of the Coastal Plain of Georgia. (See fig. 4.) The maximum thickness listed by Herrick (1961) is 211 feet for a well in Dodge County.

Lithologically the Oligocene in Georgia is representative of the limestone facies, the clastic facies lying much further west in Mississippi where the entire known Oligocene section of the Gulf Coast is developed. The upper part of the limestone facies in Georgia is composed of light-gray to cream to light-brown, dense, nodular and cherty, locally somewhat sandy, fossiliferous limestones. Locally abundant chert inclusions are common particularly in the upper few feet, a characteristic that often causes difficulty in drilling.

The lower part of the Oligocene consists predominantly of cream, relatively soft, somewhat chalky, fossiliferous limestones. At the base of this unit however, are rather dense, massive, sparingly fossiliferous limestones which on the electric log, produce a pronounced resistivity "kick." These limestones contain only molds and casts of molluscan shells but no Foraminifera.

In southwest and southern Georgia the Oligocene is dolomitized locally and is composed of light to dark-brown, saccharoidal, recrystallized, unfossiliferous limestones. In Chatham County the limestones of this unit become progressively sandier to the northeast, finally grading into sand in southeastern Beaufort County, S. C.

Over most of the southeastern part of the Coastal Plain these strata have been considerably eroded, and, in southern Charlton and southwestern Camden Counties, are absent presumably having been completely eroded subsequent to their deposition.

Fossils are abundant in the Oligocene deposits but as yet they have not permitted the stratigraphy to be worked out convincingly. The upper beds of Oligocene age in Georgia generally contain as the dominant form in the smaller foraminiferal assemblages an abundance of *Rotalia mexicana* var. *mecatepecensis*. Thus figure 5 which shows the occurrences in Georgia of this form presumably also indicates the areal distribution of the upper limestone of Oligocene age. In many wells in which *R. mexicana* var. was not reported another Oligocene form was reported: *Rotalia byramensis* var. Unfortunately, in all the wells in which Oligocene Foraminifera were indentified, only one well, McIntosh 84, has both species reported. In it *R. byramensis* is reported from the sample interval 445-455 feet; *R. mexicana* var. is reported from 486-505 feet. If it were not for this the authors would favor considering the large area in southern Georgia where *R. mexicana* var. is missing to be where the upper beds of Oligocene age were eroded or never deposited. It is interesting to note that the rather large list of Foraminifera identified by Vernon (1942, p. 66) as being from the Suwanee Limestone does not mention *R. mexicana* var. but does list *R. byramensis* var?. However, Vernon (p. 56) qualifies the stratigraphic origin by pointing out that the unit from which the fossils came may "not (be) the precise equivalent of the Suwanee in its type area." He further points out that correlation is rendered difficult by the lack of larger Foraminifera in the type section of the Suwannee Limestone in Florida. The Foraminifera he lists accord closely with those found in the Oligocene beds in wells of Lowndes and Brooks Counties. The difference in fauna could be due to difference in facies with contemporaneous sedimentation or to difference in time of deposition.

Some of the more important publications dealing with the Foraminifera of the Oligocene include papers by Cushman (1922a and b), Cushman and McGlamery (1942), Cole and Ponton (1930), and Todd (1952). The Foraminifera characterizing the Oligocene of Georgia are rather abundant (at least in total numbers of specimens as found in well cuttings), distinctive, and varied. Some of the foraminiferal species that are diagnostic of the Oligocene in Georgia include *Quinqueloculina leonensis* Applin and Jordan, *Camerina dia* (Cole and Ponton), *Rotalia mexicana* Nuttall var., *Asterigerina subacuta* Cushman var. *floridensis*

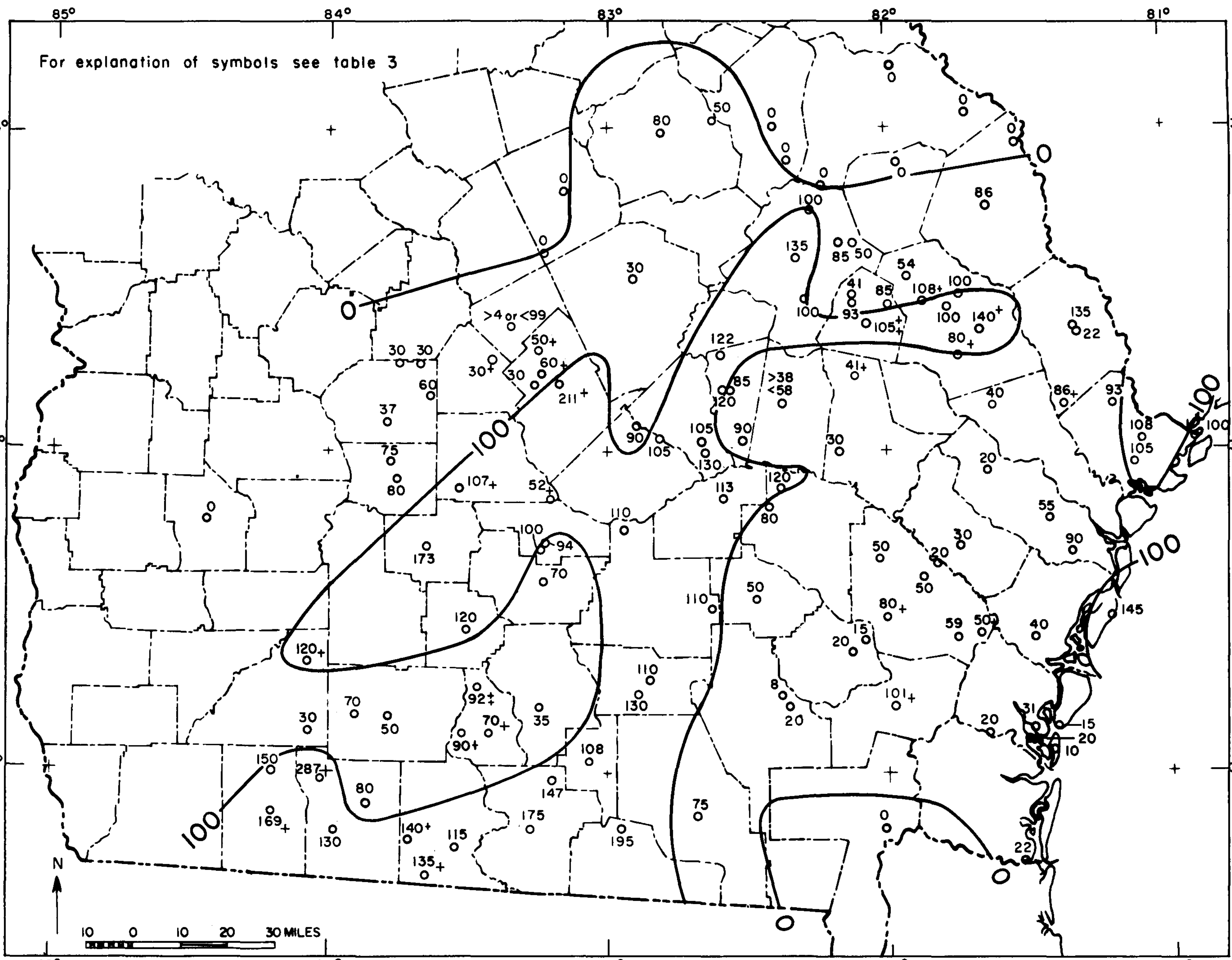

Figure 4.—Thickness-distribution map of Oligocene deposits.

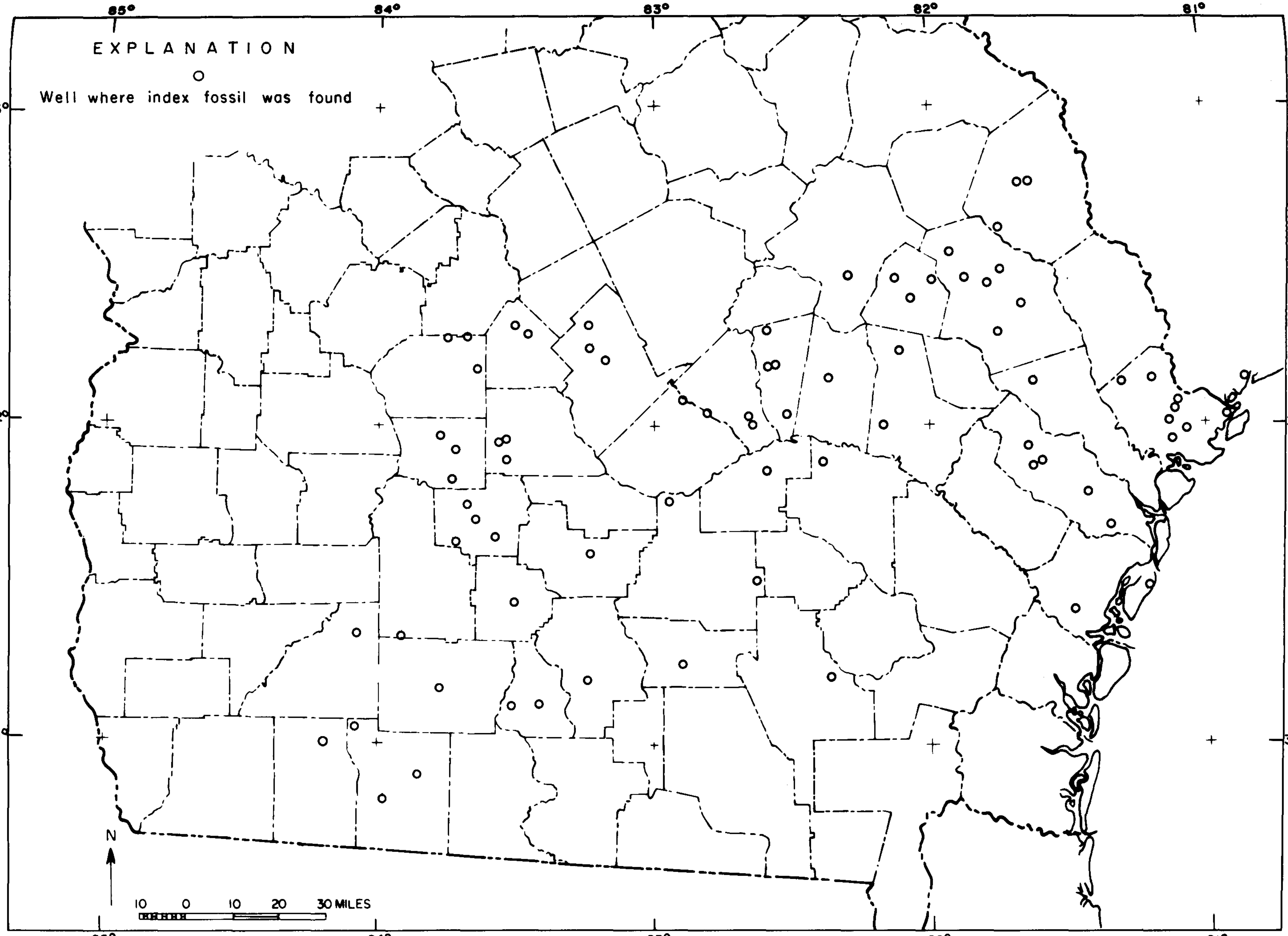

Figure 5.—Distribution of Oligocene index fossil: *Rotalia mexicana* var.

Applin and Jordan, and *Lepidocyclina mantelli* (Morton). The Foraminifera contained in the Oligocene Series in Georgia include those species that are indigenous to this unit as well as several species that represent reworked specimens from the middle Eocene, a phenomenon that has been adequately discussed by several investigators as for example Cole (1941, p. 15, 16) and the Applins (1944, p. 1682-1683). Because these reworked fossils in the Oligocene represent forms that were originally described from and are characteristic of the middle Eocene limestones of peninsular Florida, they have never been found in the middle Eocene clastics of Georgia. Thus, in attempting to find the source beds from which they were removed, they could not have come from erosion of middle Eocene clastics. Rather, they must have been weathered out of and transported away from the limestone facies. By this method of reasoning, the reworked forms so widespread in the lower Oligocene sediments of Georgia must have been transported northward and derived from middle Eocene limestone in the Gulf of Mexico, southwestern Georgia, or peninsular Florida. The following faunal list summarizes the more important foraminiferal species observed in wells penetrating the subsurface and are regarded as diagnostic of the Oligocene in Georgia.

Table 4.--*Oligocene Foraminifera of Georgia*

Textulariidae:
Spiroplectammina mississippiensis (Cushman)

Textularia adalta Cushman
conica D'Orbigny
tumidula Cushman

Miliolidae:
Quinqueloculina leonensis Applin and Jordan

Several species of *Pyrgo*

Lagenidae:
Robulus arcuato-striatus (Hantken)
articulatus (Reuss)
cultratus Montfort

Polymorphinidae:
Globulina sp.

Nonionidae:
Nonion advena (Cushman)
alabamense Cushman and Todd
inexcavatus (Cushman and Applin)

Nonionella hantkeni (Cushman and Applin) var. *byramensis* Cushman and Todd
oligocenica Cushman and McGlamery

Elphidium leonensis Applin and Jordan
texanum (Cushman and Applin)

Camerinidae:
Camerina dia (Cole and Ponton)

Operculinoides sp.

Table 4.--Oligocene Foraminifera of Georgia - Continued

Buliminidae:
- Reussella byramensis Cushman and Todd
  - oligocenica Cushman and Todd
- Angulogerina byramemsis (Cushman)
  - vicksburgensis Cushman

Rotaliidae:
- Discorbis alabamensis Cushman
  - alveata Cushman
  - assulata Cushman
  - byramensis Cushman
  - hemisphaerica Cushman
  - subaraucana Cushman
  - tentoria Todd
- Eponides byramensis (Cushman)
- Rotalia byramensis Cushman var.
  - mexicana Nuttall var. mecatepecensis Nuttall
- Siphonina advena Cushman
- Cancris sagra (D'Orbigny)
  - vicksburgensis Todd
- Baggina xenoula Hadley

Amphisteginidae:
- Asterigerina subacuta Cushman
  - subacuta Cushman var. floridensis Applin and Jordan

Cassidulinidae:
- Alabamina mississippiensis Todd

Chilostomellidae:
- Pullenia alazanensis Cushman

Anomalinidae:
- Anomalina bilateralis Cushman
- Cibicides americanus (Cushman)
  - americanus (Cushman) var. antiquus (Cushman and Applin)
  - hazzardi Ellis
  - lobatulus (Walker and Jacob)
  - mississippiensis (Cushman)
  - pseudoungerianus Cushman
  - cf. C. refulgens Montfort

Planorbulinidae:
- Gypsina globula (Reuss)

Orbitoididae:
- Lepidocyclina mantelli (Morton)
  - sp.

Table 4.--Oligocene Foraminifera of Georgia - Continued

REWORKED FORAMINIFERA:
Valvulina floridana Cole
martii Cushman and Bermudez
Discorinopsis gunteri Cole
Coskinolina floridana Cole*
Dictyoconus cookei (Moberg)
Lepidocyclina antillea (Cushman)

EOCENE SERIES

Upper Eocene rocks-- Upper Eocene deposits have been identified in more than 300 wells that are distributed over the Coastal Plain of Georgia. This unit is uncomformably overlain by beds of Oligocene age and unconformably overlies beds of middle Eocene age. The subsurface upper Eocene in Georgia is correlated, in part, with the Barnwell Formation and Cooper Marl of Georgia and the Ocala Limestone and Inglis Limestone of Florida. The subsurface areal extent of upper Eocene sediments covers a much larger part of the Coastal Plain than either of the two previously discussed stratigraphic units. (See figs. 6 and 7.)

The upper Eocene beds are composed of an updip, clastic facies, which interfingers with its middip limestone equivalent, the Tivola Tongue of the Ocala Limestone (Cooke and Shearer, 1918, p. 51), along a line trending northeastward through roughly the center of Houston, Bleckley, Washington, Jefferson, and Burke Counties and then southeastward to the Savannah River to northeastern Screven County. Moreover, the Barnwell Formation progressively overlaps geologically older formations in a northeasterly direction across east-central Georgia. Thus the Barnwell Formation, beginning in eastern Twiggs County, successively overlies middle Eocene and Upper Cretaceous strata, finally resting directly upon crystalline (basement) rocks as erosional remnants, or outliers, in southern Hancock, Warren, McDuffie, and Columbia Counties. As a result of this overlap and subsequent erosion of the overlying Barnwell Formation, particularly along the major streams, sediments of middle Eocene and Late Cretaceous age have been exposed as erosional "windows" in the northeastern part of the Coastal Plain. The updip clastic facies of the upper Eocene deposits in Georgia is composed of the Barnwell Formation and the Cooper Marl. Lithologically the Barnwell Formation consists of fine to coarse-grained, gray to yellow to pink to red (at the surface), arkosic sands interbedded with cream to bluish-gray to pale-green, blocky, glauconitic, locally fuller's earth (type), fossiliferous clay or marl, and some thin beds of rather dense light-gray, somewhat sandy, sparsely glauconitic, locally fossiliferous limestone. In this report the clays or marls of the Barnwell Formation are collectively called the Twiggs Clay Member, after Cooke and Shearer (1918, p. 41-81). Overlying these clastics and also included in the Barnwell Formation are flat white to gray, somewhat chalky, sandy, cherty, sparsely glauconitic, sparingly fossiliferous limestones which Cooke (1943, p. 65) calls the Sandersville Limestone Member. This limestone occupies a small area in the subsurface of southern Washington, Jefferson, and Burke Counties, northern Emanuel, eastern Bleckley, and probably most of Johnson County. On the basis of one echinoid, Periarchus quinquefarius (Say), Cooke regards this limey facies as representative of the youngest upper Eocene occurring in the Coastal Plain of Georgia. However, the authors feel that this limestone may belong to the late upper Eocene, or Cooper Marl, or even to the still younger Oligocene deposits. At any rate, much more subsurface data are needed in order to establish firmly the true geologic age of the Sandersville Limestone Member of the Barnwell Formation. The remainder of the updip, clastic facies of the upper Eocene sediments in Georgia belongs to the geologically younger Cooper Marl which overlies the Barnwell and Ocala Formations and was named by Cooke (1936, p. 73-75; 82-89) from exposures in the Coastal Plain of South Carolina. In the subsurface of central-east Georgia the Cooper Marl underlies a rather extensive area that includes parts of Dooly,

*Considered by Douglass (1960, p. 258) as synonymous with Dictyoconus floridanus (Cole)

Pulaski, Houston, Bleckley, Laurens, Johnson, Emanuel, Bulloch, and Screven Counties as well as most of Jenkins and Candler Counties. Lithologically, the Cooper Marl is a cream to light-gray, somewhat sandy, rather loosely consolidated, glauconitic, rather abundantly fossiliferous marl. The downdip limestone facies of the upper Eocene in Georgia is the Ocala Limestone, which is composed of two kinds of limestone. The upper division is composed of flat white, highly calcitized and somewhat saccharoidal, porous, abundantly fossiliferous limestone. It occurs as a wedge that pinches out inland somewhere in the second tier of counties, as for example in eastern Effingham and Bulloch Counties. The lower part is found throughout the subsurface of the Coastal Plain wherever the Ocala Limestone is present and consists of cream, somewhat granular, much calcitized, sparsely glauconitic, sandy (at depth), fossiliferous limestone. On the basis of lithology as well as paleontology, the outcropping Ocala Limestone in Georgia is representative of the lower division, the upper division not extending this far updip, as noted above. Like the Oligocene limestones the limestone facies of the upper Eocene is composed, through secondary alteration, of light to dark-brown, recrystallized, saccharoidal, dolomitic limestones in southwestern and extreme southern Georgia. In eastern Mitchell and Decatur Counties, and in Grady and Thomas Counties, the top of this stratigraphic unit has been arbitrarily picked in wells on the first appearance of dark-brown dolomitic limestones. These upper Eocene dolomitic limestones are only partially dolomitized in Brooks, Lowndes, Echols, and Clinch Counties, where the top of this unit may usually be picked on the basis of appropriate Foraminifera. Thicknesses of the upper Eocene vary from a few feet in the area of outcrop to over 700 feet.

A few of the more important publications on the upper Eocene Foraminifera include articles by Cushman and Applin (1926), Cushman (1935 and 1945), Gravell and Hanna (1938), Howe and Wallace (1932), Cole (1944 and 1945), and Puri (1957). The Foraminifera of the upper Eocene are the most abundant and distinctive of any Tertiary unit in the Coastal Plain of Georgia. Moreover, both the Twiggs Clay member of the Barnwell Formation and the Cooper Marl contain excellent assemblages of the smaller Foraminifera. The Ocala Limestone contains the most abundant foraminiferal faunas of any formation in the Coastal Plain. In downdip areas, where the upper division is present, this limestone is composed almost entirely of fossil remains such as molluscan shells, small brachipods, echinoid spines, bryozoan remains, ostracods, and Foraminifera. The lower division of the Ocala Limestone is not as abundantly fossiliferous as is the upper part but it contains many more of the larger foraminiferal species. Of the outstanding guide fossils of the upper Eocene in Georgia, those from the Twiggs Clay Member of the Barnwell Formation include Textularia hockleyensis Cushman and Applin, Valvulineria jacksonensis Cushman, Nonionella hantkeni (Cushman and Applin) var. spissa Cushman, and Hantkenina alabamensis Cushman. Those from the Cooper Marl include Gaudryina jacksonensis Cushman, Marginulina cocoaensis Cushman, Bulimina jacksonensis Cushman, and Eponides carolinensis Cushman. Those from the upper division of the Ocala Limestone include Textularia dibollensis Cushman and Applin var., Planularia truncana (Gümbel), Lingulina ocalana Puri, Operculinoides floridensis (Heilprin), Mississippiana monsouri Howe, Asterocyclina nassauensis Cole, and Pseudophragmina flintensis (Cushman). In addition to these diagnostic Foraminifera at least one species of a small brachiopod, Argyrotheca wegemanni Cole, often occurs in the upper division of the Ocala Limestone.

Species from the lower division of the Ocala Limestone include Textularia dibollensis Cushman and Applin var. humblei Cushman and Applin, Eponides cocoaensis Cushman, Siphonina jacksonensis Cushman and Applin, Cibicides mississippiensis (Cushman) var. ocalanus Cushman, Camerina striatoreticulata (L. Rutten), Operculina mariannensis Vaughan, Amphistegina pinarensis Cushman and Bermudez var. cosdeni Applin and Jordan, Lepidocyclina Ocalana Cushman, and Asterocyclina georgiana (Cushman).

The detailed faunal list in table 5 contains the more prominent foraminiferal species that have been observed both in surface and subsurface occurrences of the upper Eocene deposits in Georgia.

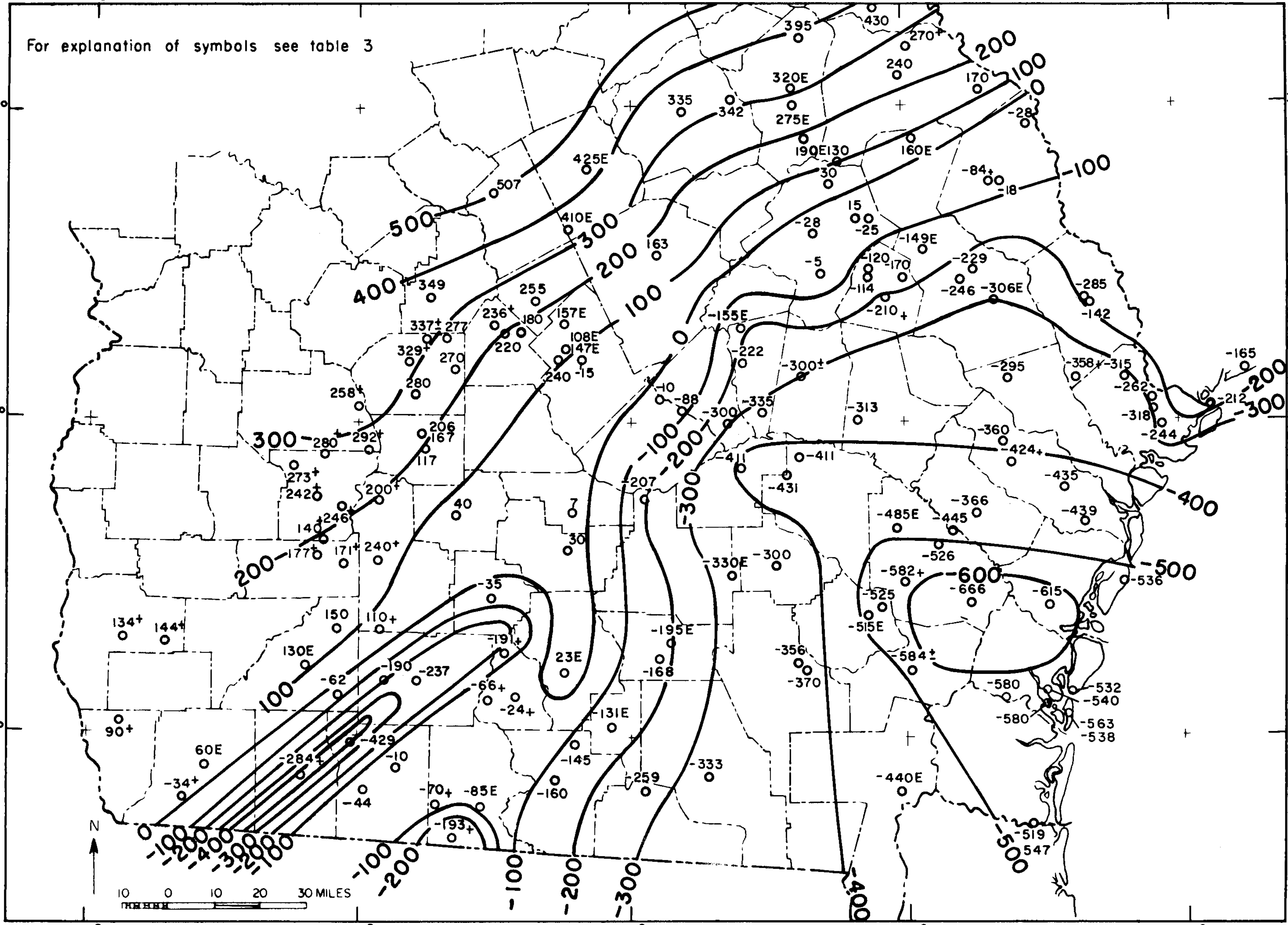

Figure 6.—Structural-contour map of the top of upper Eocene deposits.

