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SUBSURFACE GEOLOGY OF ATLANTIC COASTAL PLAIN OF NORTH CAROLINA[1]

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ABSTRACT

This paper presents a summary of the geological and geophysical methods used and data obtained in eastern North Carolina during the petroleum exploration program (1945–1947) of Esso Standard Oil Company on the Atlantic Coastal Plain.

During the exploration venture two wells were drilled: Hatteras Light well No. 1 as a stratigraphic test on the easternmost promontory of Cape Hatteras, and North Carolina Esso No. 2 as a stratigraphic and structural test. Hatteras Light well No. 1 is the deepest well drilled to date along the Atlantic Coastal Plain from Maine to Florida. The considerable data obtained during the venture have made possible new interpretations of the subsurface geology of eastern North Carolina.

INTRODUCTION

The greatest activity in petroleum exploration in the history of the Atlantic Coastal Plain occurred from 1945 to 1947. The major exploratory work, under the auspices of the Esso Standard Oil Company in the state of North Carolina, gave new interpretations of the subsurface geology of eastern North Carolina.

This paper is intended only as a general summary. Detailed paleontological studies are being conducted by various workers and only brief mention is made of the faunas found in the well samples.

LOCATION

The area covered by this report is the Atlantic Coastal Plain of North Carolina. Its western margin is the "Fall line" which is the approximate surface contact of the crystalline rocks with younger sedimentary strata. Figure 1 shows the regional location of the area. Figure 2 is an index map showing locations of wells, cross sections, and geophysical surveys.

[1] Manuscript received, January 31, 1949. The original manuscript is on file in the office of the State geologist, Department of Conservation and Development, Raleigh, North Carolina. Published with the permission of Esso Standard Oil Company.

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The writer is greatly indebted to various geologists for discussing with him many problems encountered in interpreting the subsurface geology and in making correlations. K. D. White supervised the exploratory work of the Esso Standard Oil Company and Jahn J. Peterson, another company geologist, examined and described the outcrops. Their work, their comments, and their association with the writer have been most helpful in preparing this report.

The writer thanks Roderick A. Stamey, president of the Carolina Petroleum Company, for permission to use and publish the electric logs of wells drilled by his company; L. W. Stephenson and J. B. Reeside, Jr., of the United States National Museum, for determining the ages of fossils from many of the cores; Horace G. Richards of the Philadelphia Academy of Sciences for information on the age of macrofaunas in many well samples; and W. S. Pike of the Shell Oil Company for age correlations based on the foraminiferal studies of Miss Doris Malkin.

The writer is greatly indebted to Jasper L. Stuckey, State geologist of North Carolina, and the members of his staff who have given their cooperation and have made it possible to publish this work.

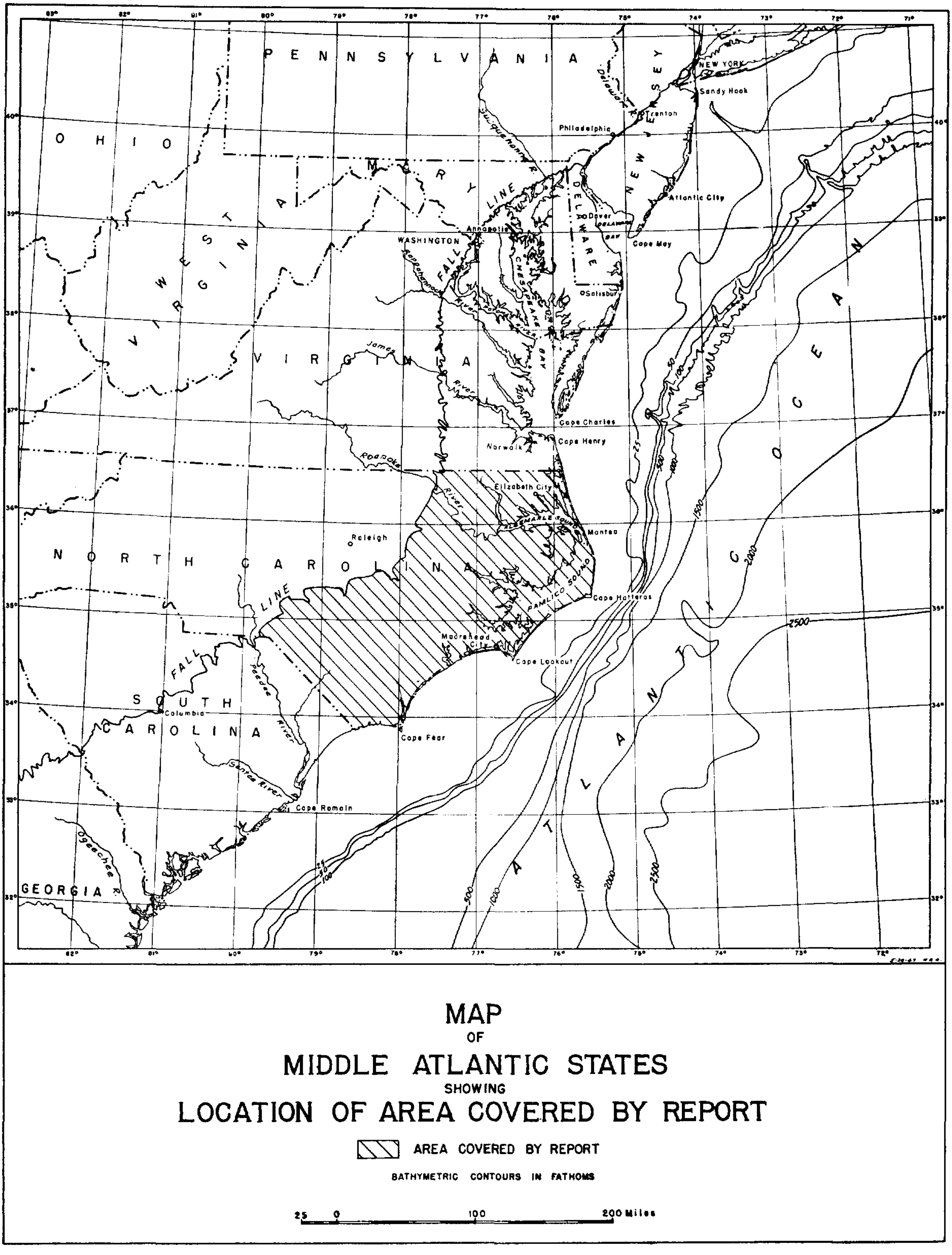


FIG. 1.—Map of middle Atlantic states showing area of North Carolina covered in this article.

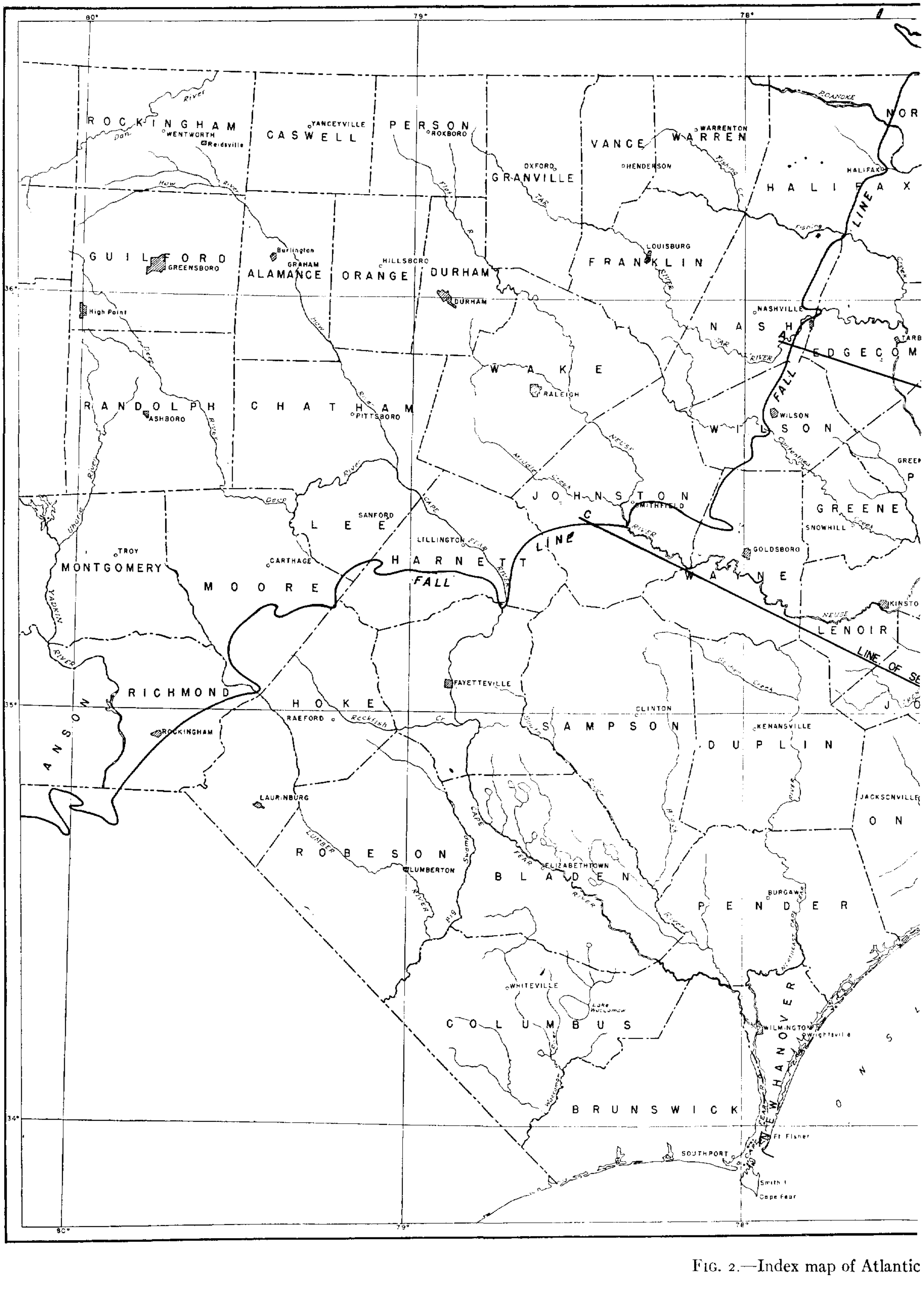
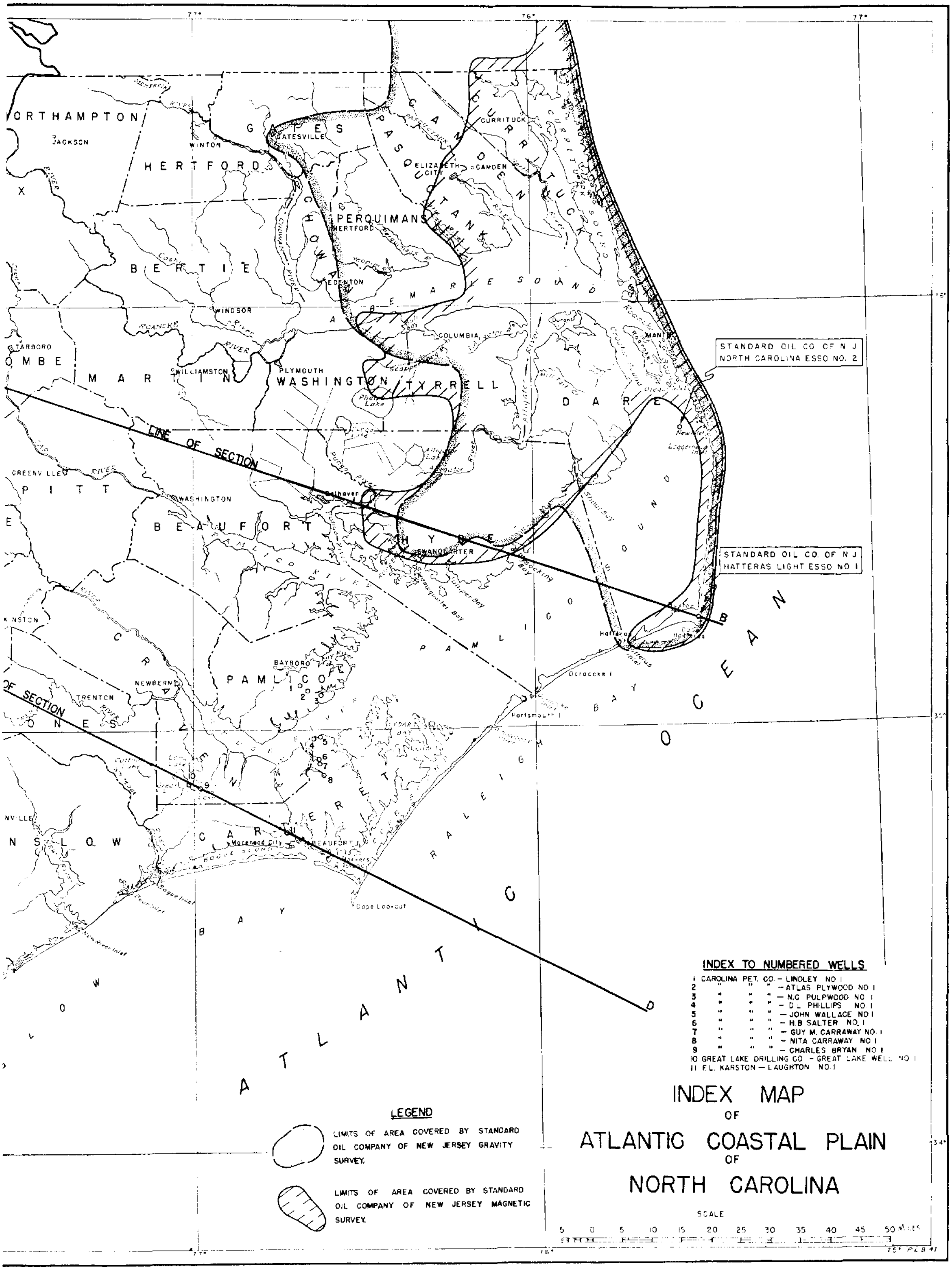


Fig. 2.—Index map of Atlantic



Coastal Plain of North Carolina.

