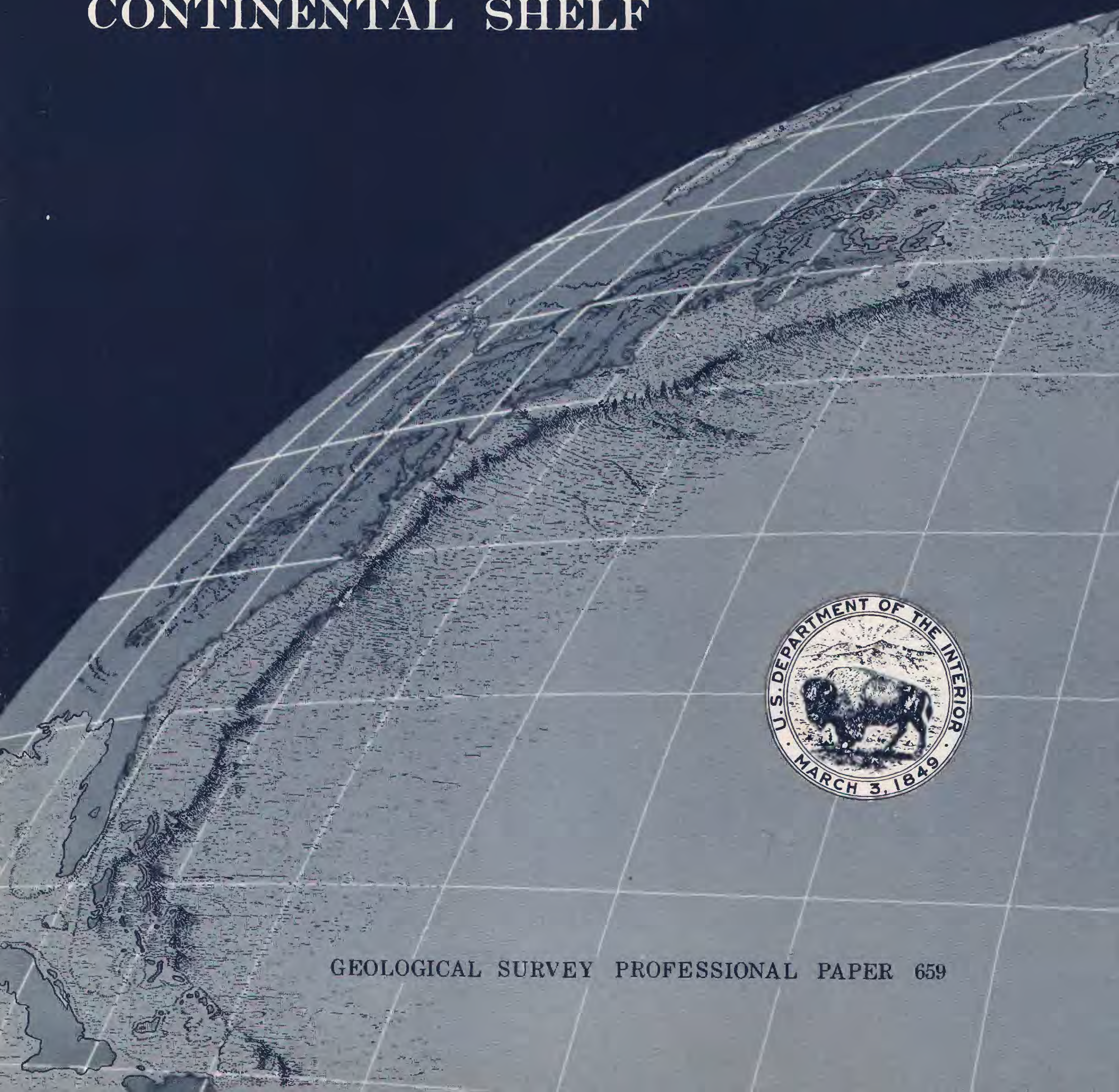
GEOLOGIC FRAMEWORK AND PETROLEUM POTENTIAL OF THE ATLANTIC COASTAL PLAIN AND CONTINENTAL SHELF



GEOLOGICAL SURVEY PROFESSIONAL PAPER 659

GEOLOGIC FRAMEWORK AND PETROLEUM POTENTIAL OF THE ATLANTIC COASTAL PLAIN AND CONTINENTAL SHELF

By John C. Maher

ABSTRACT

The Atlantic Coastal Plain and Continental Shelf of North America is represented by a belt of Mesozoic and Cenozoic rocks, 150 to 285 miles wide and 2,400 miles long, extending from southern Florida to the Grand Banks of Newfoundland. This belt of Mesozoic and Cenozoic rocks encompasses an area of about 400,000 to 450,000 square miles, more than three-fourths of which is covered by the Atlantic Ocean. The volume of Mesozoic and Cenozoic rocks beneath the Atlantic Coastal Plain and Continental Shelf exceeds 450,000 cubic miles, perhaps by a considerable amount. More than one-half of this is far enough seaward to contain marine source rocks in sufficient proportion to attract exploration for oil. A larger fraction, perhaps three-quarters of the volume, may be of interest in exploration for gas.

The Coastal Plain consists of land between the crystalline rocks of the Piedmont province of the Appalachian Mountain System and mean low tide from southern Florida to the tip of Long Island plus a few small offshore islands and Cape Cod. This is an area of more than 100,000 square miles.

The continental shelf extends from mean low tide to the break marking the beginning of the continental rise, which is somewhat less than 600 feet in depth at most places. It is a gently sloping platform, about 350,000 square miles in area, that widens from less than 3 miles off southern Florida to about 285 miles off Newfoundland.

The Blake Plateau occupies an area of about 70,000 square miles between the 500- and 5,000-foot bottom contours from the vicinity of Cape Hatteras to the northernmost bank of the Bahamas. It has a gentle slope with only minor irregularities and scattered patches of Holocene sediments.

Gravity and magnetic anomalies along the Atlantic coast primarily reflect compositional differences in the earth's crust at great depths, but they are also related to some extent to the structure and composition of the Coastal Plain sedimentary rocks and shallow basement. Four alternating belts of predominantly positive and predominantly negative Bouguer gravity anomalies extend diagonally across the region from southwest to northeast. These correspond roughly with the continental rise and slope, the continental shelf and Coastal Plain, the Appalachian Mountain System front, and the Piedmont Plateau-Blue Ridge-Appalachian Basin region.

Long, linear, northeastward-trending magnetic anomalies roughly parallel the Appalachian Mountain System and the edge of the continental shelf. These trends are interrupted along the 40th parallel, about 50 miles south of New York, by a linear anomaly, suggesting a transcurrent fault, more or less alined with a string of seamounts extending down the continental rise to the abyssal plain. The trends parallel to the Appalachians terminate in Florida against a southeasterly magnetic trend thought by some to represent an extension of the Ouachita Mountain System. One large anomaly, known as the slope anomaly, parallels the edge of the continental shelf north of Cape Fear and seemingly represents the basement ridge located previously by seismic methods.

Structural contours on the basement rocks, as drawn from outcrops, wells, and seismic data, parallel the Appalachian Mountains except in North and South Carolina, where they bulge seaward around the Cape Fear arch, and in Florida, where the deeper contours follow the peninsula. The basement surface is relatively smooth and dips seaward at rates ranging from 10 feet per mile inland to as much as 120 feet per mile near the ocean. A decided steepening of the slope is apparent below a depth of 5,000 feet in most of the area. The principal structural features are the Southwest Georgia embayment, South Florida embayment, Peninsular arch, Bahama uplift, Southeast Georgia embayment, Cape Fear arch, Salisbury embayment, Blake Plateau trough, Baltimore Canyon trough, Georges Bank trough, and Emerald Bank trough.

Triassic, Cretaceous, and Tertiary rocks crop out roughly parallel to the present Atlantic coastline. Triassic outcrops are confined to scattered down-faulted basins within the piedmont. Lower Cretaceous outcrops are recognized in the Salisbury embayment of New Jersey, Delaware, Maryland, and Virginia, and may be represented farther south as thin clastic beds mapped with the basal Upper Cretaceous. Upper Cretaceous rocks crop out almost continuously along the Fall Line from eastern Alabama to the north flank of the Cape Fear arch in North Carolina and from Virginia to New York. Tertiary rocks crop out in broad patterns throughout the Coastal Plain except on the Cape Fear arch and where masked by a veneer of alluvial deposits.

The Cretaceous and Tertiary rocks exposed from southern Georgia northward to Long Island are mainly continental clastics interspersed with some thin lignitic layers and marl beds. Seaward, these rocks become marine in character and thicken to more than 10,000 feet at the coastline. Cretaceous rocks do not crop out in southern Georgia and Florida, and Tertiary rocks are only partially exposed. Both are predominantly marine carbonates in the subsurface and exceed 15,000 feet in thickness in the Florida Keys and Bahama Islands.

The subsurface correlations of the Mesozoic and Cenozoic rocks beneath the Coastal Plain are traced along eight cross

sections. One section extends subsurface correlations from the marine carbonate facies beneath the Florida Keys northward into the mixed marine and continental clastic facies beneath Long Island. The other sections trace units of the predominantly clastic outcrops downdip into marine facies along the coast.

The pre-Mesozoic basement rocks beneath the Coastal Plain are primarily igneous and metamorphic rocks of Precambrian and Paleozoic age. Some Paleozoic sedimentary rocks ranging from Early Ordovician to Middle Devonian in age are in the basement in northern Florida. The oldest rock recovered from the sea bottom along the Atlantic coast has come from the Paleozoic granite pinnacles at a depth of about 30 feet on Cashes Ledge near the middle of the Gulf of Maine.

Triassic(?) rocks, which consist of red arkose, sandstone, shale, tuff, and basalt flows, in places intruded by diabase, are present in downfaulted basins in the basement. Rocks of Late Jurassic or Early Cretaceous (Neocomian) age are present beneath southern Florida. There the sequence, as much as 1,100 feet thick, consists principally of limestone, dolomite, and anhydrite with a marginal clastic facies at the base where it rests on igneous basement. Equivalent rocks about 900 feet thick are present at Cape Hatteras, N.C., and extend northward along the coast into New Jersey.

In Florida, the Lower Cretaceous rocks, subdivided into rocks of Trinity, Fredericksburg, and Washita age, are predominantly carbonates and exceed 6,700 feet in thickness beneath the Florida Keys. Northward along the coast, the rocks wedge out on the Peninsular arch and then reappear as a thin clastic unit across Georgia and South Carolina. They are missing from the higher parts of the Cape Fear arch in North Carolina but are present on the east flank as a thickening wedge of mixed clastic and carbonate rocks more than 2,800 feet thick at Cape Hatteras and 2,600 feet thick in Maryland. Lower Cretaceous rocks probably extend into northern New Jersey but do not reach Long Island. Lower Cretaceous submarine outcrops are present in the Blake Escarpment.

Upper Cretaceous rocks, which can be subdivided into rocks of Woodbine, Eagle Ford, Austin, Taylor, and Navarro age, are about 1,200 to 3,000 feet thick in wells along the coast. In Florida, they are almost totally marine carbonates. These grade northward along the coast into mixed marine carbonates and clastics in North Carolina and then into marine and continental clastics beneath Long Island. Rocks of Taylor and Navarro age have been dredged from Oceanographer and Gilbert Canyons off Georges Bank and rocks of probable Woodbine age from the Blake Escarpment. In addition, cobbles of chalk containing Cretaceous Foraminifera have been found in a core from the floor of Northeast Providence Channel, 11,096 feet beneath the sea between the Bahama Islands, and reworked Cretaceous Foraminifera have been identified in a core of coarse glauconitic sand on the continental rise, 155 miles southwest of Cape Hatteras.

Tertiary rocks and thin Quaternary deposits are present along the Atlantic coast. The thickness of Tertiary rocks along the coast ranges from 4,300 feet in southern Florida to 130 feet on Long Island. In general, the Tertiary rocks are predominantly carbonates along the southern half of the Atlantic coastline and are mostly sandstone and limy shale along the northern half. Marl of early Miocene age crops out on the fishing banks known as Black Rocks off the coast of North and South Carolina. The Ocala Limestone of late Eocene age is not far beneath the sea bottom where artesian submarine springs issue along the east coast of Florida. Short cores and dredgings of Tertiary rocks, mostly Late Eocene (Jackson) and younger in age, have been recovered at more than 3 dozen localities concentrated for the most part between Georges Bank and the Hudson Canyon and in the Blake Plateau-Bahama Banks region. Pleistocene silts and clays have been found in many cores, and gravel and boulders of glacial origin have been dredged north of New York City.

Tertiary strata beneath the continental shelf have been penetrated by two test holes about 10 miles off Savannah, Ga. The test holes, which stopped in the Ocala Limestone, revealed that rather uniform thicknesses of Oligocene, lower Miocene, and middle Miocene strata extend from the shore seaward for at least 10 miles; that the upper Miocene rocks and the Pleistocene and Holocene deposits decrease in thickness seaward; and that only the Oligocene rocks exhibit a pronounced facies change, from carbonates to clastics in a seaward direction.

Tertiary rocks beneath the continental shelf have also been penetrated by six test holes 27 to 221 miles off Jacksonville, Fla. Stratigraphic data from these test holes indicate that Paleocene beds probably continue from the Coastal Plain to the edge of the Blake Plateau and are exposed as sea bottom along the lower part of the slope. The Eocene, Oligocene, and Miocene beds appear to be prograded seaward beneath the outer shelf and slope and are greatly thinned on the plateau. They appear to be especially thin or even absent along the lower slope, which corresponds approximately with the axis of maximum velocity of the Gulf Stream. Conclusions drawn from the test-holes data and some sparker profiles are that the shelf was built seaward rather continuously during Tertiary time and that the edge of the continental shelf has been prograded about 9.3 miles by a mass of sediment 300 to 600 feet thick.

Upper Jurassic and Lower Cretaceous rocks offer the most promising prospects for oil and gas production in the Atlantic coastal region. Offshore, their combined thickness probably exceeds 7,500 feet in the South Florida embayment and Blake Plateau trough, 5,000 feet in the Southeast Georgia embayment and Baltimore Canyon trough, and 3,000 feet in the Georges Bank trough. Marine beds generally regarded as potential sources of petroleum are predominant, and the environment of their deposition, at least in the southern areas, probably favored reef growth. Thick, very porous salt-water-bearing reservoirs, both sandstone and carbonate, are numerous. Important unconformities are present not only at the top but within the sequence. Three small accumulations of oil have been found in Lower Cretaceous rocks of southwestern Florida.

In rocks of Late Cretaceous age good possibilities for oil and gas production exist beneath the continental shelf, but only fair possibilities, chiefly for gas, exist in the Coastal Plain. Although the thickness of these rocks does not exceed 3,500 feet onshore and may be only a few thousand feet more beneath the shelf, the beds are buried sufficiently beneath the Tertiary rocks to provide ample opportunity for the accumulation of petroleum. Reservoirs are thick and numerous in the Upper Cretaceous rocks of the Coastal Plain and these reservoirs seem to extend beneath the shelf, where marine source rocks may be expected. Rocks of Woodbine and Eagle Ford age appear to be a favorable reservoir-source rock combination

whose thickness probably exceeds 2,000 feet offshore. The basal unconformity is important from the standpoint of petroleum accumulation, as in places it permits the basal Upper Cretaceous sandstones of Woodbine age to overlap the underlying, more marine Lower Cretaceous rocks.

Tertiary rocks along the Atlantic coast exhibit very good reservoir and fair source-rock characteristics; however, they are less promising for large accumulations of petroleum than the Jurassic and Cretaceous rocks. Tertiary rocks are probably less than 4,000 feet thick in most of the area north of southern Florida and the Bahama Islands; they contain fresh-to-brackish artesian water in much of that area; and they crop out in part along the continental shelf and in other places give rise to submarine springs in sink holes. In addition, structural features are reflected less distinctly in the Tertiary rocks than in the older rocks, and unconformities and overlaps within the Tertiary rocks are less significant regionally than those in older rocks.

The continental shelf offers more promise as a potential petroleum province than the Coastal Plain because it has a thicker sedimentary column with better source beds and trapping possibilities. The probabilities for discovery of large accumulations of petroleum in the Atlantic coastal region on a well-for-well basis seem to favor the Upper Jurassic and Lower Cretaceous rocks beneath the continental shelf.

INTRODUCTION

AREA AND PURPOSE OF REPORT

The Atlantic Coastal Plain and Continental Shelf of North America is represented by a belt of Mesozoic and Cenozoic rocks, 150 to 300 miles wide and 2,400 miles long, extending from southern Florida to the Grand Banks of Newfoundland (fig. 1). This belt encompasses an area of about 450,000 square miles, more than three-fourths of which is covered by the Atlantic Ocean. The submerged part forms the Atlantic Continental Shelf, which widens northward from 3 miles off Florida to about 285 miles at the Grand Banks off Newfoundland. The area of the continental shelf, including the Gulf of Maine, approximates 350,000 square miles. The emergent part, the Coastal Plain, narrows northward from a 200-mile width in Georgia to the terminal point of Long Island. Beyond this point, remnants of the Coastal Plain are present in the form of the New England Islands of Woodworth and Wigglesworth (1934) and Cape Cod. The area of the Coastal Plain, including the eastern half of the Florida Peninsula, approximates 100,000 square miles.

The volume of Mesozoic and Cenozoic rocks beneath the Atlantic Coastal Plain and Continental Shelf of North America exceeds 450,000 cubic miles, perhaps by a considerable amount. (See Gilluly (1964, p. 484) for estimates of volume between Nova Scotia and Virginia.) More than one-half of this is far enough seaward to contain marine source rocks in sufficient proportion to attract exploration for oil. A larger fraction, perhaps three-quarters of the volume, may be of interest in exploration for gas.

This report outlines the structure along the Atlantic coast from southern Florida to northern Nova Scotia (fig. 1) and discusses the stratigraphy of the area between southern Florida and Cape Cod, Mass. The continental shelf off Newfoundland is omitted because of lack of geological and geophysical information. Particular emphasis has been placed on the regional stratigraphic aspects of the subsurface rocks.

The purpose of this report is to establish a stratigraphic framework within this large sedimentary mass, to outline the structure of the continental margin, and to evaluate the petroleum possibilities of this relatively unexplored province to the extent that is possible at this time. It is not intended to be a summation of all geology and oceanography along the Atlantic coast but rather a selective review and synthesis of the regional aspects of the possible petroleum-producing rocks beneath the Coastal Plain and continental shelf, based on data available October 1, 1966. A preliminary version of this report (Maher, 1967a) was released to open file on October 30, 1967.

Earlier reports and maps prepared by the U.S. Geological Survey have provided a broad review of the general characteristics, problems, and potential mineral resources of the continental shelves of the Western Hemisphere (Trumbull and others, 1958); an estimate of the potential petroleum reserves of the Atlantic Coastal Plain and Continental Shelf based primarily on thickness of sediments (Johnston and others, 1959); a representation of the basement structure along the Atlantic coast from Florida to the Gulf of Maine (Cohee, 1962; Bayley and Muehlberger, 1968) based on both geological and geophysical data published up to 1959; a report on correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic coast (Maher, 1965); and summary discussions of petroleum possibilities in relation to the stratigraphy (Maher, 1966a, b; 1967b). In addition, numerous publications have resulted from cooperative investigations with the Woods Hole Oceanographic Institution. These include a map showing the relation of land and submarine topography, Nova Scotia to Florida (Uchupi, 1965a), a summary of the geology of the continental margin off Eastern United States (Emery, 1965a), and many reports of lesser scope, most of which are mentioned herein where appropriate.

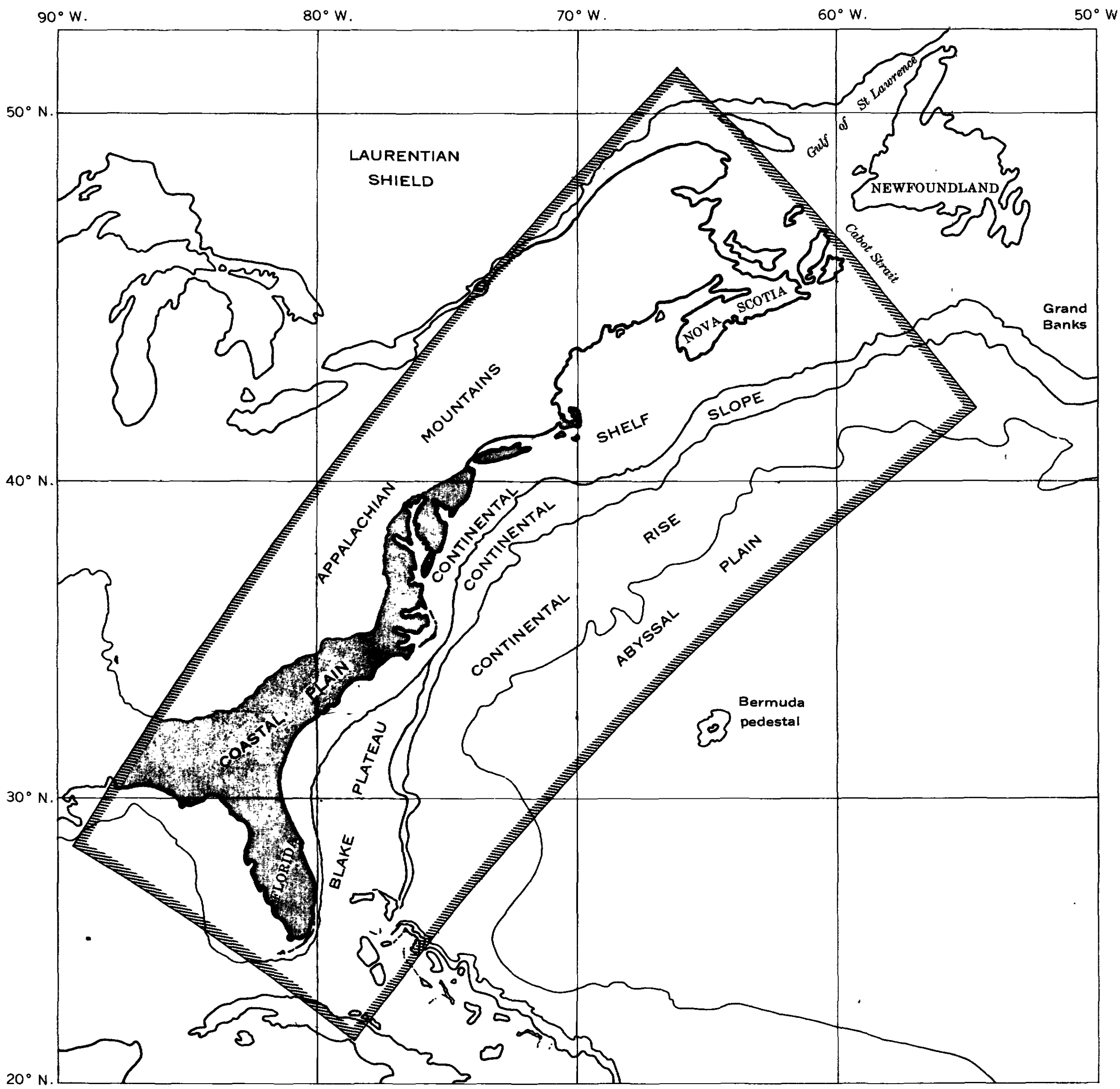


Figure 1.—Physiographic province map of eastern North America, showing area discussed in this report.

SOURCES AND RELIABILITY OF DATA

Many organizations provided well records and geological information: The Pure Oil Co. permitted use of nonconfidential data from a reconnaissance report prepared by J. C. Maher and Irvin Bass in 1959; the Gulf Oil Corp. and Anchor Gas Co. loaned samples and cores of their wells; State agencies and U.S. Geological Survey field offices engaged in ground-water investigations supplied a wealth of shallow subsurface data. The State agencies involved were the Florida Geological Survey; Georgia Department of Mines, Mining, and Geology; South Carolina Development Board; North Carolina Department of Conservation and Development; Virginia Division of Mineral Resources; Maryland Department of Geology, Mines, and Water Resources; and New Jersey Department of Conservation and Economic Development. The U.S. Geological Survey field offices include those at Tallahassee, Fla., Atlanta Ga., Columbia, S.C., Raleigh, N.C., Baltimore, Md., Trenton, N.J., Mineola, N.Y., and Boston, Mass.

The amount and reliability of subsurface well data on which this report is based differs greatly from one part of the region to another. For example, the records of 422 oil and deep water wells in 12 states and the Bahama Islands have been used (pl. 1 and table 1), but 213 records are for wells in only two states—Florida and Georgia. Also, the geological records for the wells in Florida and Georgia are more complete and accurate than those for wells in the northern part of the Coastal Plain. No deep tests have been drilled in offshore waters on the continental shelf, except in the Florida Keys area. In general, the geological data is much more reliable south of the Cape Fear arch than north of it.

Especially useful publications on regional stratigraphy and structure of the Coastal Plain are those of Cooke and Munyan (1938), Applin and Applin (1944, 1947, 1965), Richards (1945, 1948, 1950), Southeastern Geological Society (1949), Spangler (1950), Spangler and Peterson (1950), Skeels (1950), Bonini (1957), Meyer (1957), Pooley (1960), Bonini and Woollard (1960), LeGrand (1961), and Murray (1961). Local reports that present important basic data in detail include those of Cederstrom (1943, 1945), Siple (1946), Swain (1947, 1951, and 1952), Anderson (1948), Applin (1951), Brown (1958), Puri and Vernon (1959), Herrick (1961), Herrick and Vorhis (1963), and Seaber and Vecchioli (1963); most of these are publications of State geological surveys. Other reports on the Coastal Plain geology are included in the list of references.

Geophysical data on the continental shelf have been taken from reports prepared by the Woods Hole Oceanographic Institution and the Lamont Geological Observatory. These include articles by Miller (1936), Ewing, Crary, and Rutherford (1937), Ewing, Woollard, and Vine (1939, 1940), Ewing, Worzel, Steenland, and Press (1950), Oliver and Drake (1951), Officer and Ewing (1954), Drake, Worzel, and Beckmann (1954), Press and Beckmann (1954), Katz and Ewing (1956), Hersey, Bunce, Wyrick, and Dietz (1959), Drake, Ewing, and Sutton (1959), Heezen, Tharp, and Ewing (1959), Ewing, Ewing, and Leyden (1966), and Sheridan, Drake, Nafe, and Hennion (1966). Bathymetry of the shelf has been taken from the tectonic map of the United States (Cohee, 1962) and charts of the U.S. Navy Hydrographic Office (1951, 1952b, 1955, 1962a, b), the U.S. Coast and Geodetic Survey (1945, 1957, 1959, 1961, 1962), and the International Hydrographic Bureau (1958).

Numerous seismic refraction profiles of the continental shelf have been published. The locations of most of these are shown on plate 2, but space does not permit plotting of some short ones such as those off Sable Island (Berger, Blanchard, Keen, McAllister, and Tsong, 1965), Rhode Island (Birch and Dietz, 1962), Georgia (Antoine and Henry, 1965, fig. 1), and Florida (Rona and Clay, 1966). The profiles are well distributed from northern Florida to Nova Scotia but little agreement exists on their stratigraphic interpretation, partly because of the pronounced effect of lateral facies changes on seismic velocity measurements. Some seismic profiles off southern Newfoundland (Press and Beckmann, 1954; Bentley and Worzel, 1956) have been published, but little or no information is available on the Grand Banks. The available geophysical information outlines the regional structure of the shelf, but provides only speculative results for the stratigraphy.

Systematic investigations of subbottom sediments and strata along the Atlantic coast by means of dredging, coring, and undersea photography were begun about 1930 by several oceanographic institutions. Large quantities of data have been accumulated in these continuing programs. Data on the composition and age of samples and cores have been reported by many workers including Burbank (1929), Alexander (1934), Shepard, Trefethen, and Cohee (1934), Shepard and Cohee (1936), Bassler (1936), Cushman (193[illegible], 1939), Stephenson (1936), Stetson (1936, 1938, 1949), Northrop and Heezen (1951), Ericson, Ewing, and Heezen (1952), and Heezen, Tharp, and Ewing (1959). The regional aspects of bottom sediment and submarine outcrop distribution in the Atlantic Ocean are discussed at length by Ericson, Ewing, Wollin, and Heezen (1961), and Uchupi (1963). Detailed studies of samples and photographs of the bottom of the Tongue of the Ocean in the Bahama Islands have been reported by the Miami University Marine Laboratory, (1958), Busby (1962a, b, and c), and Athearn (1962a, b). The location and age of samples and cores listed in these publications are shown on plate 2.

ACKNOWLEDGMENTS

Numerous individuals have contributed to the completion of this report. E. R. Applin and P. L. Applin, who pioneered in the Mesozoic stratigraphy of Florida, provided much basic data that are summarized in numerous publications by the U.S. Geological Survey. They also made available much unpublished paleontologic data for wells in Alabama, Georgia, South Carolina, and North Carolina, offered useful suggestions on many stratigraphic problems, and reviewed sections *K–L*, *M–N*, and *O–P*. E. R. Applin, who contributed the paleontologic basis for age assignments discussed in this report in the section on stratigraphy, worked on the project several months studying paleontology

of selected wells in Florida and the Anchor Gas Dickinson 1 well in New Jersey.

S. M. Herrick, of the U.S. Geological Survey, Atlanta, Ga., whose paleontologic studies have established the stratigraphic framework of subsurface rocks in Georgia, was most generous with unpublished data. His cooperation and knowledge of regional subsurface concepts were important to the completion of the cross sections. Sections *I–J* and *K–L* were reviewed by Mr. Herrick.

P. M. Brown, of the U.S. Geological Survey, Raleigh, N.C., provided data for several wells in North Carolina. He reviewed section *G–H*.

R. E. Peck, of the University of Missouri, identified and gave an age opinion for a specimen of Charophyta from the Anchor Gas Co. well in New Jersey. J. M. Schopf and R. H. Tschudy, of the U.S. Geological Survey, provided opinions of the age of spores and pollen in the same well.

N. M. Perlmutter and Ruth Todd, of the U.S. Geological Survey, allowed the writer to read the manuscript of their report on the Monmouth group in the well at the Bellport Coast Guard Station, Long Island (well 6, pl. 1).

Cores, samples, and data for key wells were provided by the following: R. S. Stewart, of Anchor Gas Co.; L. J. Franz and Roy A. Worrell, of Gulf Oil Corp.; W. D. Lynch and Marvin Horton of Chevron Oil Co.; L. R. McFarland, of Mobil Oil Co.; K. N. Weaver, of the Maryland Department of Geology, Mines and Water Resources; H. G. Richards, of the Philadelphia Academy of Natural Sciences; W. E. Wilson, of the North Carolina Geological Survey; J. L. Ruhle, of the Virginia Geological Survey; and Clarence Babcock of the Florida Geological Survey.

PHYSIOGRAPHIC FEATURES

PROVINCES OF WESTERN NORTH ATLANTIC REGION

The physiographic provinces of the western North Atlantic region, as defined by Heezen, Tharp, and Ewing (1959) and as outlined in figure 1, are the abyssal plain, the continental rise, the continental slope, the Continental Shelf, the Coastal Plain, and the Appalachian Mountains. The abyssal plain is a part of the ocean-basin floor; the continental rise, continental slope, and continental shelf make up the continental margin.

The abyssal plain is the nearly flat ocean bottom that has slopes generally less than 5 feet per mile. Except in a small, isolated area near the Blake Plateau and Bahama Banks where calcareous sediments predominate, the surface is covered with quartz silt that Heezen, Tharp, and Ewing (1959, p. 58) suggest may come from the Cape Hatteras region or the Hudson Canyon. (See fig. 2.) Numerous seamounts are present on the northern part of the abyssal plain.

The continental rise extends westward and upward from the edge of the abyssal plain to the continental slope. It is relatively wide, reaching several hundred miles in places, and has gentle slopes, generally between 5 and 50 feet per mile. The depth of water ranges from 4,200 to 16,800 feet. The relief is low for the most part but is represented by an outer ridge adjacent to the eastern side of the Blake Plateau. Several submarine canyons extend across the continental rise (Ericson and others, 1951, p. 964), and several seamounts rise above it off the New England coast.

The relatively steep and narrow continental slope parallels the continental rise and continental shelf at depths ranging from 600 to 10,500 feet. The base is marked by a gradient in excess of 132 feet per mile (Heezen and others, 1959, p. 19) and the top by the sharp break at the edge of the shelf. Numerous submarine canyons traverse the continental slope.

The continental shelf extends from mean low tide to the shelf break, or beginning of the continental rise, which is somewhat less than 600 feet in depth at most places. It is a gently sloping surface with a gradient generally less than 5 feet per mile, and it ranges in width from a few miles off Florida to more than 285 miles off Newfoundland. The relief is relatively low, although the surface is cut by numerous submarine canyons.

The Coastal Plain is the belt of nearly flat land that lies between the Piedmont province of the Appalachian Mountains and the shoreline; isolated parts include Cape Cod and a few small offshore islands. The width narrows northeastward from a maximum of about 200 miles in Georgia. The altitude decreases gently seaward from about 800 feet at the edge of the Piedmont province.

The Appalachian Mountains form a highland of Precambrian, Paleozoic, and Triassic rocks stretching from the Canadian Maritime Provinces southwestward into Alabama. In the central and southern part, the Appalachian Mountains comprise, from east to west, four distinct, subparallel physiographic subdivisions: (1) the Piedmont province, of moderate relief, carved in deformed crystalline rocks with maximum altitudes of about 2,000 feet, (2) the rugged Blue Ridge province, composed of igneous and metamorphic rocks

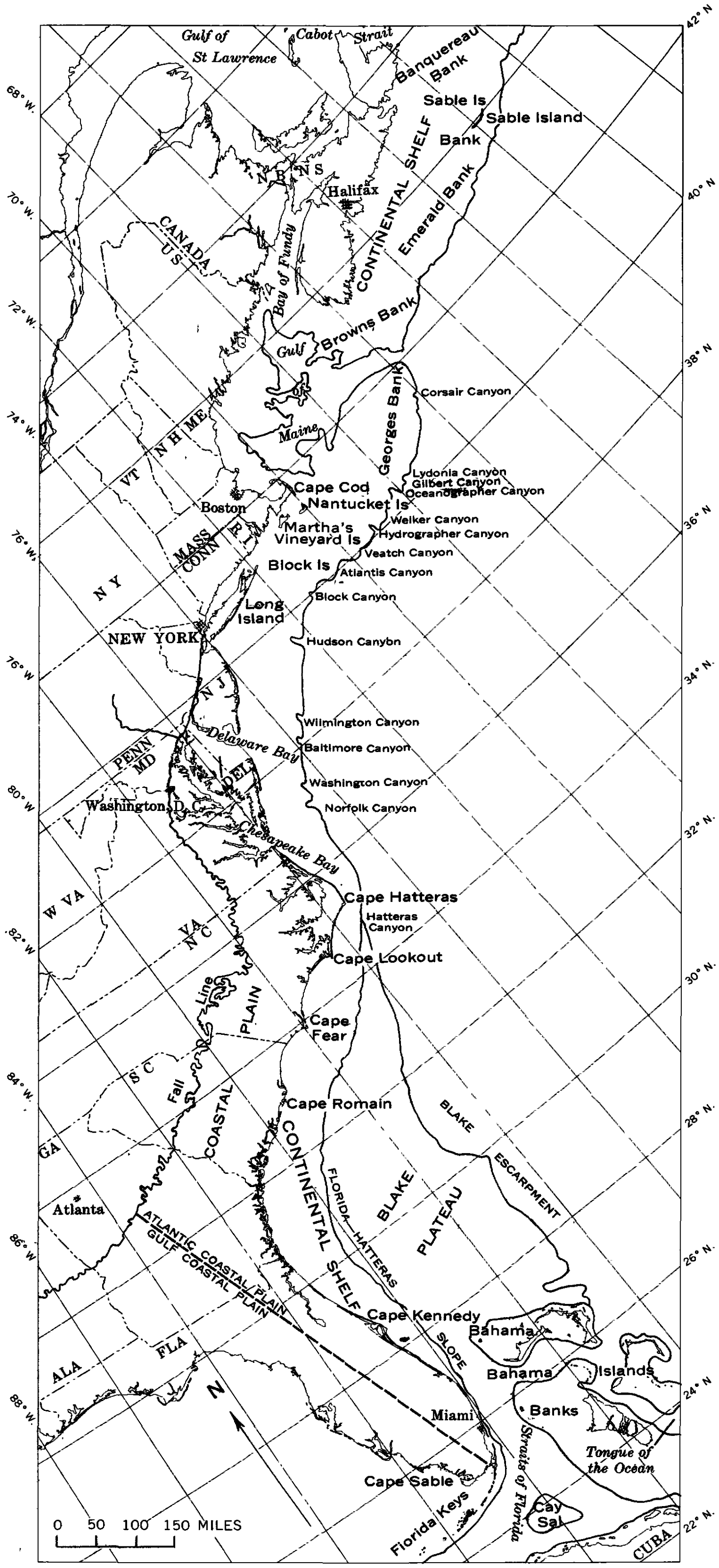


FIGURE 2.—Principal physiographic features of the Atlantic Coastal Plain and Continental Shelf.

that rise to a maximum altitude of 6,711 feet at Mount Mitchell, N.C., (3) the Valley and Ridge province of considerable relief carved in deformed sedimentary rocks with maximum altitudes of 5,000 feet, and (4) the Appalachian Plateaus province of highly dissected, flat-lying sedimentary rocks, mostly 1,000 to 4,000 feet above sea level. These belts are less readily recognized in New England and Newfoundland.

