The Gulf Series in the Subsurface in Northern Florida and Southern Georgia

GEOLOGICAL SURVEY PROFESSIONAL PAPER 524-G

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By PAUL L. APPLIN *and* ESTHER R. APPLIN

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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Stratigraphy, structure, lithofacies, and micropaleontology of the buried rocks of the pre-Gulf surface, the Atkinson Formation, and the stratigraphic units of Austin, Taylor, and Navarro age

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THE GULF SERIES IN THE SUBSURFACE IN NORTHERN FLORIDA AND SOUTHERN GEORGIA

By Paul L. Applin and Esther R. Applin

ABSTRACT

The stratigraphy, structure, micropaleontology, lithofacies, and biofacies of the Gulf Series in the subsubsurface of an area of about 45,000 square miles in northern Florida, southern Georgia, and southeastern Alabama have been studied from the data provided by more than 150 oil test wells drilled in the area before January 1962. Microscopic examination of hundreds of cores and samples of drill cuttings from more than 100 of these wells provide the basic data for this report. Electric logs, which are available from most of the wells, aid in the correlation of the data from the samples. This report integrates data from the scattered test wells into an interpretation of the regional geology.

The surface on which the sedimentary rocks of the Gulf Series were deposited is composed of various types of metamorphic, igneous, and sedimentary rocks that range in age from Precambrian(?) or early Paleozoic to Comanche. The rocks of Comanche age are considered to be absent at the outcrop of the Cretaceous in Georgia, and the oldest strata of the Gulf Series rest unconformably on the crystalline rocks of the Piedmont along a narrow belt extending northeastward across the State. Lower Paleozoic sedimentary rocks, and igneous rocks that are probably older, are unconformably overlain by the Gulf Series in an irregularly shaped area in northeastern Florida and southeastern Georgia. In the central and southern parts of the Florida peninsula, the basal rocks of the Gulf Series rest unconformably on the carbonate-evaporite facies of the beds of Washita (Comanche) age. Except in the three areas mentioned, the Gulf Series rests unconformably on an unfossiliferous marginal clastic facies of undifferentiated Comanche rocks that are composed, in general, of red and varicolored micaceous clay and shale and poorly sorted fine- to coarse-grained argillaceous noncalcareous to slightly calcareous sandstones. A shallow-water marine facies in the upper part of the Comanche Series in a well in Franklin County, Fla., contains specimens of microfossils of Buda (Washita) age, which mark a significant environmental change from the widely distributed unfossiliferous marginal clastic facies.

The Gulf Series in the subsurface is divisible into four major stratigraphic units. The Atkinson Formation, the oldest, is a shallow-water marine deposit composed mainly of dark fossiliferous shale, medium- to fine-grained sandstone, and some interbedded lenses of limestone. The unit merges northward from southern Georgia into the unfossiliferous littoral or nonmarine beds of the outcropping Tuscaloosa Formation. The Atkinson Formation has been divided on the basis of microfossils into a lower member of Woodbine age and an upper member of Eagle Ford age. The formation, which is absent in several wells in northeastern Florida and is less than 200 feet thick in many other wells in the northern part of the peninsula, thickens gradually toward the gulf and Atlantic coasts and toward a depocenter in the west-central part of the Coastal Plain of Georgia. In this depocenter, about 900 feet of sediments of the basal unit of the Gulf Series shows clearly the interfingering of the marine sediments of the Atkinson Formation to the south with the littoral or nonmarine beds of the Tuscaloosa Formation to the north. The Tuscaloosa Formation thins northward from this depocenter toward the outcrop.

The stratigraphic unit of Austin age has been identified chiefly on the basis of the similarity of its microfauna to that of the Austin Chalk and its equivalent facies in Texas. In most wells the beds of Austin age overlie the Atkinson Formation; but in a few wells in northeastern Florida, the Atkinson Formation is absent, and the beds of Austin age rest unconformably on Lower Ordovician strata. The contact of the unit of Austin age and the underlying stratigraphic units is indicated by marked changes in the lithologic, microfaunal, and electrical characteristics of the sediments. The base of the unit of Austin age in many wells is a conglomerate about 3–5 feet thick characterized by fragmental fish bones and teeth, *Inoceramus* prisms, fragments of bivalves, and specimens of Foraminifera. For the most part the beds of Austin age are composed of moderately hard white to light-gray fine-textured chalky limestone. Lenses of white-speckled shaly chalk are common in the lower part of the unit. In marked contrast to the prevailing lithology of the unit, a distinctive chalky gypsiferous sandstone facies of the lower part of the beds of Austin age has been penetrated in 18 wells in a belt across the northern part of the peninsula.

Overlying the beds of Austin age, the unit of Taylor age has been identified chiefly on the basis of the similarity of its microfauna to that of the Taylor Group of Texas. The thickness of the beds of Austin and Taylor age, which in this report are considered as a unit, shows a rather wide range in different parts of the area. In the northern part of the Florida peninsula, the beds of Austin and Taylor age are about 700 feet thick. The units are about 400 feet thick in several wells along a trend from southeastern Georgia to north-central Florida, but they are about 1,100 feet thick in a depocenter in the west-central part of the Coastal Plain of Georgia. Two laterally intergrading facies can be differentiated in the beds of Taylor age. A carbonate facies occupies the Florida peninsula, and a lithologically variable facies, in which clastic rocks predominate, occupies north-central Florida and southern Georgia. Throughout most of the report area the beds of Taylor age are overlain by beds of Navarro age; however, in western and north-central Florida and a part of southern Georgia, the beds of Navarro age are absent, and the beds of Taylor age are unconformably overlain by clastic beds of Paleocene age whose microfauna is close to that of the Tamesí fauna (Velasco Formation) of Mexico.

The stratigraphic unit of Navarro age, which is the youngest unit of the Gulf Series, is composed of two lithologically, faunally, and geographically distinct facies that are considered to be virtually equivalent in age. Beds containing a typical Navarro fauna constitute the clastic facies of the uppermost Cretaceous in much of the Coastal Plain of Georgia. The carbonate facies of the uppermost Cretaceous, which has been named the Lawson Limestone, is present in southeastern Georgia, in the Florida peninsula, and about as far west as the Aucilla River in north-central Florida. The Lawson Limestone has been divided into a lower and an upper member, each having characteristic lithologic features and a distinctive microfauna. Both the clastic beds of Navarro age and the Lawson Limestone have been correlated with the Maestrichtian Age of Europe. The clastic beds of Navarro age were deposited in a shallow-water marine environment that received mainly terrigenous material; the Lawson Limestone was formed on a shallow partly restricted marine shelf that received almost no terrigenous debris. The two areas were separated during Navarro time by a gently upwarped southwestward-trending barrier that extended from southeastern Georgia into western Florida. Along the axis of this barrier the beds of Taylor age are the youngest Cretaceous rocks that have been penetrated in oil-test wells. The clastic beds of Navarro age thickened northward from the barrier, and the Lawson Limestone thickened southward. During the Tertiary the barrier was depressed, relative to the areas to the north and south of it, and formed a syncline.

The general southward and southeastward dip of the buried rocks of the Gulf Series in Georgia and western Florida is interrupted by the northeastward, northward, and southwestward dip of the rocks at the northern end of the Peninsular arch, the dominant subsurface structural feature of the northern part of the Florida peninsula. The syncline formed by the opposing dips is herein called the Suwannee saddle, a name substituted for the older historical name Suwannee strait. The Okefenokee, or southeast Georgia basin, and the Apalachicola, or southwest Georgia basin, seem to coincide, respectively, with the northeastern and southwestern ends of the Suwannee saddle. A structurally high area off the gulf coast in the bight of Florida is postulated on the basis of the gulfward thinning shown by the different units of the Gulf Series and by the regional structure of the units in the area adjacent to the bight.

INTRODUCTION

In 1943 the U.S. Geological Survey began, as a part of the war effort, a program of regional stratigraphic, paleontologic, and sedimentary studies of many areas that seemed to hold possibilities for oil and gas accumulation. In connection with this program, we studied the regional aspects of subsurface stratigraphy, structure, micropaleontology, and facies of the Mesozoic rocks from Florida to Mississippi. Our project has been a continuing one, and our earlier reports describe various facets of the geology of the area.

The present report deals with the subsurface geology of the Gulf Series in the Florida peninsula and the adjacent part of Georgia. At the beginning of our investigations in that area, data on the buried rocks were available from relatively few deep wells. The discovery of oil in 1943 in the Humble Oil & Refining Co. Gulf Coast Realties Corp. 1, Collier County, Fla., gave impetus to the search for oil in the peninsula and in southern Georgia. Since that time, especially during 1943–54, a wealth of significant subsurface data have been provided by the different oil companies that made available the cores and cuttings from many deep wells. The well samples and electric logs that are the basic data for this report have been released to the public.

The location of each oil test well in the report area is shown by a number on the index map (pl. 1), and data on these wells are shown in connection with corresponding numbers on plates 2–7, figures 1–4, and in tables 1–6. The Georgia Geological Survey index numbers (GGS wells on pl. 1 and others) are not shown in tables 1–6, but references to Georgia Geological Survey wells in the text and tables are made to page numbers in published articles.

The present account of the stratigraphic units of the Gulf Series updates and expands our earlier interpretations of the regional geology of these rocks. First, the rocks composing the pre-Gulf surface are described, and then the stratigraphy, lithofacies, micropaleontology, and structural features of the Gulf Series in an area of more than 45,000 square miles in northern Florida, southern Georgia, and southeastern Alabama are discussed. The major stratigraphic units of the Gulf Series are, from oldest to youngest, the Atkinson Formation, the beds of Austin age, the beds of Taylor age, and the beds of Navarro age. The area covered by our subsurface investigations is shown by the thickness maps (pls. 3, 4, 5, 6) and the structure-contour maps (pls. 2, 4, 6). As is true of most papers dealing with regional subsurface investigations, some of the interpretive data contained in this paper may be appreciably altered as a result of future drilling.

ACKNOWLEDGMENTS

Many of our friends and colleagues in the geologic profession helped in various ways to facilitate the preparation of this report and to them we express our sincere thanks and appreciation.

The excellent sets of samples from many oil test wells, which were made available to us through the courtesy of oil company geologists, provide the basic data for this report. For this indispensable service, and assistance in many other ways, we are particularly indebted to geologists who were stationed in Florida during 1944–51. Among them are Dr. Louise Jordan, Eleanor T. Caldwell, Eugene A. Murchison, Albert C. Raasch, Marion F. Kirby, Edward H. Rainwater, Henry Glenn Walter, Hilding A. Sellin, Joseph E.

Banks, Wendell L. Roberts, the late Robert B. Campbell, and the late Donald J. Munroe. We express our appreciation, also, to the following geologists in Jackson, Miss., who contributed sets of samples of wells in the report area: Emmett R. Adams, Jules Braunstein, Robert T. Violette, and Russell J. Alexander.

Our deep appreciation is expressed to Dr. Herman Gunter, former Director of the Florida State Geological Survey, to Dr. Robert O. Vernon, present Director, and to members of the Survey staff for the courtesies and assistance given us during many years.

The late Captain Garland Peyton, former Director of the Georgia Department of Mines, Mining and Geology, gave us unfailing support, as does Dr. A. S. Furcron, the present director.

We acknowledge our indebtedness to Mrs. Katherine Mather, Chief of the Petrographic Section, Concrete Research Division, Waterways Experiment Station, Jackson, Miss., installation, U.S. Army Corps of Engineers, who made the petrographic reports used in this paper and prepared the thin sections of rocks illustrated by photomicrographs.

PREVIOUS WORK

Relatively few published articles on the subsurface geology of Florida and the Coastal Plain of Georgia have presented detailed information on the rocks of the Gulf Series. Among the more significant publications dealing with the Gulf Series in the report area are those mentioned below.

Cole (1938, p. 19–48; 1942; 1944, p. 18–161; 1945, p. 77–129) reported on the stratigraphy and paleontology of five deep wells that penetrated Upper Cretaceous rocks in the northern part of Florida. The four reports cited describe, respectively, a well in Jackson County, two wells in Levy County, a well in Nassau County, and a well in Wakulla County.

Bowles (1941) published logs of oil test wells in Alabama, among which are logs of wells in Barbour County and Houston County (p. 252–268).

On the basis of data available from wells drilled before 1944, Applin and Applin (1944, p. 1708–1720) reported on the areal distribution, lithofacies, and regional structure of the stratigraphic units of the Gulf Series in Florida and the adjacent part of Georgia. E. R. Applin and Louise Jordan (1945) gave faunal lists of diagnostic Foraminifera from several subsurface formations in Florida, including the Lawson Limestone and the beds of Taylor age, both of which are units of the Gulf Series. Applin and Applin (1947) presented additional data on the facies changes, structure, and correlation of middle and lower Upper Cretaceous stratigraphic units in northern Florida and southern Georgia. P. L. Applin (1952) discussed the volume of Mesozoic sediments in Florida and Georgia, and E. R Applin (1955) described a biofacies of the lower member of the Atkinson Formation in northern Florida and southeastern Georgia.

The Southeastern Geological Society (1945, p. 57–64) published an account of the Upper Cretaceous stratigraphic units in western Florida.

Banks (1947, p. 61–64) reported on the subsurface Cretaceous units in Levy County, Fla., and adjacent areas.

The Southeastern Geological Society (1949) published a set of five stratigraphic cross sections through wells in Florida, Georgia, and southeastern Alabama showing the lithology and facies changes in the Mesozoic rocks and the occurrence of diagnostic microfossils in some of the stratigraphic units.

Vernon (1951, p. 74–84) described the stratigraphic units of the Gulf Series that were penetrated in several deep wells in Levy County, Fla.

Jordan (1952) published preliminary notes on the Mesozoic rocks in Florida; in a later article (Jordan, 1954) she discussed the oil possibilities of Florida and presented an interpretation of the subsurface stratigraphy and structure of Florida and the Coastal Plain of Georgia.

Puri and Vernon (1959, p. 16–24; 1964, p. 24–33) reviewed published data on the different units of the Gulf Series in Florida.

Hurst (1960) published a list of 113 oil test wells drilled in Georgia.

Herrick (1961) made a valuable contribution to the surface geology of the Coastal Plain of Georgia by publishing his descriptive logs of 354 wells, some of which penetrated the rocks of the Gulf Series.

Herrick and Vorhis (1963) reported on the stratigraphy, structure, and micropalentology of Cretaceous, Tertiary, and Quaternary rocks in the subsurface in the Coastal Plain of Georgia.

Hull (1962) presented an interpretation of the origin of the Suwannee strait in Georgia and Florida and explained its role as a boundary between two distinct sedimentary facies of Upper Cretaceous rocks.

At the request of the Georgia Geological Survey, E. R. Applin and P. L. Applin (1964) published descriptive logs based on the microscopic examination of samples from 31 selected wells in the Coastal Plain of Georgia.

At the request of the Florida Geological Survey, Applin and Applin (1964) contributed an article on the Cretaceous and older rocks in the subsurface in the Florida peninsula for publication in the Florida Survey's Special Publication 5, revised (Puri and Vernon, 1964).

The Comanche Series and associated rocks in the subsurface in central and south Florida were described by Applin and Applin (1965).

Chih Shan Chen (1965) discussed the lithology and thickness of the successive Paleocene and Eocene stratigraphic units in the subsurface in panhandle and peninsular Florida. These data are the basis for sets of structure maps, isopach maps, isopach-lithofacies maps, paleographic maps, and stratigraphic cross sections, chiefly of the Paleocene and Eocene units of Florida. Chih also gives his interpretation of the origin and nature of his "Suwannee Channel."

STRATIGRAPHY

ROCKS OF THE PRE-GULF SURFACE

The surface (pl. 2*A*) on which the sedimentary rocks of the Gulf Series were deposited in the northern part of the Florida peninsula and the Coastal Plain of Georgia is composed of various types of metamorphic, igneous, and sedimentary rocks that range in age from Precambrian(?) or early Paleozoic to Comanche.

The rocks of Comanche age are considered to be absent at the outcrop of the Cretaceous in Georgia (Cooke, 1936, p. 17; 1943, p. 1, 6, 8; Eargle, 1955, p. 8). On the basis of published subsurface stratigraphic data (LaMoreaux, 1946; Herrick, 1961), the Gulf Series overlies unconformably the pre-Comanche rocks in a narrow belt extending across central Georgia from the Chattahoochee River on the west to the Savannah River on the east. As the sea advanced progressively northward during the Cretaceous, the rocks of the Tuscaloosa Formation of the Gulf Series evidently overlapped the subcrop of the Comanche rocks not far downdip from the present inner margin of the Coastal Plain and were deposited on the deeply weathered surface of the crystalline rocks of the Piedmont. We suggest, as an alternative interpretation, that the Comanche rocks may, in places, extend northward to the inner margin of the Coastal Plain. Neither the outcropping Tuscaloosa Formation nor the updip subsurface clastic rocks of Comanche age in central Georgia contain marine fossils, and these units are differentiated, if at all, on a lithologic basis. As an example, the age of the Vick Formation (Conant, 1946), which crops out near Centreville, Bibb County, Ala., has been classified by different geologists as ranging from Jurassic to equivalent to the Tuscaloosa of the Gulf Series.

The Gulf Series also unconformably overlies pre-Cretaceous rocks (pl. 2*A*; tables 1, 2) in 18 wells in a fairly large irregularly shaped area in northeastern Florida and southeastern Georgia (table 2: F2–F4, Alachua County, Fla.; F5 and F6, Baker County, Fla.; F8, Bradford County, Fla.; F23, Clay County, Fla.; F36 and F38, Columbia County, Fla.; F128 and F131, Marion County, Fla.; F154, Putnam County, Fla.; F162 and F163, Suwannee County, Fla.; G8, Clinch County, Ga.; G27, Echols County, Ga.; G47 and G48, Pierce County, Ga.; location of wells shown on pl. 2*A*). Part of this area in southeastern Georgia is not clearly delimited by the available subsurface data, so that the boundary shown on plate 2*A* is provisional. The lithologic character of these pre-Cretaceous rocks and tentative determinations of their geologic age have been discussed in preliminary reports by Applin (1951) and by Bridge and Berdan (1951). The subsurface "basement" rocks in the Coastal Plain of Georgia were described by Milton and Hurst (1965).

TABLE 1.—*Well data and thickness of the Gulf Series*

[nd, not determined; ns, not studied. Source of stratigraphic and structural data: S, samples; E, electric logs]

Well (pl. 1)	Operator	Well name and No.	Date of completion	Location				Elevation (feet)	Total depth (feet)	Thickness (feet) of Gulf Series (pl. 6)	Source of data
				County	Sec.	T.	R.				
				Alabama							
A3	W. B. Hinton et al	J. S. Creel 1	Oct. 26, 1939	Barbour	14	9 N.	26 E.	504	5,546	2,120	S, E
5	H. A. Stebinger	Mrs. Alice S. Robertson 1	Mar. 14, 1939	do	19	10 N.	26 E.	554	5,215	nd	S
25	Renwar Oil Corp	H. D. Granberry 1	Mar. 2, 1956	Henry	6	4 N.	29 E.	192	6,610	1,960	S, E
26	Southeastern Operators Committee.	Mrs. Beatrice Gamble and O. A. Gamble 1.	Dec. 4, 1952	do	13	4 N.	28 E.	302	6,395	1,955	S
61	Columbia Oil Co	State Land 1	Apr. 23, 1939	Houston	8	2 N.	29 E.	200?	2,150		ns
62	Intercoastal Oil Co	McNair 1	1923	do	23	3 N.	29 E.	116	2,650		ns
63	do	McNair 2	1923	do	23	3 N.	29 E.	118	3,100		ns
64	J. S. Neilson	A. L. Shell 1	Nov. 22, 1950	do	10	2 N.	29 E.	217	4,012	1,940	E
65	Rice Oil & Gas Co	Oakley Estate 1	Feb. 8, 1936	do	9	3 N.	29 E.	(1)	3,440		ns
66	do	Oakley Estate 2	Apr. 10, 1938	do	9	3 N.	29 E.	191	5,214		ns
67	J. R. Sealy	Fee 1	1927 or 1928	do	23	1 N.	27 E.	(1)	2,900 or 3,100		ns
27	Union Producing Co	E. P. Kirkland 1	July 15, 1949	do	20	7 N.	11 W.	140	8,100	1,730	S, E
68	R. W. Williams	T. H. Whitfield 1	June 5, 1953	do	18	3 N.	26 E.	270	6,008	1,880	E

See footnotes at end of table.