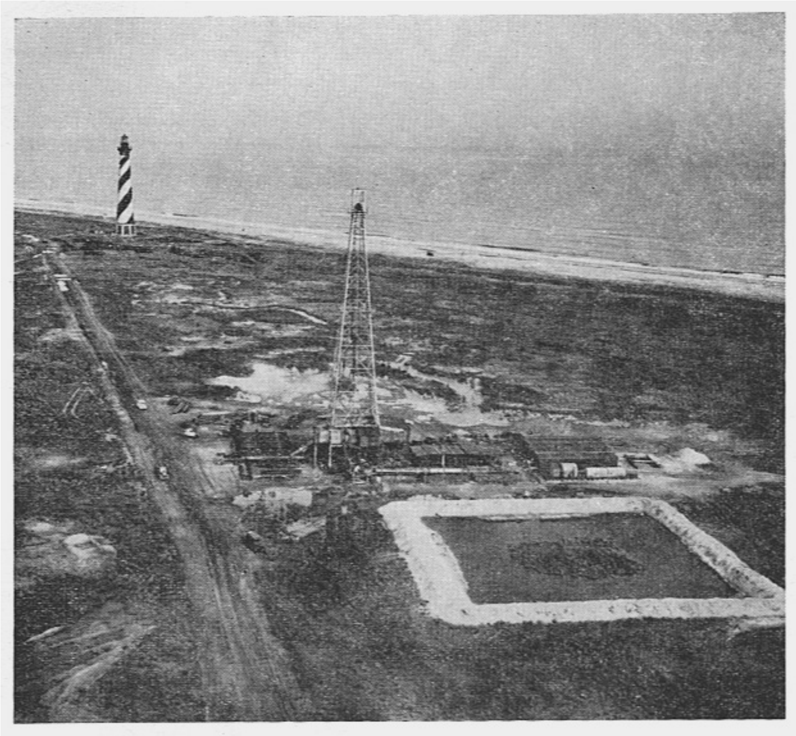


FIG. 3.—Esso Standard Oil Company's Hatteras Light well No. 1.

SUMMARY OF EXPLORATORY AND DRILLING PROGRAMS

In the latter part of 1924 the Great Lake Drilling Company drilled an oil prospecting well, known as the Great Lake well No. 2, about 5 miles west of Havelock, Craven County, North Carolina. This was the first well in the state of North Carolina in the search for petroleum. The well reached the total depth of 2,404 feet, reportedly encountering the top of the crystalline basement at 2,318 feet, and was abandoned as a dry hole with no evidence of either oil or gas. This well has been discussed in detail in a paper by Wendell C. Mansfield.[3]

Following the drilling of this well at Havelock there was a long period of inactivity. In 1944 the Esso Standard Oil Company established the Eastern Seaboard Exploration Venture, and geologic field work, leasing, and geophysical surveys were started. The field work covered the Coastal Plain of South Carolina, North Carolina, Virginia, Maryland, Delaware, and New Jersey. Geophysical surveys were made in North Carolina and some work was done in southeastern Virginia. In May, 1945, F. L. Karston of the Coastal Plains Company completed the Laughton No. 1 near Moorehead City, North Carolina. This well reached

[3] Wendell C. Mansfield, "Oil Prospecting Well near Havelock, North Carolina," *North Carolina Dept. Conserv. and Dev. Econ. Paper 58* (1927).

the total depth of 4,044 feet and was abandoned as a dry hole. The top of the crystalline basement was reported to have been found at the depth of 4,030 feet. Prior to the drilling of the Laughton well, the Coastal Plains Company had conducted a magnetometer survey in Pamlico and Carteret counties, North Carolina. This work was later continued by the Carolina Petroleum Company.

On December 1, 1945, the Esso Standard Oil Company spudded its Hatteras Light well No. 1[4] (Fig. 3). This well, at West Longitude 75° 31′ 4″ and North Latitude 35° 15′ 5″, was 1,696 feet South 48° 30′ West of the old lighthouse on Cape Hatteras, Dare County, North Carolina, and was to become the deepest well drilled along the Atlantic Coastal Plain from Maine to Florida. On July 9, 1946, a depth of 10,054 feet had been reached, with the top of the basement at 9,878 feet. On July 19, 1946, the well was officially abandoned as a dry hole at the total depth of 10,054 feet. No occurrences of oil or gas were found. Due to a concentrated coring and sampling program and numerous scientific tests, a great many useful data were obtained. The well was unique in the varied equipment used. Both wire-line and conventional cores were taken, in all 125 cores being obtained. A gas detector was in continuous operation during the drilling though at no time did it give any indication of the presence of oil or gas. The well was also equipped with an automatic mud scale, a Sperry inclinometer, and a Geolograph. All samples and cores were carefully studied on location by means of microscope and fluoroscope, and were checked for oil showings with ether and carbon tetrachloride. Samples and cores were distributed among oil-company, industrial, and educational geologists for further study.

An electric log of Hatteras Light No. 1 was run from 507 feet to 10,044 feet. During the logging, temperatures were obtained as follows.

Depth (Feet)	*Temperature (°F.)*
4,604	133
8,426	150
9,148	160
9,878	168
10,044	170

In any analysis of these temperatures the reader should consider the following facts: (1) the temperatures were obtained during the electric logging; (2) the well was drilled by rotary methods and mud was continuously circulated in the hole during the drilling; (3) a maximum of 6 hours elapsed from the time circulation was stopped until the temperatures were obtained.

Two drill-stem tests were made. The first was in Lower Cretaceous sand, the top of the sand being at 6,477 feet and the bottom at 6,575 feet. The total depth at the time of the test was 6,512 feet. Packers were set at 6,474 and 6,483 feet. Half-inch choke, open 10 minutes, produced 6 barrels of mud and muddy salt water and 55 barrels of salt water. Bottom-hole pressure was 2,900 pounds per square inch.

[4] This well has been called North Carolina Esso No. 1 by some writers and Hatteras Light Esso No. 1 by others. It was officially named Hatteras Light well No. 1 by the Esso Standard Oil Company.

An analysis of the water obtained from this test follows.

	Parts per Million (Milligrams per Liter)	Reacting Values (Percentage)
Sodium	36,097	38.64
Calcium	7,100	8.72
Magnesium	1,302	2.64
Sulphate	840	0.43
Chloride	71,335	49.53
Bicarbonate	99	0.04
Carbonates	Nil	--
Total	116,773	100.00

Specific gravity—1.087 at 15.6°C. (60°F.)

The second drill-stem test was made in a sand whose top was at 7,017 feet. This sand continued down to 7,220 feet, broken by minor shale beds in the lower part. The total depth at the time of the test was 7,081 feet. Packers were set at 7,018 and 7,027 feet. Tool open 10 minutes produced 7 barrels of mud and muddy salt water and 51 barrels of salt water. Bottom-hole pressure was 3,100 pounds per square inch.

An analysis of this water follows.

	Parts per Million
Sodium	42,858
Calcium	5,856
Magnesium	1,258
Sulphate	840
Chloride	79,460
Bicarbonate	47
Carbonates	none
Total	130,319

	Percentage
Primary salinity	82.48
Secondary salinity	17.48
Primary alkalinity	0.00
Secondary alkalinity	.04
Total	100.00

Cuts of the cores from the major sand bodies in Hatteras Light No. 1 were analyzed; the results appear in Table I.

During 1946 and the first half of 1947 the Carolina Petroleum Company drilled 9 wells in Pamlico, Craven, and Carteret counties, North Carolina. These were as follows.

Well Name	*Location (County)*	*Index No. (Figs. 2 and 5)*	*Date Completed*	*Total Depth (Feet)*
Guy M. Carraway 1	Carteret	7	July 1946	4,069
Nita Carraway 1	Carteret	8	Aug. 1946	4,126
D. L. Phillips 1	Carteret	4	Sept. 1946	3,964
H. B. Salter 1	Carteret	6	Oct. 1946	3,963
John Wallace 1	Carteret	5	Dec. 1946	4,024
Charles Bryan 1	Craven	9	Jan. 1947	2,435
N. C. Pulpwood 1	Pamlico	3	Feb. 1947	3,666
Atlas Plywood 1	Pamlico	2	Mar. 1947	3,425
Lindley* 1	Pamlico	1	June 1947	3,196

* Rig moved 25 feet and drilling new hole to obtain cores. Coring ahead, July, 1947.

TABLE I

Core No.	*Depth (Feet)*	*Recovery (Feet)*	*Porosity %*	*Permeability (M.D.)*	*Acid Insoluble %*	*Sodium Chloride %*	*Lump Density*
51	3,657–66	$1\frac{1}{2}$	41.2	Undet.	99	0.67	1.93
52	3,693–3,703	3	27.6	5.7	99	0.99	2.02
53t	3,827–37	3	31.8	4.5	99	0.95	1.98
53b	3,827–37	3	15.9	5.7	2.1 77	0.32	2.41
54	3,930–40	$\frac{5}{6}$	39.2	Undet.	100	0.05	1.71
55	4,042–52	$4\frac{1}{2}$	32.2	5.0	100	0.71	1.98
56	4,152–62	10	40.9	Undet.	99	0.11	1.76
57	4,275–85	4	28.0	5.4	99	0.52	2.05
77	6,487–97	10	27.0	65.0	95	0.01	2.02
77	6,487–97	10	33.7	73.6	95	0.04	2.01
77	6,487–97	10	33.2	70.0	96	0.07	1.99
78	6,497–6,507	9	24.7	Undet.	91	0.03	2.09
78	6,497–6,507	9	30.2	184	91	0.01	1.99
78	6,497–6,507	9	3.1	0	98	0.02	2.62
79	6,507–12	5	27.2	58.3	95	0.03	2.06
79	6,507–12	5	26.9	Undet.	97	0.02	2.11
80	6,512–22	$7\frac{1}{2}$	29.3	Undet.	99	0.02	1.98
80	6,512–22	$7\frac{1}{2}$	27.8	Undet.	96	0.02	1.98
80	6,512–22	$7\frac{1}{2}$	32.1	Undet.	98	0.05	1.87
81	6,522–32	4	19.8	118	88	0.03	2.22
81	6,522–32	4	25.9	191	78	0.04	2.06
82	6,532–42	3	27.8	247	96	0.03	2.00
83	6,542–52	7	28.9	1,546	93	0.09	1.91
84	6,552–62	10	26.4	999	95	0.04	2.02
84	6,552–62	10	33.6	Undet.	97	0.07	1.84
84	6,552–62	10	33.9	2,103	99	0.04	1.84
85	6,562–72	10	28.0	142	99	0.28	1.97
85	6,562–72	10	31.4	1,024	97	0.14	1.90
86	6,572–81	7	30.8	605	84	0.53	1.93
86	6,572–81	7	2.5	0	56	0.30	2.64
91	7,021–26	$2\frac{1}{12}$	32.6	2,080	97	0.12	1.84
92	7,034–39	$2\frac{2}{3}$	31.4	Undet.	90	0.05	1.87
93	7,076–81	4	22.0	58.3	87	0.08	2.11
94	7,081–91	4	19.3	391	80	0.05	2.20
94	7,081–91	4	16.5	11.7	82	0.08	2.27
95	7,091–96	$2\frac{1}{2}$	24.1	Undet.	83	0.41	1.97
96	7,096–7,106	10	27.3	301	98	0.08	1.97
96	7,096–7,106	10	29.1	537	100	0.06	1.81
97	7,106–7,113	7	28.4	386	94	0.16	1.92
98	7,113–23	9	29.0	810	92	0.15	1.87
98	7,113–23	9	31.5	943	63	0.17	1.82
99	7,123–33	10	26.8	205	88	0.11	1.99
99	7,123–33	10	12.8	2.1	84	0.50	2.34
100	7,191–7,201	10	25.4	Undet.	97	0.80	2.02
100	7,191–7,201	10	26.1	Undet.	90	1.20	2.04

All of these wells ended in crystalline igneous basement and were abandoned as dry holes.

On January 7, 1947, the Esso Standard Oil Company spudded its North Carolina Esso No. 2 (Fig. 4). This well was located in Pamlico Sound, Dare County, North Carolina, at North Latitude 35° 42′ 12″, and West Longitude 75° 33′ 54″, approximately 11 miles south of Wanchese and $3\frac{1}{2}$ miles west-northwest of Pea Island Coast Guard Station (Fig. 2). It was drilled as a stratigraphic

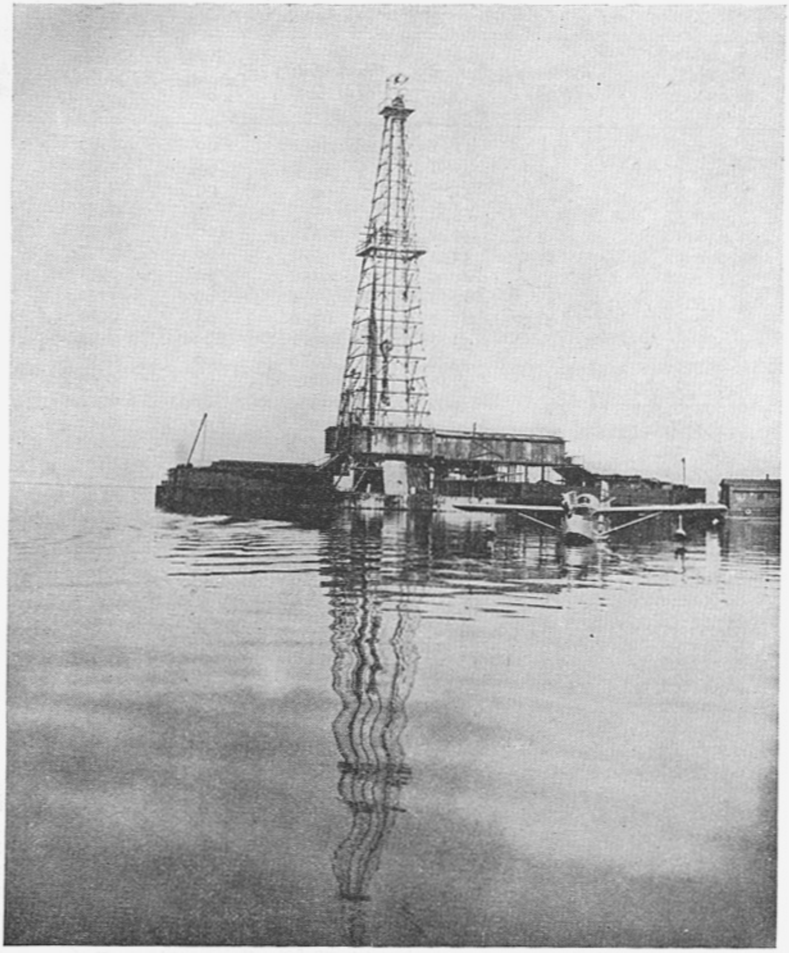


FIG. 4.—Esso Standard Oil Company's North Carolina Esso well No. 2.

and structural test on a gentle eastward-plunging nose trending west-northwest. This nose is present on the basement (Fig. 8), but does not show on the top of the Cretaceous (Fig. 9).