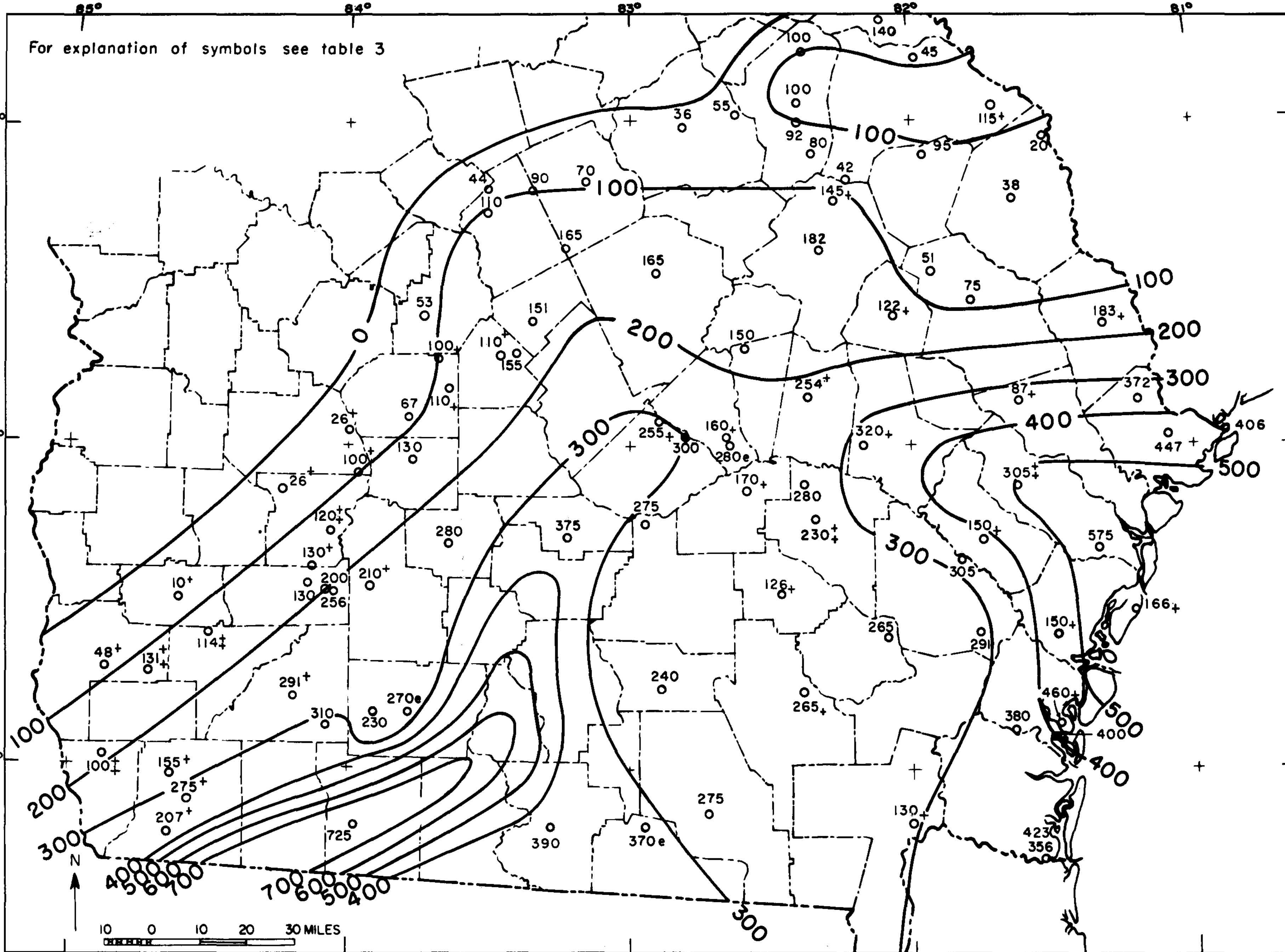

Figure 7.—Thickness-distribution map of upper Eocene deposits.

Table 5.--Upper Eocene Foraminifera of Georgia

	Twiggs Clay	Cooper Marl	Ocala Limestone	
			Upper	Lower
Textulariidae:				
Spiroplectammina mississippiensis (Cushman) var. alabamensis Cushman	X	X	—	X
Textularia adalta Cushman	X	X	X	X
dibollensis Cushman and Applin var. humblei Cushman and Applin	—	—	X	X
hannai Davis	—	—	X	X
hockleyensis Cushman and Applin	X			
plummerae Lalicker	—	X		
subhauerii Cushman	X	X	X	
Verneuilinidae:				
Gaudryina jacksonensis Cushman	—	X		
Lagenidae:				
Robulus alato-limbatus (Gümbel)	—	X	X	X
arcuato-striatus (Hantken) var. carolianus Cushman	X	X	X	X
articulatus (Reuss) var. texanus (Cushman and Applin)	—	X		
limbosus (Reuss) var. hockleyensis (Cushman and Applin)	—	—	—	X
Planularia georgiana Cushman and Herrick	—	X		
truncana (Gümbel)	X	X	X	
Marginulina cocoaensis Cushman	X	X	X	
fragaria (Gümbel) var. texasensis (Cushman and Applin)	—	X		
sublituus (Nuttall)	—	X		
Dentalina cooperensis Cushman	X	X		
cocoaensis (Cushman)	—	X		
jacksonensis (Cushman and Applin)	X	X	X	
Nodosaria latejugata Gümbel var. carolinensis Cushman	X	X	X	
fissicostata (Gümbel)	—	X	X	X
Saracenaria moresiana Howe and Wallace	—	X	X	
Lingulina ocalana Puri	—	—	X	
Lagena acuticosta Reuss	X	—	—	X
Polymorphinidae:				
Guttulina irregularis (D'Orbigny)	X	X	X	X
spicaeformis (Roemer)	—	—	X	X
Globulina gibba D'Orbigny	—	—	X	
gibba D'Orbigny var. globosa (Von Muenster)	X	X	—	X
Pseudopolymorphina decora (Reuss)	—	—	—	X
dumblei (Cushman and Applin)	X			
Sigmomorphina jacksonensis (Cushman)	X	X		
jacksonensis (Cushman) var. costifera (Cushman and Ozawa)				
semitecta (Reuss) var.	—	—	X	
Sigmoidella plummerae Cushman and Ozawa	—	X		
Nonionidae:				
Nonion advena (Cushman)	X	X	—	X
chapapotense Cole	X			
inexcavatus (Cushman and Applin)	X	X		
micrus Cole	X			

Table 5.--Upper Eocene Foraminifera of Georgia - Continued

	Twiggs Clay	Cooper Marl	Ocala Limestone	
			Upper	Lower
Nonionidae (Continued)				
Nonion planatus Cushman and Thomas	X		X	X
Nonionella hantkeni (Cushman and Applin) var. spissa Cushman	X			X
Elphidium twiggsanum Cushman	X			
Elphidioides americanus Cushman	X			
Camerinidae:				
Camerina striatoreticulata (L. Rutten)				X
Operculinoides floridensis (Heilprin)			X	
Operculina mariannensis Vaughan			X	X
Heterostegina ocalana Cushman			X	X
Buliminidae:				
Buliminella elegantissima (D'Orbigny)	X			
Bulimina jacksonensis Cushman		X		
Bolivina jacksonensis Cushman and Applin	X	X		
jacksonensis Cushman and Applin var. striatella Cushman and Applin	X	X		
Reussella eocena (Cushman)	X			X
sculptilis (Cushman)			X	
Uvigerina cocoaensis Cushman	X	X		
dumblei Cushman and Applin			X	
gardnerae Cushman	X	X		
glabrans Cushman		X		
jacksonensis Cushman		X		
topilensis Cushman		X		
Angulogerina ocalana Cushman	X	X	X	
Trifarina bradyi Cushman var. advena Cushman				
Rotaliidae:				
Discorbis alveata Cushman	X			
assulata Cushman	X			X
cocoaensis Cushman and Garrett		X	X	X
globulo-spinosa Cushman	X	X		
subaraucana Cushman	X			
Valvulineria jacksonensis Cushman	X	X		
jacksonensis Cushman var. dentata Cushman	X			
texana Cushman and Ellisor		X		
Gyroidina crystalriverensis Puri			X	
nassauensis Cole			X	
soldanii D'Orbigny var. octocamerata Cushman and G. D. Hanna	X	X		
springfieldensis Puri			X	
Eponides carolinensis Cushman		X		
cocoaensis Cushman		X	X	X
jacksonensis (Cushman and Applin)	X	X	X	X
Mississippina monsouri Howe			X	
Siphonina danvillensis Howe and Wallace		X		
jacksonensis Cushman and Applin	X	X	X	
Cancris vicksburgensis Todd			X	

Table 5.--Upper Eocene Foraminifera of Georgia - Continued

	Twiggs Clay	Cooper Marl	Ocala Limestone	
			Upper	Lower
Amphisteginidae:				
Amphistegina pinarensis Cushman and Bermudez var. cosdeni Applin & Jordan				X
Cassidulinidae:				
Cassidulina globosa Hantken		X	X	
subglobosa Brady		X		
twiggsana Cushman	X			
Alabamina atlantisae (Cushman)		X		
danvillensis Howe and Wallace	X			
mississippiensis Todd			X	X
obtusa (Burrows and Holland)		X	X	
Hantkeninidae:				
Hantkenina alabamensis Cushman	X	X		
Globorotaliidae:				
Globorotalia cocoaensis Cushman		X		X
Anomalinidae:				
Planulina cocoaensis Cushman	X			
cocoaensis Cushman var. cooperensis Cushman		X	X	
Cibicides americanus (Cushman)	X			
americanus (Cushman) var. antiquus (Cushman and Applin)		X		X
danvillensis Howe and Wallace		X		X
lobatulus (Walker and Jacob)	X	X	X	X
mississippiensis (Cushman)	X	X	X	X
mississippiensis (Cushman) var. ocalanus Cushman			X	X
ouachitaensis Howe and Wallace			X	
pseudoungerianus (Cushman)		X	X	
Planorbulinidae:				
Gypsina globula (Reuss)			X	X
vesicularis (Parker and Jones)			X	
Orbitoididae:				
Lepidocyclina chaperi Lemoine and R. Douvillé *				X
ocalana Cushman				X
Discocyclinidae:				
Asterocyclina georgiana (Cushman)				X
nassauensis Cole			X	
Pseudophragimina flintensis (Cushman)			X	

*Comes in at top of lower division

Middle Eocene rocks--Sediments of middle Eocene* age have been observed from over 100 wells in 44 counties of the Coastal Plain of Georgia. This stage uncomformably overlies the lower Eocene, is overlain unconformably by the upper Eocene, and is composed of the Lisbon and Tallahatta Formations.

The Lisbon Formation is the subsurface equivalent of the McBean Formation (Veatch and Stephenson, 1911, p. 237) which crops out at McBean and on McBean Creek in Richmond County in eastern Georgia. The Lisbon Formation includes the rocks in the subsurface between the underlying Tallahatta Formation and the overlying Gosport Sand. Both the Lisbon and McBean as now used by the Federal Geological Survey include only the equivalent of the Cook Mountain Formation or the Ostrea sellaeformis zone. As originally defined the McBean included some beds of late Eocene (Jackson) age and as used by Cooke (1943) it included beds of the Tallahatta west of the Flint River. In order to eliminate such inconsistencies in stratigraphic terminology when applied to the subsurface, Counts and Donsky (in press) and Herrick (1961) have extended the use of the formational names Lisbon and Tallahatta throughout eastern Georgia. Based on known occurrences as given in the well-log report, the Lisbon Formation has been found east of the Flint River in the subsurface of the following Georgia counties: Appling, Atkinson, Bleckley, Burke, Chatham, Coffee, Crisp, Dooly, Emanuel, Jenkins, Liberty, Montgomery, Pulaski, Screven, Toombs, and Turner.

The Tallahatta Formation as reported by Herrick (1961) is found in the following Georgia counties east of the Flint River: Appling, Atkinson, Chatham , Coffee, Crisp, Dooly, Emanuel, Liberty, Pulaski and Toombs.

The Lisbon and Tallahatta Formations compose the updip, clastic facies of the middle Eocene in Georgia and are correlated with the same formations in Alabama. They also correlate with their downdip limestone equivalents, the Avon Park and Lake City Limestones of peninsular Florida.

In the subsurface the areal extent of the middle Eocene (see figure 8) is somewhat less than that of the upper Eocene, although solution of the Ocala Limestone of southwestern Georgia tends to cause the maps to fail to show this. In southeastern Twiggs County the middle Eocene is overlapped by beds of late Eocene age (Barnwell Foramtion), the middle Eocene appearing along the major stream valleys as erosional "windows". Furthermore, the Tallahatta Formation of early middle Eocene age is overlapped by the geologically younger Lisbon Formation of late middle Eocene age--such overlap taking place in eastern Sumter County. From this point the line of overlap continues in a northeasterly direction across the Coastal Plain through southern Houston County and through the middle of Bleckley, Laurens, Emanuel, and Screven Counties.

The updip, clastic facies of the Lisbon Formation consists of interbedded, fine to coarse, subangular, sparsely phosphatic, locally fossiliferous sand; cream to gray to pale-bluish-green to dark green, sandy, finely glauconitic, cherty, fossiliferous clay or marl; and white to light-gray, rather dense, massive, sandy, coarsely but sparsely glauconitic, fossiliferous limestone. These sediments interfinger with their downdip limestone equivalents along a line that runs approximately through northern Seminole County east northeastward through the centers of Mitchell, Tift, Telfair, Treutlen, and Emanuel Counties, thence easterly through northeastern Effingham County to the Savannah River. White to gray, coarsely glauconitic limestone is prominent in deep wells in Toombs and Emanuel Counties, thus proving the existence of this facies of the Lisbon Formation this far north in the Coastal Plain. In updip areas the base of the Lisbon Formation is often composed of white to cream, rather massive, sparsely glauconitic, shelly, coquina-like limestones, which show up on an electric log as prominent resistivity "kicks". Downdip from Montgomery and Toombs Counties these white to gray, coarsely glauconitic, rather massive limestones are replaced by cream, somewhat chalky, much calcitized, granular, gypsiferous, sparingly fossiliferous, locally dolomitized limestones. In Echols, Clinch, Camden, and Glynn Counties the Lisbon consists entirely of alternating beds of cream, chalky, and brown, dolomitic limestones, a type of lithology that is similar to that of the Avon Park Limestone of northeastern Florida. Where present, the bulk of the limestone facies of the Lisbon is composed of these cream, chalky, granular limestones. The chalky limestones are for the most part lacking in microfossils, except for certain horizons where such fossils occur abundantly.

The updip or clastic facies of the Tallahatta Formation consists of interbedded, fine to coarse, sparsely phosphatic, fossiliferous sand; thin, dark-green to dark-brownish-gray, silty, micaceous, glauconitic,

*Owing to a lack of fossils the Gosport Sand is not always differentiated from the underlying and geologically older Lisbon Formation. For this reason it has been thought best to include this formation as part of the Lisbon in the discussion that follows.

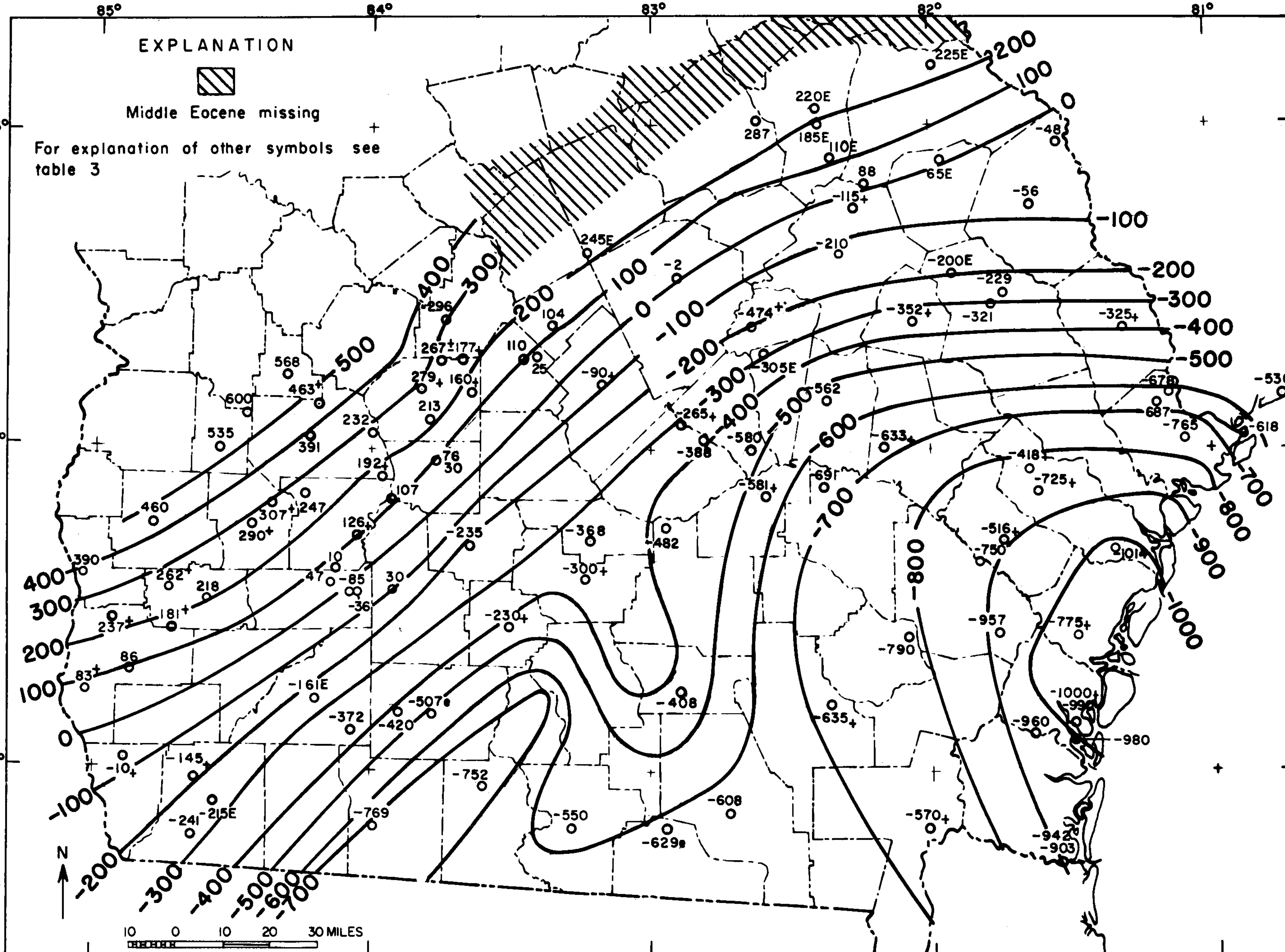

Figure 8.—Structural—contour map of the top of the middle Eocene deposits.

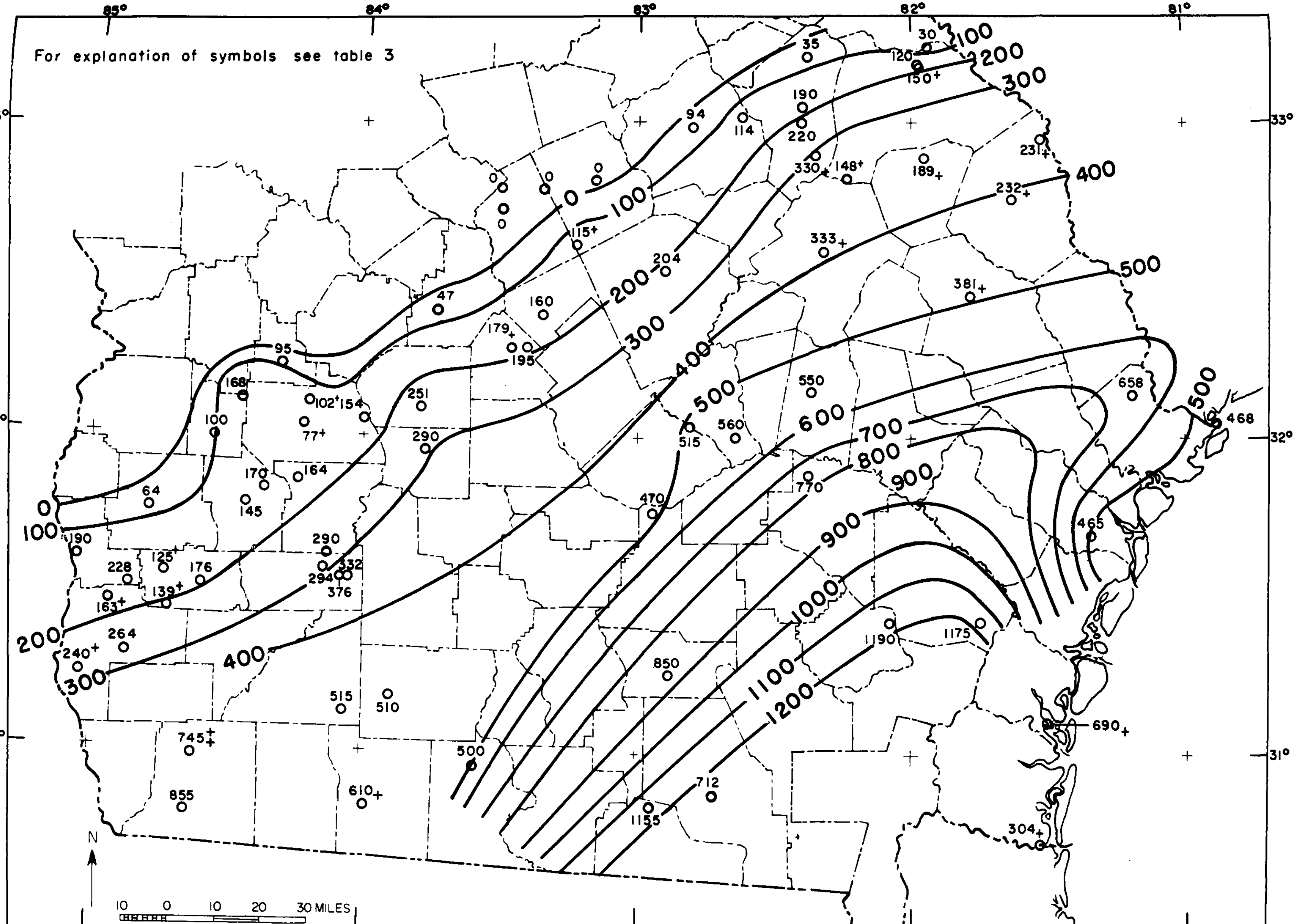

Figure 9.—Thickness-distribution map of middle Eocene deposits.

locally cherty clay or marl; and occasional beds of light-gray, sandy, coarsely glauconitic limestone. The top of the sand section, which generally is also the top of the Tallahatta Formation in updip areas, usually contains abundant molluscan shells, giving a coquina-like appearance. Examples of this type of lithology are found in wells situated in southwest Georgia, particularly in Terrell, Lee, and Dougherty Counties. At the base of the Tallahatta in updip areas, prominent chert beds are often found, a feature that is so particularly characteristic of this formation is southwest Georgia that the bed was formerly called "buhrstone." Interfingering with these clastics, the downdip Tallahatta consists of light to dark-brown, saccharoidal, coarsely glauconitic, locally fossiliferous limestone that is interbedded with occasional beds of fine to coarse-grained, granular limestone. The downdip limestone facies of the Tallahatta Formation is similar to that of the overlying Lisbon but is much more dolomitized and considerably more glauconitic. The middle Eocene gradually increases in thickness from a few feet in its outcrop area to over 1,300 feet in southeastern Georgia (see fig. 9). An area of greatest thickness, or depocenter may occur in southwest Georgia.

Some of the published articles in which many of the middle Eocene Foraminifera are described and illustrated include those by Howe (1939), Cushman and Todd (1945), Cushman and Herrick (1945), Cole (1929), Applin and Jordan (1945), and Bandy (1949). A few of the more commonly occurring guide Foraminifera of the Lisbon Formation in Georgia include: Buliminella robertsi (Howe and Ellis), Discorbis inornatus Cole, Asterigerina lisbonensis Cushman and Todd, Cibicides westi Howe, Cibicides pseudoungerianus (Cushman) var. lisbonensis Bandy, and Lepidocyclina antillea Cushman. Some of the fossils indicative of the Tallahatta Formation include Valvulineria danvillensis (Howe and Wallace) var. gyroidinoides Bandy, Cibicides blanpiedi Toulmin, Cibicides pippeni Cushman and Garrett var. stavensis Bandy, Cibicides tallahattensis Bandy, and Asterocyclina monticellensis Cole and Ponton. The faunal lists in table 6, though by no means exhaustive, reflect the Foraminifera found in the two types of facies-environment that existed in early and late middle Eocene time in Georgia.