TABLE 1.—*Well data and thickness of the Gulf Series*—Continued

Well (pl. 1)	Operator	Well name and No.	Date of completion	Location				Elevation (feet)	Total depth (feet)	Thickness (feet) of Gulf Series (pl. 6)	Source of data
				County	Sec.	T.	R.				
				Florida							
F1	The Texas Co.	A. M. Creighton 1	Aug. 27, 1955	Alachua	16	11 S.	19 E.	77	3,527	1,370	S, E
2	Tidewater Associated Oil Co.	R. H. Cat 1	Feb. 14, 1947	do	23	8 S.	18 E.	112	3,150	1,215	E
3	do	Josie Parker 1	May 11, 1947	do	33	7 S.	19 E.	168	3,220	1,220	S, E
4	do	J. A. Phifer Estate 1	Apr. 2, 1947	do	24	9 S.	21 E.	132	3,228	1,202	S, E
5	Hunt Oil Co.	H. L. Hunt 1	June 1, 1947	Baker	21	1 N.	20 E.	134	3,349	1,212	S, E
6	National Turpentine & Pulpwood Co.	Fee 1	June 28, 1950	do	7	4 S.	19 E.	155	3,043	1,189	S, E
8	Tidewater Associated Oil Co.	M. F. Wiggins 1	Jan. 5, 1947	Bradford	15	6 S.	20 E.	142	3,167	1,130	S, E
9	D. E. L. Byers	Hardaway Construction Co. 1	Oct. 21, 1947	Calhoun	31	2 N.	9 W.	225	4,876	1,548	S, E
10	Pure Oil Co.	International Paper Co. 1	Aug. 19, 1945	do	25	1 N.	11 W.	127	3,460	[2]	S, E
11	do	International Paper Co. 2	Sept. 25, 1945	do	31	1 S.	10 W.	107	5,096	1,610	S, E
12	do	International Paper Co. 3	Nov. 20, 1945	do	5	1 S.	10 W.	160	3,040	[2]	E
13	do	St. Andrews Bay Properties Co. 1	July 21, 1945	do	2	1 S.	11 W.	197	3,580	[2]	E
14	do	St. Andrews Bay Properties Co. 2	Oct. 25, 1945	do	25	1 N.	11 W.	186	4,457	1,610	S, E
15	Sun Oil Co	E. L. Jordan et al 1	Feb. 12, 1953	do	36	1 N.	11 W.	160	5,002	1,570	E
16	do	E. L. Jordan et al 2	Jan. 20, 1954	do	32	1 N.	11 W.	159	4,611		ns
17	A. R. Temple and A. W. Williams Inspection Co.	International Paper Co. 1	July 31, 1954	do	16	2 S.	10 W.	84	4,680		ns
18	do	International Paper Co. 3	Dec. 22, 1954	do	32	1 S.	10 W.	90	4,520		ns
19	do	Neal Lumber and Manufacturing Co. 1A.	Sept. 2, 1953	do	33	1 N.	10 W.	152	4,600	nd	E
20	A. W. Williams Drilling Co., Inc.	E. L. Jordan et al 1	Dec. 6, 1957	do	12	1 S.	11 W.	102	4,650		ns
23	Humble Oil & Refining Co.	Foremost Properties Corp. 1	Aug. 12, 1947	Clay	4	6 S.	25 E.	115	5,862	1,235?	S, E
34	Gulf Oil Corp.	Kie Vining 1	May 9, 1950	Columbia	2	4 S.	15 E.	117	3,470	1,470	S, E
35	Humble Oil & Refining Co.	J. P. Cone 1	July 14, 1948	do	22	1 N.	17 E.	141	4,444	1,487	S, E
36	Sun Oil Co.	Ruth M. Bishop 1	Aug. 24, 1949	do	10	4 S.	17 E.	174	2,828	1,003	S, E
37	do	W. F. Johnson 1	May 31, 1949	do	27	4 S.	16 E.	87	3,051	1,330	S, E
38	do	Clarence Loyd 1	July 4, 1949	do	11	5 S.	17 E.	124	2,929	1,152	S, E
39	do	M. W. Sapp 1A	Nov. 16, 1948	do	24	2 S.	16 E.	138	3,311	1,440	S, E
49	Florida Oil Development Co.	Putnam Lumber Co. 1	1942	Dixie	7	11 S.	12 E.	25	4,780	nd	S, E
50	Stanolind Oil & Gas Co. and Sun Oil Co.	Perpetual Forest, Inc. 1	Aug. 8, 1946	do	5	11 S.	11 E.	33	7,510	1,900	S, E
51	Sun Oil Co.	P. C. Crapps A1	Mar. 6, 1949	do	36	8 S.	10 E.	41	5,104	1,822	S, E
52	do	Hazel Langston 1	Nov. 10, 1946	do	8	8 S.	14 E.	33	3,671	1,529	S, E
54	Humble Oil & Refining Co.	J. W. Campbell 1	Feb. 26, 1947	Flagler	8	11 S.	28 E.	31	4,633	1,903	S, E
55	California Co. and Coastal Petroleum Co.	State of Florida, Lease 224A 1	Nov. 6, 1959	Franklin	7	9 S.	5 W.	26	7,031	1,505	E
174	do	State of Florida, Lease 224A 2	Jan. 7, 1961	do	(*)	(*)	(*)	34	10,560	1,260	S, E
56	Humble Oil & Refining Co.	A. S. Mitchell et al. 1	Feb. 13, 1953	do	21	6 S.	5 W.	20	4,736	1,470	E
57	Magnolia Petroleum Co.	State of Florida Block 5B 1A	Aug. 4, 1947	do	23?	9 S.	9 W.	11	7,021	1,780	S, E
58	Pure Oil Co.	Gex-Lewin 3	Sept. 30, 1946	do	3	8 S.	6 W.	15	5,060	1,555	S, E
59	do	H. C. Lister 1	Apr. 17, 1946	do	17	7 S.	7 W.	28	4.976	1,645	S, E
60	do	St. Joe Paper Co. 2	Aug. 14, 1946	do	34	6 S.	4 W.	21	4,787	1,460	S, E
61	A. R. Temple and others	A. S. Mitchell et al. 1	Nov. 13, 1953	do	14	7 S.	5 W.	18	4,819	1,480	E
62	Havana Syndicate, Inc	A. M. Butler (formerly H. H. Swisher) 1.	Mar. 15, 1947	Gadsden	30	3 N.	1 W.	234	4,010	nd	E
63	D. E. Hughes	Clara McDonald 1	Aug. 16, 1948	do	7	2 N.	5 W.	296	4,223	1,430	S, E
64	P. S. Oles and J. W. Naylor	Florida Power Corp. 1	July 23, 1948	do	35	2 N.	3 W.	200	4,240	1,460	S, E
65	E. R. Smith	Dr. C. K. Wall 1	May 12, 1955	do	19	2 N.	6 W.	245	4,024	1,425	E
66	Sun Oil Co.	American Sumatra Tobacco Co. 1	Feb. 15, 1959	do	23	2 N.	4 W.	221	4,186	1,440	E
67	do	Dr. C. K. Wall 1	Jan. 30, 1956	do	25	2 N.	6 W.	270	4,223	1,465	E
68	do	Alto Adams 1	Mar. 27, 1946	Gilchrist	15	9 S.	15 E.	93	3,753	1,580	S, E
69	do	Williams Bros. 1	Sept. 30, 1948	do	12	8 S.	15 E.	77	3,366	1,428	S, E
72	Pure Oil Co.	Kate Gaskins 1	Apr. 27, 1945	Gulf	19	5 S.	9 W.	43	5,606	1,800	S, E
73	do	Pick Hollinger et al. 1	Nov. 13, 1946	do	12	9 S.	11 W.	19	5,656	1,815	E
74	do	C. C. Hopkins 1	Dec. 8, 1944	do	22	6 S.	9 W.	32	8,708	1,805	S, E
75	do	C. C. Hopkins 2	Mar. 7, 1945	do	21	6 S.	9 W.	33	7,255	1,800	E
76	do	E. L. McMillan and Ed Leigh 1	Feb. 1, 1947	do	25	4 S.	11 W.	49	5,069	1,815	E
77	do	St. Joe Paper Co. 1	June 11, 1945	do	10	7 S.	9 W.	21	5,796	1,740	E
78	do	St. Joe Paper Co. 3	Jan. 2, 1947	do	3	6 S.	11 W.	25	5,025	nd	E
177	A. R. Temple and A. W. Williams Inspection Co.	Mary E. Lister 1	June 20, 1954	do	33	5 S.	9 W.	30	4,996	1,810	E
85	The Ohio Oil Co.	Hernasco Corp. 1	June 23, 1946	Hernando	19	23 S.	18 E.	47	8,472	2,290	S, E
90	Mrs. Mamie Hammonds	Granberry 1	July 14, 1936	Jackson	15	5 N.	9 W.	124	5,022	1,580	S
91	Humble Oil & Refining Co.	W. C. Tindel 1	Mar. 14, 1949	do	8	5 N.	11 W.	128	9,245	1,613	S, E
92	I. P. and Fred La Rue	L. A. Spencer 1	Jan. 4, 1953	do	30	4 N.	8 W.	142	4,120	1,470	E
93	Sun Oil Co.	McRae Land and Timber Co. 1	Feb. 17, 1953	do	12	6 N.	11 W.	138	3,823	1,655	E
94	do	McRae Land and Timber Co. 2	Jan. 7, 1954	do	9	6 N.	11 W.	134	3,819	1,630	E
95	do	McRae Land and Timber Co. 3	Jan. 15, 1955	do	25	6 N.	11 W.	118	3,660	1,570	E
96	Thompson Exploration Drilling Co.	B. K. Shivers 1	July 16, 1955	do	11	5 N.	8 W.	95	3,456	1,490	E
97	do	J. J. Still 1	July 13, 1955	do	13	5 N.	13 W.	136	3,920	1,620	E
98	Coastal Petroleum Co.	E. P. Larsh 1	Jan. 7, 1949	Jefferson	1	2 S.	3 E.	52	7,913	1,315	S, E
99	Southern States Oil Corp.	Miller and Gossard 1	May 11, 1928	do	17	2 N.	5 E.	230	3,838	744	S
100	Coastal Petroleum Co.	Ronald Sapp 1	Mar. 19, 1949	Lafayette	18	6 S.	14 E.	45	3,507	1,594	S, E
101	Gulf Oil Corp.	Brook-Scanlon, Inc. Block 49 1	Oct. 5, 1949	do	36	5 S.	10 E.	87	4,512	1,851	S, E
102	Humble Oil & Refining Co.	R. L. Henderson 1	Feb. 19, 1948	do	20	4 S.	11 E.	52	4,235	1,735	S, E
103	Sun Oil Co.	P. C. Crapps et al. 1	Jan. 26, 1946	do	25	6 S.	12 E.	70	4,133	1,757	S, E
104	Oil Development Co. of Florida	J. Ray Arnold (South Lake well) 2.	Feb. —, 1937	Lake	17	24 S.	25 E.	120	6,120	2,022	S, E
110	Central Florida Oil and Gas Co.	Rhodes 1	Feb. ?, 1924	Leon	11	2 S.	1 E.	50	3,755	nd	S
111	Stanolind Oil & Gas Co.	St. Joe Paper Co. 1A	Nov. 18, 1944	do	15	2 S.	2 E.	41	6,520	1,400	S, E
112	Coastal Petroleum Co.	J. B. and J. P. Ragland 1	Oct. 18, 1947	Levy	16	15 S.	13 E.	14	5,850	2,082	S, E
113	Florida Oil Discovery Co.	Sholtz 2	1939	do	9	15 S.	13 E.	9	5,266	2,030	S, E
114	Humble Oil & Refining Co.	C. E. Robinson 1	Aug. 20, 1949	do	19	16 S.	17 E.	58	4,609	1,890	S, E
115	Sphinx Syndicate	Prudential Timber Co. 1	Aug. 17, 1954	do	31	13 S.	16 E.	26	3,857		ns
116	Sun Oil Co.	J. T. Goethe 1	June 8, 1946	do	31	14 S.	17 E.	34	3,997	1,704	S, E
117	Suwannee Petroleum Corp.	Sholtz 1	June 1, 1929	do	9	15 S.	13 E.	18	4,010	nd	S
118	R. T. Adams Drilling Co.	St. Joe Paper Co. 1	Aug. 4, 1948	Liberty	6	1 S.	6 W.	188	4,268	1,435	S, E
119	Gulf Coast Drilling & Exploration Co.	U.S.A. 1	Apr. 6, 1959	do	4	5 S.	7 W.	49	10,011	1,670	S, E
120	Pure Oil Co.	Gex-Lewin 1	May 29, 1946	do	24	5 S.	6 W.	25	4,745	1,515	S, E

See footnotes at end of table.

TABLE 1.—*Well data and thickness of the Gulf Series*—Continued

Well (pl. 1)	Operator	Well name and No.	Date of completion	Location: County	Sec.	T.	R.	Elevation (feet)	Total depth (feet)	Thickness (feet) of Gulf Series (pl. 6)	Source of data
				Florida—Continued							
F121	Pure Oil Co	Neal Lumber & Manufacturing Co. 1.	Feb. 21, 1946	Liberty	33	2 S.	8 W.	69	4,507	1,625	S, E
122	Sun Oil Co	St. Joseph Land & Development Co. 1.	July 23, 1956	do	14	1 N.	6 W.	206	4,119	1,440	E
123	Hunt Oil Co	J. W. Gibson 1	1943	Madison	16	1 S.	11 E.	91	3,380	(2)	E
124	do	J. W. Gibson 2	May 31, 1944	do	6	1 S.	10 E.	107	5,385	1,470	S, E
125	do	J. W. Gibson 3	Nov. ?, 1944	do	18	2 S.	11 E.	89	3,667	1,415	E
126	do	J. W. Gibson 4	May 18, 1945	do	5	2 S.	11 E.	73	4,096	1,425	S, E
128	J. S. Cosden, Inc	W. L. Lawson 1	Mar. 13, 1928	Marion	25	13 S.	20 E.	195	4,334	1,565?	S
129	Ocala Oil Corp	"York well" 1	July ?, 1928	do	10	16 S.	20 E.	79	6,180	(1)	
130	Sun Oil Co	Henry N. Camp 1	May 20, 1947	do	16	16 S.	23 E.	74	4,637	1,582	S, E
131	do	H. T. Parker 1	Apr. 23, 1949	do	24	14 S.	22 E.	79	3,845	1,379	S, E
143	St. Marys River Oil Corp	Hilliard Turpentine Co. 1	Jan. ?, 1940	Nassau	19	4 N.	24 E.	110	4,824	1,807	S
145	Warren Petroleum Corp	George Terry 1	Sept. 13, 1955	Orange	21	23 S.	31 E.	100	6,589	2,113	S, E
154	Sun Oil Co. and Seaboard Oil Co.	Q. I. Roberts 1A	July 23, 1947	Putnam	19	9 S.	25 E.	206	3,328	1,120?	S, E
155	Sun Oil Co	H. E. Westbury et al. 1	Jan. 16, 1947	do	37	11 S.	26 E.	32	3,892	1,610	S, E
159	Field & Randall Drilling Co	G. D. Crawley 1	Sept. 10, 1950	Suwannee	6	2 S.	13 E.	118	3,840	1,470+	S, E
160	Humble Oil & Refining Co	Squire Taylor 1	Dec. 10, 1952	do	25	3 S.	13 E.	110	3,684	1,705	E
161	J. L. McCord	J. M. Starling 1B	Nov. 5, 1948	do	28	3 S.	12 E.	90	3,819	1,730	S, E
162	Sun Oil Co	Earl Odom et al. 1	Jan. 4, 1947	do	31	5 S.	15 E.	73	3,157	1,475	S, E
163	do	A. B. Russell 1	July 31, 1949	do	8	5 S.	15 E.	96	3,139	1,516	S, E
164	do	J. H. Tillis 1	Sept. 1, 1947	do	28	2 S.	15 E.	162	3,571	1,552	S, E
165	Gulf Oil Corp	Brooks-Scanlon, Inc. Block 33 1	Jan. 4, 1950	Taylor	18	4 S.	9 E.	96	5,243	1,625	S, E
166	do	Brooks-Scanlon, Inc. Block 37 1A	Apr. 5, 1950	do	18?	6 S.	9 E.	67	4,877	1,393	S, E
167	do	Brooks-Scanlon, Inc. Block 42 1	July 1, 1949	do	9	8 S.	9 E.	41	5,517	1,720	S, E
168	Humble Oil & Refining Co	G. H. Hodges 1	Oct. 28, 1948	do	12	5 S.	6 E.	36	6,254	1,650	S, E
169	Grace Drilling Co	Retail Lumber Co. 1	Jan. 30, 1949	Volusia	2	15 S.	30 E.	44	5,424	2,285	S, E
170	Sun Oil Co	Powell Land Co. 1	Sept. 14, 1946	do	11	17 S.	31 E.	48	5,958	2,239	S, E
171	Ravlin and Brown	V. G. Phillips 1	Mar. 26, 1943	Wakulla	14	3 S.	1 E.	28	5,766	1,500	S, E

Well (pl. 1)	Operator	Well name and No.	Date of completion	Location: County	Land district	Land lot	Elevation (feet)	Total depth (feet)	Thickness (feet) of Gulf Series (pl. 6)	Source of data
				Georgia						
G1	Felsenthal and Weatherford	Mrs. W. E. Bradley 1	July 30, 1947	Appling	2	522	229	4,106	nd	S, E
2	Sun Oil Co	Doster-Ladson 1	Jan. 31, 1945	Atkinson	7	71	222	4,296	2,066	S, E
86	Humble Oil & Refining Co	W. F. Hellman ST-1	Mar. 20, 1961	Brantley	2	95	52	4,512		ns
3	D. E. Hughes	E. M. Rogers 1B	Apr. 12, 1949	Brooks	12	454	136	3,850	1,390	S, E
4	Three Creeks Oil Co	2	1921 or 1923	Burke	(*)	(*)	(1)	1,033	(1)	Herrick (1961, p. 52-53).
5	Sowega Minerals, Inc	J. W. West 1	Jan. 13, 1950	Calhoun	4	328	345	5,265	2,360	S, E
6	The California Co	J. A. Buie 1	Mar. 26, 1948	Camden	(*)	(*)	65	4,955	1,983?	S, E
7	Wiley P. Ballard, Jr	Timber Products Co. 1B	Feb. 8, 1956	Clinch	7	306	215	4,232	1,450	S, E
8	Grace Drilling Co. or G. J. Marott.	Lem Griffis 1	Jan. 24, 1953	do	13	36	176	4,588	1,053?	S, E
9	H. L. Hunt	Alice Musgrove 1	Jan. 18, 1944	do	12	198	147	4,088	1,005	S, E
10	do	Alice Musgrove 2	June 30, 1944	do	12	523	171	3,513	(2)	E
11	Sun Oil Co	W. J. Barlow 1	Mar. 5, 1947	do	12	373	177	3,848	934	S, E
12	Carpenter Oil Co	J. H. Knight 1	May 12, 1956	Coffee	1	144	(1)	4,151	nd	S, E
13	do	C. T. Thurman 1	Sept. 21, 1955	do	1	189	317	4,130	nd	S, E
13a	do	C. T. Thurman 2	May 1, 1956	do	1	189	308	3,550	(2)	S, E
13b	do	W. D. Wall 1	May 24, 1956	do	1	86	(1)	2,734	(2)	S
14	R. T. Adams	D. G. Arrington 1	Aug. 25, 1948	Colquitt	8	270	270	4,904	1,830	S, E
15	Kerr-McGee Oil Industries	Cecil Pate 1	Feb. 21, 1946	Crisp	13	144	364	5,010	2,150	S, E
16	Calvary Development Co	J. W. Scott 1	June 16, 1950	Decatur	22	25	276	4,195	1,450	E
17	D. E. Hughes	H. W. Martin 1	Dec. 15, 1947	do	15	189	132	3,717	1,780	S, E
18	Hunt Oil Co	Metcalf 1	Aug. 19, 1944	do	21	260	104	6,152	1,550	S, E
19	Renwar Oil Co	G. E. Dollar 1	(1)	do	15	111	129	4,995	1,790	E
20	J. R. Sealy	Fee 1	Apr. 17, 1953	do	21	247	78	3,005		ns
21	Merica Oil Co	B. F. Hill 1	July 4, 1954	Dooly	1	74	371?	2,317		ns
73	Georgia-Florida Oil Co	H. E. Walton 1	June 3, 1960	do	6	163	446	3,748	2,125	Herrick (1961, p. 167-169).
22	J. R. Sealy et al	Reynolds Bros. 1	Mar. 24, 1942	Dougherty	2	116	209	5,013	2,439	S, E
23	do	Reynolds Bros. 2	June 17, 1942	do	2	374	192	5,310	2,410	S, E
24	Mont Warren et al	A. C. Chandler 1	Oct. 2, 1943	Early	26	406	187	7,320	1,940	S, E
25	Humble Oil & Refining Co	Bennett and Langsdale 1	May 6, 1949	Echols	12	146	181	4,185	950	S, E
26	Hunt Oil Co	Superior Pine Products Co. 1	Oct. 10, 1944	do	13	364	148	3,865	1,045	E
27	do	Superior Pine Products Co. 2.	Apr. 7, 1945	do	13	317	142	4,062	1,030	S, E
28	do	Superior Pine Products Co. 3.	July 29, 1947	do	13	532	144	4,003	1,035	S, E
29	do	Superior Pine Products Co. 4.	Mar. 16, 1948	do	13	219	156	3,916	1,019	S, E
30	Beddingfield-Lewis-Fallin	J. J. and Perry Kennedy 1	Nov. 11, 1948	Emanuel	(*)	(*)	(1)	1,780		ns
31	Georgia Oil Co	(1)	1932	do	(*)	(*)	(1)	2,232 or 2,332		Richards (1945, p. 926).
79	City of Gibson, Ga	Water well	(1)	Glascock	(*)	(*)	355	176	nd	Le Grand and Furcron (1956, p. 69, 71).
87	Humble Oil & Refining Co	W. C. McDonald ST-1	Apr. 24, 1961	Glynn	(*)	(*)	25	4,737		ns
88	do	Union Bag-Camp Paper Corp. ST-1.	May 28, 1961	do	(*)	(*)	24	4,632		ns
32	E. B. La Rue, et al	R. H. Massey 1	Oct. 25, 1953	do	(*)	(*)	20	4,615	nd	S, E

See footnotes at end of table.

TABLE 1.—*Well data and thickness of the Gulf Series*—Continued

Well (pl. 1)	Operator	Well name and No.	Date of completion	Location			Elevation (feet)	Total depth (feet)	Thickness (feet) of Gulf Series (pl. 6)	Source of data
				County	Land district	Land lot				
				Georgia—Continued						
G33	Tricon Minerals	J. D. Duke 1	Sept. 7, 1949	Houston	14	44	419	1,494		ns
34	do	H. B. Gilbert 1	Sept. 25, 1949	do	13	266	367	1,698	1,350	Herrick (1961, p. 227–228).
36	Hinson Oil, Gas & Development Co.	(1)	1908	Jeff Davis	(*)	(*)	(1)	985		Prettyman and Cave (1923, p. 57).
37	Middle Georgia Oil & Gas Co.	Lillian B. 2	1920	do	(*)	(*)	225	1,975	nd	Prettyman and Cave (1923, p. 57, 102, 124).
38	Captain A. F. Lucas and Georgia Petroleum Oil Co.	(1)	1907	Jefferson	(*)	(*)	(1)	1,143	nd	Prettyman and Cave (1923, p. 56); Le Grand and Furcron (1956, p. 76). In crystalline rocks at total depth.
39	Calaphor Manufacturing Co.	Grace McCain 1	July 10, 1945	Laurens	(*)	(*)	280	2,548	nd	S, E
40	E. B. La Rue et al	Jelks-Rogers 1	Jan. 14, 1954	Liberty	(*)	(*)	26	4,264	1,792	S, E
41	Merica Oil Co.	J. F. Forhand 1	July 24, 1954	Macon	1	182	290	2,139		ns
42	Lee Oil & Gas Co.	J. S. Burgin 1	Feb. , 1956	Marion	31	207	600±	1,764	1,570	Herrick (1961, p. 296–298).
43	Stanolind Oil & Gas Co.	J. H. Pullen 1	Aug. 14, 1944	Mitchell	10	133	338	7,487	1,950	S, E
46	J. E. Weatherford	Lonnie Wilkes 1	May 9, 1946	Montgomery	(*)	(*)	293	3,433	nd	S, E
47	W. B. Hinton	Adams-McCaskill 1	May 7, 1939	Pierce	4	332	75	4,355	1,633	S, E
48	Pan American Production Co.	do	May 13, 1938	do	4	329	80	4,376	1,610	S, E
49	Ainsworth, Inc.	E. H. Tripp 1	1954 or 1955	Pulaski	21	306	280	2,750	1,710	Herrick (1961, p. 330–333).
50	Leighton Drilling Co.	Dana 1	Apr. 26, 1957	do	12	280	290	6,035	1,210	(3).
51		Georgia Training School water well 2.	(1)	Richmond	(*)	(*)	136	1,200	305	Herrick (1961, p. 338–339).
52	Three Creeks Oil Co.	Well at Allen's Station	1921	do	(*)	(*)	(1)	400	nd	Prettyman and Cave (1923, p. 57).
53		Circular Court, water well 1.	(1)	do	(*)	(*)	136	329	162	Herrick (1961, p. 337–338).
74	G. F. A. Oil Co.	J. R. Sealy 1	(1)	Seminole	21	214	90	238		ns
76	Humble Oil & Refining Co.	do	Jan. 12, 1961	do	14	42	(1)	4,500		ns
75	J. R. Sealy	Fee 2	(1)	do	21	214	90	5,100		ns
55	do	Ruth Rambo 1	(1)	do	21	235	80	3,804		ns
54	do	Seminole Naval Stores 1	(1)	do	21	142	108	7,518 or 7,620		ns
56	Mont Warren	Grady Bell 1A	Mar. 10, 1950	do	27	61	114	3,810	1,520	S, E
57	do	W. E. Harlow Estate 1	Feb. 27, 1949	do	27	82	145	3,572	1,847	S, E
58	Heinz-Spanel	W. C. Bradley 1	(1)	Stewart	21	135	548	2,916		ns
59	Flinn-Austin Co.	Walter Stevens 1	Dec. 5, 1955	Sumter	17	210	431	5,240		ns
60	W. B. Flinn	Sullivan 1	June 29, 1956	do	17	211	(1)	2,250		ns
61	Dixie Oil Co.	Wilcox 1	Aug. 9, 1923	Telfair	10	219	240?	3,384		ns
62	Paul Parsons-Hoake	Henry Spurlin 1	Sept. 25, 1953	Telfair	7	260	241	4,008	nd	E
63	T. R. Davis	Bonny Brown 1	Oct. 26, 1947	Toombs	(*)	(*)	198	3,120 or 3,280	nd	Furcron (1949, p. 4).
64	Meadows Development Co.	(1)	1939	do	(*)	(*)	300?	1,562	nd	Richards (1945, p. 926).
65	Tropic Oil Co.	Gibson 1	June 28, 1945	do	(*)	(*)	198	3,681	nd	S, E
66	Glen Rose Oil Co.	James Fowler 1	Feb. 1, 1941	Treutlen	(*)	(*)	291	2,125	(2)	Herrick (1961, p. 408–410).
84		Frank Lawson water well	1919	Twiggs	(*)	(*)	271	1,000	nd	Lamoreaux (1946, p. 94, 98, 99, 108).
85		Sgoda Corp. water well	(1)	do	(*)	(*)	272	194	nd	Lamoreaux (1946, p. 106).
67	Layne-Atlantic	NSC water well	1945	Washington	(*)	(*)	460	872	(1)	(3).
68	Middle Georgia Oil & Gas Co.	Lillian B. 1	1920	do	(*)	(*)	(1)	400	nd	Herrick (1961, p. 428).
80		Sandersville, Ga., Public water well 51.	1944	do	(*)	(*)	465	872	605	Lamoreaux (1946, p. 121–122).
81	U.S.A. War Department	Gilmore Hutchins water well.	Sept. ?, 1942	do	(*)	(*)	270	304	nd	Lamoreaux (1946, p. 132, 138).
82	do	J. P. Veale water well	Aug. ?, 1942	do	(*)	(*)	278	178	nd	Lamoreaux (1946, p. 130, 134).
83	Layne Atlantic Well Drilling Co.	Mattie M. Veale water well	(1)	do	(*)	(*)	280	178	nd	Lamoreaux (1946, p. 118, 134).
69	The California Co.	Brunswick Peninsula Corp. 1.	Dec. 17, 1944	Wayne	(*)	7	73	4,626	1,600	S, E
70	Humble Oil & Refining Co.	Union Bag-Camp Paper Corp. 1	Nov. 20, 1960	do	(*)	54	65	4,553	nd	S
71	T. R. Davis & Dixie Drilling Co.	C. W. Jordan Heirs 1	June 22, 1956	Wheeler	7	486	195	4,082	(2)	Herrick (1961, p. 446–447).
72	Paul Parsons	C. E. Hinson 1	Oct. 28, 1953	do	10	288	206	3,630	nd	E