North Carolina Esso No. 2 was abandoned as a dry hole, March 13, 1947, at the total depth of 6,410 feet. Though the top of the basement was not reached, it was estimated to be at an approximate depth of 8,000 feet. The equipment used in drilling this hole was the same as used in drilling Hatteras Light No. 1. Thirteen cores were cut but no drill-stem tests were made.

With the completion of North Carolina Esso No. 2 the Esso Standard Oil Company abandoned all activity along the Atlantic Coastal Plain.

STRATIGRAPHY

A study of the samples, cores, and fossil faunas from the recent wells drilled in eastern North Carolina has greatly added to the geologic knowledge of the subsurface stratigraphy. Many geologists and paleontologists have received samples from these wells and have discussed their interpretations with the writer. It is hoped that all who have studied the samples, in time, can arrive at definite conclusions about the true stratigraphy of the Atlantic Coastal Plain. At present, there are still many questions unanswered and only general conclusions can be drawn.

Due to lithologic similarity of most strata, formational recognition is dependent on faunal content. However, below the beds of Taylor age, the outcropping sediments on the west are predominantly non-marine and no reliable fauna has been found.

Following the drilling of the recent wildcat wells, it was discovered that these lower continental beds are marine downdip and in part contain a fauna upon which a more reliable age correlation can be made. Though the beds become marine downdip and contain a fairly large fossil assemblage, it is still difficult, due to facies changes, to be certain which of the beds downdip are the marine equivalent of the non-marine beds in outcrop. It is also difficult to determine whether beds that are present downdip pinch out updip or have equivalents in outcrop. Though unconformities are recognizable on the exposures, it is extremely difficult to identify them from well cuttings. Also, it is usually expected that unconformities decrease basinward, and though they are present, their character is such that it precludes recognition in the wells.

It is believed that the area was subjected to recurrent transgressive and regressive seas. Such conditions greatly complicate the identification of contemporaneous time units unless continuous faunal horizons are present. Since there is a change in sedimentation from marine to non-marine updip, no continuous faunal horizons can be found, excepting along the strike.

As a result, age determinations have been made from faunas in the marine units in the deeper wells. These units are correlated with updip equivalents in shallow wells on the basis of their electric-log characteristics, and the units are then correlated with the outcropping formations on the basis of lithologic characteristics. Figures 5, 6, and 7 show the correlative formations in the various wells as determined by this method of study. Table II is a comparison of the stratigraphy of eastern North Carolina with that of the Gulf Coast.

The greatest difficulty in determining formational tops in wells occurred at the Eocene-Cretaceous contact and between all formations below that point.

The first Cretaceous fauna recognized in the Carolina Petroleum Company wells in North Carolina occurs above a unit (Unit A–B, Fig. 6) that can readily be identified on the electric logs of all other wells in the state. In the Hatteras

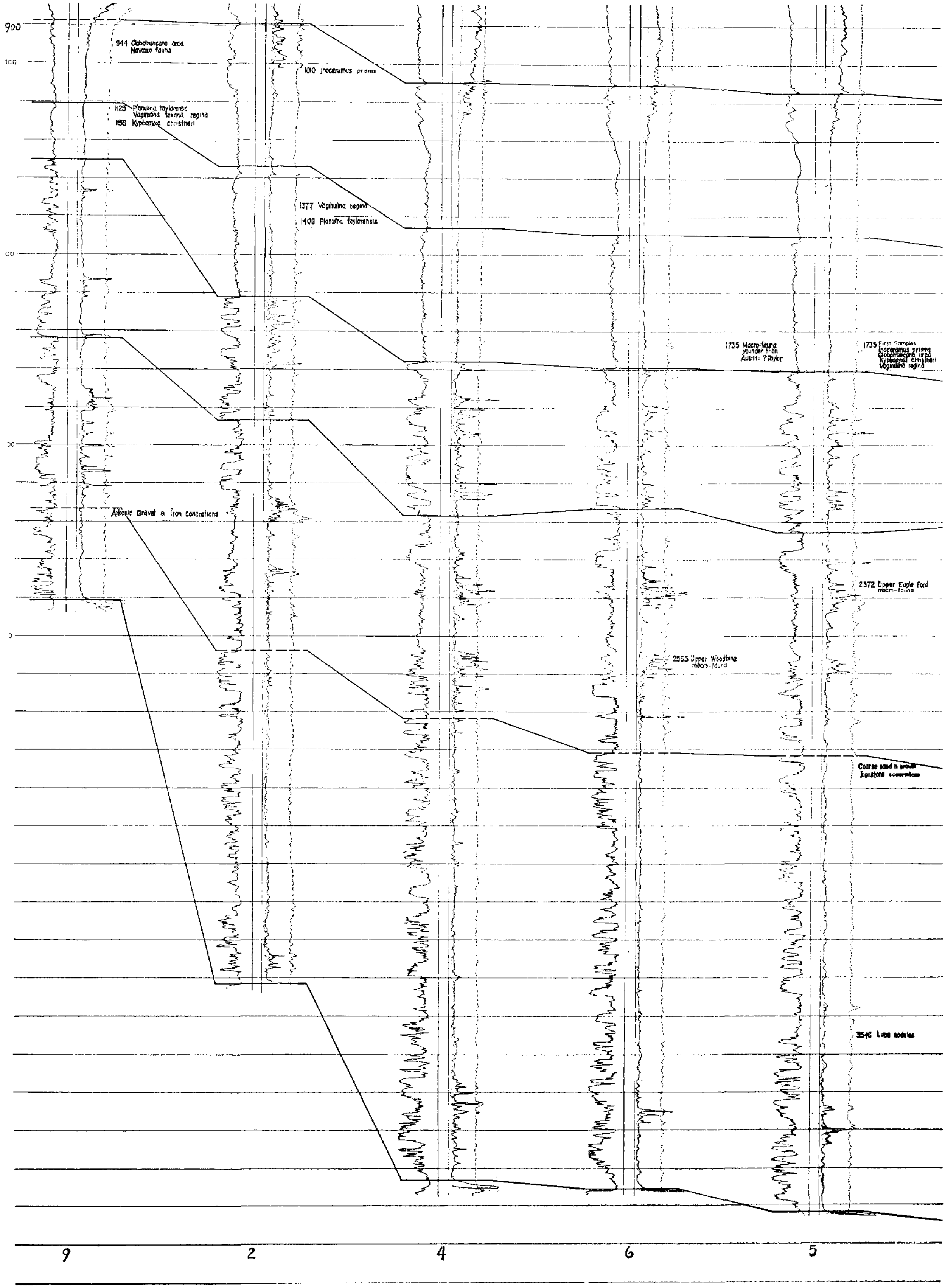
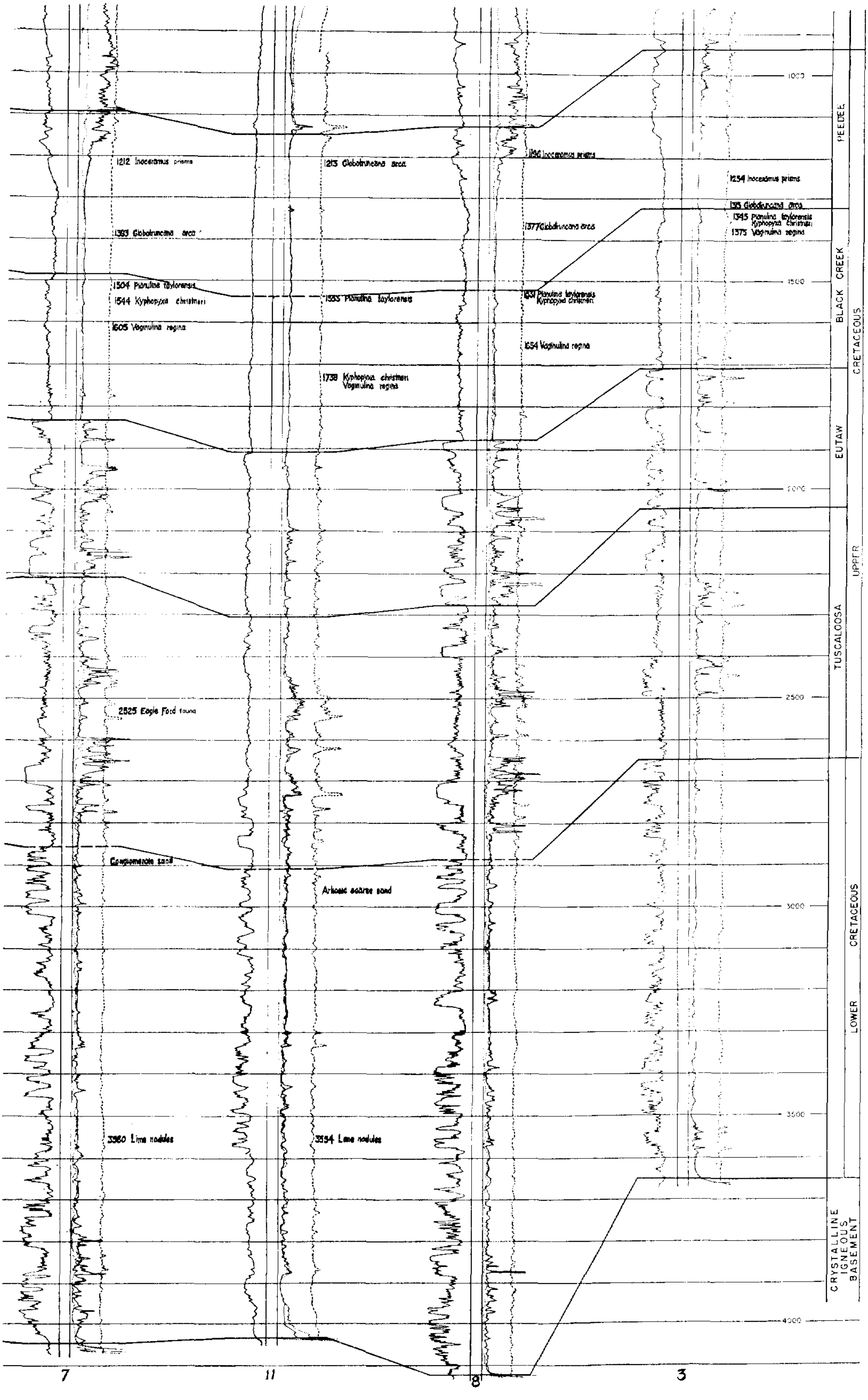


Fig. 5.—Electric-log and faunal correlations of wells drilled in Carteret, Craven, and Pamlico



counties, North Carolina. Well numbers at bottom indicate names and locations shown in Figure 2.