The physiographic setting of the Coastal Plain and continental margin is represented graphically on plate 3. The gradient of the continental slope in this diagram is exaggerated considerably to emphasize the steeper slope of the shelf break along the Blake Plateau in contrast to the gentler slope to the north.

ATLANTIC COASTAL PLAIN

AREA AND CONFIGURATION

The Atlantic Coastal Plain, shown in figure 2, has an area in excess of 100,000 square miles. It is a relatively low area when compared with the Appalachian Mountains that border it on the west, but it is not a featureless plain. Terrace remnants with 200 feet of relief are present in much of the inland area. Marine and fluvial terraces are well developed on its surface as a result of ancient changes in sea level. These terraces are traceable for long distances and are characterized by features of ancient shorelines, such as wave-cut cliffs, beaches, spits, bars, and emerged deltas. The altitudes of the terraces range from about 25 to 270 feet above sea level—the higher terraces are older and are less well preserved.

The poorly indurated sedimentary rocks beneath the Coastal Plain wedge out against the crystalline rocks of the Piedmont province. Along this boundary the more resistant rocks form a topographic demarcation, known as the Fall Line, where falls and rapids are found in most of the seaward-flowing rivers. This line marks the upper limit of river navigation and many important cities, including Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, Columbia, and Augusta, are located along it.

The Coastal Plain is deeply indented by branching bays or drowned river valleys, and the highly irregular shoreline at its eastern edge exhibits numerous large spits and bars from Cape Lookout, off North Carolina, northward to New York (pl. 3). South of Cape Lookout, drowned river valleys and barrier beaches are not as common. Numerous small islands fringe the coast of the Carolinas and Georgia.

PROMINENT COASTAL FEATURES

GULF OF MAINE

The Gulf of Maine, about 25,000 square miles in area, is the largest reentrant in the Atlantic coast south of Cabot Strait. (See fig. 2.) It is almost enclosed by banks and shoals that are submerged beneath 18 to 300 feet of water and that swing southward in an arc linking Cape Cod and Nova Scotia. (See Murray (1947) for topography of the gulf.) One deep channel, 600 to 900 feet deep, cuts through the enclosing banks and shoals near Nova Scotia to connect with the deeper floor of the ocean (Torphy and Zeigler, 1957). The waters behind the banks are 300 to 1,140 feet deep; the somewhat irregular floor relief is suggestive of a former glacial lake-and-river drainage system behind a cuesta of Cretaceous and Tertiary rocks (Johnson, 1925, p. 267; Chadwick, 1949, p. 1967; Uchupi, 1965b; 1966, p. 166–167). A long arm of the gulf, the Bay of Fundy, extends northeastward between New Brunswick and Nova Scotia.

CAPE COD

Cape Cod, a seaward projection of Massachusetts, is the most prominent emergent feature of the Atlantic shoreline. (See fig. 2.) Its geography and geology have been described by Davis (1896), Shaler (1898), and Woodworth (1934a, p. 237–249). The great size and bold projection of this peninsula into the Atlantic Ocean are remarkable. In the shape of a man's arm bent at the elbow, the peninsula projects about 40 miles eastward into the ocean and then an equal distance northward into the Gulf of Maine. A long spur of sand trails southward from the elbow as Monomoy Island, a continuation of the long, straight, sandy shoreline along the entrance to the Gulf of Maine. The interior shore around Cape Cod Bay is low and swampy, whereas that facing the ocean is more abrupt and indented farther by inlets. The topography of the peninsula is dominated by morainal ridges and glacial hills with altitudes of 200 to 300 feet. Glacial drift masks the underlying geology, but Cretaceous and Tertiary rocks have been reported in wells near Provincetown at the tip of the peninsula (Zeigler and others, 1960; 1964, p. 708). Hoskins and Knott (1961) have interpreted continuous seismic profiles in the adjacent bay as showing marine Tertiary strata and erosional remnants of Cretaceous rocks. The age and development of the hook have been discussed by Zeigler, Tuttle, Tasha, and Giese (1965).

DELAWARE BAY

Delaware Bay is the drowned lower valley of the Delaware River, which separates New Jersey from Delaware and Pennsylvania. (See fig. 2.) It is about 52 miles long and, at its broadest point, about 28 miles wide. Although most of the bay is less than 120 feet deep, the main channel ranges in depth from 210 feet in the upper reaches to 900 feet near the mouth. The lower end is partially closed by Cape May of New Jersey and Cape Henlopen of Delaware. Shoals ring the point of Cape May and parallel the channels upstream. The shoreline of the bay is predominantly marshland.

CHESAPEAKE BAY

Chesapeake Bay, which splits Maryland and Virginia (see fig. 2), represents a drowned drainage system that includes the lower valleys of the Susquehanna, Potomac, Rappahannock, York, and James Rivers. It is over 160 miles long, more than 25 miles wide in its central part, and about 13 miles wide at its mouth between Cape Charles and Cape Henry. The main channel ranges in depth from 20 to 82 feet and leaves the bay close to Cape Henry on the south shore. A crescent-shaped series of shoals parallels the north shore around Cape Charles.

CAPE HATTERAS

Cape Hatteras, about 32 miles eastward from the mainland of North Carolina, marks the meeting point of two series of offshore bars. These offshore bars extend almost without interruption from a few miles south of Cape Henry at the mouth of Chesapeake Bay to Cape Lookout (see fig. 2), a distance of about 120 miles. The bars are as much as 2 or 3 miles wide and 25 feet high, but generally they are less than 1 mile wide and 10 feet high. They enclose two sizeable shallow bodies of water—Albemarle Sound at the north and Pamlico Sound at the south. These sounds include not only the lagoonal area behind the bars but also parts of the drowned valleys of the Chowan and Pamlico Rivers. The waters of the sounds are 24 feet deep in some places, particularly near the rivers, but they are mostly less than 15 feet deep in the lagoonal areas. A part of the large tract of marshland that separates the two drainage systems is known as East Dismal Swamp. The formation of the offshore bars at Cape Hatteras has been attributed by Davis (1849, p. 148) to reverse flow of great eddies along the shoreward margin of the northward-flowing Gulf Stream.

CAPE FEAR

Cape Fear protrudes about 20 miles beyond the general coastline midway between Cape Lookout, N.C., and Cape Romain, S.C. (See fig. 2.) Shoals associated with the cape jut out another 34 miles into the Atlantic Ocean. Two cuspate bays that are about 95 miles long and indent the coastline 20 to 25 miles flank the point in concave symmetry. Cape Fear is related not only to marginal eddies in the Gulf Stream but also to a structural arch prominent in the ancient rocks.

CAPE KENNEDY

Cape Kennedy, about midway along the eastern coast of Florida (see fig. 2), projects about 14 miles eastward as a low, triangular mass of islands, bars, and coastal lagoons whose highest land surface is about 12 feet above sea level. Shoals extend only a few miles seaward from Cape Kennedy; another shoal area, known as False Cape, lies about 8 miles to the north. The suggestion has been made by White (1958, p. 47) that Cape Kennedy is the result of deformation, and perhaps faulting, of the ancient rocks along a line from Indian Rocks on the west coast to Cape Kennedy.

ISLANDS

At times during the Pleistocene, the Coastal Plain has included a considerable part of the present continental shelf. The numerous islands along the Atlantic coast were then the higher parts of the emerged Coastal Plain. The larger of these include Long Island, Block Island, Martha's Vineyard, the Elizabeth Islands, Nantucket Island, Sable Island, and the Florida Keys, most of which are shown in figure 2.

Long Island, Block Island, Martha's Vineyard, the Elizabeth Islands, and Nantucket Island, which make up most of the New England Islands of Woodworth and Wigglesworth (1934, p. 3), represent a former cuesta of Cretaceous and Tertiary rocks continuing mostly submerged from the New Jersey coast to the Cape Cod Peninsula (Johnson, 1925, p. 108). Thick Pleistocene glacial deposits that mantle these islands suggest that the scarps of older rocks interfered with the southward advance of the ice masses and caused the local accumulation of glacial debris in moraines and outwash plains. A comprehensive report on these islands written by Woodworth and Wigglesworth (1934), articles by Kaye (1964a, b, c), and summaries by Shafer and Hartshorn (1965, p. 115–116) have been drawn upon for the brief descriptions that follow.

LONG ISLAND

Long Island, 1,411 square miles in area, projects eastward from the East River of New York City to the longitude of Rhode Island. The island is about 120 miles long, less than 25 miles wide, and less than 200 feet in altitude except for a few ridges and hills reaching a maximum of 340 feet. The topography is essentially that of a glacial outwash plain sloping to the south, interrupted by two ridges of terminal moraines joined at the western end but extending separately eastward along the remainder of the island's length. One ridge runs along the north shore and the other through the middle to the eastern end, where they diverge as peninsulas about 14 miles apart. The southern shore of the island is flat and protected by long barrier beaches most of its length. The eastern part of the northern shore is relatively straight and smooth due to active wave erosion, but the western part of the northern shore is deeply embayed. The steep-sided bays and inlets there are related to preexisting valleys eroded into southward-dipping Cretaceous beds. Long Island Sound, a shallow arm of the sea less than 20 miles wide and 160 feet deep, intervenes between the northern shore and the New England coast. The geological formations underlying Long Island are late Cretaceous and Pleistocene in age. The geology is discussed in Veatch (1906), Fuller (1914), Suter, deLaguna, and Perlmutter (1949), deLaguna (1963), and Perlmutter and Geraghty (1963).

BLOCK ISLAND

Block Island, approximately 6 miles long and 4 miles wide, lies about 15 miles northeast of Long Island and about 10 miles south of the Rhode Island coast. A small inlet separates the island into north and south parts connected only by a strip of marshland and beach. Steep cliffs, 100 to 150 feet high, mark the southern coast. The island is formed of thick glacial deposits thought to rest on and against a higher part of the former Cretaceous cuesta between New Jersey and Cape Cod (Fenneman, 1938, p. 14, 15). Tuttle, Allen, and Hahn (1961) have correlated a seismic velocity zone beneath the glacial deposits with the Magothy clay outcrops identified by Woodworth (1934b, p. 212).

MARTHA'S VINEYARD

Martha's Vineyard is a triangular-shaped island approximately 4 miles off the southwestern part of Cape Cod. It is about 20 miles long and 10 miles wide and rises to 308 feet above sea level near the southwestern corner. The northwestern side of the island is lined with glacial hills and ridges, 100 to 200 feet higher than the central and southeastern lowlands. The lowlands slope gently southeastward; numerous embayments closed by sand bars indent the south shore. The hills and ridges are composed of coarse glacial debris and the lowlands are composed of glacial outwash in which Kaye (1964a, b) recognizes six glacial drifts and one interglacial deposit. Cretaceous and Tertiary rocks are at or near the surface in several places (Shaler, 1885, p. 325–328, pl. 20; Wigglesworth, 1934, p. 140–160; Kaye, 1964c) and form the westernmost promontory of the island known as Gay Head.

ELIZABETH ISLANDS

The Elizabeth Islands compose a short chain of a half-dozen islands, too small to show in figure 2, extending 16 miles southwest from Cape Cod. They are alined subparallel to and 4 to 5 miles northwest of the ridges on Martha's Vineyard. These islands are covered with glacial materials for the most part, but one island, Nonamesset, next to the mainland, is reported to have exposures of Cretaceous lignite and Tertiary (Miocene) greensand on its south shore (Woodworth and Wigglesworth, 1934, p. 309–310).

NANTUCKET ISLAND

Nantucket Island, 51 square miles in area, is the southeasternmost island off New England. It is about 15 miles east of Martha's Vineyard and 10 to 20 miles south of Cape Cod. The land surface is covered with glacial drift and is relatively low and flat. The few isolated hills range from 50 to 108 feet above sea level. The harbor on the north side of the island is protected by a long barrier beach. Cretaceous and Tertiary rocks may underlie the several hundred feet of glacial deposits penetrated by water wells on the island. Reworked Eocene pollen has been reported in Pleistocene deposits penetrated by a boring on nearby Nantucket Shoals (Groot and Groot, 1964, p. 488; Livingstone, 1964). The geology of Nantucket Island has been described by Shaler (1889) and Woodworth (1934c).

SABLE ISLAND

Sable Island, about 1 mile wide and 30 miles long, is a thin arc of sand bowed seaward about 100 miles east of Nova Scotia. It is the emergent part of a large shoal area called Sable Island Bank. The surface consists of stabilized sand dunes at the east end and along the north side. Sand flats surface the remainder of the island. A narrow lake, a few miles long, splits the island down the middle near its widest part. According to Willmore and Tolmie (1956, p. 13), the island may be composed entirely of glacial deposits reworked in part by waves, or it may have a glacially mantled scarp of Cretaceous or Tertiary rocks as a shallow substructure. Recent deep seismic observations by Berger, Blanchard, Keen, McAllister, and Tsong (1965, p. 959) suggest that the ridge in the basement which has been proposed to underlie the shelf edge off Halifax (Officer and Ewing, 1954, fig. 2) continues northeastward beneath Sable Island and that the thickness of sedimentary rocks under the island approximates 14,750 feet.

FLORIDA KEYS

The Florida Keys, well described by Cooke (1939, p. 68–70; 1945, p. 11, 256–265), constitute a low island arc curving along the Straits of Florida from Biscayne Bay near Miami 200 miles southwestward to the Dry Tortugas. (See fig. 3.) Between Biscayne Bay and Big Pine Key, the arc of islands consists of an ancient coral reef that is interrupted by tidal channels, and the islands are elongate parallel to the Straits of Florida. Between Big Pine Key and Key West, the islands are composed of Miami oolite, such as crops out on the mainland, and the islands tend to be elongate to the northwest at right angles to the chain. The Marquesas, about 20 miles west of Key West, and the Dry Tortugas, about 45 miles beyond the Marquesas, are coral sand banks in the form of atolls (Cooke, 1939, p. 70–72). About 5 miles seaward from the Florida Keys is a submerged living coral reef that parallels the island arc throughout the entire length. The largest island of the Florida Keys is Key Largo south of Biscayne Bay. It is 27 miles long and up to 3½ miles wide; most of the islands are less than 6 miles long, a mile wide, and 10 feet in altitude. The Florida Keys are separated from southern Florida by the Florida Bay, a shallow embayment mostly less than 12 feet deep containing many mud banks and shoals. Mangrove swamps occupy much of the shallow water at the head of the Florida Bay and behind the Florida Keys.

ATLANTIC CONTINENTAL SHELF

DEFINITION

Continental shelves, which exist along the margins of oceans throughout the world, extend from the mean low-water line to the abrupt change in slope known as the continental slope. The depth at which this change occurs differs considerably around the world but the average depth is about 432 feet, or 72 fathoms. Commonly, the 100-fathom (600-foot) bathymetric contour shown on the hydrographic charts of the U.S. Navy Hydrographic Office (1948, 1949, and 1952a) and the U.S. Coast and Geodetic Survey (1961, charts 1000 and 1003; 1962, charts 1001 and 1002) is used to represent the seaward limit of the shelves around the United States. In this report, the 500-foot bathymetric contour from the tectonic map of the United States (Cohee, 1962) is used. Because of the abrupt declivity at the edge of the Continental Shelf, no appreciable difference in position or area of the shelf is apparent on the small-scale maps of this report.

AREA AND CONFIGURATION

The Atlantic Continental Shelf is a 2,400-mile-long submerged platform, about 350,000 square miles in area, which widens from less than 3 miles off southern Florida to about 285 miles off Newfoundland (fig. 1). It extends subparallel to the shoreline and without interruption from the Straits of Florida to Cape Cod (fig. 2). At Cape Cod, the continental shelf swings eastward about 200 miles to include Georges Bank; there it is interrupted by the deep outlet of the Gulf of Maine. It continues off Nova Scotia and parallels the open coast around Emerald Bank, Sable Island Bank, and Banquereau to Cabot Strait. Cabot Strait, the deep entrance to the Gulf of St. Lawrence, breaks the continuity of the continental shelf, but the shelf resumes around Newfoundland and eastward as the Grand Banks. This report discusses the part of the Atlantic Continental Shelf south of Cabot Strait, including the Gulf of Maine.

Along the entire Atlantic coast, the 50-fathom (300-foot) bathymetric contour, as shown on U.S. Coast and Geodetric Survey charts 1000, 1001, and 1002, closely parallels the edge of the Continental Shelf at a distance of only a few miles. Farther inshore adjacent to nonglaciated regions, the bottom contours are more widely spaced and show more parallelism to coastal shapes than to the edge of the continental shelf. This 50-fathom (300-foot) contour may approximate the limit of subaerial erosion near the close of Pleistocene (Wisconsin) time. Earlier Pleistocene shorelines may have ranged from this level to greater depths on the continental shelf.

The 5,000-foot bathymetric contour, as shown on the tectonic map of the United States (Cohee, 1962), parallels the edge of the Continental Shelf at a seaward distance of 10 to 20 miles from Nova Scotia to as far south as Cape Lookout (pl. 1), where, instead of following the coastline and shelf, it continues almost due south along a steep slope east of the Bahama Banks. The 150-to-200 mile wide flat area between this steep slope, the shelf edge, and the Bahama Banks

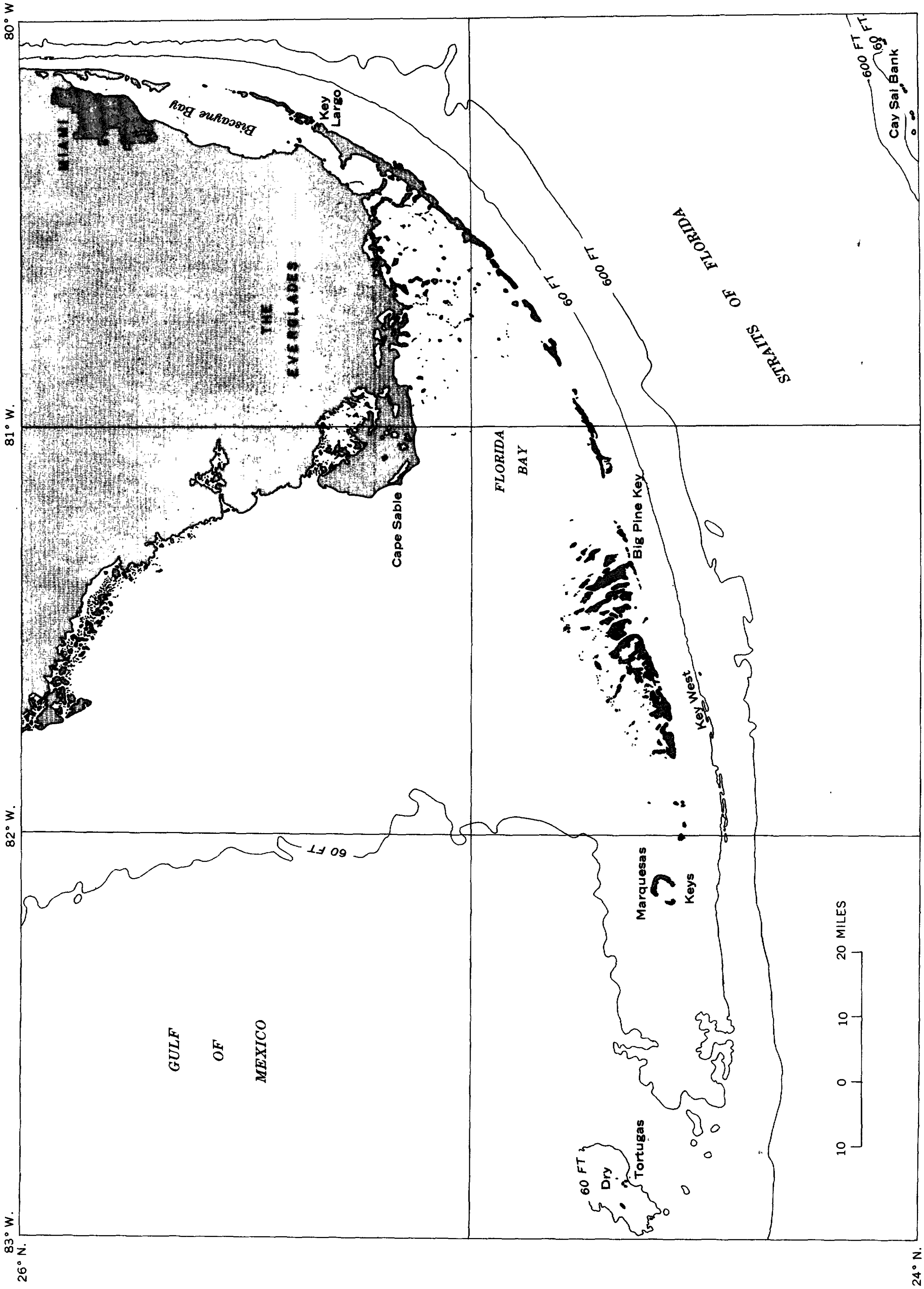


FIGURE 3.—Physiographic features of Florida Keys region.

is termed the Blake Plateau. The gentle slope at the shelf edge is referred to as the Florida-Hatteras slope to distinguish it from the true continental slope outside the Blake Plateau.

BLAKE PLATEAU

The Blake Plateau is a deep-water plateau at depths from 650 to 3,600 feet (Uchupi, 1965a) between Cape Lookout, N.C., and the northernmost bank of the Bahama Islands (fig. 2). It has a very gentle slope of less than 0.5° with only minor irregularities and little, if any, cover of Holocene sediments. Small hills and small elongate depressions are present on the surface at places. The relatively steep eastern edge, known as the Blake Escarpment, has only two large irregularities—a reentrant at lat 27° N., and a seaward projection, the Blake Spur, at lat 30° N. Rocks of Late Cretaceous to Holocene age have been recovered from the Blake Escarpment (Ericson and others, 1952, p. 504–506). Early oceanographic studies of the region were reported by Bartlett (1883) and Agassiz (1888). Details of some recent investigations are available in reports by Stetson, Squires, and Pratt (1962), Pratt (1963, 1966), Pratt and Heezen (1964), Uchupi and Tagg (1966), Ewing, Ewing, and Leyden (1966), and Sheridan, Drake, Nafe, and Hennion (1966).

The development of the Blake Plateau has been described by Ewing, Ewing, and Leyden (1966). They (1966, p. 1970) regard the Blake Plateau as a gradually subsiding segment of an ancient continental shelf whose eastern margin was supported by a basement arch (see pl. 4) and which subsided more slowly than the interior and western parts. A barrier reef flourished along the southern part of the eastern margin until the end of Cretaceous time, whereas the main area of the plateau received nearly horizontal carbonate deposits. The barrier reef appears to have died at the end of Cretaceous time, and detrital sediments were deposited on the plateau. Rate of deposition and subsidence was more rapid on the western part. By the end of Eocene time, the plateau had sunk to considerable depth, and deposition of sediments on it was restricted mostly to the western edge because of the sweeping effect of the Gulf Stream. The Gulf Stream continued to modify the plateau surface both by preventing deposition and by erosion until the present time.

BAHAMA BANKS

The Bahama Banks constitute a shallow carbonate elongate platform parallel to the Florida coast and situated between the Straits of Florida, Bahama Channel, and the much deeper part of the continental rise (fig. 4). This platform, which begins about 50 miles offshore, extends with some interruptions as far southeast as Haiti and includes about 50,000 square miles of banks, shoals, rocks, cays, and islands. The northernmost banks, about 200 miles wide, are the most extensive. They are outlined in figure 2 by lines that coincide with the 500-foot bottom contours. The edges of the banks, particularly the oceanward edges, have steep slopes averaging 10° to 20°; some are nearly vertical. Most of the platform is covered by less than 60 feet of water, and parts of it, such as the Bahama Islands, are emergent. Comprehensive reports on the stratigraphy and structure of the Bahama Banks include those by Field and others (1931), Lee (1951), Sheridan, Drake, Nafe, and Hennion (1966), and Ewing, Ewing, and Leyden (1966). Detailed studies of present-day sedimentation around the islands are discussed by Cloud (1962).

Great submarine valleys, such as the Tongue of the Ocean (fig. 2), separate some of the banks. These valleys are as much as 5,000 to 6,000 feet deep and have steep sides and flat bottoms that slope gently oceanward. The floors are covered with bioclastic turbidites interbedded with pelagic deposits (Rusnak and Nesteroff, 1964). Two limestone outcrops have been photographed on the walls of the Tongue of the Ocean (Busby, 1962b, c). Busby (1962b, p. 5–12) believes that one of these (lat 24°41′49″ N., long 77°35′01″ W.) at a depth of 6,000 feet is in place, that the surface features shown on the photograph have resulted from solution in a subaerial or littoral environment, and that the outcrop has been lowered about 6,000 feet either by gradual subsidence or block faulting. The origin of these valleys has been attributed to coral reef growth on submarine volcanoes (Schuchert, 1935, p. 26, 27, 531) or on drowned pre-Cretaceous topography (Hess, 1933, 1960; Newell, 1955, p. 314), to turbidity currents (Ericson and others, 1952, p. 506), and to grabenlike downfaulting (Talwani and others, 1960, p. 156–160). Recently published interpretations of seismic records indicate that reef growth was a dominant factor in the maintenance of carbonate banks of the Bahamas (Ewing and others, 1966, p. 1970) throughout Late Cretaceous and Tertiary time. This tends to support the conclusions of Hess (1933, 1960) and Newell (1955, p. 314).

CAY SAL BANK

Cay Sal is a relatively small, somewhat rectilinear bank located at approximately lat 24° N. and long 80° W., midway between the Florida Keys, Cuba, and

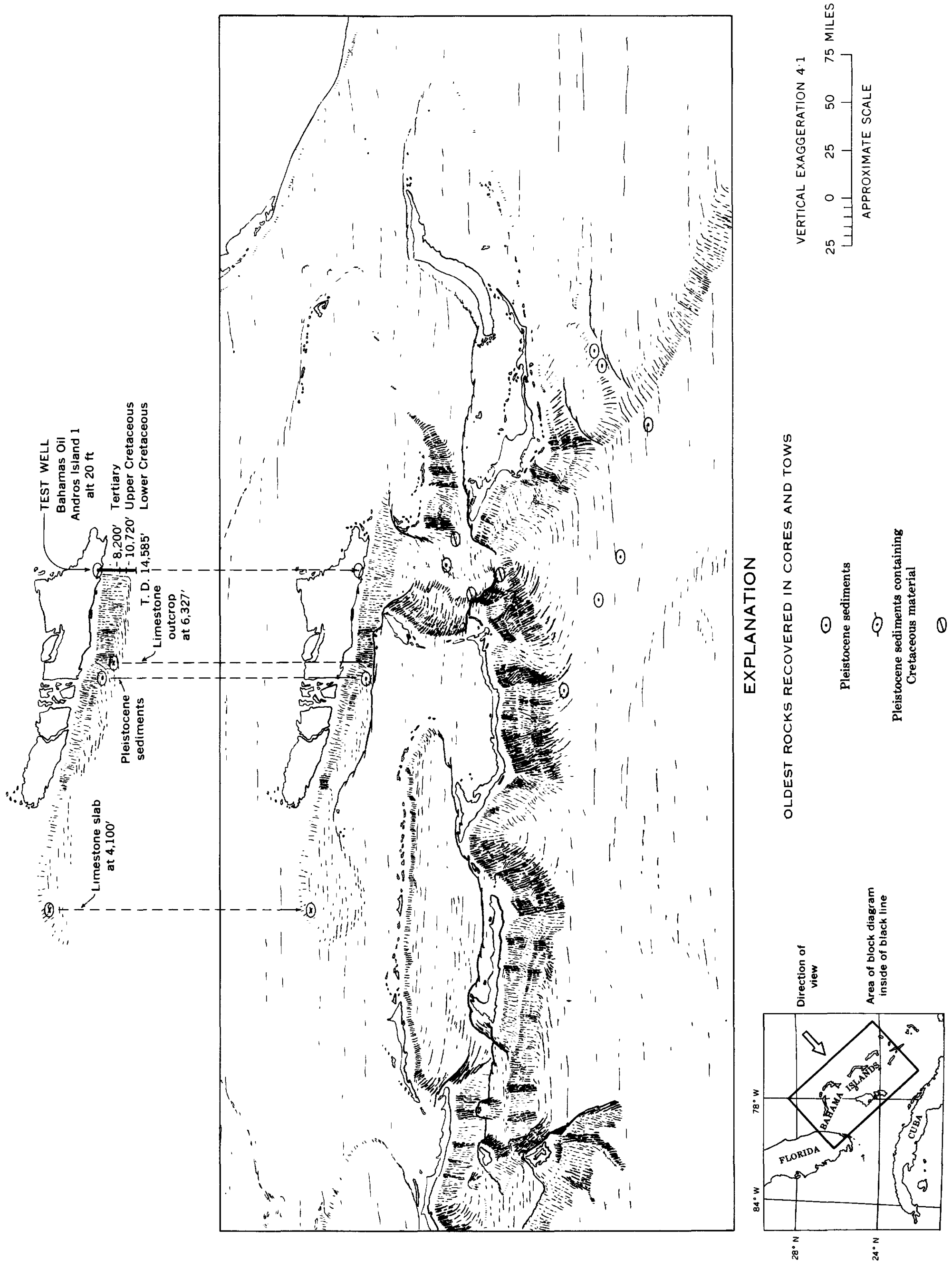


FIGURE 4.—Physiographic diagram of Bahama Banks showing relation of geologic data to bathymetry. Bathymetric data from U.S. Navy Hydrographic Office (1951, sheet BC-0805N).

the Bahama Banks (fig. 2). Numerous small islands, cays, rocks, and shoals outline its periphery, but most of the bank is covered by 18 to 60 feet of water. The edges slope abruptly to depths of 900 to 2,400 feet. An oil test was drilled on this bank by the Bahama California Oil Co. and the Bahama Gulf Oil Co. in 1958 and 1959, but no information has been released.

NORTH ATLANTIC BANKS

A series of banks on the outer continental shelf parallel the North Atlantic coast from a point several hundred miles east of Newfoundland to the vicinity of Cape Cod. The Grand Banks off Newfoundland (fig. 1) are the most extensive. They consist of a large number of irregular banks that average 180 feet in depth. Cabot Strait separates the Grand Banks from those along the Nova Scotian coast.

South of Cabot Strait, closely spaced banks less than 360 feet deep and 10 to 25 miles wide dominate the outer continental shelf. Banquereau, which lies under 120 to 240 feet of water, is the northernmost of these. Next is Sable Island Bank, less than 120 feet deep, around Sable Island, and then Emerald Bank and several other small banks at depths of 240 to 300 feet occur off Halifax. Browns Bank lies south of Nova Scotia parallel to the entrance to the Gulf of Maine in 120 to 360 feet of water. Georges Bank is a very large bank stretching from the shoals off Cape Cod eastward to Northeast Channel; it is 6 to 300 feet deep and exhibits shoals in the shape of subparallel ridges pointing into the Gulf of Maine (Stewart and Jordan, 1964). Cretaceous and Tertiary fossils and glacial materials have been dredged from Georges Bank and Banquereau (Verrill, 1878; Stetson, 1936; Cushman, 1936). Johnson (1925, p. 267) considered both Georges and Browns Banks as parts of a drowned cuesta of Cretaceous and Tertiary strata, and Shepard, Trefethen, and Cohee (1934, p. 281–302) emphasized the effect of glaciation on and behind the cuesta. Recent seismic profiles over Georges Bank (Emery and Uchupi, 1965) and along the Northeast Channel (Uchupi, 1966, p. 166–167) between Georges and Browns Banks tend to confirm these earlier views.

SUBMARINE CANYONS

Numerous submarine canyons have been charted along Georges Bank and southward to Cape Hatteras (U.S. Coast and Geodetic Survey, 1945; 1961, chart 1109; and 1962, chart 1108). These have been described and discussed in detail by Bucher (1940), Stetson (1936), Shepard (1933; 1934; 1948; 1951a; 1951b; 1963, p. 327–329), Veatch and Smith (1939, p. 1–48), Daly (1936), Ewing, Luskin, Roberts, and Hirshman (1960), Johnson (1938, 1939), Kuenen (1950, p. 485–493), and Roberson (1964). The locations of 15 principal canyons are shown in figure 2. From north to south, these are Corsair, Lydonia, Gilbert, Oceanographer, Welker, and Hydrographer Canyons off Georges Bank; Veatch, Atlantis, Block, and Hudson Canyons off Cape Cod and Long Island; Wilmington, Baltimore, Washington, and Norfolk Canyons off the Delaware, Maryland, and Virginia coasts, and Hatteras Canyon off Cape Hatteras, N.C. Most of these canyons head in broad notches in the edge of the continental shelf at depths of 300 to 600 feet, but the Hatteras Canyon appears to start considerably deeper, in the vicinity of the 1,200-foot depth. The canyons that notch the Continental Shelf have steep, winding, V-shaped gorges with many tributaries and are cut in consolidated and semiconsolidated rocks. They range in width from about 1 mile to more than 10 miles and extend far down the continental slope to depths of 6,000 feet or more.

Only the Hudson Canyon has a channel which crosses the continental shelf to connect with a present-day river mouth, although bottom contours for depths of less than 300 feet indicate drainage patterns that may have once connected with Corsair, Oceanographer, Hydrographer, Block, Baltimore, and Norfolk Canyons. This suggests that many rivers drained across the continental shelf when it was exposed during the Pleistocene glacial stages and that their channels were modified or eliminated by encroaching seas during the interglacial stages (Veatch and Smith, 1939, p. 44–48). Many large gullys, some of which appear to be dendritic, are cut into the slope below the continental shelf. These bear no apparent relation to the principal canyons and may have a different origin.