1 Data not available. 2 Total depth in Gulf Series. 3 Oil company scouts.

* Location:

F174. Offshore; 6 miles south of Lighthouse Point.
G4. 2.5 miles east of Greens Cut.
6. 4 miles west, 2 miles north of Tarboro, Ga.
30. North of Stevens Crossing.
31. At Graymont, Ga.
79. At Gibson, Ga.
87. Military District 1499.
88. Military District 27.
32. On Colonel's Island.
36. 8 miles southwest of Hazelhurst, Ga.
37. 12–15 miles west of Hazelhurst, Ga.
G38. 3.5 miles southwest of Louisville, Ga.
39. 0.5 mile southeast of Minter, Ga.
40. 5 miles south; 5 miles east of Riceboro, Ga.
46. 0.5 mile south of Higgston, Ga.
51. Gracewood, Ga.
52. 9 miles south of Augusta, Ga.
53. 6.5 miles south of Augusta, Ga.
63. 7 miles south and east of Lyons, Ga.
64. At Vidalia, Ga.
65. 6 miles south of Lyons, Ga.
66. 6 miles west of Soperton, Ga.
G84. Huber, Ga.
85. Huber, Ga.
67. 2 miles southwest of Tennille, Ga.
68. 12 miles northwest of Sandersville, Ga.
80. Sandersville, Ga.
81. 1.5 miles south of Deepstep, Ga.
82. 1.5 miles north of Deepstep, Ga.
83. 2.3 miles northeast of Deepstep, Ga.
69. Williams Survey.
70. Military District 333.

TABLE 2.—*Depth (in feet) and geologic age of rocks of the pre-Gulf surface and depth and thickness (in feet) of the Atkinson Formation*

[nd, not determined; np, not penetrated]

Well (pl. 1)	Elevation (feet)	Rocks of pre-Gulf surface: Geologic age (pl. 2A)	Rocks of pre-Gulf surface: Depth to top	Atkinson Formation, Lower member: Depth to top	Atkinson Formation, Lower member: Thickness (pl. 3B)	Atkinson Formation, Upper member: Depth to top	Atkinson Formation, Upper member: Thickness (pl. 3E)	Total thickness (pl. 3A)	Overlying rocks	Remarks
Alabama										
A3	504	Comanche	2,480	2,230	250	1,540	690	940	Beds of Austin age	
5	554	do	2,490	2,114	376	1,507	607	983	do	
25	192	do	2,960	2,725	235	2,140	585	820	do	
26	302	do	3,130	2,905	225	2,330	575	800	do	
64	217	do	3,230	3,000	230	2,460	540	770	do	
27	140	do	3,430	3,095	335	2,700	395	730	do	
68	270	do	3,280	3,040	240	2,500	540	780	do	
Florida										
F1	77	Comanche?	3,400	3,300	100	3,170	130	230	Beds of Austin age	
2	112	Early Ordovician	3,125	3,050	85	Absent	----	85	do	
3	168	do	3,170	3,100	70	Absent	----	70	do	
4	132	do	3,217	3,130	87	Absent	----	87	do	
5	134	do	3,342	Absent	----	Absent	----	----	do	
6	155	do	3,039	3,001	38	Absent	----	38	do	
8	142	do	3,140	3,080	60	Absent	----	60	do	
9	225	Comanche	4,078	3,800	278	3,360	440	718	do	
11	107	do	4,450	4,277	173	3,700	577	750	do	
14	186	do	4,390	4,063	327	3,610	453	780	do	
15	160	do	4,370	nd	nd	3,610	nd	760	do	
19	152	do	nd	nd	nd	3,590	nd	nd	do	
23	115	Early Ordovician	3,725	3,610?	115?	Absent	----	115?	do	
34	117	Comanche	3,180	3,150	30	3,100	50	80	do	
35	141	do	3,436	3,326	110	3,260	66	176	do	
36	174	Early Ordovician	2,813	2,780	33	Absent	----	33	do	
37	87	Comanche	3,000	2,955	45	2,935	20	65	do	
38	124	Early Ordovician	2,922	2,861	61	Absent	----	61	do	
39	138	Comanche	3,220	3,150	70	3,050	100	170	do	
49	25	do	nd	Present?	nd	3,530	nd	nd	do	
50	33	do	3,765	3,647	118	3,068	39	157	do	
51	41	do	3,602	3,548	54	3,520	28	82	do	
52	33	do	3,239	3,184	55	3,110	74	129	do	
54	31	do	4,360	4,270	90	4,180	90	180	do	
55	26	do	4,830	4,670	160	4,370	300	460	do	
174	34	do	4,410	4,290	120	4,020	270	390	do	
56	20	do	4,650	4,530	120	4,070	460	580	do	
57	11	do	5,250	5,130	120	4,730	400	520	do	
58	15	do	4,890	4,710	180	4,350	360	540	do	
59	28	do	4,880	4,675	205	4,205	470	675	do	
60	21	do	4,550	4,410	140	4,005	405	545	do	
61	18	do	4,670	4,530	140	4,125	405	545	do	
62	234?	np	----	3,670	----	3,315	265?	----	do	In lower member at total depth.
63	296	Comanche	3,990	3,710	280	3,330	380	660	do	
64	200	do	4,010	3,740	270	3,365	375	645	do	
65	245	do	3,910	3,640	270	3,240	400	670	do	
66	221	do	3,930	3,630	300	3,270	340	640	do	
67	270	do	4,040	3,770	270	3,360	410	680	do	
68	93	do	3,360	3,299	61	3,198	101	162	do	
69	77	do	3,208	3,168	40	2,997	171	211	do	
72	43	do	4,925	4,689	236	4,090	599	835	do	
73	19	do	5,360	5,235	125	4,815	420	545	do	
74	32	do	5,015	4,775	240	4,185	590	830	do	
75	33	do	5,020	4,785	235	4,185	600	835	do	
76	49	do	4,935	4,700	235	4,115	585	820	do	
77	21	do	5,050	4,810	240	4,310	500	740	do	
78	25	nd	nd	4,820	nd	4,240	580	nd	do	In Comanche(?) rocks or lower member of Atkinson(?) Formation at total depth.
177	30	Comanche	4,960	4,720	240	4,100	620	860	do	
85	47	do	5,600	5,470	130	5,410	60	190	do	
90	124	do	3,514	3,156	358	2,781	375	733	do	
91	128	do	3,647	3,250	397	2,875	375	772	do	
92	142	do	3,600	3,230	370	2,870	360	730	do	
93	138	do	3,500	3,130	370	2,740	390	760	do	
94	134	do	3,520	3,140	380	2,765	375	755	do	
95	118	do	3,520	3,150	370	2,790	360	730	do	
96	95	do	3,340	2,990	350	2,610	380	730	do	
97	136	do	3,770	3,390	380	3,020	370	750	do	
98	52	do	3,875	3,700	175	3,400	300	475	do	
99	230	do	3,800	3,665	135	3,410	255	390	do	
100	45	do	3,214	3,165	49	3,085	80	129	do	
101	87	do	3,555	3,470	85	3,369	101	186	do	
102	52	do	3,405	3,314	91	3,236	78	169	do	
103	70	do	3,377	3,308	69	3,268	40	109	do	
104	120	do	5,402	5,322	80	5,265	57	137	do	
110	50?	np	----	Present?	----	3,465	nd	nd	do	In Atkinson Formation at total depth.
111	41	Comanche	4,010	3,790	220	3,500	290	510	do	
112	14	do	4,362	4,260	102	4,070	190	292	do	
113	9	do	4,270	4,170	100	4,000	170	270	do	
114	58	do	4,300	4,122	178	3,945	177	355	do	
116	34	do	3,894	3,830	64	3,650	180	244	do	
118	188	do	4,000	3,800	200	3,290	510	710	do	
119	49	do	4,700	4,490	210	3,980	510	720	do	
120	25	do	4,540	4,430	110	3,930	500	610	do	

See footnotes at end of table.

TABLE 2.—*Depth (in feet) and geologic age of rocks of the pre-Gulf surface and depth and thickness (in feet) of the Atkinson Formation*—Continued

Well (pl. 1)	Elevation (feet)	Rocks of pre-Gulf surface: Geologic age (pl. 2A)	Rocks of pre-Gulf surface: Depth to top	Atkinson Formation, Lower member: Depth to top	Atkinson Formation, Lower member: Thickness (pl. 3B)	Atkinson Formation, Upper member: Depth to top	Atkinson Formation, Upper member: Thickness (pl. 3E)	Atkinson Formation: Total thickness (pl. 3A)	Overlying rocks	Remarks
					Florida—Continued					
F121	69	Comanche	4,420	4,200	220	3,690	510	730	Beds of Austin age	
122	206	do	3,960	3,730	230	3,310	420	650	do	
123	91	np	--------	Present?	--------	3,150	nd	nd	do	In Atkinson Formation at total depth.
124	107	Comanche	3,580	3,400	180	3,208	192	372	do	
125	89	do	3,450	3,260	190	3,160	100	290	do	
126	73	do	3,435	3,250	185	3,130	120	305	do	
128	195	Early Ordovician	3,830	Present?	nd	3,670	nd	160	do	
130	74	Comanche	4,122	4,075	47	4,040	35	82	do	
131	79	Early Ordovician	3,679	Absent	--------	Absent	--------	--------	do	
143	110	Comanche	4,547	4,500	47	4,254	246	293	do	
145	100	do	5,443	5,358	85	5,255	103	188	do	
154	206	Early Ordovician	3,290	Absent	--------	Absent	--------	--------	do	
155	32	Comanche	3,860	3,826	34	3,790	36	70	do	
159	118	do	3,420	3,270	150	3,170	100	250	do	
160	110	do	3,320	nd	nd	3,150	nd	170	do	
161	90	do	3,390	3,280	110	3,170	110	220	do	
162	73	Middle Ordovician	3,040	3,000	40	2,970	30	70	do	
163	96	Early Ordovician	3,136	3,050	86	3,011	39	125	do	
164	162	Comanche	3,322	3,237	85	3,135	102	187	do	
165	96	do	3,595	3,425	170	3,300	125	295	do	
166	67	do	3,553	3,500	53	3,380	120	173	do	
167	41	do	3,720	3,635	85	3,560	75	160	do	
168	36	do	3,775	3,600	175	3,415	185	360	do	
169	44	do	4,985	4,770	215	4,680	90	305	do	
170	48	do	5,130	4,960	170	4,864	96	266	do	
171	28	do	4,170	3,950	220	3,550	400	620	do	
					Georgia					
G1	229	Comanche	nd	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	Top of Tuscaloosa Formation at 3,480(?) ft.,[2] top of diabase at 4,104 ft.
2	222	do	3,870	3,723	147	3,135	588	735	Beds of Austin age	
3	136	do	3,620	3,390	230	3,090	300	530?	do	
4	(1)	Pre-Cretaceous*	1,028	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	Top of Tuscaloosa Formation at 278 ft. (Herrick, 1961, p. 52–53).
5	345	Comanche	2,920	2,650	270	2,100	550	820	Beds of Austin age	
6	65	do	4,563	4,390	173	4,000	390	563	do	
7	215	do	4,010	3,820	190	3,360	460	650	do	
8	176	Early Paleozoic*	3,843	3,800	43?	3,620	180?	223?	do	
9	147	Comanche	3,825	3,615	210	3,390	225	435	do	
11	177	do	3,789	3,608	181	3,360	248	429	do	
12	--------	nd	nd	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	Top of Tuscaloosa Formation at 3,250 ft; top of igneous rock at 4,115 ft.
13	317	nd	nd	Absent	--------	Absent	--------	--------	do	Top of Tuscaloosa Formation at 3,270 ft; top of granite at 4,110 ft.
13a	308?	np	--------	Absent	--------	Absent	--------	--------	do	Top of Tuscaloosa Formation at 3,250 ft.
14	270	Comanche	3,510	3,290	220	2,806	484	704	Beds of Austin age	
15	364	do	3,190	2,960	230	2,355	605	835	do	
16	276	do	3,880	3,600	280	3,235	365	645	do	
17	132	do	3,450	3,190	260	2,770	420	680	do	
18	104	do	3,600	3,320	280	2,900	420	700	do	
19	129	do	3,450	3,220	230	2,790	430	660	do	
73	446	do	2,952	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	Top of Tuscaloosa Formation at 2,210 ft: top of "basement" 3,512 ft (Herrick, 1961, p. 167–169).
22	209	do	3,209	2,805	404	2,265	540	944	Beds of Austin age	
23	192	do	3,260	2,835	425	2,300	535	960	do	
24	187	do	3,140	2,915	225	2,395	520	745	do	
25	181	do	3,760	3,550	210	3,340	210	420	do	
26	148	do	3,645	3,440	205	3,270	170	375	do	
27	142	Early Ordovician	3,730	3,578	152	3,460	118	270	do	
28	144	Comanche	3,625	3,465	160	3,320	145	305	do	
29	156	do	3,629	3,450	179	3,272	178	357	do	
79	355	Pre-Cretaceous*	100	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	LeGrand and Furcron (1956, p. 69, 71).
32	20	nd	nd	Present	--------	4,219	nd	nd	do	
33	419	Pre-Cretaceous*	1,490	Absent	--------	Absent	--------	--------	do	Applin (1951, table 1).
34	364	Early Cretaceous	1,685	Absent	--------	Absent	--------	--------	do	Top of Tuscaloosa at 910 ft (Herrick, 1961, p. 227–228).
38	(1)	Pre-Cretaceous*	(1)	Absent	--------	Absent	--------	--------	do	Prettyman and Cave (1923, p. 56); LeGrand and Furcron (1956, p. 76).
40	26	Comanche	4,032	3,880	152	3,476	404	556	Beds of Austin age	
42	600±	Pre-Cretaceous*	1,590	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	Top of Tuscaloosa Formation t 960 at (Herrick, 1961, p. 296–298).
43	338	Comanche	3,640	3,360	280	2,830	530	810	Beds of Austin age	
47	75	Pre-Cretaceous*	4,348	4,210	138	3,770	440	578	do	Applin and Applin (1944, p. 1725).
48	80	do.*	4,345	4,220	125	3,800	420	545	do	Applin and Applin (1947).
49	280	Early Cretaceous?	2,160	Absent	--------	Absent	--------	--------	Coastal Plain sediments.	Top of Tuscaloosa Formation at 1,370 ft (Herrick, 1961, p. 330–333).
50	290	do	1,480	Absent	--------	Absent	--------	--------	do	Top of Tuscaloosa Formation at 550 ft.[3]
51	136	Pre-Cretaceous*	330	Absent	--------	Absent	--------	--------	do	Top of Tuscaloosa Formation at surface (Herrick, 1961, p. 338–339).
52	(1)	do.*	(1)	Absent	--------	Absent	--------	--------	do	Prettyman and Cave (1923, p. 57). In crystalline rock at total depth (±400 ft).
53	136	do.*	162	Absent	--------	Absent	--------	--------	do	Top of Tuscaloosa Formation at surface (Herrick, 1961, p. 337–338).

See footnotes at end of table.

248-931 O—67——2

TABLE 2.—*Depth (in feet) and geologic age of rocks of the pre-Gulf surface and depth and thickness (in feet) of the Atkinson Formation*—Continued

Well (pl. 1)	Elevation (feet)	Rocks of pre-Gulf surface		Atkinson Formation					Overlying rocks	Remarks
		Geologic age (pl. 2*A*)	Depth to top	Lower member		Upper member		Total thickness (pl. 3*A*)		
				Depth to top	Thickness (pl. 3*B*)	Depth to top	Thickness (pl. 3*E*)			
Georgia—Continued										
G56	114	Comanche	3,420	3,110	310	2,700	410	720	Beds of Austin age	
57	145	do.	3,277	3,050	227	2,540	510	737	do.	
65	198	Comanche or older	nd	Absent		Absent				Top of Tuscaloosa Formation at 3,000(?) ft; top of "conglomeratic arkose" at 3,679 ft.
84	271	Pre-Cretaceous*	(1)	Absent		Absent			Coastal Plain sediments.	Top of Tuscaloosa Formation at surface (Lamoreaux, 1946, p. 94, 98, 99, 108, well 27).
85	272	do.*	194	Absent		Absent			do.	Lamoreaux (1946, p. 94, 106, well 25).
67	460	do.*	871	Absent		Absent			do.	P. L. Applin (1951, table 1).
68	(1)	do.*	392	Absent		Absent			do.	In Tuscaloosa at 300 ft (Herrick, 1961, p. 428).
80	465	do.*	871	Absent		Absent			do.	Lamoreaux (1946, p. 121-122).
81	270	do *	304	Absent		Absent			do.	Lamoreaux (1946, p. 132, 138, well 65).
82	278	do.*	163	Absent		Absent			do.	Lamoreaux (1946, p. 130, 134, well 18).
83	280	do.*	120	Absent		Absent			do.	Lamoreaux (1946, p. 118, 134, well 17).
69	73	Comanche	4,462	4,308	154	3,889	419	573	Beds of Austin age	

[1] Data not available.
[2] The Tuscaloosa Formation as used in this table is the approximate age equivalent of the Atkinson Formation (Applin and Applin, 1947; Applin, E. R., 1955, p. 187).
[3] Oil company scouts.

*Rock type:

G4. Crystalline rocks (Herrick, 1961, p. 53; Milton and Hurst, 1965, p. 16).
8. Rhyolitic rocks (Ross, 1958, p. 545; Applin, P. L., 1951, p. 11; Milton and Hurst, 1965, p. 29–30).
79. Granite (LeGrand and Furcron, 1956, p. 69).
33. Biotite gneiss (Applin, P. L., 1951, table 2; Milton and Hurst, 1965, p. 17).
38. Diorite gneiss (LeGrand and Furcron, 1956, p. 76; Milton and Hurst, 1965, p. 16).
42. Biotite gneiss (Herrick, 1961, p. 298; Milton and Hurst, 1965, p. 18).
47. Granite (Applin, P. L., 1951, table 1; Milton and Hurst, 1965, p. 39–42).
48. Granite (Applin, P. L., 1951, table 1; Milton and Hurst, 1965, p. 39).
51. Crystalline rock (Herrick, 1961, p. 338).
52. Crystalline rock (Prettyman and Cave, 1923, p. 57; Milton and Hurst, 1965, p. 16).
53. Crystalline rock (Herrick, 1961, p. 337).
84. Crystalline rock (Lamoreaux, 1946, p. 94).
85. Crystalline rock (Lamoreaux, 1946, p. 94).
67. Granite (Applin, P. L., 1951, table 1; Milton and Hurst, 1965, p. 17).
68. Biotite gneiss (Herrick, 1961, p. 428; Milton and Hurst, 1965, p. 16).
80. Crystalline rock (Lamoreaux, 1946, p. 122).
81. Granite (Lamoreaux, 1946, p. 132).
82. Granite (Lamoreaux, 1946, p. 130).
83. Crystalline rock (Lamoreaux, 1946, p. 118).

In the southern and southeastern parts of the report area in Florida, oil test wells (table 2) in Hernando County (F85), Lake County (F104), Orange County (F145), and Volusia County (F169, F170) penetrated the carbonate-evaporite facies of the beds of Washita (Comanche) age (Applin and Applin, 1965) that are unconformably overlain by the lower member of the Atkinson Formation of the Gulf Series (pl. 2*A*). This sequence has also been penetrated in the deep wells farther south in central and southern Florida.

Except in the three areas mentioned above, the Gulf Series throughout most of northern Florida and southern Georgia rests on an unfossiliferous marginal clastic facies of the Comanche rocks in which the stratigraphic units of Trinity, Fredericksburg, and Washita age are probably present but are largely undifferentiated. Although the uppermost beds of the clastic facies differ lithologically from place to place, owing to differences in source areas and depositional conditions, these Comanche beds are generally composed of red and varicolored micaceous clay shale and poorly sorted fine- to coarse-grained argillaceous noncalcareous or slightly calcareous sandstone. The sandstone, which is composed chiefly of rounded to subangular frosted grains of quartz, commonly contains various amounts of pink and yellow quartz grains and irregularly distributed grains of feldspar, mica, and light-bluish-green chlorite.