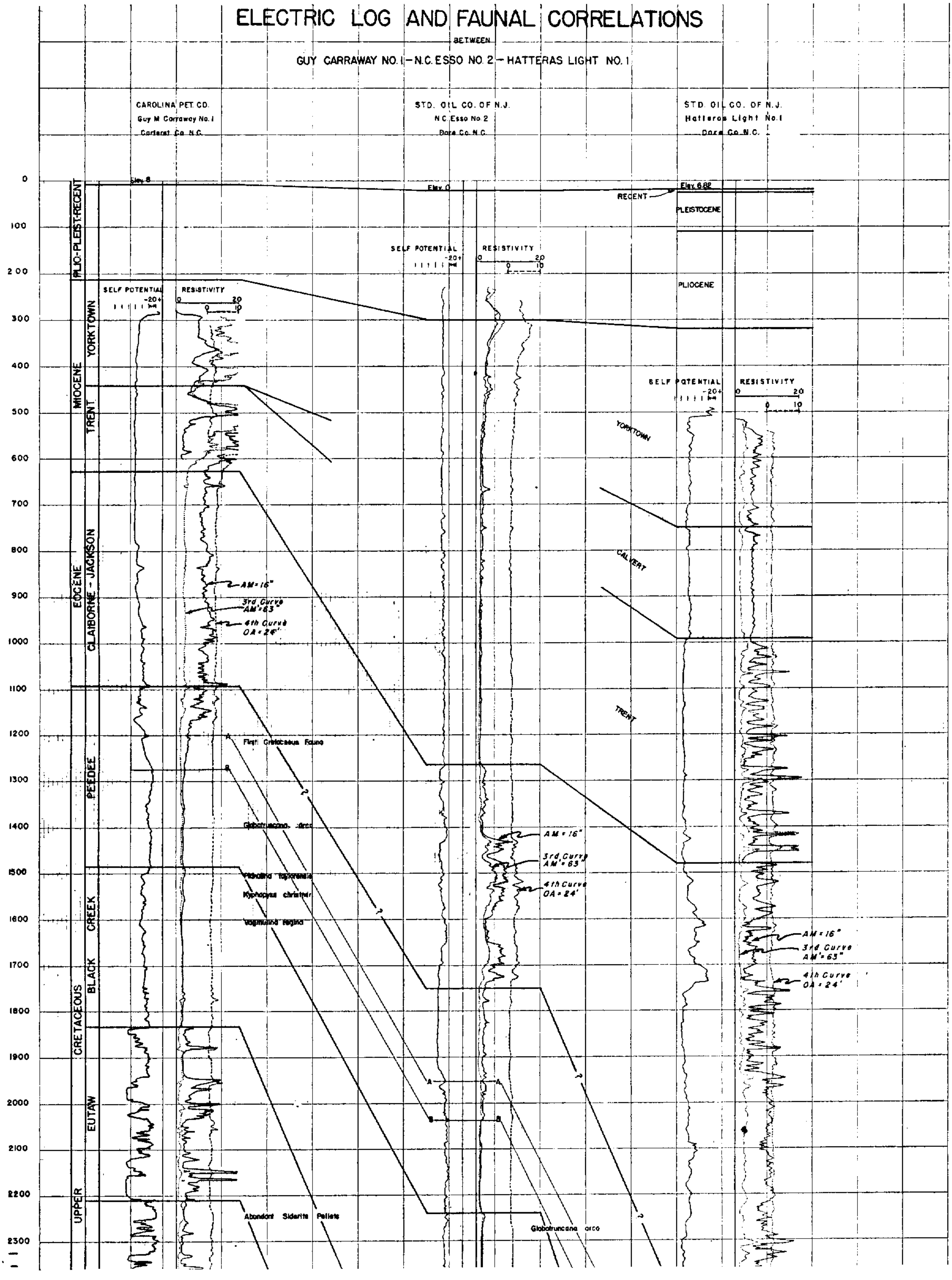
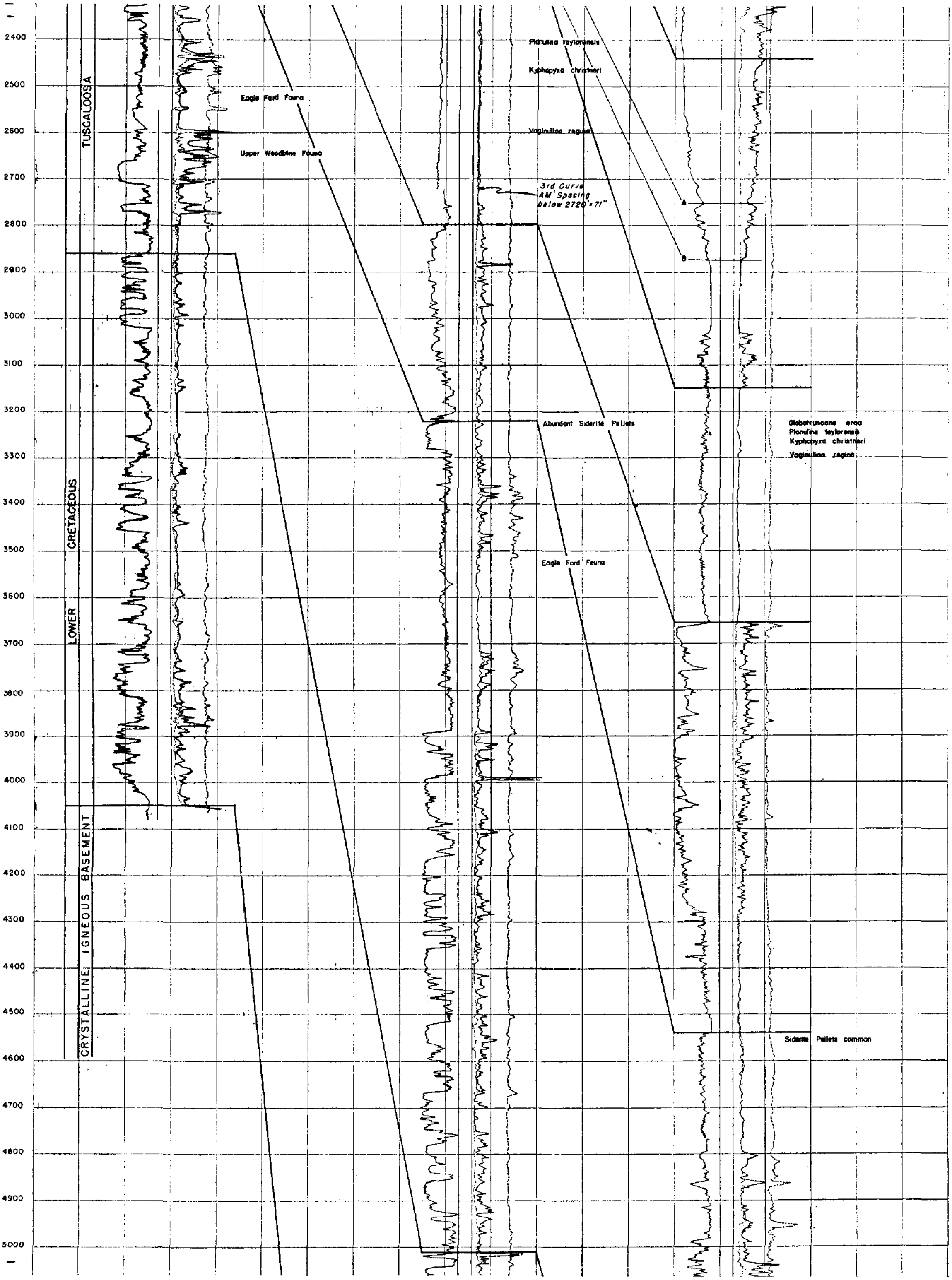


Fig. 6.—Electric-log and faunal correlations between Guy Carraway



No. 1, North Carolina Esso No. 2, and Hatteras Light No. 1.

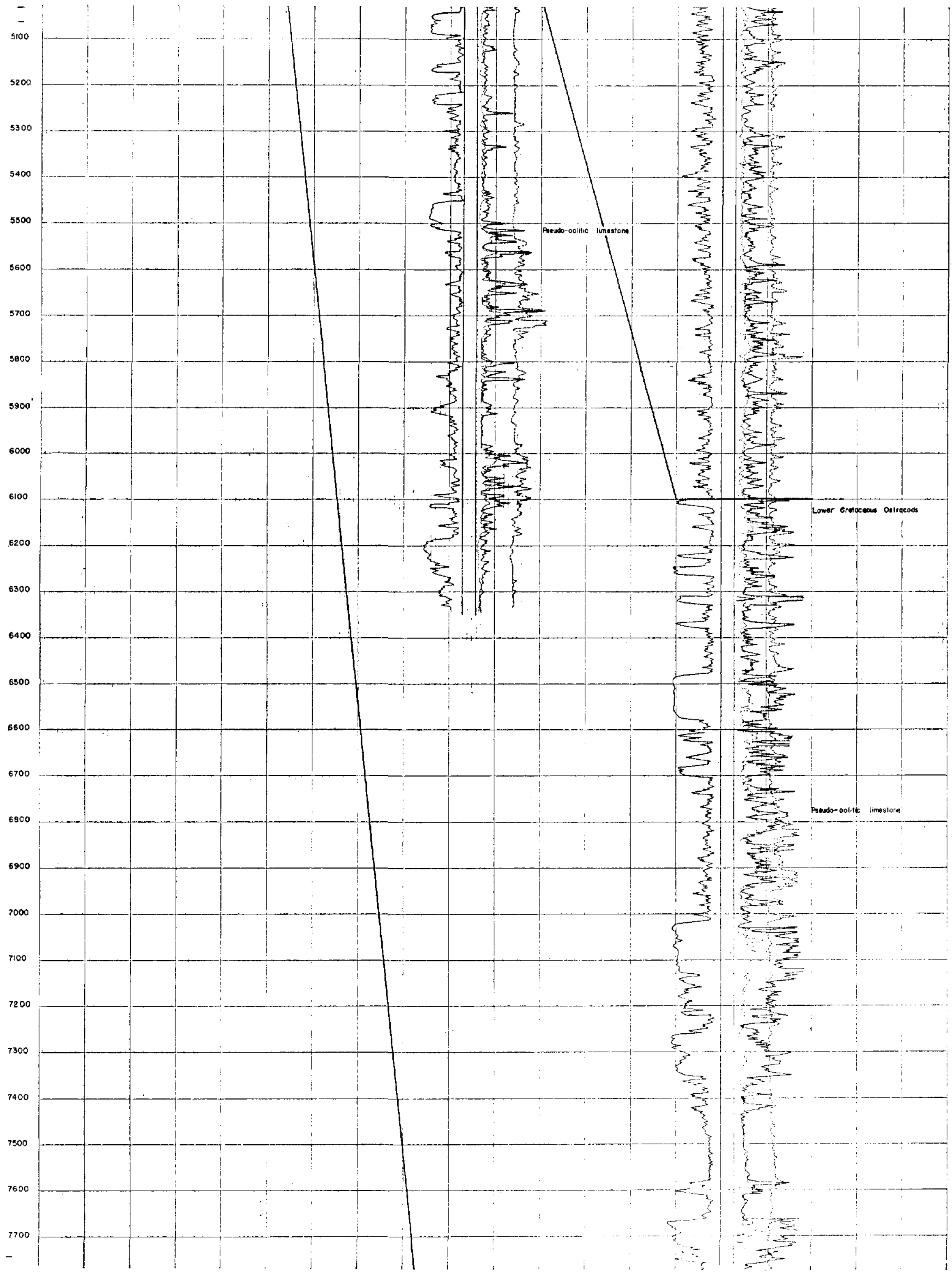
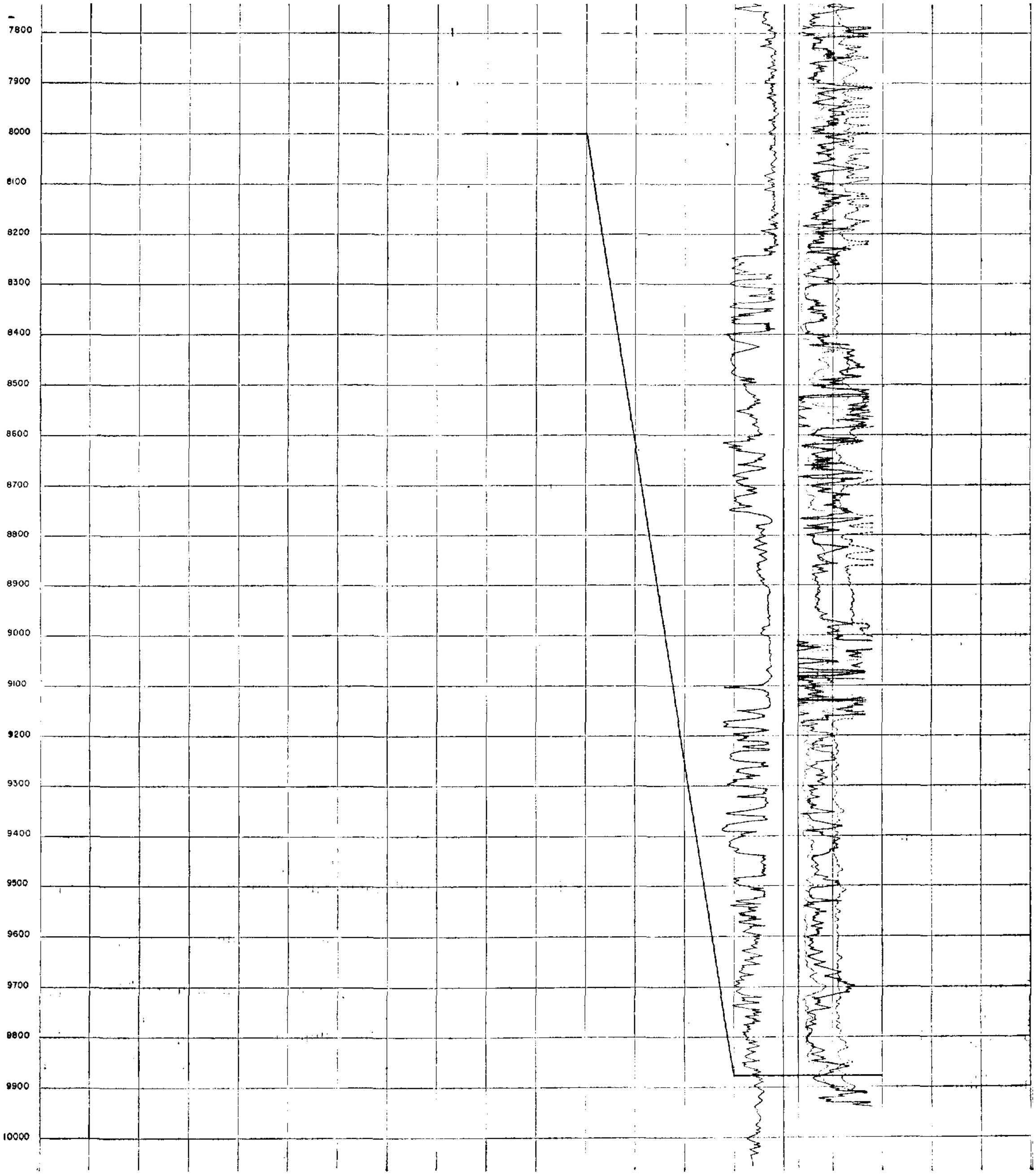


FIG. 6 (continued).—Electric-log and faunal correlations between Guy Carraway



No. 1, North Carolina Esso No. 2, and Hatteras Light No. 1.

TABLE II

COMPARISON OF STRATIGRAPHY OF EASTERN NORTH CAROLINA WITH THAT OF GULF COAST

Gulf Coast		*North Carolina*
Recent Pleistocene Pliocene		Not separated in this paper
Miocene	Upper Middle Lower	Yorktown Unnamed. Present in deep wells* Trent
Oligocene		Absent; may be present in Hatteras Light No. 1
Eocene	Jackson Claiborne Wilcox	Castle Hayne Unnamed. Present in deep wells* Questionably present in Hatteras Light No. 1†
Paleocene	Midway	Questionably present in Hatteras Light No. 1†
	Navarro Taylor Austin	Peedee Black Creek Eutaw
	Eagle Ford Woodbine	Tuscaloosa. Eagle Ford and Woodbine faunas present in wells
	Washita Fredericksburg Trinity	Lower Cretaceous. Lower beds in Hatteras Light No. 1 may be older than Lower Cretaceous

* Hatteras Light No. 1 and North Carolina Esso No. 2.
† Some paleontologists recognize a foraminiferal fauna which they have questionably referred to the Wilcox and Midway.