The Hudson Canyon (Veatch and Smith, 1939, p. 14) is the longest and deepest of the North Atlantic coast canyons (fig. 5). The channel of the Hudson River is entrenched about 50 to 150 feet into the Continental Shelf from the mouth of the river to the 360-foot depth marking the beginning of the gorge. Beyond this, the canyon walls reach a maximum height of 4,000 feet as they descend the slope and rise to a terminal depth of approximately 15,900 feet (Northrop, 1953, p. 223). The lower part of the 180-mile-long canyon is a relatively shallow trench across a large alluvial fan on the continental rise. Miocene clays have been found on the sides of the gorge; coarse sand, gravel, shells, and clay cobbles were cored in the canyon at a depth of 12,000 feet; and cleanly washed sand has been sampled in the outer trench and alluvial

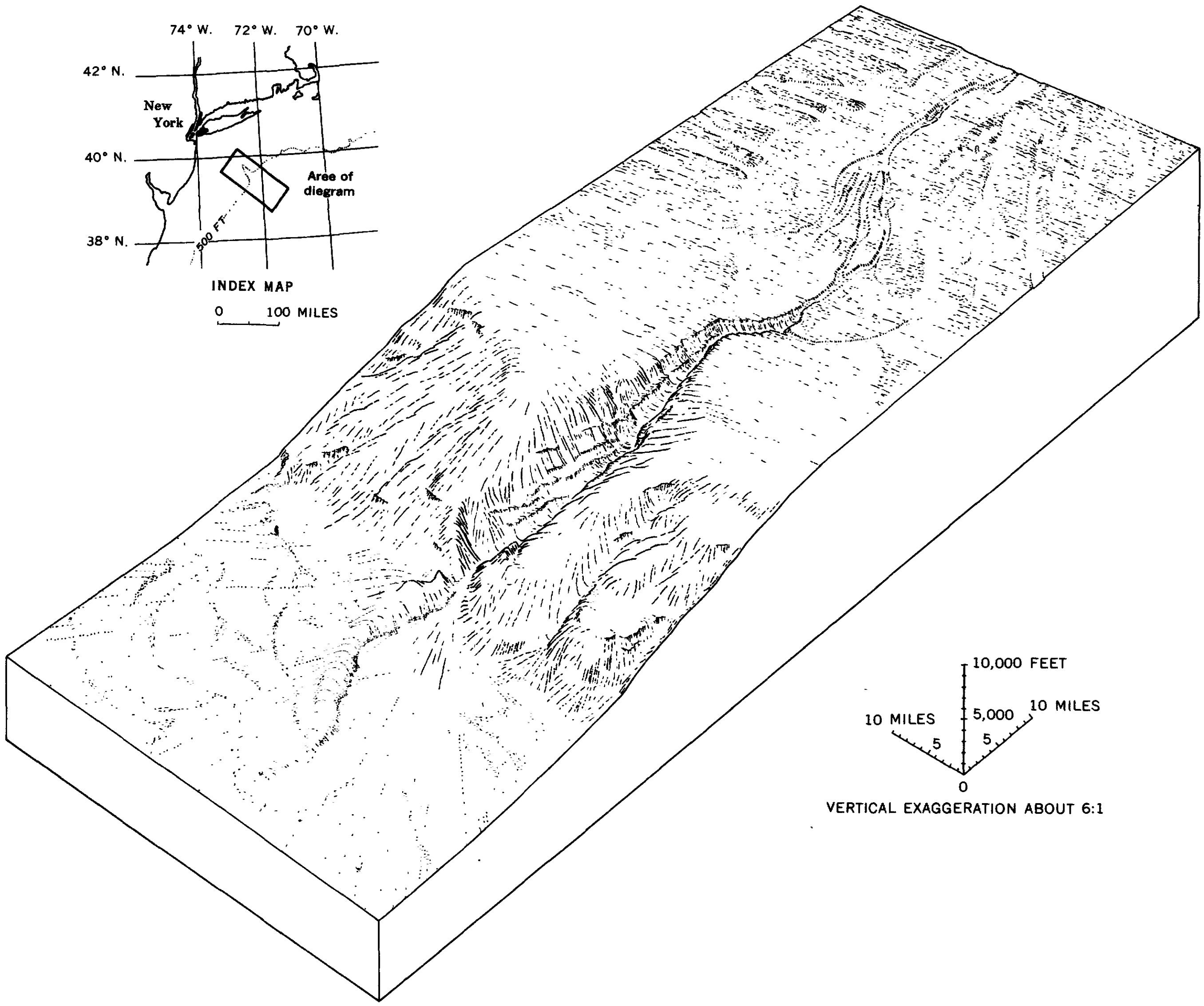


FIGURE 5.—Physiographic diagram of Hudson Canyon. Sources of information: U.S. Coast and Geodetic Survey (1962, chart 1108) and U.S. Navy Hydrographic Office (1951, BC–0807N).

fan. The results of acoustic probes and cores of the canyon walls (Ewing and others, 1960, p. 2849–2855) suggest inclined erosional surfaces between beds adjacent to the canyon edge at depths of 360 and 480 to 540 feet. These are thought to correlate with wave erosion of the continental shelf at different times during the Pleistocene, as suggested by Veatch and Smith (1939, p. 44–48).

The origin of submarine canyons has been a subject of speculation, discussion, and investigation for more than 50 years. The theories that have been advanced and restated at different times include subaerial erosion (Veatch and Smith, 1939, p. 48; Du Toit, 1940; Shepard, 1948 and 1963, p. 335–347; Umbgrove, 1947; and Emery, 1950), turbidity currents (Daly, 1936; Kuenen, 1950, p. 496–526), diastrophic movements (Wegener, 1924, p. 177), artesian springs (Johnson, 1939), tsunamis (Bucher, 1940), hydraulic and tidal currents (Davis, 1934), and landslides and mudslides. Shepard (1963, p. 337) points out that all but two of these have been generally discarded in recent years. The surviving theories are turbidity currents, and subaerial erosion with the drowning and maintenance of the canyons by turbidity currents, submarine slides, and sand flows. The first considers the canyons to have been cut by turbidity currents during low sea-level stages of the Pleistocene. The second assumes the canyons to have been cut by rivers prior to the Pleistocene and modified subsequently by submarine phenomena including turbidity currents.

ORIGIN OF SHELVES

The origin of continental shelves is directly related to that of the continental slopes. Numerous theories of origin have been advanced over the years, but none has been completely acceptable for all parts of the earth. These theories have been reviewed and discussed in detail by Kuenen (1950, p. 157–163) and Shepard (1963, p. 300–310).

The oldest theory, which prevailed before very much geophysical and geological data could be obtained from beneath the seas, postulated that the slope is the front of a huge pile of sediment eroded from the continent, the inner shelves are wave-cut terraces, and the outer shelves are wave-built terraces. This theory has been generally discredited by then-unknown facts such as the absence of sedimentation on the outer shelf in many regions, the unpredictable grain-size distribution of sediments on the shelf, the presence of large areas of bare bed rock on both the shelf and slope, the irregular topography of the outer shelf, the lack of correlation between the size of waves and depths of the outer shelf, and the relatively high inclination of the slope surface.

Another concept, not in current favor, suggests that the slopes are downwarped remnants of Miocene peneplains (Veatch and Smith, 1939, p. 35). Du Toit (1940, p. 398–403) and Umbgrove (1946, p. 251; 1947) offered somewhat similar views, involving arching along the coast, but with different mechanics. Features that tend to discredit most of the concept of downwarping are the presence of exposed bedrock on the slope where sediments would be expected, the lack of observed downward bending of strata in the slope and outer shelf, and seismic evidence of a rise in the basement along the outer shelf.

The most acceptable theories regarding the origin of the shelf and slope now center around diastrophic movements near the contact of the continental and oceanic crust, according to Shepard (1963, p. 310), who cites as supporting evidence the general straightness of the slopes, the angular changes in trend, the excessive steepness, the association with earthquake belts and deep trenches in the Pacific, and the outcrop of rocks along the slopes at different places.

Numerous writers have invoked faulting in their explanations of the continental shelf and slope, but few have agreed on the mechanics. Shepard (1963, p. 303–306) and Heezen, Tharp, and Ewing (1959, p. 51) have favored normal faulting. The slope appears to represent the juncture between the heavy oceanic crust and the lighter continental crust, where isostatic adjustments might be expected to compensate for erosion lightening the continental mass and deposition weighting the ocean floor. Such adjustments could produce long normal-fault scarps, possibly a band of step faults, dipping away from the continent. Some warping of the continental margin also could accompany this. However, most continental slopes are not active fault zones now and their inclination is much less than most fault scarps on land. Heezen (1962, p. 242) believes that the continental slope seems to be a relic related to normal faulting which occurred at some earlier time and that the upper part of the slope has been modified since by deposition and erosion.

Emery (1950) suggested that high-angle thrust faults extend beneath the continental mass from the margins. This idea is supported by the distribution of earthquake epicenters in an ever-deepening pattern beneath the continents. Emery thought it possible that these thrust faults elevated the continental margins sufficiently to permit subaerial erosion of the canyons now present on the shelf and slope.

Drake, Ewing, and Sutton (1959, p. 176–185, 191–194) have compared the continental shelf and slope of eastern North America to the miogeosyncline and eugeosyncline of the Appalachian Mountain System and have discussed the mechanics of thrusting and folding necessary to add the contained sediments to the land mass of the continent. Dietz (1963a, p. 1–21; 1963b) has proposed along similar lines that the slopes have been constructed by the compressional collapse and folding of the continental rise sedimentary prism against the continental block—the flanks of the resulting eugeosynclinal orogen have become the continental slope. However, he also suggests that continental drift and rifting have given rise to some rift scarps that have been modified as continental slopes.

Van Bemmelen (1956, p. 139, fig. 3) depicted a graben structure along the Atlantic coast of North America. Later, Engelen (1963, p. 65–72) expanded on this concept and showed diagrams of the development of the graben structure based on his interpretation of geophysical profiles published by Heezen, Tharp, and Ewing (1959, pl. 26). According to his hypothesis, block faulting started in Early Cretaceous time in the northern part and progressed slowly southward through Tertiary time.

STRUCTURE

REGIONAL STRUCTURAL PATTERN

The Appalachian Mountains, raised by late Paleozoic orogeny, form the structural backbone of eastern North America, extending from Newfoundland southwestward to central Alabama. (See P. B. King (1959, p. 41–66; 1964.) for a comprehensive analysis of this mountain system.) In the United States, it consists mainly of a narrow anticlinorium of Precambrian and early Paleozoic rocks at the west known as the Blue Ridge province, and a long, broad belt of intensely deformed and intruded Precambrian and Paleozoic rocks at the east called the crystalline Appalachians. (See pl. 4.) The crystalline Appalachians, which form the New England Upland to the north and the Piedmont province to the south, exhibit the most intense deformation. These intensely metamorphosed rocks crop out in a fairly continuous belt as much as 130 miles wide from Alabama to Canada. Several downfaulted basins of Triassic continental clastic rocks are present in the Piedmont province and in the basement beneath Coastal Plain deposits of Mesozoic and Cenozoic age (Cohee, 1962). The Coastal Plain deposits, which wedge out against the eastern flank of the Appalachian Mountains, reflect the major structural anomalies and trends of the Precambrian and Paleozoic rocks.

The regional structure of the pre-Cretaceous basement rocks as known from outcrops and wells, and inferred from geophysical surveys, is depicted by contours on plate 4, adapted from the tectonic map of the United States (Cohee, 1962), Antoine and Henry (1965, fig. 9), and Sheridan, Drake, Nafe, and Hennion (1966, fig. 9). The basement rocks include not only the igneous and metamorphic rocks of Precambrian and Paleozoic age and volcanic and sedimentary rocks of Triassic(?) age but also unmetamorphosed sedimentary rocks of Paleozoic age beneath the Florida Peninsula.

The structural contours on the basement rocks beneath the Coastal Plain parallel the Appalachian Mountain System except at the boundary between North and South Carolina, where they bulge seaward on the Cape Fear arch, and beneath the Florida Peninsula, where the deeper contours are deflected around the southeasterly elongated Peninsular arch. The basement surface dips seaward at rates ranging from 10 feet per mile inland to as much as 120 feet per mile near the ocean. It reaches the coast at depths in excess of 20,000 feet in southernmost Florida, 5,000 feet in southeastern Georgia, 1,500 feet in southeastern North Carolina, 9,500 feet in southeastern New Jersey, and 2,000 feet along the south shore of Long Island. A decided steepening of the slope is apparent below a depth of 3,000 feet in most of the area. Prouty (1946, p. 1918) first recognized this steepening in wells in North Carolina.

Seismic data (see pl. 2) have been sufficient to permit the contouring of the basement surface beneath the continental margin in much of the offshore area north of Cape Hatteras. There the basement surface slopes abruptly downward offshore and descends into what Kay (1951, p. 82) has called the Atlantic geosyncline. This geosyncline, a paraliageosyncline of Mesozoic rocks along the Atlantic coast according to Kay (1951, p. 82), consists of parallel troughs separated by a ridge beneath the edge of the continental shelf. (See pl. 4.) Ewing, Worzel, Steenland, and Press (1950) first concluded from seismic surveys between Cape Henry, Va., and Cape Cod, Mass., that the basement surface does not slope uninterruptedly across the continental margin but upon reaching a depth of about 16,000 feet, 40 miles off Delaware Bay, rises to a depth of about 10,000 feet at the edge of the continental shelf. (See section *E–F–F′*, pl. 5). Similar findings off Nova Scotia were reported by Officer and Ewing (1954, fig. 2). Drake, Ewing, and Sutton (1959, fig. 29) presented a thickness map of total sedimentary rocks on the basement between Cape Hatteras and Halifax, Nova Scotia. They show two troughs, one beneath the continental shelf and a second one subparallel to the first, beneath the continental slope. They liken these two troughs separated by a basement ridge to the early Paleozoic troughs of the Appalachians as restored by Kay (1951, pl. 9) and suggest that the inner trough may represent the miogeosyncline and the outer trough, the eugeosyncline. (See sections *C–D–D′* and *E–F–F′*, pl. 5).

South of Cape Hatteras, the basement surface has been contoured to the edge of the continental shelf, across the southern half of the Blake Plateau, and around the Bahama Banks. The contours for the shelf area parallel the coast for the most part, but bulge seaward off Cape Fear and landward in the Southeast Georgia embayment. Contours on the basement beneath the Blake Plateau show a trough, more than 20,000 feet deep, trending northward about 150 miles east of the coast of northern Florida, and a corresponding ridge, less than 15,000 feet deep, paralleling the continental margin (Sheridan and others, 1966, fig. 9). This combination of trough and outer ridge beneath the Blake Plateau is very similar to those reported beneath the continental shelf north of Delaware Bay. Contours around the Bahama Banks outline a basement uplift of several thousand feet whose axis trends northwestward beneath Little Bahama Bank toward the Peninsular arch of Florida (Sheridan and others, 1966, p. 1988, fig. 9). This uplift separates the trough beneath the Blake Plateau from an embayment, more than 35,000 feet deep, extending from the Gulf of Mexico across southernmost Florida to Andros Island.

The structure of the continental shelf between Jacksonville, Fla., and Cape Hatteras, N.C., is illustrated by plate 6. Offshore seismic section *A–A′* adapted from Hersey, Bunce, Wyrick, and Dietz (1959, fig. 3) is compared with stratigraphic section *A–B* (pl. 9) of this report. The comparison suggests that the seismic velocities approximating 6 kmps (kilometers per second) represent the pre-Mesozoic basement rocks and that these rocks are about 12,000 feet deep offshore north of Cape Hatteras, about 2,500 feet deep off Cape Fear, and more than 20,000 feet deep offshore south of Jacksonville. Hersey, Bunce, Wyrick, and Dietz (1959, p. 448) have tentatively correlated the 5.16- to 5.35-kmps layer off Florida and the 4.30-kmps layer off North Carolina with the top of the Lower Cretaceous. The 3.27- to 3.88-kmps layer off North Carolina is correlated by them with the top of the Black Creek Formation (top of rocks of Taylor age) but is not correlated off Florida. The Black Creek correlation off North Carolina seems uncertain, as the top of rocks of Taylor age is not a distinct lithologic horizon in the nearest wells (pl. 11). The top of rocks of Austin age and that of rocks of Woodbine age would seem to offer better possibilities for seismic velocity change. The 2.26- to 2.89-kmps layer they consider to be near the top of the Upper Cretaceous rocks offshore between Jacksonville and Cape Hatteras. This, too, seems very uncertain as comparison to the stratigraphic cross section suggests the 2.26- to 2.89-kmps layer is too shallow to be Upper Cretaceous and may be closer to the top of the Eocene rocks. This velocity layer is less than 1,500 feet deep at Cape Hatteras; the top of the Upper Cretaceous rocks in the Cape Hatteras well (NC–14) has been placed at 3,033 feet and the top of the Eocene (Castle Hayne Limestone) rocks at 1,738 feet in this study. The irregular and rising velocity layers south of Cape Fear suggest that they result from a general facies change to carbonate in that direction and cannot be relied upon for stratigraphic equivalence.

REGIONAL BOUGUER GRAVITY ANOMALIES

Early gravity investigations along the Atlantic seaboard were concerned primarily with relating gravity to surface geology and to seismic and magnetic data (Swick, 1937; Woollard and others, 1938; Woollard, 1939, 1940a, 1941, 1943, 1944, and 1948). One of the early papers that dealt with gravity interpretations of subsurface geology in the Atlantic region was that on the Bahamas by Hess (1933, p. 38–53). He concluded "that the general field of negative anomalies is due to a great thickness of light sediments beneath the Bahamas, but that the dolomitic reef material is relatively heavy, thus making the anomalies on the reef material less negative than those over the submarine valleys." Many years later, Worzel and Shurbet (1955a, p. 97) estimated the great thickness of light sediments beneath the Bahamas to be 93,000 feet. In addition, they stated (p. 97), "If this calcareous system were laid down on an oceanic crust, and approximate isotasy were maintained at all times, the final 16,000 feet would have been laid down in water depths less than 2,000 feet." Other papers that make geological interpretations from gravity measurements along the Atlantic coast include those of Woollard (1940b, 1949), Skeels (1950), Worzel and Shurbet (1955b), and Worzel, Ewing, and Drake (1953).

A summary map of Bouguer gravity anomalies along the Atlantic coast has been published recently by Woollard and Joesting (1964). Plate 7, which is adapted from their map, shows the regional anomalies along the Atlantic coast. These anomalies primarily reflect compositional differences at considerable depths in the earth's crust but are related to some extent to the structure and composition of the Coastal Plain sedimentary rocks and shallow basement. Four alternating belts of predominantly positive and predominantly negative gravity anomalies extend diagonally across the region from southwest to northeast. These correspond roughly to the continental rise and slope, the continental shelf and Coastal Plain, the Appalachian Mountain front, and the Piedmont Plateau-Blue Ridge-Appalachian Basin region.

CONTINENTAL RISE AND SLOPE

Positive gravity values extend over a wide area parallel to the outer continental shelf and increase rather regularly oceanward across the continental slope and rise. They range from 0 to 40 milligals along the outer continental shelf to more than 300 milligals near the boundary between the continental rise and the abyssal plain (fig. 1). A single, slightly negative anomaly about 20 miles wide and 190 miles long is present off South Carolina. The general increase of positive gravity values oceanward probably reflects a transition between the lighter continental crust and the heavier oceanic crust underlying the ocean basins of the earth.

CONTINENTAL SHELF AND COASTAL PLAIN

Negative gravity values predominate on the continental shelf and Coastal Plain, although irregular positive anomalies are numerous and large enough to create a confusing pattern not readily related to known surface and shallow subsurface features. The area is underlain by light continental crust on which sedimentary rocks containing some igneous intrusions and flows are irregularly distributed. In general, the areas of negative values are elongate subparallel to the continental shelf and Coastal Plain. The values range from 0 milligals along the eastern and western limits of the combined provinces to as little as −40 milligals in isolated anomalies in between. In Alabama and from Virginia northward, the western zero-gravity contour is as much as 75 miles inside the Coastal Plain and continental shelf. A large, positive anomaly breaks the regional pattern across the Coastal Plain of Alabama and Georgia and extends about 60 miles offshore. Another positive anomaly crosses the regional pattern in southern Florida, and long reentrants are present in the negative pattern at several places south of Virginia.

The largest unbroken area of negative values in the Coastal Plain and continental shelf is a crescent-shaped anomaly more than 100 miles wide and 600 miles long between Cape Hatteras and the Gulf of Maine. Several sizeable negative anomalies are present within the larger one. One in northeastern North Carolina and southeastern Virginia reaches a value of −40 milligals. Another smaller anomaly, which reaches a value of −20 milligals and is about 200 to 250 miles long, is present in the Coastal Plain and continental shelf near Atlantic City, N.J.; it does not coincide with the Baltimore Canyon trough, although it crosses one arm of this basement feature. The large crescent-shaped negative anomaly as a whole conforms somewhat to the zone of maximum compression in the Appalachian Mountains. Whether it is related to this or to Triassic deposition is not known.

A large area in southwestern Georgia and the Florida Panhandle has negative values that seem to be related somewhat to the composition of the shallow basement rocks; wells there penetrate Paleozoic limestone, sandstone, and shale beds beneath the Mesozoic. The outline of the area underlain by these Paleozoic rocks conforms in a rough way to the zero contour from Alabama to eastern Georgia, but the relationship becomes vague southeastward in Florida where pre-Mesozoic volcanics are found in some wells.

APPALACHIAN MOUNTAIN FRONT

Positive gravity values ranging from zero to 50 milligals extend in a narrow belt 30 to 80 miles wide along the front of the Appalachian Mountains. This belt coincides with the Blue Ridge province in Virginia and the Newark Basin in New Jersey (Cohee, 1962) but does not conform well to geologic and physiographic boundaries throughout its length. It cuts diagonally across the Piedmont Plateau southward to Alabama and continues beneath the Coastal Plain to the Florida Panhandle. It also encroaches on the Coastal Plain and continental shelf northward from Virginia to the Gulf of Maine. The exposed rocks within this belt are mainly Paleozoic metamorphics, including the Carolina slate belt (Cohee, 1962).

PIEDMONT PLATEAU, BLUE RIDGE, AND APPALACHIAN BASIN

West of the belt of positive gravity values along the front of the Appalachian Mountains is a broad expanse with negative gravity anomalies ranging from zero to −100 milligals. The minimum anomalies of −100 milligals are present in the Blue Ridge province in northeastern Tennessee and northwestern North Carolina, where, according to King (1964, p. 19), the −80 milligal contour encloses all the major windows of the thrust sheets of the Southern Appalachians. King suggests that these data indicate that the "surface Precambrian rocks of the southwestern segment of the Blue Ridge Province are underlain by a thick body of overridden, deformed Paleozoic and possibly earlier sedimentary rocks." Anomalies having minimum values of −80 milligals lie within the Appalachian Basin, which contains considerable thicknesses of unmetamorphosed Paleozoic sedimentary rocks.

REGIONAL MAGNETIC ANOMALIES

COASTAL PLAIN

Magnetic observations on the Coastal Plain date back to the early 1930's (MacCarthy and others, 1933; MacCarthy and Alexander, 1934; Jenny, 1934; Johnson and Straley, 1935; and MacCarthy, 1936). Jenny (1934, p. 413) found northeastward magnetic trends in the Coastal Plain of Alabama and Florida and related them to the structural trends in the Appalachian Mountains, as did Lee, Schwartz, and Hemburger (1945) later. MacCarthy (1936, p. 405, 406) drew similar conclusions about subparallel high and low intensity trends in the Coastal Plain of North and South Carolina. He noted also that these trends curve around the southeastward-trending basement uplift (Cape Fear arch) at Wilmington, that they outline a subsurface Triassic basin near Florence, S.C., and that they indicate a distinct change in basement slope near and parallel to the coast.

Maps of vertical magnetic intensity anomalies on the Coastal Plain of North Carolina were published by Skeels (1950, pls. 3 and 4) after the drilling of the deep well at Cape Hatteras (NC–14) in 1946. He compared these with gravity maps and seismic maps of the same area and noted that both the magnetic and gravity anomalies showed north-to-south trends (Skeels, 1950, pls. 1, 2; figs 2, 3, 19, 20). He concluded that the magnetic maps tend to accentuate effects from the upper part of the basement more than do the gravity maps and that the magnetic properties of the igneous rocks seem to be much more variable than their densities.

In 1959, E. R. King (1959, fig. 1) published a regional magnetic map of Florida from which the structural trends of the Precambrian and Paleozoic rocks beneath the Coastal Plain were inferred. Two regional magnetic trends dominate the map: one extends diagonally southeastward from the Florida panhandle along the southwest side of the peninsula and across the tip of southern Florida toward the Bahama Islands; the second, parallel to and east of the Appalachian Mountains, crosses northeastern Florida and seemingly intersects the first trend at the gulf coast. Small nonlinear anomalies, possibly due to intrusive rocks, separate the two trends in central eastern Florida. Like Woollard (1949), E. R. King suggests that the southeastward magnetic trend is a continuation of the Ouachita Mountains whose subsurface extension in Alabama and relationship to the Appalachian Mountains has been the subject of much speculation (King, P. B., 1950, p. 667–668).

CONTINENTAL SHELF AND SLOPE

Magnetic observations on the continental shelf and slope were reported first by Keller, Meuschke, and Alldredge (1954), who discussed two aeromagnetic profiles from Fire Island, N.Y., to Bermuda, and from Ludlam Beach, N.J., to Bermuda. They recognized a linear magnetic anomaly near the edge of the continental shelf parallel to the coast and attributed it to an igneous intrusion about 30 miles wide in the basement. This magnetic anomaly was noted also by Miller and Ewing (1956, p. 412), Drake, Ewing, and Sutton (1959, p. 175), and Heezen, Tharp, and Ewing (1959, p. 51).

An analysis of 10 aeromagnetic profiles across the continental shelf and slope by King, Zietz, and Dempsey (1961, p. D302, D303) indicated that the anomaly along the outer edge of the continental shelf corresponds in position with the basement ridge found by seismic refraction (Drake and others, 1959) but that the intensities do not correspond with depth to basement as suggested by seismic refraction. They concluded that although basement topography may have some effect on the magnetic intensity, the anomaly "may be at least partly the expression of a large mass or series of masses of more magnetic rocks within the basement—possibly intrusive bodies along a zone parallel to the continental margin at the transition from a continental to an oceanic crust" (King and others, 1961, p. D303).

A marine magnetic survey by the U.S. Navy Oceanographic Office (1962) along the edge of the continental shelf between lat 34°30′ N. and lat 39°00′ N. also supported the idea that the anomaly is an expression of a large mass of more highly magnetic rocks in the basement.

Off Nova Scotia, marine magnetic surveys indicate a broad, low-intensity magnetic anomaly beneath the edge of the continental shelf southeast of Sable Island (Bower, 1962, p. 8). The bathymetric position of this anomaly is similar to that of the one found by Keller, Meuschke, and Alldredge (1954) off the east coast of the United States. Bower (1962, p. 8) believes that the magnetic anomaly near Sable Island could be produced by a large intrusion buried beneath thousands of feet of nonmagnetic material. The surveys off Nova Scotia offer no basis for disagreement with seismic evidence (Press and Beckman, 1954, p. 308) for large thicknesses of sedimentary rocks beneath the continental shelf in this area.

In 1963, the numerous magnetic observations on the continental shelf and slope were summarized and the anomaly trends were plotted on a chart by Drake, Heirtzler, and Hirshman (1963). Plate 8 shows these high-intensity trends and significant regional trends are labelled. The width of the trend lines indicates amplitude, not width, of the anomaly. The anomalies are attributed primarily to compositional differences within the basement, yet the alinement of these anomalies carries certain connotations of regional tectonics.

Long, linear southwesterly trends, despite their crossing and branching at places, roughly parallel the Appalachian Mountains and the edge of the continental shelf. This dominant pattern, indicated on plate 8 as the "Appalachian trend," terminates in Florida against a southeasterly magnetic trend that E. R. King (1959) has suggested is an extension of the Ouachita Mountains ("Ouachita(?) trend", pl. 8). The Ouachita trend extends from the vicinity of Tallahassee in northwestern Florida along the southwest coast and across southeastern Florida near Miami to the Bahama Islands. Its identity is lost there in arcuate patterns, perhaps related to an intersection with slope anomaly(?) A of plate 8.

The dominant Appalachian trend is interrupted along the 40th parallel, about 50 miles south of New York, by a linear anomaly more or less alined with a string of seamounts extending down the continental rise to the abyssal plain. (See pl. 8.) This anomaly has been interpreted by Drake, Heirtzler, and Hirshman (1963, p. 5270) as a transcurrent fault in the basement with right-lateral displacement of about 100 miles and a total length in excess of 600 miles.

The large anomaly along the edge of the continental shelf, commonly referred to as the "slope anomaly," extends from north of Halifax (Bower, 1962, p. 8) to Cape Fear (pl. 8) with one offsetting interruption by the transcurrent fault(?) trend near New York. South of Cape Fear, the slope anomaly branches—one trend (slope anomaly A, pl. 8) continues parallel to the edge of the Blake Plateau and the other (slope anomaly B, pl. 8) extends southwest to its termination against the Ouachita(?) trend. Slope anomaly A seems to coincide with a northward trending basement ridge along the Blake Escarpment between lat 28° N. and lat 31° N., as interpreted from seismic refraction data by Sheridan, Drake, Nafe, and Hennion (1966, p. 1984, and fig. 9). The significance of slope anomaly B is not yet apparent.

Recently, Watkins and Geddes (1965) reported on the slope anomaly between Cape Hatteras, N.C., and Cape May, N.J., where it is 19 to 50 miles wide with peak intensities generally 350 gammas more than those of adjacent areas. By comparing this anomaly with those along the Aleutian Islands chain and across the island of Puerto Rico, they drew the inference that the basement ridge along the Atlantic Continental Shelf is a buried, quiescent island arc and that the slope anomaly reflects intrusive and extrusive phases of volcanism during the active tectonic development of the island arc (Watkins and Geddes, 1965, p. 1357).

PRINCIPAL STRUCTURAL FEATURES

The principal structural features of the basement rocks beneath the Coastal Plain and continental shelf are outlined by contours on plate 4. All but Emerald Bank trough, which is located off Nova Scotia, are also shown in figure 6. The principal structural features are discussed separately in the following sections; for fuller discussion, see Stephenson (1926, 1928), Eardley (1962, p. 135–153), and Murray (1961, p. 92–98).

CAPE FEAR ARCH

The Cape Fear arch, also known as the Great Carolina ridge, Wilmington anticline, and Carolina ridge, is a southeastward plunging basement nose, the axis of which intersects the North Carolina coastline near Cape Fear. It is the most prominent structural feature of the central part of the Atlantic Coastal Plain (Stephenson, 1928, p. 891) and is evident from the Cretaceous outcrop pattern, well data, magnetometer surveys (MacCarthy, 1936, p. 405), and seismic surveys (Bonini, 1955, p. 1533; 1957; Meyer, 1957). The general shape is a gentle warp, with the axial plunge increasing sharply near the shoreline and gradually diminishing updip toward the Fall Line. Along the axis of the arch from the Fall Line to the coast, the basement rocks dip at an average of about 13 feet per mile. The arch is asymmetric in cross section, the north limb being steeper. Lower Cretaceous rocks and some Upper Cretaceous rocks are missing from the crest of the feature but are present on the flanks. The formation of the Cape Fear arch is thought to have been accompanied by downwarping of the flanks, which Cooke (1936, p. 158) believed took place during late Eocene time. Other geologists have dated the origin at different times ranging from Early Cretaceous to early Miocene. Both Siple (1946, p. 37) and Eardley (1951, p. 131) have suggested that uplift and erosion probably occurred during more than one stage.

Seismic information (Meyer, 1957, p. 81, pl. 2; Hersey and others, 1959, p. 445) indicates that the Cape Fear arch protrudes seaward across the continental shelf as a large regional nose in the basement rocks. At the crest of the arch on the coastline, the basement rocks are present at a depth of about 1,100 feet. The basement surface slopes northward to a depth of 5,000 feet at Cape Lookout, N.C., and southward to 2,500 feet at Cape Romain, S.C. At the edge of the continental shelf, the basement rocks on the crest of the arch are 4,000 feet below sea level. Ewing, Ewing, and Leyden (1966, p. 1965, fig. 16) suggest a more southerly direction for the seaward extension of

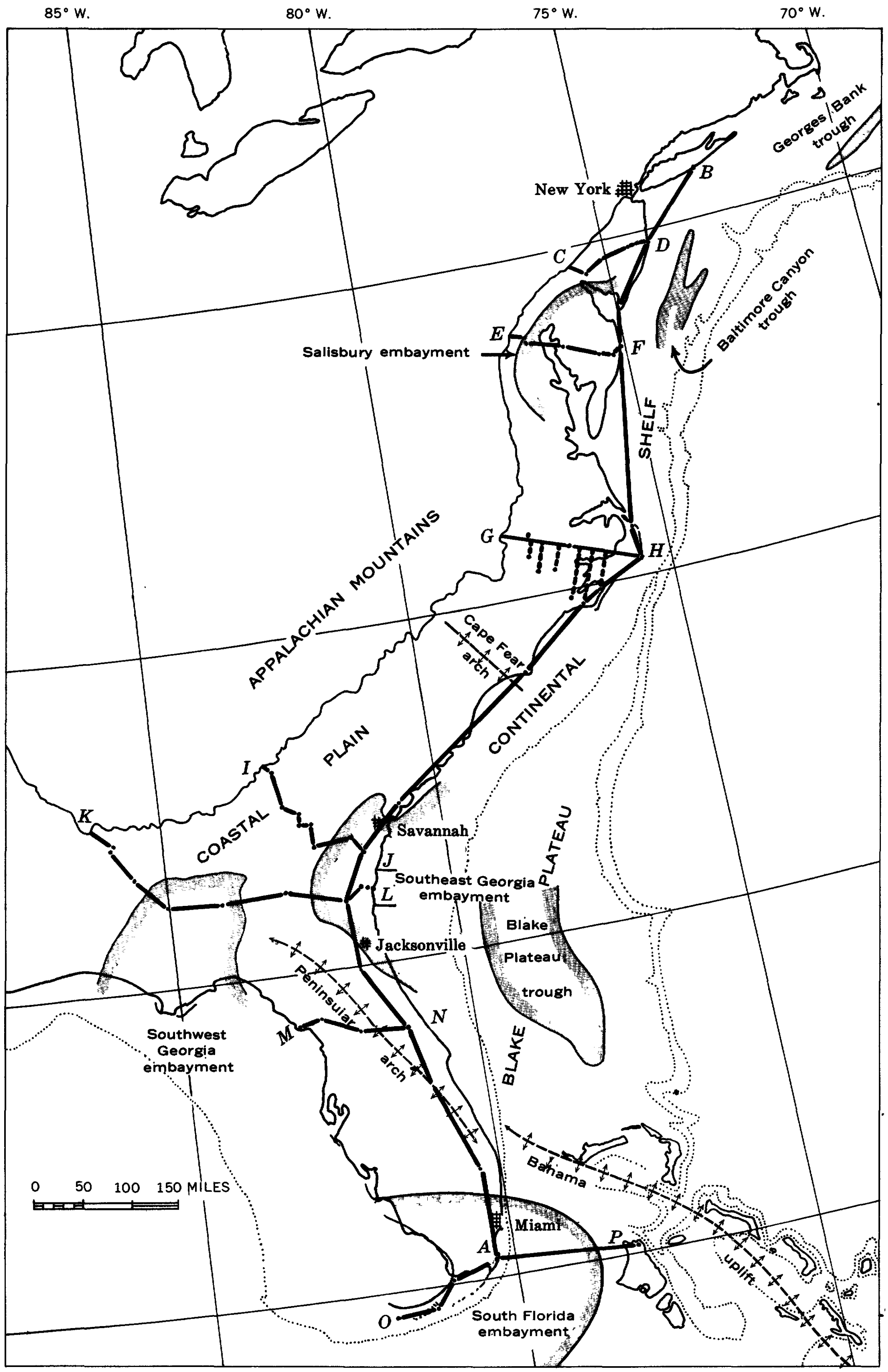


Figure 6.—Index map of Atlantic Coastal Plain and Continental Shelf showing principal structural features and lines of sections.

the Cape Fear arch than that indicated by the earlier seismic interpretations but do not present basement contours.