A shallow-water marine facies in the upper part of the Comanche Series in the Magnolia Petroleum Co. State of Florida Block 5B well 1A (table 2, F57), Franklin County, Fla., contained microfossils of Buda (Washita) age, which mark a significant environmental change from the widely distributed unfossiliferous marginal clastic facies described above. Shallow-water marine sediments were present, also, in the uppermost part of the Comanche Series in the Pure Oil Co. Gex-Lewin 3 (table 2, F58), Franklin County, Fla.; but in this well, microfossils and determinable species of macrofossils were absent. The fossiliferous shallow-water marine facies may be present, however, on the submerged part of the Continental Shelf off the coast of western Florida, inasmuch as it occurs in the Zach Brooks Drilling Co. Caldwell-Garvin 1 (sec. 31, T. 2 S., R. 31 W.), near Pensacola, Escambia County, Fla. This well is west of the report area about 150 miles N. 80° W. of the Magnolia well.

The top of the Comanche Series in the Magnolia well is placed at a depth of 5,250 feet on the basis of paleontologic data and electric-log correlation. Drill cuttings from 5,250–5,310 feet and a set of four consecutive cores from 5,310–5,370 feet are composed chiefly of interbedded and interlensing thin layers of light-gray fine-grained calcareous micaceous argillaceous sandstone containing fragments of *Ostrea*-like bivalves and ostracodes, light-gray sandy limestone containing fragments of *Ostrea*(?) sp. and ostracodes, gray micaceous argillaceous siltstone, dark-gray silty micaceous clay shale, and bluish-green waxy shale containing shreds of carbonaceous material, ostracode carapaces, Foraminifera, Chara seedpods, and fragments of Bryozoa and other macrofossils. Fragments of fish teeth, fish bones, and other phosphatic material are common in the cores.

The foraminiferal fauna in samples from the Magnolia well from depths of 5,270–5,345 feet consists of abundant specimens of *Flabellammina denisonensis* (pl. 8, figs. 1–3) and some specimens of *F. brachylocula* Tappan, *Reophax woodbinensis* Tappan, and *Ammomarginulina cragin* Lœblich and Tappan. Ostracodes were found in samples from 5,270–5,375 feet. According to H. A. Sellin, Magnolia Petroleum Co. (oral commun., 1948), Dr. C. I. Alexander, Magnolia Petroleum Co., identified specimens of the ostracodes as *Cythereis fredericksburgensis* Alexander, *Cytheridea* sp., and *Eocytheropteron* sp. Many fragments of *Ostrea* sp. and abundant fragments of carbonaceous material occur in cuttings and cores from depths of 5,250–5,510 feet.

The foraminiferal species, *Flabellammina denisonensis*, *F. brachylocula*, and *Reophax woodbinensis*, were described by Tappan (1941) from an outcrop in the city of Denison, Tex., and were classified as Woodbine (Late Cretaceous) in age. On the basis of geologic investigations of outcropping Cretaceous beds in Cooke, Fannin, and Grayson Counties, Tex., Bergquist (1949) stated, "*Flabellammina denisonensis* was first described as a Woodbine fossil, but its presence with fossils of Buda age now precludes considering it a criterion of basal Woodbine." Lozo (1951, p. 74) considered the exposures on which Bergquist had based his statement and the outcrop from which the type specimen of *F. denisonensis* was described to be for the most part contemporaneous and informally called them all the "Cherry Mound shale." Lozo seems to agree that the shale is the age equivalent of the Buda Limestone.

GULF SERIES

The rocks of the Gulf Series of Late Cretaceous age are present throughout Florida and the Coastal Plain of Georgia, but they are known chiefly in the subsurface. In the northern part of the Georgia Coastal Plain an irregular outcrop belt of sandstone and shale belonging to the lower Upper Cretaceous Tuscaloosa Formation borders on the south the crystalline rocks of the Piedmont. Southward from its outcrop in west-central Georgia, the Tuscaloosa Formation dips under roughly parallel belts of the progressively younger Eutaw Formation, the formations equivalent to the Selma Group, and the Tertiary formations. In central and east-central Georgia the Eutaw Formation and the formations equivalent to the Selma Group are overlapped by Tertiary formations. Conclusions in regard to the stratigraphy, structure, and thickness of the buried rocks of the Gulf Series are based largely on the study of cores and cuttings from oil test wells. The major stratigraphic units of the buried rocks—the Atkinson Formation of Woodbine and Eagle Ford age and the beds of Austin, Taylor, and Navarro age—are differentiated chiefly by distinctive microfaunal assemblages that occur in a uniform sequence in wells in the area. Certain microlithologic characteristics provide additional criteria for differentiating the units, and electric logs are valuable aids in correlation. Paleontologic investigations show that the sequence of microfaunal assemblages in the units of the Gulf Series in Florida and southern Georgia closely resembles the sequence in the standard outcropping and subsurface stratigraphic sections of the Gulf Series in Texas. The diagnostic Foraminifera that aid in distinguishing the Woodbine, Eagle Ford, Austin, Taylor, and Navarro units in Texas provide a basis for the correlation of the approximately synchronous units in Florida and southern Georgia. The diagnostic Foraminifera of the Lawson Limestone of latest Cretaceous age in the Florida peninsula are, however, an exception to this generalization since the Lawson's faunal assemblage does not resemble that of the Navarro Group in Texas but is closely related to the diagnostic faunal assemblage found in beds of Maestrichtian age in Cuba. Neither the continuity of the several units nor the identity of their boundaries from Texas on the west to Florida and Georgia on the east has been definitely established, and the nomenclature of the major subdivisions has been applied in a correlative sense to the units of the Gulf Series in the southeastern area. No attempt is made in this report to correlate precisely the subsurface stratigraphic units of the Gulf Series with the outcropping formations in Georgia.

The following discussion of the stratigraphy of the Gulf Series is supplemented by three stratigraphic cross sections (pl. 7) through selected wells. The sections show graphically the lithology, paleontology, correlation, and electrical characteristics of the different stratigraphic units. The lithologic logs and paleontologic data are based on E. R. Applin's microscopic studies of cores and cuttings from each well; the curves showing the electrical characteristics are based on commercial logs.

ATKINSON FORMATION

The name Atkinson Formation (Applin and Applin, 1947) was introduced, with three unnamed members (upper, middle, and lower), for the dominantly marine pre-Austin rocks of the Gulf Series in the subsurface in southern Alabama, southern Georgia, and northern Florida. Subsequently, the stratigraphic equivalent of the Atkinson Formation has been traced through a series of wells as far south as the Florida Keys. In general, the upper member of the Atkinson Formation contains a microfauna of Eagle Ford age; the middle and lower members contain a microfauna of Woodbine age. In Alabama and Georgia the middle and lower members of the Atkinson Formation were differentiated on a lithologic basis. There the middle member of the Atkinson is predominantly a marine shale, correlated with the so-called marine-shale zone of the Tuscaloosa. The unfossiliferous littoral or nonmarine sandstone and red shale, which constitute the lower member of the Atkinson in the northern part of the Coastal Plain of Alabama and Georgia, merge southward into a fossiliferous marine facies. In the Florida peninsula the distinguishing lithologic characteristics of the middle and lower members of the Atkinson Formation are indistinct. To clarify the correlation of the Atkinson Formation of the subsurface in the southeastern Gulf region with the Eagle Ford and Woodbine Formations of Texas, the Atkinson Formation was divided into (Applin, 1955, p. 187) two members, an upper member of Eagle Ford age as formerly used and a lower member of Woodbine age consisting of the former lower and middle members.

The Atkinson Formation (pl. 3; table 2) in scattered areas in northern Florida and southern Georgia is relatively thin or absent. In the Florida peninsula the formation is absent in three wells (pl. 3*A*; table 2: F5, Baker County; F131, Marion County; F154, Putnam County) and is less than 200 feet thick in many others. In wells along the Atlantic and gulf coasts it is 200–300 feet thick; in the bight of Florida, off the gulf coast, the available data indicate that the formation may be less than 400 feet thick. Along the coast of Georgia the formation is about 600 feet thick.

In general, the Atkinson Formation thickens northwestward from northern Florida toward an area in the west-central part of the Coastal Plain of Georgia where it is more than 900 feet thick. The northwestward thickening is shown by the isopachs on plate 3*A*. Both members (pl. 3*B*, *E*) show a similar variation in thickness. The samples from the wells in the depocenter show clearly the interfingering of the marine beds of the Atkinson Formation on the south with the littoral or nonmarine beds of the Tuscaloosa Formation on the north. The Tuscaloosa Formation thins gradually northward toward its outcrop at the inner margin of the Coastal Plain.

LOWER MEMBER

The lower member of the Atkinson Formation (pl. 3*B*) unconformably overlies Comanche rocks throughout most of the report area, but in 12 wells it rests unconformably on Ordovician strata (table 2: F2–F4, Alachua County; F6, Baker County; F8, Bradford County; F23, Clay County; F36, F38, Columbia County; F128(?), Marion County; F162, F163, Suwannee County, all in Florida; and G27, Echols County, Georgia); in 3 other wells it rests on igneous rocks that are possibly older (Applin, 1951) (table 2: G8, Clinch County; G47 and G48, Pierce County, all in Georgia). The lower and upper members of the Atkinson are both present (pl. 3*B*, *E*) in most wells in the report area, but the upper member is absent in eight wells where the lower member is unconformably overlain by the beds of Austin age (table 2: F2–F4, Alachua County; F6, Baker County; F8, Bradford County; F23, Clay County; F36 and F38, Columbia County, all in Florida). The lower member, which is absent in three wells in the northern part of the peninsula and is less than 100 feet thick in many other wells, is nearly 400 feet thick in wells in Jackson County, Fla.

Fossiliferous marine shale, siltstone, sandstone, and unconsolidated soft sand are the principal lithologic constituents of the lower member. In many wells in southern Georgia, the uppermost beds commonly contain one or more closely associated lenses of gray sandy coquinoid limestone in which fragments of oyster shells and other fossil bivalves are common. A fossiliferous oolitic limestone facies (Applin and Applin, 1965, p. 68) in the lower part is a distinctive lithologic feature overlying the carbonate-evaporite facies of the beds of Washita (Comanche) age in Hernando, Lake, Orange, and Volusia Counties, Fla., and in several other wells south of the report area.

Four intergrading lithofacies of the lower member are recognized; their areal distribution is shown on plate 3*C*. The distribution of the facies is evidently controlled, in part, by the regional structure.

The predominant shale facies of the lower member (pl. 3*C*), which is widespread in the report area, is composed largely of hard, platy or splintery, dark-gray to dark-brownish-gray shale, but greenish-gray shale has been penetrated in some wells. Carbonaceous material and pyrite are commonly present in the shale; glauconite is present in some lenses; and mica, though present, is not usually abundant. Very thin lenses of hard platy siltstone are commonly interbedded with the shale, and various amounts of sandstone are present, especially in the basal part of the lower member. Dark-brownish-gray shale having a conspicuous speckled appearance is found at various stratigraphic levels in the lower member and is most common in northern Florida near the present coastline. One type of speckling that occurs in shale having an oily luster is due to closely spaced fragments of crushed and finely comminuted shells of pelagic Foraminifera. In places where the Foraminifera have been crushed but not completely disintegrated, we have been able to identify the small tests of *Globigerina* and *Gümbelina*. Crickmay, Ladd, and Hoffmeister (1941) pointed out that sediments containing abundant specimens of *Globigerina* and other pelagic Foraminifera do not necessarily indicate deep-water depositional environment. Perhaps storm-driven waters or periodic inundations from a nearby open sea carried great numbers of the pelagic Foraminifera into the relatively unfavorable shallow-water environment of the lower member where they died and were soon buried. Another type of speckling that occurs in shale having an earthy texture is due to abundant tests of dwarf specimens of several calcareous species of Foraminifera.

The glauconitic sandstone facies of the lower member (pl. 3*C*) is composed of subangular fine- to medium-grained quartz sandstone and soft unconsolidated sand that is slightly calcareous to noncalcareous. The sandstone is similar to the basal sandstone of the shale facies. Glauconite is generally present, and in places there are appreciable amounts of phosphatized nodules, fish bones, and molds of other fossil debris. Thin lenses of gray to very dark gray shale are irregularly distributed vertically throughout the sandstone facies; some lenses are microfossiliferous. In some wells the sandstone near the base of the lower member is poorly sorted and fine to coarse grained and contains lenslike accumulations of lignite and other carbonaceous material. In a few wells this lower part also contains one or more layers of oyster-shell fragments.

A study of consecutive cores from several wells in the report area shows that the basal sandstone in the lower member has several significant lithologic differences from the underlying sandstone of Comanche age. The sandstone of the Atkinson Formation (fig. 1) has better sorting, greater compositional variety, more elongate grains, and more closely packed grains than does the underlying sandstone of Comanche age. More detailed differences may be observed in typical thin sections of each of the rocks (fig. 1).

The study of a typical thin section (fig. 1*A*) made from a core taken at depths of 3,209–3,214 feet in the Coastal Petroleum Co. Ronald Sapp 1 (pl. 3*D* and table 2, F100), Lafayette County, Fla., shows that the basal part of the Atkinson Formation consists of medium-grained argillaceous calcareous sandstone. The sand-sized particles which make up 80 percent of the rock consist predominantly of quartz with small amounts of feldspar, muscovite, and other grains that may be derived from silicified volcanic rocks; some grains of cataclastic quartz probably indicate derivation of the sand from metamorphic rocks. Less than half of the quartz grains show undulatory extinction, and the feldspar, which makes up less than 5 percent of the rock, consists of fresh microcline and a trace of plagioclase. The grains are angular to rounded; a few are elongated. The maximum grain diameter ranges from 0.14 to 1.2 mm, and the mode is between 0.25 and 0.35 mm. The cement consists of clay mineral and scattered subhedral to anhedral silt-sized carbonate grains. The rock also contains pyrite as euhedral crystals and nodules.

The study of a thin section (fig. 1*B*) made from a core taken at 3,214–3,224 feet also in Coastal Petroleum Co. Ronald Sapp 1 shows that this rock, which is of Comanche age, is fine- to medium-grained silty very argillaceous sandstone. The sand and silt grains, which make up about 50 percent of the rock, are more than 99 percent quartz, most of which has undulatory extinction. A few small grains of zircon, staurolite, and weathered rutile(?) are present, but no feldspar, rock fragments, or mica was found. The sand and silt grains are composed of the most durable minerals only. The larger grains in this sandstone are subrounded to rounded; the smaller grains are subangular to angular.

Wells in the northeastern part of the Florida peninsula penetrated a dominantly sandstone facies (pl. 3*C*) that differs lithologically from the characteristic lower member of the Atkinson in other parts of the area. The lower member in northeastern Florida is chiefly chalky, dolomitic, highly anhydritic, and gypsiferous sandstone containing scattered thin lenses of soft grayish-green shale. The sandstone is white to light gray or light greenish gray, usually fine to medium grained, and well sorted. Glauconite, which is comparatively rare, is found in thin bands in the chalky sandstone, and relatively thick accumulations of carbonaceous material are found at irregularly spaced levels; chalky fossiliferous limestone that seems to be chemically altered was penetrated in a few wells.

The microfauna is distinctive. The shallow brackish water and muddy bottom that characterized the lagoonal and estuarine depositional environment of the lower member of the Atkinson provided a favorable habitat for the arenaceous Foraminifera composing

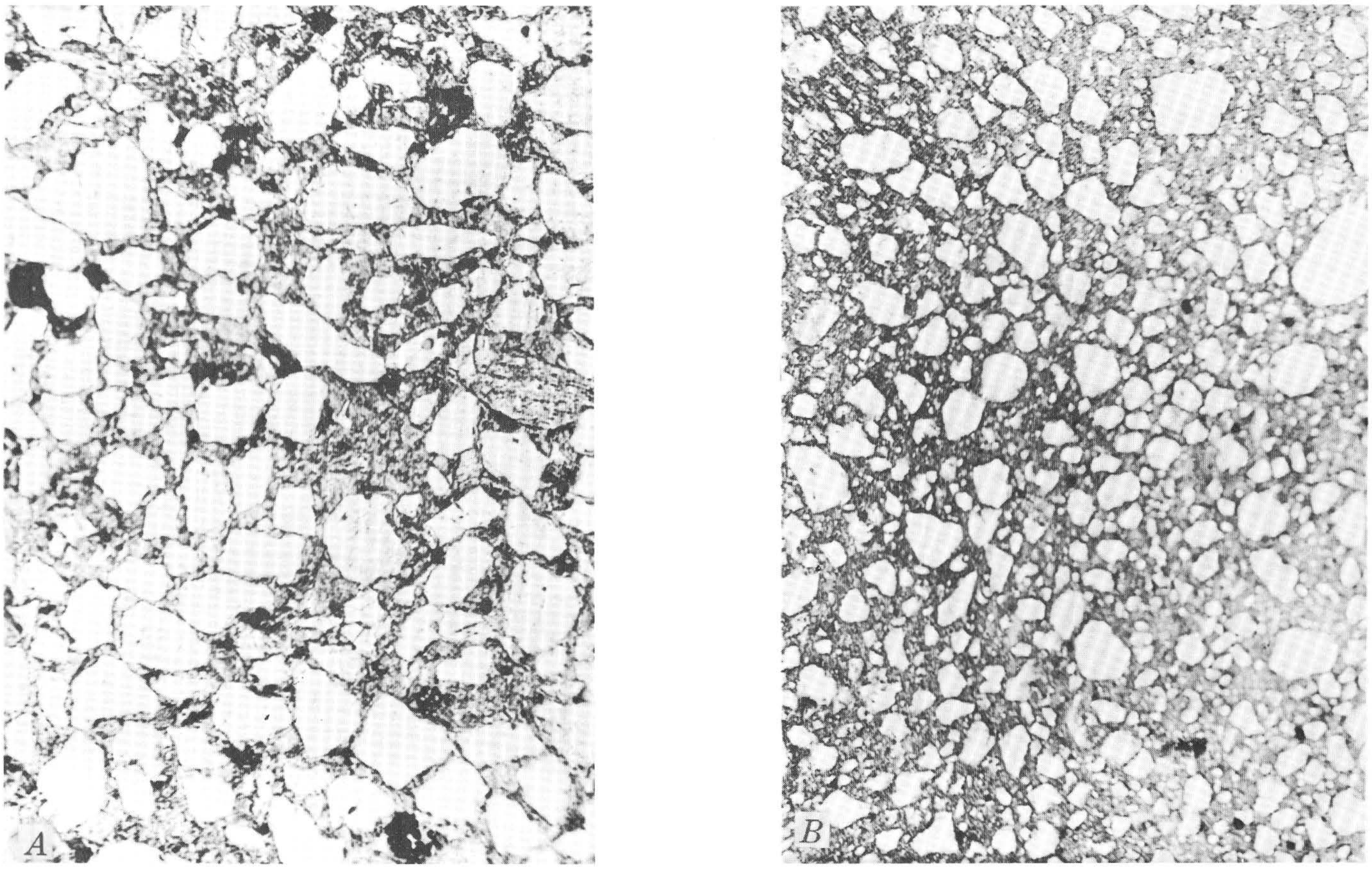


FIGURE 1.—Photomicrographs (× 30) of thin sections of consecutive cores showing the contrast between a sandstone at the base of the lower member of the Atkinson Formation of the Gulf Series (*A*) and a sandstone at the top of the underlying Comanche Series (*B*). The cores are from the Coastal Petroleum Co. Ronald Sapp 1 (pl. 3*D* and table 2, F100), Lafayette County, Fla. Figure *A* shows part of a core at depths of 3,209–3,214 feet. Figure *B* shows part of a core at depths of 3,214–3,224 feet.

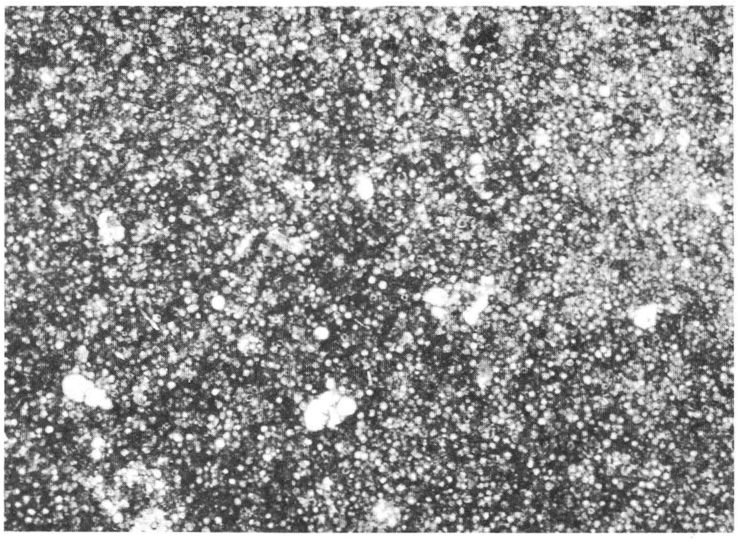


FIGURE 2.—Photomicrograph (× 30) of a thin section of *Oligostegina* limestone in cuttings of beds of Austin age at depths of 4,540–4,550 feet in the Grace Drilling Co. Retail Lumber Co. 1, Volusia County, Fla.

the typical microfauna of the unit. Most of the species comprising the microfauna of the lower member have been described from outcrops of the Woodbine Formation in northeast Texas (Cushman and Applin, 1946; 1947), and from the Pepper Shale in central Texas (Loeblich, 1946) which was considered to be a member of the Woodbine by Stephenson in 1952. Although not all the species of the microfauna of the lower member in the Florida-Georgia area are present in a single assemblage, several species are commonly present, and the variations in their grouping probably indicate the tolerance and adaptability of different species to the changing local environments. Though widely distributed geographically, the microfauna is sparse and restricted to various stratigraphic levels in the lower member. The species of Foraminifera typical of the lower member of the Atkinson Formation are:

Ammotium braunsteini (Cushman and Applin)
Ammobaculites plummerae Loeblich
  junceus Cushman and Applin
  comprimatus Cushman and Applin
  bergquisti Cushman and Applin
  stephensoni Cushman
  agrestis Cushman and Applin
Trochammina rainwateri Cushman and Applin
Haplophragmoides advenus Cushman and Applin

A new and unusual biofacies (Applin, 1955) of the lower member of the Atkinson Formation, usually called the "Barlow fauna," has been found in 13 scattered wells in the area extending northward from Levy and Putnam Counties, Fla., to Clinch County, Ga., and westward to Crenshaw County, Ala. The locations of all the wells except the one in Crenshaw County, Ala., are shown on plate 3*B* and *C* (this report). The so-called Barlow fauna contains, in addition to several species of arenaceous Foraminifera, several calcareous species that are generally associated with clearer water environments than are the typical species of the lower member cited in the preceding list. The assemblage is found in gray silty marl and silty limestone and seems to have developed in very localized environments, possibly on submerged peaks or knolls that were elevated above the surrounding muddy bottom and covered by clear normally saline well-aerated sea water.

The chalky dolomitic gypsiferous sandstone lithofacies of the lower member of the Atkinson (pl. 3*C*) in the northeastern part of the Florida peninsula contains several species of miliolids that are too poorly preserved for specific identification. Two wells (pl. 3*C*: F4, Alachua County; F36, Columbia County) penetrated thin strata of chalky very sandy slightly glauconitic fossiliferous limestone that contained many fragments of Bryozoa, some fragments of *Inoceramus*, specimens of miliolid Foraminifera, ostracodes, and some identifiable fragments of *Cuneolina walteri* Cushman and Applin. *C. walteri* has been reported only from the oolitic limestone facies of the lower part of the lower member (pl. 3*C*) that has been penetrated in several wells in central Florida (Applin and Applin, 1965). The available data do not show the precise stratigraphic relation between the oolitic limestone facies in central Florida and the chalky dolomitic gypsiferous sandstone facies (pl. 3*C*) in the northeastern part of the peninsula.