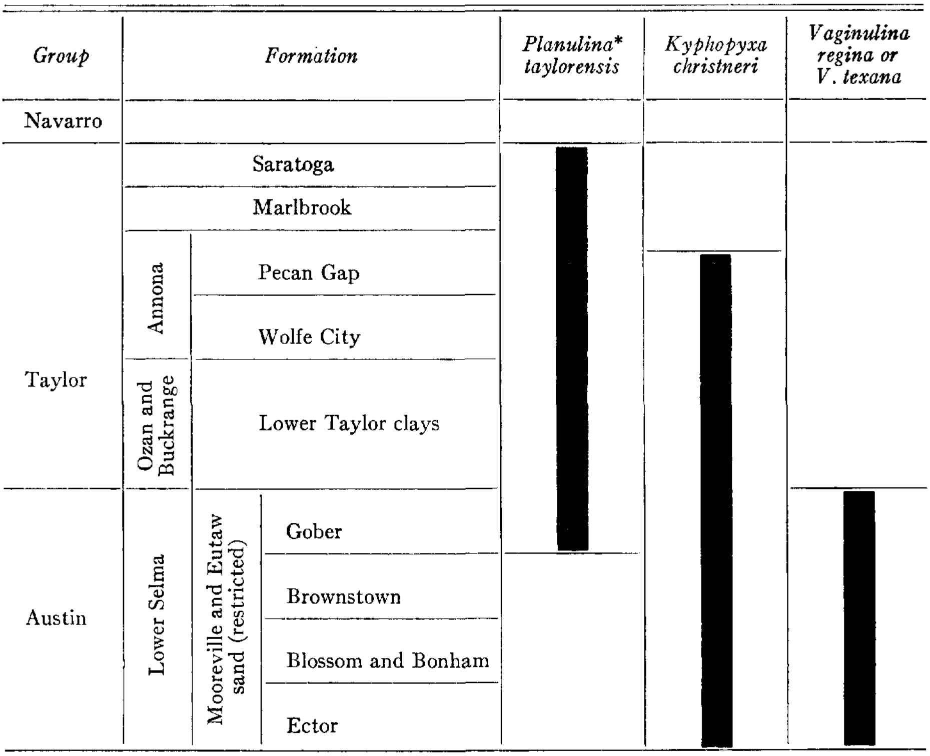
Light No. 1 and North Carolina Esso No. 2 the first Cretaceous fossils were found below Unit A–B and are believed to be Taylor forms. However, since a Cretaceous fauna was consistently found above this unit in the Carolina Petroleum Company wells it is believed that the top of the Upper Cretaceous is considerably higher in Esso No. 2 and Hatteras Light No. 1 than the fauna indicates. The top of the Cretaceous is easily identified by a marked break on the electric logs of the Carolina Petroleum Company wells but can not definitely be recognized on the Hatteras Light No. 1 and Esso No. 2 logs.

The top of beds of Taylor age was recognized at the first occurrence of a Taylor fauna and, as can be seen in Figures 5 and 6, it is marked by a distinct break on the electric logs. Within the beds of Taylor age occurs *Vaginulina regina*, which in the Gulf Coastal area is found no higher than upper Austin (Table III). However, a macrofauna "younger than Austin perhaps Taylor" was identified by L. W. Stephenson from these beds in the John Wallace well No. 1. As a result, it is thought that *Vaginulina regina* ranges into younger beds along the east coast than in the Gulf Coast.

The top of the Eutaw was identified both on the basis of the first Eutaw type lithology and because its microfauna was common to beds of Eutaw age of the Gulf Coastal area, though as previously mentioned this fauna ranged into younger beds.

TABLE III

RANGES OF PLANULINA TAYLORENSIS, KYPHOPYXA CHRISTNERI AND VAGINULINA REGINA IN GULF COASTAL AREA



* A similar species, *Planulina texana*, considered the ancestral form of *P. taylorensis*, occurs in the lower Taylor clays and in the Austin group.

The top of the Tuscaloosa formation is difficult to recognize. However, at or very near the horizon at which the top of the Tuscaloosa would be expected, is found the first occurrence of small, round, brown pellets, which the writer believes are siderite. They are found in the samples of all the recent wells drilled along the Atlantic Coast and nowhere have they been found in beds younger than Tuscaloosa. As the first occurrence of these pellets is apparently the most outstanding lithologic feature, they have been considered by the writer as marking the top of the Tuscaloosa formation. There is at this horizon a noticeable break on the electric logs (Fig. 6).

In Mississippi and Louisiana, ankerite pellets are common in the upper part of the Tuscaloosa formation. The ankerite pellets are similar in size and appearance to the pellets in the Tuscaloosa of the East Coast sediments. The writer does not recommend their use as a criterion for determining the top of the Tuscaloosa over widely separated areas and it would seem rather remarkable if these pellets do mark a contemporaneous horizon. They may represent the

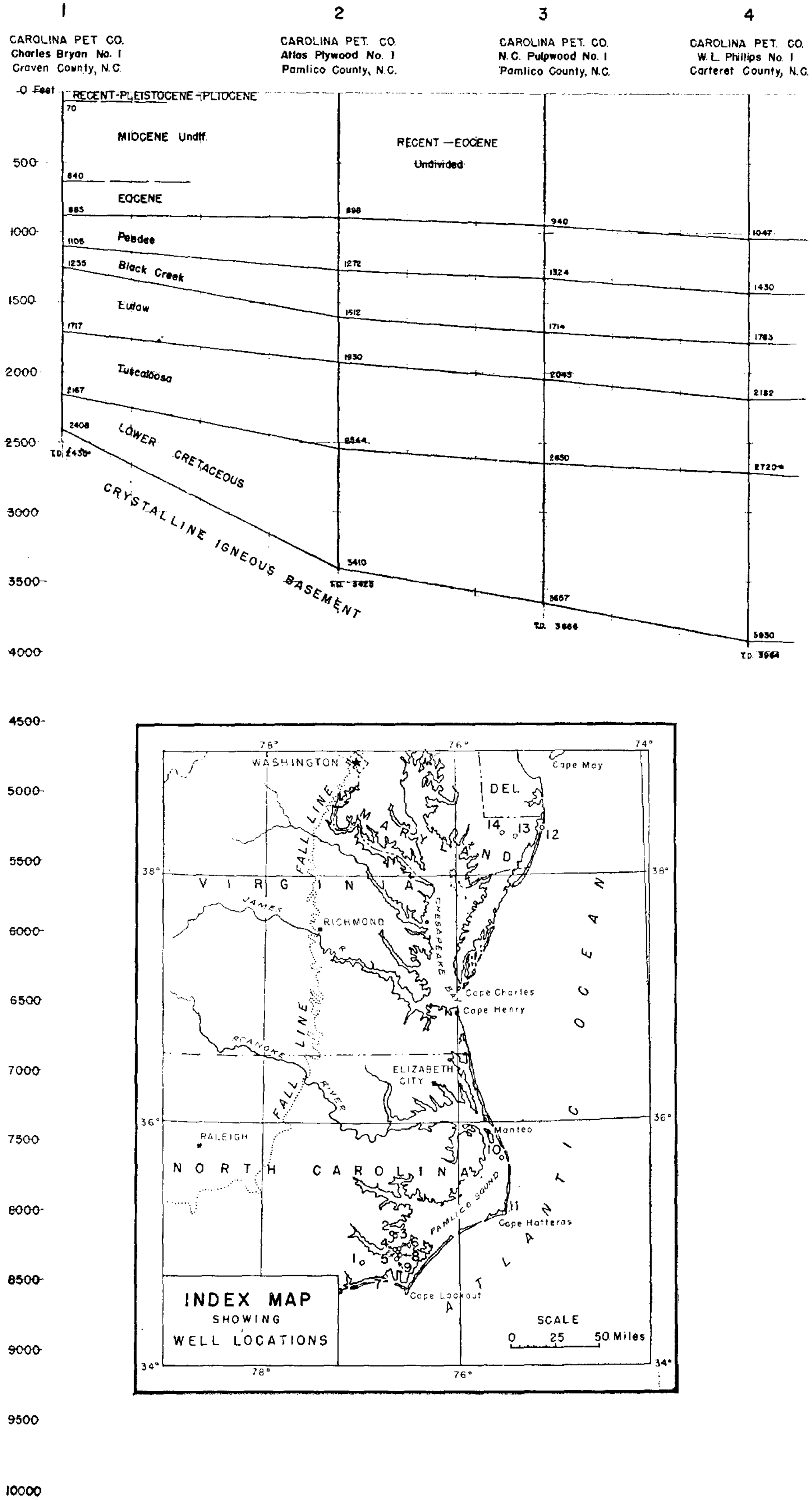
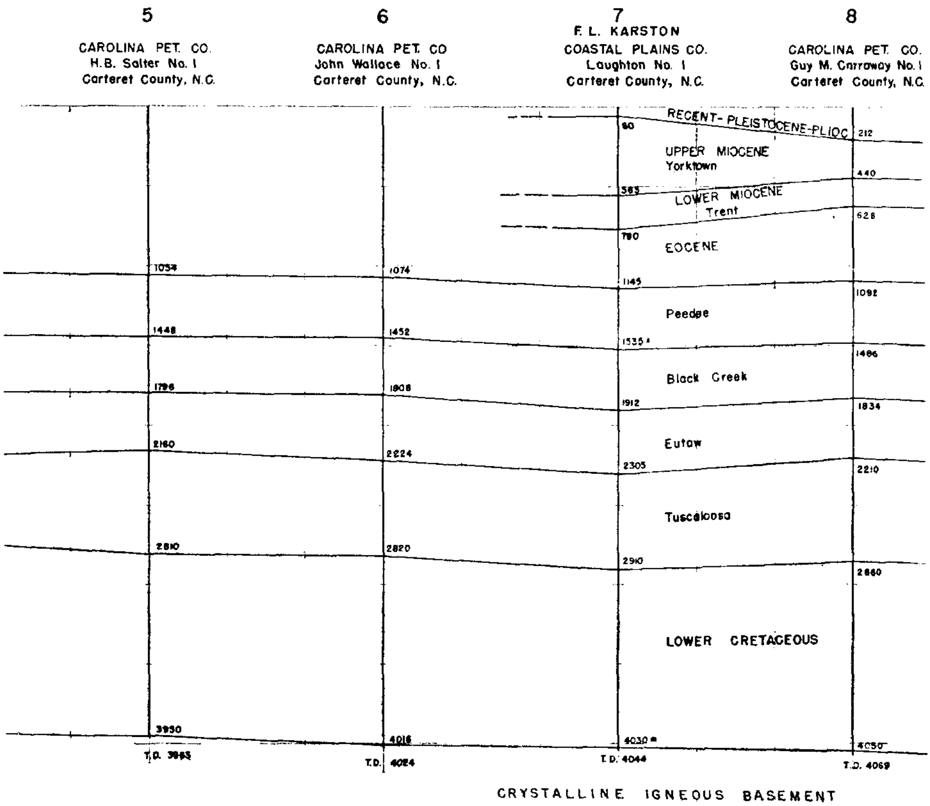


FIG. 7.—Comparative thicknesses and tops in



COMPARATIVE THICKNESSES AND TOPS IN WILDCAT WELLS DRILLED ALONG THE ATLANTIC COASTAL PLAIN

wildcat wells drilled along Atlantic Coastal Plain.

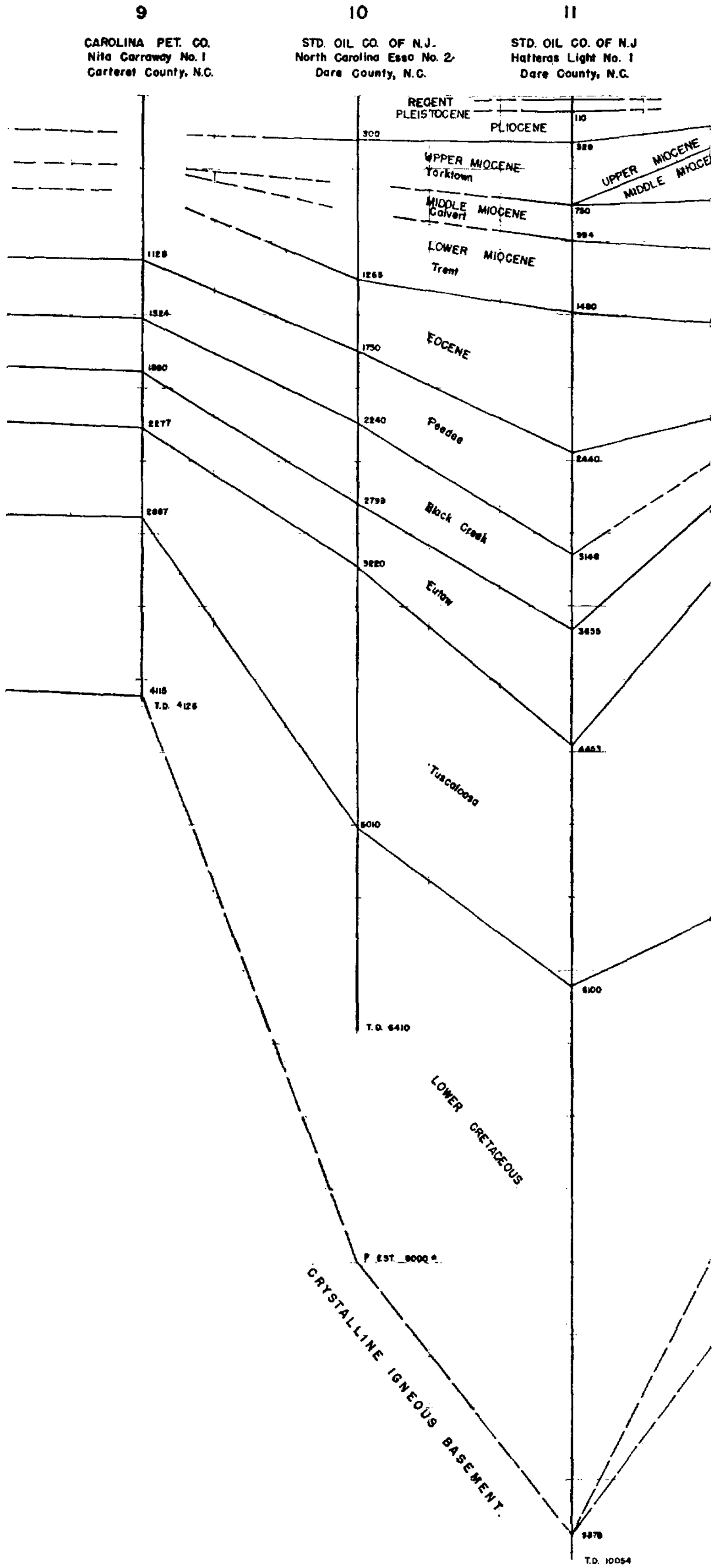
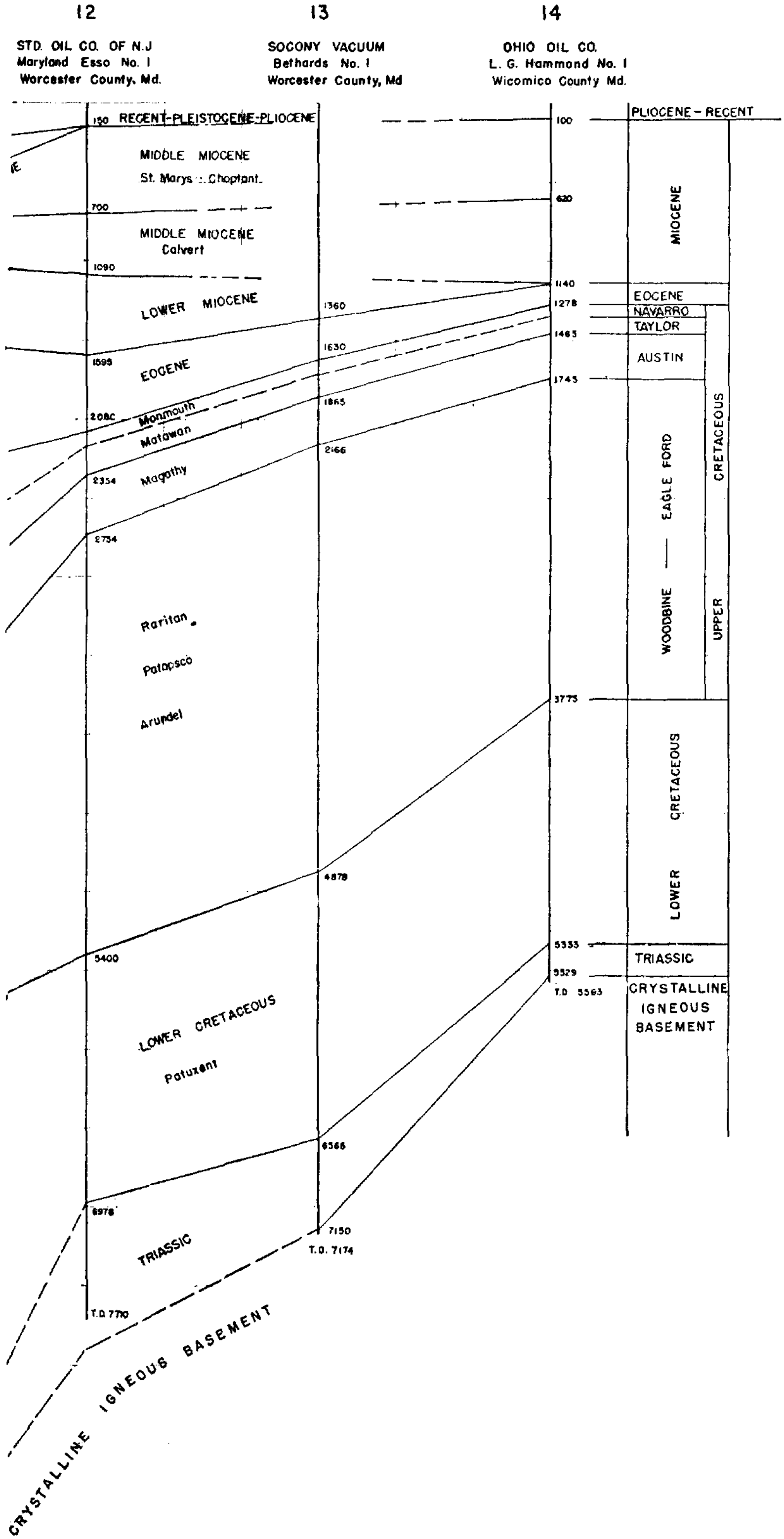