PENINSULAR ARCH

The dominant subsurface structural feature of Florida and southeastern Georgia is the Peninsular arch. It has a southeast trend and extends from southern Georgia down the axis of the Florida Peninsula (Applin, 1951, p. 3; Toulmin, 1955, p. 210). The structure was topographically high in Early Cretaceous and early Late Cretaceous time, during which sediments were deposited around it, but not over it—beds of Austin age rest on Paleozoic rocks in places on the crest. A later (Miocene) auxiliary uplift known as the Ocala uplift occurred on the southwest flank of the Peninsular arch. The Peninsular arch slopes northward toward the Southeast Georgia embayment.

SOUTHWEST GEORGIA EMBAYMENT

The Southwest Georgia embayment encompasses parts of southwestern Georgia, southeastern Alabama, and the Florida Panhandle between the Chattahoochee uplift of Alabama and Georgia and the Peninsular arch. It appears to be a relatively shallow reentrant in the Upper Cretaceous (Austin) rocks, as shown by the tectonic map of the United States (Cohee, 1962). However, it is quite prominent in the older sedimentary and basement rocks. The contained sedimentary rocks exceed 7,500 feet in thickness north of the Florida-Georgia boundary and probably exceed 15,000 feet offshore. Considerable thicknesses of Lower Cretaceous rocks have been penetrated by wells in this embayment. The stratigraphy suggests that this embayment was well filled by Early Cretaceous sediments before Late Cretaceous deposits were laid down in it.

Antoine and Harding (1963, fig. 8) have postulated on geophysical evidence a protrusion of the Peninsular arch (Ocala uplift) southwestward into the Gulf of Mexico. They present structure maps (Antoine and Harding, figs. 6 and 7) showing this in Cretaceous rocks as well as in the basement rocks. This protrusion in the basement rocks marks the south flank of the Southwest Georgia embayment (pl. 4).

BAHAMA UPLIFT

A positive structural element extending northwestward through the Bahama Islands was inferred first by Hess (1933, p. 42–45 and fig. 9) from the submarine topography and gravity measurements in that region. He believed that the formation of the long, parallel northwestward-trending submarine valleys between the Bahamas had been controlled by ancient folding of sedimentary formations. Hess pointed out the need for further geophysical data to determine whether or not the folded Appalachians, or a branch of them, extend under the Bahama region. The same gravity data with many more contributed by oil companies were interpreted by Talwani, Worzel, and Ewing (1960, p. 159) as indicative of grabenlike downfaulting along the same trend.

In 1947, Pressler (1947, p. 1858) suggested on the basis of the sea-bottom configuration "that the Florida peninsula is bounded on the east and south by major fault zones, and that the Bahaman and Cuban areas are very large faulted segments of the Gulf of Mexico plate or basin." His sketch map (Pressler, 1947, fig. 1) indicated an anticlinal flexure, which he named the Bahama uplift, plunging northwestward through the eastern rim islands of the Bahama group toward Cape Kennedy (see fig. 6) and terminating against a major fault zone at the edge of the continental shelf. Pressler (1947, p. 1853) also suggested a probable close relationship between the Bahama uplift and the southeast-trending basement ridge now known as the Peninsular arch.

Seismic refraction investigations by Sheridan, Drake, Nafe, and Hennion (1966) have confirmed Pressler's general concept of the relationship between the Peninsular arch and the Bahama uplift. The results indicate that the Peninsular arch extends southeastward under the western end of Little Bahama Bank (Sheridan and others, 1966, fig. 9, p. 1986). However, seismic reflection investigations by Ewing, Ewing, and Leyden (1966, p. 1960) indicate that the continental slope between Florida and the Bahama Islands is a depositional feature and that no major fault zone is present at the edge of the continental shelf. Sheridan, Drake, Nafe, and Hennion (1966, p. 1976) agree and conclude that seismic refracting horizons cannot be equated with stratigraphic boundaries through the marked physiographic changes between Florida and the Bahama Banks.

SOUTH FLORIDA EMBAYMENT

The South Florida embayment as described by Pressler (1947, p. 1856) embraced the synclinal area between the Peninsular arch, the Bahama Islands, and Cuba. The axis was believed to extend "along a general line through Great Inagua Island to a point near the south end of Andros Island, thence across the Bahama Banks to the Florida Keys near the north end of Key Largo and across Dade and Monroe Counties to the southwest coast of Florida." Patton

(1954, p. 160) restricted the term to the area between the south flank of the Ocala uplift, a Tertiary feature offsetting the Peninsular arch, to the Straits of Florida just south of the Florida Keys. Murray (1961, p. 101) followed Pressler's geographic name and description of the area but referred to the feature as a basin rather than an embayment.

Applin and Applin (1965, p. 15, 16) applied Pressler's term "South Florida embayment" to the negative area, in Lower Cretaceous rocks, whose axis "trends about N. 65° W. from the eastern end of Florida Bay across the southern tip of the Peninsula and plunges toward the Gulf of Mexico." Oglesby (1965) used the term "South Florida Basin" for the same general area on his structural maps of Lower Cretaceous rocks, but he added a hypothetical northwesterly closure at 12,500 feet beneath the Gulf of Mexico.

Sheridan, Drake, Nafe, and Hennion (1966, fig. 10), on the basis of refraction seismic surveys, confirmed the general structure of the Lower Cretaceous rocks as shown by Applin and Applin (1965, fig. 52). However, their structural map of the pre-Jurassic basement (Sheridan and others, 1966, fig. 9) extended the negative feature eastward to Andros Island under the name "South Florida-Andros Island Basin." This negative feature, which is more than 35,000 feet deep, is outlined by the 20,000-foot contour on the basement rocks on plate 4. The original name "South Florida embayment," proposed by Pressler in 1947 (p. 1856), is retained in this report.

SOUTHEAST GEORGIA EMBAYMENT

The Southeast Georgia embayment (Toulmin, 1955), also called the Okefenokee embayment (Pressler, 1947, p. 1856), is recessed into the Atlantic coast between Savannah, Ga., and Jacksonville, Fla. It interrupts the long, uniform slope of the basement away from the south flank of the Cape Fear arch and extends southwestward to the Peninsular arch. This embayment is primarily a tectonically passive feature, although it may have undergone some downwarping on the continental shelf, where the rocks exceed 10,000 feet in thickness. Recently, Murray (1961, p. 96) used the term "Savannah basin" in lieu of Southeast Georgia embayment, but he extended the northern limit to the Cape Fear arch in South Carolina so that the terms are not synonymous.

A basement ridge, the Yamacraw ridge, was described from seismic studies by Meyer and Woollard (1956), Meyer (1957, p. 71), and Woollard, Bonini, and Meyer (1957, p. 49) as a southwestward projection into the embayment about 15 to 30 miles inland from the coast. A later, more detailed seismic survey by Pooley (1960, p. 21) confirmed the existence of an elongate seismic anomaly but located its axis at the coastline between Parris Island, S.C., and Sea Island, Ga. Pooley (1960, p. 21, and pl. 2) depicts this anomaly as a basement ridge, about 110 miles long and 40 miles wide, with more than 1,000 feet of relief that is not reflected in the overlying beds. Data from wells drilled since 1960 at the southern extremity of the anomaly do not substantiate these dimensions. However, they do not necessarily preclude the existence of a relatively minor structural nose in the basement rocks farther north near the South Carolina border.

SALISBURY EMBAYMENT

The name "Salisbury embayment" was applied by Richards (1948, p. 54) to the low area in the basement rocks between Washington, D.C., and Ocean City, Md., without definite north or south limits. More recent well and seismic data (Cohee, 1962) suggest that the Salisbury embayment lies between the latitudes of Newport News, Va., and Atlantic City, N.J. This embayment is fairly prominent in the basement rocks, but it loses form in the younger beds, which suggests that it is a pre-Cretaceous feature nearly filled by Cretaceous sediments. At the coastline in Delaware, it contains about 10,000 feet of Mesozoic and Cenozoic rocks.

The Salisbury embayment is a part of the much larger Chesapeake-Delaware embayment of Murray (1961, p. 92), which includes a large part of the geosynclinal province north and east of the Cape Fear arch to the Grand Banks off Newfoundland. Despite the fact that both the Chesapeake and Delaware Bays, from which the name is derived, are located within the more restricted Salisbury embayment, the newer name does not supercede the term "Salisbury embayment."

BLAKE PLATEAU TROUGH

Seismic investigations of the continental margin east of Florida by Sheridan, Drake, Nafe, and Hennion (1966) have revealed a broad trough in the basement rocks about 150 miles east of the coast of northern Florida. (See pl. 4 and fig. 6.) This trough is more than 20,000 feet deep and extends from the Bahama uplift northward beneath the middle of the Blake Plateau. The northward limit of this trough is not known as yet, but the part now mapped within the 20,000-foot contour is about 220 miles long and 80 miles wide. The western flank rises gradually into the

Southeast Georgia embayment, which is outlined by the 4,000-foot contour. The eastern flank rises more abruptly to an outer ridge, less than 15,000 feet deep beneath the Blake Escarpment. The name "Blake Plateau trough" is used herein for identification of this large negative feature.

BALTIMORE CANYON TROUGH

Seismic work by Drake, Ewing, and Sutton (1959, fig. 29) has revealed a long narrow trough in the basement rocks off the New Jersey and Delaware coasts. According to the tectonic map of the United States (Cohee, 1962), the basement rocks descend below sea level from 10,000 feet near the mouth of Delaware Bay to more than 16,000 feet about 40 miles offshore and then rise to somewhat less than 10,000 feet at the edge of the continental shelf before dropping abruptly to 20,000 feet beneath the continental slope. The trough, as outlined by the 10,000 foot contour, parallels the edge of the continental shelf for about 150 miles from about lat 40° N. to about lat 38° N., where it apparently crosses the shelf edge to the slope. Along its western side, it bulges landward toward Delaware Bay. This bulge corresponds somewhat to the much wider Salisbury embayment that lies beneath the Coastal Plain.

Inasmuch as this relatively unexplored trough is important not only to the geologic history of the eastern margin, but also to petroleum exploration, this negative feature has been designated the Baltimore Canyon trough (Maher, 1965, p. 6). Baltimore Canyon is a submarine canyon shown on the U.S. Coast and Geodetic Survey Nautical Charts (1961, chart 1109; 1962, chart 1108) at the approximate location where the trough intersects the edge of the continental shelf.

GEORGES BANK TROUGH

A long, canoe-shaped trough in the basement rocks off Cape Cod was located by geophysical programs of oceanographic institutions (Drake and others, 1959, fig. 29). This trough is outlined by the 10,000-foot contour shown on the tectonic map of the United States (Cohee, 1962) and does not reach 15,000 feet in depth. It is about 215 miles long and 25 to 30 miles wide in places. Seismic velocities suggest that it also contains Mesozoic and Cenozoic rocks. The name "Georges Bank trough" has been used for identification (Maher, 1965, p. 6) because of its close proximity and subparallelism to Georges Bank. (See U.S. Coast and Geodetic Survey Nautical Charts (1945; 1962, chart 1108).)

EMERALD BANK TROUGH

Using refraction seismic methods, Officer and Ewing (1954, fig. 6) located an oval-shaped trough in the crystalline basement beneath the continental shelf about 120 to 150 miles off Halifax, Nova Scotia. (See pl. 4.) Its axis crosses long 62° W. at approximately lat 43°15′ N. (pl. 4) near Emerald Bank (U.S. Navy Hydrographic Office, 1949), for which it is named (Maher, 1966a,b; 1967 a,b). The east end has not been defined by seismic work, but assuming that the 10,000-foot contour closes eastward about as it does westward, the trough may be as much as 120 miles long and 40 miles wide. East of Halifax, the basement rocks slope very gently from shore to a depth of 8,000 feet; then they descend to 14,000 feet and rise to 10,000 feet before dropping abruptly to 20,000 feet beyond the Shelf edge. Seismic velocities suggest that this basin is filled by consolidated sediments that Officer and Ewing (1954, p. 664) regard as most likely to be Triassic in age. Woollard, Bonini, and Meyer (1957, p. 70) agree that the consolidated sediments could be Triassic, but believe that they are more likely to be Paleozoic in age. The overlying semiconsolidated and unconsolidated rocks thought to be Cretaceous and Cenozoic in age respectively do not seem to reflect the underlying structure or topography (Officer and Ewing, 1954, fig. 2).

STRATIGRAPHY

By John C. Maher and Esther R. Applin

REGIONAL ASPECTS

Triassic, Cretaceous, and Tertiary rocks flank the crystalline Appalachians from New York southward and crop out roughly parallel to the present Atlantic coastline (pl. 4). Triassic outcrops are confined to scattered down-faulted basins within the piedmont. Lower Cretaceous outcrops are recognized in part of the Salisbury embayment (Stose, 1932) and may be represented farther south as thin clastic beds mapped with the basal Upper Cretaceous. Upper Cretaceous rocks crop out almost continuously along the Fall Line from eastern Alabama to the north flank of the Cape Fear arch in North Carolina, and from Virginia to New York. Tertiary rocks crop out in broad patterns throughout the Coastal Plain except on the Cape Fear arch and where they are masked by a veneer of alluvial deposits.

The Cretaceous and Tertiary rocks exposed from central Georgia northward to Long Island are mainly nearshore marine and continental clastics interspersed with some thin lignitic layers and marl beds. Seaward, these rocks become marine in character and thicken to more than 10,000 feet at the coastline. Cretaceous rocks do not crop out in Florida and southern Georgia, and only part of the Tertiary sequence is exposed in that area. Both are predominantly marine carbonates in the subsurface and exceed 15,000 feet in thickness in the Florida Keys and Bahama Islands. The marine carbonate units in southern Georgia and Florida, though less distinctly separable lithologically, are more uniform in character and thickness and more susceptible to paleontologic dating than the clastic beds farther north along the coast. In addition, much more subsurface control is available from the more than 300 wells drilled in Florida alone.

Although more than 10,000 feet of shelf-type sedimentary rock is present at the Cape Hatteras shoreline (well NC–14, table 1) and refraction seismic surveys indicate more than 10,000 feet of sedimentary rocks in several offshore negative features (pl. 4), very little is known about the stratigraphy of the continental shelf. The first information came from rocks dredged by trawlers along the Grand Banks, Banquereau, and Georges Bank. These were collected in 1878 by Upham and were reported by Verrill (1878, p. 323) and Upham (1894, p. 127) to contain Tertiary fossils. Much later, Dall (1925) revised the paleontology of these rocks and noted Late Cretaceous species in one boulder from Banquereau (Dall, 1925, p. 215). He expressed "little doubt that Late Cretaceous and Tertiary fossiliferous deposits originally existed along the northeastern coast from Newfoundland southward, as far as the area of glaciation extended, though in most cases the only evidence remaining is the presence in the glacial debris of fragmentary portions of the original deposits" (Dall, 1925, p. 213). The first Cretaceous and Tertiary rocks thought to be in place on the continental shelf were dredged from submarine canyon walls in Georges Bank (Stetson, 1936; Stephenson, 1936; Cushman, 1936). Since then, dredge samples and short cores of Cretaceous and Tertiary rocks have been taken at a few places on the continental shelf and Blake Plateau. These have been summarized by Stetson (1949), Ericson, Ewing, Wollin, and Heezen (1961), and Uchupi (1963). The most significant of these are located on plate 2 and are discussed under the appropriate stratigraphic unit. In addition to dredging and taking short cores, a few test holes (pl. 1, wells GA–88 and FL–118 through FL–123) have been drilled several hundred feet into the continental shelf off Georgia and Florida.

REGIONAL CORRELATIONS

A regional stratigraphic study such as this is necessarily based to a large extent upon published reports. Many of these reports cannot present detailed supporting data in the form of measured sections, sample logs, electric logs, and paleontology because of lack of space. It is necessary, therefore, not only to examine the published reports critically, but also to search out the supporting detail in records, files, and unpublished reports. These basic data may be supplemented with later information and then restudied.

About 400 wells in 11 states and three wells in the Bahama Islands and vicinity (table 1, in back of report) were selected for their stratigraphic significance in this study. Drilling records of some sort are available for all these wells, but sample logs with some paleontology are available for less than half of them. Electric logs for about 200 wells, most of them in Florida and Georgia, were obtained and correlated. The regional cross sections of this report show 49 electric logs, nine sample logs, and two driller's logs. For the sake of uniformity and simplicity, electric logs, rather than sample logs, have been shown on sections where available.

Both electric logs and sample logs are available for many of the deep wells along the coast. In general, the characteristics of rock units in the region are more distinctively and accurately recorded on the electric logs than on the available logs prepared from rotary samples by many different workers. Selectively, however, the sample logs and detailed paleontology of key wells provide the stratigraphic age assignments to which the electric log correlations must be reconciled; so the electric logs serve principally as objective records of relatively uniform value for selecting traceable rock-unit boundaries within paleontologic control and for the tracing of these rock units through areas lacking substantial paleontologic and lithologic control.

Two approaches have been made to the correlation of the Mesozoic and Cenozoic rocks along the east coast—one from the gulf coast marine facies in Florida northward through deep wells at the coastline, and the other from the outcrops at the Fall Line downdip through shallow wells to the same deep wells at the coastline. The first approach utilized the well-known and documented microfossil zones used in distinguishing both surface and subsurface rock units in the gulf coast region. The deep wells along the coast penetrate a greater proportion of marine rocks than those farther inland and, as a result, offer more paleontologic evidence and stratigraphic uniformity. The second approach attempts to relate local rock units and names to those carried northward from the gulf coast. Numerous difficulties are involved in this. The rocks exposed near the Fall Line are predominantly clastic and relatively nonfossiliferous in character, and many subdivisions and contacts in these rocks are based entirely upon lithology. These rocks thicken and change facies downdip so that many of the distinguishing features on which local outcrop names are based become indistinct in the deep wells. Fossils are not sufficiently abundant nor definitive enough to delimit the units in many of the shallow wells.

The technique employed in correlating the electric logs has been to plot all paleontologic data and reported tops of geologic units on the electric-log strips. The principal subdivisions of the rocks and bounding unconformities are drawn in key wells with paleontologic control. These are extended to adjacent wells by zoning the electric logs with both a number and a color code into the smallest traceable units within the larger units. This permits the recognition of the addition of new beds downdip and the absence of rocks at unconformities updip. In effect, it requires an accounting for all changes from well to well within the larger units controlled by paleontology. In doing this, no electric log correlations have been made knowingly in violation of available paleontologic data, although numerous changes of earlier opinions based on lithology have been suggested.

In general, the boundaries of most rock units shown

TABLE 2.—*Stratigraphic units and their gulf*

System	Series		Gulf coast equivalent	Florida units	Georgia units
TERTIARY AND QUATERNARY	Holocene, Pleistocene, and Pliocene		Post-Miocene rocks	Post-Miocene rocks	Post-Miocene rocks
	Miocene		Miocene rocks	Miocene rocks	Miocene rocks
TERTIARY	Oligocene		Oligocene rocks	Oligocene rocks	Oligocene rocks
	Eocene		Rocks of Jackson age	Ocala Limestone	Rocks of Jackson age
			Rocks of Claiborne age	Avon Park Limestone Lake City Limestone	Tallahhatta and Lisbon Formations undifferentiated
			Rocks of Wilcox age	Oldsmar Limestone	Rocks of Wilcox age
	Paleocene		Rocks of Midway age	Cedar Keys Limestone	Clayton Formation
CRETACEOUS	Upper	Gulf	Rocks of Navarro age	Rocks of Navarro age	Rocks of Navarro age
			Rocks of Taylor age	Rocks of Taylor age	Rocks of Taylor age
			Rocks of Austin age	Rocks of Austin age	Rocks of Austin age
			Rocks of Woodbine and Eagle Ford age	Atkinson Formation	Rocks of Eagle Ford age
					Tuscaloosa Formation
	— ? — Lower	Comanche	Rocks of Washita age	Rocks of Washita age	Lower Cretaceous rocks
			Rocks of Fredericksburg age	Rocks of Fredericksburg age	
			Rocks of Trinity age	Rocks of late Trinity age Sunniland Limestone Rocks of early Trinity age	
— ? —	Lower Cretaceous (Neocomian) or Upper Jurassic		Lower Cretaceous (Neocomian) or Upper Jurassic	Lower Cretaceous (Neocomian) or Upper Jurassic	Lower Cretaceous (Neocomian) or Upper Jurassic absent

on these cross sections are drawn within fossil control on lithology as reflected by electric-log characteristics. These boundaries are not subject to exact agreement among geologists. Difference of opinion as to the top and bottom of units within thick sequences of clastic or carbonate rocks may be expected in the magnitude of a hundred feet or more in some of the areas without indicating significant disagreement on the regional history. This difference often arises as a result of new nonfossiliferous beds appearing downdip that can equally well be placed in the overlying or the underlying rock unit on the basis of current information. As a region is more thoroughly explored by the drill, better agreement on correlations develops, partly on more conclusive evidence but also as accepted communication practice in day-to-day operations.

The subsurface stratigraphy of the Mesozoic and Cenozoic rocks is outlined diagrammatically in this report by eight regional cross sections, whose traces are shown in figure 6. Section *A–B* (pl. 9) follows the Atlantic coastline and carries the gulf coast equivalents from the Florida Keys to Long Island. Sections *C–D*, *E–F*, *G–H*, *I–J*, and *K–L* (pls. 10, 11, 12, 13, and 14) attempt to tie these equivalents to the outcrops and local terminology in New Jersey, Maryland, North Carolina, and Georgia. Section *M–N* (pl. 15) extends correlations across the Florida Peninsula. Section *O–P* (pl. 16) suggests correlations from the Florida Keys to Andros Island in the Bahamas and points out the possible relationship of stratigraphy to

coast equivalents in wells along the Atlantic coast

South Carolina units	North Carolina units	Maryland units	New Jersey units	Long Island units
Post-Miocene rocks	Post-Miocene rocks	Post-Miocene rocks	Post-Miocene rocks	Post-Miocene rocks
Absent on Cape Fear arch	Upper and middle Miocene rocks	Upper and middle Miocene rocks	Miocene and Eocene rocks undifferentiated	Tertiary rocks undifferentiated
	Lower Miocene rocks	Lower Miocene rocks		
Absent on Cape Fear arch	Rocks of uncertain age, possibly Oligocene in part	No Oligocene known		
Rocks of Jackson age	Upper and middle Eocene rocks	Eocene rocks undifferentiated		
Middle and lower Eocene and Paleocene rocks undifferentiated				
	Lower Eocene rocks			
	Beaufort Formation	Paleocene rocks	Paleocene(?) rocks	
Rocks of Navarro age	Pedee Formation	Monmouth Formation	Monmouth Group	Monmouth Group
Rocks of Taylor age	Black Creek Formation	Matawan Formation	Magothy Formation and Matawan Group undifferentiated	Magothy Formation and Matawan Group undifferentiated
Rocks of Austin age		Rocks of Austin age		
Rocks of Eagle Ford age	Rocks of Eagle Ford age	Rocks of Eagle Ford age	Raritan Formation	Raritan Formation
Tuscaloosa Formation	Tuscaloosa Formation	Rocks of Woodbine age		
Lower Creatacous rocks	Rocks of Washita(?) age	Rocks of Washita(?) age	Rocks of Washita(?) and Fredericksburg(?) age undifferentiated	Lower Cretaceous rocks absent
	Rocks of Fredericksburg(?) age	Rocks of Fredericksburg(?) age		
	Rocks of Fredericksburg or Trinity age	Rocks of Fredericksburg or Trinity age	Rocks of Trinity(?) age and older	
	Rocks of Trinity(?) age	Rocks of Trinity(?) age		
Lower Cretaceous (Neocomian) or Upper Jurassic absent	Mesozoic rocks of uncertain age, possibly Cretaceous (Neocomian)	Mesozoic rocks of uncertain age, possibly Cretaceous (Neocomian)		Lower Cretaceous (Neocomian) or Upper Jurassic rocks absent

the sea bottom. The nomenclature used on these cross sections for subsurface rocks in different states is summarized in table 2.

Reliance has been placed largely on assemblages of Foraminifera for age assignments of lithologic units in wells on these cross sections. The age relationships of these assemblages were first worked out and used extensively in the gulf coast region, where several hundred thousand wells have been drilled in the search for petroleum. The most significant Foraminifera in the assemblages found in cores and samples from the wells on the cross sections are listed in table 3 prepared by E. R. Applin. Hundreds of additional microfossil identifications and many detailed lithologic descriptions for these wells and nearby wells have been available not only from the published sources noted on each cross section but also from unpublished sources such as the files and collections of P. L. and E. R. Applin, State geological surveys, and some oil companies. Publication of complete fossil lists and lithologic descriptions for wells in this huge province is beyond the scope of this report.

PRE-MESOZOIC BASEMENT ROCKS

The surface upon which Mesozoic rocks were deposited appears to be relatively smooth, having well-rounded topographic features and few structural irregularities. Not enough wells have been drilled to be certain of this, but the few well records available and published seismic work suggest a gentle slope of about 15 feet per mile from pre-Mesozoic outcrops to a depth of about 3,000 feet. Below this depth the slope steepens somewhat sharply to more than 100 feet per mile.

The basement rocks are primarily igneous and metamorphic rocks of Precambrian and Paleozoic age. These include a wide variety of granite, diorite, gneiss, schist, tuff, volcanic ash, rhyolite porphyry, gabbro, basalt, and diabase. The basic igneous intrusives are found in both Paleozoic and Triassic rocks, and in some wells the Triassic intrusives have been regarded incorrectly as pre-Mesozoic basement. Paleozoic sedimentary rocks ranging from Early Ordovician to Middle Devonian in age are present in the basement in northern and western Florida and in southern Georgia (Applin, 1951, p. 11–15; Bridge and Berdan, 1951; Carroll, 1963).

TABLE 3.—*Distribution of definitive*

[Depth in feet; italic number indicates fossil found in core.

Well No. (plate numbers in parentheses)	Rocks of Late Jurassic or Early Cretaceous (Neocomian) age							Rocks of early Trinity age						Rocks of late Trinity age			
	Choffatella decipiens	Verneuilinid fauna	*Pseudocyclammina* sp.	*Cuneolina*-like form	*Coskinolina?* sp.	*Nubeculinella* sp.	*Anchispirocyclina henbesti*	*Choffatella decipiens*	*Orbitolina texana*	*Reophax* n.sp.	*Dufrenoya texana*	*Atopochara trivolvis*	*Arcellites disciformis*	*Orbitolina* cf. *minuta*	*Orbitolina texana*	*Dictyoconus floridanus*	Caprinid fragments
FL-57 (9, 15)																	
58 (15)																	
64 (15)																	
73 (9)																	
86 (9)		12,730		*12,736*			*13,094*	11,200 11,580 *12,259*		11,100 11,200				10,120 10,360	*10,674*	*10,674*	
104 (9, 16)	*11,709* *11,847*	*11,660*	*11,709* *11,923*	*11,836* *11,923*							*11,549*			9,780	10,028 10,122	10 028 10 122	
109 (16)				14,584	14,517				13,400 13,510					11,490 11,680 13,850		12,610	12,190
111 (16)		15,375	15,255												*12,624* *12,824*	*12,624* *12,824*	
GA-42 (9, 13)																	
59 (14)																	
61 (14)																	
72 (14)																	
75 (14)																	
87 (9, 14)																	
AL-1 (14)																	
2 (14)																	
SC-21 (9)																	
14 (9, 12)						8,980	*9,120*	8,910				8,505					
NJ-25 (9)												4,430	4,400				

The oldest rock recovered from the sea bottom along the Atlantic coast has come from the granite pinnacles of late Paleozoic to early Mesozoic(?) age (Toulmin, 1957, p. 914) at a depth of about 30 feet on Cashes Ledge near the middle of the Gulf of Maine (pl. 2 and fig. 2). This granite is similar in composition to the Quincy Granite exposed in large areas of nearby eastern Massachusetts and Rhode Island. LaForge (1932, p. 35) considered the Quincy Granite to be either Devonian or early Carboniferous in age.

MESOZOIC ROCKS

TRIASSIC(?) ROCKS

Triassic rocks consisting of red arkose, sandstone, shale, tuff, and basalt flows, in places intruded by diabase, are exposed in basins downfaulted in the basement rocks of the piedmont. Similar Triassic-filled basins are thought to exist beneath the Coastal Plain on the basis of well and seismic data (Bonini and Woollard, 1960, p. 304, 305; Cohee, 1962). Rocks lithologically similar to the exposed Triassic rocks, shown on sections *E–F* and *K–L* (pls. 11 and 4), have been penetrated by several wells and are referred to as Triassic(?).

Well GA–61 (Mont Warren Chandler 1) and well GA–72 (Stanolind Oil and Gas Pullen 1) in southwestern Georgia, shown on section *K–L* (pl. 14), penetrated more than 900 feet of red and green shale and sandstone beds; some diabase sills in well GA–72 are generally regarded as representative of Triassic sequences. Well AL–3 (W. B. Hinton Creel 1) in southeastern Alabama, about 40 miles updip from well GA–61, penetrated a 700-foot thick sequence of basic igneous sills interspersed with thin clastic beds beneath rocks of Early Cretaceous age. This predominantly igneous sequence may be Triassic in age also, although the lithology is less distinctive.

Rocks assigned to the Triassic(?) are present also in the subsurface of Maryland along the line of section *E–F* (pl. 11). Well MD–6 (Washington Gas Light Mudd 3) near the Fall Line is reported (Ball and Winer, 1958) to have penetrated 237 feet of Triassic clastic beds beneath the Lower Cretaceous Patuxent Formation. The presence of these rocks close to the Fall Line suggests that they may be preserved in a grabenlike feature similar to those downfaulted Triassic blocks more or less on strike in the piedmont of Virginia.

fossils in wells on sections

Well numbers keyed to table 1, plate 1, and plates 9–16]

Rocks of Fredericksburg age			Rocks of Washita age	Rocks of Woodbine age								Rocks of Eagle Ford age					
Coskinolinoides texana	*Lituola subgoodlandensis*	*Dicyclina* cf. *schlumbergeri*	*Nummoloculina heimi*	*Cuneolina walteri*	*Trocholina floridana*	*Ammobaculites comprimatus*	*Ammotium braunsteini*	*Acruliammina longa*	*Trochammina rainwateri*	*Ammobaculites agrestis*	*Placopsilina langsdalensis*	*Planulina eaglefordensis*	*Valvulineria infrequens* var.	*Trochammina wickendeni*	*Gumbelina moremani*	*Hastigerinella moremani*	*Gaudryina* cf. *bosquensis*
...	*5,372*	...	5,150	5,090	5,090	...	...	...	...	...	...	*4,868*	*4,868*	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	4,130	4,130	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	*4,050*	*4,050*	...	...	...	...
...	6,760	...	*5,984*	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	7,390		6,182														
8,963	9,070	...	7,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9,000																	
8,360	...	...	6,900	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9,840	...	*10,724*	*7,735*	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10,000			8,500														
			9,470														
10,005	...	...	*7,902*	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10,645			8,445														
11,080			8,550														
...	...	...	...	...	...	3,920	3,970	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	*4,220*	...	...	...	...	*4,220*
...	...	...	...	...	...	3,007	3,037	3,034	...	...	...	2,605	2,605	...	2,605	...	...
...	...	...	...	...	...	...	...	...	3,495	3,510	...		2,830	...	...	...	2,865
...	...	...	...	...	...	...	3,810	...	...	3,810	...	*3,195*	*3,195*	...		*3,195*	...
...	...	...	...	...	...	...	...	...		...	...	*4,125*	*4,125*	...	...	...	...
												4,290					
...	...	...	...	...	...	*1,025*	*1,025*	...	...	...	...	400	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...		...	840	840	...	...	840	...
...	...	...	...	...	...	3,149	3,149	...	...	...	...	2,646	...	2,646	2,646	...	...
...	6,770	...	...	...	5,790	...	...	5,310	...	...	5,310	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 3.—*Distribution of definitive*

Well No. (plate numbers in parentheses)	Rocks of Austin age														Rocks of Taylor age				
	Citharina texana	*Planulina austinana*	*Pseudogaudryinella serrulata*	*Kyphopyxa christneri*	*Ventilabrella austinana*	*Ventilabrella eggeri*	*Loxostomum cushmani*	*Valvulineria infrequens*	*Darbyella brownstownensis*	*Globorotalites umbilicatus*	*Gumbelina moremani*	*Heterostomella austinana*	*Dorothia alexanderi*	*Planulina texana*	*Stensioina americana*	*Bolivinoides decoratus*	*Planulina dumblei*	*Anomalina sholizensis*	*Pseudogaudryinella capitosa*
FL-57 (9, 15)																3,600		3,610	
58 (15)															3,180				
64 (15)															3,030			3,290	
73 (9)																			
86 (9)															5,785	5,785			
105 (16)																			
111 (16)																			
GA-26[1] (13)																		1,695	
37 (13)																	2,157–2,162		
38 (13)				2,900													2,580		
42 (9, 13)	*3,278*	3,278															2,740		
59 (14)	*3,779*																		
61 (14)	2,000								1,940	2,260					1,358	1,213	1,510		
72 (14)	2,625			2,370								2,370				1,890	1,905		
75 (14)	3,050	2,853		2,910	2,883								3,125			2,410, 2,447	2,447		
87 (9, 14)	3,830, 3,905																3,430		3,430
AL-1 (14)					35		35												
2 (14)	530				370	370		460									220		320
SC-21 (9)	2,325		2,145	2,325													1,645		
NC-7 (9)																	2,400		
14 (9, 12)	4,380			4,380							4,380			4,380			3,150		
43 (12)																	1,125		
47 (9, 12)																	1,563		
MD-11 (11)																			820
12 (11)												1,480		1,480	1,390		1,400		1,430
13 (11)																*1,894*	1,750		
14 (9, 11)																	2,150		
NJ-25 (9)															2,020	2,020	2,020		2,150

Well No. (plate numbers in parentheses)	Paleocene rocks													
	Borelis gunteri	*Borelis floridanus*	*Borelis* sp.	*Valvulammina nassauensis*	*Planispirina kissengenensis*	*Cribrospirina? bushnellensis*	*Lenticulina pseudomamiligerus*	*Lenticulina midwayensis*	*Vaginulina longiforma*	*Marginulina tuberculata*	*Anomalina midwayensis*	*Cibicides vulgaris*	*Eponides lotus*	*Discorbis midwayensis*
FL-52 (9)		*1,835*												
57 (9, 15)		*2,139* *2,800*												
58 (15)	2,000	2,050 2,160												
59 (15)	1,658	1,880			2,142									
64 (15)	2,000	2,030 2,430				2,280								
73 (9)	3,460	3,078 3,360												
86 (9)			*3,960, 4,170*											
104 (9, 16)	3,510	3,800		3,610										
105 (16)	3,970	3,310 3,580		4,200										
111 (16)	3,705	4,150 4,500												
GA-26[1] (13)													1,275	1,275
38 (13)														
42 (9, 13)							1,960	1,960	1,960					
59 (14)														
72 (14)														
75 (14)								1,740						
BA-2 (16)	5,940 6,600		7,170 7,700 8,046											
SC-21 (9)							1,265	1,315			1,205			
MD-11 (11)								660		590				
12 (11)										1,330				
NJ-25 (9)										1,770		1,770		