Table 6.--Middle Eocene Foraminifera of Georgia

	Lisbon Formation		Tallahatta Formation	
	Clastic facies	Limestone facies	Clastic facies	Limestone facies
Textulariidae:				
Spiroplectammina mississippiensis (Cushman) var. alabamensis (Cushman)	X			
Textularia adalta Cushman	X			
cuyleri Davis	X			
dibollensis Cushman and Applin	X			
Valvulinidae:				
Valvulina cushmani Applin and Jordan		X		
Cribrobulimina cushmani Applin and Jordan		X		
Coskinolina floridana Cole*				X
Dictyoconus americanus (Cushman)		X		
Miliolidae:				
Various species	X	X		
Lagenidae:				
Robulus alato-limbatus (Gümbel)	X			
inornatus (D'Orbigny)	X			
Planularia georgiana Cushman and Herrick	X			
Marginulina cocoaensis Cushman	X			
vacavillensis (Hanna)	X			
Dentalina jacksonensis (Cushman and Applin)	X			
Lagena acuticosta Reuss	X			
Polymorphinidae:				
Guttulina irregularis (D'Orbigny)	X			
spicaefomis (Roemer)	X			
Sigmomorphina jacksonensis (Cushman)	X			
Sigmoidella plummerae Cushman and Ozawa	X			
Polymorphina advena Cushman var. nuda Howe and Roberts	X			
Nonionidae:				
Nonion advena (Cushman)	X			
inexcavatus (Cushman and Applin)	X			
micrus Cole	X			
planatus Cushman and Thomas	X			
Nonionella hantkeni (Cushman and Applin) var. spissa Cushman	X			
Elphidium texanum (Cushman and Applin)	X			

* Not observed by the authors but should be looked for in early middle Eocene of southeastern Georgia

Table 6.--Middle Eocene Foraminifera of Georgia - continued

	Lisbon Formation		Tallahatta Formation	
	Clastic facies	Limestone facies	Clastic facies	Limestone facies
Buliminidae:				
Buliminella robertsi (Howe and Ellis)	X			
Virgulina dibollensis Cushman and Applin	X			
mcguirti Howe and Roberts	X			
zetina Cole	X			
Bolivina broussardi Howe and Roberts	X		X	
gracilis Cushman and Applin	X			
Reussella subrotundata (Cushman and Thomas)	X		X	
Angulogerina cooperensis Cushman	X			
vicksburgensis Cushman	X			
Trifarina wilcoxensis (Cushman and Ponton)			X	
Rotaliidae:				
Spirillina Vicksburgensis Cushman	X			
cf. S. vivipara Ehrenberg	X			
Patellina advena Cushman	X			
Discorbis assulata Cushman	X			
georgiana Cushman and Herrick	X			
inornatus Cole				X
tallahattensis Bandy			X	
yeguaensis Weinzierl and Applin	X			
Valvulineria danvillensis (Howe and Wallace) var. gyroidinoides Bandy			X	
jacksonensis Cushman var. persimilis Bandy			X	
texana Cushman and Ellisor	X			
Gyroidina nassauensis Cole		X		
soldanii D'Orbigny var. octocamerata Cushman and G. D. Hanna	X			
Eponides cocoaensis Cushman	X			
mexicanus (Cushman)	X			
Siphonina clabornensis Cushman	X			
jacksonensis Cushman and Applin	X			
Amphisteginidae:				
Asterigerina lisbonensis Cushman and Todd	X			
Amphistegina lopeztrigoi D. K. Palmer				X

Table 6.--Middle Eocene Foraminifera of Georgia - continued

	Lisbon Formation		Tallahatta Formation	
	Clastic facies	Limestone facies	Clastic facies	Limestone facies
Cassidulinidae:				
Alabamina atlantisae (Cushman)	X			
danvillensis (Howe and Wallace)	X			
	X			
Cassidulina globosa Hantken	X			
winniana Howe				
Hantkeninidae:				
Hantkenina longispina Cushman	X			
Globorotaliidae:				
Globorotalia cocoaensis Cushman	X			
Anomalinidae:				
Anomalina bilateralis Cushman	X			
Cibicides americanus (Cushman) var. *antiquus* (Cushman and Applin)	X			
blanpiedi Toulmin			X	
danvillensis Howe and Wallace	X			
lobatulus (Walker and Jacob)	X			
mauricensis Howe and Roberts	X			
mississippiensis (Cushman)	X			
pippeni Cushman and Garrett var. *stavensis* Bandy			X	
pseudoungerianus (Cushman) var. *lisbonensis* Bandy	X			
pseudowuellerstorfi Cole			X	
tallahattensis Bandy			X	
westi Howe	X			
Orbitoididae:				
Lepidocyclina antillea Cushman	X	X		X
Discocyclinidae:				
Asterocyclina monticellensis (Cole and Ponton)				X

Lower Eocene rocks.--In the Coastal Plain of Georgia, strata of early Eocene age have been identified in approximately 50 wells, the majority of which, however, are in southwest Georgia. The updip, clastic facies of this unit is correlated with the Wilcox Group of Alabama, whereas its downdip limestone equivalent is correlated with the Oldsmar Limestone of Florida. In southwestern Georgia, where the lower Eocene deposits are of the clastic type, this unit can be broken down into the Tuscahoma and the underlying Nanafalia Formations. Moreover , in some wells, particularly in Sumter and Dougherty Counties, the top of the lower Eocene is often represented by abundantly glauconitic, silty, abundantly micaceous, somewhat fossiliferous marl which doubtless represents erosional remnants of the Bashi Marl Member of the Hatchetigbee Formation. Elsewhere in the Coastal Plain of Georgia these beds have not been observed. The subsurface areal extent of the lower Eocene in Georgia is considerably less than the previously discussed stratigraphic units (see fig. 10). This is due, in part, to overlap by geologically younger formations and in part to offlap causing the sea to have been restricted in Georgia during early Eocene time. The lower Eocene deposits crop out along the Chattahoochee River as far north as the center of the west edge of Clay County. From here the northern limit of this unit trends northeastward across the Coastal Plain through the centers of Webster and Schley Counties to the south-central part of Macon County where these sediments are overlapped by geologically younger deposits. From the point of overlap in eastern Macon County, the updip limit of the lower Eocene is approximated in wells as a line trending eastward across the Coastal Plain through Treutlen County, thence east to southeastern Screven County. The updip, clastic facies of the lower Eocene consists of interbedded, dark-gray to dark-brownish-gray to chocolate-brown, blocky, silty, carbonaceous, micaceous, pyritiferous, glauconitic, fossiliferous clay or marl; fine to coarse, glauconitic, lignitic, pyritiferous sand; and a few beds of white to light-gray, sandy, coarsely glauconitic, micaceous, shelly, coquina-like limestone. As noted in wells the clastics gradually grade into limestones far down the dip, with the transition zone extending from southwestern Echols County northeasterly through Clinch, Brantley, Wayne, Glynn, and McIntosh Counties to northeastern Chatham County. The limestone facies of the lower Eocene in Georgia consists of cream, much calcitized, somewhat granular, coarsely glauconitic, locally cherty and dolomitized, somewhat fossiliferous limestone. Lithologically the limestone is similar to the overlying limestone of the Tallahatta Formation. A shelly, somewhat indurated, coquina-like sand persists in the basal part of the lower Eocene unit as far downdip as Echols County and possibly as far as Clinch and Camden Counties. This shell-bearing sand is correlated with the basal part of the Nanafalia Formation of Alabama. The lower Eocene deposits gradually increase in thickness from a few feet in the outcrop area to over 400 feet in Clinch, Charlton, Glynn, and Camden Counties (see fig. 11). Owing to lack of subsurface control, the presence (or absence) of possible depocenters belonging to this stratigraphic unit is difficult to determine. However, it is possible that such areas may occur off the coasts of western Florida and northeastern Georgia, the latter area possibly centering off the coast of southeastern Chatham and eastern Bryan Counties.

Literature dealing with the Foraminifera of the lower Eocene is not as voluminous as that for the preceding units. Some of the paleontologic articles deserving mention here are those by Cushman (1944), Cushman and Ponton (1932), Toulmin (1941), Loeblich and Tappan (1957), and McLean (1953). A few of the guide fossils for the lower Eocene include *Valvulineria wilcoxensis* Cushman and Ponton, *Valvulineria scrobiculata* (Schwager), *Eponides dorfi* Toulmin, and *Globorotalia wilcoxensis* Cushman and Ponton. *Helicostegina gyralis* Barker and Grimsdale has been observed in one well in Clinch County. The faunal list in table 7 summarizes the more important smaller Foraminifera occurring in beds of early Eocene age in Georgia.

Table 7.--*Lower Eocene Foraminifera of Georgia*

Textulariidae:
Spiroplectammina wilcoxensis Cushman and Ponton

Lagenidae:
Robulus wilcoxensis Cushman and Ponton
inornatus (D'Orbigny)

Nodosaria latejugata Gümbel var.

Rotaliidae:
Valvulineria wilcoxensis Cushman and Ponton
scrobiculata (Schwager)

Eponides dorfi Toulmin

Siphonina prima Plummer
wilcoxensis Cushman

Amphisteginidae:
Helicostegina gyralis Barker and Grimsdale

Cassidulinidae
Alabamina wilcoxensis Toulmin

Globorotaliidae:
Globorotalia wilcoxensis Cushman and Ponton

Anomalinidae:
Anomalina acuta Plummer
umbonifera (Schwager)

Cibicides blanpiedi Toulmin
howelli Toulmin
praecursorius (Schwager)

Discocyclinidae:
Pseudophragmina sp.*

* Probably *Pseudophragmina (Proporocyclina) cedarkeysensis* Cole.

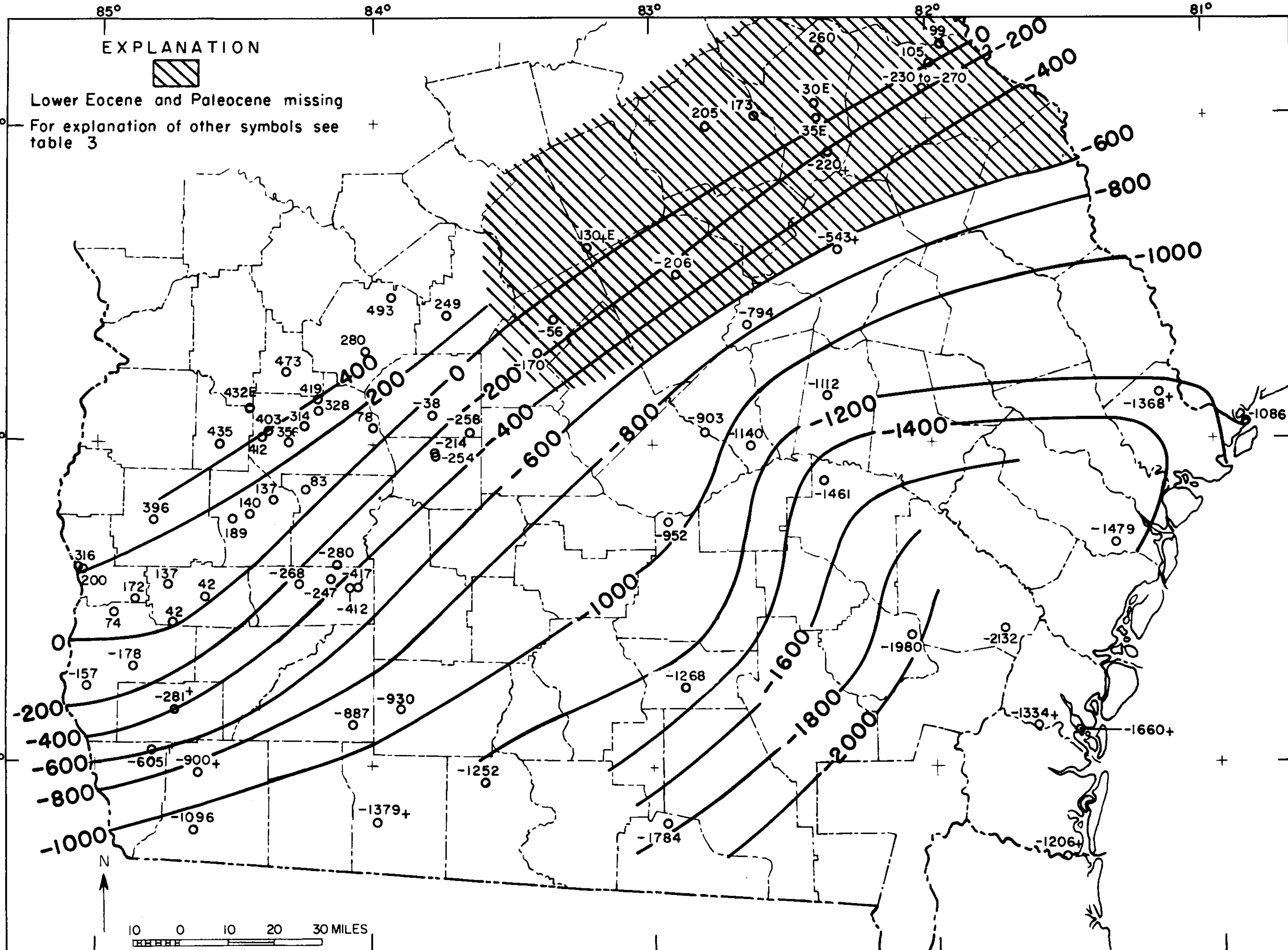

Figure 10.—Structural-contour map of the top of lower Eocene deposits and erosion surface.

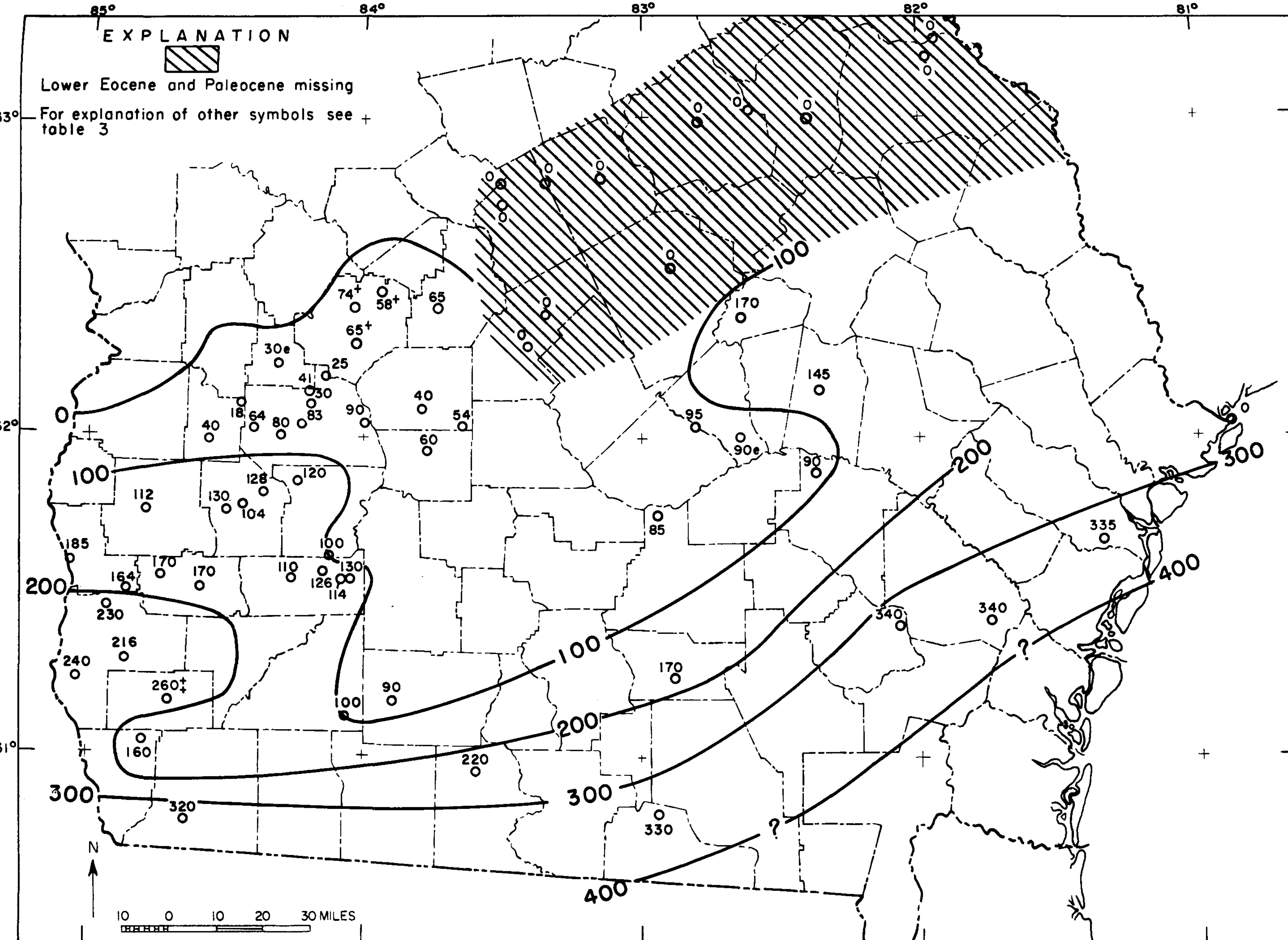

Figure 11.—Thickness-distribution map of lower Eocene deposits.

PALEOCENE SERIES

The Paleocene Series represents one of the best known stratigraphic units, having been identified in more than 70 wells that are fairly well distributed over the Coastal Plain of Georgia. In southwest Georgia and southeastern Alabama, it is best developed and thickest of any place in the entire Gulf Coast. Beds of Paleocene age underlie the lower Eocene and overlie the Upper Cretaceous. Except for extreme southeastern Georgia, the Paleocene uniformly consists of limestones with some overlying clays and indurated sands, all of which are correlated with the Clayton Formation of Alabama. In southeastern Georgia, in eastern Echols and in Clinch, Camden, and Glynn Counties, the Paleocene is considered equivalent to the Cedar Keys Limestone of Florida. The oldest Paleocene, which occurs in extreme south Georgia, is composed of a series of clastics that occupies a position intermediate between the base of the Clayton (above) and the Upper Cretaceous (below), and is correlated with the Tamesí* of Mexico. The subsurface areal extent of the Paleocene deposits in Georgia (see fig. 12) is approximately the same as that for the previously discussed lower Eocene. Also, the Paleocene like the lower Eocene, is overlapped in eastern Macon County by geologically younger sediments. In its outcrop area, the Paleocene consists of dark-gray to black to dark-chocolate-brown, blocky to laminated, silty, glauconitic, micaceous, fossiliferous clay and marl that overlie light-gray to cream, somewhat dense, crystalline, sandy, coarsely glauconitic, pyritiferous, fossiliferous limestone. In the Chattahoochee Valley at Fort Gaines, the Clayton Limestone consists in the upper part of cream, somewhat chalky, earthy, porous, fossiliferous limestone that changes at depth to more massive, crystalline, sandy limestone. Downdip the overlying brown to black clay of latest Paleocene age gradually merges into light-gray, fine-grained, finely glauconitic, micaceous, fossiliferous, indurated sandy limestone or indurated sand. In extreme southeastern Georgia the Paleocene consists of white to cream, somewhat calcitized, gypsiferous, fossiliferous limestones that are lithologically similar to the Cedar Keys Limestone of northeastern Florida. Between the base of the Clayton Limestone proper and the top of the underlying Upper Cretaceous, the earliest Paleocene, or Tamesí, is present in extreme south Georgia and in the subsurface of northeastern Chatham County. In these areas it consists of dark-brown, laminated, silty, glauconitic, finely micaceous, abundantly fossiliferous marl. As noted above these fossiliferous marls are, in this report, included in the Clayton Formation but are Tamesí (earliest Paleocene) in age. The Paleocene increases in thickness down the dip from a few feet along its northern boundary to over 600 feet in southern Georgia (see fig. 13). In the Chattahoochee Valley, MacNeil (1944, p. 22) reported 130 feet of outcropping limestone belonging to this stratigraphic unit. On the basis of available evidence the Paleocene apparently did not undergo any particular localized thickening. As with the Lower Eocene, possible depocenters of the Paleocene may exist off the coast of western Florida as well as off the coast of Bryan or Liberty Counties, Ga.

Some of the articles dealing with the Paleocene Foraminifera include papers by Plummer (1926), Cushman (1926 and 1951), White (1928 and 1929), Muir (1936), Cole and Herrick (1953), and Shifflett (1948). The Paleocene in Georgia contains an abundant and varied foraminiferal fauna. Some of the commonly occurring guide fossils that are found either at or close to the top of this unit include Operculinoides catenula (Cushman and Jarvis), Pseudophragmina (Athecocyclina) stephensoni (Vaughan), Robulus Midwayensis (Plummer), Discorbis midwayensis Cushman var. trinitatensis Cushman and Renz, Eponides lotus (Schwager), Parrella expansa Toulmin, and Anomalina midwayensis (Plummer). The Foraminifera of the Paleocene illustrate probably better than any other single fauna in Georgia a close faunal relationship to the Paleocene of the West Indies and Mexico, a fact that can be gleaned from the faunal lists in table 8.

*As pointed out by P. L. and E. R. Applin (1944, p. 1703, 1705) the Tamesí (Velasco) of Mexico was, for a long time considered to be latest Cretaceous in age but is now known to represent earliest Paleocene.

Table 8.--Paleocene Foraminifera of Georgia

	Clayton Formation	Tamesí Equivalent
Textulariidae:		
Spiroplectammina laevis (Roemer) var. cretosa Cushman		X
semicomplanata (Carsey)		X
plummerae Cushman	X	
wilcoxensis Cushman and Ponton	X	
Verneuilinidae:		
Gaudryina pyramidata Cushman		X
Clavulinoides midwayensis Cushman	X	
Lagenidae:		
Robulus midwayensis (Plummer)	X	
pseudo-mamilligerus (Plummer)	X	
turbinatus (Plummer)	X	
pseudo-costatus (Plummer)	X	
wilcoxensis Cushman and Ponton	X	
alabamensis Cushman	X	
degolyeri (Plummer)	X	
cf. R. rosettus (Gümbel)	X	
Dentalina gardnerae (Plummer)	X	
colei Cushman and Dusenbury	X	X
wilcoxensis Cushman	X	
Nodosaria latejugata Gümbel	X	
affinis Reuss	X	X
Pseudoglandulina manifesta (Reuss)	X	X
Vaginulina midwayana Fox and Ross	X	
longiforma (Plummer)	X	
Polymorphinidae:		
Guttulina problema D'Orbigny	X	
Globulina gibba D' Orbigny	X	
Sigmomorphina soldadoensis Cushman and Renz	X	
Polymorphina cushmani Plummer	X	
Camerinidae:		
Operculinoides catenula (Cushman and Jarvis)	X	
Alveolinellidae:		
Borelis gunteri Cole	X	
Heterohelicidae:		
Guembelina midwayensis Cushman	X	
Buliminidae:		
Bulimina cacumenata Cushman and Parker	X	
kugleri Cushman and Renz		X
(Desinobulimina) quadrata Plummer		X
Bolivina midwayensis Cushman	X	

Table 8.--Paleocene Foraminifera of Georgia - continued

	Clayton Formation	Tamesí Equivalent
Rotaliidae:		
Discorbis midwayensis Cushman var. *soldadoensis* Cushman and Renz	X	
midwayensis Cushman var. *trinitatensis* Cushman and Renz	X	
Valvulineria wilcoxensis Cushman and Ponton	X	
cf. *V. umbilicatula*(?) (D'Orbigny)		X
Gyroidina aequilateralis (Plummer)	X	
subangulata (Plummer)	X	X
Eponides lotus (Schwager)	X	
plummerae Cushman	X	
Parrella expansa Toulmin	X	
Rotalia havenensis Cushman and Bermudez	X	
Siphonina prima Plummer	X	
Cassidulinidae:		
Alabamina wilcoxensis Toulmin	X	
Chilostomellidae:		
Allomorphina paleocenica Cushman		X
subtriangularis (Kline)		
velascoensis Cushman		X
Chilostomella ovoidea Reuss		X
Chilostomelloides eocenica Cushman		X
Globorotaliidae:		
Globorotalia cf. *G. membranacea* (Ehrenberg)		X
velascoensis (Cushman)		X
crassata (Cushman) var. *aequa* Cushman and Renz	X	X
Anomalinidae:		
Anomalina midwayensis (Plummer)	X	
acuta Plummer	X	X
umbonifera (Schwager)	X	
Boldia madrugaensis Cushman and Bermudez	X	
Cibicides alleni (Plummer)	X	
howelli Toulmin	X	
newmanae (Plummer)	X	
Discocyclinidae:		
Pseudophragmina (*Athecocyclina*) *stephensoni* (Vaughn)	X	

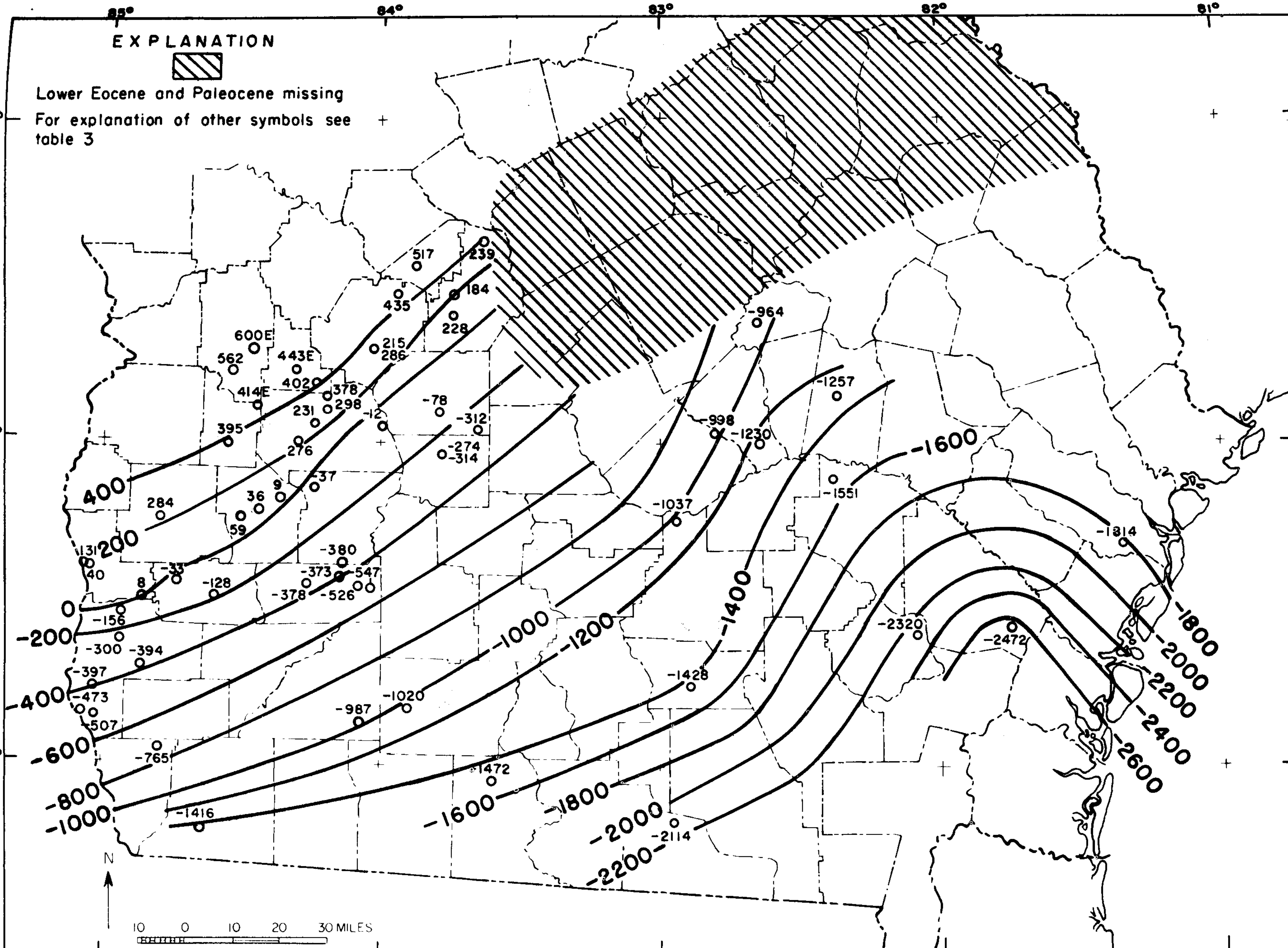

Figure 12.—Structural-contour map of the top of Paleocene deposits.