UPPER MEMBER

The upper member of the Atkinson Formation (pl. 3*E*) throughout its areal extent in the report area, overlies the lower member and underlies the beds of Austin age. It is absent (p. G12) in 11 wells in northeastern Florida and is less than 200 feet thick in most of the other wells in the northern part of the peninsula (pl. 3*E*; table 2). From the northern part of the peninsula, the member thickens gradually toward the northeast, north, and northwest; it is 400–500 feet thick in wells in southeastern Georgia and about 600 feet thick in wells in the central part of the Coastal Plain of Georgia and in Gulf County, Fla.

The upper member, like the lower, is of shallow-water marine origin and is composed, for the most part, of shale, sandstone, siltstone, and a few lenses of limestone. Plate 3*F* shows our interpretation of the areal distribution of four lithofacies of the upper member that merge with the stratigraphically equivalent beds of the Tuscaloosa Formation. As in the lower member, the four lithofacies do not have sharply defined boundaries, but each is characterized by a dominant type of lithology.

The shale and sandstone facies (pl. 3*F*) that occupies much of the mapped area is composed chiefly of gray and greenish-gray smooth-textured thinly flaky calcareous shale and fine-grained to very fine even-grained white to light-gray sandstone and siltstone. The shale is irregularly silty and in many places contains small grains of glauconite and shreds of carbonaceous material in various amounts. Mica is generally present but rarely common, and pyrite is locally abundant. The sandstone is composed chiefly of clear quartz grains and commonly contains small grains of glauconite. In some wells the sandstone beds are found at fairly evenly spaced levels in the member; in other wells they seem to be concentrated mainly in the upper or lower part. Spherules and small irregularly shaped nodules of siderite are generally present in the upper member of the Atkinson. Scattered microfossiliferous lenses in the shale contain many specimens of a few benthonic species of Foraminifera and ostracodes. Shell fragments of oysterlike bivalves are also characteristic faunal features of this facies. Thin lenses of light-gray rough-textured irregularly silty limestone are a minor constituent. Wells drilled near the coast of the peninsula commonly penetrate dark-brownish-gray white-speckled shale closely similar in lithology to the speckled shale that is characteristic of the lower member. As noted above, the speckled appearance of this shale is due to closely spaced fragments of crushed and finely comminuted shells of *Globigerina* and *Gümbelina*. Sandstone lenses are comparatively rare in the part of the upper member characterized by the white-speckled shale (pl. 3*F*).

The thin lenses of gray silty limestone in the shale and sandstone facies increase southward in number and thickness and are dominant in the upper member of the Atkinson near the south border of the report area (pl. 3*F*). The upper member is composed almost entirely of limestone in a well (pl. 3*F*, F85) in Hernando County, Fla., on the gulf coast of the peninsula. This limestone facies may extend southward throughout the southern part of the peninsula where the rocks of the Gulf Series are largely undifferentiated.

The shale and sandstone lithofacies (pl. 3*F*) of the upper member grades northward into fine- to medium-grained sandstone containing scattered thin lenses of the characteristic gray and greenish-gray shale. The sandstone facies forms a belt across southern Georgia that extends westward into southeastern Alabama and western Florida. Glauconite and mica are generally present, and carbonaceous material is commonly coarser and more abundant than in the sandstone and shale lithofacies to the south. Oyster-shell beds and oyster-shell debris are common. In most wells, marine-shale lenses containing the benthonic microfauna of Eagle Ford age are found in the uppermost beds of this facies.

The sandstone lithofacies, in turn, merges northward into a transitional coarse-grained sandstone, shale, and mudstone facies (pl. 3*F*), which, in several wells, contains features of both the upper member of the Atkinson Formation to the south and the Tuscaloosa Formation to the north. The lower half or two-thirds of the facies, which is unfossiliferous and lithologically similar to the Tuscaloosa Formation, is dull brownish-red shale; multicolored mudstone; and poorly sorted fine to coarse subangular quartz sand containing pink and yellow-tinted grains and sparse grains of feldspar. The shale usually contains siderite spherules; the sand is commonly micaceous. The uppermost part of the facies is evidently of marine origin. It is composed of interbedded greenish-gray shale and very fine grained sandstone that is characteristic of the upper member elsewhere and contains a fauna of Eagle Ford age composed of benthonic Foraminifera and Ostracoda.

The benthonic microfauna of the upper member, which is composed of only a few species of Foraminifera and several species of Ostracoda, is found at various stratigraphic levels in localized irregularly distributed assemblages. The pelagic specimens that are abundant in the shale and sandstone lithofacies are, for the most part, crushed or finely fragmented, but some well-preserved specimens are generally found in each faunal assemblage. Characteristic species of the microfauna of the upper member of the Atkinson Formation are:

Globigerinelloides eaglefordensis (Moreman)
Valvulineria infrequens Morrow, var. Applin
Pleurostomella cf. *P. watersi* Cushman
Ammobaculites coprolithiformis (Schwager) Cushman
    stephensoni Cushman
    sp.
Hedbergella brittonensis Loeblich and Tappan
Heterohelix moremani (Cushman) Gallitelli
Several species of ostracodes

BEDS OF AUSTIN AGE

The beds of Austin age (pl. 4; table 3) in the report area have been identified, chiefly by the similarity of their microfauna to that of the Austin Chalk and its equivalent facies in Texas. In most wells the beds of Austin age overlie the upper member of the Atkinson Formation, but they rest unconformably on the lower member of the Atkinson in eight wells (p. G12) in northeastern Florida and on Lower Ordovician strata in three other nearby wells (p. G12). The lower contact of the unit is defined by marked lithologic and microfaunal differences observed in the cuttings and cores from many wells and by characteristics of the self-potential and resistivity curves of the electric logs of the wells. The beds of Austin age are overlain by lithologically similar beds of Taylor age with apparent conformity throughout the area. Also, the contact is not clearly defined paleontologically because few of the species of Foraminifera that are common in the beds of Austin age are limited in their upward range, and the stratigraphically useful species are usually very small and of rare occurrence in cutting samples. Few cores have been taken in the upper part of the unit and, as a consequence, the stratigraphic sequence of the diagnostic species of Foraminifera has not been definitely determined. Somewhat arbitrarily selected characteristics on the curves of electric logs of oil test wells have been found useful for correlating the approximate top of the unit in parts of the report area.

The beds of Austin age are composed mainly of moderately hard white to light-gray fine-textured chalky limestone. Pyrite is commonly present, either as large crystals and crystal clusters or as aggregates of very small particles replacing shell structure. In the lower

TABLE 3.—*Depth and thickness (in feet) of the beds of Austin age and the beds of Taylor age*

[nd, not determined; np, not penetrated]

Well (pl. 1)	Elevation (feet)	Underlying rocks	Beds of Austin age		Beds of Taylor age		Beds of Austin and Taylor age, total thickness (pl. 4A)	Overlying rocks	Remarks
			Depth to top	Thickness	Depth to top (pl. 4)	Thickness			
Alabama									
A3	504	Upper member, Atkinson Formation	1,060	480	nd		nd	Clastic beds of Navarro age	
5	554	do	1,004	502	nd		nd	nd	First sample, at 1,004 ft, in beds of Austin age.
25	192	do	1,590	550	1,100	490	1,040	Clastic beds of Navarro age	
26	302	do	1,785	545	1,285	500	1,045	do	
64	217	do	2,000	460	1,450	550	1,010	do	
27	140	do	2,160	540	1,790	370	910	do	
68	270	do	1,910	590	1,545	365	955	do	
Florida									
F1	77	Upper member, Atkinson Formation	2,800	370	2,420	380	750	Lower member, Lawson Limestone	
2	112	Lower member, Atkinson Formation	2,780	270	2,305	475	745	do	
3	168	do	2,770	330	2,340	430	760	do	
4	132	do	2,800	330	2,400	400	730	do	
5	134	Lower Ordovician	3,030	312	2,530	500	812	do	
6	155	Lower member, Atkinson Formation	2,615	386	2,230	385	771	do	
8	142	do	2,798	282	2,352	446	728	do	
9	225	Upper member, Atkinson Formation	2,960	400	2,530	430	830	Paleocene, Tamesí facies	
10	127	np	nd		2,829			do	In beds of Austin(?) age at total depth.
11	107	Upper member, Atkinson Formation	3,217?	483	2,840	377	860	do	
12	160	np	np		2,790	nd	nd	do	In beds of Taylor(?) age at total depth.
13	197	np	nd		2,790	nd	nd	do	In beds of Austin(?) age at total depth.
14	186	Upper member, Atkinson Formation	nd		2,780	nd	830	do	
15	160	do	nd		2,800	nd	810	nd	
19	152	do	nd		2,770	nd	820	nd	
23	115	Lower member, Atkinson Formation	nd		2,900?	nd	710?	Lower member, Lawson Limestone	
34	117	Upper member, Atkinson Formation	2,730	370	2,260	470	840	do	
35	141	do	2,890	370	2,460	430	800	do	
36	174	Lower member, Atkinson Formation	2,550	230	2,180	370	600	do	
37	87	Upper member, Atkinson Formation	2,560	375	2,150	410	785	do	
38	124	Lower member, Atkinson Formation	2,570	291	2,168	402	693	do	
39	138	Upper member, Atkinson Formation	2,680	370	2,270	410	780	do	
49	25	do	3,150	380	2,683	467	847	do	
50	33	do	3,250	358	2,785	465	823	do	
51	41	do	3,120	400	2,635	485	885	do	
52	33	do	2,765	345	2,315	450	795	do	
54	31	do	3,780	400?	3,270	510?	910?	do	
55	26	do	3,880	490	3,325	555	1,045	nd	
174	34	do	3,530	490	3,150	380	870	Paleocene, Tamesí facies	
56	20	do	3,585	485	3,180	405	890	do	
57	11	do	4,150	580	3,470	680	1,260?	do	
58	15	do	3,795	555?	3,335	460	1,015?	do	
59	28	do	3,690	515	3,235	455	970	do	
60	21	do	3,470	535	3,090	380	915	do	
61	18	do	3,620	505	3,190	430	935	nd	
62	±234	do	3,000	315	2,525	475	790	nd	
63	296	do	3,010	320	2,560	450	770	Paleocene, Tamesí facies	
64	200	do	2,960	405?	2,550	410	815	do	
65	245	do	2,940	300	2,485	455	755	nd	
66	221	do	2,930	340	2,470	460	800	nd	
67	270	do	3,040	320	2,575	465	785	nd	
68	93	do	2,890	308	2,440	450	758	Lower member, Lawson Limestone	
69	77	do	2,675	322	2,269	406	728	do	
72	43	do	3,635	455	3,125	510	965	Paleocene, Tamesí facies	
73	19	do	4,235	580	3,545	690	1,270	nd	
74	32	do	3,730	455	3,210	520	975	Paleocene, Tamesí facies	
75	33	do	3,722	463	3,220	502	965	nd	
76	49	do	3,630	485	3,120	510	995	nd	
77	21	do	3,820	490	3,310	510	1,000	nd	
78	25	do	3,785	455	3,228	557	1,012	nd	
177	30	do	3,610	490	3,150	460	950	nd	
85	47	do	4,700?	710?	4,300	400	1,110?	Lower member, Lawson Limestone	
90	124	do	2,322	459	1,934	388	847	Paleocene, Tamesí facies	
91	128	do	2,450	425	2,034	416	841	do	
92	142	do	2,360	510	2,130	230	740	nd	
93	138	do	2,200	570	1,875	325	895	nd	
94	134	do	2,220	545	1,890	230	875	nd	
95	118	do	2,280	510	1,950	330	840	nd	
96	95	do	2,140	470	1,850	290	760	nd	
97	136	do	2,480	540	2,150	330	870	nd	
98	52	do	2,890	510	2,560	330	840	Paleocene, Tamesí facies	
99	230	do	3,268	142?	3,056?	212?	354?	do	
100	45	do	2,720	365	2,260	460	825	Lower member, Lawson Limestone	
101	87	do	2,915	454	2,450	465	919	do	
102	52	do	2,800	436	2,340	460	896	do	
103	70	do	2,835	433	2,368	467	900	do	
104	120	do	4,800?	465?	3,900	900	1,365?	do	
110	±50	do	2,965	500	2,765?	200+	700?	Paleocene, Tamesí facies	
111	41	do	3,035	465	2,610	425	890	do	
112	14	do	nd		3,180	nd	890	Lower member, Lawson Limestone	
113	9	do	3,620	380	3,165	455	835	do	
114	58	do	3,700	245	3,185	515	760	do	

See footnote at end of table.

TABLE 3.—*Depth and thickness (in feet) of the beds of Austin age and the beds of Taylor age*—Continued

[nd, not determined; np, not penetrated]

Well (pl. 1)	Elevation (feet)	Underlying rocks	Beds of Austin age		Beds of Taylor age		Beds of Austin and Taylor age, total thickness (pl. 4A)	Overlying rocks	Remarks
			Depth to top	Thickness	Depth to top (pl. 4)	Thickness			
Florida—Continued									
F116	34	Upper member, Atkinson Formation	3,420?	230	2,920	500	730	Lower member, Lawson Limestone	
118	188	do	3,000	290	2,565	435	725	Paleocene, Tamesí facies	
119	49	do	3,500	480	3,030	470	950	do	
120	25	do	3,470	460	3,025	445	905	do	
121	69	do	3,260	430	2,795	465	895	do	
122	206	do	2,990	320	2,520	470	790	nd	
123	91	do	2,760	390	2,350	410	800	Lower member, Lawson Limestone	
124	107	do	2,820	388	2,405	415	803	do	
125	89	do	2,800	360	2,325	475	835	do	
126	73	do	2,740	390	2,310	430	820	do	
128	195	do	3,180	490	2,770	410	900	do	
130	74	do	3,700	340	3,025	675	1,015	do	
131	79	Lower Ordovician	3,400	279	2,796	604	883	do	
143	110	Upper member, Atkinson Formation	3,766	488	3,165	601	1,089	do	
145	100	do	4,650±	605	3,975?	675?	1,280?	do	
154	206	Lower Ordovician	3,060?	230	2,600?	460	690?	do	
155	32	Upper member, Atkinson Formation	3,440	350	2,950	490	840	do	
159	118	do	2,775	395	2,370	405	800	do	
160	110	do	2,755	395	2,270	485	880	do	
161	90	do	2,790	380	2,320	470	850	do	
162	73	do	2,640	330	2,159	481	811	do	
163	96	do	2,660	351	2,180	480	831	do	
164	162	do	2,790	345	2,340	450	795	do	
165	96	do	2,945	355	2,490	455	810	do	
166	67	do	2,980	400	2,537	443	843	do	
167	41	do	3,170	390	2,680	490	880	do	
168	36	do	3,030	385	2,560	470	855	do	
169	44	do	4,260	420	3,460	800	1,220	do	
170	48	do	4,460	404	3,600	860	1,264	do	
171	28	do	3,090	460	2,670	420	880	Paleocene, Tamesí facies	
Georgia									
G1	229	Tuscaloosa(?)	nd		2,580	nd	nd	Clastic beds of Navarro age	Fossils listed (2,580–2,590 ft) by Herrick (1961, p. 8) are classified as Taylor age by E. R. Applin.
2	222	Upper member, Atkinson Formation	2,798	337	2,447	351	688	do	
3	136	do	2,550	540	2,230	320	860	Paleocene, Tamesí facies	
5	345	do	1,420	680	970	450	1,130	Clastic beds of Navarro age	
7	215	do	3,020	340	2,880	140	480	do	
8	176	do	nd		2,900?	nd	720?	Upper member, Lawson Limestone	
9	147	do	3,080	310	2,860	220	530	do	
10	171	np	nd		2,925	nd	nd	nd	In beds of Austin(?) age or Taylor(?) age at total depth.
11	177	Upper member, Atkinson Formation	3,055	305	2,855	200	505	Paleocene, Tamesí facies	
12	(1)	Tuscaloosa Formation	3,000	250	2,260	740	990	Clastic beds of Navarro age	
13	317	do	3,000	270	2,270	730	1,000	do	
13a	308	do	3,015?	235	2,260	755	990	do	
14	270	Upper member, Atkinson Formation	2,440?	366?	1,900	540	906	do	
15	364	do	1,760	595	1,330	430	1,025	do	
16	276	do	2,917?	318	2,430?	487	805	nd	
17	132	do	2,500	270	1,880?	620	890?	Clastic beds of Navarro age	
18	104	do	2,480	420	2,100	380	800	do	
19	129	do	2,500	290	1,890	610	900	do	
73	446	Tuscaloosa(?) Formation	nd		1,135	nd	nd	do	Fossils listed (1,135–1,145 ft; 1,215–1,225 ft) by Herrick (1961, p. 168) are classified as Taylor age by E. R. Applin.
22	209	Upper member, Atkinson Formation	1,525	740	1,070	455	1,195	do	
23	192	do	1,645	655	1,159	486	1,141	do	
24	187	do	1,830	565	1,358	472	1,037	do	
25	181	do	3,050	290	2,810	240	530	Paleocene, Tamesí facies	
26	148	do	2,935	335	2,655	280	615	Upper member, Lawson Limestone	
27	142	do	3,070	390	2,785	285	675	do	
28	144	do	2,950	370	2,670	280	650	do	
29	156	do	2,950	322	2,680	270	592	do	
32	20	do	nd		3,270?	nd	949?	Clastic beds of Navarro(?) age	
40	26	do	3,080	396	2,740	340	736	Clastic beds of Navarro age	Fossils listed (2,740–2,750 ft) by Herrick (1961, p 261) are classified as Taylor age by E. R. Applin.
43	338	do	2,350	480	1,910	440	920	do	
47	75	do	nd		3,384	nd	386	do	
48	80	do	nd		3,400?	nd	400?	do	
56	114	do	2,400	300	1,955	445	745	do	
57	145	do	2,150	390	1,510	640	1,030	do	
62	241	Tuscaloosa(?) Formation	nd		2,040	nd	nd	do	Electric-log correlation.
65	198	do	nd		2,157	nd	nd	do	Fossils listed (2,157–2,162 ft) by Herrick (1961, p. 407) are classified as Taylor age by E. R. Applin.
69	73	do	3,571?	318	3,497?	74	392	do	
70	69	nd	nd		3,170	nd	nd	do	
72	206	Tuscaloosa(?) Formation	nd		1,870	nd	nd	do	Electric-log correlation.

[1] Data not available.

half or three-fourths of the unit, the lenses of white-speckled gray shaly chalk or marly shale increase in number downward and become a progressively darker shade of gray. The dark color of the speckled lenses seems to be due to oil staining. The speckled appearance of the shale in the lower part of the beds of Austin age, as in the Atkinson Formation, is due to large quantities of finely crushed and broken fragments of the tests of globigerine Foraminifera. Near the base of the unit, shaly beds commonly contain phosphatic nodules; glauconite; fragments of *Ostrea* sp.; and fish scales, teeth, and bones. Some thin chalky lenses near the base are packed with very small fragments of calcite molds of Foraminifera and *Inoceramus* prisms.

A significant lithologic feature marking the base of the beds of Austin age in many wells is a conglomeratic layer, commonly not more than 5 feet thick, composed for the most part of dark-brownish gray chalky shale. The shale matrix contains various amounts of fragmental fish bones and teeth; abundant *Inoceramus* prisms and fragments of other bivalves among which *Ostrea* sp. is common; and abundant specimens of *Globigerina*, *Gümbelina*, and *Globotruncana*. Some cores of the conglomerate contain pebbles of limestone, clay, and phosphatic material. The top and middle parts of a core from the Gulf Oil Corp. Brooks-Scanlon, Inc., Block 49 well 1 (pl. 4 and table 3, F101), Lafayette County, Fla., are a typical example of the conglomerates; the lower part of the core contains an Eagle Ford microfauna. This core was described by E. R. Applin as follows:

Core 18

[Depth, 3,364–3,369 ft; recovery, 5 ft]

Beds of Austin age:

Top.—Shale, brownish-gray, chalky, thinly laminated; contains some fine sand, interbedded thin layers of bluish-gray marly shale, abundant fragments of fish scales and fish bones, many specimens of *Globigerina*, *Globotruncana*, and *Planulina austiniana* Cushman.

Middle.—Shale, gray and dark-brownish-gray, speckled, microfossiliferous; contains a lens of olive-green flaky waxy shale.

Atkinson Formation, upper member:

Bottom.—Shale, light-brownish-gray; contains lenses of bluish-green to gray shale. The light brownish-gray part of the shale is speckled with crushed fossil shells and contains specimens of *Gümbelina* sp., *Globigerina* sp., and *Planulina eaglefordensis*. Some fish scales and fragments of a thin-shelled species of *Inoceramus* are also present.

The conglomerate at the base of the beds of Austin age seems to be lithologically and faunally similar to the fish-bed conglomerate described by Taff (1893, p. 303–304) in beds in northeast Texas which he classified as Eagle Ford age. Stephenson (1918, p. 148–149) regarded the conglomerate as an evidence of unconformity and placed it at the base of the Austin Chalk. According to Adkins (1932, p. 440), "Stephenson has traced Taff's fish-bed conglomerate from the Red River region southward to Hays County. It contains fossil material reworked from the underlying Eagle Ford, including several kinds of oyster shells and the teeth of several kinds of fish."

A chalky sandstone facies (pl. 4*B*; table 4) in the lower part of the unit of Austin age in northern Florida is strikingly different lithologically from the chalky limestone and marl that characterize the unit elsewhere in the report area. The facies, which has been penetrated in 18 wells in a belt across the peninsula from Taylor County on the west to Putnam and Clay Counties on the east, is present in three seemingly separate areas (pl. 4*B*). In the eastern area, which is the largest, the facies is rather poorly defined and is nearly 200 feet thick in several wells (table 4). In the central area, which is smaller and better defined than the eastern area, the greatest thickness is nearly 100 feet. The western area was penetrated by a single well in Taylor County (pl. 4*B*, and table 4, F168), where the unit correlated with the chalky sandstone facies is 35 feet thick.

TABLE 4.—*Depth and thickness, (in feet), of the chalky sandstone facies of the beds of Austin age*

[Data from cores unless otherwise indicated]

Well (table 1, pls. 1, 4*B*)	Depth to sandstone		Thickness of sandstone (pl. 4*B*)	Depth to base of beds of Austin age (table 2)
	Top	Base		
F2	2,900	3,050	150	3,050
3	2,920	3,100	180	3,100
4	2,950	3,130	180	3,130
6	2,850	3,001	151	3,001
8	2,900	3,080	[1] 180	3,080
23	3,440	3,610	[1] 170	3,610
34	3,012	3,100	88	3,100
37	2,840	2,935	95	2,935
38	2,850	2,861	11	2,861
100	3,075	3,085	10	3,085
101	3,330	3,358	28	3,369
102	3,203	3,236	33	3,236
154	3,110	3,290	[1] 180	3,290
159	3,150	3,160	[1] 10	3,170
161	3,150	3,170	20	3,170
162	2,880	2,945	65	2,970
163	2,920	3,011	91	3,011
168	3,380	3,415	35	3,415

[1] Cuttings.