See footnotes at end of table.

fossils in wells on sections—Continued

Rocks of Taylor age—Con.					Rocks of Navarro age																				
Gaudryina bentonensis	*Globorotalites conicus*	*Kyphopyxa christneri*	*Anomalina cosdeni*	*Planulina texana*	Rudistid fragments	*Asterorbis rooki*	*Sulcoperculina cosdeni*	*Lepidorbitoides* several sp.	*Vaughanina cubensis*	*Rotalia?* n. sp.	*Globotruncana arca*	*Globotruncana canaliculata*	*Globotruncana cretacea*	*Globotruncana* sp.	*Anomalina pseudopapillosa*	*Cibicides harperi*	*Anomalina pinguis*	*Lenticulina navarroensis*	*Pseudoclavulina clavata*	*Loxostomum plaitum* var.	*Planulina correcta*	*Dorothia bulleta*	*Pseudoguembelina striata*	*Gumbelina glabrans*	*Neoflabellina reticulata*
					2,910		3,030, 3,160	3,030, 3,160																	
					2,420		2,520	2,520								2,760									
						2,730	2,660	2,660	3,810							2,890									
							3,841	3,841																	
					4,870		6,640	6,580																	
					5,110					5,200															
		1,795																							
															1,851										
															2,155	2,480							2,300		
	2,840	3,090										2,240						2,240							
			3,676																						
		1,591												1,213									1,213		
											1,850				1,845										
															1,890			1,890							2,310
290													110												
																1,325	1,525					1,435			
		2,450																							
		3,150																							
		1,156									944														
		1,738									1,213														
																		760	760						
												1,360								1,380				1,390	
				1,894									1,709				1,709			1,709					
		2,150											1,980			1,980					1,980				

Paleocene rocks—Continued							Lower Eocene rocks										
Clavulinoides midwayensis	*Ammobaculites paleocenicus*	*Globigerina triloculinoides*	*Globorotalia acuta*	*Gyroidina aequilateralis*	*Vaginulina midwayana*	*Cibicides alleni*	*Pseudophragmina cedarkeysensis*	*Coskinolina elongata*	*Miscellanea nassauensis*	*Eponides dorfi*	*Spiroplectammina wilcoxensis*	*Valvulineria wilcoxensis*	*Rotalia? rochidiformis*	*Helicostegina gyralis*	*Alabamina wilcoxensis*	*Pseudophragmina stevensoni*	*Globorotalia wilcoxensis*
							1,435		*1,655*								
							1,410	1,540									
							1,300	1,500 1,650						1,300			
							1,150	1,330 1,560						1,120			
								2,845					2,943				
										1,570							1,570
										1,500	1,500	1,500					
																1,500	
					1,545	1,590				1,255					1,255		
				1,340													
1,770	1,890	1,890	1,890														

TABLE 3.—*Distribution of definitive*

Well No. (plate numbers in parentheses)	Middle Eocene rocks																	
	Dictyoconus floridanus	*Lituonella floridana*	*Spirolina coryensis*	*Flintina avonparkensis*	*Dictyoconus americanus*	*Discorinopsis gunteri*	*Peronella dalli*	*Lituola watersi*	*Cribrobulimina cushmani*	*Fabularia vaughani*	*Textularia coryensis*	*Discorbis inornatus*	*Epistomaria semimarginata*	*Helicostegina gyralis*	*Asterigerina texana*	*Asterocyclina monticellensis*	*Gyroidina nassauensis*
FL-52 (9)	680				*830*					*830*							
57 (9, 15)	100				470						350	1,100	1,100	1,250			
58 (15)	390		410		500, 630, 920					870		890					
59 (15)	45		75		255, 675					255		675					
64 (15)																	
73 (9)	410	410			*1,400*												
86 (9)	1,040	1,250	1,010		1,300		970	1,010	1,110	1,330							
104 (9, 16)	1,100	1,140	1,140	1,200	1,310, 1,860	1,350											
105 (16)					2,327							2,327					
109 (16)	1,240		1,240		*2,250*			1,240									
111 (16)	1,370, 1,960	1,390	1,390		2,020							1,460					
GA-26 [1] (13)																83[illegible]-845	
37 (13)																	
38 (13)																	
42 (9, 13)												1,040				1.040	1,040
59 (14)												1,420				1.000	
72 (14)																	
75 (14)						810						1,060				960	
87 (9, 14)															1,550		
BA-2 (16)	2,460, 4,230																
MD-12 (11)																	
NJ-25 (9)																	

Well No. (plate numbers in parentheses)	Upper Eocene rocks																
	Lepidocyclina ocalana	*Heterostegina ocalana*	*Amphistegina cosdeni*	*Operculinoides floridensis*	*Pseudophragmina flintensis*	*Asterocyclina nassauensis*	*Operculina mariannensis*	*Operculinoides moodysbranchensis*	*Bulimina jacksonensis*	*Marginulina cooperensis*	*Lenticulina virginiana*	*Eponides cocoaensis*	*Eponides jacksonensis*	*Uvigerina cocoaensis*	*Sphaerogypsina globula*	*Marginulina texasensis*	*Nonion advenum*
FL-52 (9)	420		520	460	460												
64 (15)	35			35													
73 (9)	300	300	350														
86 (9)																	
104 (9, 16)																	
105 (16)	1,656			1,656					1,772				1,772	1,772	1,656	1.772	
109 (16)																	
111 (16)																	
GA-8 [2] (13)																	132
26 [1] (13)													765–815				
37 (13)							740										
38 (13)				650			780										
41 (13)			730												511		
42 (9, 13)		520	680	460	500	500	820	960									
59 (14)		780	900	600	700								780				
60 (14)															635		
72 (14)						450											
75 (14)		470	570	420													
MD-11 (11)												470					
12 (11)									1,160	1,160		1,240					
NJ-25 (9)									1,420	1,420	1,420–1,520	1,520		1,520			

See footnotes at end of table.

fossils in wells on sections—Continued

Middle Eocene rocks—Continued																							
Haplophragmoides tallahattensis	*Cibicides blanpiedi*	*Eponides mexicanus*	*Lenticulina mexicanus*	*Lenticulina alatolimbatus*	*Anomalina umbonata*	*Lockhartia cushmani*	*Lepidocyclina cedarkeysensis*	*Gunteria floridana*	*Fabiania cubensis*	*Amphistegina lopeztrigoi*	*Dictyoconus walnutensis*	*Clavulina floridana*	*Cibicides westi*	*Globorotalia spinulosa*	*Valvulineria cubensis*	*Lepidocyclina antillea*	*Cibicides mauricensis*	*Cibicides americanus* var.	*Cibicides tallahattensis*	*Discorbis assulata*	*Gyroidina soldanii* var.	*Valvulineria persimilis*	*Spiroplectammina plummerae*
						870	890	1,040, 1,220	1,220														
							675			945													
											130												
		2,572											2,572	2,572									
						2,250						2,250											
						2,200																	
																815–825	915						
																		760		760	760		
													1,260						1,570				
1,460	1,460																						
										1.420						1,000							
													860			760			1,045			1,045	
																1,030							
															2,370, 2,460								
													1,280										1,290
		1,610	1,610	1,610	1.610																		

Upper Eocene Rocks—Continued						Oligocene rocks														
Nonion inexcavatum	*Valvulineria jacksonensis*	*Camerina striatoreticulatus*	*Operculinoides* sp.	*Nonionella hantkeni*	*Discorbis assulata*	*Miogypsina gunteri*	*Heterostegina antillea*	*Camerina dia*	*Dictyoconus* sp. (r.w.)	*Miogypsina* sp.	*Pararotalia mexicanus* var.	*Pararotalia byramensis* var.	*Asterigerina subacuta*	*Dictyoconus walnutensis* (r.w.)	*Discorinopsis gunteri* (r.w.)	*Dictyconus floridanus*	*Quinqueloculina leonensis*	*Lepidocyclina mantelli*	*Nonionella leonensis*	*Operculinoides* sp.
									880	880										
						980, 1,070	990	1,020												
														1,210	1,210					
							1,140	1,140			1,260									
132	132																			
765–815																				
		512–520									449–456									
		700							580		540									
											400		400							
											560		560						560	
			575								575									575
		450										370								
												570				280	300	410		
				540	550															

TABLE 3.—*Distribution of definitive*

Well No. (plate numbers in parentheses)	Miocene Rocks													
	Amphictegina lessonii	*Globorotalia menardii*	*Bucella mansfieldi*	*Lenticulina americana*	*Hanzawaia concentrica*	*Archaias floridanus*	*Miogypsina antillea*	*Miogypsina staufferi*	*Textulariella barrettii*	*Chione ulocyma*	*Chione procancellata*	*Nonion mediocostatum*	*Nonion pizarrense*	*Cibicides floridanus*
FL–57 (9, 15)											47			
73 (9)										130				
88 (9)				510					510					
104 (9, 16)	250	280	320	330	610	710	750	770						
105 (16)	270, 620													
109 (16)					380		845	905						
111 (16)				580		920	920		900					
MD–12 (11)				650										
NJ–25 (9)												920	920	1,080

[1] Fossil data for well GA–26 from nearby Root and Ray Fowler 1 (Herrick, 1961, p. 408–410).
[2] Fossil data for well GA–8 from nearby Layne-Atlantic City of Sandersville 5 (Herrick, 1961, p. 424–426).

Well MD–12 (Ohio Oil Hammond 1), well MD–13 (Socony-Vacuum Oil Bethards 1), and well MD–14 (Standard Oil of New Jersey Maryland Esso 1) near the coastline on section *E–F* (pl. 11) penetrated rock sequences, 165 to 525 feet thick, that were assigned to the Triassic by Spangler (1950, p. 121). Anderson (1948, p. 100) regarded the same sequences in well MD–12 and MD–13 as Triassic, and the sequence in well MD–14 he regarded as the Lower Cretaceous Patuxent on the basis of differing hardness and color. This unit in wells MD–12 and MD–13 consists of beds of hard dark-gray shale and sandy shale with maroon mottling, quartz conglomerate with some white feldspars, and hard reddish-brown and green shale, sandy shale, and arkosic sandstone. In well MD–14 farther downdip, the sequence consists of beds of coarse-grained sandstone containing pebbles, gravel, and kaolinized feldspars, beds of gray, green, and brown shale, and some calcareous layers.

The lithologies and electric-log curves for these nonfossiliferous sequences are not dissimilar enough to rule out the possibility that these sequences may be correlative facies. If so, they could be either Triassic(?) or equivalent to the Upper Jurassic or Lower Cretaceous (Neocomian) rocks in the Cape Hatteras well (NC–14, pls. 9 and 12). For these reasons, the broad, relatively noncommittal term "Mesozoic rocks of uncertain age, possibly Neocomian" is used on both plates 9 and 11.

UPPER JURASSIC OR LOWER CRETACEOUS (NEOCOMIAN) ROCKS

Rocks of Late Jurassic or Early Cretaceous (Neocomian) age, which do not crop out in eastern North America, are present beneath southern Florida, where they have been partially penetrated by deep wells. Applin and Applin (1965, p. 18–25) have described these rocks in the Amerada Petroleum Cowles Magazine 2 in St. Lucie County and have named the sequence the Fort Pierce Formation for a nearby city. The type sequence is 2,220 feet thick and consists of a lower red clastic unit, 170 feet thick, that rests on highly altered igneous basement rock, and an upper carbonate unit, 2,050 feet thick. The upper carbonate unit is made up of alternating finely crystalline, partly oolitic and bioclastic limestone, dolomitic limestone, and dolomite beds interspersed with thin gray shale and anhydrite beds. The characterizing faunal assemblage of the Fort Pierce Formation contains fossils that are partly of Late Jurassic and partly of Early Cretaceous age. The distinctive features of the microfaunal assemblage were illustrated in an earlier report by Applin and Applin (1965, pls. 3, 4). The fauna is characterized, mainly, by abundant specimens of Foraminifera belonging to the family Ataxophragmiidae, subfamily Verneuilininae, that are small and biserial throughout the larger part of their development. A large conical species of *Cuneolina?* is another definitive fossil, and several undescribed species of *Pseudophragmina* are moderately common.

Rocks in part equivalent to the Fort Pierce Formation may crop out along the base of the Blake Escarpment. Dredgings of algal limestone of Neocomian to Aptian in age from depths exceeding 10,000 feet have been reported by Heezen and Sheridan (1966, p. 1645) and are discussed herein under "Lower Cretaceous rocks."

The Fort Pierce Formation has been penetrated by wells FL–104, FL–86, FL–111, and FL–109 on sections *A–B* and *O–P* (pls. 9 and 16). The deepest penetra-

fossils in wells on sections—Continued

Miocene rocks—Continued																	
Spiroplectammina mississippiensis	*Textularia mayori*	*Uvigerina superegrina*	*Uvigerina calvertensis*	*Gypsina vesicularis*	*Marginulina dubia*	*Robulus iota*	*Amphistegina chipolensis*	*Sorites? spi?*	*Lepidocyclina yurnagunensis*	*Valvulineria floridana*	*Rotorbinella? rosacca*	*Peneroplis bradyi*	*Bulimina inflata*	*Gyroidina marylandica*	*Angulogerina occidentalis*	*Siphogenerina lamellata*	*Buliminella elegantissima*
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----------	----------	----------	----------	----------	----------	----------	----------	630	----------	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	----------	----------	----------	----------	----------	*500*	915	380	420	745	----------	----------	420	----------	----------
----------	----------	----------	----------	370	580	700	790, 900	920	1, 080	----------	----------	----------	----------	----------	----------	----------	----------
----------	----------	----------	910	----------	----------	----------	----------	----------	----------	----------	----------	----------	1, 100	1, 100	----------	1, 020	----------
1, 080	1, 080	1, 080	920	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	920

tion (1,115 feet) was made by well FL–109 (Gulf Oil State lease 373 1) on Big Pine Key, Fla. (pl. 16). The formation wedges out northward along section *A–B* and is absent from well FL–73 (Humble Oil and Refining Carroll 1) in Osceola County, Fla., where rocks of Trinity age rest upon biotite granite of pre-Mesozoic age.

Rocks of Late Jurassic or Early Cretaceous (Neocomian) age are also present in well NC–14 (Standard Oil of New Jersey Hatteras Light 1) on section *G–H* (pl. 12) in North Carolina. There the sequence, 8,960 to 9,878 feet in depth, grades downward from finely crystalline, partly oolitic limestone and gray shale beds to red and green sandy shale layers and red-stained, fine- to coarse-grained sandstone beds, partly conglomeratic and arkosic, at the base. The lower red clastic beds may correspond roughly to those noted by Applin and Applin (1965) in the Amerada Petroleum Cowles Magazine 1 in Florida. Swain (1947, p. 2058) assigned the beds between 9,150 and 9,878 feet to the pre-Trinity (Coahuila?) in 1947. Later, in 1952, he reassigned the beds from 8,500 to 9,878 feet to the Upper Jurassic(?) and referred to them as "beds of Schuler(?) age" (Swain, 1952, p. 66). E. R. Applin reports molds of *Atopochara* sp., suggestive of early Trinity age, between 8,505 and 8,515 feet and *Anchispirocyclina henbesti* Jordan and Applin in a core at a depth of 9,115 to 9,116 feet. Maync (1959, p. 66) considered the latter fossil to be closely similar to *Iberina lusitanica* (Egger), which in Europe "straddles the Jurassic-Lower Cretaceous boundary." It is possible that *Anchispirocyclina henbesti* is also indicative of beds of Late Jurassic or Early Cretaceous age. Therefore, the base of rocks of Trinity(?) age may be at 8,800 feet, where it is drawn tentatively in this report, or it may be as deep as 8,960 feet.

The sequence of rocks termed "Mesozoic rocks of uncertain age, possibly Neocomian" in well MD–14 on section *A–B* (pl. 9) may be equivalent to the Upper Jurassic or Lower Cretaceous (Neocomian) in well NC–14 at Cape Hatteras. The same rocks probably are represented in the lower part of the interval marked "rocks of Trinity(?) age and older" in well NJ–25 (Anchor Gas Dickinson 1) in New Jersey and wedge out updip between that well and well NJ–26 (U.S. Geological Survey Island Beach 1). As pointed out in the discussion of Triassic(?) rocks, the relation of the hard reddish clastic sequence resting on basement in wells MD–12 and MD–13 on section *E–F* (pl. 11) to the lower soft-gray clastic beds in well NC–14 is in doubt.

LOWER CRETACEOUS ROCKS

SUBDIVISIONS

The Cretaceous system in the gulf coast region is divided into the Comanche Series and the Gulf Series. The Comanche Series is subdivided into the Trinity, Fredericksburg, and Washita Groups. The lower two groups are entirely Early Cretaceous in age, but the Washita Group is regarded as mostly Early Cretaceous but partly Late Cretaceous in age by the U.S. Geological Survey (Imlay, 1944) on the basis of worldwide fossil zones. The boundary between Lower and Upper Cretaceous rocks on the cross sections of this report is indefinite because of lack of paleontologic detail and is shown diagrammatically with a query. The top of rocks of Washita age can be readily identified within a few tens of feet in most sets of drill cuttings and can be mapped consistently in the subsurface. In discussion of distribution of Lower Cretaceous rocks in this report, all rocks of Washita age are grouped with those of Trinity and Fredericksburg age as a matter of convenience only.

The Lower Cretaceous is subdivided on these cross sections only in Florida, North Carolina, and Maryland, and in one well in New Jersey where the rocks are sufficiently thick, uniform, and fossiliferous to provide fairly reliable unit correlations. These subdivisions and their correlations from well to well are most reliable in the southern Florida carbonate section and least reliable in the mixed clastic and carbonate section in Maryland and New Jersey. Little fossil evidence suitable for subdividing the Lower Cretaceous rocks exists north of Cape Fear, and the dashed correlation lines on the cross sections represent an opinion based mainly on lithology and electric log data available in 1965.

LITHOLOGY AND DISTRIBUTION

Rocks of Early Cretaceous age, several hundred feet of sandstone and shale beds, are recognized at the surface in part of the Salisbury embayment, as shown by the geologic map of the United States (Stose, 1932). They may be represented at or near the surface in northern North Carolina, western Georgia, and Alabama by thin clastic beds inseparable lithologically from the basal Upper Cretaceous beds. Lower Cretaceous beds dip seaward from the Fall Line at rates that increase from about 15 feet per mile to more than 60 feet per mile (pl. 11). The thickness and marine constituents increase accordingly.

Submarine outcrops of Early Cretaceous age have been reported by Heezen and Sheridan (1966). They dredged four samples from the Blake Escarpment at depths of 7,790, 10,266, 10,496, and 15,574 feet. The samples from 15,574 and 10,496 feet were algal calcarenite and algal dolomitic calcarenite, respectively; both were assigned an age range of Neocomian to Aptian, which corresponds to that of the Coahuila Series and Trinity Group of the gulf coast. The sample from a depth of 10,266 feet consisted of gray, oolitic, fragmental calcarenite to which was assigned an Aptian(?) age, corresponding to Trinity(?) in the gulf coast. The upper sample from a depth of 7,790 feet was gray and tan calcilutite of Aptian to Albian age, the age range of the combined Trinity and Fredericksburg Groups of the gulf coast. Heezen and Sheridan (1966, p. 1645) concluded that the calcarenites from depths of 10,266, 10,496, and 15,574 feet represented sediments deposited near sea level and that the sample of calcilutite from a depth of 7,790 feet represents sediment laid in water about as deep as the waters over the Blake Plateau today (650 to 3,600 feet). This indicates continuing subsidence since Early Cretaceous time in a total amount exceeding 15,000 feet.

In southern Florida, the Lower Cretaceous rocks are predominantly carbonates and exceed 6,700 feet in thickness in the Florida Keys (well FL–109, pl. 16). Northward along section *A–B* (pl. 9), the rocks wedge out on the Peninsular arch, then reappear as a thin clastic unit across parts of Georgia and South Carolina. They are missing from the higher parts of the Cape Fear arch in North Carolina but are present on the east flank as a thickening wedge of mixed clastic and carbonate rocks more than 2,800 feet thick at Cape Hatteras (well NC–14), as correlated on Foraminifera by E. R. Applin (written commun. to J. B. Reeside, Jr., 1957), and 2,600 feet thick in Maryland (well MD–14). Lower Cretaceous rocks probably extend into northern New Jersey but do not reach Long Island.

Considerable thicknesses of Lower Cretaceous rocks are present in southwestern Georgia. Section *K–L* (pl. 14) shows more than 2,500 feet of dominantly clastic, undifferentiated, Lower Cretaceous beds in wells GA–61 and GA–72.

REGIONAL THICKNESS

The regional thickness of Lower Cretaceous rocks and the underlying rocks classed as Late Jurassic or Early Cretaceous (Neocomian) in age in this report is outlined on plate 17*A*. These rocks are present at or near the Fall Line in New Jersey, Maryland, Virginia, northern North Carolina, western Georgia, and Alabama but are absent beneath most of the Coastal Plain in southern North Carolina, South Carolina, and eastern Georgia and on the crest of the Peninsular arch in northern Florida. Thicknesses of about 3,000 feet at Cape Hatteras and about 6,000 feet in the Florida Panhandle and Keys are present beneath the Coastal Plain. Thick sequences are probably also present offshore on the Atlantic Continental Shelf, where geologic data are lacking and seismic data too sparse and contradictory to permit representation of thicknesses on plate 17. Form lines are used to suggest depositional shapes, and minimum estimates of maximum thicknesses are shown for general use in exploration planning. It seems probable that thicknesses may exceed 7,500 feet in the South Florida embayment and Blake Plateau trough, 5,000 feet in the Southeast Georgia embayment and Baltimore Canyon trough, and 3,000 feet in the Georges Bank trough, judging by the rate of thickening onshore and the scattered seismic profiles offshore (pl. 5).

ROCKS OF TRINITY AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Trinity age along sections *A–B* and *O–P* (pls. 9 and 16) have a maximum thickness of 3,030 feet in well FL–111 (Gulf Oil SFL 826–Y 1) at the western end of the Florida Keys, where they are principally anhydrite, limestone, and dolomite. The thickness decreases northeastward to 2,200 feet in well FL–104 (Sinclair Oil and Gas Williams 1) on Key Largo and continues to decrease northward along section *A–B* (pl. 9) to a wedge edge of clastic rocks against the Peninsular arch (well FL–57). Rocks of Trinity age are absent from wells on section *A–B* (pl. 9) in northern Florida, Georgia, and South Carolina.

A sequence largely of sandstone, siltstone, and shale beds in well NC–14 at Cape Hatteras, N.C., and in wells MD–12, MD–13, and MD–14 in Maryland (pls. 9, 11, and 12) has been assigned an age of Trinity (?). This sequence is at least 1,150 feet thick and may be as much as 1,455 feet thick if the overlying beds of Trinity or Fredericksburg age are included. It is present in well NJ–25 (Anchor Gas Dickinson 1) at Cape May, N.J., but has not been differentiated from underlying sedimentary rocks of Mesozoic age. In well NJ–26 at Island Beach farther north in New Jersey, rocks of Early Cretaceous age are thought to be about 518 feet thick, but no fossil evidence was reported from these beds and no subdivisions are apparent.

Limestones of Trinity age crop out along the middle of the Blake Escarpment (Heezen and Sheridan, 1966, p. 1645). Samples of gray oolitic limestone of Aptian(?) age and gray slightly pyritic limestone of Aptian-to-Albian age have been dredged from depths of 10,226 and 7,790 feet, respectively.

CHARACTERISTIC MICROFAUNA

Many specimens of *Atopochara trivolvis* Peck were found at 8,505 feet in well NC–14 and at 4,430 feet in well NJ–25, indicating the presence of beds of Early Cretaceous age in these wells. R. E. Peck, who checked the specific determination of these fossils, stated (1957, p. 21) that "*Atopochara trivolvis* is widely distributed in the Lower Cretaceous Aptian nonmarine deposits of the Gulf Coast and Rock Mountain regions," and he (p. 21) considered it "an excellent guide fossil." In the Hatteras Light Well (NC–14), *Choffatella decipiens* Schlumberger is present about 400 feet below the highest occurrence of *A. trivolvis.*

Another type of microfossil, the megaspore *Arcellites disconformis* (Miner) Ellis and Tschudy (Ellis and Tschudy, 1964, p. 75), was identified by R. H. Tschudy in a sample of cuttings at 4,400 to 4,410 feet in the Anchor Gas Dickinson 1 (NJ–25), Cape May, N.J. In his analysis of the sample, Tschudy (written commun., April 30, 1964) stated that "*Arcellites disconformis* is found in Lower Cretaceous samples. In eastern United States it has been found only in the Patuxent Formation. I am fairly confident of a pre-Albian, Early Cretaceous age determination * * *." Tschudy listed a number of other plant fossils in the sample and stated, "The absence of any Angiosperm pollen suggests pre-Albian."

ROCKS OF EARLY TRINITY AGE

LITHOLOGY AND DISTRIBUTION

In Florida, rocks of Trinity age have been divided by Applin and Applin (1965, p. 36, 45) into rocks of early and late Trinity age within which two formational units have been defined. The rocks of early Trinity age are about 1,500 to 2,100 feet thick in wells along the Florida Keys (pl. 16). At the west end of the Keys (well FL–111), the 1,589-foot interval is composed primarily of thick anhydrite beds containing some lenses of salt. This evaporite facies has been termed the Punta Gorda Anhydrite (Applin and Applin, 1965, p. 39). Eastward along the Keys, the evaporite facies continues to mark the top of rocks of early Trinity age, but it gives way to thick oolitic limestone and dolomite beds and thin dark shale layers in the lower half. (See well FL–104, pl. 16.) The Punta Gorda Anhydrite is 783 feet thick in well FL–104, on Key Largo; no anhydrite was penetrated in well BA–2 on Andros Island in the Bahamas. Evaporite beds have been reported in well BA–1 drilled to a depth of 18,906 feet on Cay Sal (pl. 1 and fig. 3), but no samples have been available to confirm this or to suggest any correlations. However, known thicknesses do suggest that a sizeable evaporite basin existed in Early Cretaceous time to the south and southwest of Florida. Northward from Key Largo along section *A–B* (pl. 9), the rocks of early Trinity age grade from the evaporite and carbonate facies (well FL–104) into nearshore marine and continental clastic facies (wells FL–73 and FL–57) and wedge out against the Peninsular arch.

CHARACTERISTIC MICROFAUNA

Rocks of early Trinity age in well FL–104 (Sinclair Oil and Gas Williams 1) on Key Largo are reported to have yielded two specimens of the ammonite *Du-*

frenoya texana Burckhardt in a core taken about 120 feet above the top of the Fort Pierce Formation (Applin and Applin, 1965, p. 45). *D. texana* is a diagnostic fossil of the outcropping Cow Creek Limestone Member of early Trinity age in central Texas (Adkins, 1928, p. 252–253) and of the underlying Pine Island Shale Member of the Pearsall Formation of the Trinity Group) in the subsurface of the Coastal Plain in Texas, Louisiana, and Arkansas (Imlay, 1944).

Choffatella decipiens Schlumberger also is a characterizing fossil in the marine beds of early Trinity age in southern Florida, and in this area, one or more fossiliferous lenses generally contain many specimens. *C. decipiens* has a world-wide distribution, and Maync (1949, p. 535) records its stratigraphic range as "from the earliest Cretaceous to somewhere in the Albian." It is present at depths of 11,200, 11,580, and 12,259 feet in well FL–86 (Humble Oil and Refining Tucson 1) and in several other wells in the southern part of the Florida Peninsula.

Orbitolina texana (Roemer) is usually well represented in beds of early Trinity age in southern Florida. The stratigraphic range of this species in Florida and in the western gulf coast is well described by Douglass (1960a, p. 6, fig. 2). Specimens were found at depths of 13,400 and 13,510 feet in well FL–109 (Gulf Oil State of Florida lease 373 1) on Big Pine Key.

ROCKS OF LATE TRINITY AGE

Lithology and Distribution

Rocks of late Trinity age in Florida, as defined by Applin and Applin (1965, p. 46), range from 1,441 to 713 feet thick west to east along section *O–P* (pl. 16) in the Florida Keys. They wedge out northward on the peninsula between wells FL–86 and FL–73 on section *A–B* (pl. 9). These rocks consist of a lower unit of limestone, dolomite, and shale beds termed the Sunniland Limestone (Pressler, 1947, p. 1859, and fig. 3; Applin, 1960, p. B209) and an upper unnamed unit composed of a thick anhydrite bed overlain by interbedded limestone, dolomite, and shale.

Sunniland Limestone

The Sunniland Limestone, which is the oil reservoir in the three oil fields of southern Florida, is 496 feet thick in well FL–111 at the west end of the Florida Keys (pl. 16). It decreases in thickness northeastward along the Keys and northward up the peninsula. At most places it consists of dark fine-grained argillaceous limestone and light-tan chalky limestone interbedded with lenses of brown granular dolomite and dark-gray shale. Lenses of bioclastic limestone and porous algal limestones are interspersed in the unit. Many lenses contain closely packed specimens of *Dictyoconus floridanus* Cole accompanied by many specimens of *Orbitolina texana.* Numerous specimens of both fossils are reported from wells FL–86, FL–104, FL–109, and FL–111 in table 3. *Dictyoconus floridanus* was formerly called *Coskinolina sunnilandensis* Maync, and its occurrence in Florida was believed to be restricted to the Sunniland Limestone. According to Douglass (1960b, p. 258), however, this species, which is found in Trinity rocks throughout the gulf coast region, is conspecific with *Dictyconus floridanus*, a species common in and described from the Avon Park Limestone of middle Eocene age in Florida.

Upper Unnamed Unit

The upper unnamed unit overlying the Sunniland Limestone is 988 feet thick at the western end of the Florida Keys (well FL–111, pl. 16), but it decreases northeastward to less than 500 feet at Key Largo (well FL–104) and then wedges out northward up the peninsula between wells FL–86 and FL–73 as shown on section *A–B* (pl. 9). Directly overlying the Sunniland Limestone is a sequence of interbedded anhydrite and argillaceous limestone that has been termed the "upper massive anhydrite" by oil geologists. It ranges in thickness from about 30 feet to 200 feet in southern Florida. Above the "upper massive anhydrite" are dark- to light-tan, fine-grained to chalky limestones, lenses of granular dolomite, and dark shale beds. Some anhydrite layers are interbedded with the carbonates in the southern wells, and oolitic limestones are present in wells on the southwest flank of the Peninsular arch.

Specimens of *Orbitolina* that are generally referred to *Orbitolina minuta* Douglass are commonly found near the top of the beds of late Trinity age and are also found at one or more lower levels within the unnamed post-Sunniland unit. The specimens are not abundant, but they are helpful in defining the upper and lower boundaries of the post-Sunniland beds of Trinity age. Specimens have been identified from wells FL–86, FL–104, and FL–109 (table 3).

ROCKS OF FREDERICKSBURG AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Fredericksburg age are present beneath southern Florida and have been tentatively identified in wells in North Carolina and New Jersey (pl. 9).

In southernmost Florida, the unit is composed mainly of dark-colored, fine-grained limestone and finely granular dolomite beds overlain by light-colored, chalky limestone beds. Bioclastic limestone beds, lenses of oolitic limestone, and some anhydrite layers are also included. Numerous oil stains and tarry residues have been reported mostly in the upper part of the rocks of Fredericksburg age by Applin and Applin (1965, p. 59). The thickness of the unit ranges from 1,850 feet in well FL–111 at the western end of the Florida Keys to its termination as a clastic wedge on the flank of the Peninsular arch (wells FL–57 and FL–52, pl. 9).

Rocks tentatively assigned a Fredericksburg(?) age in wells in North Carolina and Maryland are 415 to 660 feet thick (pls. 9 and 11) and consist principally of sandstone and shale beds with some thin limestone and limy shale beds interspersed in the Cape Hatteras well (NC–14). About 300 feet of lithologically similar and unfossiliferous beds that overlie rocks questionably assigned a Trinity age may be either Trinity or Fredericksburg and are querried on the sections (pls. 9, 11, and 12).

Limestone of Fredericksburg age probably crops out along the Blake Escarpment. Heezen and Sheridan (1966, p. 1645) dredged a sample of gray and tan, slightly pyritic limestone of Aptian to Albian age from a depth of 7,790 feet on the escarpment. (See discussion of Lower Cretaceous rocks.)

CHARACTERISTIC MICROFAUNA

The beds of Fredericksburg age in southern Florida generally contain abundant specimens of *Coskinolinoides texanus* Keijzer. This species, which was described from the Walnut Clay of the Fredericksburg Group of Texas, is believed to be restricted to the Fredericksburg Group. Specimens are reported from wells FL–86, FL–104, FL–109, and FL–111 in table 3. *Lituola subgoodlandensis* (Vanderpool) is also restricted to the Fredericksburg in its recorded upward range and is generally found near the top of the beds of Fredericksburg age in the Florida Peninsula. However, specimens of the species also occur at several lower levels within the group. *L. subgoodlandensis* is generally found some distance above the highest occurrence of *C. texanus* and has a wider areal distribution in Florida than *C. texanus*. Specimens are reported in table 3 from wells FL–57, FL–73, and FL–86. Specimens of *Lituola subgoodlandensis* (Vanderpool), known only from rocks of Fredericksburg age or older and generally present in the upper part of rocks of Fredericksburg age in Florida, were found by E. R. Applin at a depth of 6,770 feet in well NC–14 at Cape Hatteras. Little fossil evidence suitable for separating these rocks from those of Trinity(?) and Washita(?) age is available in this region, and the correlations suggested by lithologic and electric-log characteristics are highly uncertain.

ROCKS OF WASHITA AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Washita age range from 1,987 to 1,380 feet in thickness in wells on section *O–P* (pl. 16) along the Florida Keys and wedge out northward against the Peninsular arch as shown on section *A–B* (pl. 9). The lithology is predominantly very fine grained calcitic dolomite containing chalky limestone and anhydrite layers in the upper part in some wells. The evaporites are thicker and more abundant in the southernmost wells in Florida. Traces of glauconite are present in the beds penetrated in wells on the flank of the Peninsular arch. Oil stains and tarry residues have been reported from both limestone and dolomites of Washita age in wells scattered over southern Florida (Applin and Applin, 1965, p. 63).

North of the Cape Fear arch, a sequence of rocks 320 to 600 feet thick in wells on sections *A–B*, *E–F*, and *G–H* (pls. 9, 11, and 12) has been tentatively assigned a Washita(?) age. It consists mainly of thick beds of dark-gray sandy to limy shale and fine-grained sandstone with a few thin layers of lignite in wells farthest inland; the sequence grades seaward into thinner bedded sandstone, alternating with gray limy shale and limestone in the upper two-thirds and with thick beds of siltstone and shale in the lower one-third (well NC–14, pls. 9 and 12). Rocks of Washita(?) age are not differentiated from underlying rocks northward into New Jersey and New York. Southward, they seem to extend high up the flank of the Cape Fear arch, where they appear to overlap older Lower Cretaceous rocks and rest on pre-Mesozoic igneous and metamorphic rocks. Correlations in this area are relatively uncertain, as few definitive fossils have been reported in any of the wells drilled to date.