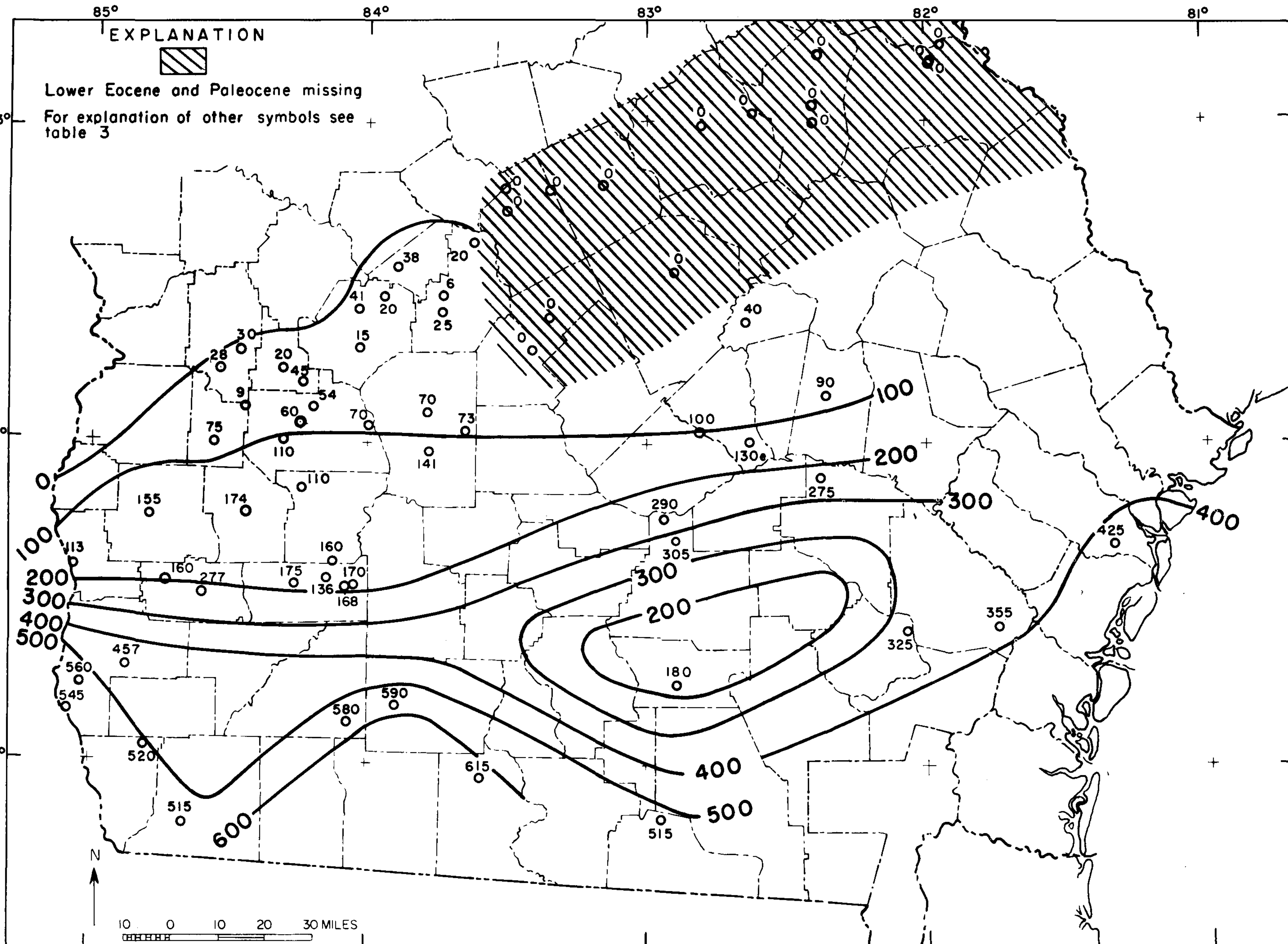

Figure 13.—Thickness-distribution map of Paleocene deposits.

Cretaceous System

UPPER CRETACEOUS SERIES

Post-Tuscaloosa deposits.--Cretaceous sediments of post-Tuscaloosa age have been identified in 90 wells in 33 counties of the Georgia Coastal Plain. Post-Tuscaloosa deposits have been found throughout the Georgia Coastal Plain except in the northeastern part where the lithology of the post-Tuscaloosa is identical with that of the underlying Tuscaloosa Formation. As pointed out by Eargle (1955, p. 5-6) the "Tuscaloosa" as found in this northeastern part has been identified on the basis of lithology rather than by stratigraphy. However, because foraminiferal evidence is nonexistent to support this opinion, the Tuscaloosa-type sediments in the northeastern part have all been logged as Tuscaloosa Formation (Herrick, 1961). In preparing maps however the data in the northeast were considered to indicate only the top of the post-Tuscaloosa (see fig. 14). On the map showing thickness and distribution of the post-Tuscaloosa deposits (fig. 15) as well as the maps showing the Tuscaloosa top (fig. 16), and its thickness distribution (fig. 17), the northeastern part was left uncontoured because of this uncertainty.

From study of outcrops in western Georgia, the post-Tuscaloosa has been divided from top downward into Providence Sand, Ripley Formation, Cusseta Sand, Blufftown Formation, and Eutaw Formation, all of which are extensions of the same formations as found in eastern Alabama (Eargle, 1955). These formations when traced downdip in the subsurface gradually merge into three units that are faunally distinctive and which for lack of formational names are considered to be equivalents of beds of Navarro, Taylor, and Austin age. The updip formations correlate with the downdip beds as shown in Table 9. It has been

Table 9.--Correlation of surface and subsurface units of post-Tuscaloosa Cretaceous age

Geologic formations at surface	Subsurface units
Providence Sand Ripley Formation, upper part	Beds of Navarro age (= Lawson Limestone of Florida)
Ripley Formation, lower part Cusseta Sand Blufftown Formation, upper part	Beds of Taylor age
Blufftown Formation, lower part Eutaw Formation	Beds of Austin age

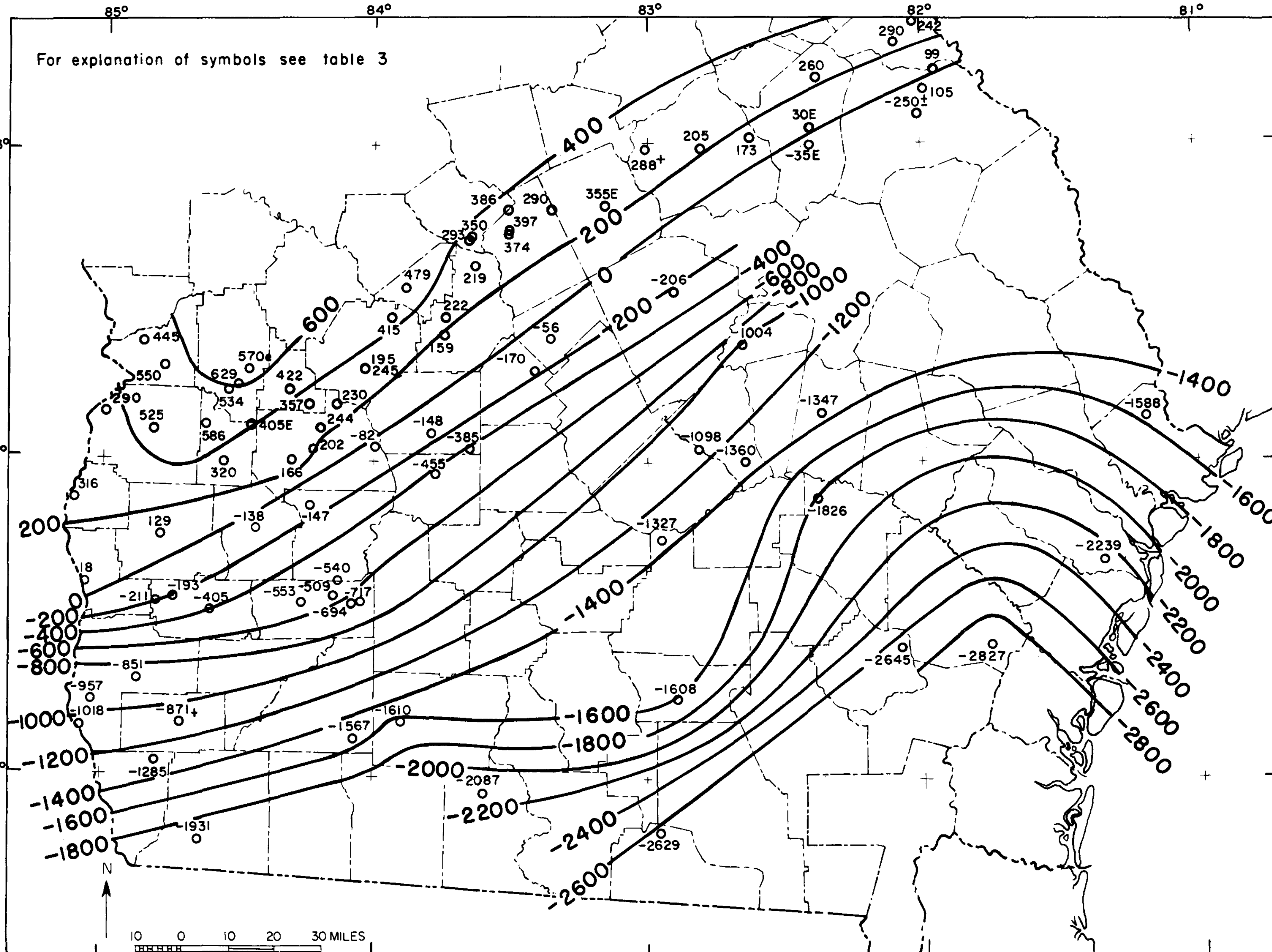

Figure 14.—Structural-contour map of the top of Upper Cretaceous post-Tuscaloosa deposits.

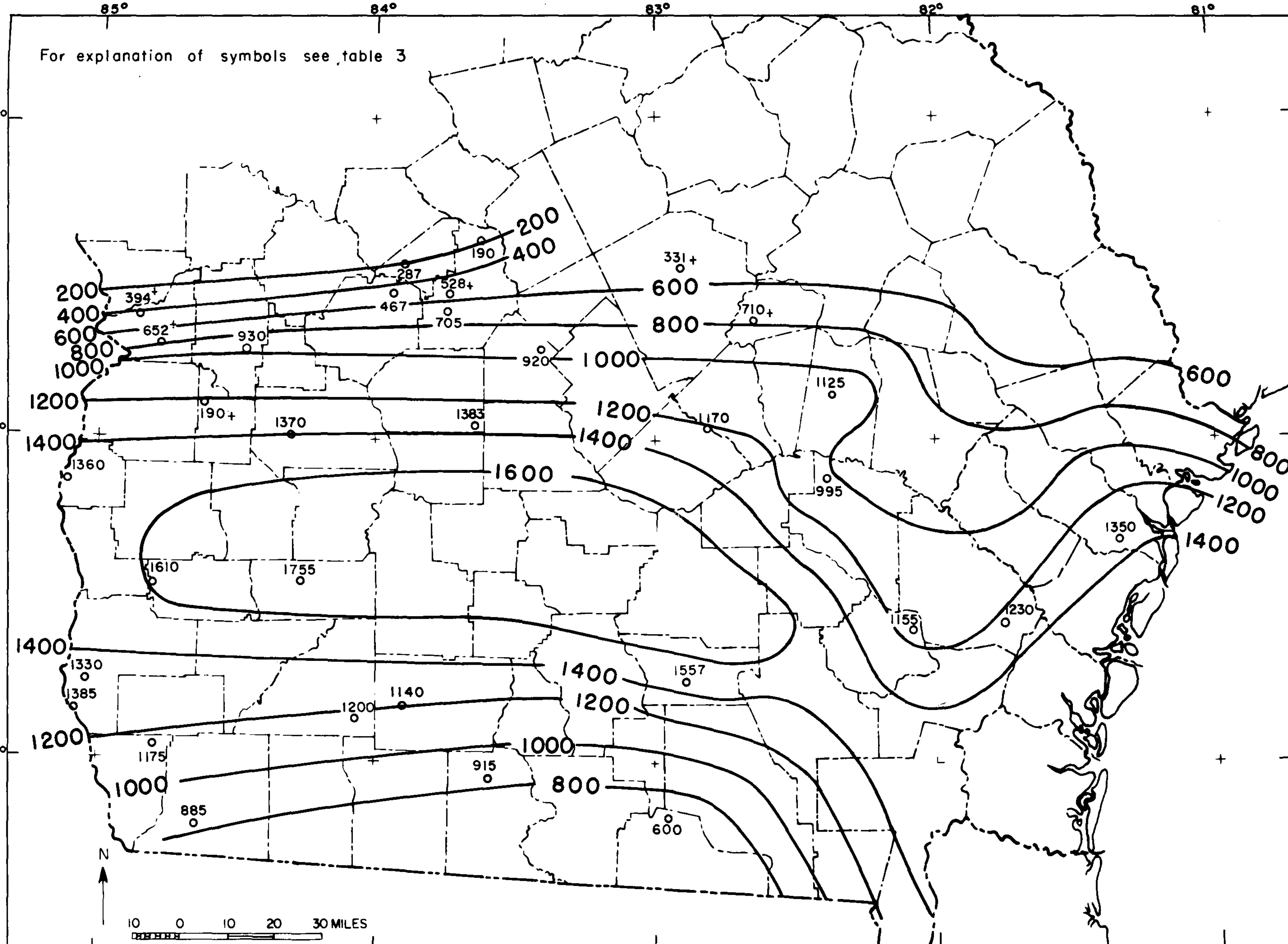

Figure 15.— Thickness-distribution map of post-Tuscaloosa Cretaceous deposits.

thought best to include all these formations under the term post-Tuscaloosa for the following reasons:

1. Originally these formations were named for surface deposits that were mappable units in updip areas of the Coastal Plain. Subsequently, as a result of a search for oil and fresh-water aquifers, it was learned that the majority of these formations, owing to downdip facies changes, tended to lose their identities in the subsurface. Similarly, east of Ocmulgee River, even the updip surface outcrops of these formations have undergone facies changes in an easterly (along the strike) direction, causing the entire Upper Cretaceous Series to grade laterally to a lithology identical with that of the Tuscaloosa Formation.

2. In addition to facies changes, faunal changes have also taken place in a downdip direction. Certain foraminiferal species have been found to persist over more and more of the vertical subsurface stratigraphic section thus increasing their vertical ranges and at the same time lessening, to some extent, their value as guide fossils. A good example of this is Anomalina pseudopapillosa Carsey, a foraminifer that is a reliable index fossil for the Ripley Formation in some updip areas. Down the dip, however, this foraminifer has been found higher in the section, appearing (in wells) in the lower, or marine, part of the geologically younger Providence Sand for which it has become one of its guide fossils. Thus, these formational names, particularly as regards the Providence and Ripley Formations, cannot be used over the greater part of the subsurface of the Coastal Plain of Georgia. An exception to this is the Eutaw Formation, which extends from outcrops to downdip areas, overlying the Tuscaloosa Formation as a fine to medium, phosphatic, glauconitic, shelly, somewhat indurated sand.

The subsurface areal extent of the post-Tuscaloosa is next to the largest of all the stratigraphic units making up the Coastal Plain of Georgia, being second only in size to the underlying and geologically older Tuscaloosa Formation (see fig. 14.) Thus, this unit, except for a narrow strip immediately south of the Fall Line, underlies the entire Coastal Plain. The greatest surface exposures of the post-Tuscaloosa are found just east of the Chattahoochee River Valley, in Stewart and Chattahoochee Counties. Northeast of this area, however, this unit is progressively overlapped as far as the Ocmulgee River, east of which the post-Tuscaloosa is completely covered by geologically younger sediments. Except for southeastern Georgia the post-Tuscaloosa consists of clastics throughout its subsurface areal extent in Georgia. In the updip parts of the Coastal Plain this unit is composed of light-gray to dark-bluish-gray to dark-brown (mottled in surface exposures), blocky to laminated, sandy, abundantly, micaceous, locally lignitic and kaolinitic, pyritiferous, glauconitic, fossiliferous clay and marl. These clays are interbedded with numerous tongues of fine to coarse-grained, subangular to subrounded, pyritiferous, lignitic, micaceous, arkosic, locally glauconitic and fossiliferous sand, and some relatively thin beds of gray, dense, sandy, coarsely glauconitic micaceous, somewhat phosphatic, fossiliferous limestone. In downdip areas these clastics gradually change to light-bluish-gray, chalky, micaceous, pyritiferous, fossiliferous marls which are interbedded with beds of sand or limestone, the latter similar to those of updip areas. In extreme southeastern Georgia, the upper part of the post-Tuscaloosa, of Navarro age, is composed of somewhat chalky, much calcitized, granular, locally gypsiferous, fossiliferous limestones, the latter representing the limestone facies of this unit in Georgia. The greatest thickness of the post-Tuscaloosa, or depocenter, occurs in central and coastal areas of the Coastal Plain (see fig. 15), attaining a total thickness of more than 1,400 feet. South of the central part of the Coastal Plain the post-Tuscaloosa in extreme south Georgia thins to 800 feet or less.

A few of the more important contributions to the paleontology of the Upper Cretaceous include articles by Carsey (1926), Plummer (1931), Cushman (1940), and Cole (1944). The post-Tuscaloosa represents the lowest stratigraphic unit in Georgia with abundant and characteristic Foraminifera. Some of the diagnostic fossils occurring in the upper division of Navarro age are Gaudryina rudita Sandidge, Robulus spisso-costatus Cushman, Vaginulina webbervillensis Carsey, Guembelina globulosa (Ehrenberg), Loxostoma plaitum (Carsey), Epistomina caracolla (Roemer), Anomalina pseudopapillosa Carsey, and Cibicides harperi (Sandidge). In the middle division, or Taylor, one should mention such species as Robulus stephensoni Cushman, Robulus muensteri (Roemer), Bolivinoides decorata (Jones), Globotruncana arca (Cushman), Planulina texana Cushman, and Planulina taylorensis (Carsey). Likewise Kyphopyxa christneri (Carsey) and Vaginulina texana Cushman are considered diagnostic of the lower division of Austin age of this stratigraphic unit. The faunal lists in table 10 show in greater detail the more important smaller Foraminifera that have been observed in the post-Tuscaloosa of Georgia.

Table 10.--Foraminifera from the post-Tuscaloosa Cretaceous of Georgia

FORAMINIFERA OF NAVARRO AGE:

Lituolidae:
Haplophragmoides sp.

Textulariidae:
Spiroplectammina semicomplanata (Carsey)
Textularia ripleyensis W. Berry

Verneuilinidae:
Gaudryina rudita Sandidge
Pseudoclavulina amorpha (Cushman)
clavata (Cushman)

Lagenidae:
Robulus navarroensis (Plummer)
pondi Cushman
spisso-costatus Cushman
Marginulina texasensis Cushman
Dentalina alternata (Jones)
basiplanata Cushman
gracilis D'Orbigny
legumen Reuss
Nodosaria affinis Reuss
Vaginulina webbervillensis Carsey
suturalis Cushman
Palmula reticulata (Reuss)
Frondicularia inversa Reuss

Polymorphinidae:
Guttulina adhaerens (Olszewski)
Globulina lacrima Reuss

Heterohelicidae:
Guembelina globulosa (Ehrenberg)
striata (Ehrenberg)

Buliminidae:
Bulimenella carseyae Plummer var.
Bulimina aspera Cushman and Parker
Loxostoma plaitum (Carsey)

Rotaliidae:
Valvulineria cf. *V. umbilicatula* (D'Orbigny)
Gyroidina depressa (Alth)
Eponides haidingerii (D'Orbigny)
Epistomina caracolla (Roemer)
Siphonina prima Plummer

Cassidulinidae:
Ceratobulimina cretacea Cushman and Harris

Chilostomellidae:
Pullenia americana Cushman
coryelli White

Globigerinidae:
Globigerina cretacea D'Orbigny

Globorotaliidae:
Globotruncana cretacea Cushman

Anomalinidae:
Anomalina clementiana (D'Orbigny)
henbesti Plummer
pinguis Jennings.
pseudopapillosa Carsey
Planulina correcta (Carsey)
Cibicides harperi (Sandidge)

FORAMINIFERA OF TAYLOR-AUSTIN AGE:

Verneuilinidae:
- Gaudryina rudita Sandidge
- Clavulinoides trilatera Cushman
  - trilatera Cushman var. concava (Cushman)

Valvulinidae:
- Dorothia bulletta (Carsey)

Lagenidae:
- Robulus muensteri (Roemer)
  - stephensoni Cushman
- Marginulina austinana Cushman
  - cretacea Cushman
  - dorsata Cushman
  - silicula (Plummer)
  - sp.
- Dentalina alternata (Jones)
  - gracilis D'Orbigny
  - lorneiana D'Orbigny
- Nodosaria affinis Reuss
  - obscura Reuss
  - sp.
- Vaginulina cretacea Plummer
  - taylorana Cushman
  - texana Cushman
- Frondicularia cf. F. inversa Reuss
- Kyphopyxa christneri (Carsey)
- Lagena hispida Reuss

Polymorphinidae:
- Globulina lacrima Reuss
- Bullopora sp.