The facies in the well in Taylor County is composed of hard white to light-gray fine-grained to very fine grained calcitic sandstone containing small amounts of glauconite and mica, some phosphate nodules, fragments of fish bones and fish teeth, a lens of hard sandy chalk, and thin partings of dark-brownish-gray and dark-gray slightly speckled flaky shale.

The wells in the central area penetrated moderately hard to soft light-colored mostly fine-grained chalky argillaceous sandstone that is commonly calcitic, and, in some wells, gypsiferous and dolomitic. The sandstone contains phosphatic nodules, shell fragments, glauconite, fish remains, and a little mica. Thin lenses of black shale and white-speckled gray shale are interbedded with the sandstone in most of the walls, and thin lenses of tan sandy limestone are present in a few. In this area the chalky sandstone facies of the beds of Austin age rests on the upper member of the Atkinson Formation.

The chalky sandstone in the wells in the eastern area seems to be fine- to coarse-grained and more gypsiferous and dolomitic than the sandstone in the central area. Shell fragments, fish remains, phosphatic nodules, and glauconite are less abundant in the eastern area. In this area the chalky sandstone facies of the beds of Austin age rests on the chalky dolomitic gypsiferous sandstone facies of the lower member of the Atkinson Formation (p. G13, G15). Certain lithologic and microfaunal differences, however, aid in distinguishing the two units of somewhat similar appearance. The chalky sandstone facies of the beds of Austin age is generally more chalky than the calcareous facies of the lower member of the Atkinson. The chalky sandstone facies in the lower member of the Atkinson, on the other hand, is usually more highly gypsiferous and contains carbonaceous lenses and streaks of gray-green sandy shale or argillaceous sand not commonly present in the beds of Austin age. Each facies contains glauconite, phosphatic nodules, shell fragments, and, in some wells, specimens of miliolids. Although the miliolids have not been specifically determined, those in the beds of Austin age are definitely distinguishable from those in the lower member of the Atkinson. Samples of the lower member of the Atkinson in two wells (pl. 4*B*, F4, Alachua County; F36, Columbia County) contained specimens of the diagnostic fossil, *Cuneolina walteri* Cushman and Applin, and a core from one well (pl. 4*B*, F6, Baker County) contained specimens of *Pseudofrondicularia lanceola* (Reuss) var. *bidentata* (Cushman), a fossil that has not been reported from beds older than Austin age.

Another distinctive lithologic characteristic of the beds of Austin age is the occurrence over a broad area of thin lenses of *Oligostegina limestone* (pl. 4*B*; table 5; fig. 2), not previously reported from the subsurface in the southeastern gulf region. These limestone lenses are composed almost entirely of closely packed minute spherical to ovoid bodies of organic origin. The usage of the name *Oligostegina* for this group of microfossils of uncertain affinities and the stratigraphic and geographic distribution of the organisms in different parts of the world were discussed by Galloway (1933, p. 334) and Glaessner (1948, p. 21–22). Table 5 indicates that, in the report area, lenses of *Oligostegina* limestone occur in the beds of Austin age at various levels ranging from the base to the top. The scattered distribution of the wells (pl. 4*B*) containing *Oligostegina* suggests that the fossils might, in fact, have been present in the intervening wells, but they were not observed owing to the vagaries of cutting samples. On the basis of stratigraphic position and lithologic similarity, we correlated the *Oligostegina* limestone at the top of the beds of Austin age with the outcropping Arcola Limestone Member of the Mooreville Chalk. The Arcola (Stephenson and Monroe, 1938, p. 1655–1657; figs. 1, 2) is a unit, 4–16 feet thick, composed of alternating layers of hard limestone and marl that form the upper member

TABLE 5.—*Distribution of* Oligostegina *limestone in the beds of Austin age*

[Data from cuttings unless otherwi4e indicated]

Well (table 1, pls. 1, 4*B*)	Depth to beds of Austin age (feet)		Depth to sample containing *Oligostegina* limestone (feet)
	Top (table 3)	Base (table 2)	
Florida			
F5	3,030	3,342	3,060–3,070
6	2,615	3,001	2,620–2,630
34	2,730	3,100	2,730–2,740
			[1] 2,962–2,972
			[1] 2,982–3,012
35	2,890	3,260	2,980–3,000
36	2,550	2,780	2,650–2,660
37	2,560	2,935	2,710–2,720
38	2,570	2,861	[1] 2,839–2,845
51	3,120	3,520	3,470–3,480
69	2,675	2,997	2,830–2,840
98	2,890	3,400	2,990–3,000
100	2,720	3,085	2,950–2,960
101	2,915	3,369	[1] 3,327–3,332
103	2,835	3,268	[1] 3,250–3,260
104	4,800	5,265	[1] 4,965–4,985
			[1] 5,140
126	2,740	3,130	2,900–2,910
131	3,400	3,679	3,450–3,460
155	3,440	3,790	[1] 3,760–3,766
			[1] 3,778–3,788
159	2,775	3,170	2,780–2,790
161	2,790	3,170	2,860–2,870
165	2,945	3,300	2,950–2,960
166	2,980	3,380	3,350–3,360
167	3,170	3,560	3,500–3,540
169	4,260	4,680	4,540–4,550
Georgia			
G11	3,055	3,360	3,060–3,070
25	3,050	3,340	3,055–3,060
69	3,571	3,889	[1] 3,571–3,587
			[1] 3,612–3,626
			[1] 3,746–3,760

[1] Core sample.

of the Mooreville Chalk in Alabama as far east as eastern Montgomery County (Monroe, 1946; Eargle, 1948, p. 68–69). The Mooreville Chalk with its upper member, the Arcola, is correlated (Monroe, 1946) with the upper part of the Austin Chalk in northeastern Texas. According to Braunstein (1950, p. 19). "The Arcola limestone member of the Mooreville, an excellent surface unit at the Taylor-Austin contact, is so thin as to be not often observed in the subsurface samples; where found it retains the typical surface character of hard, white chalk containing abundant minute spherical bodies." Lenses of *Oligostegina* limestone, as a characteristic feature of the basal part of the Austin Chalk in Texas, have been observed by E. R. Applin as well as others, but, as far as we know, this has not been previously reported. Figure 2 is a photomicrograph of a thin section of *Oligostegina* limestone that was present in a sample of cuttings at 4,540–4,550 feet in the Grace Drilling Co., Retail Lumber Co. (pl. 1; pl. 4*B* and table 6, F169), Volusia County, Fla. A petrographic study of the thin section showed that the limestone consists of closely packed specimens of *Oligostegina*, a few specimens of *Globigerina*-like Foraminifera, and a small quantity of interstitial calcite. Examination with an oil-immersion objective indicates that the specimens of *Oligostegina* show the following characteristics:

1. Smooth outer surfaces with a slight discontinuity between the surfaces and the interstitial calcite matrix.
2. Concentric-layered structure; the layers are more smooth and regular than the chamber walls of Foraminifera in the thin section.
3. Rough inner surfaces overgrown, in some instances, with rhombic or prismatic calcium carbonate.
4. No indication that the bodies were originally solid.
5. No evidence of fibrous radiating structure of the shell, such as can often be recognized at low magnification in oolites.
6. An optical orientation similar to that of the foraminifers, in which the slow ray of the calcium carbonate crystals is parallel to the tangent of the concentric structure.

The microfauna of the beds of Austin age, which consists mainly of planktonic Foraminifera and lacks numerous diagnostic fossils, is less diversified than that of the overlying beds of Taylor age. *Citharina texana* (Cushman), one of the well-known characteristic species of the Austin in Texas, is rarely found in the Florida peninsula, but it is found at various stratigraphic levels in the beds of Austin age in other parts of the southeastern gulf coast. A few other microfossils that seem to be restricted to the beds of Austin age (or to beds of late Austin and early Taylor age) are found in sufficient quantity to be useful in identifying the unit of Austin age. These fossils are:

Heterostomella austiniana Cushman
Guadryina (*Siphogaudryina*) *austiniana* Cushman
Eouvigerina plummerae Cushman
Neobulimina irregularis Cushman and Parker
Valvulineria infrequens Morrow. (Typical form; a variety is common in the Atkinson.)
Hastigerinoides alexanderi (Cushman)
Globorotalities umbilicatus (Loetterle)
Planulina austiniana Cushman

BEDS OF TAYLOR AGE

The beds of Taylor age (pl. 4; table 3) have been identified chiefly by the similarity of their microfauna to that of the Taylor Group of Texas. They overlie beds of Austin age (p. G16), and in most of the report area they are directly below the Upper Cretaceous strata of Navarro age. In western and north-central Florida and a part of southern Georgia (pls. 5*C*, 6*A*), however, the beds of Navarro age are absent, and the beds of Taylor age are unconformably overlain by clastic beds of Paleocene age whose microfauna is close to that of the type Tamesí fauna (Velasco Formation) of Mexico (Applin, E. R., 1964).

We did not prepare an isopach map for each unit because the contact of the older unit of Austin age with the younger unit of Taylor age is not clearly defined. The combined thickness of the unit of Austin age and the unit of Taylor age in the various wells is shown in table 3, and the isopachs are shown on plate 4*A*.

The combined thickness of the beds of Austin and Taylor age ranges from about 400 to about 1,300 feet in the report area. In a depocenter in southwestern Georgia (pl. 4*A*, area A), the unit is more than 1,100 feet thick, but it thins gradually northward toward the outcrop of the Cretaceous rocks and southward toward north-central Florida and southeastern Georgia. The isopachs indicate a thickness ranging from about 400 to 800 feet in an elongate narrow area whose axis (pl. 4*A*, trend 1) extends southwestward from Pierce and Wayne Counties in southeastern Georgia to Jefferson County in north-central Florida. On this axis the unit seems to be abnormally thin in the Southern States Oil Corp. Miller and Gossard 1 (pl. 4*A* and table 3, F99), Jefferson County, Fla., where it is 354 feet thick, and in the California Co. Brunswick Peninsula Corp. 1 (pl. 4*A*, and table 3, G69), Wayne County, Ga., where it is 392 feet thick. The axis of a roughly parallel narrow area to the south (pl. 4*A*, trend 2) extends from Duval and St. Johns Counties in the northeastern part of the Florida peninsula, southwestward to Levy County on the gulf coast. In this area the unit is about

700–800 feet thick. Between the two elongate narrow areas, the combined unit is about 900 feet thick, and seems to be more than 1,100 feet thick in a depocenter (pl. 4*A*, area B) on the Atlantic Coast in southeastern Georgia and northeastern Florida. A gradual southward thickening of the combined unit in the central part of the peninsula is shown by the isopachs south of trend 2 (pl. 4*A*). The unit ranges in thickness from about 750 to 900 feet in wells in Jackson, Gadsden, Liberty, and Wakulla Counties in north-central Florida and in Seminole and Decatur Counties in southwestern Georgia. The axis of this elongate narrow area (pl. 4*A*, trend 3), which trends northwest, is nearly perpendicular to the trend of the axes (trends 1 and 2) of the two narrow areas described above.

In general, the beds of Taylor age can be differentiated into two facies: a carbonate facies that occupies the Florida peninusla and a lithologically variable facies, in which clastic rocks predominate, that occupies north-central Florida and southern Georgia.

The carbonate facies is composed mainly of chalk, in which lenses of dolomite and dolomitic chalk are irregularly interbedded. Local variations in the chalk facies have been observed in wells in the northern part of the peninsula. Wells near the crest of the Peninsular arch in Alachua, Bradford, and Putnam Counties, Fla., penetrated beds of Taylor age that are composed largely of chalky dolomite and dolomitic chalk containing distinctive inclusions of gypsum and anhydrite. Small colorless crystals of anhydrite that are nearly uniform in size are common to abundant in the lower and middle parts of the unit, and scattered clusters of moderately large crystals are present in the samples from some wells. The upper part of the unit in the Sun Oil Co. Ruth M. Bishop 1 (pl. 4*C* and table 3, F36) and W. F. Johnson 1 (pl. 4*C* and table 3, F37), Columbia County, Fla., is composed of gypsiferous dolomite and dolomitic chalk. About 100 feet below the top of the unit of Taylor age, the Bishop well penetrated nearly 50 feet of light-brown dolomite having a honeycomb appearance that is due to abundant molds and impressions of oolites. Most of the molds are filled with secondary gypsum. Samples taken at the top of the unit of Taylor age in a number of wells in Columbia and Suwannee Counties, Fla., are composed of chalk containing a small amount of fine-grained glauconite. In contrast to the noticeably dolomitic character of the chalk at the crest of the Peninsular arch, the beds of Taylor age on the southwest flank of the arch are predominantly chalk containing a few scattered lenses of dolomite. An unusual variation in the lithology and fauna of the unit was observed in the samples from the St. Marys River Corp. Hilliard Turpentine Co. 1 (pl. 4*C* and table 3, F143), Nassau County, Fla. The upper part of the unit in this well is chalk, and the lower part is soft flaky somewhat bentonitic(?) carbonaceous shale interbedded with white chalk. The shale, which is sparsely microfossiliferous, contains scattered lenses composed chiefly of the shell fragments of fresh- or brackish-water bivalves, intermingled with which are a few bone fragments of small land animals. The unusual nonmarine fauna in the Hilliard well is indicative of a local deltaic environment during the early stages of deposition of the beds of Taylor age.

A thin bed, or several closely associated beds, of a distinctive light-gray to light-greenish-gray soft thinly flaky bentonitic(?) clay characterize the top of the unit of Taylor age in the northern part of the peninsula. The bentonitic nature of the clay, indicated by its rapid disintegration in water, and its widespread and stratigraphically uniform occurrence, suggest an ash-fall origin for the clay. This bed, which is indicated on electric logs by a sharp retraction of the spontaneous-potential and resistivity curves, has been accepted by geologists as a useful guide for identifying the top of the beds of Taylor age and for correlating the unit from well to well.

The lower part of the unit of Taylor age in north-central Florida, west of the Aucilla River, is composed largely of gray marl and shale that grades eastward into white chalk. The ratio of marl to chalk in the different wells in the area seems to vary with their geographic position; the marl thickens toward the west and north at the expense of the chalk. Toward the north and west, also, the marl and shale facies is sparsely sprinkled with small flakes of mica. Glauconite is common in the beds of Taylor age in wells drilled in Jackson County, Fla.

The beds of Taylor age in southern Georgia are composed mainly of interbedded gray marl and shale, sandy shale, and fine to medium sand and fine- to medium-grained sandstone. Chalk occurs at the top and in the upper part of the unit in southeastern Georgia, as shown by the samples from wells in Brooks and Echols Counties, and some wells in Clinch County. Beds of sand, sandstone, and sandy shale that are common in the lower part of the unit in southeastern Georgia make up a progressively larger part of the unit toward the north and west. Glauconite, which seems to be irregularly distributed in the beds of marly shale, sand, and sandstone, is most common near the top of the unit in southern Georgia; small flakes of mica are usually present in the shale.

The fauna of the beds of Taylor age is characterized by the common to abundant *Inoceramus* prisms and fragments. In the Florida peninsula this material is usually abundant at and near the top of the unit; in north-central Florida and southern Georgia, it is usually more common in the middle and lower parts. Fragments of other bivalves, including *Ostrea* sp., have been reported from some wells, generally in the basal part of the unit.

Several species of Foraminifera that are commonly found at or near the top of the unit and that aid in the recognition of its upper boundary throughout the report area are:

Stensiöina americana Cushman and Dorsey
Bolivinoides decorata Jones
Globorotalites conicus (Carsey)
Bolivina incrassata Reuss

The following foraminiferal species are commonly found near the base of the unit throughout the report area:

Pseudogaudryinella capitosa (Cushman)
Kyphopyxa christneri (Carsey)
Planulina texana Cushman

Other characteristic species of Foraminifera that are present in the unit of Taylor age in the Florida peninsula are:

Cibicides harperi (Sandidge) large var. (Small varieties occur in the overlying lower member of the Lawson Limestone.)
Anomalina cosdeni Applin and Jordan
Anomalina sholtzensis Cole
Planulina cedarkeysensis Cole
Globotruncana cretacea Cushman
Buliminella carseyae Plummer

In addition to the species of Foraminifera listed above as occurring near the top and near the base of the beds of Taylor age, the following species are common and characteristic of the entire unit in north-central Florida and southern Georgia.

Arenobulimina americana Cushman
Planulina dumblei Applin
Globotruncana arca Cushman
marginata (Reuss)
canaliculata (Reuss)
Pseudotextularia plummerae (Loetterle)
elegans (Rezak)
excolata (Cushman)
Globigerina saratogaensis Applin

BEDS OF NAVARRO AGE

The beds of Navarro age (pls. 5, 6; table 6) compose the youngest subsurface stratigraphic unit of the Gulf Series in the report area. The unit is present in two geographically separate areas and is composed of two lithologically and faunally distinct facies that are considered to be virtually equivalent in age. Subsurface beds containing a typical Navarro fauna constitute the clastic facies of the uppermost Cretaceous (pls. 5*C*, 6*A*) in much of the Coastal Plain of Georgia. The carbonate facies of the uppermost Cretaceous (pls. 5*C*, 6*A*)—the Lawson Limestone (Applin and Applin, 1944, p. 1681, 1708–1709)—is found in southeastern Georgia, in the Florida peninsula, and about as far west as the Aucilla River in north-central Florida. Lawson Limestone has been divided into two members, upper and lower, each having characteristic lithologic features and a distinctive microfauna. Stephenson (1941, p. 35) stated, "The Navarro group of Texas and formations of Navarro age in the Atlantic and Gulf Coastal Plain in general, have long been accepted by most authorities as a high Upper Cretaceous (Maestrichtian) age." The lower member of the Lawson Limestone is characterized by several species of *Lepidorbitoides* found also in the Maestrichtian of Europe (Douvillé, 1929; Applin and Applin, 1944, p. 1708–1709). Fragments of rudistids that are found in the upper member of the Lawson Limestone in Florida have not been determined generically; but rudistid-bearing beds are exposed at many localities in the West Indies, and according to Stephenson (1938, p. 2), the prevailing opinion seems to be that they are high in the Upper Cretaceous Series. A few specimens of large Foraminifera characteristic of the upper member of the Lawson Limestone are present also in the so-called Monroe gas rock of Louisiana and the so-called Jackson gas rock of Mississippi, both of which are usually classified as Navarro age. The clastic beds of Navarro age and the Lawson Limestone rest on beds of Taylor age with apparent conformity. The clastic beds of Navarro age, in most wells, are unconformably overlain by clastic beds of Midway (Paleocene) age; the Lawson Limestone throughout most of its extent is unconformably overlain by a Paleocene limestone that has been named the Cedar Keys Limestone (Cole, 1944, p. 27–28). The beds of Navarro age are absent in a part of southern Georgia and in Florida, west of the Aucilla River (pls. 5*C*, 6*A*); in this area, as already pointed out, the beds of Taylor age are the youngest Cretaceous rocks that have been penetrated by drills. According to our interpretation, gentle upwarping occurred during Taylor and Navarro time in the area occupied by the beds of Taylor age (pl. 6*A*). The upwarped beds of Taylor age formed a southwestward-trending barrier that separated two areas of widely different depositional environment. On the north the clastic beds of Navarro age were deposited in a shallow-water marine environment; on the south the Lawson Limestone was deposited on a shallow partly restricted marine shelf (Rainwater, 1960, p. 61, fig. 25). The data on which the interpretation is based are discussed on page G31.

TABLE 6.—*Depth and thickness (in feet) of the beds of Navarro age*

[nd, not determined]

Well (pl. 1)	Elevation (feet)	Underlying rocks	Clastic rocks		Lawson Limestone					Overlying rocks
					Lower member		Upper member		Total thickness (pl. 5C)	
			Depth to top	Thickness (pl. 5C)	Depth to top	Thickness (pl. 5A)	Depth to top	Thickness (pl. 5A)		
					Alabama					
A3	504	Beds of Taylor age	360	nd	Absent		Absent			Paleocene.
5	554	nd	nd		Absent		Absent			nd.
25	192	Beds of Taylor age	1,000	100	Absent		Absent			Paleocene.
26	302	do	1,175	110?	Absent		Absent			Beds of Midway (Paleocene) age.
64	217	do	1,290	160	Absent		Absent			nd.
27	140	do	1,700	90	Absent		Absent			Beds of Midway (Paleocene) age.
68	270	do	1,400	145	Absent		Absent			nd.
					Florida					
F1	77	Beds of Taylor age	Absent		2,250	170	2,030	220	390	Cedar Keys Limestone (Paleocene).
2	112	do	Absent		2,140	165	1,920	220	385	Do.
3	168	do	Absent		2,200	140	1,950	250	390	Do.
4	132	do	Absent		2,250	150	2,015	235	385	Do.
5	134	do	Absent		2,340	190	2,130	210	400	Do.
6	155	do	Absent		2,010	220	1,850	160	380	Do.
8	142	do	Absent		2,240	112	2,010?	230	342	Do.
23	115	do	Absent		2,690?	210	2,490?	200?	410?	Do.
34	117	do	Absent		2,010	250	1,710	300	550	Do.
35	141	do	Absent		2,230	230	1,949	281	511	Do.
36	174	do	Absent		1,940	240	1,810	130	370	Do.
37	87	do	Absent		1,900	250	1,670	230	480	Do.
38	124	do	Absent		1,930	238	1,770	160	398	Do.
39	138	do	Absent		2,035	235	1,780	255	490	Do.
49	25	do	Absent		2,163	520	1,894	269	789	Do.
50	33	do	Absent		2,250	535	1,869	385	920	Do.
51	41	do	Absent		2,150	485	1,780	370	855	Do.
52	33	do	Absent		1,900	415	1,710	190	605	Do.
54	31	do	Absent		2,830	440	2,457	373	813	Do.
68	93	do	Absent		2,094	346	1,780	314	660	Do.
69	77	do	Absent		2,020	249	1,780	240	489	Do.
85	47	do	Absent		3,600	700	3,310	290	990	Do.
93	138	do	Present?		Absent		Absent			nd.
94	134	do	Present?		Absent		Absent			nd.
95	118	do	Present?		Absent		Absent			nd.
100	45	do	Absent		1,860	400	1,620	240	640	Cedar Keys Limestone (Paleocene).
101	87	do	Absent		1,970	480	1,707	266	746	Do.
102	52	do	Absent		1,900	440	1,670	230	670	Do.
103	70	do	Absent		1,900	468	1,620	280	748	Do.
104	120	do	Absent		3,510	390	3,380?	130?	520	Do.
112	14	do	Absent		2,520	660	2,280	240	900	Do.
113	9	do	Absent		2,531	634	2,240?	291?	925	Do.
114	58	do	Absent		2,810	375	2,410	400	775	Do.
116	34	do	Absent		2,535	385	2,190	345	730	Do.
123	91	do	Absent		2,160	190	2,030	130	320	Do.
124	107	do	Absent		2,230	175	2,110	120	295	Do.
125	89	do	Absent		2,190	135	2,035	155	290	Do.
126	73	do	Absent		2,140	170	2,010?	130	300	Do.
128	195	do	Absent		2,450	320	2,265?	185?	505	Do.
130	74	do	Absent		2,670	355	2,540	130	485	Do.
131	79	do	Absent		2,470	326	2,300	170	496	Do.
143	110	do	Absent		2,970	195	2,740	230	425	Do.
145	100	do	Absent		3,600?	375?	3,330?	270?	645?	Do.
154	206	do	Absent		nd	140?	2,170?	290?	430?	Do.
155	32	do	Absent		2,540	410	2,250?	290	700	Do.
159	118	do	Absent		1,950	420	nd	nd	420+	Do.
160	110	do	Absent		1,895	375	1,615?	280	655	Do.
161	90	do	Absent		1,980	340	1,660	320	660	Do.
162	73	do	Absent		1,940	219	1,565	375	594	Do.
163	96	do	Absent		1,960	220	1,620	340	560	Do.
164	162	do	Absent		2,000	340	1,770	230	570	Do.
165	96	do	Absent		2,070	420	1,970	100	520	Do.
166	67	do	Absent		2,310	227	2,160	150	377	Do.
167	41	do	Absent		2,250	430	2,000	250	680	Do.
168	36	do	Absent		2,296	264	2,125?	171	435	Do.
169	44	do	Absent		2,965	495	2,700?	265?	760	Do.
170	48	do	Absent		3,025	575	2,891	134	709	Do.
					Georgia					
G1	229	Beds of Taylor age	2,055	525	Absent		Absent			Paleocene(?).
2	222	do	1,804	643	Absent		Absent			Beds of Midway (Paleocene) age.
5	345	do	560	410	Absent		Absent			Do.
6	65	do	Absent		Present?	nd	2,580?	nd	nd	nd.
7	[1] 215	do	2,560	320	Absent		Absent			Beds of Midway (Paleocene) age.
8	176	do	Absent		Absent		2,790?	110?	110?	nd.
9	147	do	Absent		Absent		2,820?	40?	40?	Paleocene, Tamesí facies.
12	([2])	do	1,830	430	Absent		Absent			Paleocene(?).
13	[1] 317 [3] 308	do	1,835	435	Absent		Absent			Do.
13a	[1] 308? [3] 299	do	1,835	425	Absent		Absent			Do.
14	[4] 270	do	1,680	220	Absent		Absent			Beds of Midway (Paleocene) age.
15	364	do	1,040	290	Absent		Absent			nd.