CHARACTERISTIC MICROFAUNA

Nummoloculina heimi Bonet is the key fossil of beds of Washita age in the Florida peninsula. The "*Nummoloculina* limestone" at the top of the beds of Washita age is composed chiefly of large specimens of this fossil and the species is also abundant at many lower levels within the unit. The fauna of the beds of Washita age in Florida is strikingly similar to that of the upper part of the El Abra Limestone of Mexico and is also similar to the top foot of the Devils River Limestone (Georgetown) of Texas (Conkin and Conkin, 1956, fig. 3). *N. heimi* is found in older units of the Comanche Series, but its size and abundance in the beds of Washita age in southern Florida make it a dependable guide fossil for the late Comanche rocks in that area. Specimens have been found by E. R. Applin in wells FL–57, FL–73, FL–86, FL–104, FL–109, and FL–111 (table 3).

UPPER CRETACEOUS ROCKS

SUBDIVISIONS

Upper Cretaceous rocks of the gulf coast region include, in ascending order, the upper part of the Washita Group of the Comanche Series, and the Woodbine, Eagle Ford, Austin, Taylor, and Navarro Formations of the Gulf Series. The equivalents of these formations are shown on the cross sections. All rocks of Washita age are excluded from the discussion of Upper Cretaceous rocks because the paleontologic boundary drawn within the Washita Group cannot be identified in the drill cuttings.

LITHOLOGY AND DISTRIBUTION

Rocks of Late Cretaceous age crop out almost continuously along the Fall Line from Alabama to North Carolina and from Maryland to Long Island. Upper Cretaceous rocks bordering the piedmont of northeastern North Carolina and Virginia are concealed by overlapping Tertiary deposits. The surface exposures, which range in thickness from a few hundred to more than 2,000 feet, are largely nearshore marine and continental clastics.

Submarine outcrops of Late Cretaceous age are known in canyons along Georges Bank and in the lower part of the Blake Escarpment (pl. 2) and may be present over considerable distances along the remainder of the continental slope. Cobbles of Cretaceous chalk have been found in the floor of Northeast Providence Channel, 11,096 feet beneath the sea between the Bahama Islands. In the nearby Andros Island well (BA–2), Upper Cretaceous rocks were identified between depths of 8,220 and 10,760 feet. This suggests that Upper Cretaceous beds are exposed in the canyon walls which connect with the Blake Escarpment on the continental slope. Reworked Cretaceous Foraminifera identified in a bottom core at a depth of about 15,000 feet on the continental rise, 155 miles southwest of Cape Hatteras, also indicate a good possibility that Upper Cretaceous outcrops are present along the continental slope near Cape Hatteras. The Hatteras Light well (NC–14), only 22 miles inland from the slope, penetrated Upper Cretaceous beds between depths of 3,033 and 6,100 feet. Assuming a regional dip of no less than 50 feet per mile, as is common for Upper Cretaceous beds beneath the outer Coastal Plain, Upper Cretaceous strata might be expected to crop out or be thinly mantled by Cenozoic deposits between depths of 3,900 and 9,300 feet, and possibly deeper.

Upper Cretaceous rocks, 1,235 to 3,067 feet thick, in wells along the line of section *A–B* (pl. 9) are predominantly marine carbonates and clastics. In Florida, they are almost entirely marine carbonates and range in thickness from about 2,900 feet in the Florida Keys to less than 1,250 feet on the Peninsular arch (well FL–52, pl. 9). In wells along the coast of Georgia and South Carolina, the rocks are mixed marine carbonates and clastics about 2,000 feet thick. They are only 1,286 feet thick in well NC–58 on the Cape Fear arch, but they range northward from 3,000 feet thick in well NC–14 at Cape Hatteras, N.C., to 1,800 feet thick in well NY–6 on Long Island. The percentage of clastics is higher in wells in Maryland, New Jersey, and Long Island than in the Cape Hatteras well, because the Cape Hatteras well is considerably farther down the regional dip than the other wells.

The Upper Cretaceous rocks in southern Florida, where they consist of a thick succession of similar carbonate beds, are not subdivided on sections *A–B* and *O–P* (pls. 9 and 16). They are subdivided in central Florida on sections *A–B* and *M–N* (pls. 9 and 15) and northward on the remainder of the sections. No test holes on the shelf or Blake Plateau have reached Cretaceous rocks.

REGIONAL THICKNESS

The regional thickness of the Upper Cretaceous Gulf Series in the Atlantic Coastal Plain is outlined on plate 17*B*. These rocks are present at or near the Fall Line from Alabama to New York and dip seaward at rates increasing from 10 feet per mile near the outcrop to more than 30 feet per mile at the coast (pls. 11 and 12). Accordingly, the thickness increases to reach an onshore maximum of about 3,000 feet at Cape Hatteras and along the southern coast of Florida, as shown on plate 17*B*. Form lines on plate 17*B* suggest minimum thicknesses to be expected offshore, not total thicknesses. Such form lines have a general or directional usefulness in selecting or comparing large areas for exploration but are not suitable for local predictions. Thicknesses considerably in excess of 3,000 feet may be present offshore in the Baltimore Canyon trough, the Southeast Georgia embayment, the Blake Plateau trough, and the South Florida embayment. In western Georgia, more than 2,000 feet of Upper Cretaceous rocks lie in a troughlike pattern parallel to the outcrops. A short distance to the south, a thinner sequence, 1,000 to 1,500 feet thick, reflects the influence of the Peninsular arch on deposition in Late Cretaceous time (pl. 9, well FL–52). A wide platform of carbonate deposition extending across the southern third of Florida and the Bahama Islands is suggested by the large area of uniform thicknesses between 2,500 and 3,000 feet.

ROCKS OF WOODBINE AND EAGLE FORD AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Woodbine and Eagle Ford age crop out almost continuously along the Fall Line from Alabama to New Jersey. They rest directly upon basement rocks at the surface and in the subsurface in a wide area of southern North Carolina, South Carolina, and eastern Georgia. (See pls. 16 and 17*C*.) Woodbine strata may crop out in the Blake Escarpment, opposite Cape Kennedy, Fla. A core of dark grayish-green, slightly sandy clay from a depth of 5,724 feet at lat 28°52′ N., long 76°47′ W. yielded Foraminifera that A. R. Loeblich, Jr. (in Ericson and others, 1961, p. 236), regarded as Cenomanian and a little younger than the surface Washita in Texas and Oklahoma (fig. 7). Inasmuch as the Cenomanian Stage of Europe includes rocks of both Washita and Woodbine age in North America, the clay probably is Woodbine in age.

Rocks of Woodbine and Eagle Ford age cannot be separated consistently from other Upper Cretaceous rocks in southern Florida, but they can be traced from central Florida northward to Long Island along the line of section *A–B* (pl. 9). They are reported to be absent from some wells on the crest of the Cape Fear arch (Brown, 1958, p. 38, 43), but they may be represented by a 200-foot-thick sequence of nonfossiliferous sandstone at the bottom of well NC–58 at Fort Caswell, N.C. In central and northern Florida, rocks of Woodbine and Eagle Ford age are represented by the Atkinson Formation, 115 to 266 feet of limestone, sandstone, and shale, which is subdivided into a lower member of Woodbine age and an upper member of Eagle Ford age. Northward, they are represented by the Tuscaloosa and overlying pre-Austin rocks, 563 to 1,850 feet of sandstone and shale, in Georgia, South Carolina, and North Carolina and by the Raritan Formation, 810 feet of sandstone, on Long Island. No formation names are applied here to the correlatives in deep wells in Maryland and New Jersey, although a general equivalence to the Patapsco and Raritan Formations, undifferentiated, is indicated. Considerable confusion and overlap exists in the use of the terms "Patapsco" and "Raritan" on the outcrops between the two states, and somewhat more may exist in the subsurface. It seems best not to use local terms in the deep wells until problems of correlation along the outcrops are resolved and more deep wells offer both lithologic and paleontologic evidence.

CHARACTERISTIC MICROFAUNA

Foraminifera characteristic of the Woodbine Formation in Texas are present in wells along the Atlantic coast. (See table 3.) Widely distributed species, *Ammobaculites comprimatus* Cushman and Applin, *Ammobaculites advenus* Cushman and Applin, *Ammotium braunsteini* (Cushman and Applin), and *Trochammina rainwateri* Cushman and Applin, occur in wells in Alabama, Florida, Georgia, and South Carolina. *Cuneolina walteri* Cushman and Applin and *Trocholina floridana* Cushman and Applin have been identified from depths of 5,090 feet in well FL–57 (Sun Oil Powell Land 1) in Volusia County, Fla., and 5,790 feet in well NC–14 (Standard Oil of New Jersey Hatteras Light 1) in Dare County, N.C. Abundant specimens of *Acruliammina longa* (Tappan), *Placopsilina langsdalensis* Applin, and *Haplophragmoides langsdalensis* Applin were found at 5,310 feet in beds assigned to the part of the Tuscaloosa Formation that is of Woodbine age in the latter well.

A microfauna closely related to that of the Chispa Summit Formation of Adkins (1933, p. 437) of Eagle Ford age in Texas is present in wells along the Atlantic coast (table 3). The species of Foraminifera by which rocks of Eagle Ford age can be most readily identified are *Planulina eaglefordensis* (Moreman), *Valvulineria infrequens* var. (Applin, 1955, p. 196), and *Hastigerinella moremani* Cushman. The occurrence of these species in cores at depths of 3,195 to 3,205 feet in well GA–75 (Sun Oil Doster-Ladson 1), Atkinson County, Ga., is noted on cross section *K–L* (pl. 14). The interval from 3,155 to 3,387 feet is the type sequence for the upper member of the Atkinson Formation (Applin and Applin, 1947, sheet 3) of Eagle Ford age. Herrick (1961, p. 13) assigned part of this sequence to the Blufftown Formation and part to the Eutaw Formation (restricted), both of which he considered as Austin in age. However, he identified no fossils below a depth of 3,050 feet, and he believes the species named above support an Eagle Ford age for the interval (written commun., 1964).

REGIONAL THICKNESS

The thickness of rocks of Woodbine and Eagle Ford age penetrated by wells ranges from a few feet to a maximum of 1,812 feet in well NC–14 (Standard Oil of New Jersey Hatteras Light 1) as correlated by Spangler (1950, p. 113, 114) and E. R. Applin (written commun. to J. B. Reeside, Jr., 1957). Offshore thicknesses may be expected to exceed 1,000 feet in the Southeast Georgia embayment and 2,000 feet in the Baltimore Canyon trough, perhaps by a considerable amount (pl. 17*C*). Uniform thicknesses of less than 250 feet over much of the Florida Peninsula perhaps result from a stable platform in the Florida-Bahama region during Late Cretaceous time. Rocks of Woodbine and Eagle Ford age are absent on the Peninsular arch and the Cape Fear arch, where rocks of Austin age rest directly upon basement rocks.

ROCKS OF AUSTIN AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Austin age can be separated fairly consistently from overlying rocks of Taylor age in deep wells from central Florida northward to southern New Jersey (pl. 9). They range in thickness from 225 to 457 feet between central Florida and the Cape Fear arch and from 550 to 638 feet between the Cape Fear arch and southern New Jersey. The lithology of the unit changes northward from light-colored limestone beds that cannot be delimited in the predominantly carbonate sequence of Upper Cretaceous rocks in southern Florida to dark-gray shale, siltstone, and sandstone in southern New Jersey. Chalk, marly limestone, and limy sandstone characterize the unit at intermediate points in Georgia and the Carolinas. In well NC–14 at Cape Hatteras, the entire 628-foot sequence is composed of fine- to coarse-grained sandstone with some beds of conglomerate. This represents the lower part of the Black Creek Formation (pls. 9 and 12), a South Carolina and North Carolina unit that encompasses sandstone and shale beds of Austin and Taylor age.

In New Jersey and Maryland (pls. 10 and 11), rocks of Austin age, mainly dark-gray shale and sandstone in deep wells, are equivalent to the Magothy Formation, which is predominantly sandstone in shallow wells near the outcrop. They cannot be separated easily from the overlying Matawan Group of Taylor age in deep wells of northern New Jersey and Long Island.

No submarine outcrops of Austin age have been reported. The few test holes drilled into the continental shelf have been too shallow to penetrate rocks of Austin age.

CHARACTERISTIC MICROFAUNA

Citharina texana Cushman is the diagnostic species of Foraminifera that most commonly distinguishes the beds of Austin age in Georgia, Alabama, and South Carolina (table 3). In North Carolina, some question seems to exist about the upward range of this species. Spangler (1950, p. 116) stated "* * * a macrofauna 'younger than the Austin, perhaps Taylor', was identified by L. W. Stephenson from these beds in the John Wallace 1 well. As a result, it is thought that *Vaginulina regina* (now *Citharina texana*) (Cushman) ranges into younger beds along the east coast than in the Gulf Coast." Spangler (1950, fig. 5) recorded the occurrence of *C. texana* in several wells from the Black Creek Formation, and he (1950, p. 116, table 2) correlated the Black Creek in North Carolina with the Taylor in the gulf coast. However, Spangler and Peterson (1950, p. 8, fig. 4) correlated the Black Creek in North Carolina with both the Austin and the Taylor in the gulf coast, and this usage is followed in this report.

In the Florida Peninsula, *Citharina texana* Cushman and other time-restricted Foraminifera, *Globorotalites umbilicatus* (Loetterle), *Darbyella brownstownensis* Cushman and Deaderick, and *Planulina austinana* Cushman, are rare, and certain distinctive and widely distributed lithologic features are generally used for recognition of the beds of Austin age.

Kyphopyxa christneri Carsey is frequently reported from beds of Austin age, but this species is present also in the lower part of the beds of Taylor age.

ROCKS OF TAYLOR AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Taylor age can be identified in deep wells along the coast from central Florida to southern New Jersey; only on the Cape Fear arch do inadequate well records make upper and lower boundaries uncertain (pl. 9). Along section *A–B* (pl. 9), they are thickest in well FL–57 (Sun Oil Powell Land 1) in central Florida, where 860 feet of light-colored limestone beds have been assigned a Taylor age. Applin and Applin (1944, p. 1715) reported a thickness of more than 1,200 feet in southernmost Florida (Peninsular Oil and Refining Cory 1, Monroe County), but the unit could not be identified readily in the wells used for the cross sections in this report. Thicknesses range from 368 to 482 feet between central Florida and the Cape Fear arch. North of the Cape Fear arch, the thickness decreases from 585 feet in North Carolina (well NC–49) to 176 feet in Maryland (well MD–14). The composition also changes from limestone in southern Florida to marly limestone and limy shale in central Florida to sandstone and shale in northern Florida and Georgia. Northward in the deep wells, it is predominantly gray marl, limy shale, and siltstone. In North Carolina, it is represented by the upper part of the Black Creek Formation (pl. 12) and in southern New Jersey by the Matawan Group (pls. 10 and 11). The limits of this group are not apparent in deep wells in northern New Jersey and Long Island (pl. 10), although rocks of Taylor age are most likely present.

Rocks of Taylor age crop out someplace between depths of 758 and 1,955 feet in a submarine canyon in Georges Bank (Stetson, 1949, p. 33). Material dredged from the wall consisted of poorly sorted, glauconitic and feldspathic, in part silty, coarse-grained sandstone, assigned to the Matawan Group (Bassler, 1936, p. 411; Stephenson, 1936, p. 369–370, and in Stetson, 1949, p. 8).

CHARACTERISTIC MICROFAUNA

Planulina dumblei (Applin) is the diagnostic species for beds of Taylor age in the Atlantic Coastal Plain from Georgia northward to Long Island, and it generally occurs near the top of the unit. The highest occurrence of the beds of Taylor age in the Florida Peninsula, however, is generally indicated by many specimens of *Stensiöina americana* Cushman and Dorsey and *Bolivinoides decorata* (Jones). *S. americana* and *B. decorata* are present in the upper part of the beds of Taylor age throughout the report area except at the southern end of the peninsula. In southern Florida, rocks of Taylor age are present in a thick sequence of very sparsely fossiliferous chalk, but they are not differentiated in this report. *Planulina dumblei* has not been reported from the Florida Peninsula, but another species of the Anomalinidae, *Anomalina sholtzensis* Cole, is fairly common in the peninsula but rare in the part of the Atlantic Coastal Plain north of Florida. *Tritaxia capitosa* (Cushman) is usually found in the lower part of the beds of Taylor age in the northern part of the Florida Peninsula and farther to the northeast.

ROCKS OF NAVARRO AGE

LITHOLOGY AND DISTRIBUTION

Rocks of Navarro age, which mark the top of the Cretaceous System, can be traced in deep wells from central Florida northward to Long Island (pl. 9). They have not been separated from the underlying rocks of Taylor age in well NC–58 on the Cape Fear arch, but this is partly because of the inadequate well records in that area. They range in thickness from a maximum of 798 feet in well FL–73 (Humble Oil and Refining Carroll 1) in central Florida to a minimum of 70 feet in well NJ–25 (Anchor Gas Dickinson 1) at Cape May, N.J.

In northeast and central Florida, rocks of Navarro age are represented by a carbonate facies, 410 to 798 feet thick along section *A–B* (pl. 9) and 485 to 900 feet thick along section *M–N* (pl. 15). Applin and Applin (1944, p. 1708) called this facies the Lawson Limestone, and they divided it into upper and lower members. The lower limit of the Lawson Limestone is not distinct in wells in southern Florida, where the entire Upper Cretaceous sequence is composed of sparsely fossiliferous, lithologically similar carbonates.

Northward from Florida, the rocks of Navarro age grade into chalk, marl, and fine-grained clastics containing large amounts of glauconite. The Peedee Formation in North Carolina is 114 to 212 feet thick along section *A–B* (pl. 9) and consists primarily of marl, calcareous and siliceous shale, and fine-grained sandstone. The Monmouth Group, 70 to 170 feet thick in wells along section *A–B* in Maryland, New Jersey, and New York, are Navarro in age. The beds are primarily dark-colored silty and sandy clay, and at the extremity of section *A–B* in Long Island, they consist of greenish glauconitic clay and sandy clay (Perlmutter and Todd, 1965, p. I7).

Submarine outcrops of Navarro age are present in two canyons cut in Georges Bank (fig. 2). Samples were dredged by Stetson (1949, p. 33) from depths of 3,116 feet along the east side of Oceanographer Canyon and from 1,968 to 1,738 feet and 2,486 feet along the east side of Gilbert Canyon. The material dredged from Oceanographer Canyon consisted of a dark-colored, partly indurated, micaceous silty clay that contained a late Maestrichtian or Navarro fauna that J. A. Cushman (in Stetson, 1949, p. 10) correlated with the Kemp Clay of northeast Texas. Rocks of Navarro age from Gilbert Canyon consisted of a friable, coarse greensand and limonite-stained, micaceous, fine-grained sandstone containing Foraminifera characteristic of beds of Navarro age (Maestrichtian), according to Cushman (1936, p. 413, and in Stetson, 1949, p. 10).

CHARACTERISTIC MICROFAUNA

Published reports on planktonic species of Foraminifera show that occurrences of the genus *Globotruncana* are restricted to beds of Cretaceous age.

Consequently, the highest indigenous occurrence of the genus in a set of well samples is *prima facie* evidence of the Cretaceous age of the containing beds. *Globotruncana arca* Cushman and *Globotruncana cretacea* Cushman are the species generally found in the samples from the wells that are shown on the cross sections in this report. Because these species range downward into beds older than Navarro and are not always present at the top of the unit, other species, such as *Anomalina pseudopapillosa* Carsey, *Cibicides harperi* (Sandidge), and *Lenticulina navarroensis* (Cushman), reported only from the Navarro, have been used to delimit the rocks of Navarro age.

The Lawson Limestone of Navarro age in the Florida peninsula differs in lithologic character and in microfaunal population from the clastic beds of equivalent age in the Coastal Plain of the Middle Atlantic States. The fauna of the lower member of the Lawson Limestone is characterized by several species of *Lepidorbitoides* found also in the Maestrichtian of Europe, the Madruga Chalk of Cuba, and the Cardenas beds of Mexico. *Sulcoperculina cosdeni* Applin and Jordan is another definitive species. *Globotruncana cretacea* and *Anomalina cosdeni* Applin and Jordan characterize the lower member in some wells. The upper member of the Lawson Limestone is highly altered chemically; hence diagnostic fossils are rare. Rudistid fragments are commonly found near the top of the member and are fairly prevalent at irregularly spaced lower levels. Specimens of a small, undescribed Rotalid are also fairly common in the upper member of the Lawson.

The reported stratigraphic ranges of most of the Cretaceous species of smaller Foraminifera mentioned in this report are given by Cushman (1946).

CENOZOIC ROCKS

DISTRIBUTION AND THICKNESS

Outcrops of Cenozoic rocks parallel the Fall Line from Georgia to New Jersey except in South and North Carolina, where the outcrops swing seaward around the flanks of the Cape Fear arch. Cenozoic deposits are thickest in the southern Florida-Bahamas region (pl. 17*D*). Thicknesses in excess of 4,000 feet are present in wells in the southern half of the Florida peninsula, and a thickness of 8,220 feet is present in well BA-2 (Bahamas Oil Andros Island 1) in the Bahamas (pl. 16). Along the coast (pl. 9), the thickness of Cenozoic rocks ranges from 4,307 feet in southern Florida (well FL-86) to 254 feet on the Cape Fear arch (well NC-58), and, from 3,020 feet at Cape Hatteras (well NC-14) to 130 feet on Long Island (well NY-6). Beneath the continental shelf, Cenozoic thicknesses in excess of 5,000 feet may be present in the Southeast Georgia embayment and the Baltimore Canyon trough judging by the rate of thickening onshore and scattered seismic profiles (pl. 6).

SUBDIVISIONS

In this report, Cenozoic rocks have been subdivided into the Paleocene, Eocene, Oligocene, and Miocene Series of Tertiary age, and undifferentiated post-Miocene rocks of Tertiary and Quaternary age. In some wells, mostly in Florida and Georgia, the Eocene Series is further subdivided into rocks of Wilcox, Claiborne, and Jackson age. The Miocene Series is partially subdivided in wells in North Carolina, Maryland, and New Jersey.

TERTIARY ROCKS

The Tertiary rocks are predominantly carbonates in Florida but grade northward into heterogeneous sequences of limestone, marl, limy shale, sandstone, and clay. Thick beds of limestone and sandstone characterize the sequence in well NC-14 at Cape Hatteras, which is farther down the regional dip than other wells north of Florida. The faunal assemblages in the carbonate rocks of Tertiary age in the Florida Peninsula are most closely related to faunal groups of equivalent age in Cuba, Panama, and other parts of the Caribbean and Central American region. The faunal groups of the northern part of the report area resemble most closely those of west Florida and the central and western gulf coast. A few of the distinctive Florida species also are reported from Tertiary beds in the subsurface in Georgia.

Shore cores and dredgings of Tertiary sand, chalk, marl, and *Globigerina* ooze have been recovered at three dozen localities between Georges Bank and the Hudson Canyon, and in the Blake Plateau-Bahama Banks region (pl. 2 and fig. 2). Silt and sand of probable Tertiary age have been reported in a submarine canyon off Nova Scotia (Marlowe, 1965).

Offshore, Tertiary rocks have been penetrated by eight test holes that range in depth from 171 to 1,050 feet. Two were drilled by the U.S. Coast Guard at one location (GA-88, fig. 7) about 10 miles offshore from Savannah, Ga. (McCollum and Herrick, 1964). Six were drilled under the JOIDES (Joint Oceanographic Institutions Deep Earth Sampling) program at locations (FL-117 to FL-122, fig. 7) ranging from

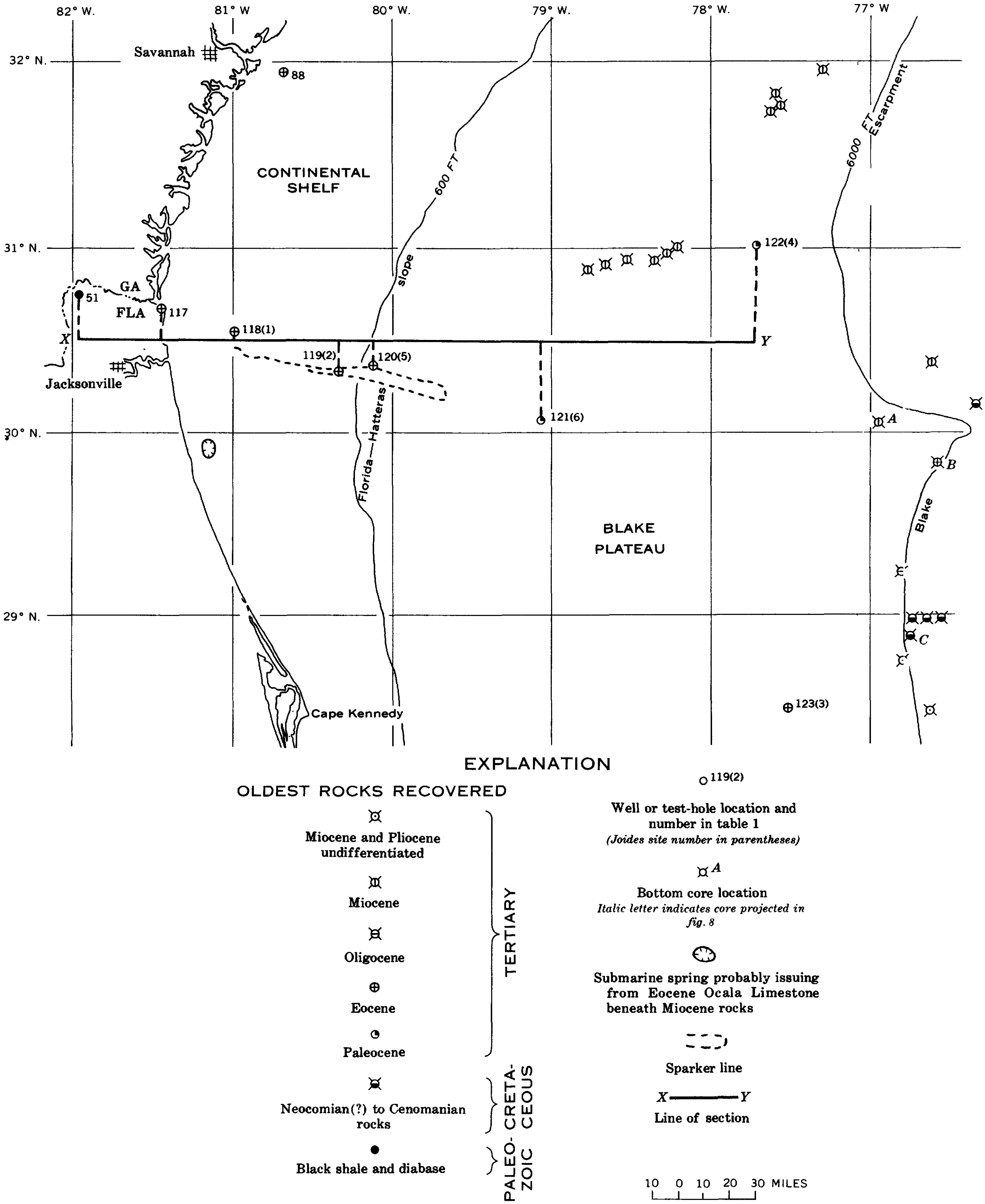

Figure 7.—Location of JOIDES test holes, section, and sparker line off southeastern Georgia and northeastern Florida. See figure 8.

27 to 221 miles offshore from Jacksonville and Cape Kennedy, Fla. (Bunce and others, 1965).

The U.S. Coast Guard test holes were drilled in 1962 on the Shelf in 54 feet of water at lat 31°56′53.5″ N., long 80°41′ 00″ W. The oldest formation reached was the Ocala Limestone of late Eocene age. Comparison of the test holes with water wells on land reveals that rather uniform thicknesses of Oligocene, lower Miocene, and middle Miocene strata extend from shore seaward for at least 10 miles. However, both the upper Miocene rocks and the Pleistocene and Holocene deposits decrease in thickness seaward, the most significant decrease being in the upper Miocene rocks, which range from about 145 feet inland to only 10 feet offshore. No facies changes were reported in the upper part of the Ocala Limestone or in the Miocene rocks, but it was noted that the Oligocene rocks grade seaward from a sandy limestone at the coast into a limy sandstone facies offshore.

The JOIDES test holes (wells FL–118 to FL–123, figs. 7 and 8) were drilled in water 90 to 3,888 feet deep on the continental shelf, Florida-Hatteras slope, and the Blake Plateau (Bunce and others, 1965; Schlee and Gerard, 1965; Charm, 1965). In addition, sparker profiles were made normal to the coast. Two test holes reached Paleocene rocks, three penetrated middle Eocene rocks, and one stopped in upper Eocene rocks.

Figure 8 is a cross section made by projecting the JOIDES stratigraphic data from the test holes to a 253-mile-long line normal to the seacoast at lat 30°30′ N. (section *X–Y*, fig. 7). This line is tied to two onshore wells, the St. Mary's River Hilliard Turpentine 1 (FL–51) that reached Paleozoic rocks and a Fernandino Beach water well (FL–117) that stopped in middle Eocene rocks. The structure and topography are vertically exaggerated (1:251) to bring out the stratigraphy. The syncline along the coast and the anticline beneath the continental shelf are gentle warps with the steepest dips, found in the Eocene rocks, not exceeding 15 feet per mile. These gentle structures resemble the parallel warps along the coast at Savannah, Ga., as reported by McCollum and Counts (1964, pl. 1) and McCollum and Herrick (1964, p. C63).

The test holes on this section and a bottom core (fig. 7) from the Blake Escarpment indicate that Paleocene beds probably continue from the Coastal Plain to the edge of the Blake Plateau and may be exposed as sea bottom along the lower part of the Florida-Hatteras slope. The Eocene, Oligocene, and Miocene beds appear to be prograded seaward beneath the outer Continental Shelf and slope, and are greatly thinned on the Blake Plateau. They appear to be especially thin or even absent along the lower slope, which corresponds approximately with the axis of maximum velocity of the Gulf Stream. Bottom cores (fig. 7) show that Eocene and Oligocene strata crop out in the Blake Escarpment and that Miocene and Neogene deposits blanket the outer plateau and part of the escarpment. Conclusions (Bunce and others, 1965, p. 715) drawn from the test-hole data and sparker profiles are that the continental shelf has been built seaward rather continuously during Tertiary time and that the edge of the shelf has been prograded since Eocene time about 9.3 miles by a mass of sediments, 300 to 600 feet thick. Rates of deposition have been estimated for the upper Eocene sequence as 1.6 cm (centimeters) per thousand years on the continental shelf and 0.3 cm per thousand years on the Blake Plateau.

PALEOCENE ROCKS

LITHOLOGY AND DISTRIBUTION

Paleocene rocks equivalent to the Midway Group of the gulf coast are present along the lines of all cross sections of this report, but they are absent or indistinguishable from Eocene rocks in some wells near the Fall Line and on the Cape Fear arch. They are apparently overlapped by younger Tertiary rocks toward the Fall Line in northern Georgia (pl. 13). A maximum thickness of 2,270 feet has been tentatively assigned to rocks of Midway age in well BA–2 on Andros Island (pl. 16).

Along section *A–B* (pl. 9), the Paleocene rocks range in thickness from 1,210 feet in well FL–104 in southern Florida to 0 feet on the flanks of Cape Fear arch. They are relatively thin and less readily identified north of the Cape Fear arch. The Paleocene rocks in Florida are represented by the Cedar Keys Limestone, a light-colored limestone containing *Borelis*. The equivalent formation in Georgia and South Carolina is the Clayton Formation, which is composed mainly of marl, sandy limestone, and limy sandstone beds. This correlates with the Beaufort Formation in North Carolina, a sequence of gray glauconitic shale interbedded with thin limestone and chert beds. Farther north, identification of Paleocene rocks is more difficult. The sequence tentatively assigned to this age in well NJ–26 at Island Beach, N.J., is composed mostly of dark-greenish-gray fossiliferous limy clay and gray glauconitic siltstone. The underlying Monmouth Formation of Navarro age has a similar appearance and the two units can be separated only by means of fossils.

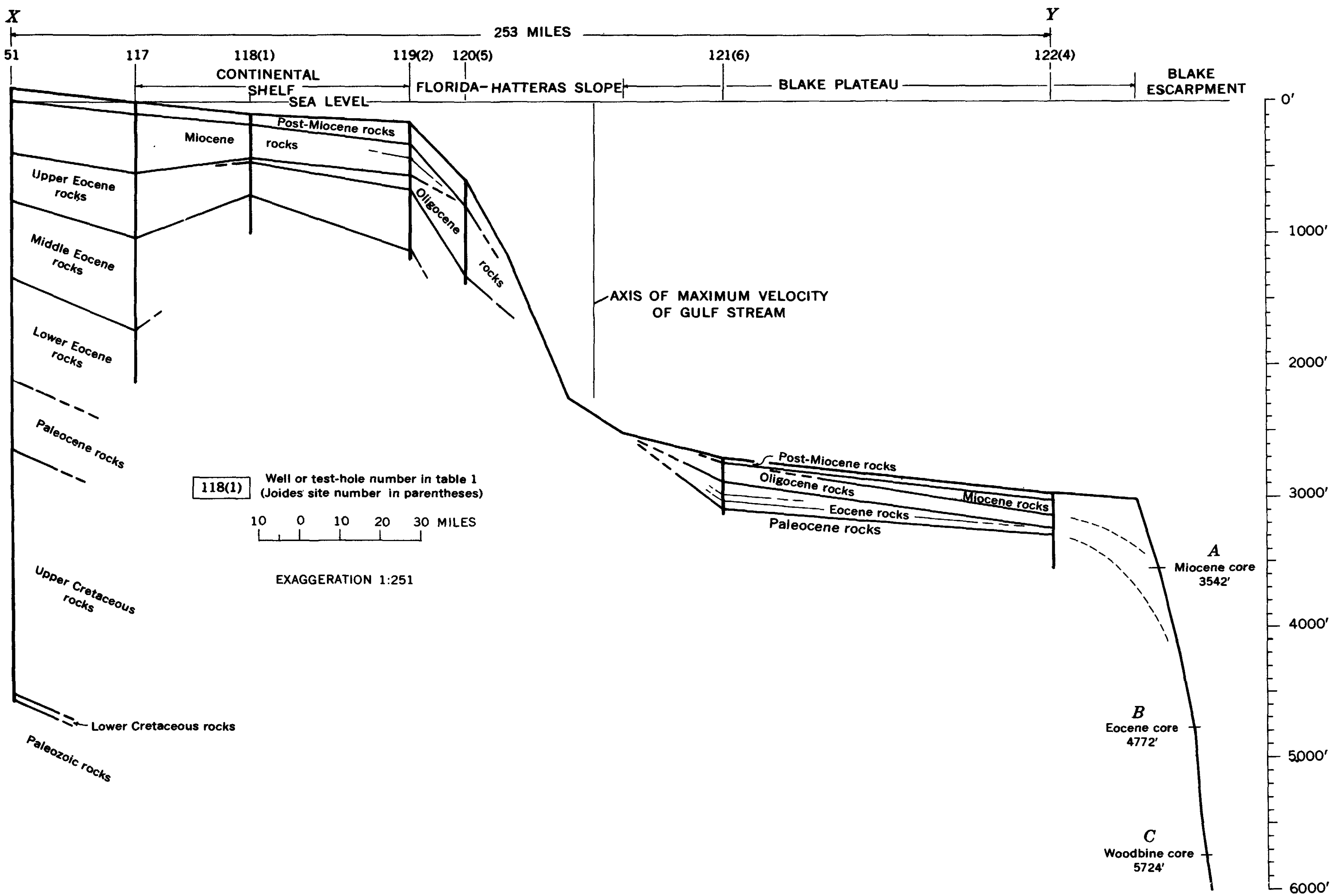

FIGURE 8.—JOIDES section across continental shelf and Blake Plateau off Jacksonville, Fla. Core locations projected along Blake Escarpment for diagrammatic purposes. (See fig. 7.)