Nonionidae:
- Nonionella austinana Cushman
  - cretacea Cushman

Heterohelicidae:
- Guembelina striata (Ehrenberg)
- Bolivinoides decorata (Jones)

Buliminidae:
- Virgulina tegulata Reuss

Rotaliidae:
- Valvulineria allomorphinoides (Reuss)
  - infrequens Morrow
- Stensioina americana Cushman and Dorsey
- Gyroidina depressa (Alth)

Globigerinidae:
- Globigerina cretacea D'Orbigny

Globorotaliidae:
- Globotruncana arca (Cushman)
  - fornicata Plummer
- Globorotalia micheliniana (D'Orbigny)

Anomalinidae:
- Anomalina sp.
- Planulina austinana Cushman
  - taylorensis (Carsey)
  - texana Cushman

Tuscaloosa Formation.--The Tuscaloosa Formation* has been identified in the subsurface in about 70 wells, the majority of which are situated along the northern limit of the Coastal Plain. Sediments of Tuscaloosa age underlie the post-Tuscaloosa and overlie the Lower Cretaceous(?) and are correlated with the Tuscaloosa Group of Alabama and, in part, with the Eagle Ford and Woodbine Formations of Texas. In subsurface areal extent the Tuscaloosa underlies the entire Coastal Plain of Georgia, hence is the largest of the stratigraphic units discussed. (See fig. 16.) Geographically, this unit is bounded on the north by the crystalline rocks of the Piedmont. To the south these strata merge with equivalent subsurface sediments in northern Florida. The Tuscaloosa Formation consists entirely of clastics, which may be broken down into three readily recognizable lithologic divisions. The upper part is composed on nonmarine, fine to coarse, subangular, micaceous, arkosic, pyritiferous, locally lignitic sands that are interbedded with nonmarine, gray to green (mottled in outcrop), blocky to laminated, locally iron-stained, kaolinitic and lignitic, micaceous, sandy clays. The middle division is composed of interbedded sands and clays, which, in updip areas, resemble those of the upper part. Downdip these deposits change to marine, dark-gray to dark-brown to black, laminated, somewhat fissile, abundantly micaceous, speckled**, glauconitic, carbonaceous, fossiliferous clay and shale, that are interbedded with thin beds of fine to medium-grained, micaceous sand. The lower division of the Tuscaloosa is usually composed, in its uppermost part, of a fine-grained, somewhat micaceous, glauconitic, locally indurated, marine sand. Below this sand the remainder of the lower division consists of interbedded nonmarine, coarsely-grained, subrounded, highly arkosic, micaceous sands and red to purple, blocky, sandy, sideritic, micaceous clays. Prominent and extensive inclusions of kaolin, originally derived from the weathering of crystalline rocks to the north of the Coastal Plain, occur in the upper part of the Tuscaloosa Formation. These deposits are found only a few miles south of the Fall Line in a belt extending from Taylor County eastward into southern McDuffie and Columbia Counties in east-central Georgia. Thickness of the Tuscaloosa Formation approximates that of the post-Tuscaloosa Cretaceous unit (see fig. 17) with the area of greatest thickness, or depocenter, lying in an east-west, linear belt in the central part of the Coastal Plain. Southeast of this belt the Tuscaloosa tends to thin to less than 300 feet in southeastern Georgia. The maximum thickness in this depocenter is somewhat in excess of 900 feet.

Literature dealing with the microfossils of the Tuscaloosa Formation and equivalent deposits is limited compared with that of the previously discussed unit. This is doubtless due in part to a failure until comparatively recent times to recognize the marine character of the Tuscaloosa in downdip areas of the Coastal Plain. Munyan (1943) was the first to note the marine Tuscaloosa in the subsurface of Georgia and Cushman and Applin (1946) were the first to demonstrate the presence of smaller Foraminifera in the marine portions of the Tuscaloosa in Georgia. A summary of the important literature dealing with the Foraminifera of the Tuscaloosa Formation and equivalent deposits elsewhere in the Gulf Coast includes articles by Lozo (1944), Loeblich (1946), Cushman and Applin (1946 and 1947), Frizzell (1954), and Applin (1955). Foraminifera have been observed by the senior author in several wells penetrating marine portions of the Tuscaloosa Formation in downdip areas of Georgia. These fossils, however, are not identified as to species though they clearly belonged to at least two genera, Ammobaculites and Haplophragmoides, which make up an appreciable part of the foraminiferal faunas identified by various investigators from the Tuscaloosa of Georgia. For the sake of completeness in this report the following faunal list has been prepared from the above noted articles.

---

*In this report the formational name Tuscaloosa is used in preference to Atkinson. The name Tuscaloosa is considered by the authors to be more applicable to the continental deposits whereas the name Atkinson is more applicable to the marine equivalents as found in extreme south Georgia and Florida.

**Finely disseminated mica flakes impart a speckled appearance to these shales.

Table 11.--*Foraminifera from the marine facies of the Tuscaloosa Formation in Georgia*

Lituolidae:
Haplophragmoides langsdalensis Applin
advenus (Cushman and Applin)
Ammobaculites bergquisti Cushman and Applin

Textulariidae:
Ammobaculoides plummerae Loeblich

Verneuilinidae:
Gaudryina barlowensis Applin

Placopsilinidae:
Acruliammina longa (Tappan)
Placopsilina langsdalensis Applin

Lagenidae:
Frondicularia barlowensis
Citharina recta (Reuss)

Rotaliidae:
Valvulineria infrequens Morrow var.

Globigerinidae:
Globigerina cretacea D'Orbigny

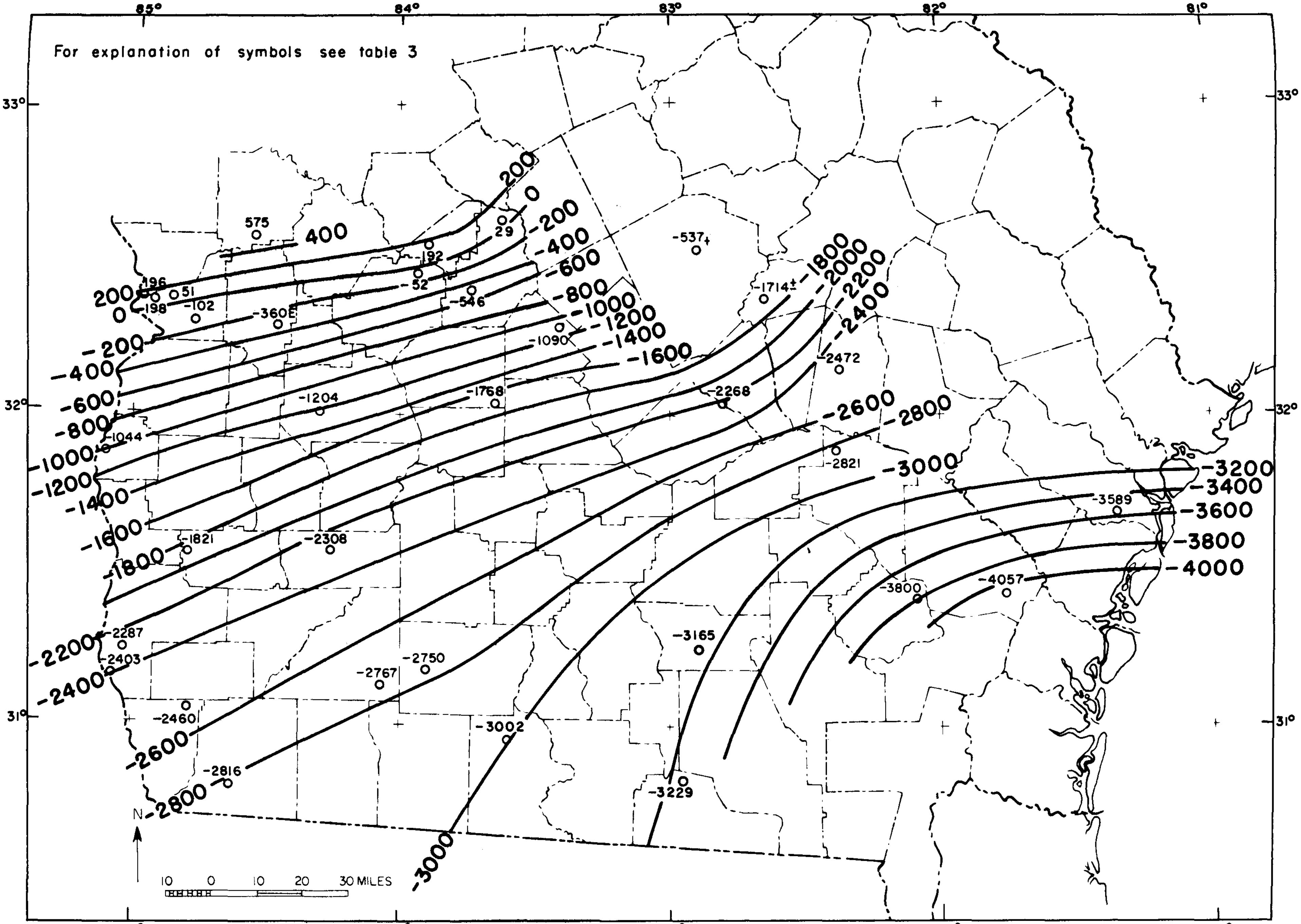

Figure 16.—Structural-contour map of the top of Tuscaloosa Formation.

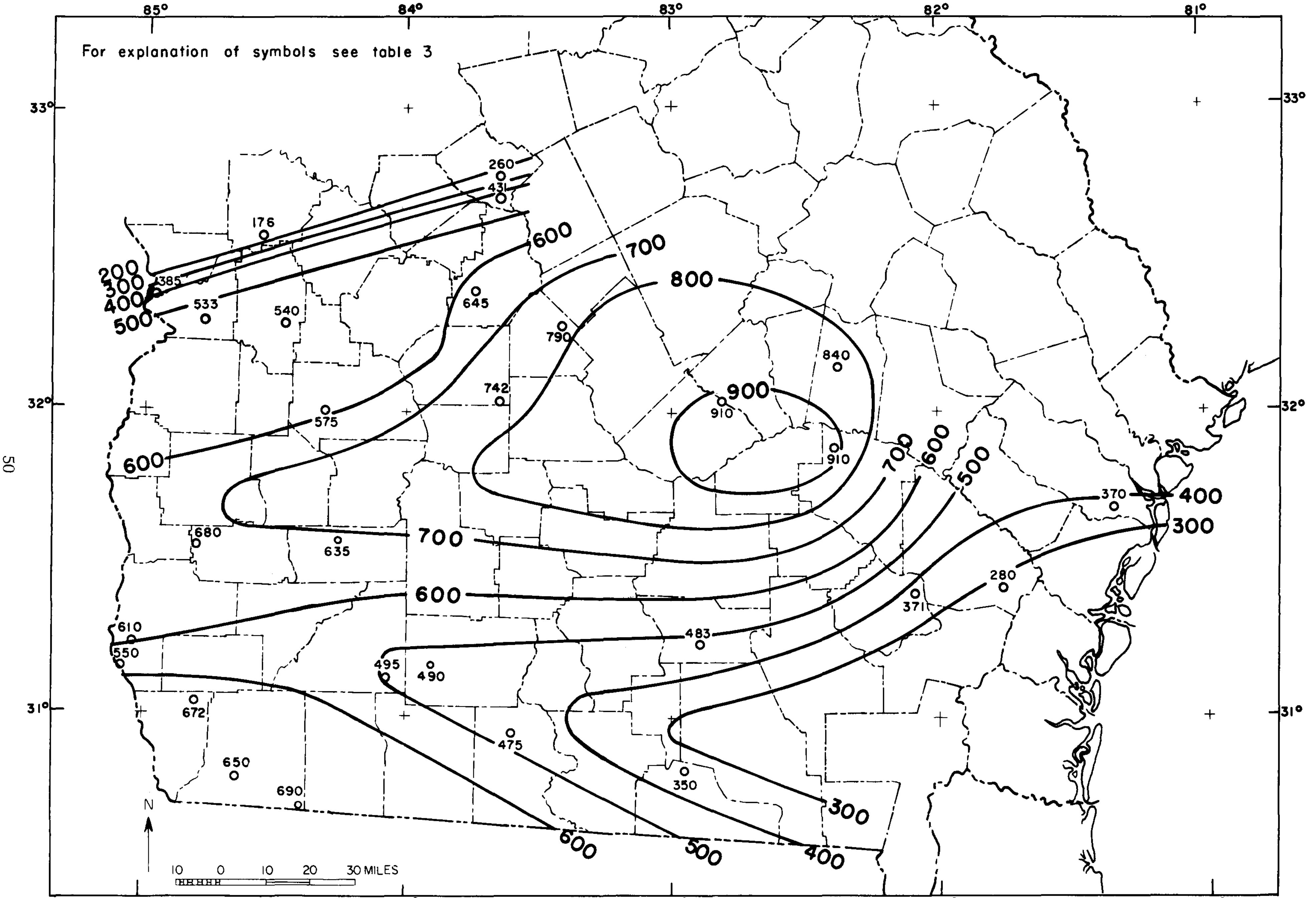

Figure 17.—Thickness-distribution map of Tuscaloosa Formation.

LOWER CRETACEOUS(?) SERIES

Strata of Lower Cretaceous(?) age, have been identified in 18 wells that are distributed over 16 counties in the Coastal Plain of Georgia. These sediments underlie the Tuscaloosa Formation and overlie older rocks ranging in age from Triassic(?), to Paleozoic, to Precambrian.

From available data the subsurface areal extent of this stratigraphic unit is considerably less than that of the overlying Tuscaloosa Formation. The northern limit of recognizable Lower Cretaceous(?) begins in Georgia at the Chattahoochee River in southern Chattahoochee County, trends eastward approximately to central Houston County, thence southeastward to the coast of Georgia, in eastern Bryan County (see fig. 18). If this interpretation is true then this unit is absent from the entire northeastern part of the Coastal Plain as well as from a somewhat restricted, linear area situated immediately south of the Fall Line. However, in the latter area this may or may not represent the true subsurface picutre. In this part of the Coastal Plain both the Tuscaloosa and Lower Cretaceous(?) units are nonmarine in origin, hence are lithologically so similar as to be practically impossible to differentiate. It is possible, therefore, that beds of Early Cretaceous(?) age may have been included with the Tuscaloosa in wells situated in this part of the Coastal Plain. Although these deposits were mapped by Eargle (1955, pl. 1)as belonging to the lower part of the Tuscaloosa Formation, some inconclusive shreds of evidence support a possible Lower Cretaceous(?) age for these sediments: 1) these strata underlie conventional sediments of Tuscaloosa age, 2) they overlie crystalline rocks of Precambrian age in western Muscogee County and 3) they appear to be lithologically somewhat different from the usual, updip Tuscaloosa of this part of the Coastal Plain. In much of the northeastern part of the Coastal Plain, wells are not deep enough to reach the Lower Cretaceous(?) hence the presence (or absence) of this unit here is not known. Many more additional data are needed before this problem can be solved. The Lower Cretaceous(?) in Georgia is composed entirely of clastics which consist of interbedded nonmarine, varicolored, coarse, subrounded, very arkosic, micaceous sand and brick-red to pale-yellowish-green, blocky, abundantly micaceous, locally sideritic, sandy clay. Owing to their brilliant red color these clays are often referred to by drillers as "red beds," when encountered in wells. The Lower Cretaceous(?) thickens greatly in southwestern Georgia (see fig. 19) where more than 2,600 feet have been logged as belonging to this stratigraphic unit. Using the map of the pre-Cretaceous surface (see fig. 20) as a base, the maximum thickness in Georgia of lower Cretaceous(?) may be on the order of 3,5000 feet. Such a thick series of sediments would indicate the existence of a possible depocenter in this part of Georgia during Lower Cretaceous(?) time.

Due to the nonmarine nature of all the Lower Cretaceous(?) deposits found in Georgia, no microfossils have been observed in the series. Further downdip in Florida, where this unit becomes marine in character, these strata have been identified as being of Early Cretaceous age -- the reason for assigning an Early Cretaceous(?) age to this unit in Georgia.

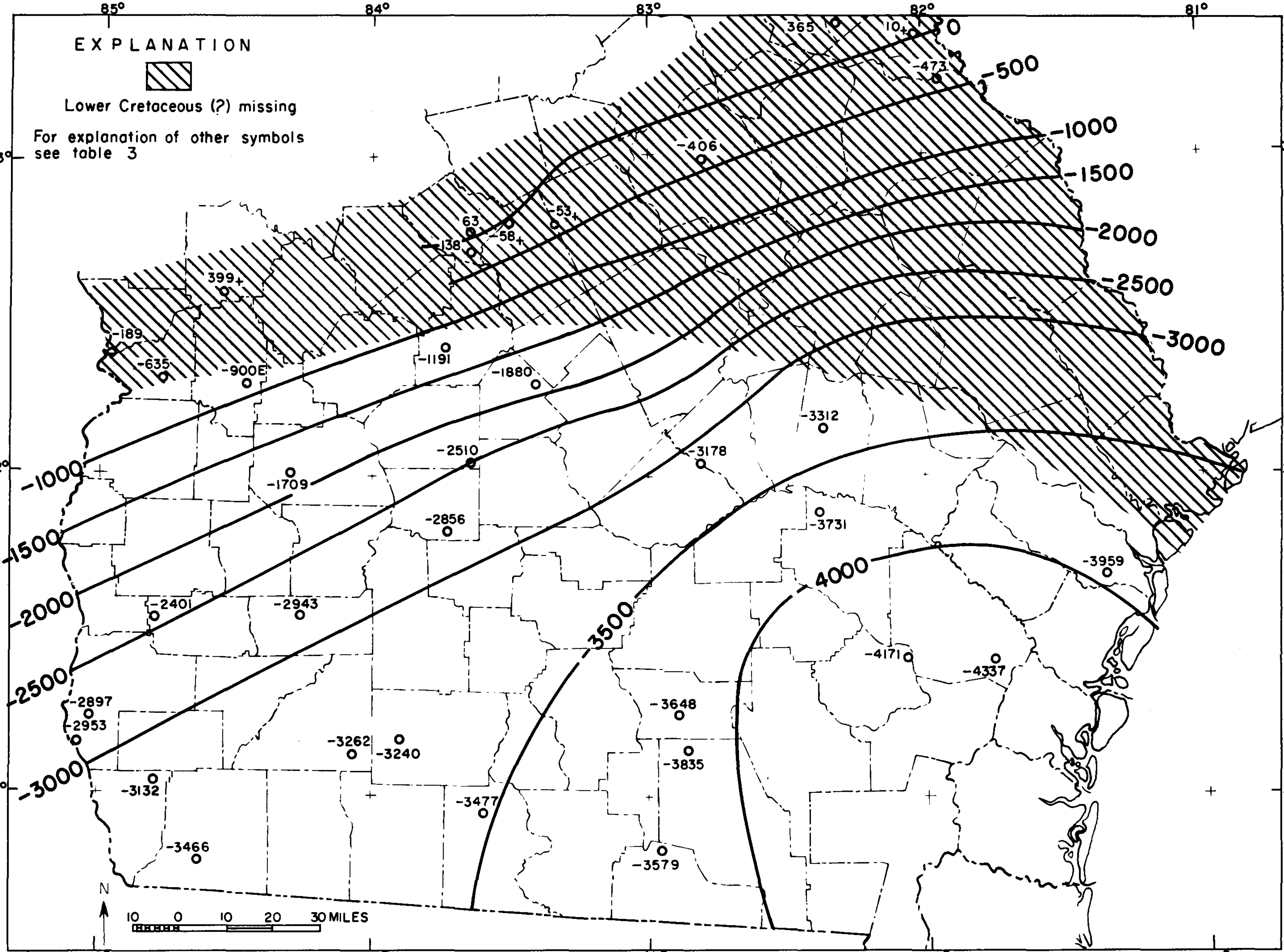

Figure 18.—Structural-contour map of the top of Lower Cretaceous (?) deposits and

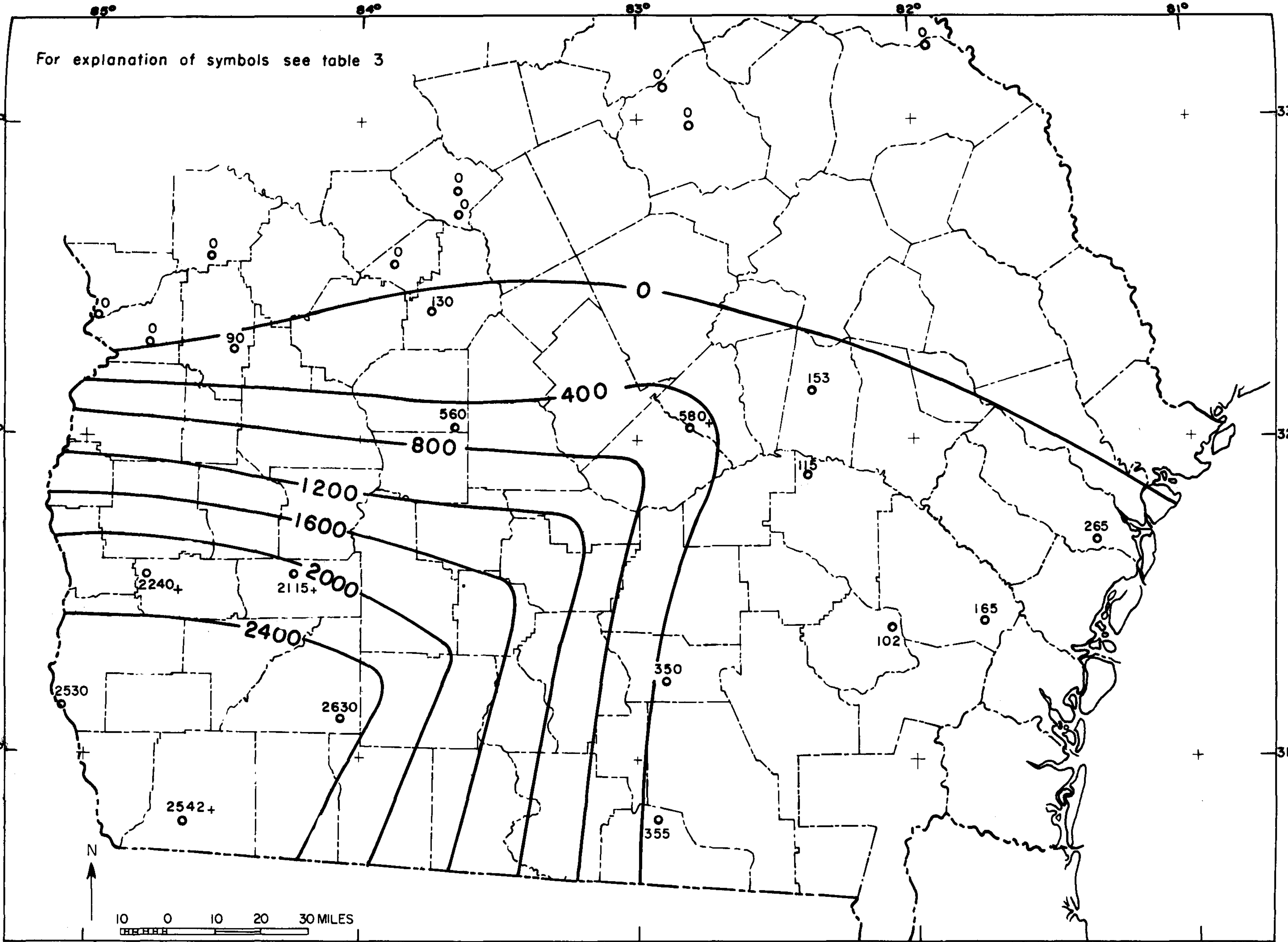

Figure 19.—Thickness-distribution map of Lower Cretaceous (?) deposits.

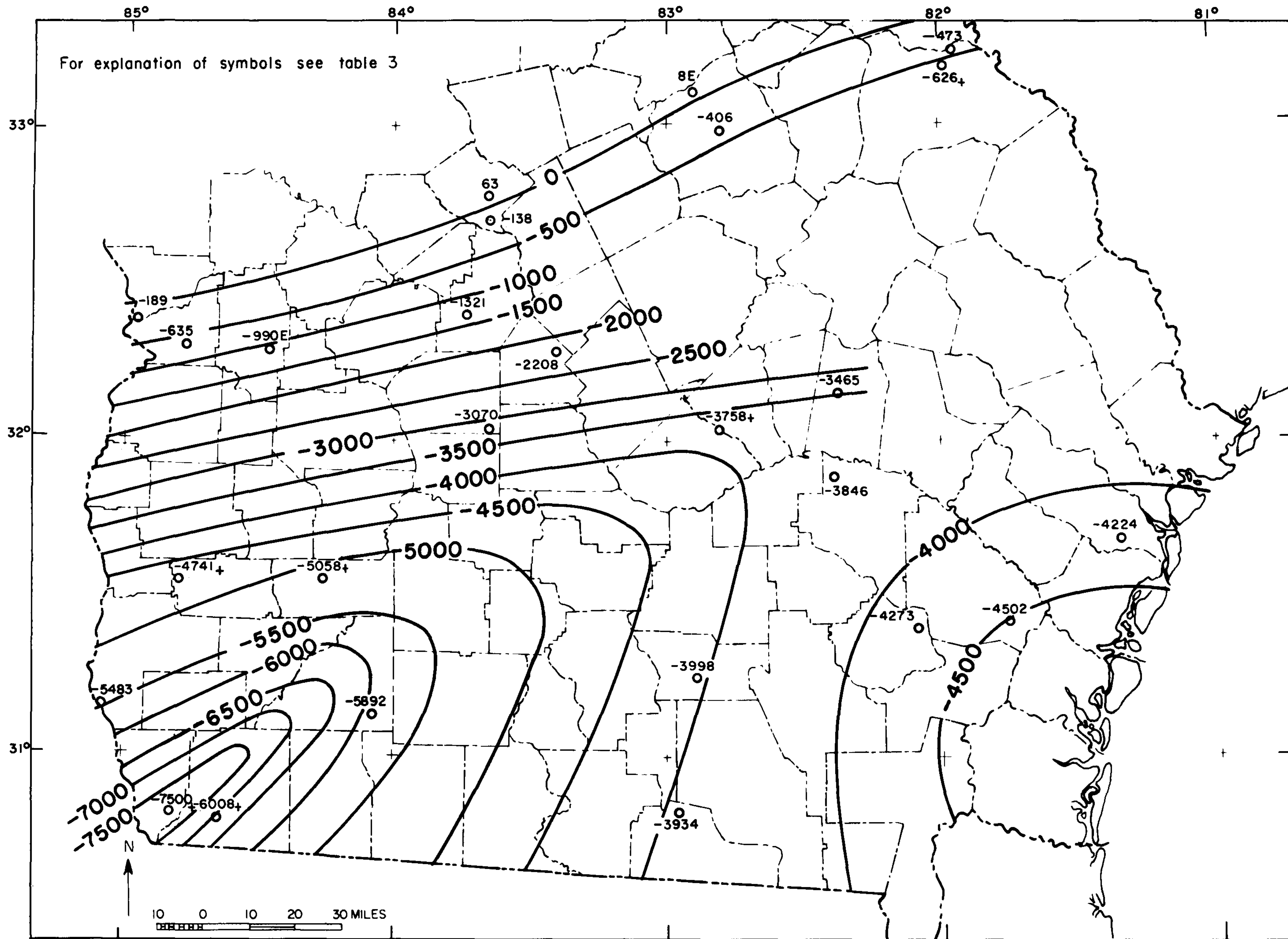

Figure 20.—Structural-contour map of the pre-Cretaceous surface.