See footnotes at end of table.

TABLE 6.—*Depth and thickness (in feet) of the beds of Navarro age*—Continued

[nd, not determined]

Well (pl. 1)	Elevation (feet)	Underlying rocks	Clastic rocks		Lawson Limestone					Overlying rocks
					Lower member		Upper member		Total thickness (pl. 5*C*)	
			Depth to top	Thickness (pl. 5*C*)	Depth to top	Thickness (pl. 5*A*)	Depth to top	Thickness (pl. 5*A*)		
Georgia—Continued										
G16	276	Beds of Taylor age	Present?	----------	Absent	----------	Absent	----------	----------	nd.
17	132	-----do	1,670	210	Absent	----------	Absent	----------	----------	Beds of Midway (Paleocene) age.
18	104	-----do	2,050	50	Absent	----------	Absent	----------	----------	Paleocene, Tamesí facies.
19	129	-----do	1,660	230	Absent	----------	Absent	----------	----------	nd.
[5] 73	446	-----do	827	308	Absent	----------	Absent	----------	----------	Beds of Midway (Paleocene) age.
22	209	-----do	770	300	Absent	----------	Absent	----------	----------	Do.
23	192	-----do	850	309	Absent	----------	Absent	----------	----------	Do.
24	187	-----do	1,200?	158?	Absent	----------	Absent	----------	----------	Do.
26	148	-----do	Absent	----------	Absent	----------	2,600?	55	55	nd.
27	142	-----do	Absent	----------	Absent	----------	2,700?	85	85	nd.
28	144	-----do	Absent	----------	Absent	----------	2,590?	80	80	nd.
29	156	-----do	Absent	----------	Absent	----------	2,610	70	70	Paleocene, Tamesí facies.
40	26	-----do	2,240	500	Absent	----------	Absent	----------	----------	Beds of Midway (Paleocene) age.
43	338	-----do	1,690	220	Absent	----------	Absent	----------	----------	Do.
47	75	-----do	2,715	669	Absent	----------	Absent	----------	----------	Do.
48	80	-----do	2,735	665	Absent	----------	Absent	----------	----------	Do.
56	114	-----do	1,900	55	Absent	----------	Absent	----------	----------	Paleocene, Tamesí facies.
57	57	-----do	1,430	80	Absent	----------	Absent	----------	----------	Beds of Midway (Paleocene) age.
62	241	-----do	1,630	410	Absent	----------	Absent	----------	----------	Do.
65	198	-----do	1,700	457	Absent	----------	Absent	----------	----------	Do.
69	73	-----do	2,862	635?	Absent	----------	Absent	----------	----------	Do.
70	69	-----do	2,400	770	Absent	----------	Absent	----------	----------	nd.
[6] 71	195	-----nd	1,780	nd	Absent	----------	Absent	----------	----------	Paleocene(?).
72	206	Beds of Taylor age	1,510	360	Absent	----------	Absent	----------	----------	nd.

[1] Kelly bushing.
[2] Elevation not available.
[3] Ground elevation.
[4] Estimated.
[5] Fossils listed (900–910 ft) by Herrick (1961, p. 168) are classified as Navarro age by E. R. Applin.
[6] Fossils listed (1,790–1,800 ft) by Herrick (1961, p. 440) are classified as Navarro age by E. R. Applin.

CLASTIC BEDS

Data on the thickness of the clastic beds of Navarro age are provided by relatively few, rather widely scattered wells, allowing alternative interpretations of the thickness map. According to our interpretation (pl. 5*C*), the clastic beds thicken northward from a pinchout at their southern limit to about 400 feet in a well (pl. 5*C* and table 6, G5) in Calhoun County, Ga.; 640 feet in a well (pl. 5*C* and table 6, G2) in Atkinson County, Ga.; and 770 feet in a well (pl. 5*C* and table 6, G70) in Wayne County, Ga. Northward from this axis of thickening, the beds of Navarro age thin towards the outcrop of the Gulf Series. A prominent area of gradual thinning in the beds of Navarro age in Jeff Davis, Coffee, Irwin, and Tift Counties, Ga., suggests a structural upwarp.

The clastic facies of the subsurface beds of Navarro age (pls. 5*C*, 6*A*) near its southern limit in Georgia is composed, in general, of gray to dark-brownish-gray calcareous shale and clay that is commonly silty and micaceous, and contains lenses of fine-grained argillaceous calcareous sandstone. The upper part of the unit in many wells contains comminuted fragments of carbonaceous material and unfossiliferous sandstone. The uppermost Cretaceous beds that were penetrated in some of the wells in the west-central part of the Coastal Plain of Georgia were correlated by Herrick (1961) with the outcropping Providence Sand (pl. 6*A*). On the basis of microfossils listed by Herrick, E. R. Applin classified the uppermost Cretaceous beds in some of these wells as Navarro in age. For information on the lithology and fauna of these Upper Cretaceous beds, the reader is referred to Herrick's excellent descriptions of the well samples.

Microfaunal species characteristic of the clastic beds of Navarro age in the subsurface in the Coastal Plain of Georgia are listed below. The species marked with an asterisk (*) have been reported only from the Navarro.

Clavulinoides trilatera (Cushman) Cushman
Marsonella oxycona (Reuss) Cushman
Dorothea bulleta (Carsey) Plummer
Robulus navarroensis (Plummer) Cushman*
Palmula rugosa (d'Orbigny) Cushman
Heterohelix globulosa (Ehrenberg) Egger
Planoglobulina acervulinoides (Egger) Cushman*
Siphogenerinoides plummeri (Cushman) Cushman*
Bulimina aspera Cushman and Parker
Anomalina cf. *A. rubiginosa*
Nodosaria affinis Reuss
Gaudryina rudita Sandidge
Trochammina sp.
Valvulineria cf. *V. umbilicatula* (d'Orbigny) Cushman
Bulimina kickapooensis Cole
Loxostoma plaitum (Carsey) Cushman
Globotruncana cretacea Cushman
Globotruncana fornicata Plummer
Anomalina pseudopillosa Carsey*
Cibicides harperi (Sandidge) Cushman
Globigerina cretacea

LAWSON LIMESTONE

The Lawson Limestone (pl. 5*C*) thickens gradually southward from its northern limit to about 400 feet in the northeastern part of the peninsula and to about 900 feet along the gulf and Atlantic coasts. A southwestward-trending axis of thickening in the northwestern part of the peninsula extends from Baker County, Fla., at the northeast, to Dixie County, Fla., at the southwest. The nature and location of the respective northern limits of the lower and upper members of the Lawson Limestone are not clearly defined by the available subsurface data. As interpreted in this report, however, the lower member (pl. 5*A*, *D*) is overlapped at its northern limit by the upper member. The postulated northern limit of the upper member is shown on plates 5*B*, *C*, and 6*A*. Evidence supporting the overlap in a small area in southeastern Georgia is provided by stratigraphic data from four wells in Echols County (pl. 5*B*, *C*, *E*, and table 6, G26–G29) and two wells in Clinch County (pl. 5*B*, *C*, *E*, and table 6, G8 and G9). The lower member of the Lawson is absent in these six wells which penetrated 40–100 feet of the upper member unconformably overlying the beds of Taylor age. The isopachs indicate that the thickness maps of the lower and upper members are each roughly similar to the total thickness map of the Lawson Limestone. (See pl. 5*A*, *B*, *C*.) The lower member (pl. 5*A*) ranges in thickness from a pinchout at its northern limit to about 200 feet in wells in northeastern Florida and to about 600 feet in wells along the Atlantic and gulf coasts of the peninsula. The upper member (pl. 5*B*) ranges in thickness from a pinchout at its northern limit to about 200 feet in wells in northeastern Florida and to about 300 feet in wells along the Atlantic and gulf coasts.

LOWER MEMBER

The lower member of the Lawson Limestone (pl. 5*A*) is mostly white chalk; irregularly interbedded at various levels are lenses of chalky dolomite and dolomitic chalk. Small gypsum blebs are a minor constituent in the lenses. The dolomitic lenses, which constitute a small part of the lower member, are commonly found both near the base and close to the top. The characteristic soft white chalk grades abruptly upward into dolomitic chalk and is overlain by relatively thin layers of finely crystalline dolomite in the uppermost part of the lower member. Other lithologic characteristics were observed in cuttings from scattered wells. Traces of glauconite are found in samples of chalk taken near the top of the lower member in the Hunt Oil Co. J. W. Gibson 2 (pl. 5*A* and table 6, F124), Madison County, Fla., and Sun Oil Co. H. T. Parker 1 (pl. 5*A* and table 6, F131), Marion County, Fla. In the Sun Oil Co. Alto Adams 1 (pl. 5*A* and table 6, F68), Gilchrist County, Fla., 236 feet of soft white chalk in the lower part of the lower member contains a well-preserved characteristic microfauna. Overlying the chalk is 60 feet of coquina composed of worn fragments of fossils that are coarser and better preserved near the top, and 50 feet of indurated cream-colored chalk containing rounded and worn fragments of microfossils. In general, the upper boundary of the lower member seems to be gradational; the dolomitic chalk or chalky dolomite of the lower member grades upward into finely granular brown dolomite in the basal part of the upper member. The highest occurrence of the genus *Lepidorbitoides*, which is commonly accompanied by *Sulcoperculina cosdeni*, Applin and Jordan, coincides generally with the upper boundary of the lower member.

A uniform and distinctive microfauna characterizes the lower member of the Lawson Limestone in the Florida peninsula, and with few exceptions the species are restricted to that stratigraphic unit. Specimens of Foraminifera are abundant in samples of the lower member from nearly all wells, and several species of the large foraminiferal genus *Lepidorbitoides* are dominant in the fauna. Of common occurrence are specimens of several species of immature brachiopods (pl. 8, figs. 4–7), fragments of a number of species of Bryozoa, and distinctive echinoid spines. The microcrinoid, *Saccocoma* sp. (pl. 8, fig. 10), is present in samples of the lower member of the Lawson from nearly all wells that penetrated the unit.

Foraminifera characteristic of the lower member of the Lawson are:

Lepidorbitoides nortoni (Vaughan)
- *minima* H. Douvillé
- *floridensis* Cole
- (*Asterorbis*) *aquayoi* D. K. Palmer
- (*Asterorbis*) *rooki* Vaughan and Cole

Sulcoperculina cosdeni Applin and Jordan
Robulus cf. *R. munsteri* (Roemer)
Robulus cf. *R. alexanderi* Sandidge
Lenticulina rotulata Lamarck
Cibicides harperi (Sandidge) (Small specimens are present in the upper part; large specimens are abundant near the base.)
Globotruncana cretacea Cushman
Loxostoma plaitum (Carsey) Cushman
Palmula rugosa (d'Orbigny) Cushman
Frondicularia cf. *F. dimidia* Bagg
Arenobulimina americana Cushman. (Common close to the base.)
Marsonella oxycona (Reuss)

In regard to specimens of *Saccocoma* (pl. 8 fig. 10) from the lower member of the Lawson Limestone in Florida, Raymond E. Peck (written commun., 1952) reported: "*Saccocoma* is a pelagic type crinoid that occurs commonly in the Solnhofen Limestone of

Bavaria, the Kimmeridge clays of England, and the Campanian chalks (zone of *Actinocamax quadratus*) of Sussex, England. This is the first record of the genus in North America." Peck (written commun., 1957) also reported: "* * * I have specimens of this crinoid from the Navarro from several localities of the gulf coast, ranging in distribution from central western Texas to Florida."

Several species of algae, including very characteristic disk- and ball-shaped forms (pl. 8, figs. 8, 9) are found in the fauna of the lower member. Richard Rezak (written commun., 1954) reported: "The ball- and disk-shaped objects resemble very closely the Recent genus *Bornetella* Munier-Chalmas 1877. The genus contains four species that are restricted to the warm waters of the Pacific and Indian Oceans. As far as I have been able to determine, representatives of this genus have not previously been recognized in fossil form * * *." Rezak reported to Allison R. Palmer (written commun., 1954) that "The ball- and disk-shaped objects that the Applins submitted are very similar to a Recent genus of Dasycladaceae * * *." The Dasycladaceae are a family of green algae which developed the ability to precipitate lime in and about their tissue.

UPPER MEMBER

The upper member of the Lawson Limestone (pl. 5*B*) is chiefly an algal and rudistid biostrome that has been greatly altered by secondary mineralization. The rock originally composing the greater part of the upper member was fabricated directly by colonies of lime-secreting algae. Unaltered or little altered typical fragments of the algae are shown on plate 8, figures 14 and 15. In samples of the rock, however, these structures are for the most part abraded and partly dissolved, giving the limestone its finely nodular appearance and its characteristically irregular porosity. Rudistids are found chiefly as fragments (pl. 8, figs. 11 and 12) in samples of cuttings, although nearly complete specimens have been observed in some cores. The rudistids are commonly found at or near the top of the upper member, but they are also found at deeper levels in the unit throughout the peninsula.

The chemical action of percolating water, aided by the primary porosity of the upper member, altered much of the limestone to cream-colored and light-tan coarsely crystalline dolomite; however, many wells penetrated lenses of brown finely crystalline dolomite near the base of the member. Secondary calcite has filled small pockets and crevices in the limestone. Gypsum is abundant, and in some places fills interstices of the algal structures. Anhydrite commonly fills the cone-shaped hollow centers of rudistids, and bedded anhydrite is found at various levels in the upper member. Wave action seems to have contributed to the alteration of the sediments before lithification as indicated by the abrasion, partial disintegration, and destruction of much of the original organic matter. The processes that altered the rock-forming organisms seem to have affected unfavorably the preservation of Foraminifera, as shown by the poorly preserved specimens and fragments of these microfossils that occur in many of the wells drilled in the peninsula.

A few other fossils having a wide geographic distribution in the upper member of the Lawson Limestone are considered to be characteristic in addition to the rudistids and algae. Two species of large Foraminifera, *Vaughanina cubensis* Palmer (pl. 8, fig. 13), and *Orbitoides brownii* Ellis, are fairly abundant in chalky pocketlike areas in the limestone, where they were probably protected and preserved in recognizable form. A small undescribed rotalid form is even more abundant and probably more characteristic than the orbitoids, but the tests are commonly recrystallized.

Relatively few wells in the report area have cored the contact of the Cedar Keys Limestone (Paleocene) and the underlying upper member of the Lawson Limestone; consequently, the lithologic differences that distinguish the units are known chiefly from cutting samples. Contrasting lithologic differences in the samples, however, indicate a fairly sharp contact. In contrast to the characteristically dolomitic lithology of the upper member of the Lawson, the overlying Cedar Keys Limestone in northern Florida is typically gray and white porous chalky limestone containing an abundance of gray capsule-shaped nodules and a large amount of selenite and other forms of gypsum which, in general, is evenly distributed through the unit as pore-space filling. Local lithologic variations require somewhat different sets of criteria for distinguishing the thick units in different parts of the peninsula. For example, a conspicuous bed of anhydrite occurs at the base of the Cedar Keys Limestone in a number of wells; in others the base of the unit is marked by brown finely crystalline dolomite that is distinct from the light-colored coarsely crystalline dolomite that is commonly found at the top of the underlying upper member of the Lawson. The microfaunal break between the Cedar Keys Limestone (Paleocene) above, and the upper member of the Lawson Limestone below, is clearly marked. Two species of *Borelis* characterize the Cedar Keys Limestone, and a small undescribed rotalid (as mentioned above) is the most common form in the upper member of the Lawson of northern Florida.

Inconclusive evidence suggests an unconformity between the upper member of the Lawson and the overlying Cedar Keys Limestone in northeastern Florida.

The dolomite at the top of the upper member of the Lawson in the Hunt Oil Co. H. L. Hunt 1 (pl. 5*B* and table 6, F5), Baker County, Fla., is dark, indurated, and apparently weathered, but only a trace of this kind of dolomite has been found in other wells in the northern part of the peninsula.

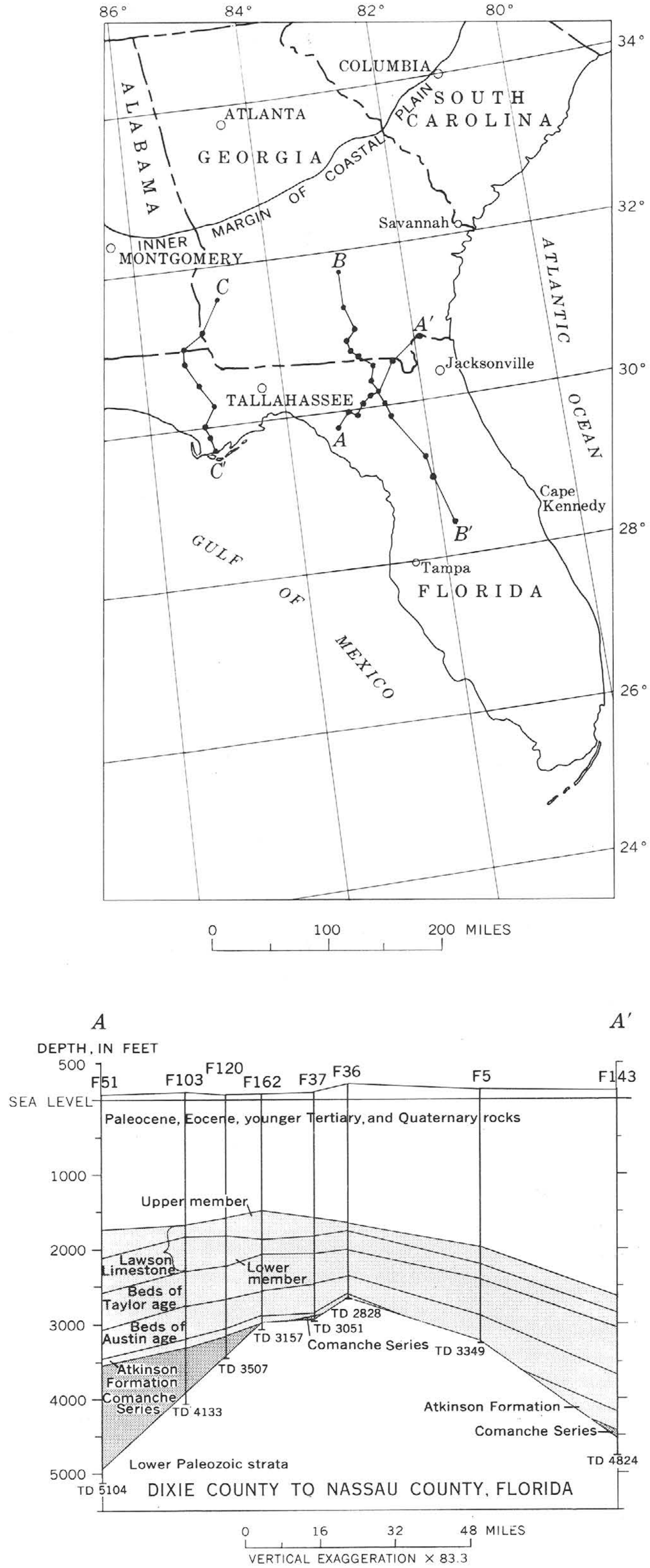
THICKNESS OF THE GULF SERIES

The thickness map of the Gulf Series (pl. 6*B*; table 1) is a composite of the thickness maps of the different stratigraphic units that have been discussed in this report, and the thickness pattern is similar, for the most part, to that of the beds of Austin and Taylor age (pl. 4*A*). In the northeastern part of the Florida peninsula, where the Atkinson Formation is thin or absent (pl. 3*A*), the Gulf Series is 1,000–1,300 feet thick and thickens gradually to more than 2,000 feet in central Florida and along the gulf and Atlantic coasts; the Gulf Series seems to be relatively thin, locally, in several wells in Columbia County and in Taylor County. A prominent axis of thinning in the rocks of the Gulf Series has been traced southwestward from near Savannah, in southeastern Georgia, as far as Jefferson County, in western Florida. The rocks of the Gulf Series, which are about 1,000 feet thick in wells along the axis in Clinch County, Ga., and Jefferson County, Fla., thicken northwestward to more than 2,000 feet in wells in the central part of the Coastal Plain of Georgia, and southeastward to more than 1,500 feet in wells in the northwestern part of the Florida peninsula. From the depocenter in Georgia, the Gulf Series thins northward toward the outcrop of the Cretaceous beds at the inner margin of the Coastal Plain.

The rocks of the Gulf Series have a fairly uniform thickness of about 1,400–1,500 feet in wells in a northwest-trending elongate area (pl. 6*B*) in Gadsden, Jackson, Liberty, and Wakulla Counties in north-central Florida that is nearly perpendicular to the trend of the axis of thinning from Clinch County, Ga., to Jefferson County, Fla. The uppermost Cretaceous beds of Navarro age are absent (pl. 6*A*) in the wells in a large area in north-central Florida and in the wells on the axis of thinning.