Submarine outcrops of Paleocene rocks have not been reported, but considerable thicknesses have been drilled or cored by wells on the Blake Plateau and Bahama Islands. A Paleocene sequence consisting of 263 feet of hard, cherty, very fine grained limestone interbedded with gray limy clay was penetrated in JOIDES test hole 4 (FL–122), 221 miles east of the Georgia coast (figs. 7, 8) Dolomitic limestone and limestone beds tentatively assigned to the Paleocene were penetrated at depths of 5,950 to 8,220 feet in well BA–2 on Andros Island of the Bahamas (pl. 16). Judging by the close proximity of the Northeast Providence Channel and Tongue of the Ocean (5 to 10 miles), which descend to depths of about 10,000 feet, similar thicknesses of Paleocene strata may crop out or be thinly mantled along these canyon walls.

CHARACTERISTIC MICROFAUNA

The foraminiferal species *Borelis gunteri* Cole and *Borelis floridanus* Cole are key species of the Cedar Keys Limestone (Cole, 1944, p. 28) in the Florida Peninsula. These species, and additional ones that have been described (Applin and Jordan, 1945), were present in many Florida wells used on cross sections herein (table 3).

The most common species of Paleocene age in Georgia, South Carolina, Maryland, and New Jersey are *Lenticulina pseudomamilligera* (Plummer), *Vaginulina longiforma* (Plummer) *Anomalina midwayensis* (Plummer), and *Lenticulina midwayensis* (Plummer). The last species has also been reported from the Salt Mountain Limestone and from the Nanafalia Formation of Paleocene and early Eocene age, respectively, in Alabama (Toulmin, 1941, p. 579; Cooke, 1959).

EOCENE ROCKS

LITHOLOGY AND DISTRIBUTION

Eocene rocks crop out in a continuous band on the Coastal Plain from Alabama to the Cape Fear arch. They are absent from the crest of the arch and are somewhat intermittently exposed through a cover of younger rocks northward to Long Island. Eocene rocks are present in most of the wells on the cross sections. They are thickest in wells off southern Florida (pl. 16), where they range from 2,000 to 4,000 feet in thickness, and are thinnest in Maryland (pl. 11), where they are 100 to 350 feet thick.

Along section *A–B* (pl. 9), the Eocene rocks range in thickness from 2,328 feet in well FL–86 to 176 feet in well NC–58 on the Cape Fear arch and from 1,132 feet in well NC–14 at Cape Hatteras to less than 500 feet in New Jersey. The Eocene rocks are mostly limestone in Florida. In central and northern Florida, they are subdivided in ascending order into the Oldsmar Limestone of Wilcox (early Eocene) age, the Lake City and Avon Park Limestones of Claiborne (middle Eocene) age, and the Ocala Limestone of Jackson (late Eocene) age. In Georgia and South Carolina, the Eocene rocks consist of limestone, marl, and sandstone beds readily subdivided into rocks of Wilcox, Claiborne (Lisbon and Talahatta Formations), and Jackson age. Farther northward, the Eocene Series exhibits a gradual change from sandy limestone and sandstone beds in North Carolina into a sequence of shale and sandstone in Maryland and New Jersey. Limestones of middle and late Eocene age can be separated from lower Eocene rocks in North Carolina wells, but in Maryland and New Jersey wells (pl. 9) the Eocene rocks are neither readily subdivided nor easily distinguished from the overlying Miocene rocks.

Rocks of Eocene age probably are not far beneath the sea bottom where artesian submarine springs issue off the Florida coast. An oceanic spring about 2½ miles east of Crescent Beach near St. Augustine (pl. 2) has been described by Rude (1925); others have been reported along the east coast between lat 28° N. and 30° N. (V. T. Stringfield, written commun., 1964). Stringfield and Cooper (1951, p. 63) believe that these submarine springs discharge through sink holes formed during Pleistocene time when the sea stood at lower levels. They conclude that the aquifer is the Ocala Limestone of late Eocene age and the confining beds are the Hawthorn Formation of Miocene age and younger deposits.

The wide distribution of rocks of Eocene age beneath the continental shelf and Blake Plateau has been established by bottom cores along the continental slope, by test holes drilled offshore from Georgia and Florida, and by a deep well on Andros Island.

Five short cores of Eocene marl and chalk were obtained from the continental slope between Georges Bank and the Bahama Islands. (See pl. 2.) Two were taken near the middle of the continental slope about 90 miles southeast of Martha's Vineyard. One by Stetson (1949, p. 33) from a depth of 2,886 feet at lat 39°50′ N., long 70°48′ W. consisted of chalk and contained Foraminifera of Jackson age. The second one, from a depth of 3,280 feet at lat 39°50′ N., long 70°50′ W. (Northrop and Heezen, 1951, p. 397–398), consisted of *Globigerina* ooze and contained Foraminifera most nearly resembling fauna of Jackson age.

Two cores of Eocene marl have been taken near the base of the continental slope in the vicinity of the Hudson Canyon. Stetson (1949, p. 33) reported that a core from a small gully southwest of Hudson Canyon (lat 38°58′ N., long 72°28.5′ W.) at a depth of 5,133 feet contained a late Eocene fauna, rich in Radiolaria. Ericson, Ewing, and Heezen (1952, p. 502) recorded another core of Eocene marl from the base of the slope near Hudson Canyon (lat 39°12′ N., long 71°48′ W.) at a depth of 7,108 feet.

A single core of foraminiferal chalk has been recovered from the escarpment of the Blake Plateau (lat 29°49′ N., long 76°35′ W.) at a depth of 4,772 feet, by Ericson, Ewing, Wollin, and Heezen (1961, p. 236). They state that the age of the deposit, based on H. M. Bolli's examination of the planktonic Foraminifera, is late Eocene.

The U.S. Coast Guard test hole (well GA–88) off Georgia penetrated only 5 feet of upper Eocene rocks, the Ocala Limestone (McCollum and Herrick, 1964, p. C61–C62). In onshore wells in Chatham County, Ga., the Ocala is about 400 feet thick and consists of gray to buff fossiliferous limestone. It is the principal aquifer throughout much of eastern Georgia. No facies change was noted in the Ocala between the coastal wells and the offshore test hole.

The JOIDES test holes (FL–118 through FL–123, figs. 7 and 8) off Jacksonville, Fla., penetrated 48 to 550 feet of Eocene rocks. Only two test holes, 6 and 4 (FL–121 and FL–122), were drilled completely through the Eocene sequence. Test hole 6 (FL–121), about 136 miles offshore near the middle of the Blake Plateau, penetrated 63 feet of lower Eocene beds, 35 feet of middle Eocene beds, and 95 feet of upper Eocene beds. Test hole 4 (FL–122), about 221 miles offshore near the edge of the Blake Plateau, found only 53 feet of Eocene beds, all of which were assigned an early Eocene age.

Thicknesses in excess of 550 feet were penetrated in test holes 1 and 2 (FL–118 and FL–119), about 27 and 64 miles, respectively, offshore on the continental shelf. These thicknesses included only beds of late and middle Eocene age that were mainly porous medium- to coarse-grained clastic limestones and dolomitic limestones. Lower Eocene beds are present in onshore wells and in test holes 6, 3, and 4 (FL–121, FL–122, and FL–123) farther out on the Blake Plateau, which suggests that the two test holes on the continental shelf would have reached lower Eocene rocks if drilling had continued. Test hole 3, (FL–123) about 181 miles offshore on the outer Blake Plateau opposite Cape Kennedy, Fla., penetrated 85 feet of middle and lower Eocene rocks, composed mainly of limy sand, fine-grained limestone, chert, and clay. About 75 miles north on the outer Blake Plateau, test hole 4 (FL–122) penetrated 55 feet of lower Eocene ooze and chert. The lithology and thickness of lower, middle, and upper Eocene units in the JOIDES test holes suggest that Eocene rocks became less porous and thin seaward both internally and by loss of beds at the top.

The Bahamas Oil Andros Island 1 (well BA–2) in the Bahama Islands penetrated 4,000 feet of limestone, dolomitic limestone, and dolomite beds tentatively assigned to the Eocene. These beds of reeflike carbonates are present at depths of 1,950 to 5,950 feet and are very likely exposed or are thinly mantled in the nearby canyon wall of Northeast Providence Channel and the Tongue of the Ocean, both of which reach depths of 10,000 feet.

CHARACTERISTIC MICROFAUNA

Several of the species of Foraminifera that characterize lower Eocene rocks (Oldsmar Limestone) in northern and central Florida are *Pseudophragmina cedarkeysensis* Cole, *Coskinolina elongata* Cole, *Miscellanea nassauensis* Applin and Jordan, and *Helicostegina gyralis* Barker and Grimsdale. The last species is known to occur in the basal part of the middle Eocene (Cole and Applin, 1964, p. 14), as well as in the lower Eocene. Foraminiferal species of early Eocene age recovered from samples from wells drilled in the Middle Atlantic States (table 3) are *Eponides dorfi* Toulmin, *Spiroplectammina wilcoxensis* Cushman and Ponton, *Alabamina wilcoxensis* Toulmin, and *Pseudophragmina stevensoni* (Vaughan).

The middle Eocene rocks in the report area contain many foraminiferal species that are stratigraphically restricted to the unit but differ in their geographic distribution. Species that have been reported from wells in both Florida and Georgia are: *Asterocyclina monticellensis* Cole and Ponton, *Discorbis inornatus* Cole, *Gyroidina nassauensis* Cole, *Discorinopsis gunteri* Cole, *Amphistegina lopeztrigoi* D. K. Palmer, *Asterigerina texana* (Stadnichenko), *Cibicides westi* Howe, and *Lepidocyclina antillea* Cushman. The well-known definitive species *Eponides mexicanus* Cushman is widespread; it is present in middle Eocene beds at the depth of 2,572 feet in the Gulf Oil State of Florida Lease 826–G 1 in Florida Bay, Monroe County, Fla., and in middle Eocene beds at the depth of 2,610 feet in the Anchor Gas Dickinson 1 at Cape May, N.J. A few species that have been reported only from Florida are: *Dictyoconus americanus* (Cushman), *Fabularia vaughani* Cole and Ponton, *Lockhartia cushmani* Applin and Jordan, *Lepidocyclina cedarkeysensis* Cole, *Dictyoconus floridanus* (Cole), *Lituonella floridana* Cole, *Spirolina coryensis* Cole, and *Flintina avonparkensis* Applin and Jordan. The recurrence of *Dictyoconus floridanus* in the middle Eocene rocks in the Florida Peninsula has been mentioned in the discussion of rocks of late Trinity age.

Definitive species reported from upper Eocene rocks in Florida and Georgia and found in wells on the cross sections of this report are: *Lepidocyclina ocalana* Cushman, *Heterostegina ocalana* Cushman, *Nummulites floridensis* (Heilprin), *Nummulites mariannensis* (Vaughan), *Nummulites moodysbranchensis* (Gravell and Hanna), *Amphistegina cosdeni* Applin and Jordan, *Sphaerogypsina globula* (Reuss), *Asterocyclina nassauensis* Cole, and *Eponides jacksonensis* Cushman and Applin. *Bulimina jacksonensis* Cushman and *Uvigerina cocoaensis* Cushman are not only found in wells of Florida but are also found in the Anchor Gas Dickinson 1 (well NJ-25) at Cape May, N.J. Additional upper Eocene species in the Anchor Gas well are: *Marginulina cooperensis* Cushman at 1,420 feet, *Eponides cocoaensis* Cushman at 1,520 feet, and *Lenticulina virginiana* (Cushman and Cederstrom) at 1,520 feet. Cushman (1948, p. 228, 234, 240) reported the occurrence of *M. cooperensis*, *E. cocoaensis*, and *B. jacksonensis* in the Ohio Oil L. G. Hammond 1 well, Wicomico County, Md. Upper Eocene Foraminifera have been reported from several other wells in Maryland (Anderson, 1948, p. 85–86, 94; Shifflet, 1948, p. 25–26).

OLIGOCENE ROCKS

LITHOLOGY AND DISTRIBUTION

Oligocene rocks are present both at the surface and in the subsurface from Florida northward to the Cape Fear arch. They are not known at the surface north of the Cape Fear arch but may be present in the interval marked "Rocks of uncertain age, possibly Oligocene in part" in wells NC-7 and NC-14 in North Carolina (pls. 9 and 12). The Oligocene rocks are composed of limestone beds from 35 to 250 feet thick south of the Cape Fear arch. The rocks of uncertain age, possibly Oligocene in part, in wells NC-14 and NC-7 in North Carolina include sandy limestone, shale, and sandstone beds. Offshore, the Oligocene rocks have been recovered from the Blake Escarpment and penetrated by test holes on the continental shelf and Blake Plateau (fig. 7).

Oligocene chalk has been cored by Ericson, Ewing, Wollin, and Heezen (1961, p. 236) on the Blake Escarpment (lat 29°12.5′ N., long 76°49′ W.) at a depth of 7,019 feet. H. M. Bolli (in Ericson and others, 1961, p. 236) likened the assemblage of Foraminifera to that of the *Globigerina ciperoensis* Zone within the Cipero Formation of Trinidad (middle or late Oligocene).

The U.S. Coast Guard test holes (well GA-88) off Georgia were drilled through about 76 feet of limy sand of Oligocene age between depths of 90 and 166 feet below sea bottom. Oligocene rocks appear to grade from fossiliferous limestone in inland wells to sandy limestone in coastal wells and then into limy sandstone offshore. This facies change may be related to the development of the upwarp along shore mapped on a Miocene limestone by McCollum and Counts (1964, pl. 1)

Considerable thicknesses of Oligocene rocks were drilled in the six JOIDES test holes off Jacksonville, Fla. (figs. 7, 8). The sequences recorded range from 30 feet of calcareous clay in test hole 1 (FL-118) on the continental shelf to 532 feet of calcareous silt and limestone in test hole 5 (FL-120) on the slope. Only 94 feet of foraminiferal sand was found in test hole 4 (FL-122) on the outer Blake Plateau.

CHARACTERISTIC MICROFAUNA

The Oligocene rocks in Florida and Georgia contain closely similar faunal populations. Among the larger Foraminifera, *Heterostegina antillea* Cushman, and *Miogypsina gunteri* Cole are probably the most important faunal elements in southern Florida, and *Lepidocyclina (Eulepidina) undosa* Cushman and *M. gunteri* have also been reported from wells in the Georgia Coastal Plain. Of the smaller foraminiferal species, *Pararotalia mecatepecensis* (Nuttall) and *Pararotalia byramensis* (Cushman) are probably the most abundant and the most widely distributed. Specimens of *Asterigerina subacuta* Cushman and *Nonionella leonensis* Applin and Jordan are common.

An unusual but characteristic feature of the Oligocene rocks in Florida and Georgia is the common occurrence of specimens of *Dictyoconus floridanus* (Cole) and *Discorinopsis gunteri* Cole. Both are diagnostic fossils of the upper middle Eocene Avon Park Limestone in the Florida Peninsula. Their recurrence in the Oligocene of Florida and Georgia has been attributed to secondary deposition by Cole (1941, p. 12–16), although Applin and Applin (1944, p. 1682–1683), among others, suggest that these fossils may be indigenous. Because they are generally accompanied by many specimens of *Pararotalia mecatepecensis* and other typical Oligocene species, the age of the containing beds is readily determinable.

Cole and Applin (1961, p. 130-131) discussed the stratigraphic distribution of some larger Foraminifera in Florida; they showed that certain species of *Miogypsina* are confined to the upper Oligocene, certain other species are confined to the lower Miocene, possibly the basal Tampa Limestone, and some species are common in both the upper Oligocene and lower Miocene. Consequently, the occurrence of the genus *Miogypsina* alone is not indicative of either stratigraphic unit.

Common species of smaller Foraminifera present from 920 to 1,080 feet in the Anchor Gas well at Cape May, N.J., are: *Cibicides floridanus* (Cushman), *Nonion mediocostatum* (Cushman), *Nonion pizarrense* W. Berry, *Spiroplectammina mississippiensis* (Cushman), *Textularia mayori* Cushman, and *Uvigerina subperegrina* Cushman and Kleinpell.

MIOCENE ROCKS

LITHOLOGY AND DISTRIBUTION

Only a few large patches of Miocene deposits are exposed on the surface of the Coastal Plain south of the Cape Fear arch. These include areas of several thousand square miles in South Carolina and along the Gulf of Mexico side of Florida. North of the Cape Fear arch, broad flat-lying Miocene deposits blanket the Coastal Plain from North Carolina across the Salisbury embayment to the northeastern tip of New Jersey. At Cape Fear, Miocene marl beds form the nearshore shoals termed "Black Rocks" (Pearse and Williams, 1951).

Subsurface Miocene rocks along the line of section *A–B* (pl. 9) are about 800 feet thick in the Florida Keys (well FL–104), less than 60 feet thick at the Peninsular arch (well FL–57), and about 350 feet thick in the Southeast Georgia embayment (well GA–87). They wedge out in South Carolina on the flank of the Cape Fear arch. The lithology changes gradually from chalky coquinoidal limestone in southern Florida to dark sandy limestone and claystone in South Carolina. North of the Cape Fear arch, the Miocene rocks reach a thickness in excess of 1,300 feet at Cape Hatteras (well NC–14) and about 1,400 feet in the center of the Salisbury embayment (well MD–14). Miocene rocks are not delimited in the Tertiary sequence in well NJ–26 in northeastern New Jersey and are not present in well NY–6 on Long Island. The lithology grades northward from sandy limestone and sandstone in North Carolina to clay, sand, and gravel in New Jersey.

Lower Miocene rocks are separated from middle and upper Miocene rocks in wells NC–14 and NC–7 in North Carolina on section *A–B* (pl. 9), but they are not identified in well MD–14 in Maryland and well NJ–25 in New Jersey. Lower, middle, and upper Miocene rocks are separated on section *G–H* (pl. 12) in North Carolina. Local formation names—Calvert, Choptank, St. Marys, and Yorktown—are applied to the shallow subsurface Miocene rocks in Maryland on section *E–F* (pl. 11).

The sea bottom off the Atlantic coast has yielded cores and samples of Miocene deposits at many places. Miocene strata beneath the continental shelf, Blake Plateau, and Bahama Islands have been penetrated and sampled by the test holes off Georgia and Florida and by wells drilled on the Bahama Islands (BA–2 and BA–3).

Miocene rocks have been recovered in 19 tows and cores along the Atlantic coast. These have come from submarine canyons off Georges Bank, from shoals on the Cape Fear arch, and from the top and edge of the Blake Plateau.

Highly indurated, greenish, fine-grained sandstone of middle to late Miocene age was found in place along the east wall of Lydonia Canyon (lat 40°23′ N., long 67°38.5′ W.) at a depth of 928 feet. This location is well up the continental slope, just beneath the edge of the continental shelf. Similar sandstone has been dredged up as talus in two places along the east side of Hydrographer Canyon (lat 40°09′ N., long 69°03′20″ W.; depth, 1,319 to 1,53° feet) and in one place in Corsair Canyon (lat 40°21′20″ N., long 66°08′20″ W.; depth, 1,617 to 1,787 feet) (Stetson, 1949, p. 11, 33).

Stetson and Pratt (Elazar Uchupi, written commun., 1963) dredged 10 samples of semiconsolidated and consolidated *Globigerina* and pteropod ooze from the top of the Blake Plateau, three samples of which contained fossils. Ruth Todd identified Foraminifera assemblages that are either fossil (Miocene) or a mixture of Miocene and Holocene forms. They are from lat 31°58′ N., long 77°18.5′ W., at a depth of 2,427 feet; lat 31°48′ N., long 77°35′ W., at a depth of 2,096 feet; and lat 30°58′ N., long 78°31′ W., at a depth of 2,657 feet.

Three cores of Miocene rocks have come from the edge of the Blake Plateau. One from lat 28°35.5′ N., long 77°10′ W., at a depth of 3,296 feet, consisted of clayey sand, and it contained a fauna ranging in age from late Miocene at the bottom to Holocene at the top, through a thickness of only 14.5 feet (Ericson and others, 1961, p. 235). Because the core bore no evidence of slumping, it is assumed that sedimentation from late Miocene time to Holocene is represented in this short core. Another core, at lat 30°04′ N., long 76°57′ W., from a depth of 3,542 feet, consisted of 21.7 feet of Miocene chalk and 5.1 feet of Pleistocene and Holocene ooze (Ericson and others, 1961, p. 236). The third core, from lat 30°23′ N., long 76°35′ W., at a depth of 6,117 feet, was made up of 10.7 feet of pyritic clay of Miocene age and 1.8 feet of *Globigerina* and pteropod ooze of Pleistocene and Holocene age.

A single specimen of Miocene marl (Chipola Formation) has been reported by Bush (1951) from the sea bottom in the western part of the Straits of Florida. It was accidently dredged from a depth of 2,250 feet at lat 24°10′ N., long 81°31′ W., and it is thought to have come from an outcrop.

Numerous samples recovered by Ericson, Ewing, Wollin, and Heezen (1961, p. 234–241) contained a mixed assemblage of Miocene and Pliocene microfossils. These rocks were assigned a general Neogene age but are thought most likely to be late Miocene in age. Four of these cores were marcasitic silt from the Hudson Canyon near the base of the continental slope at depths of 10,922 to 12,530 feet, and two cores were *Globigerina* ooze from the Blake Escarpment (lat 28°42′ N., long 76°46′ W., and lat 28°26′ N., long 76°40′ W.) at depths of 4,133 feet and 5,674 feet. Three cores from the walls of Northeast and Northwest Providence Channels in the Bahamas found Neogene green marcasitic silt, hydrotroilite, and *Globigerina* ooze beneath 3.6 to 7.1 feet of Pleistocene and Holocene *Globigerina* ooze.

A Miocene sequence, 80 feet thick, was drilled in the U.S. Coast Guard test hole (GA–88) off Georgia. McCollum and Herrick (1964, p. C63) subdivided this into lithologic units of early, middle, and late Miocene age. They report the lower Miocene unit to be a fossiliferous phosphatic sandy conglomeratic limestone, 12 feet thick. Unconformably overlying this limestone are beds of pale-green phosphatic sandy clay and clayey sand, 50 feet thick, that are considered to be middle Miocene in age. The upper Miocene unit, 18 feet thick, consists of sand, clay, and a layer of sandy dolomitic limestone. The Miocene sequence thins seaward to the test hole, mainly at the expense of the upper Miocene beds.

Miocene rocks were drilled and cored in four of the six JOIDES test holes off Jacksonville, Fla. (figs. 7, 8). Test holes 1 (FL–118) and 2 (FL–119), on the continental shelf, recorded 238 and 258 feet, respectively, of phosphatic silt and clay of Miocene age. Middle Miocene deposits are missing at test hole 2 (FL–119) on the outer continental shelf, and the unconformity is marked by a phosphate pebble zone. Test hole 5 (FL–120) near the top of the continental slope and test hole 6 (FL–121) near the middle of the Blake Plateau did not record any Miocene rocks but went from post-Miocene deposits directly into a thick Oligocene sequence. A Miocene sequence, 260 feet thick and composed mainly of calcareous ooze and some ash beds, was logged in test hole 3 (FL–123) on the outer Blake Plateau. In test hole 4 (FL–122), much farther north on the outer Blake Plateau, only beds of early Miocene age were recognized; these consisted chiefly of foraminiferal sand.

A vuggy to cavernous limestone and dolomite sequence, 1,420 feet thick, is present in well BA–2 on Andros Island in the Bahamas. A water well (BA–3) on the nearby Eleuthera Island is reported to have drilled 250 to 300 feet into similar rocks of Miocene age. In general, the Miocene deposits seem to be at or near the top of the continental shelf, the outer Blake Plateau, and the Blake Escarpment. They are absent from the Florida-Hatteras slope and the innermost Blake Plateau where the JOIDES test holes were drilled off Jacksonville, Fla.

CHARACTERISTIC MICROFAUNA

The foraminiferal faunas of the Miocene rocks of the Atlantic and eastern Gulf Coastal Plain have been described by Cushman and Cahill (1933), Puri (1953), Cushman (1948, p. 214–225), and by Dorsey (1948), among others. Only a few of the most common diagnostic species of Miocene Foraminifera are shown in table 3, and most of these faunal data relate to wells in the southern part of the Florida Peninsula. However, some data are available on Miocene Foraminifera from a well in Maryland and from the Anchor Gas Dickinson 1 well in New Jersey.

A few of the species of smaller Foraminifera present in wells in Florida are: *Globorotalia menardii* (d'Orbigny), *Buccella mansfieldi* (Cushman), *Lenticulina americana* (Cushman), *Hanzawaia concentrica* (Cushman), *Elphidium chipolense* (Cushman), *Peneroplis bradyi* Cushman, *Amphistegina chipolensis* Cushman and Ponton, *Textulariella barretti* (Jones and Parker), *Archaias floridanus* (Conrad), and *Sorites?* sp. Cushman and Ponton.

Several important species of larger Foraminifera are: *Miogypsina antillea* (Cushman), *Miogypsina staufferi* Koch, and *Lepidocyclina (Eulepidina) yurnagunensis* Cushman.

Cole and Applin (1961, p. 130–131) discussed the stratigraphic distribution of some larger Foraminifera in Florida; they showed that certain species of *Miogypsina* are confined to the upper Oligocene, certain other species are confined to the lower Miocene, possibly the basal Tampa Limestone, and some species are common in both the upper Oligocene and lower Miocene. Consequently, the occurrence of the genus *Miogypsina*, alone, is not indicative of either stratigraphic unit.

Common species of smaller Foraminifera present from 920 to 1,080 feet in the Anchor Gas Dickinson 1 well at Cape May, N.J., are: *Cibicides floridanus* (Cushman), *Nonion mediocostatum* (Cushman), *Nonion pizarrense* W. Berry, *Spiroplectammina mississippiensis* (Cushman), *Textularia mayori* Cushman, and *Uvigerina subperegrina* Cushman and Kleinpell.

TERTIARY AND QUATERNARY ROCKS

POST-MIOCENE ROCKS

Pliocene, Pleistocene, and Holocene deposits along the Atlantic coast are represented by beds of marl, clay, sand, and gravel that cannot be readily separated on an age basis in the scattered wells of these cross sections. These are treated as undifferentiated post-Miocene rocks.

The thickest sequence of post-Miocene rocks on these cross sections is 530 feet thick and is present on Andros Island (well BA–2, pl. 16). Thicknesses in excess of 250 feet are present in wells on the Florida Keys (wells FL–109 and FL–111, pl. 16). The rocks are predominantly marl in Florida and the Bahamas. Along section *A–B* (pl. 9), the thickness exceeds 200 feet only in the Salisbury embayment (well NC–7 and well MD–14). Sand and gravel beds predominate in this area.

The U.S. Coast Guard test holes (GA–88) off Georgia revealed very thin undifferentiated post-Miocene deposits on the shelf there. Fossiliferous sand, only 10 feet thick and possibly all Holocene in age, was logged above the Miocene rocks. The six JOIDES test holes off Jacksonville, Fla., (fig. 7) penetrated thicknesses of post-Miocene deposits ranging from 220 feet in test hole 5 (FL–120), 76 miles offshore beneath the Florida-Hatteras slope (fig. 7), to 20 feet in test hole 6 (FL–121), 136 miles offshore near the middle of the Blake Plateau (fig. 8). The lithologies ranged from silty fine- to medium-grained quartzose partly shelly sand beneath the continental shelf to foraminiferal-pteropod limy sand and silty foraminiferal ooze beneath the Blake Plateau. The thickest deposits in this offshore area in post-Miocene time appear to have been silty limy sand just seaward from the edge of the present-day continental shelf.

Stetson (1936, p. 350; 1949, p. 12) dredged a friable very fine grained greensand of probable Pliocene age from depths of 2,099 to 1,679 feet up the east wall of Lydonia Canyon (lat 40°27′00″ N., long 67°39′ 30″ W.). Cushman (1936, p. 414) thought the greensand to be late Tertiary in age because the Foraminifera are warm-water forms that have not been present in the area since the Pleistocene.

Samples of hard green silt of either late Pliocene or Pleistocene age have been dredged by Stetson (1949, p. 13) from Oceanographer Canyon (lat 40°24′30″ N., long 68°07′30″ W.) at depths of 2,055 to 1,574 feet, from Gilbert Canyon (lat 40°29′45″ N., long 67°51′15″ W.) at depths of 1,968 to 1,738 feet, and from Lydonia Canyon (lat 40°27′00″ N., long 67°39′00″ W.) at depths of 2,099 to 1,679 feet. Some Foraminifera in these samples had the same late Pliocene resemblances that were found in the greensand referred to the Pliocene, but the rest of the assemblage suggested a distinctly colder sea environment. In addition, there was a greater proportion of living species in the green silt than in the greensand. Cushman (1936, p. 414) thought the green silt to be younger than the greensand and therefore late Pliocene or Pleistocene. Ericson, Ewing, Wollin, and Heezen (1961, p. 234) thought it improbable that the green silts from canyons on Georges Bank were Pleistocene because the lithology and fauna differ strikingly from sediments of known Pleistocene age found elsewhere in the Atlantic.

QUATERNARY BOTTOM DEPOSITS

Bottom deposits along the Atlantic coast were first known from ship soundings, storm deposits on the beaches, and sediments accidently dredged in fishing and anchoring operations. Pebbles and boulders of granite, gneiss, and schist found in nets and lobster traps gave early evidence of glacial debris on bottom in the fishing grounds. Pourtales (1850, 1854, 1871, 1872) and Bailey (1851, 1854) produced much of the early information about the sea bottom along the Atlantic coast. As early as 1879, the U.S. Coast and Geodetic Survey (Mitchell, 1879) published bottom studies of the Gulf of Maine pointing out the presence of pebbles and small stones on the top of Georges Bank. Agassiz (1888, p. 260–293) discussed submarine deposits and presented a map (1888, fig. 191) of bottom sediments in the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean. Later publications concerning bottom sediments along the Atlantic coast are numerous and detailed. Uchupi (1963) has summarized those published prior to 1963. More recent ones include Moore and Curray (1963), Schlee (1964), Gorsline (1963), Pilkey (1964), Uchupi (1964), Stewart and Jordan (1964), Emery, Merrill, and Trumbull (1965), Emery, Wigley, and Rubin (1965), Nota and Loring (1964), Merrill, Emery, and Rubin (1965), and Pratt and McFarlin (1966).

Numerous samples of Pleistocene and Holocene materials have been dredged by Stetson (1949, p. 15–21) from Corsair Canyon on the north to Norfolk Canyon on the south. (See pl. 2 and fig. 2.) F. B. Phleger, Jr. (in Stetson, 1949, p. 53), reported a subarctic foraminiferal fauna beneath the Holocene temperate fauna and assigned a Wisconsin age to the lower sediments in the cores. Stetson (1949, p. 15) pointed out that these glacial sediments are mainly pink and gray clay (color when damp) and that the overlying Holocene sediments are mainly coarser grades of greenish silt.

Ericson, Ewing, Wollin, and Heezen (1961, p. 202–228) have presented much later information on the lithology, particle-size distribution, and areal distribution of Pleistocene and Holocene sediments in both the Atlantic and Caribbean regions. They concluded from variations in the planktonic Foraminifera in 108 cores and by extrapolation of rates of sediment accumulation determined by 37 radiocarbon dates in 10 cores that the last period of climate comparable with the present ended about 60,000 years ago and that a faunal change caused by a warming climate, and probably corresponding to the beginning of postglacial time, began about 11,000 years ago.

In addition to the Pleistocene silts and clays found in cores, patches of Pleistocene gravel are present on the continental shelf from Cape Hatteras northward to Nova Scotia (Uchupi, 1963, fig. 94.1). Shepard, Trefethen, and Cohee (1934, p. 294) reported that pebbles and granules of granite and gneiss predominate in the gravels on Georges Bank and that quartzite and felsite are common. Wigley (1961, p. 183, figs. 2, 8) showed the bottom sediments of Georges Bank to be mainly well-sorted sands on much of the bank and less well-sorted gravel in the channels and on the northern and eastern parts of the bank. Schlee (1964) recently pointed out the possible economic value of extensive fluvial gravel deposits off New Jersey that were first noted by Shepard (1932, fig. 1, p. 1020).

Holocene sediment on the channel floor in the Tongue of the Ocean (see fig. 2) is poorly sorted unconsolidated ooze composed largely of tests of planktonic Foraminifera and pteropods and reef detritus (Miami University Marine Laboratory, 1958; Nesteroff and Rusnak, 1962; Athearn, 1962a,b; Busby, 1962a,b,c). Radiocarbon measurements of samples gave ages ranging from 300±70 years to 29,120±850 years (Östlund and others, 1962; Rusnak and others, 1963). More than 50 percent of the sediment column sampled in the central and cul-de-sac areas of the Tongue of the Ocean gave evidence of turbidity current deposition, whereas samples from the flanks of the platform suggested that the sediment particles there settled from the overlying water. Apparently turbidity currents originate on the upper flanks of the platform, flow down gullies at relatively high velocities, and spread the sediment locally on the lower channel floor.

The areal distribution of bottom sediments of Quaternary age on the continental margin off the Eastern United States has been compiled on a map and discussed in a report by Uchupi (1963). The complete list of references dating from 1850 through 1962 attached to the report can be useful for anyone seeking more detailed information. Uchupi (1963, p. C132) summarizes the areal distribution as follows:

"Relict glacial sediments blanket most of the continental shelf north of Hudson Canyon, and relict fluvial or nearshore quartzose sands occur throughout most of the shelf from Hudson Canyon to Cape Hatteras. Calcareous organic and authigenic sediments are the dominant sediment types on the continental margin farther south. Present-day detrital sediments are restricted to a narrow zone near shore, to the outer edge of the shelf off Long Island, and to the continental slope of Cape Hatteras. The predominance of relict and calcareous sediments indicates that present rate of deposition of detritus derived from land is very low over most of the continental shelf."

PETROLEUM POTENTIAL

HYDROCARBONS AND SOURCE BEDS

Oil and gas have not been discovered in commercial quantities in the Atlantic Coastal Plain and Continental Shelf, but three accumulations have been found along the eastern edge of the Gulf Coastal Plain in the southwestern part of the Florida Peninsula. These are the Sunniland field in Collier County, the Forty-Mile Bend field in Dade County, and the Felda field in Hendry County (pl. 1).

Sunniland field, Collier County, Fla., was discovered in 1943 after intensive exploration with seismograph, gravity meter, and core drilling (Hughes, 1944,

p. 804). The early history of this field has been described by Gunter (1946, 1950), Puri and Banks (1959), and Roberts and Vernon (1961, p. 218). The discovery well, the Humble Oil and Refining Gulf Coast Realties 1, in sec. 29, T. 48 S., R. 30 E., produced 110 barrels of 20° API. gravity oil and 475 barrels of salt water a day by pumping from depths of 11,613 to 11,626 feet in the Sunniland Limestone of Trinity (Lower Cretaceous) age. The field was developed by drilling a total of 20 wells between 1943 and 1950. Thirteen wells were successful, with initial production tests ranging from 97 to 527 barrels of oil a day.

The reservoir, the Sunniland Limestone, lies "above the thick anhydrite bed in the Trinity, which is equivalent to some part of the Glenrose formation of Texas" (Jordan, 1954, p. 375). Puri and Banks (1959, p. 123) state that the trap is formed by a small fold not evident in the rocks above 5,000 feet. They ascribe 150 feet of relief to the structure at a depth of 11,500 feet, but they explain that tilting to the northeast by 50 feet per mile has reduced the fold closure to only 36 feet.