STRUCTURE

The geologic structure in the Coastal Plain of Georgia is shown on nine structure-contour maps and eight geologic sections (figs. 21-28).

Geologic data are unavailable for large areas of the Coastal Plain making the problem of structural interpretation more uncertain. Even for the Oligocene, the data of which are reasonably well distributed, the thickness-distribution map (fig. 4) has been one of the most difficult to contour satisfactorily.

Knowing that as more data become available, the contours will need revision, it was believed desirable to give on each map the data used. The elevations and thicknesses so given can thus be used by future workers who may wish to modify the interpretations as made for this report. It is probable that additional drilling may indicate greater dips, structures, and faults than have been interpreted from data now available.

The name "Gulf Trough of Georgia" is herein proposed for a major structural feature of the subsurface in southwest Georgia. This feature was recognized by P. L. and E. R. Applin (1944, p. 1727) as "extending southwestward across Georgia through the Tallahassee area of Florida to the Gulf of Mexico." This trough is a linear feature extending northeastward from Grady County through northwestern Thomas and Colquitt Counties (See figs. 3 and 6). The thickness of Recent to Miocene deposits (see fig. 12) suggests that the trough may also continue through Tift, Irwin, and northern Coffee Counties. The fauna found in the rocks of this trough is similar to that from the Gulf of Mexico. Furthermore, the presence of a tropical Oligocene sea in central Georgia as found by Esther R. Applin (1960) suggests a connection of that sea with the Gulf of Mexico which presumably could have involved this trough. The trough appears quite prominently on the maps showing the top of the Oligocene (fig. 3) and the top of the upper Eocene (fig. 6). The top of the middle Eocene (fig. 8) indicates that the axis of the trough parallels that of upper Eocene and Miocene deposits but displaced a few miles to the southeast. Below the top of the middle Eocene nothing is known regarding this feature, but the deep paralles trough in the pre-Cretaceous surface (see fig. 20) suggests that it may persist in the intervening sediments.

A major structural feature in southeastern Georgia is herein proposed to be called the "Atlantic Embayment of Georgia" (see figs. 3, 6, 8, and 27). The deposits in the embayment contain fossils that are similar to forms living in the Atlantic Ocean for which reason the name has been chosen. Although the lack of data hinders an understanding of the deeper buried units, the embayment appears to have originated in middle Eocene time and continued as a depositional basin intermittently through Miocene time.

Overlap has been mentioned previously in connection with the discussions of stratigraphy. Examples appear on the east-west trending geologic sections. A Cretaceous high in Wilkinson 441 (fig. 21) is overlain by upper Eocene with middle Eocene deposited down the flanks of the high. Similarly a Cretaceous high is found in Pulaski 472 (fig. 27) with Paleocene and lower Eocene deposited northwest of it and Paleocene deposited to the southeast of it but the Cretaceous high and the younger sediments on its flanks are all overlain by middle Eocene.

The sedimentary units in the northwestern half of the Georgia Coastal Plain all have a gentle dip to the southeast. The tops of the Oligocene and upper Eocene both dip about 9.5 feet per mile. The dips on tops of successively lower units increase to about 24 feet per mile on the Cretaceous (see table 12.)

The dips of sedimentary units in the southeastern half of the Coastal Plain are slightly less than those in the northwestern half but they are more variable in direction. The dips range from 4.0 to 23 feet per mile from southward to eastward. The direction of dip can be determined from figures 3, 6, 8, 10, 12, and 14.

Table 12.--Generalized dip of formational contacts in the Coastal Plain of Georgia

Surface measured	Dip in feet per mile	
	Upper or northwest half	Lower or southeast half
Top of Oligocene	9.5	4.0 to 8.5
Top of upper Eocene	9.5	5.0 to 8.3
Top of middle Eocene	14	5.5
Top of lower Eocene	22	17
Top of Paleocene	20	23
Top of Cretaceous	24	23

The dip of 24 ft/mi (feet per mile) is equal to an angle of dip of 0°16′. The steepest mapped dips, found in Colquitt County, amount to 48 ft/mi or only 0°31′. Thus nowhere in the area discussed can dips be found that would be apparent even if outcrops were available and exposures ideal. The great extent of the area however permits considerable vertical change to occur due to these exceedingly gentle dips.

An unconformity as indicated by paleontologic evidence occurs in the northeastern part of the Coastal Plain where middle Eocene deposits lie on Cretaceous. The approximate areal extent of the unconformity is shown on figures 10 and 12 and it is also shown on the sections in figures 21, 22, and 27. A block uplift or tilting at the end of Cretaceous time may have raised the area above sea level and prevented deposition of Paleocene and lower Eocene sediments. The areal extent of the unconformity in the subsurface agrees with the few available surface data. A geologic map by MacNeil (1947) shows that the Paleocene is found at the surface only as far east as Houston County and that no exposures are found east of the Ocmulgee River. This has generally been inferred to be caused by overlap. The subsurface data now indicate that overlap occurs only in the downdip area and that a major unconformity separates the Cretaceous from the overlying middle Eocene sediments.

Unconformities are known in the Coastal Plain but except for the major one discussed above they are usually difficult or impossible to recognize solely from study of well samples. Marine and continental conditions are known to have alternated but such alternation is represented by sands for the continental deposits and fossiliferous, glauconitic, phosphatic clastics and limestones for the marine deposits. Weathered zones indicating a hiatus in sedimentation are not generally recognized in the study of well cuttings but have to be inferred from other data. Unconformities at the tops of all the units that have been mapped in this report are thus either known or inferred. These are in every case disconformities rather than angular unconformities.

From comparison of logs in the well-log report by Herrick, faults seemingly occur in Crisp County between wells 155 and 390 (see fig. 22) and in Clay County between wells 402 and 435 (see fig. 26.) The fault in Crisp County has a vertical displacement of about 40 feet in the Tertiary beds. Figure 22 suggests that in Crisp County a vertical displacement of about 90 feet may have occurred and that in early Tertiary or pre-Tertiary time displacement may have been about 400 feet. Other faults may occur in the Coastal Plain but the distance between the logged wells is so great that differences in elevation of formational tops are more easily explained by gentle dips rather than by faults. Later work may possibly reveal structure that is impossible to determine with available data.

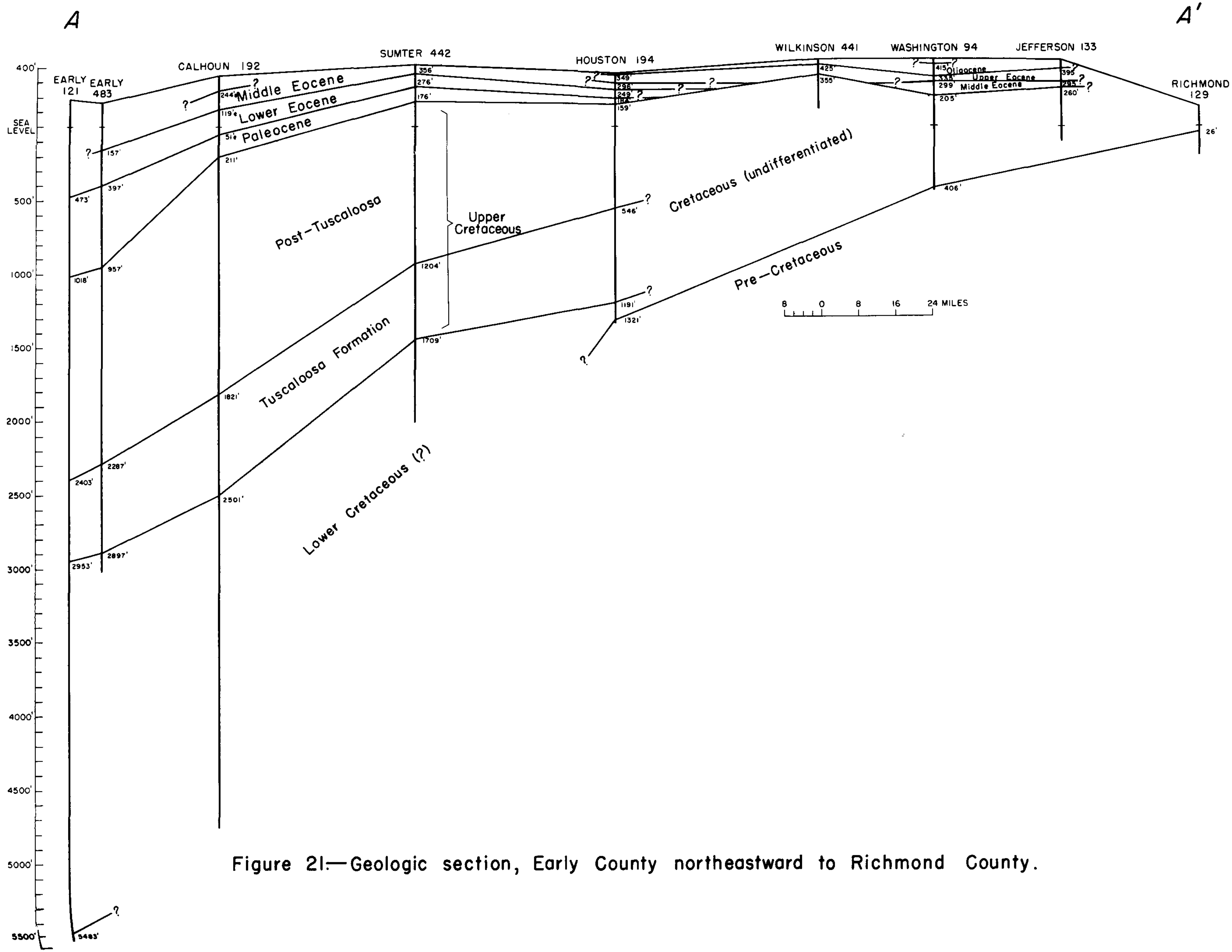

Figure 21.—Geologic section, Early County northeastward to Richmond County.

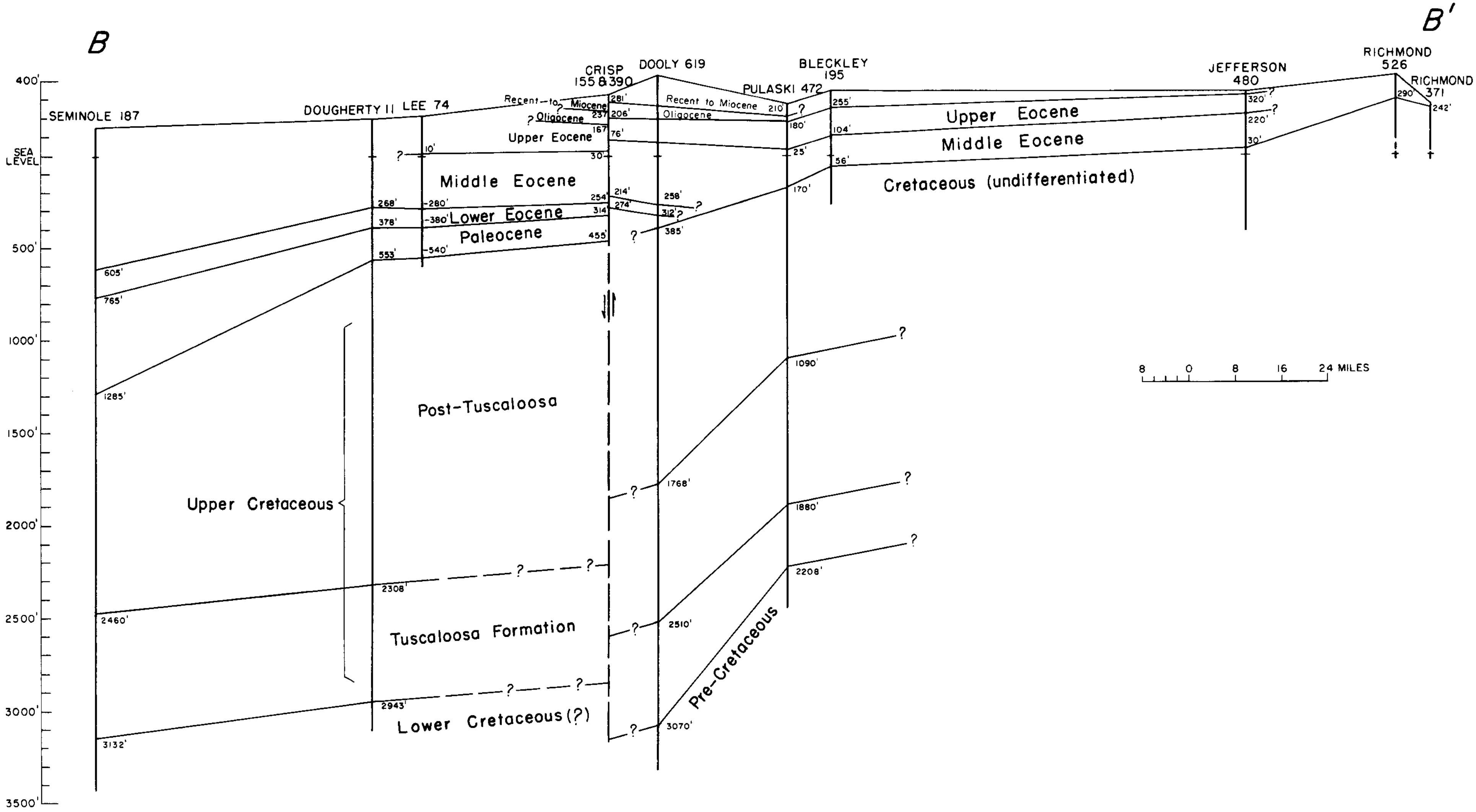

Figure 22.—Geologic section, Seminole County northeastward to Richmond County.

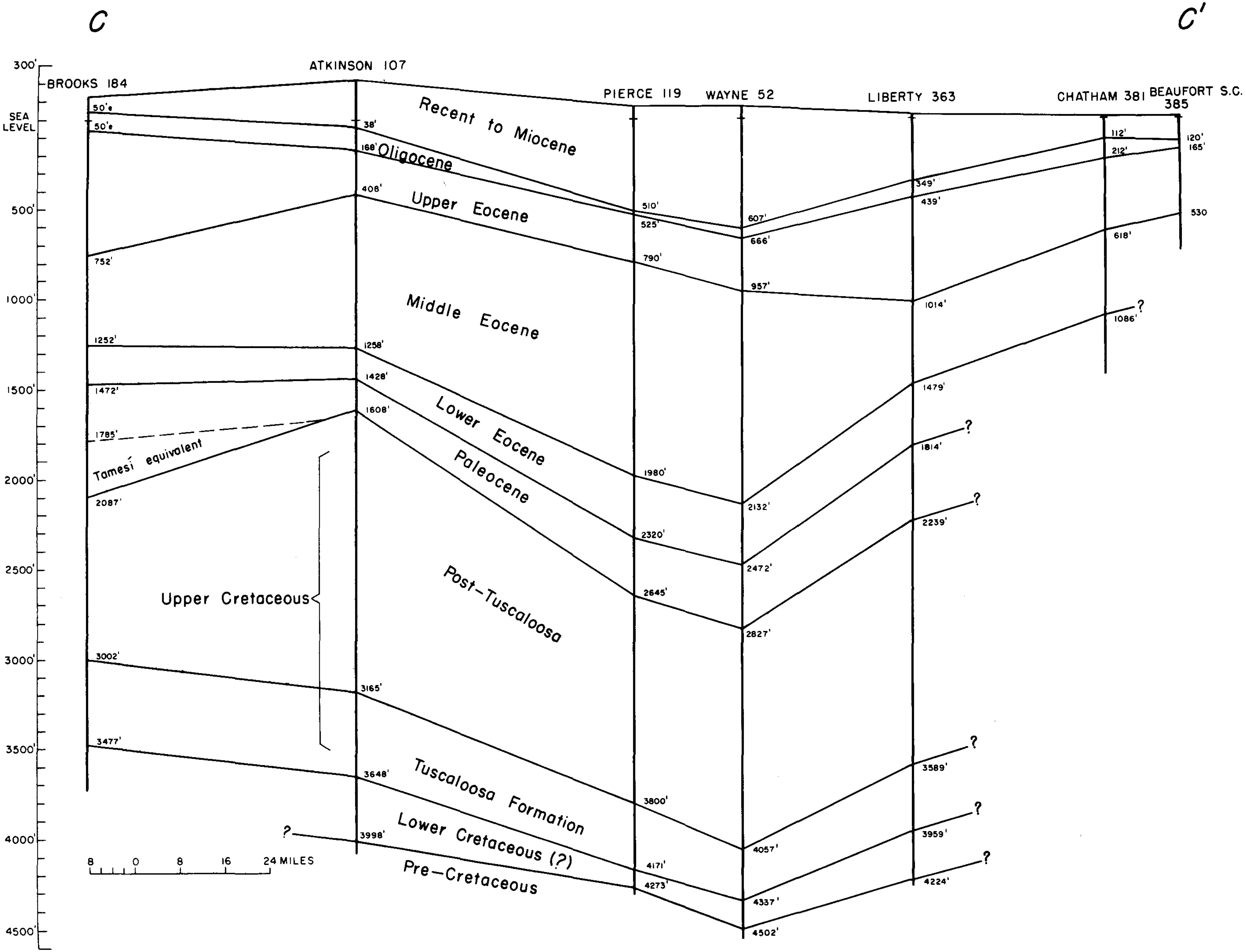

Figure 23.—Geologic section, Brooks County northeastward to Beaufort County, S. C.

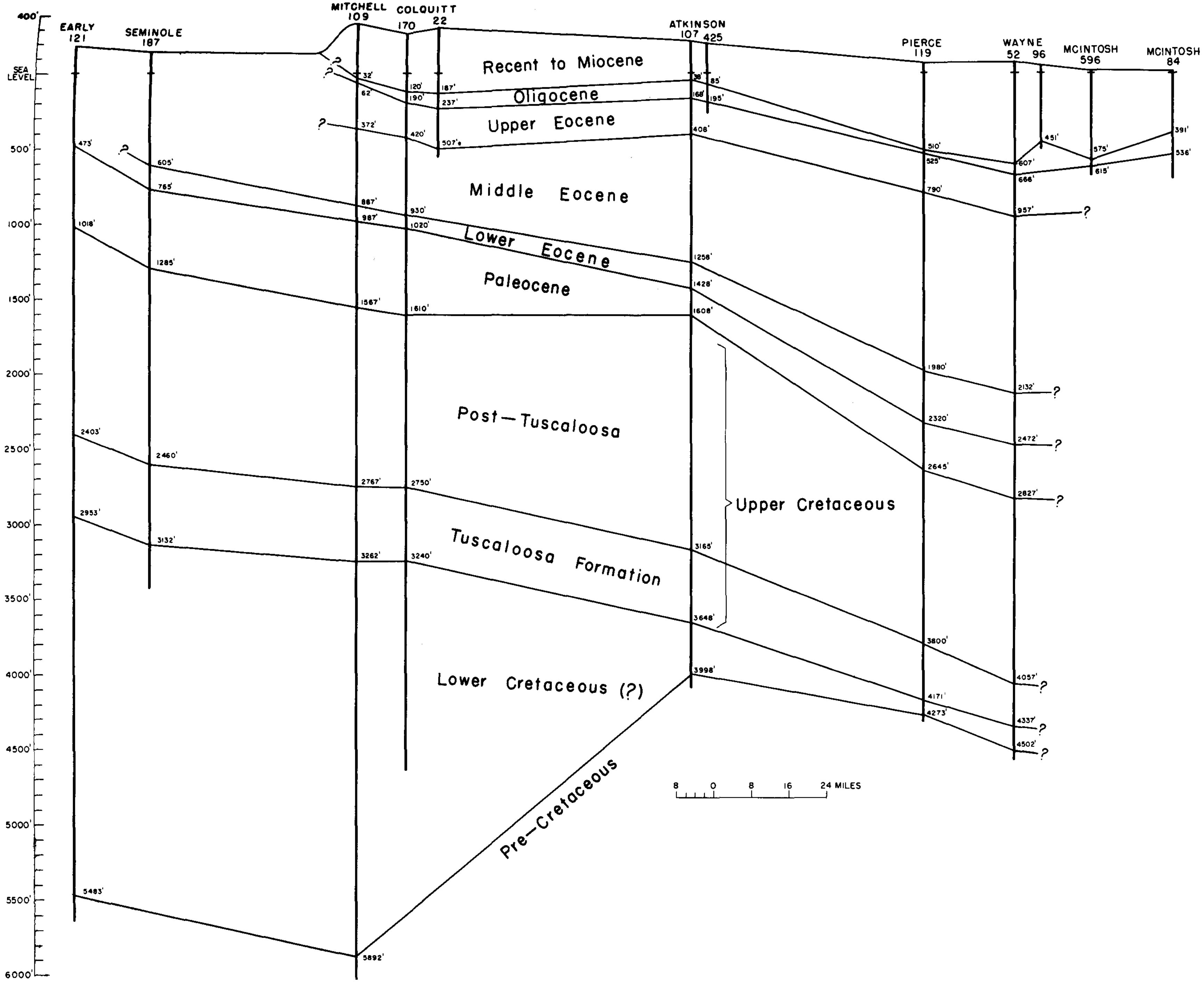

Figure 24.—Geologic section, Early County easterly to McIntosh County.

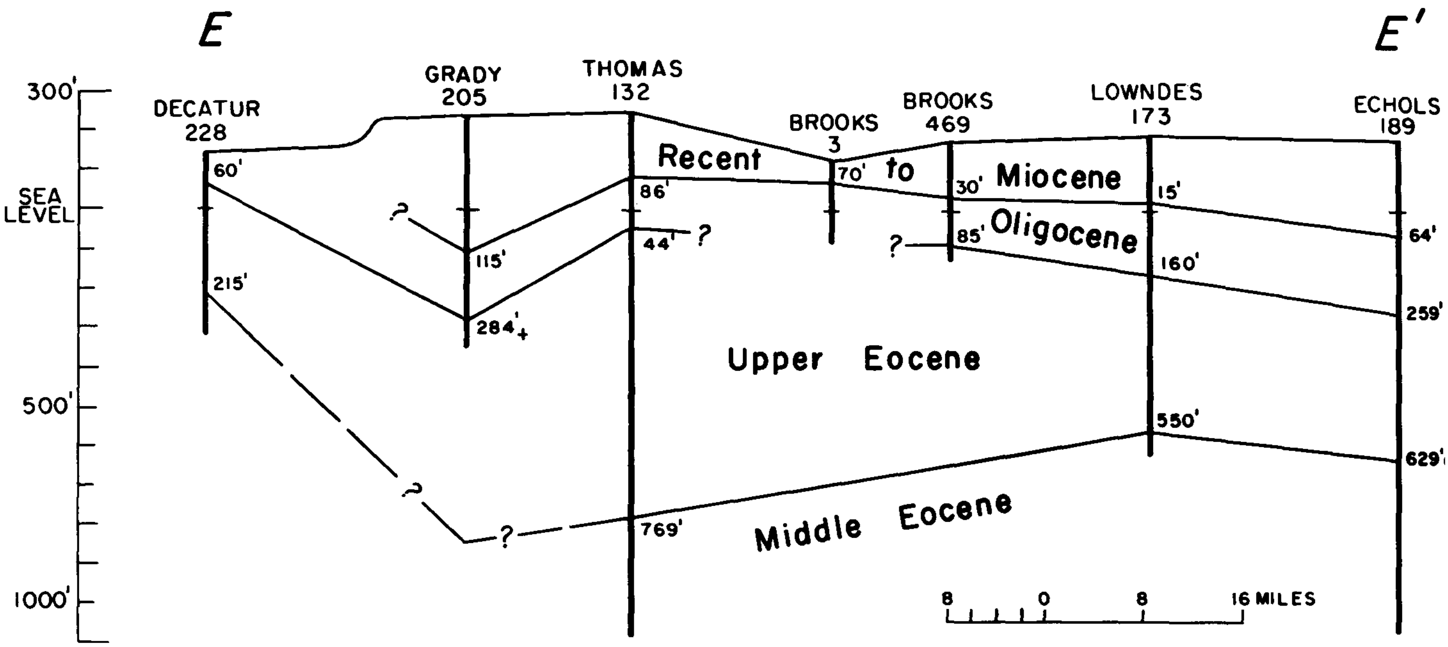

Figure 25.—Geologic section, Decatur County eastward to Echols County.