FIG. 7 (continued).—Comparative thicknesses and tops



in wildcat wells drilled along Atlantic Coastal Plain.

activity of some organism which flourished at that particular time or they may be of physical or chemical origin.

Somewhat below the first occurrence of these pellets, excepting in the Hatteras Light well where a restudy of the fauna may be necessary, both microfaunas and macrofaunas of Eagle Ford age were found. Still lower in the section in the H. B. Salter well No. 1 an *Exogyra* suggesting upper Woodbine age was identified by L. W. Stephenson and J. B. Reeside, Jr.

The top of the Lower Cretaceous is very difficult to determine. In Hatteras Light No. 1 it was based on the first occurrence of ostracods that were common to the Glen Rose of the Gulf Coast area. This unit was then correlated in the other wells on basis of electric-log characteristics.

A few geologists have recognized a similarity of some of the lower beds in the Hatteras well to the Hosston, and others believe that these beds may be older than Lower Cretaceous.

BASEMENT COMPLEX

Underlying the sediments of the North Carolina Coastal Plain (as determined from samples from recent wells) are crystalline rocks classified as pre-Cambrian in age. Analyses of cores taken in the basement from the Esso Standard Oil Company's Hatteras Light No. 1 are shown in Table IV.

TABLE IV*

General appearance: Granitoid to pegmatitic texture, some schistosity—appears highly weathered—lateritic
Texture: Weathered igneous
Original structure: Granitoid
Secondary structure: Flaser granitoid, complicated by fracturing and re-cementing
Mineralogy: Minerals are grouped for interpretation purposes and are arranged in each group in approximate order of abundance

Primary	*Secondary*	*Metamorphic*	*Changes and Enrichment Effects*
Orthoclase Oligoclase Microcline Quartz	Chlorite Kaolinite Paragonite Sericite		Later fractured and re-cemented with calcite
Accessory Minerals	*Nature of Ground-Mass or Cement*	*Introduced Substances or Mineralization*	
None recognizable	Fractured and cemented with calcite	Calcite Pyrite Chlorite?	

Special features: Plagioclase more highly altered than potash feldspars. Complete absence of ferromagnesian minerals—probably all altered to chlorite. Some chlorite may be introduced. There appear to be shear zones with mylonitic quartz. Calcite fills some fractures. Feldspars and quartz are not strained, indicating absence of dynamic metamorphism. None of the minerals shows effect of transportation by water (flaser denotes a rock with zones of shearing and crushing—not completely crushed as in a mylonite—both are low-grade metamorphism)
Classification: Lateritic—in place—little or no transportation—much weathered
Origin of rock: Originally quartz monzonite—later sheared to form flaser quartz monzonite

* Analyses by Thornton W. Dennis.

The top of the crystalline basement in Hatteras Light No. 1 was determined from a core which cut the contact of the crystalline rocks with the overlying sediments. The upper part of the basement was highly weathered and even 170 feet below its top it was so altered that it drilled, on the average, at a rate of 30 minutes per foot.

The surface of the basement in exposures dips up to 35 feet per mile southeast. Well data show this dip increases to slightly more than 100 feet per mile southeast after passing the 2,500-foot subsea basement contour.

Figure 8 shows in general the basement configuration.

LOWER CRETACEOUS

Unconformably overlying the crystallines, occur beds considered as Lower Cretaceous in age. These beds are believed to be equivalent in part to the lower part of the Tuscaloosa in the outcrops in North Carolina. Exposures of the Tuscaloosa consist entirely of continental, arkosic, lignitic, gravelly sands, and red, white, and dark lignitic clays. In the wells of Carteret and Pamlico counties these lower beds consist of continental clastics interbedded with marine sands, shales, and minor limestones. Calcareous nodules and lignite are common and siderite is abundant, but glauconite occurs only sparingly. The lowermost sands are arkosic and gravelly.

In Hatteras Light No. 1 the entire section assigned to the Lower Cretaceous, with possibly the exception of the arkosic sands and varicolored shales beginning at 9,150 feet, is marine in origin. It contains numerous limestones and dolomites which are readily recognizable on the electric log. From a core taken in the dolomitic limestones at 9,115 feet, J. B. Reeside, Jr., obtained several oysters and a *Pecten* which he and his colleagues at the National Museum considered as being no younger than Lower Cretaceous nor older than Jurassic.

The entire Lower Cretaceous section was not penetrated in the Esso Standard Oil Company's North Carolina Esso No. 2. The section drilled consists of sands, shales, pseudo-oölitic limestones, sandy limestones, and minor anhydrite and lignite which are comparable with the sediments found in Hatteras Light No. 1. The pseudo-oölitic limestones beginning at 5,515 feet and 6,770 feet in the North Carolina Esso No. 2 and Hatteras Light No. 1, respectively, are correlative. These pseudo-oölitic limestones were not found in the wells in Pamlico and Carteret counties.

At 6,170 feet in the North Carolina Esso well No. 2, a Chara seed was found in the samples. This, to the writer's knowledge, is the first noted occurrence of Chara seeds from sediments along the Atlantic Coast, though they are found in the Lower Cretaceous Trinity group of the Gulf Coastal area.

UPPER CRETACEOUS

Tuscaloosa formation.—As has been mentioned, the sediments in outcrop that previously have been referred to the Tuscaloosa formation are thought to

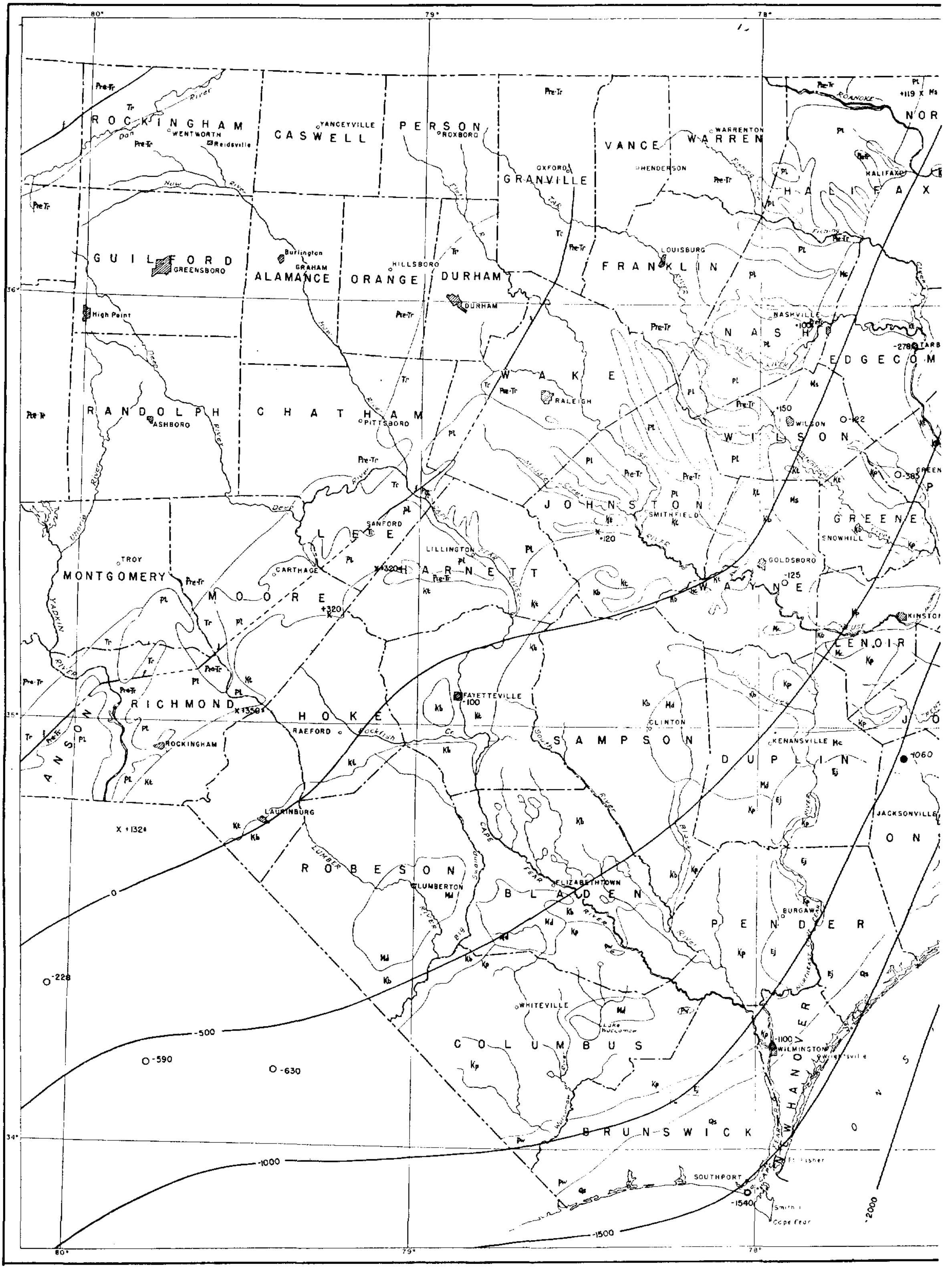
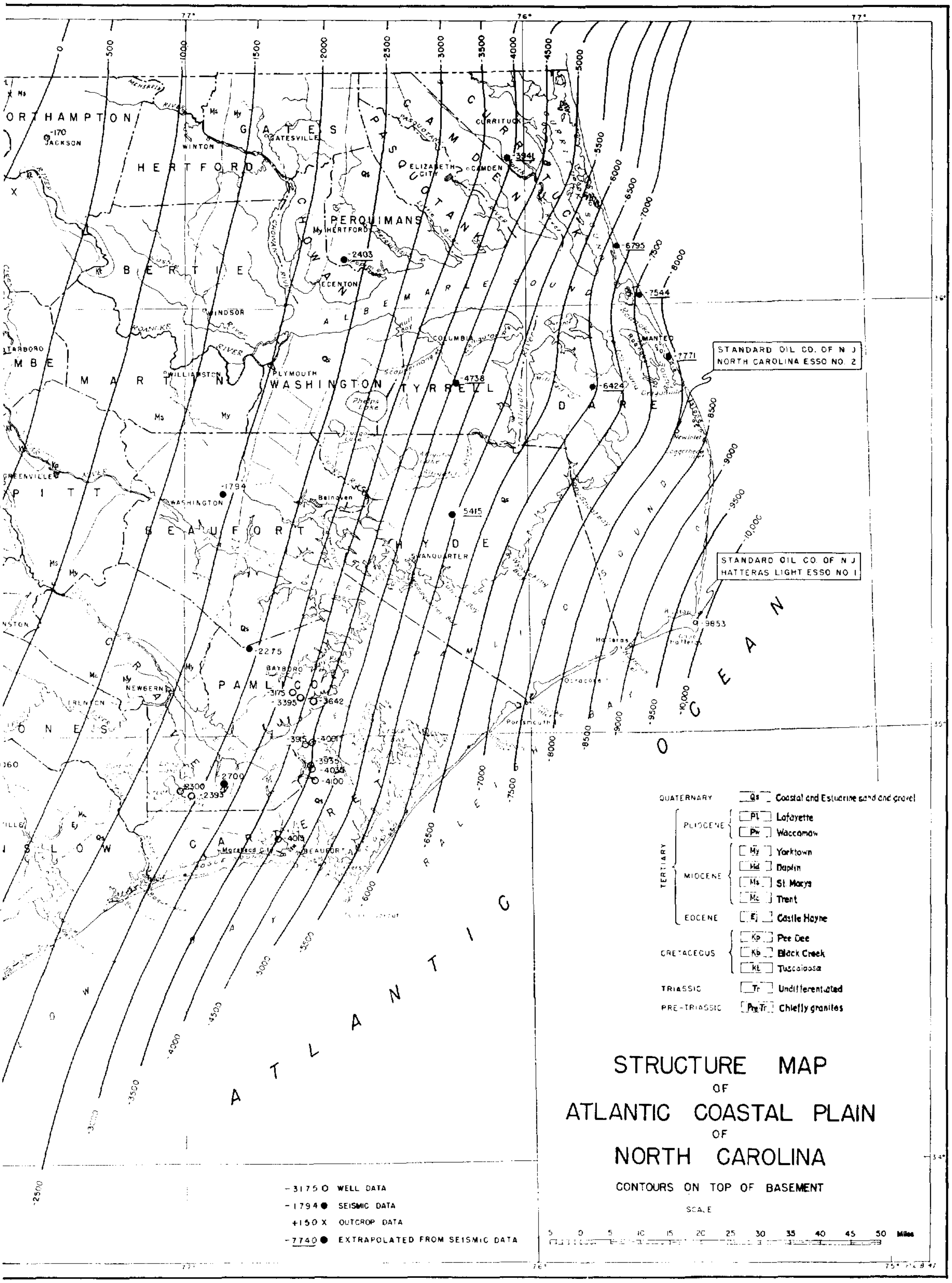


FIG. 8.—Structure map of Atlantic Coastal Plain



of North Carolina contoured on basement rocks.