STRUCTURE

The regional subsurface structure of the Gulf Series in northern Florida and southern Georgia is shown by contour maps on five different datums. In sequence from the oldest to the youngest datum, the maps show the structure of the pre-Gulf surface (pl. 2*B*), the base of the beds of Austin age (pl. 4*D*), the top of the beds of Taylor age (pl. 4*E*), the top of the lower member of the Lawson Limestone (pl. 5*D*), and the surface of the Gulf Series (pl. 6*C*). Structure cross sections (fig. 3),



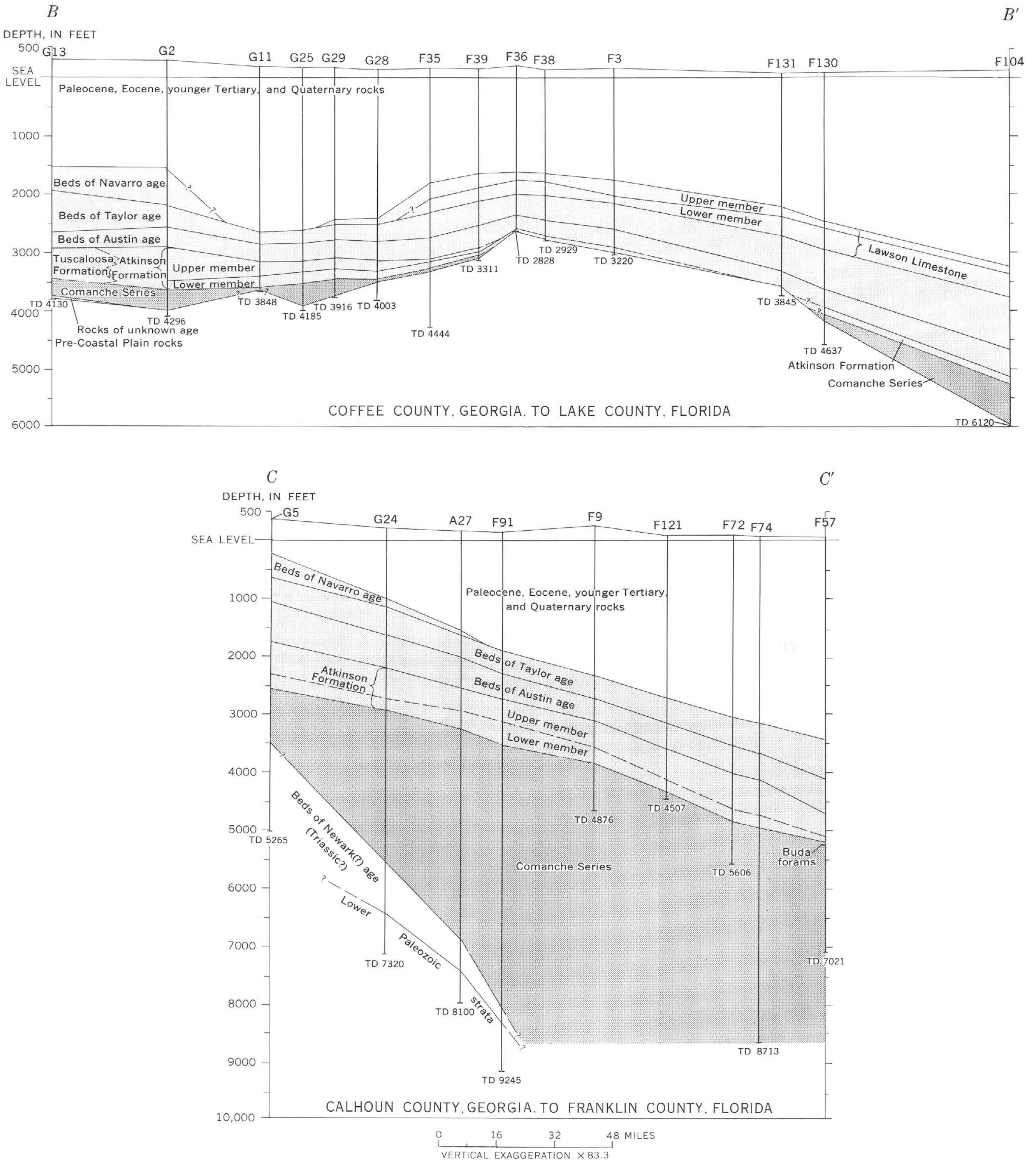


FIGURE 3.—Structure cross sections through wells in the Coastal Plain of Georgia and northern Florida. (See also stratigraphic sections, pl. 7). Rocks of Cretaceous age are stippled: light, Gulf Series; dark, Comanche Series. The upper and lower members of the Atkinson Formation are present in all areas on sections *A–A′*, *B–B′*, and *C–C′* but they are not shown where the scale of the section will not permit differentiation. TD, total depth of well, in feet.

as well as the thickness maps, supplement the structure-contour maps. Local and possibly regional faulting may have been a significant factor in the formation of some of the structural features; but because of the absence of conclusive data on the location and nature of the possible faults, faults are not shown on the maps.

Major features shown on the structure-contour maps and cross sections are the Peninsular arch (Applin, 1951, p. 3–5, figs. 2–4), the Okefenokee embayment of the Atlantic basin (Pressler, 1947, p. 1856), the Apalachicola embayment (Pressler, 1947, p. 1853, 1856), and the Suwannee saddle, a name substituted in this report for the older name Suwannee strait (Dall and Harris, 1892, p. 111, 120–122. These structural features as mapped on the different datums coincide, in general, and are discussed below.

PENINSULAR ARCH

The axis of the Peninsular arch, as mapped on the pre-Gulf surface (pl. *2B*), extends southeastward from Hamilton County, Fla., to Palm Beach County, Fla., a distance of nearly 300 miles. In the northern part of the Florida peninsula, which is the part covered in this report, the axis of the arch at the base of the beds of Austin age (pl. *4D*) and at the top of the beds of Taylor age (pl. *4E*) is virtually in the same geographic location as the axis at the pre-Gulf surface. The highest part of the arch on these datums centers around Union County and the southern part of Columbia County. At the top of the lower member of the Lawson Limestone (pl. *5D*) and at the top of the upper member of the Lawson (pl. *6C*), however, the axis seems to have shifted southward along a westerly trend from Alachua County to Taylor County, the highest part of the arch in the Lawson Limestone being in Suwannee County. The explanation for the shift is not clear, but it may be related to the thickening in the Lawson Limestone in the northwestern part of the peninsula (pl. *5C*). Pressler (1947, p. 1852, fig. 1) indicated, without further explanation, the alternative interpretation that the axis of his Ocala arch bifurcates in northern Florida.

The relatively low dip along the crest of the Peninsular arch (pls. *2B*, *4D*, *E*) in northern Florida contrasts markedly with the steeper dips on the northeast and southwest flanks. In general, the rate of dip is greatest on the pre-Gulf surface (pl. *2B*) and decreases progressively in the younger units (pls. *4D*, *E*, *5D*, *6C*). On the basis of the structure-contour maps, the approximate rate of dip of the different units on the northeast flank ranges from about 50 feet per mile on the pre-Gulf surface (pl. *2B*) to about 20 feet per mile on the upper member of the Lawson Limestone (pl. *6C*); on the southwest flank, the dip ranges from about 30 feet per mile on the pre-Gulf surface to about 18 feet per mile on the upper member of the Lawson. The units of the Gulf Series (pls. *3A*, *4D*, *E*, *5C*, *6B*) show marked thinning over the arch, indicating that the arch was relatively stable through Late Cretaceous time. The increase in the rate of dip of the progressively older Cretaceous rocks indicates progressive downwarping on the flanks of the arch.

OKEFENOKEE AND APALACHICOLA EMBAYMENTS

The Okefenokee and Apalachicola embayments are shown on the structure-contour maps (pls. *2B*, *4D*, *E*, *6C*). The Okefenokee embayment of the Atlantic basin is known, also, as the Savannah or Southeast Georgia basin (Murray, 1961, p. 96–97), and the Apalachicola embayment is frequently called the Southwest Georgia basin (Murray, 1961, p. 103). The embayments seem to coincide, respectively, with the northeastern and southwestern ends of the Suwannee saddle which is described below.

SUWANNEE SADDLE

The name Suwannee saddle (pls. *2B*, *4D*, *E*, *6C*) is used in this report to designate a subsurface syncline that extends about 200 miles in a broad arc from southeastern Georgia to Jefferson, Leon, and Wakulla Counties in north-central Florida, bordering the Peninsular arch on the north and northwest. Suwannee saddle is substituted for the widely used name Suwannee strait because, in the opinion of some geologists, the structural name describes the feature, as now understood, more accurately than the historical name. The surface feature named the Suwannee strait (Dall and Harris, 1892, p. 122) "was a wide, and even in Miocene times a moderately deep body of water, the general trend of which did not differ much from that of a line drawn from Savannah to Tallahassee, and which had a probable width of more than 50 miles." Cooke (1943, p. 4) stated, "From a study of well logs and other data Prettyman and Cave (1923, fig. 11, p. 131, and map 2, facing p. 134) concluded that there is a gentle synclinal depression centering off the southern part of the coast of Georgia. This basin appears to be merely the result of the regional dip opposed to the northeastward slope away from the Ocala arch of Florida. The northward slope from the Ocala arch accounts also for the slight sag in the Hawthorne formation along the Florida State line farther west." Prettyman and Cave (1923, p. 131, fig. 11) showed the axis of an unnamed northwestward-trending arch in northern Florida and southern Georgia that is crossed in southern Georgia by a southwestward-trending "axis of saddle." The axis of this unnamed saddle seems to follow closely the trend of the Suwannee saddle (pls. 2, 4, 6) of the present report. The discrepancies in the position of the saddle on our structure-contour maps are explained, in part, by the widely scattered wells from which datum points are available.

Published articles by Hull (1962) and Babcock (1962, p. 40–41) summarize the ideas of some earlier writers about the origin and nature of the Suwannee strait, and Hull (1962, p. 121) explained the strait "as an area of relatively thin deposition which separated the carbonate banks from sources of terrigenous sediments." Hull stated further (p. 118), "This thinness, which is generally attributed to post-Cretaceous erosion, can be explained as a result of differential sedimentation during late Cretaceous time, when the Suwannee strait was a boundary between two distinct sedimentary facies." We agree with Hull that the Suwannee saddle is "an area of relatively thin deposition" of the Gulf Series and that it separates the clastic beds of Navarro age on the north and the lithologically and faunally distinct but stratigraphically equivalent Lawson Limestone on the south.

Chih Shan Chen (1965, p. 82–84) described his "Suwanee Channel" as "the site of relatively thin accumulation of very fine sands, silts, clays and limestones at least during the time from late Upper Cretaceous to Lower Eocene. The channel was a natural barrier and facies boundary, both sedimentational and biologic, between two distinct sedimentary facies in the area throughout the entire Early Tertiary time." Chih added, "The lesser thickness of strata ranging in age from late Upper Cretaceous to Lower Eocene within the channel might be interpreted as due to either erosion on a positive lineament or slower sedimentation within the channel." He concluded that "the evidence strongly indicates slower Paleocene-Eocene accumulation within the channel rather than differential erosion." Chih suggested "that the Suwanee Channel was a bathymetric depression and a natural barrier, both sedimentational and ecologic, during late Cretaceous and Early Tertiary time" that seems to have disappeared during middle or late Eocene time.

Although the observations of Hull (1962) and of Chih on the stratigraphy of the rocks and the relation of the clastic and nonclastic sedimentary facies in the area of the Suwannee saddle are similar in many respects to ours, we offer, nevertheless, an alternative interpretation of the time and nature of origin of the saddle.

The area of thinning in the rocks of the Gulf Series (pls. 4*A*, 6*B*) that extends southwestward from southeastern Georgia into north-central Florida is interpreted by us as an upwarped barrier that during Navarro time separated the shallow-water marine depositional environment in southern Georgia and the partly restricted marine-shelf environment in the Florida peninsula. During the Tertiary, widespread tectonic movements in the Florida peninsula and the Coastal Plain of Georgia brought about relative depression of the barrier and uplift of the area north and south of it, forming the synclinal feature now known as the Suwannee saddle (pls. 2*B*, 4*D*, *E*, 6*C*). Paleocene and younger Tertiary beds unconformably overlie the Cretaceous rocks in the Suwannee saddle and the surrounding area. Our interpretation of the progressive development of the saddle in the Cretaceous and older rocks is shown by a set of three cross sections in figure 4.

In preparing this set of cross sections, we used as a model the cross sections by Lee and others (1946, sheet 7) showing the progressive development of the Forest City basin. The three cross sections in our figure 4 illustrate two stages in the development of the Suwannee saddle during Late Cretaceous time, and also the present structure. Cross section *C* represents the structure of the pre-Navarro rocks in relation to the time line at the top of the beds of Taylor age on which the beds of Navarro age were deposited. Cross section *B* represents the structure of the Cretaceous and older rocks in relation to the unconformity on which the Paleocene and younger rocks were deposited. Cross section *A* shows the present structure.

BIGHT OF FLORIDA

In addition to the features shown on the structure-contour maps and described in the preceding paragraphs, we postulate a structurally high area off the gulf coast in the bight of Florida. This structural high is postulated on the basis of the thinning toward the bight of Florida that is shown by the different units of the Gulf Series (pls. 3*A*, *B*, *E*, 4*A*, 6*B*) and on the basis of our interpretation of the regional structure of the units on the structure-contour maps (pls. 2*B*, 4*D*, *E*, 6*C*).

After the manuscript for this report had been completed early in 1963, a published article by Antoine and Harding (1963) showed their interpretation of a structurally high area in the northeastern Gulf of Mexico based on their seismic investigations.

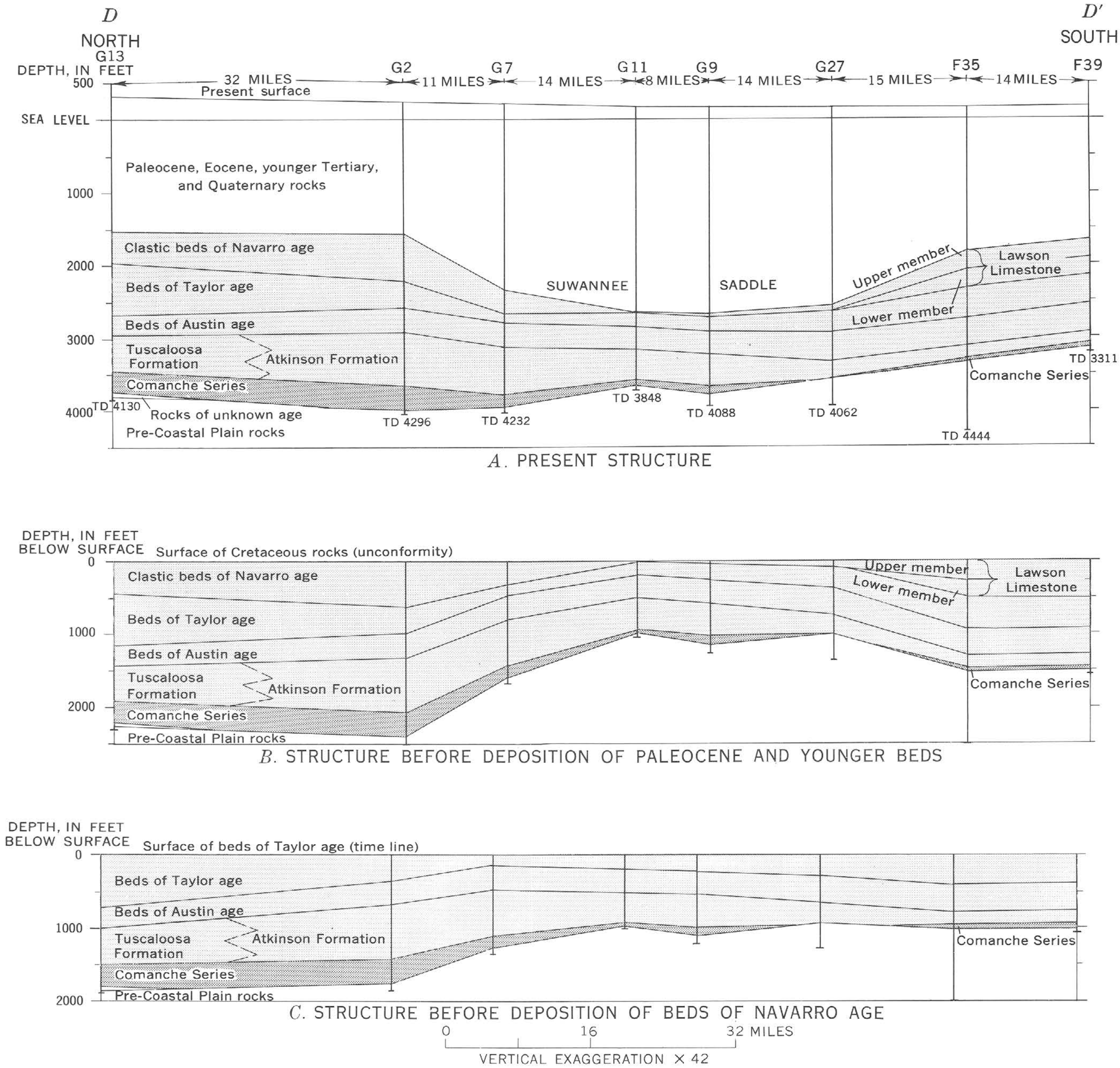


FIGURE 4.—Diagrammatic cross sections through wells from Coffee County, Ga., to Columbia County, Fla., showing stages in the progressive development of the structure of the Suwannee saddle from the end of Taylor time to the present. Rocks of Cretaceous age are stippled: light, Gulf Series; dark, Comanche Series. Line of section *D–D′* shown on plate 6*A*. TD, total depth of well, in feet.

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PLATE 8

PLATE 8

FIGURES 1–3. Three specimens (× 22.5) of *Flabellamina denisonensis* Tappan from the upper part of a marine clastic facies of beds of Buda (Washita) age in north-central Florida. The specimens were in core 16 at depths of 5,310–5,331 feet in the Magnolia Petroleum Co. State of Florida Block 5B well 1A, Franklin County, Fla.

4–10. Specimens of previously unfigured characteristic fossils from the lower member of the Lawson Limestone in the Florida peninsula.

4–7. Specimens of immature brachiopods in cuttings from the Gulf Oil Corp. Kie Vining 1, Columbia County, Fla. The specimens 4 (× 20) and 6 (× 15) were in samples at depths of 2,030–2,080 feet. The specimens 5 (× 25) and 7 (× 24) were in samples at depths of 2,150–2,200 feet.

8–9. Specimens of algae closely resembling the Recent genus *Bornetella.* 8a (× 20) is the upper surface and 8b (× 18) is the lower surface of a disk-shaped form; specimen 9 (× 18) is a ball-shaped form. The specimens were in a core at a depth of 2,300 feet in the Field and Randall G. D. Crawley 1, Suwannee County, Fla.

10. Specimen (× 18) of the microcrinoid *Saccocoma* in cuttings at depths of 1,980–1,990 feet in the Gulf Oil Corp. Brooks-Scanlon, Inc., Block 49 well 1, Lafayette County, Fla.

11–15. Specimens of previously unfigured characteristic fossils from the upper member of the Lawson Limestone in the Florida peninsula.

11, 12. Specimens of fragments of rudistids. Specimen 11 (× 7.5) was in cuttings at depths of 1,790–1,800 feet in the Sun Oil Co. Alto Adams 1, Gilchrist County, Fla. Specimen 12 (× 10) was in cuttings at depths of 1,900–1,910 feet in the Stanolind Oil & Gas Co. and Sun Oil Co. Perpetual Forest Inc. 1, Dixie County, Fla.

13. A specimen (× 25) of *Vaughanina cubensis* Palmer that was found in cuttings at depths of 1,660–1,670 feet in the Sun Oil Co. A. B. Russell 1, Suwannee County, Fla.

14, 15. Specimens (× 10 and × 30, respectively) of rock-forming coralline algae that were found in cuttings from the Coastal Petroleum Co. J. B. and J. P. Ragland 1, Levy County, Fla. Specimen 14 was in the sample at depths of 2,390–2,400 feet; specimen 15 was in the sample at depths of 2,300–2,310 feet.

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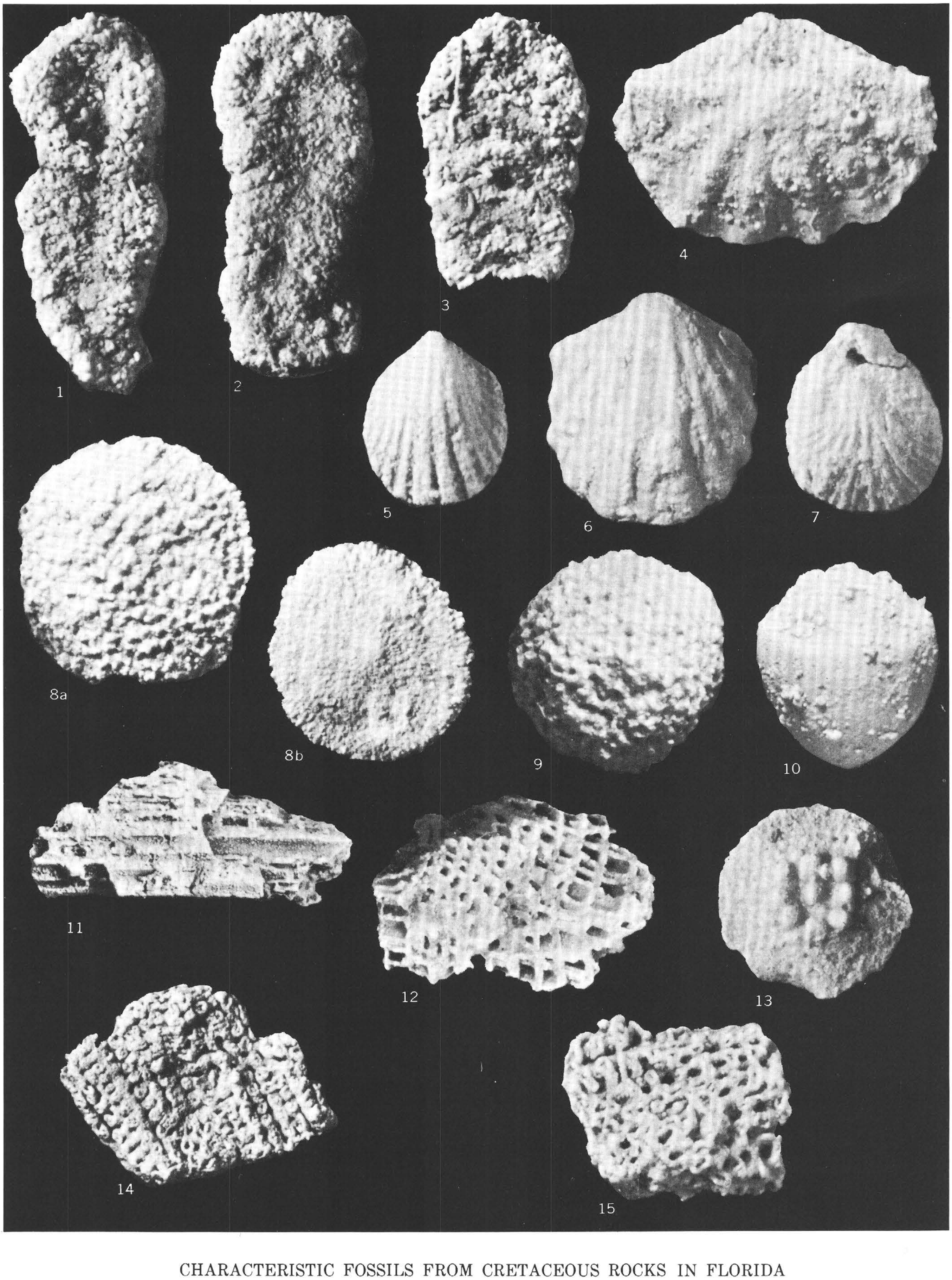

CHARACTERISTIC FOSSILS FROM CRETACEOUS ROCKS IN FLORIDA