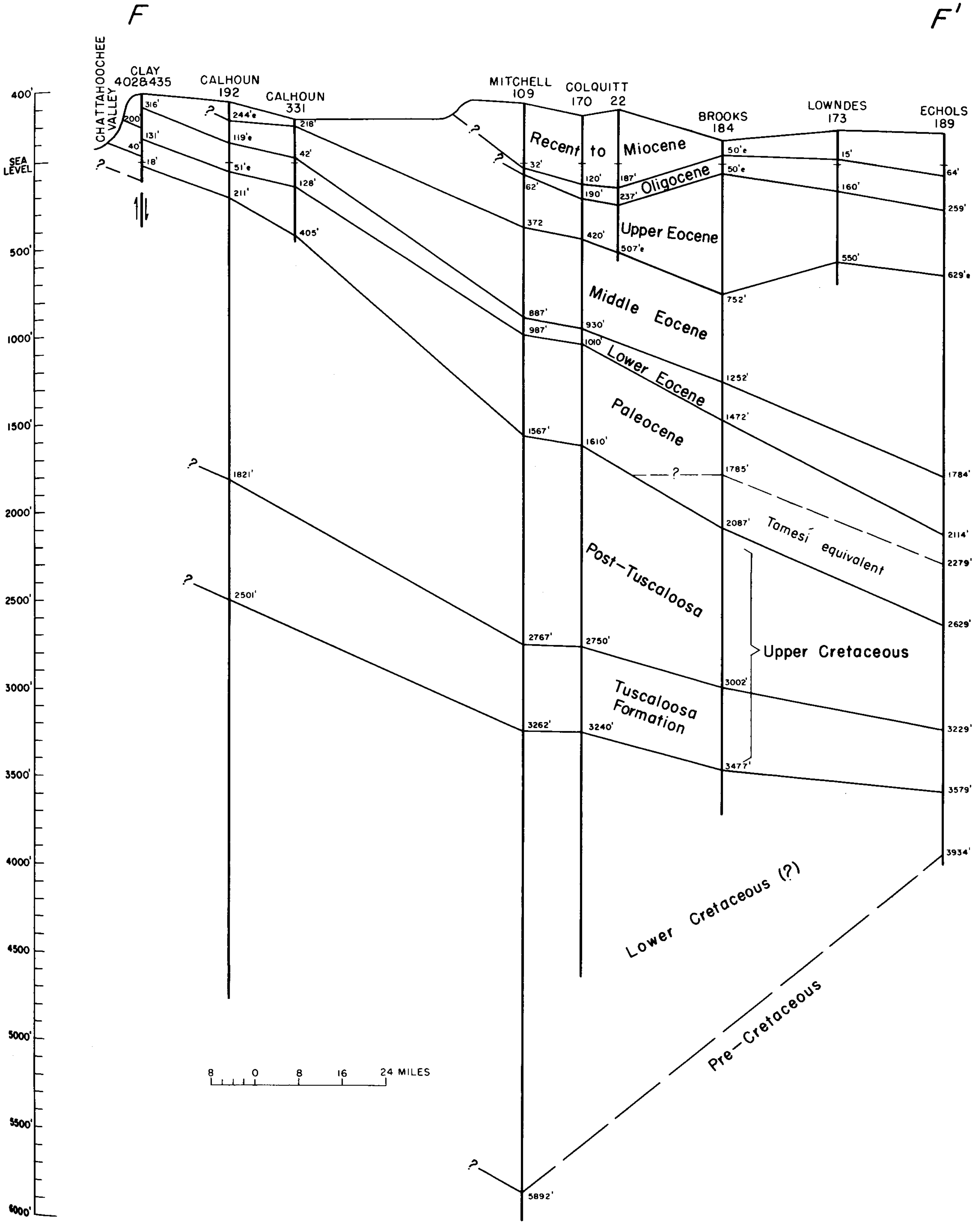

Figure 26.— Geologic section, Clay County southeastward to Echols County.

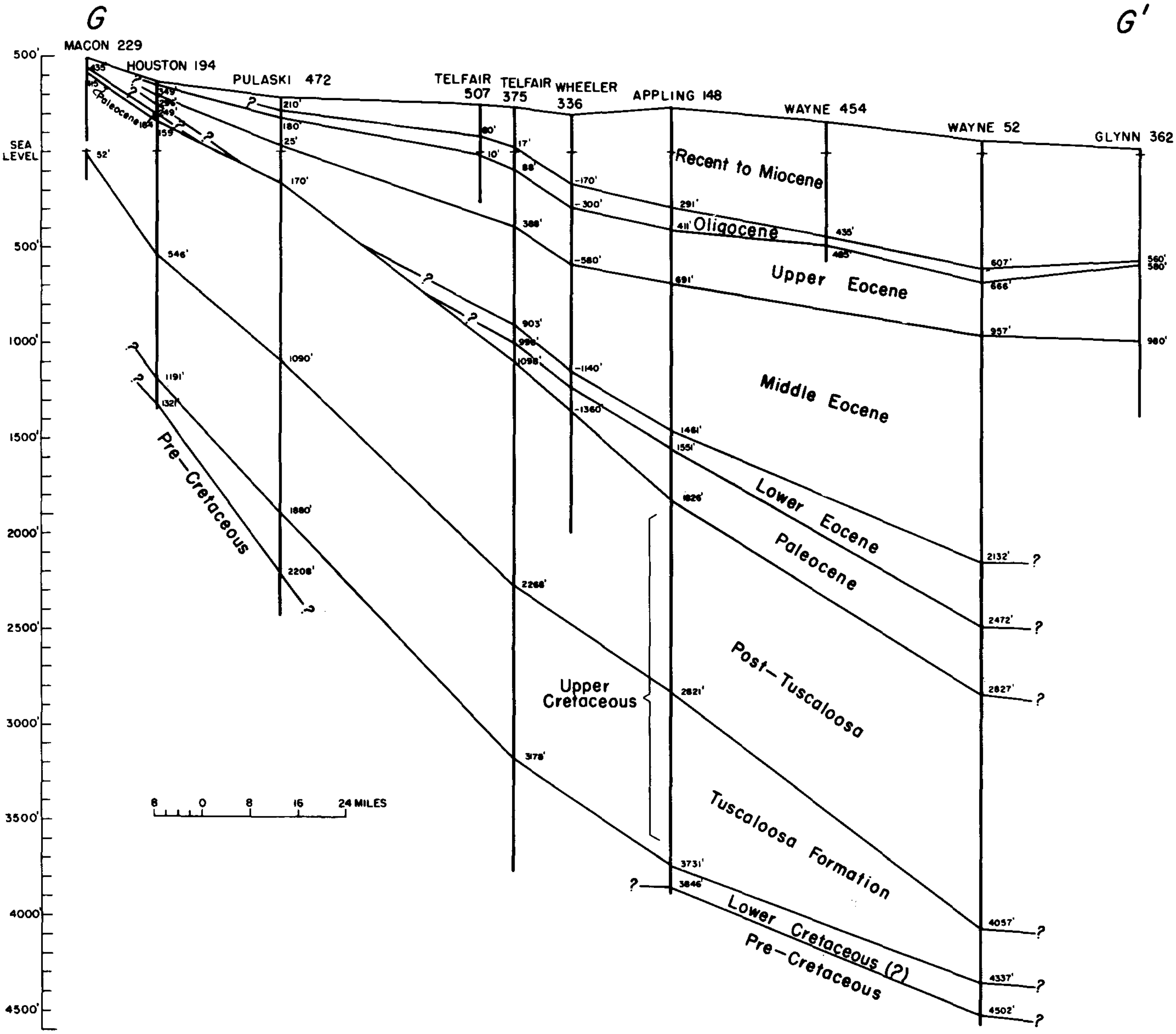

Figure 27.— Geologic section, Macon County southeastward to Glynn County.

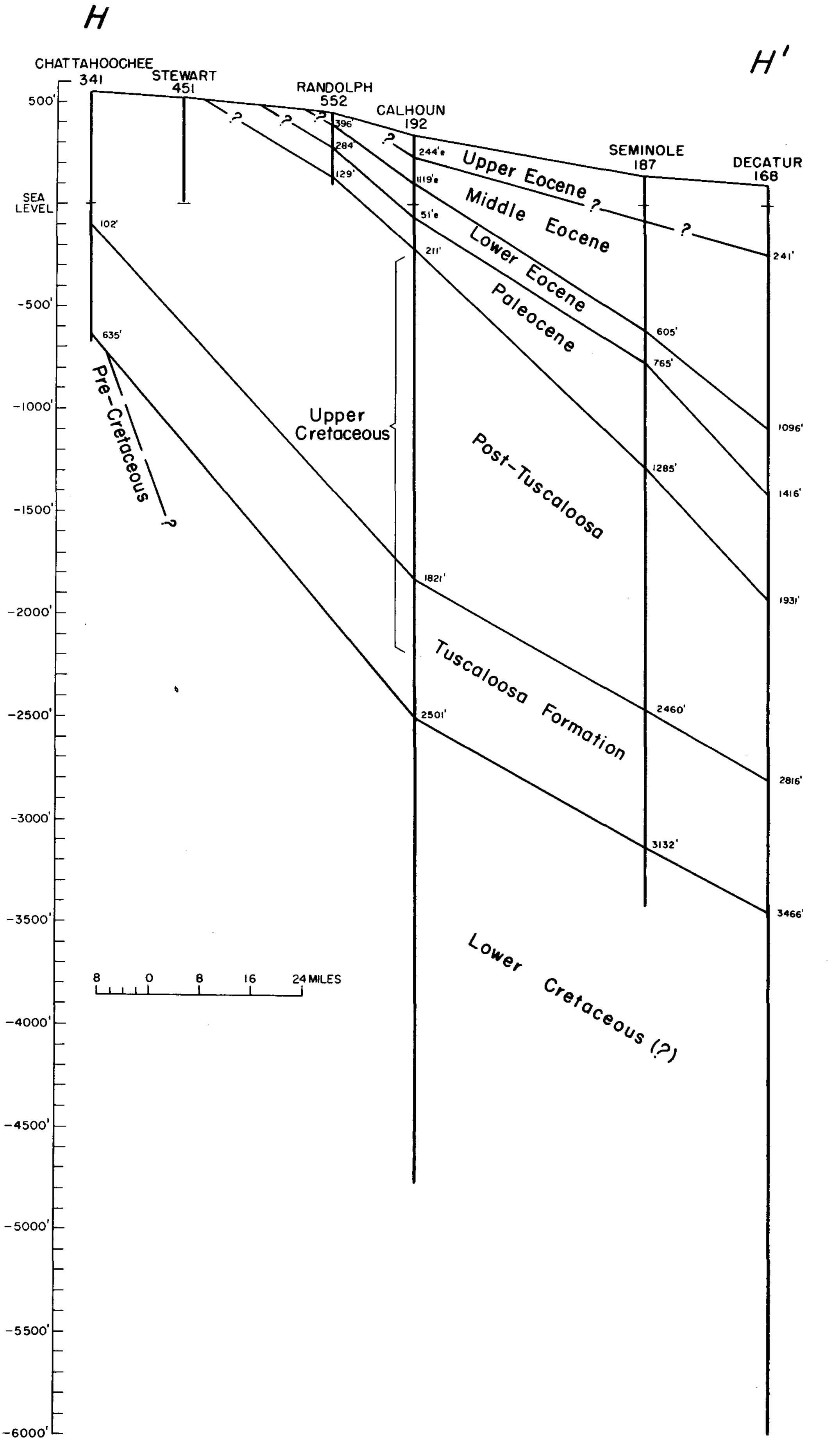

Figure 28.—Geologic section, Chattahoochee County southward to Decatur County.

UNSOLVED PROBLEMS

The interpretations as given in the text, on the maps, and in the geologic sections must be considered preliminary rather than final. The authors realize that much interpretation is based on meager data and that more detail will be added as additional data are obtained. As yet it is only conjectural as to whether anomalies found in the study of the data for the Coastal Plain are indicative of local variations in thickness of sedimentation or possible presence of two or more sets of faults. Also, some of the anomalies could be due to errors in determining land surface elevations of wells or errors in collecting and labelling well samples. The indications are enough to make tantalizing the desire for answers but inadequate to permit much more than guesses. However, it is possible that finding the answers may have considerable economic significance to Georgia.

The surficial deposits of Oligocene age in Georgia have been mapped as the Flint River Formation by Cooke (1943) and as the Suwanee Limestone by MacNeil (1947). Additional work is needed to establish whether two different formations of Oligocene age occur in Georgia or whether these two are the same formation with the Flint River Formation representing the weathered and eroded remnants of the Suwanee Limestone. This problem needs to be solved before a really valid correlation can be established between surface outcrops and the subsurface.

The age of the phosphate-bearing, sandy limestone at the base of the Miocene in southeastern Georgia and adjacent parts of South Carolina is uncertain. Owing to a lack of fossils the age of this limestone is regarded in this report as basal Miocene though it could be late Oligocene. If the Cooper Marl in Georgia is found to be Oligocene in age (now considered to be late Eocene(?)) then this phosphatic limestone lying at the base of the Miocene could be equivalent to the uppermost Cooper Marl in this part of Georgia and South Carolina.

The age and areal extent of the Cooper Marl in Georgia also needs further study. As noted previously, the fauna of the Cooper Marl in Georgia suggests that the formation is the updip equivalent of the upper unit of the Ocala Limestone. From this correlation, both would seem to be late Eocene in age. However, the Cooper Marl of South Carolina is now considered to be Oligocene in age (Malde, 1959, p. 19). Until positive correlation can be established between the Cooper Marl of both Georgia and South Carolina, the reader is urged to consider that all mention of the Cooper Marl in this report applies only to the deposits of that name as found in Georgia.

In a report on a tropical Oligocene sea in central Georgia, Esther R. Applin (1960) published a log of a well in Coffee County showing 640 feet of Oligocene sediments. This thickness is so unusual in Georgia that the senior author examined another cut of the samples and found himself in substantial agreement with Mrs. Applin. In none of the other wells does the Oligocene exceed much over 200 feet. The reason for this local thickening is as yet an enigma. The fossils found indicate an orderly sequence throughout rather than a repetition of strata such as could result from faulting. Further study is needed to explain this anomaly and to determine its areal extent and structural significance. Because the data were so anomalous they were not entered on the maps in this report.

The upper Eocene and Oligocene Foraminifera found in the Dougherty Plain of southwest Georgia suffice to indicate that rocks of those ages once covered part or all of the Plain. More work is needed to know why this large area should have been so uniformly leached of its limestone cover and when it occurred.

In Georgia the upper division of the Ocala Limestone contains *Asterocyclina nassauensis*, *Operculinoides floridensis*, and *Pseudophragmina flintensis*. The presence of these three larger Foraminifera indicates definite upper Eocene age of this unit. However, the remainder of the fauna appears to be closely related to that of the Cooper Marl suggesting that the Cooper Marl in Georgia is late Eocene in age rather than Oligocene as in South Carolina. The upper division of the Ocala in Chatham County appears to be the downdip limestone equivalent of the Cooper Marl as exposed in Jenkins and Houston Counties.

As yet, the age of the Sandersville Limestone Member of the Barnwell Formation is subject to question. It may be a limestone of Oligocene rather than late Eocene age. Further study of its occurrence in the subsurface of east-central Georgia is needed to solve this problem.

A sand is found between the Ocala Limestone of late Eocene age and the Lisbon Formation of middle Eocene age. In the logs of the well-log report (Herrick, 1961) this sand was either called Gosport Sand or included in the Lisbon Formation. Further study is needed to ascertain whether this is actually Gosport or whether it may be entirely or in part equivalent to the Moodys Marl Member of the Jackson Formation of late Eocene age.

The Gulf Trough is southwestern Georgia is known to affect the dips and thickness of units down through the upper Eocene. It would be interesting to know more about this structure at depth and what caused it. The surface formations may have been downwarped affecting the deeper formations or local differential compaction may have caused the trough with no structure reflected in the deeper sedimentary units.

In the northeastern part of the Georgia Coastal Plain, the Cretaceous deposits have been lumped together as Tuscaloosa Formation (Herrick, 1961) and as "rocks of Tuscaloosa to Providence age undifferentiated" (Eargle, 1955). To correlate those rocks with their equivalents to the west, the study of spores should be undertaken. This seems to be the only method currently available that can permit such a correlation to be made.

REFERENCES

Applin, E. R., 1955, A biofacies of Woodbine age in the southeastern Gulf Coast region: U. S. Geol. Survey Prof. Paper 264-I, p. 187-197, pls. 48-59.

__________ 1960, A tropical sea in central Georgia in late Oligocene time: U. S. Geol. Survey Prof. Paper 400-B, p. B207-B209.

Applin, E. R., and Jordan, Louise, 1945, Diagnostic Foraminifera from subsurface formations in Florida: Jour. Paleontology, v. 19, no. 2, p. 129-148, pls. 18-21.

Applin, P. L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent States: U. S. Geol. Survey Circ. 91, 28 p.

__________ 1952, Volume of Mesozoic sediments in Florida and Georgia: Geol. Soc. America Bull., v. 63, no. 12, p. 1159-1164.

__________ 1961, Atlantic Coastal Plain on Tectonic map of the United States: U. S. Geol. Survey and Am. Assoc. Petroleum Geologists.

Applin, P. L., and Applin, E. R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 12, p. 1673-1753.

__________ 1947, Regional subsurface stratigraphy, structure, and correlation of Middle and early Upper Cretaceous rocks in Alabama, Georgia, and North Florida: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 26, in 3 sheets.

Bandy, O. L., 1949, Eocene and Oligocene Foraminifera from Little Stave Creek, Clarke County, Alabama: Bull. Am. Paleontology, v. 32, no. 131, 210 p., 27 pls.

Black, A. P., and Brown, Eugene, 1951, Chemical character of Florida's waters, 1951: Florida Water Survey & Res. Paper 6, fig. 3.

Bonini, W. E. , and Woollard, G. P., 1960, Subsurface geology of North Carolina-South Carolina Coastal Plain from seismic data: Am. Assoc. Petroleum Geologists Bull., v. 44, no. 3, p. 298-315.

Braunstein, Jules, 1959, Eastern Gulf Coast oil and gas geology: Georgia Geol. Survey Mineral Newsletter, v. 12, no. 1, p. 12-16.

Carsey, D. O., 1926, Foraminifera of the Cretaceous of central Texas: Texas Univ. Bull. 2612, 56 p., 8 pls.

Cole, W. S., 1929, Three new Claiborne fossils: Bull. Am. Paleontology, v. 15, no. 56, 8 p., 2 pls.

__________ 1931, The Pliocene and Pleistocene Foraminifera of Florida: Florida Geol. Survey Bull. 6, 79 p., 7 pls.

Cole, W. S., 1941, Stratigraphic and paleontologic studies of wells in Florida, No. 1: Florida Geol. Survey Bull. 19, 91 p., 18 pls.

__________ 1944, Stratigraphic and paleontologic studies of wells in Florida, No. 3: Florida Geol. Survey Bull. 26, p. 11-101, pls. 1-29.

__________ 1945, Stratigraphic and paleontologic studies of wells in Florida, No. 4: Florida Geol. Survey Bull. 28, 160 p., 22 pls.

Cole, W. S., and Applin, E. R., 1961, Stratigraphic and geographic distribution of larger Foraminifera occuring in a well in Coffee County, Georgia: Cushman Found. Foram. Research Contr., v. 12, no. 4. p. 127-135, pls. 6-7.

Cole, W. S., and Herrick, S. M., 1953, Two species of larger Foraminifera from Paleocene beds in Georgia; Bull. Am. Paleontology, v. 35, no. 148, 16 p., 2 pls.

Cole, W. S., and Ponton, G. M. 1930, The Foraminifera of the Marianna Limestone of Florida: Florida Geol. Survey Bull. 5, p. 19-69, pls. 5-11.

Cooke, C. W., 1936, Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, 196 p., 18 pls.

__________ 1943, Geology of the Coastal Plain of Georgia: U. S. Geol. Survey Bull. 941, 121 p., 1 pl.

Cooke, C. W., and Shearer H. K., 1918, Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120, p. 41-81, pl. 7.

Counts, H. B., and Donsky, Ellis, Salt-water encroachment, geology, and ground-water resources of Savannah area, Georgia and South Carolina: U. S. Geol. Survey Water-Supply Paper 1611. (In Press)

Cushman, J. A., 1918, Some Pliocene and Miocene Foraminifera of the Coastal Plain of the United States: U. S. Geol. Survey Bull. 676, 100 p., 31 pls.

Cushman, J. A., 1922a, The Foraminifera of the Byram Calcareous Marl at Byram, Mississippi: U. S. Geol. Survey Prof. Paper 129-E, p. 87-122, pls. 14-28.

__________ 1922b, The Foraminifera of the Mint Spring Calcareous Marl Member of the Marianna Limestone: U. S. Geol. Survey Prof. Paper 129-F, p. 123-152, pls. 29-35.

__________ 1926, The Foraminifera of the Velasco Shale of the Tampico Embayment: Am. Assoc. Petroleum Geologists Bull., v. 10, no. 6, p. 581-612, pls. 17-21.

__________ 1930, The Foraminifera of the Choctawhatchee Formation of Florida: Florida Geol. Survey Bull. 4, 63 p., 12 pls.

__________ 1935, Upper Eocene Foraminifera of the southeastern United States: U. S. Geol. Survey Prof. Paper 181, 88 p., 23 pls.

Cushman, J. A., 1940, Upper Cretaceous Foraminifera of the Gulf coastal region of the United States and adjacent areas: U. S. Geol. Survey Prof. Paper 206, 241 p., 66 pls.

__________ 1944, Foraminifera from the Aquia Formation of Virginia: Cushman Lab. Foram. Research Contr., v. 20, pt. 1, p. 17-28, pls. 3-4.

__________ 1945, A foraminiferal fauna from the Twiggs Clay of Georgia; Cushman Lab. Foram. Research Contr., v. 21, pt. 1, p. 1-11, pls. 1-2.

__________ 1951, Paleocene Foraminifera of the Gulf Coastal region ofthe United States and adjacent areas: U. S. Geol. Survey Prof. Paper 232, 75 p., 24 pls.

Cushman, J. A., and Applin, E. R., 1925, Texas Jackson Foraminifera: Am. Assoc. Petroleum Geologists Bull., v. 10, no. 2, p. 154-189, 6 pls.

__________ 1946, Some Foraminifera of Woodbine Age from Texas, Mississippi, Alabama, and Georgia: Cushman Lab. Foram. Research Contr., v. 22, pt. 3, p. 71-76, pl. 13.

__________ 1947, Some new Foraminifera from the American Cretaceous: Cushman Lab. Foram. Research Contr., v. 23, pt. 3, p. 53-55, pl. 13.

Cushman, J. A., and Herrick, S. M., 1945, The Foraminifera of the type locality of the McBean Formation: Cushman Lab. Foram. Research Contr., v. 21, pt. 3, p. 55-73 pls. 9-11.

Cushman, J. A., and McGlamery, Winnie, 1942, Oligocene Foraminifera near Millry, Alabama: U. S. Geol. Survey Prof. Paper 197-B, p. 65-84, pls. 4-7.

Cushman, J. A., and Ponton, G. M., 1932, An Eocene foraminiferal fauna of Wilcox age from Alabama: Cushman Lab. Foram. Research Contr., v. 8, pt. 3, 51-72, pls. 7-9.

Cushman, J. A., and Todd, Ruth, 1945, A foraminiferal fauna from the Lisbon of Alabama: Cushman Lab. Foram. Research Contr., v. 21, pt. 1, p. 11-21, pls. 3-4.

Douglass, R. C., 1960, Revision of the family Orbitolinidae: Micropaleontology, v. 6, no. 3, p. 249-270.

Eargle, D. H., 1955, Stratigraphy of the outcropping Cretaceous rocks of Georgia: U. S. Geol Survey Bull. 1014, 101 p., 31 pl., 17 figs.

Forgotson, J. M., Jr., 1963, Depositional history and paleotectonic framework of Comanchean Cretaceous Trinity Stage, Gulf Coast area: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 1. p. 69-103.

Frizzell, D. L., 1954, Handbook of Cretaceous Foraminifera of Texas: Texas Univ. Bur. Econ. Geology Rept. Inv. 22, 232 p.

Gravell, D. W., and Hanna, M. A., 1938, Subsurface Tertiary zones of correlation through Mississippi, Alabama, and Florida: Am. Assoc. Petroleum Geologists Bull., v. 22, p. 984-1013, 7 pls.

Herrick, S. M., 1960, Some small Foraminifera from Shell Bluff, Georgia: Bull. Am. Paleontology, v. 41, no. 187, p. 117-130, pls. 14-16.

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

Herrick, S. M., and Wait, R. L., 1955, Interim report on results of test drilling in the Savannah area, Georgia and South Carolina: U. S. Geol. Survey open-file rept., 48 p., 9 figs.

______________ 1956, Ground water in the Coastal Plain of Georgia: Am. Water Works Assoc. Southeastern Sec. Jour., v. 20, no. 1, p. 73-86.

Howe, H. V. W., 1939, Louisiana Cook Mountain Eocene Foraminifera: Louisiana Dept. Conserv. Geol. Bull. 14, 122 p., 14 pls.