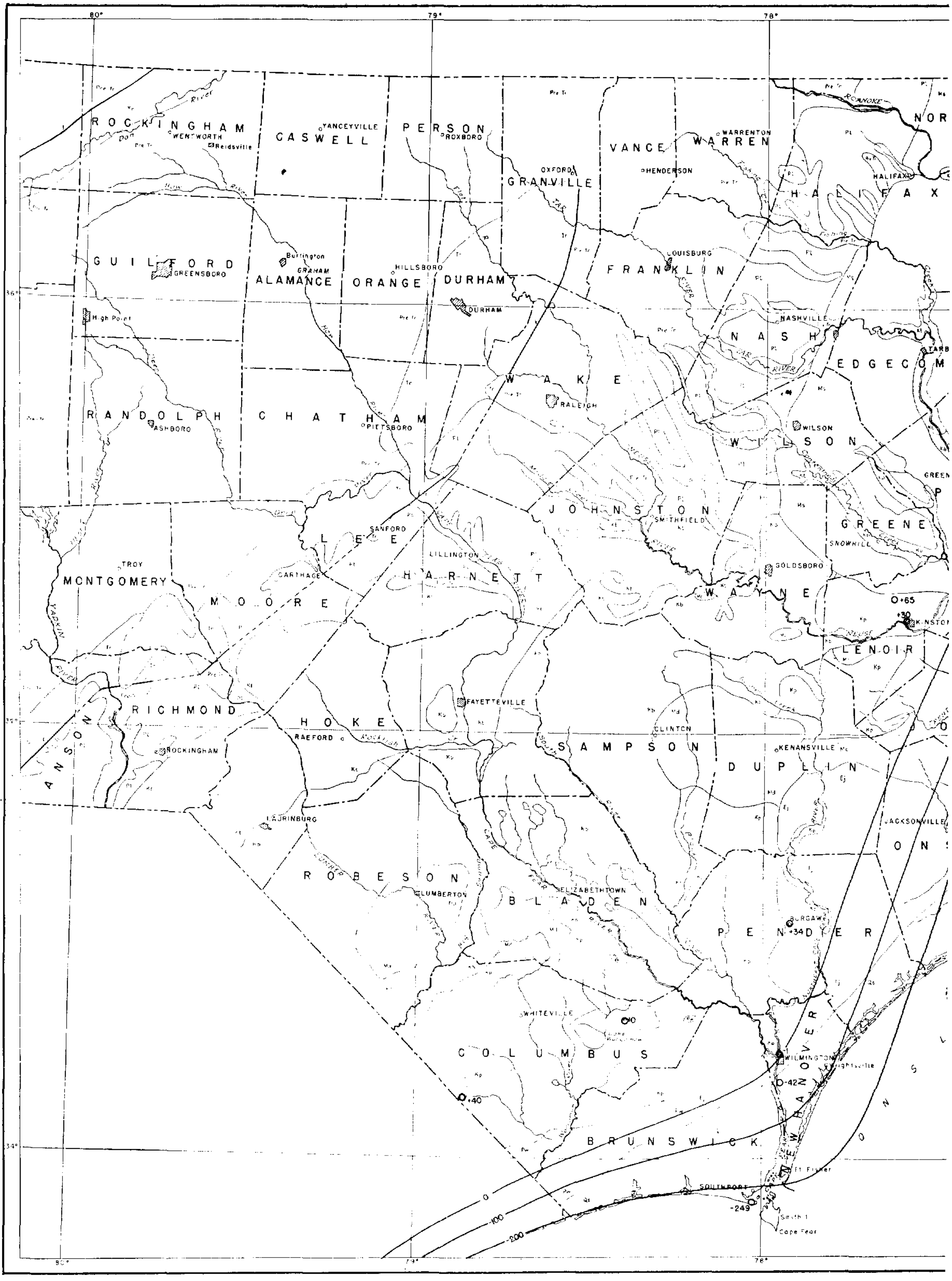
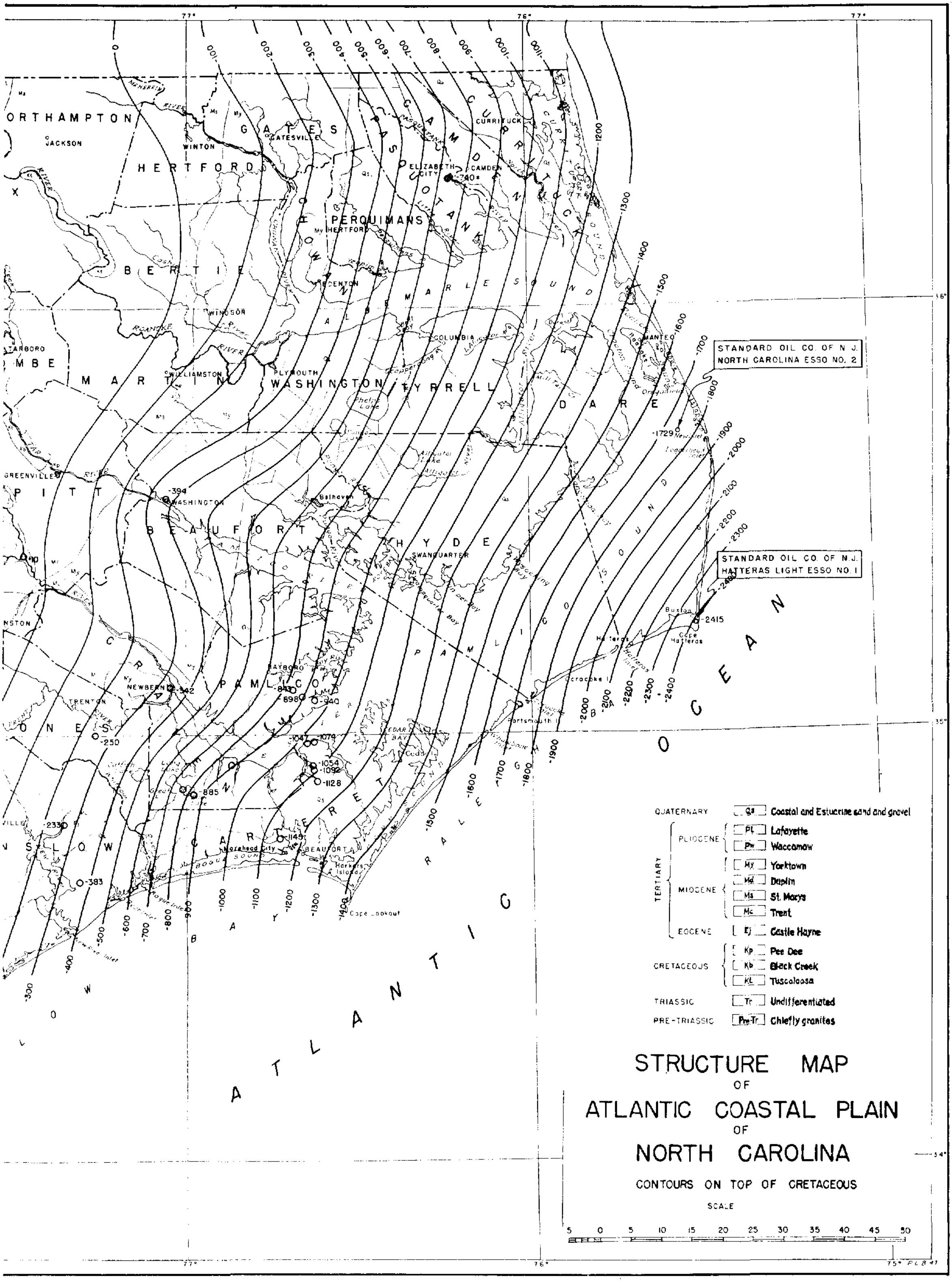


FIG. 9.—Structure map of Atlantic Coastal



Plain of North Carolina contoured on Cretaceous.