6

Howe, H. V. W., and Wallace, W. C., 1932, Foraminifera of the Jackson Eocene at Danville Landing, on the Ouachita, Catahoula Parish, Louisiana: Louisana Dept. Conserv. Geol. Bull. 2, 118 p., 15 pls.

Hull, J. P. D., Jr., 1962, Cretaceous Suwannee Strait, Georgia and Florida: Am. Assoc. Petroleum Geologists Bull., v. 46, no.1 p. 118-122.

Hurst, V. J., 1960, Oil tests in Georgia: Georgia Geol. Survey Inf. Circ. 19, 14 p.

LaMoreaux, P. E., 1946, Geology of the Coastal Plain of east-central Georgia: Georgia Geol. Survey Bull. 50, pt. 1, 26 p.

LeGrand, H. E., 1961, Summary of geology of Atlantic Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 45, no. 9, p. 1557-1571.

LeGrand, H. E., and Furcron, A. S., 1956, Geology and ground-water resources of central-east Georgia: Georgia Geol. Survey Bull. 64, 174 p.

Loeblich, A. R., Jr., 1946, Foraminifera from the type Pepper Shale of Texas: Jour. Paleontology, v. 20, no. 2, p. 130-139, pl. 22.

Loeblich, A. R., Jr., and Tappan, H. N., 1950, Foraminifera of the type Kiowa Shale, Lower Cretaceous of Kansas: Kansas Univ. Paleont. Contr. no. 6. Protozoa, art. 3, p. 1-15, 2 pls.

______________ 1957, Planktonic Foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic Coastal Plains: U. S. Natl. Museum Bull. 215, p. 173-198, pls. 40-64.

Lozo, F. E., 1944, Biostratigraphic relations of some north Texas Trinity and Fredericksburg (Comanchean) Foraminifera: Am. Midland Naturalist, v. 31, no. 3, p. 513-582, 5 pls.

MacNeil, F. S., 1944, Southwestern Georgia Field Trip: Southeastern Geol. Soc. (Guidebook) 2d Field Trip, 63 p.

MacNeil, F. S., 1947, Geologic map of the Tertiary and Quaternary Formations of Georgia: U. S. Geol. Survey Oil and Gas Inv. (Prelim.) Map 72.

Malde, H. E., 1959, Geology of the Charleston phosphate area, South Carolina: U. S. Geol. Survey Bull. 1079, 105 p.

McLean, J. D., Jr., 1953, Four new species of Foraminifera from the lower Tertiary of New Jersey: Cushman Lab. Foram. Research Contr., v. 4, pt. 3, p. 103-105, pl. 17.

Muir, J. M., 1936, Geology of the Tampico Region, Mexico: Tulsa, Okla., Am. Assoc. Petroleum Geologists, 280 p., 15 pls.

Meyer, F. W., 1962, Reconnaissance of the geology and ground-water resources of Columbia County, Florida; Florida Geol. Survey Rept. Inv. 30, 74 p.

Munyan, A. C., 1939, Well locations on Coastal Plain of Georgia: Georgia Dept. Mines, Mining, and Geology Spec. Map.

_______________ 1943, Subsurface stratigraphy and lithology of Tuscaloosa Formation in southeastern Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 27, p. 596-607.

Murray, G. E. 1961, Geology of the Atlantic and Gulf Coastal Province of North America: New York, Harper & Bros., 692 p.

Owen, Vaux, Jr., 1959, A summary of ground-water resources of Sumter County, Georgia: Georgia Geol. Survey Mineral Newsletter, v. 12, no. 2, p. 42-51.

_______________ 1961, Geology and ground-water resources of Mitchell County, Georgia: Georgia Geol. Survey Mineral Newsletter, v. 14, nos. 2-3, p. 41-51.

_______________ 1963, Geology and ground-water resources of Mitchell County, southwest Georgia: Georgia Geol. Survey Inf. Circ. 24.

_______________ Geology and ground-water resources of Lee and Sumter Counties, southwest Georgia: U. S. Geol. Survey Water-Supply Paper 1666. (In Press).

Plummer, H. J., 1926, Foraminifera of the Midway Formation of Texas: Texas Univ. Bull. 2644, 206 p., 15 pls.

_______________ 1931, Some Cretaceous Foraminifera in Texas: Texas Univ. Bull. 3101, p. 109-203, pls. 8-15.

Prettyman, T. M., and Cave, H. S., 1923, Petroleum and natural gas possibilities in Georgia: Georgia Geol. Survey Bull. 40, 164 p.

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

Richards, H. G., 1945, Subsurface stratigraphy of Atlantic Coastal Plain between New Jersey and Georgia: Am. Assoc, Petroleum Geologists Bull., v. 29, no. 7, 885-955.

_______________ 1947, The Atlantic Coastal Plain, its geology and oil possibilities: World Oil, v. 127, no. 3, p. 44-50, 58.

_______________ 1948, Studies on the subsurface geology and paleontology of the Atlantic Coastal Plain: Acad. Nat. Sci. Phila. Proc., v. 100, p. 39-76.

Shifflet, F. E., 1948, Eocene stratigraphy and Foraminifera of the Aquia Formation: Maryland Dept. Geology, Mines and Water Resources Bull. 3, p. 43-80, pls. 1-5.

Sloss, L. L., Dapples, E. C., and Krumbein, W. C., 1960, Lithofacies maps, an atlas of the United States and southern Canada: New York, John Wiley & Sons.

Southeastern Geological Society, Mesozoic Committee, 1949, Mesozoic cross section B-B', Beaufort County, South Carolina to Highlands County, Florida and Mesozoic cross section C-C', Toombs County, Georgia to Volusia County, Florida: one sheet, scale 1 inch to 10 mi.

Todd, Ruth, 1952, Vicksburg (Oligocene) smaller Foraminifera from Mississippi: U. S. Geol. Survey Prof. Paper 241, 53 p., 6 pls.

Toulmin, L. D., 1941, Eocene smaller Foraminifera from the Salt Mountain Limestone of Alabama: Jour. Paleontology, v. 15, no. 6, p. 567-611, pls 78-82.

Toulmin, L. D., 1952, Volume of Cenozoic sediments in Florida and Georgia: Geol. Soc. America Bull,. v. 63, no. 12, p. 1165-1176.

______________ 1955, Cenozoic geology of southeastern Alabama, Florida, and Georgia: Am. Assoc. Petroleum Geologists Bull., v. 39, no. 2, p. 207-235.

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

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

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

Wait, R. L., 1958, Sources of ground water for irrigation in Dougherty County, Georgia: Georgia Geol. Survey Mineral Newsletter, v. 11, no. 4, p. 123-127.

______________ 1960, Summary of the ground-water resources of Terrell County, Georgia: Georgia Geol. Survey Mineral Newsletter, v. 13, no. 3, p. 117-122.

______________ 1963, Geology and ground-water resources of Dougherty County, Georgia: U. S. Geol. Survey Water-Supply Paper 1539-P., 102p.

Warren, M. A., 1944, Artesian water in southeastern Georgia with special reference to the coastal area: Georgia Geol. Survey Bull. 49, 149 p.

White, M. P., 1928-29, Some index Foraminifera of the Tampico Embayment area of Mexico: Jour. Paleontology, v. 2, no. 3, p. 177-215, pls. 27-29; v. 2, no. 4, 280-317, pls. 38-42; v. 3, no. 1, p. 30-57, pls. 4-8.

Woollard, G. P., 1955, Preliminary report on seismic investigations in Tift and Atkinson Counties, Georgia: Georgia Geol. Survey Mineral Newsletter, v. 8, no. 2, p. 69-77.

INDEX

A

Acruliammina longa 48
Alabamina atlantisae 24, 31
danvillensis 24, 31
mississippiensis 17
obtusa 24
wilcoxensis 33, 38
Allomorphina paleocenica 38
subtriangularis 38
velascoensis 38
Alveolinellidae 37
Ammobaculites bergquisti 48
Ammobaculoides plummerae 48
Amphistegina lopeztrigoi 30
pinarensis cosdeni 19, 24
Amphisteginidae 17, 24, 30, 33
Angulogerina byramensis 17
cooperensis 30
ocalana 23
vicksburgensis 17, 30
Anomalina acuta 33, 38
bilateralis 17, 31
clementiana 45
henbesti 45
midwayensis 36, 38
pinguis 45
pseudopapillosa 44, 45
umbonifera 33, 38
Anomalinidae 17, 24, 31, 33, 38, 45, 46
Applin, P. L. and E. R. 2, 8
Appling County 9, 25
Archaias floridanus 10
Argyrotheca wegemanni 19
Asterigerina lisbonensis 28, 30
subacuta 17
subacuta floridensis 13, 17
texana - see A. lisbonensis
Asterocyclina georgiana 19, 24
monticellensis 28, 31
nassauensis 19, 24
Atkinson County 25
Atkinson Formation 47
Atlantic Embayment of Georgia 55
Austin age, beds of 41, 44, 46
Avon Park Limestone 25

B

Baggina xenoula 17
Barnwell Formation 18, 25
Bashi Marl Member 32
Beaufort County (S. C.) 10, 13
Bleckley County 10, 18, 19, 25
Blufftown Formation 41
Boldia madrugaensis 38
Bolivina broussardi 30
gracilis 30
jacksonensis 23
jacksonensis striatella 23
midwayensis 37
Bolivinoides decorata 44, 46
Borelis gunteri 37
Brantley County 10, 32
Brooks County 13, 19
Bryan County 32, 36, 51
Buhrstone 28
Bulimina aspera 45
cacumenata 37
jacksonensis 19, 23
kugleri 37
quadrata 37
Buliminella carseyae var. 45
elegantissima 23
robertsi 28, 30
Buliminidae 17, 23, 30, 37, 45, 46
Bulloch County 19
Burke County 10, 18, 25

C

Camden County 9, 10, 13, 25, 32, 36
Camerina dia 13, 16
striatoreticulata 19, 23
Camerinidae 16, 23, 37
Cancris sagra 17
vicksburgensis 17, 23
Candler County 19
Cassidulina globosa 24, 31
subglobosa 24
twiggsana 24
winniana 31
Cassidulinidae 17, 24, 31, 33, 38, 45
Cedar Keys Limestone 36
Ceratobulimina cretacea 45
Charlton County 10, 13, 32
Charlton Formation 10
Chatham County 10, 13, 25, 32
Chattahoochee County 44, 51
Chilostomella ovoidea 38
Chilostomellidae 17, 38, 45
Chilostomelloides eocenica 38
Cibicides 2
Cibicides alleni 38
americanus 17, 24
americanus antiquus 17, 24, 31
blanpiedi 28, 31, 33
danvillensis 24, 31
harperi 44, 45
hazzardi 17
howelli 33, 38
lobatulus 17, 24, 31
mauricensis 31
mississippiensis 17, 24, 31
mississippiensis ocalanus 19, 24
newmanae 38
ouachataensis 24
pippeni stavensis 28, 31
praecursorius 33
pseudoungerianus 17, 24
pseudoungerianus lisbonensis 28, 31

pseudowuellerstorfi 31
cf. C. refulgens 17
tallahattensis 28, 31
westi 28, 31
Cibicidina - See Cibicides
Citharina recta 48
Clavulinoides midwayensis 37
trilatera 46
trilatera concava 46
Clay County 32, 57
Clayton Formation 36
Clinch County 19, 25, 32, 36
Coffee County 25, 55
Cole, W. S. 8
Colquitt County 10, 55
Columbia County 18, 47
Cook Mountain Formation 25
Cooper Marl 18, 19, 66
Coskinolina floridana 18, 29
Cribrobulimina cushmani 29
Crisp County 10, 25, 57
Cusseta Sand 41

D

Decatur County 10, 19
Dentalina alternata 45, 46
basiplanata 45
cocoaensis 22
colei 37
cooperensis 22
gardnerae 37
gracilis 45, 46
jacksonensis 22, 29
legumen 45
lorneiana 46
wilcoxensis 37
Dictyoconus americanus 29
cookei 18
floridanus 18
Discocyclina - See Asterocyclina
Discocyclinidae 24, 31, 33, 28
Discorbis 2
Discorbis alabamensis 17
alveata 17, 23
assulata 17, 23, 30
byramensis 17
cocoaensis 23
georgiana 30
globulo-spinosa 23
hemisphaerica 17
inornatus 28, 30
midwayensis soldadoensis 38
midwayensis trinitatensis 36, 38
subaraucana 17, 23
tallahattensis 30
tentoria 17
yeguaensis 30
Discorinopsis gunteri 18
Dodge County 13

Dooly County 18, 25
Dorothia bulletta 46
Dougherty County 28, 32
Duplin Marl 10

E

Eagle Ford Formation 47
Early County 9
Echols County 9, 19, 25, 32, 36
Effingham County 10, 25
Elphidium leonensis 16
texanum 16, 29
twiggsanum 23
Elphidoides americanus 23
Emanuel County 18, 19, 25
Epistomina caracolla 2, 44, 45
Eponides byramensis 17
carolinensis 19, 23
cocoaensis 19, 23, 30
dorfi 32, 33
haidingerii 45
jacksonensis 23
lotus 36, 38
mexicanus 30
plummerae 38
Eutaw Formation 41

F

Faults
Clay County 55
Crisp County 55
Flint River Formation 13, 66
Frondicularia barlowensis 48
inversa 45, 46

G

Gaudryina barlowensis 48
jacksonensis 19, 22
pyramidata 37
rudita 44, 45, 46
Globigerina cretacea 45, 46, 48
Globigerinidae 45, 46, 48
Globorotalia cocoaensis 24, 31
crassata aequa 38
cf. G. membranacea 38
micheliniana 46
velascoensis 38
wilcoxensis 32, 33
Globorotaliidae 24, 31, 33, 38, 45, 46
Globotruncana arca 44, 46
cretacea 45
fornicata 46
Globulina gibba 22, 37
gibba globosa 22,
lacrima 45, 46
Glynn County 9, 10, 25, 32, 36
Gosport Sand 25, 66
Grady County 10, 19, 55

Guembelina globosa 44, 45
midwayensis 37
striata 45, 46
Gulf Trough of Georgia 55
Guttulina adhaerens 45
irregularis 22, 29
problema 37
spicaeformis 22, 29
Gypsina globula 17, 24
vesicularis 24
Gyroidina aequilateralis 38
crystalriverensis 23
depressa 45, 46
nassauensis 23, 30
soldanii octocamerata 23, 30
springfieldensis 23
subangulata 38

H

Hancock County 18
Hantkenina alabamensis 19, 24
longispina 31
Hantkeninidae 24, 31
Haplophragmoides advenus 48
langsdalensis 48
Hatchetigbee Formation 32
Hawthorn Formation 10
Helicostegina gyralis 32, 33
Heterohelicidae 37, 45, 46
Heterostegina ocalana 23
Hoglundina caracolla - See Epistomina caracolla
Houston County 9, 18, 19, 25, 51

I

Inglis Limestone 18
Irwin County 55

J

Jefferson County 18
Jenkins County 19, 25
Johnson County 18, 19

K

Kyphopyxa christneri 44, 46

L

Lagena acuticosta 22, 29
hispida 46
Lagenidae 16, 22, 29, 32, 37, 45, 46, 48
Lake City Limestone 25
Laurens County 9, 10, 19, 25
Lawson Limestone 41
Lee County 28
Lepidocyclina antillea 18, 28, 31
chaperi 24
mantelli 16, 17
ocalana 19, 24
Liberty County 9, 25, 36
Lingulina ocalana 19, 22
Lisbon Formation 25, 66
Lituolidae 45, 48
Lowndes County 13, 19
Loxostoma plaitum 44, 45

M

Macon County 32
Marginulina austiniana 46
cocoaensis 19, 22, 29
cretacea 46
dorsata 46
fragaria texasensis 22
silicula 46
sublituus 22
texasensis 45
vacavillensis 29
McBean Formation 25
McDuffie County 18, 47
McIntosh County 32
Miliolidae 16, 29
Mississippina monsouri 19, 23
Mitchell County 10, 19, 25
Montgomery County 25
Moodys Marl Member 66

N

Nanafalia Formation 32
Navarro age, beds of 41, 44, 45
Neoconorbina - See Discorbis
Neorotalia mecatepecensis - See Rotalia mexicana var.
Nodosaria affinis 37, 45, 46
fissicostata 22
latejugata 37
latejugata carolinensis 22
latejugata var. 29
obscura 46
Nonion advena 16, 22, 29
alabamense 16
chapapotense 22
inexcavatus 16, 22, 29
micrus 22, 29
planatus 23, 29
Nonionella austiniana 46
cretacea 46
hantkeni byramensis 16
hantkeni spissa 19, 23, 29
oligocenica 16
Nonionidae 16, 22, 29, 46

O

Ocala Limestone 18, 19, 25, 66
Oldsmar Limestone 32
Operculina mariannensis 19, 23
Operculinoides catenula 36, 37
floridensis 19, 23

Orbitoididae 17, 24, 31
Osangularia - See Parrella
Ostrea sellaeformis zone 25
Owen, Vaux, Jr., 2

P

Palmula reticulata 45
Parella expansa 36, 38
Patellina advena 30
Pierce County 10
Placopsilina langsdalensis 48
Placopsilinidae 48
Planorbulinidae 17, 24
Planularia georgiana 22, 29
truncana 19, 22
Planulina austiniana 46
cocoaensis 24
cocoaensis cooperensis 24
correcta 45
taylorensis 44, 46
texana 44, 46
Polymorphina advena nuda 29
cushmani 37
Polymorphinidae 16, 22, 29, 37, 45, 46
Providence Sand 41
Pseudoclavulina amorpha 45
clavata 45
Pseudoglandulina manifesta 37
Pseudophragmina cedarkeysensis 33
flintensis 19, 24
stephensoni 36, 38
Pseudopolymorphina decora 22
dumblei 22
Pulaski County 19, 25
Pullenia alazanensis 17
americana 45
coryelli 45
Pulvinulinella - See Alabamina
Pyrgo 16

Q

Quinqueloculina leonensis 13, 16

R

Reussella byramensis 17
eocena 23
oligocenica 17
sculptilis 23
subrotundata 30
Richmond County 9, 25
Ripley Formation 41
Robulus alabamensis 37
alato-limbatus 22, 29
arcuato-striatus 16
arcuato-striatus carolinianus 22
articulatus 16
articulatus texanus 22
cultratus 16
degolyeri 37
inornatus 29, 32
limbosus hockleyensis 22
midwayensis 36, 37
muensteri 44, 46
navarroensis 45
pondi 45
pseudo-costatus 37
pseudo-mamilligerus 37
cf. R. rosettus 37
spisso-costatus 44, 45
stephensoni 44, 46
turbinatus 37
wilcoxensis 32, 37
Rosalina - See Discorbis
Rotalia beccarii var. 10
bryamensis var. 13, 17
havenensis 38
mexicana mecatepecensis 2, 13, 15, 17
Rotaliidae 17, 23, 30, 33, 38, 45, 46, 48
Rotorbinella - See Discorbis

S

Sandersville Limestone Member 18, 66
Saracenaria moresiana 22
Schley County 32
Screven County 18, 19, 25
Seminole County 9, 25
Sigmoidella plummerae 22, 29
Sigmomorphina jacksonensis 22, 29
jacksonensis costifera 22
semitecta var. 22
soldadoensis 37
Siphonina advena 17
claibornensis 30
danvillensis 23
jacksonensis 19, 23, 30
prima 33, 38, 45
wilcoxensis 33
Spirillina vicksburgensis 30
cf. S. vivipara 30
Spiroplectammina laevis cretosa 37
mississippiensis 16
mississippiensis alabamensis 22, 29
plummerae 37
semicomplanata 37, 45
wilcoxensis 32, 37
Stensioina americana 46
Stewart County 44
Streblus mexicanus mecatepecensis - See Rotalia mexicana var.
Sumter County 25, 32
Suwannee Limestone 13, 66

T

Tallahatta Formation 25, 28
Tamesí equivalent 36
Tampa equivalent 10
Tattnall County 10
Taylor age, beds of 41, 44, 46
Taylor County 47
Telfair County 25
Terrell County 28

Textularia adalta 16, 22, 29
conica 16
cuyleri 29
dibollensis 29
dibollensis humblei 19, 22
hannai 22
hockleyensis 19, 22
plummerae 22
ripleyensis 45
subhauerii 22
tumidula 16
Textulariidae 16, 22, 29, 33, 37, 45, 48
Thomas County 19, 55
Tift County 25, 55
Tivola Tongue 18
Toombs County 10, 25
Treutlen County 25, 32
Trifarina bradyi advena 23
wilcoxensis 30
Turner County 25
Tuscahoma Formation 32, 47
Tuscaloosa Formation 41
Tuscaloosa Group 47
Twiggs Clay Member 18
Twiggs County 18, 25

U

Uvigerina cocoaensis 23
dumblei 23
gardnerae 23
glabrans 23
jacksonensis 23
topilensis 23

V

Vaginulina cretacea 46
longiforma 37
midwayana 37
suturalis 45
taylorana 46
texana 44, 46
webbervillensis 44, 45
Valvulina cushmani 29
floridana 18
martii 18
Valvulineria allomorphinoides 46
danvillensis gyroidinoides 28, 30
infrequens 46, 48
jacksonensis 19, 23
jacksonensis dentata 23
jacksonensis persimilis 30
scrobiculata 32, 33
texana 23, 30
cf. V. umbilicatula 38, 45
wilcoxensis 32, 33, 38
Valvulinidae 29, 46
Verneuilinidae 22, 37, 45, 46, 48
Virgulina dibollensis 30
mcguirti 30
tegulata 46
zetina 30

W

Warren County 18
Washington County 9, 18
Wayne County 10, 32
Webster County 32
Wilcox Group of Alabama 32
Woodbine Formation 47

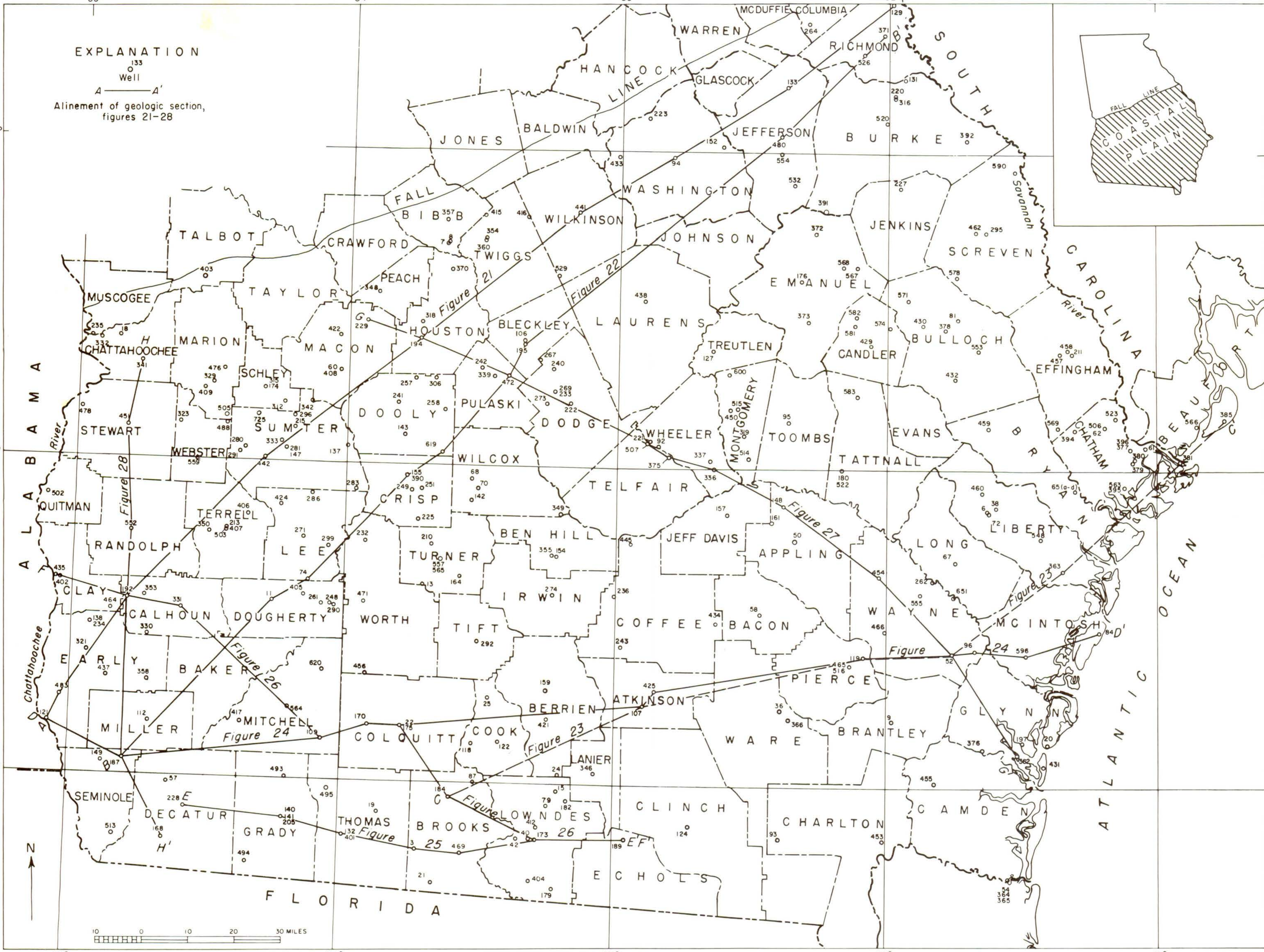

Figure 1.—Map of Coastal Plain of Georgia showing location of logged wells and geologic sections.