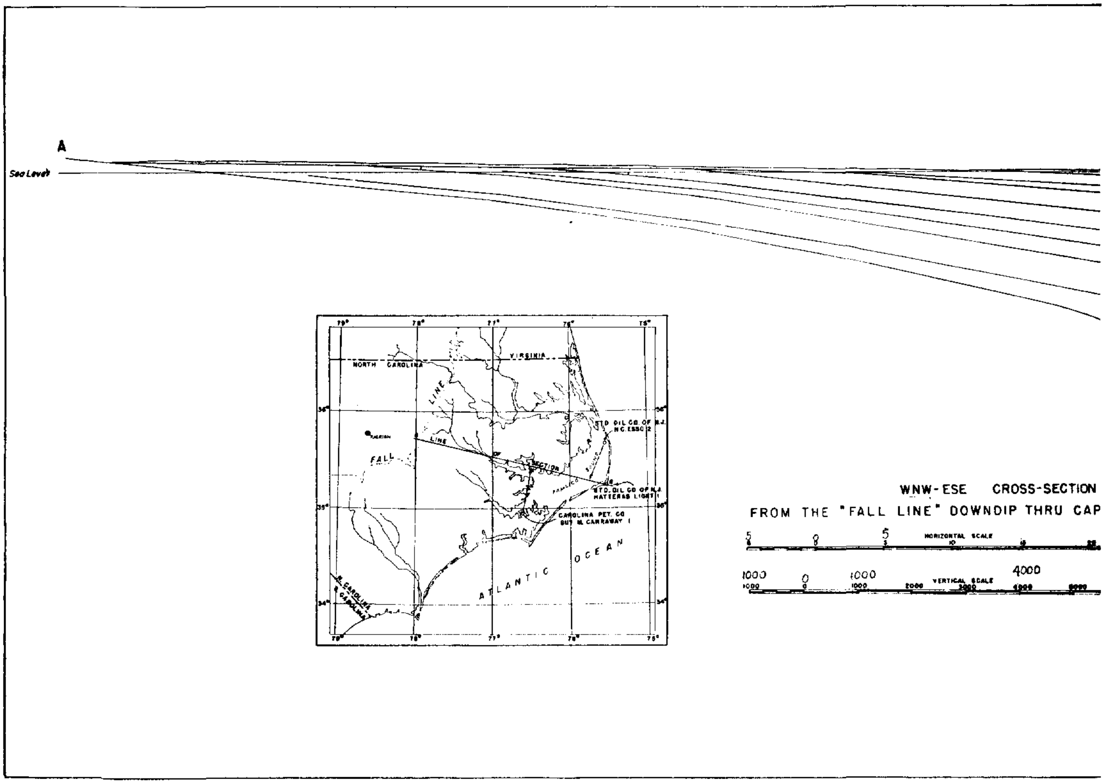


FIG. 10.—Cross section from Fall line downdip

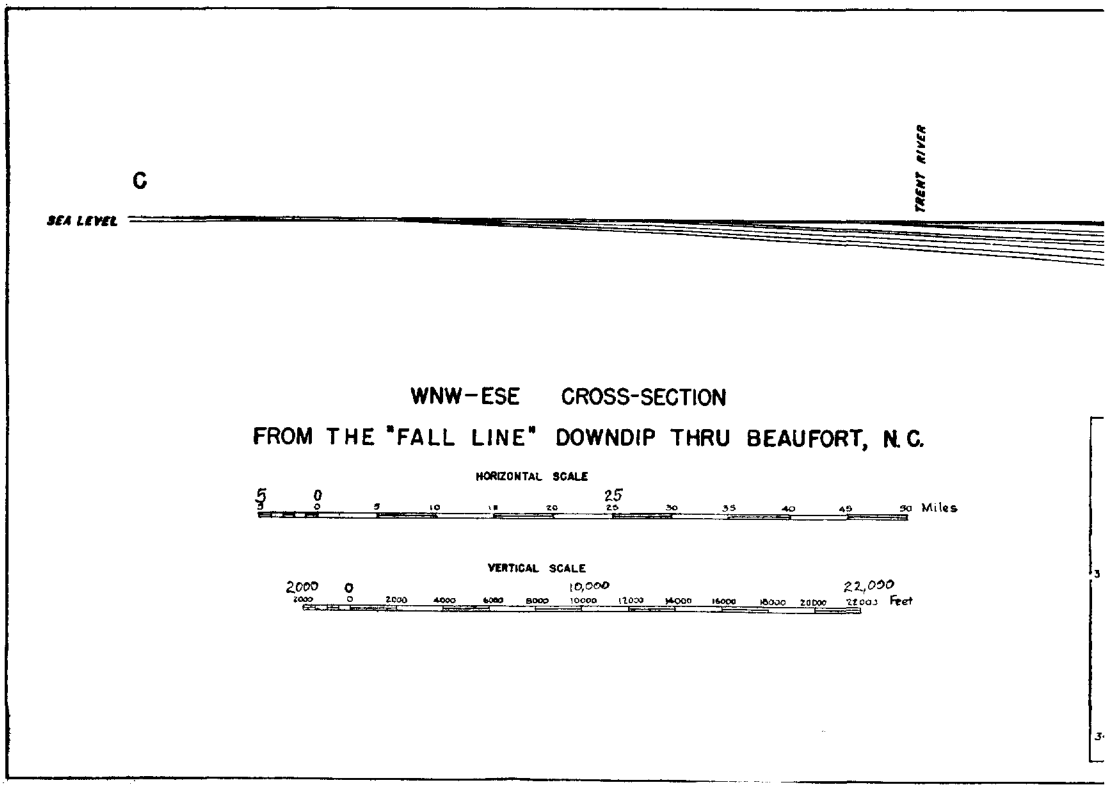
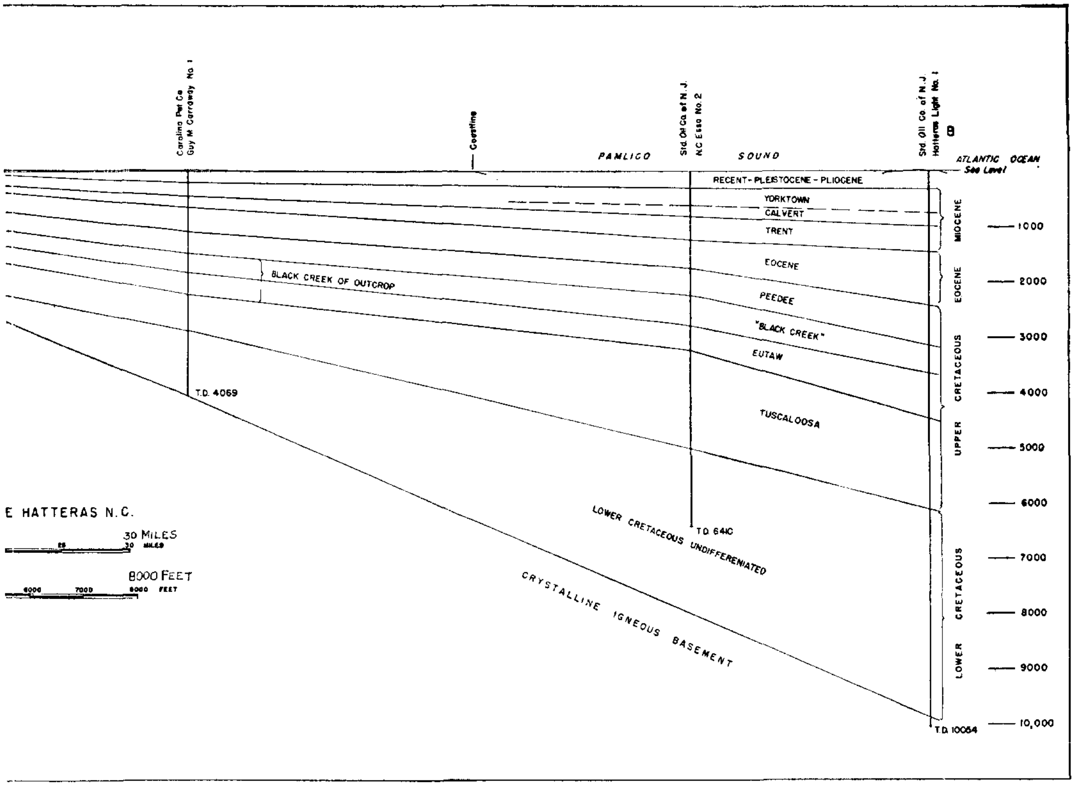
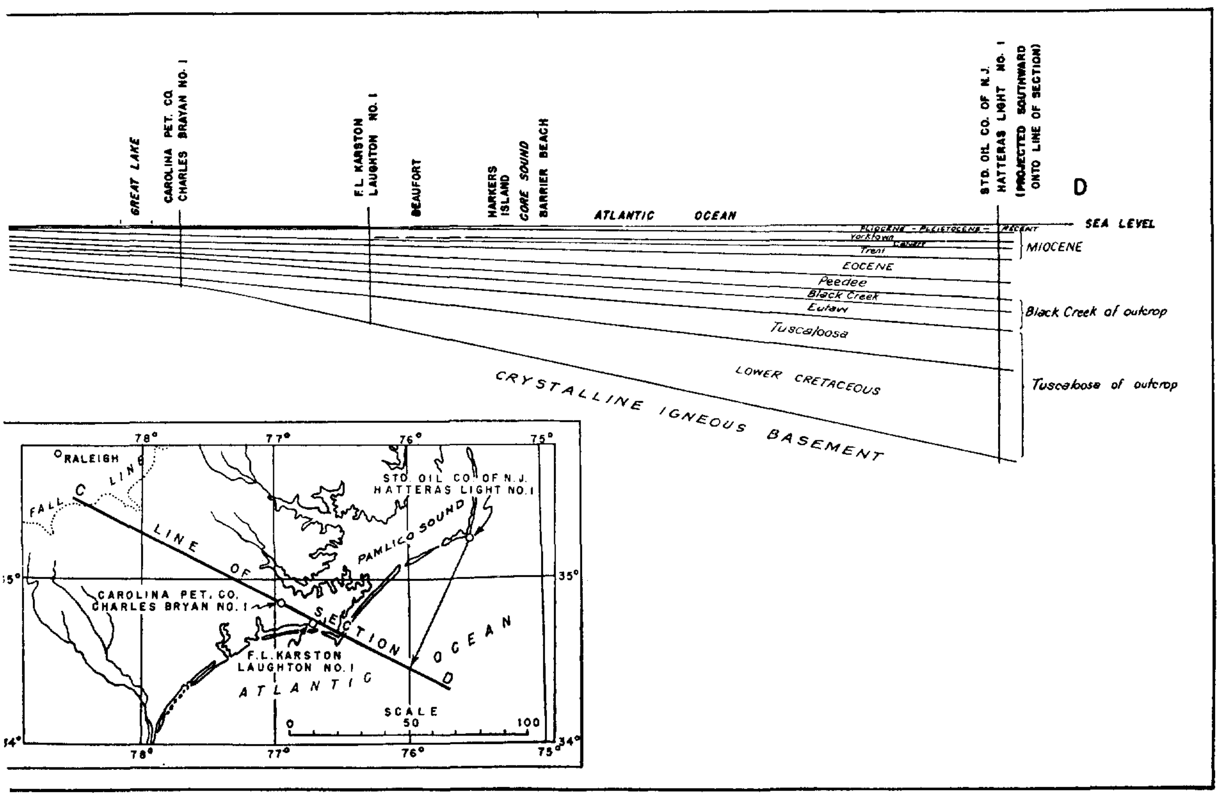


FIG. 11.—Cross section from Fall line downdip



southeast through Cape Hatteras, North Carolina.



southeast through Beaufort, North Carolina.

contain at their base, beds of Lower Cretaceous age. These Upper and Lower Cretaceous beds can not be differentiated in the exposures. However, in the subsurface, where they can be separated, the name Tuscaloosa is applied only to the beds of Eagle Ford-Woodbine age.

The Tuscaloosa in the wells consists of oyster-bearing sands and sandstones, limestones, and varicolored clay and shale. Pyrite, glauconite, lignite, and siderite were found in varying amounts and the first occurrence of siderite pellets seemed to be the best criteria for determining the top of this formation. In the wells in Pamlico and Carteret counties, the Tuscaloosa contains many sand bodies separated by sandy clay shales. In Hatteras Light No. 1 the sands have become shaly and thin, and numerous sandy limestones are present. Microfaunas are rare though both macrofaunas and microfaunas of Eagle Ford age are present. In North Carolina Esso No. 2 there is an abundance of forms identified as *Exogyra woolmani* and *Hamulus protoonyx* by Horace G. Richards.

Eutaw formation.—The Eutaw is composed of varicolored sands, gravelly sands, and clay shales. Minor amounts of lignite, pyrite, and glauconite are present. Foraminifera, among which are forms restricted to the Austin in the Gulf Coastal area, are common.

Heretofore, beds representative of Austin age were believed to be absent in North Carolina. The Black Creek formation, which consists of an upper marine Snow Hill member and a lower continental member, previously had been classified as Taylor in age. Lithologically, however, the lower continental part is like the Magothy of Maryland, Delaware, and New Jersey which is Austin in age. The lower continental part of the Black Creek formation contains no fauna by which its true age can be determined. J. J. Peterson, in studying the outcrops of the Black Creek formation, concluded that the upper marine Snow Hill member is Taylor in age and equivalent to the Matawan formation, and that the lower continental part is correlative with the Magothy. On the basis of correlations from faunas and electric-log interpretations, isopach and structure maps, and cross sections, the writer does not believe that the beds of Eutaw age pinch out updip, and he would correlate them with the lower part of the Black Creek which is thought to be Austin in age (Figs. 5, 6, 7, 10, 11).

Black Creek formation.—The beds referred to the Black Creek formation in the wells are Taylor in age and equivalent to the Snow Hill member in outcrop. In the wells, the Black Creek is made up of glauconitic, finely sandy, clay shales, and minor sands. Lithologically it is difficult to separate from the overlying Peedee; however, the Peedee is more calcareous and chalky. The beds of the Black Creek formation contain an abundant foraminiferal fauna, the assemblage being a mixture of forms common to the Taylor and Austin of the Gulf Coast.

Peedee formation.—The Peedee in the wells consists of glauconitic marly sands with minor marls, chalks, and clays. In the wells of Pamlico and Carteret counties, the Peedee contains an Upper Cretaceous foraminiferal fauna of Navarro age. No foraminiferal fauna by which the true age of the Peedee could be determined was found in North Carolina Esso No. 2 and Hatteras Light No. 1 and correlations were made on electric-log characteristics.

EOCENE

The beds assigned to the Eocene in the wells have not been divided into formational members but are composed of glauconitic, clayey sands, chalky, sandy shell limestones and coquinas, and marls. On the basis of the foraminifera which are abundant, the Eocene age of the beds is well established. Tentatively, faunas from the Eocene beds in Hatteras Light No. 1 have been identified as indicating Midway, Wilcox, Claiborne, and Jackson ages. In Esso No. 2 only Claiborne and Jackson age faunas were noted and it is believed that more study is necessary before dividing the beds of Eocene age into formations.

OLIGOCENE

No Oligocene has been identified either in outcrop or from well samples in North Carolina. A few of the beds in Hatteras Light No. 1 have been referred questionably by some geologists to the Oligocene.

MIOCENE

The beds of Miocene age in the subsurface have been divided tentatively into lower, middle, and upper Miocene. The middle Miocene is present only in Esso No. 2 and Hatteras Light No. 1, pinching out updip before reaching Pamlico and Carteret counties where it is not recognized in well samples.

The Miocene consists of glauconitic clayey sands and marls and minor sandy shell gravels. Phosphate nodules are common in its lower part. It is abundantly fossiliferous both in macrofaunas and microfaunas.

The upper Miocene in Hatteras Light No. 1 is made up of 430 feet of sands, sandy marls, calcareous sands, and shell beds. The middle Miocene consists of 244 feet of foraminiferal ooze with minor amounts of fine, sharp, glassy sand. The lower Miocene is composed of 486 feet of alternating and gradational glauconitic coquinas, marls, and sands.

The geologic map that has been used as a base for the structure maps (Figs. 8 and 9) was redrawn from the *Geologic Map of North Carolina*.[5] These maps show the Miocene outcrops divided into Yorktown, Duplin, St. Marys, and Trent formations. There is apparently considerable doubt about the recognition of these formations in outcrop. In South Carolina the Yorktown is divided into the Raysor and Duplin marl.[6] These names refer to the middle and upper Yorktown, respectively. From the legend of Figures 8 and 9 one is led to believe that the Duplin is stratigraphically lower than the Yorktown.

[5] Compiled and prepared by the Mineral Resources and Engineering Divisions, *North Carolina Dept. Conserv. and Dev.* (1937).

[6] C. W. Cooke, "Geology of the Coastal Plain of South Carolina," *U. S. Geol. Survey Bull. 867* (1936), pp. 115, 117.

In North Carolina the outcropping Miocene occurs as thin and scattered remnants which have been subdivided by White and Peterson into Yorktown and Trent of upper and lower Miocene age, respectively. They included, with the Yorktown, beds of the St. Marys formation of middle Miocene age. The age of the St. Marys seems to rest on meager evidence. It is lithologically like the Yorktown and is restricted to such small areas that the two have been treated as a single unit. It is the writer's opinion that the present geologic maps of the Coastal Plain of North Carolina show the Miocene sediments divided erroneously. It is also the writer's opinion that more field work is needed in order to show the areal limits and subdivisions of the Miocene in North Carolina.

PLIOCENE-PLEISTOCENE-RECENT

Beds of Pliocene, Pleistocene, and Recent age were not divided in subsurface excepting tentatively in Hatteras Light No. 1. The beds are composed of coarse sands, gravelly sands, shell gravels, and clays. Foraminifera are common and a careful study of this fauna may afford a means of differentiation.

STRUCTURE

The regional structure of the sedimentary rocks of the Coastal Plain area of North Carolina is a broad eastward-dipping monocline, warped in southern North Carolina by a wide nose plunging southeast approximately 15 feet per mile and known as the Great Carolina ridge. The basement floor reflects the regional structure and has been contoured in Figure 8 from well data and refraction-seismograph depth points.

The rate of dip increases eastward from the Fall line, this increase being moderate to the 2,500-foot subsea contour where it steepens sharply. The average slope of the crystalline floor to the 2,500-foot subsea contour is 35 feet per mile. From the 2,500-foot contour the dip changes to somewhat more than 100 feet per mile.

Figure 9 is a structure map with contours drawn on the top of the Cretaceous (base of the Eocene). Toward the north, first the Peedee and then the Black Creek are overlapped by Eocene sediments. In the extreme northern area along the Virginia-North Carolina state line, this erosional unconformity is marked by an overlap of the Eocene on beds considered to be the Patuxent formation. Hence, the contours in the northern area are on the top of an erosional unconformity and do not give a true structural picture.