According to Roberts and Vernon (1961, p. 218), two of the producing wells had been abandoned by 1960, and the remaining 11 wells pumped an average of 96 barrels per day. They state that the cumulative production for the Sunniland field was 6,089,470 barrels at the close of 1960 and that the best well had produced more than 800,000 barrels and the average well, more than 400,000 barrels. On March 1, 1965, Sunniland field was producing 1,800 barrels of oil and 3,600 barrels of salt water per day by pumping, and the cumulative production reached 8,475,830 barrels of oil (Kornfeld, 1965, p. 173). Pumping costs have been relatively low because of an efficient water drive.

Forty-Mile Bend field, Dade County, Fla., was discovered in 1954 about 50 miles southeast of the Sunniland field after both reflection and refraction seismic surveys had been made in the area (Powell and Culligan, 1955, p. 1008). The discovery well, the Gulf Refining Wiseheart-State of Florida 1, sec. 16, T. 54 S., R. 35 E., reached a total depth of 11,557 feet and was completed in the Sunniland Limestone of Trinity (Lower Cretaceous) age. The initial production was 76 barrels of 20° API. gravity oil and 96 barrels of salt water from depths of 11,322 to 11,339 feet. A second producing well completed with an initial production of 112 barrels per day was followed by three dry holes that delimited the small field. The field produced a total of 32,888 barrels of oil before being abandoned (Roberts and Vernon, 1961, p. 218).

Felda field, Hendry County, Fla., about 15 miles northwest of the Sunniland field, was discovered in 1964 near the Town of Felda. The discovery well was the Sun Oil Red Cattle 2 in sec. 32, T. 45 S., R. 29 E. Its initial flow was 111 barrels of 24.5° API. gravity oil from the interval of 11,471 to 11,485 feet in the Sunniland Limestone (Gardner, 1964). A second producing well was drilled to a total depth of 11,495 feet about 1¼ miles southeast of the discovery, and a third successful well was drilled about ¼ mile southeast of the first well. The third well, which is the most productive so far, had an initial pumping potential of 336 barrels of oil and one barrel of salt water. The cumulative production of Felda field reached 42,903 barrels of oil on March 1, 1965 (Kornfeld, 1965, p. 173).

Although petroleum has been produced in three countries of southern Florida, little evidence of hydrocarbons has been found in the many wells drilled in northern Florida. The St. Mary's River Oil Hilliard Turpentine 1 (well FL–51, table 1) in Nassau County was reported to have asphaltic staining in the Cedar Keys Limestone of Paleocene (Tertiary) age, in limestones of Taylor (Upper Cretaceous) age, and in the lower part of the Atkinson or Tuscaloosa Formation of Woodbine (Upper Cretaceous) age (Cole, 1944, p. 97–100). However, these shows must be regarded as doubtful in view of the State Geologist's statement (Vernon, 1951, p. 238) that "shows of oil and gas are unknown throughout the northern Peninsula."

Indications of hydrocarbons in two wells in southwestern Georgia have been reported to the Georgia Department of Mines, Mining, and Geology. Oil and gas shows at unspecified depths in the J. R. Sealy Spindle Top 3, Seminole County (well GA–65, table 1), were recorded without confirmation. This well was abandoned in Lower Cretaceous rocks at a total depth of 7,620 feet. State records of the second well, the J. R. Sealy Fee 1 (well GA–67, table 1), Decatur County, show that an unknown quantity of gas and hot water flowed from an Upper Cretaceous sandstone at a depth of 3,005 feet. The calculated heating value for this gas was only 754 Btu (British thermal units) per cubic foot. The analysis of the gas is:

	Percent
Methane	74.2
Nitrogen	24.1
Carbon dioxide	.6
Argon	.4
Helium	.3
Oxygen	.2
Hydrogen	.1
Ethane	.1
Cyclopentane	Trace

Seeps and shows of oil have been reported in central Georgia. The seeps occur in the vicinity of Scotland, Telfair County, where oil of about 30° API. gravity and gas come to the surface in a swampy area (Hull and Teas, 1919). The surface beds are sands and clays of probable Oligocene age in an area that may be structurally high, according to Hull and Teas (1919, p. 11). The oil shows in wells in Coffee and Telfair Counties have been recorded, without confirmation, in the files of the Georgia Department of Mines, Mining, and Geology. A show of oil in a sandstone of Taylor age was reported in a Carpenter Oil Co. well about 20 miles north of Douglas in Coffee County, and fluorescence and staining was reported in sidewall cores taken from sandstones of Lower Cretaceous(?), Woodbine, and Austin age in the Parsons and Hoke Henry Spurlin 1 (well GA–33, table 1) in Telfair County.

A few oil seeps and surface indications of gas in North Carolina have been reported to the North Carolina Department of Conservation and Development but none have been substantiated. Subsurface evidence for the presence of hydrocarbons is also very meager. Scattered shows of oil were reported by the driller in cuttings and sidewall cores of the F. L. Karsten Laughton 1 (well NC–47, table 1) located near the coastline in Carteret County, but these were not confirmed by later studies of the samples and cores. "Showings of a gas" of unspecified composition in Lower Cretaceous or possibly Triassic rocks between depths of 3,170 and 4,050 feet in the DuGrandlee Exploration Foreman 1 (well NC–4, table 1) in Camden County were reported to Richards (1954, p. 2565).

A minor amount of gas was produced from shallow wells in the Coastal Plain of Maryland and used as fuel for a period of 2 years near the turn of the century (Clark, Matthews, and Berry, 1918, p. 320). These wells, located in the vicinity of Parsonburg and Pittsville in Wicomico County, were less than 100 feet deep. The gas produced had a high nitrogen content (77.96 percent) and a low methane content (19.86 percent). It was concluded that this gas was marsh gas and had its origin in a buried swamp. No gas was reported below these shallow depths. Reference to well MD–12 on section *E–F* (pl. 11) of this report suggests that the gas came from Pleistocene or Pliocene alluvium.

Traces of hydrocarbons were detected at a depth of 300 feet in a water well at Cape May, N.J., and in another water well at Atlantic City, by F. J. Markewicz, of the New Jersey Geological Survey, according to M. E. Johnson (Petroleum Week, 1958, p. 23). A similar occurrence in another water well near Cape May was reported to him by an oil company geologist.

Source beds for hydrocarbons, generally regarded to be marine shales, marls, and limestones in about that order of importance, are scattered throughout the stratigraphic sequence beneath the Coastal Plain, but they only reach considerable thicknesses beneath the Florida Peninsula and in a narrow band along the coast from New Jersey to North Carolina. Thick limestone, marl, and dolomite beds make up most of the Cretaceous and Tertiary rocks in Florida and southern Georgia; shale, marl, and limestone beds make up more than half of the sequence at Cape Hatteras and in coastal Maryland. Offshore, much thicker marine deposits, particularly in the Lower Cretaceous and older rocks, may be expected beneath the continental shelf. Inland, the rocks with more continental aspects probably are more likely to be sources of dry gas than of oil.

Emery (1963, p. 6; 1965c, p. C159–C160) has suggested that fine-grained organic-rich source beds may be interbedded with coarse-grained turbidites at the base of the continental slopes of the world and that possibly large reserves of petroleum will be found there when cheap and effective methods of drilling and extraction at such water depths are developed. If this is established, a band of sedimentary rocks along the slope and rise from Newfoundland to Florida will deserve consideration for petroleum exploration.

RESERVOIRS AND FLUIDS

Reservoirs are thick and numerous beneath the Atlantic Coastal Plain. Sandstones of Late Cretaceous age and sandstones and limestones of Tertiary age supply fresh water to most of the communities on the Coastal Plain. The Upper Cretaceous sandstones, especially those of Woodbine and Austin age that are several hundred feet thick, yield large quantities of potable water for several tens of miles downdip from their outcrops. Sandstones of the Raritan (Woodbine age) and Magothy (Austin age) Formations cropping out along the Fall Line in New Jersey have porosities as large as 46 and 40 percent respectively (Barksdale and others, 1958, p. 98). Generally, the Upper Cretaceous sandstones contain salt water near the coast, although fresh-to-brackish water is present in the Raritan Formation along the New Jersey coast (Gill and others, 1963, p. 20) and the southern shore of Long Island (Perlmutter and Crandell, 1959, p. 1068). The Raritan sands yield from 200 to 2,000 gallons a minute in wells on Long Island (Perlmutter and Crandell, 1959, p. 1069, 1072), which suggests excellent porosity and permeability. The shallow Tertiary sandstones and limestones, particularly those of late Eocene, Oligocene, and Miocene age, yield potable water from their outcrops to the seacoast. The Ocala Limestone (upper Eocene) is an especially extensive fresh-water artesian aquifer in Florida and Georgia and is known to discharge fresh water in submarine springs off Florida, where indicated on plate 2 (Stringfield and Cooper, 1951, p. 61).

At present, no deep wells have been drilled on the Atlantic Continental Shelf, so the probability of adequate reservoirs for petroleum accumulations can be judged only from the wells drilled along the coast and in the Bahama Islands. Two wells, the Standard Oil of New Jersey Hatteras Light 1 at Cape Hatteras, N.C., and the Bahamas Oil Andros Island 1 on Andros Island, Bahama Islands, are particularly significant. The first penetrated 9,878 feet of predominantly marine clastics and some thick limestone sequences; the latter penetrated 14,585 feet of marine limestone and dolomite beds. Thick sandstone reservoirs are present in the Cape Hatteras well, whereas thick porous-to-cavernous limestone and dolomite beds are reservoirs in the Andros Island well.

HATTERAS LIGHT WELL

The drilling and testing of the Standard Oil of New Jersey Hatteras Light 1 (well NC–14, table 1) has been reported by Spangler (1950, p. 104–108). This well penetrated ten major sandstone bodies, numerous thin sandstone beds, and a few porous limestone and dolomite beds. The major sandstone bodies, ranging from 93 to 728 feet in thickness, are present at depths of (1) 9,150 to 9,878 feet [earliest Late Jurassic or Early Cretaceous (Neocomian) age], (2) 8,585 to 8,750 feet [Early Cretaceous (Trinity?) age], (3) 8,240 to 8,500 feet [Early Cretaceous (Trinity?) age], (4) 7,665 to 7,758 feet [Early Cretaceous (Trinity?) age], (5) 7,018 to 7,360 feet [Early Cretaceous (Fredericksburg?) age], (6) 6,475 to 6,585 feet [Early and Late Cretaceous (Washita?) age], (7) 4,800 to 5,580 feet [Late Cretaceous (Woodbine) age], (8) 3,660 to 4,288 feet [Late Cretaceous (Austin) age], (9) 2,385 to 2,755 feet [Tertiary (early Eocene) age], and (10) 575 feet to 995 feet [Tertiary (Miocene) age]. The three most promising reservoirs for petroleum—sandstones of Fredericksburg(?), Washita(?), and Austin age—were cored and tested. The porosity and permeability determinations are given in table 4, which is adapted from Spangler (1950).

The principal potential petroleum reservoir of Fredericksburg age, 7,018 to 7,360 feet in depth, consists mainly of light-gray, fine- to coarse-grained sandstone interbedded with some thin beds of light-gray, fine-grained, silty sandstone and white, slightly oolitic, finely crystalline limestone. In the upper part, porosities range from 12.8 to 32.6 percent and permeabilities from 2.1 to 2,080 millidarcys (table 4). A drill-stem test (test 2, pl. 12) taken opposite the interval between 7,018 and 7,027 feet with the tool open 10 minutes recorded a bottom-hole pressure of 3,100 psi (pounds per square inch) and yielded 7 barrels of mud and muddy salt water and 51 barrels of salt water. The analysis (Spangler, 1950, p. 106) of water from this test is:

	Parts per million
Sodium	42, 858
Calcium	5, 856
Magnesium	1, 258
Sulphate	840
Chloride	79, 460
Bicarbonates	47
Carbonates	0

The principal reservoir of Washita age, 6,487 to 6,585 feet in depth, is a 98-foot sequence of sandstone beds grading from medium grained at the top to fine grained and silty at the bottom. The porosities of these beds range from 2.5 to 33.9 percent and the permeabilities from 0 to 2,103 millidarcys. A drill-stem test (test 1, pl. 12) with packers set at 6,474 and 6,483 feet and the tool open 10 minutes recovered 6 barrels of mud and muddy salt water, and 55 barrels of salt water. Total depth was 6,512 feet during the test and the bottom-hole pressure was recorded as 2,900 psi. The analysis (Spangler, 1950, p. 106) of water from this test is:

	Parts per million
Sodium	36, 097
Calcium	7, 100
Magnesium	1, 302
Sulphate	840
Chloride	71, 335
Bicarbonates	99
Carbonates	0

Rocks of Woodbine age, which include the more or less equivalent Atkinson, Tuscaloosa, and Raritan fresh-water aquifers of the Coastal Plain, have poor reservoir characteristics in the Hatteras Light well. This interval is made up of thin, silty, fine-grained sandstones interbedded with sandy shale and a few fossiliferous limestone layers. Updip in the Standard Oil North Carolina Esso 2 (well NC–7) in Pamlico Sound, the interval is about the same thickness, roughly 1,300 feet, but it consists of thick sandstone beds interbedded with thin layers of gray shale and some limestone lenses. Generally, the sandstone beds

TABLE 4.—*Porosity and permeability determinations for reservoirs in the Standard Oil of New Jersey Hatteras Light 1*

[Adapted from Spangler, 1950, p. 107]

Age of sandstone rocks	Core No.	Depth (feet)	Recovery (feet)	Porosity (percent)	Permeability (millidarcys)
Late Cretaceous (Austin)	51	3, 657–3, 666	1. 5	41. 2	----------
	52	3, 693–3, 703	3	27. 6	5. 7
	53t	3, 827–3, 837	3	31. 8	4. 5
	53b	3, 827–3, 837	3	15. 9	5. 7
	54	3, 930–3, 940	0. 8	39. 2	----------
	55	4, 042–4, 052	4. 5	32. 2	5. 0
	56	4, 152–4, 162	10	40. 9	----------
	57	4, 275–4, 285	4	28. 0	5. 4
Late and Early Cretaceous (Washita?)	77	6, 487–6, 497	10	27. 0	65. 0
	77	6, 487–6, 497	10	33. 7	73. 6
	77	6, 487–6, 497	10	33. 2	70. 0
	78	6, 497–6, 507	9	24. 7	----------
	78	6, 497–6, 507	9	30. 2	184
	78	6, 497–6, 507	9	3. 1	0
	79	6, 507–6, 512	5	27. 2	58. 3
	79	6, 507–6, 512	5	26. 9	----------
	80	6, 512–6, 522	7. 5	29. 3	----------
	80	6, 512–6, 522	7. 5	27. 8	----------
	80	6, 512–6, 522	7. 5	32. 1	----------
	81	6, 522–6, 532	4	19. 8	118
	81	6, 522–6, 532	4	25. 9	191
	82	6, 532–6, 542	3	27. 8	247
	83	6, 542–6, 552	7	28. 9	1, 546
	84	6, 552–6, 562	10	26. 4	999
	84	6, 552–6, 562	10	33. 6	----------
	84	6, 552–6, 562	10	33. 9	2, 103
	85	6, 562–6, 572	10	28. 0	142
	85	6, 562–6, 572	10	31. 4	1, 024
	86	6, 572–6, 581	7	30. 8	605
	86	6, 572–6, 581	7	2. 5	0
Early Cretaceous (Fredericksburg?)	91	7, 021–7, 026	2. 1	32. 6	2, 080
	92	7, 034–7, 039	2. 7	31. 4	----------
	93	7, 076–7, 081	4	22. 0	58. 3
	94	7, 081–7, 091	4	19. 3	391
	94	7, 081–7, 091	4	16. 5	11. 7
	95	7, 091–7, 096	2. 5	24. 1	----------
	96	7, 096–7, 106	10	27. 3	301
	96	7, 096–7, 106	10	29. 1	537
	97	7, 106–7, 113	7	28. 4	386
	98	7, 113–7, 123	9	29. 0	810
	98	7, 113–7, 123	9	31. 5	943
	99	7, 123–7, 133	10	26. 8	205
	99	7, 123–7, 133	10	12. 8	2. 1
	100	7, 191–7, 201	10	25. 4	----------
	100	7, 191–7, 201	10	26. 1	----------

are very fine to medium grained and are limy and slightly carbonaceous with scattered conglomeratic layers composed mostly of chert and pebbles. Examination of a core between depths of 4,377 and 4,387 feet revealed a fine- to medium-grained, slightly limy, glauconitic sandstone that is extremely porous. This comparison suggests that rocks of Woodbine age may be considerably less porous and permeable a short distance offshore than they are beneath the Atlantic Coastal Plain. Such a condition is not necessarily a negative factor in the evaluation of the petroleum potential of the continental shelf, as clean, well-sorted sandstones are not common among the oil reservoirs in the United States.

The principal potential petroleum reservoir of Austin age, 3,660 to 4,288 feet in depth, is composed of fine- to coarse-grained, calcareous glauconitic sandstone with thin conglomeratic layers. Some coarse sandstones are very loosely cemented and the individual sand grains break free in the drilling. Porosities range from 15.9 to 41.2 percent and permeabilities from 4.5 to 5.7 millidarcys (table 4). Drill-stem tests were not made in this interval.

The possibility of carbonate reservoirs beneath the continental shelf in the vicinity of the Hatteras Light well is suggested by porous zones in limestone and dolomite beds in pre-Upper Cretaceous rocks. The upper part of a 100-foot carbonate sequence at the top of rocks of Late Jurassic or Early Cretaceous (Neocomian) age (8,750 feet) contains oolitic limestone, conglomeratic limestone, dolomitic limestone, porous granular dolomite, and anhydrite. The porosity of these beds is slight compared to the sandstones discussed previously, but it bears on the probability that thicker units of porous dolomite and oolitic limestone beds may be expected offshore. Another porous carbonate bed was drilled in the lower part of rocks of Trinity(?) age between depths of 8,500 and 8,585 feet. This one is composed of light-brown, sandy, coarsely crystalline dolomite and dolomitic limestone. The upper part was described as cavernous by Swain (1952, p. 66). No drill-stem tests or porosity tests were made for this interval.

ANDROS ISLAND WELL

The Bahamas Oil Andros Island 1 (well BA-2) in the Bahama Islands penetrated 14,585 feet of carbonate rocks ranging from Early Cretaceous to Tertiary in age. This sequence included many porous, fragmental and fossiliferous limestones in differing stages of recrystallization and dolomitization. Circulation of drilling mud was lost at depths of 70, 540, 2,689, 9,604, 10,020, 12,965, 13,230, and 13,383 feet before the drill pipe was lost in the hole at a depth of 14,585 feet. The well was abandoned at that depth with 11,960 feet of drill pipe not recovered. Especially viscous muds with fibre added were used to regain circulation. Cavities were reported by the driller at 10,663–10,685; 10,687–10,696; 12,963–12,965; 13,202–13,206; 13,208–13,210; 13,214–13,215; 13,225–13,230; and 13,312–13,313 feet. All of these cavities are in lower Upper Cretaceous and upper Lower Cretaceous rocks. Sample and core studies indicate considerable fracture and intergranular porosity in the rocks as well as cavernous porosity. Carbonate reservoirs are so thick and open as to create drilling problems in this area, but more suitable conditions may be present at other places beneath the continental shelf in the Bahama Banks and Blake Plateau regions.

TRAPS

Traps for petroleum have been grouped by Levorsen (1954, p. 142–143) into three basic types: structural traps, stratigraphic traps, and combination traps.

1. Structural traps are those that have been formed primarily by local deformation of the reservoir and sealing beds. The deformation may involve either folding or faulting, or both, and sometimes produces fracturing of the reservoir as an important element of the trap.
2. Stratigraphic traps are those that have been formed primarily by stratigraphic variations and discontinuities. Primary stratigraphic traps are those that are effective mainly because of original depositional characteristics, such as composition, shape, and attitude of the reservoir. These are related mainly to lateral variations of lithology, or lithofacies in the broadest sense of that term. Secondary stratigraphic traps are those that are effective primarily because of discontinuities in stratigraphic succession. Such traps may be associated with either local unconformities present in a few townships or regional unconformities present throughout a sedimentary basin or province.
3. Combination traps are those that combine both structural and stratigraphic elements of subequal importance. Combinations of unconformities and anticlines with modifications due to faults, lithofacies, and hydrodynamic conditions are probably the most common trap.

The principal components of traps are sealing beds, folds and faults, unconformities, lithofacies, and hydrodynamic conditions. The following discussion attempts to identify each component in the Mesozoic rocks along the Atlantic coast and suggests areas in which certain combinations of components may have formed traps for petroleum.

SEALING BEDS

Sealing beds of some kind are necessary for the entrapment of petroleum, except in traps sealed with asphaltic residue and in any traps that were possibly created by hydrodynamic conditions alone. The sealing beds are usually the more plastic beds of clay, shale, and salt, but they also may be anhydrite, limestone, and dolomite beds that have escaped fracturing or whose fractures have been closed by chemical precipitates.

Clay and shale beds act as aquicludes in the artesian system of the Coastal Plain north of Florida and could readily serve as sealing beds over petroleum accumulations. Some that extend seaward an unknown distance beneath the continental shelf, judging by the Hatteras Light well (NC–14) in North Carolina, include shale beds of Cretaceous (Trinity or Fredericksburg, Eagle Ford, Taylor and Navarro) and Paleocene age.

Anhydrite, which is not only a cap rock in salt-dome fields but also a common seal throughout the world in oil fields with carbonate reservoirs, overlies the oil-producing Sunniland Limestone of Early Cretaceous (Trinity?) age in the oil fields of southern Florida. This unit has been informally named the "upper anhydrite" by oil geologists of this area. A short distance below the oil-producing beds is a massive anhydrite bed once referred to as the "lower massive anhydrite" and now known as the Punta Gorda Anhydrite (Applin and Applin, 1965, p. 39). Thinner beds of anhydrite are interspersed with limestone and shale in other parts of the Lower Cretaceous rocks, in the upper Upper Cretaceous rocks, and in the lower Tertiary rocks (Cedar Keys Limestone of Paleocene age and Oldsmar Limestone of Eocene age). Similar lithologies are present in southern Florida wells and have been reported orally for the deep well on Cay Sal (well 1, table 1) about 80 miles southeast of the Florida Keys.

Massive anhydrite beds were not found in the Andros Island well (well BA–2, table 1) in the Bahamas, and only a few thin anhydrite beds have been reported along the Atlantic coast in the vicinity of Cape Hatteras (Spangler, 1950, p. 123; Swain, 1952, p. 66 and 67). This suggests that conditions suitable for deposition of evaporites may have been more prevalent in the eastern Gulf of Mexico than northward along the Atlantic coast. In general, however, it seems that sealing beds of clay, shale, and impervious chemical precipitates may be common enough beneath the Atlantic Continental Shelf to provide the vertical discontinuities necessary for trapping petroleum.

FOLDS AND FAULTS

Although the Coastal Plain deposits flank the much-folded and faulted Appalachian Mountains, they have not been involved in any major tectonic movements. As a result, they do not exhibit the abrupt folds and numerous faults commonly associated with the flanks of mountain systems. This suggests that few traps of a purely structural nature should be expected. Nevertheless, the basement structural features buried by Coastal Plain deposits are reflected to different degrees by gentle warping and normal faulting in the younger rocks. These gentle folds and faults, along with stratigraphic components, may be sufficient to provide combination traps.

The major positive features are the Cape Fear arch, the Peninsular arch, the Bahama uplift, and a long basement ridge at the edge of the continental shelf off New England. (See pl. 4.) Both the Cape Fear arch and the Peninsular arch (including the offset Ocala arch) show evidence of recurrent movement along older lines of weakness and an overlap of Lower Cretaceous beds by Upper Cretaceous beds. The Bahama uplift appears to be mainly structural. If it is, a thick marine sequence possibly containing reefs may have the traps necessary for the accumulation of petroleum. The long ridge at the edge of the continental shelf off New England (pl. 4) is completely unknown except for its expression in the basement rocks as recorded by seismic surveys. Whether or not this basement ridge is reflected in sedimentary rocks of suitable character for petroleum accumulation is unknown at present.

Several long faults or fault zones along the edge of the continental shelf and along the continental margin at the eastern edge of the Blake Plateau have been suggested by Pressler (1947, p. 1858, fig. 1). The presence and placement of these faults, inferred from bottom topography, are highly speculative, as little seismic evidence for or against their existence has been presented. In a preliminary statement of results from seismic-refraction investigations off Florida and Georgia, Sheridan, Drake, Nafe, and Hennion (1964) suggested some faulting at the edge of the shelf. In their complete report (Sheridan and others, 1966), they concluded that anomalous seismic records at the shelf edge were primarily a result of bottom topography and sedimentary facies change. Ewing, Ewing, and Leyden (1966) in a companion report based on continuous seismic-reflection profiles reached the same conclusion. Test holes in Tertiary strata off Jacksonville, Fla. (Bunce and others, 1965), do not indicate the presence of a post-Cretaceous fault along the shelf edge there but provide no information on the older beds.

A transcurrent fault in the basement beneath the shelf has been postulated along the 40th parallel about 50 miles south of New York by Drake, Heirtzler, and Hirshman (1963, p. 5270) on the basis of a linear magnetic anomaly. (See fig. 6.) Emery (1965c, p. C159 and fig. 1) has suggested that suitable petroleum-bearing structures may be associated with this "major strike-slip fault." No data suggesting the time of the major fault movements or the presence of smaller associated structures has been published.

LITHOFACIES

Lateral variations in lithology within a stratigraphic unit that may form primary stratigraphic or combination traps are difficult to predict in relatively unexplored regions such as the Atlantic Coastal Plain and Continental Shelf. Such traps may include offshore bars, channel fillings, reefs, and porosity changes between two carbonate facies or carbonate and clastic facies. Offshore bars and channel fillings might be expected in predominantly shale and marl sequences of Late Cretaceous age along the Coastal Plain north of Florida. Reefs and porosity changes at dolomite-limestone transitions may be present in Florida and along the continental shelf, particularly beneath the Bahama and Blake Plateau platforms. Limestone-shale and sandstone-limestone transitions probably are present beneath the shelf at many places. One of the likely places is the Southeast Georgia embayment. There well data are adequate to show a clastic-carbonate transition in Cretaceous rocks trending northeastward across the inner shelf. This in conjunction with faults or folds offers possibilities for combination traps.

UNCONFORMITIES

Numerous unconformities subdivide the Coastal Plain deposits, but only a few extend far enough downdip and laterally to be important as avenues of migration or loci of hydrocarbon traps. However, these few may have provided excellent opportunities for the accumulation of petroleum in both secondary stratigraphic and combination traps.

Little is known of the nature of possible unconformities separating sequences assigned to Late Jurassic or Early Cretaceous (Neocomian), Trinity(?), Fredericksburg(?), and Washita(?) ages, as only a few wells at the coastal extremities have been drilled this deep. These rocks do wedge out against the Peninsular arch (pls. 9, 15), the Cape Fear arch (pls. 9, 12), and northward from New Jersey (pl. 9). They may wedge out landward beneath the continental shelf all along the coast similar to the way they do west of the Hatteras Light well (well NC–14, pl. 12).

Probably the most important unconformity occurs at the top of the beds of Washita(?) age, essentially the top of the Lower Cretaceous rocks. The structure of the Lower Cretaceous rocks is somewhat different from that of the overlying beds. The marine Lower Cretaceous rocks not only lap out landward against the basement rocks but are overlapped by Upper Cretaceous (Woodbine) reservoirs as indicated in plates 9, 11, and 12. One of the places where this unconformity and others within Lower Cretaceous and older beds may supply the component necessary for a combination trap is on the seaward nose of the Cape Fear arch.

The unconformity at the top of the Cretaceous rocks probably is less important as a trapping component than the deeper major ones. Thinning of Upper Cretaceous rocks and overlap of Tertiary beds as exemplified in Georgia on plate 13 takes place at relatively shallow depths and rather close to the outcrops. Possibly it could be a more important factor on structures beneath the continental shelf.

HYDRODYNAMIC CONDITIONS

The accumulation of petroleum in all traps may be modified considerably by the hydrostatic or hydrodynamic forces of the water in the reservoir (Hubbert, 1953). Under hydrostatic conditions, the water is essentially at rest and the impelling force on the petroleum is upward. The boundaries of the trap alone determine the location and shape of the accumulation. Under hydrodynamic conditions, a potential exists from areas of higher pressure to those of lower pressure and this force modifies the location and shape of the accumulation by inclining it in the direction of flow. The effect of hydrodynamics may be sufficient to cause trapping in or near lithologic, depositional, and structural features that would be ineffective under hydrostatic conditions.

Fresh-water reservoirs beneath the Coastal Plain alluvium are under artesian pressure downdip from their outcrops, and flowing wells are not uncommon in lower areas. The artesian head of fresh water in the Ocala Limestone (Eocene) beneath the continental shelf is as much as 30 feet above sea level at a distance of 27 miles off Jacksonville, Fla. (Bunce and others, 1965, p. 710; Schlee and Gerard, 1965, p. 37). Submarine springs of large volume issue from the Ocala Limestone through sink holes near the shore in the same area (Stringfield and Cooper, 1951; Stringfield, written commun., 1964).

Although water-level and pressure records are available for many wells in the fresh-water part of the reservoirs, little is known about pressures where the waters become brackish or salty at depth. The one deep well for which drill-stem test pressures have been published is the Hatteras Light well (well NC–14, pl. 12) in North Carolina. In this well, drill-stem tests opposite intervals at 6,474 to 6,583 feet and 7,018 to 7,027 feet in depth recorded bottom-hole pressures of 2,900 and 3,100 psi, respectively. The reservoirs tested are Lower Cretaceous sandstones of Washita(?) and Fredericksburg(?) age that do not crop out along the Fall Line in North Carolina because of Upper Cretaceous and Tertiary overlap. These recorded bottom-hole pressures, which may not be very accurate because of the difficulties in setting packers tightly above and below the interval tested, are equivalent to a head of 6,670 and 7,130 feet, respectively. They approximate the hydrostatic head of reservoirs at depths of 6,583 and 7,027 feet plus the land elevation (80 feet) at the Cretaceous outcrop more than 100 miles westward, and they suggest that only gentle pressure gradients exist in these reservoirs in this area. Until many more drill-stem tests are available, little can be done to determine the regional effects of hydrodynamics.

SUMMATION OF PETROLEUM POTENTIAL

Pre-Cretaceous rocks have few characteristics of petroleum-producing beds. Paleozoic rocks in the pre-Mesozoic basement are highly metamorphosed except in southwestern Georgia (pl. 14) and central Florida (pls. 9 and 15), where they are not metamorphosed but are so highly indurated and folded as to have doubtful reservoir characteristics. Triassic(?) rocks (pls. 11 and 14) exhibit many continental aspects, such as red beds and conglomerate, and numerous igneous intrusions; such rocks may contain good reservoirs, but they are not generally regarded as good source rocks.

Lower Cretaceous rocks and those classed tentatively as Upper Jurassic or Lower Cretaceous (Neocomian) in this report (pls. 12 and 16) offer the most promising prospects for oil and gas production in the Atlantic coastal region. Their combined thickness probably exceeds 5,000 feet beneath the continental shelf in the Baltimore Canyon trough and in the Southeast Georgia embayment. Even greater thicknesses may exist beneath the Blake Plateau and Bahama Islands. These rocks, where penetrated along the coastal extremities, exhibit many characteristics of petroleum-producing beds. Marine beds generally regarded as potential sources of petroleum are predominant, and the enviroment of their deposition, at least in the southern areas, probably favored reef growth. Thick, very porous, salt-water-bearing reservoirs, both sandstone and carbonate, are numerous. Although not many thick shale beds have been drilled in the sequence as yet, adequate sealing beds may be provided by dense limestone and anhydrite beds. The structural attitude of these rocks is considerably different from that of the Upper Cretaceous (Woodbine) rocks that overlap them. Important unconformities are present not only at the top but within the sequence. These suggest the possibility of not only structural but combined structural and stratigraphic traps.

Upper Cretaceous rocks have good possibilities for oil and gas production beneath the continental shelf, but they have only fair possibilities, chiefly for gas, in the Coastal Plain. Although the thickness of these rocks does not exceed 3,500 feet onshore and may be only a few thousand feet more beneath the shelf (pl. 17*B*), the beds are buried sufficiently beneath the Tertiary rocks to provide ample opportunity for the accumulation of petroleum. Reservoir rocks are thick and numerous in the Upper Cretaceous rocks of the Coastal Plain and seem to extend beneath the shelf where thick marine source rocks may be expected. Rocks of Woodbine and Eagle Ford age appear to be a favorable reservoir-source rock combination whose thickness probably exceeds 2,000 feet offshore (pl. 17*C*). Unconformities at the top and base are extensive; the basal unconformity may be the more important from the standpoint of petroleum accumulation, as it permits the basal Upper Cretaceous sandstones of Woodbine age to overlap the underlying, more marine Lower Cretaceous rocks. Depending upon the juxtaposition of lithologies, this unconformity may be either a trap or an avenue of migration in different places. It appears to mark an extremely porous zone in the carbonates of the Andros Island well.

Tertiary rocks exhibit very good reservoir and fair source rock characteristics. They are less promising than Cretaceous rocks for a number of reasons:

1. They probably are less than 4,000 feet thick in most of the area north of southern Florida and the Bahama Islands (pl. 17*D*), and they contain fresh-to-brackish artesian water in much of that area.
2. They crop out in part along the continental shelf and Blake Plateau (see pl. 2 and figs. 7 and 8), and in other places they give rise to submarine springs in sink holes (Stringfield and Cooper, 1951, p. 61).
3. Structural features are reflected less distinctly in the Tertiary rocks than in the older rocks, as they have been subject to less tectonic adjustment.
4. Unconformities within the Tertiary rocks are less significant regionally than those in older rocks.

Tertiary (Paleocene and lower Eocene) beds at the basal unconformity wedge out against Upper Cretaceous rocks in places (pl. 13). However, this wedgeout occurs at depths too shallow to offer much hope for trapping commercial quantities of petroleum.

The continental shelf offers more promise as a potential petroleum province than the Coastal Plain because it has a thicker sedimentary column with better source beds and trapping possibilities. Thicknesses of 10,000 feet and more are present beneath the Coastal Plain only in southern Florida, whereas thicknesses beneath the continental shelf exceed 10,000 feet in the Southeast Georgia embayment and Georges Bank trough, 12,500 feet in the Emerald Bank trough, and 15,000 feet in the Baltimore Canyon trough (pl. 4). Comparable thicknesses may be present beyond the continental shelf beneath the Blake Plateau and Bahama platform. Extreme thicknesses of 25,000 feet underlie the continental slope in water 5,000 to 10,000 feet deep; this is not within present economic limits for commercial exploration.

Different views as to the most favorable areas of the continental shelf for petroleum exploration have been expressed by J. F. Pepper (in Trumbull and others, 1958, p. 51, 52, and 55), Johnston, Trumbull, and Eaton (1959, p. 439–441), Richards (1963, p. 150, 151), and Emery (1965b, fig. 6). These are based mainly on considerations of basement structure and gross thickness of sediments without regard to age or unconformities.

According to J. F. Pepper (in Trumball and others, 1958, p. 55), the results of an airborne magnetometer survey of the Bahamas "are said to indicate that structures are present which may be favorable for the accumulation of oil." He points out favorable thicknesses of sediments at places only 60 miles offshore on the continental shelf between Florida and New Jersey, but he states (in Trumbull and others, 1958, p. 51, 52) that "the possibility of finding oil in commercial quantities in any of the shelf areas between New Jersey and Newfoundland is not considered to be favorable."

In discussing structural factors related to petroleum possibilities, Johnston, Trumbull, and Eaton (1959, p. 440, 441) give favorable mention to the Cape Fear arch and its seaward extension, a high at Fort Munroe, Va., and the basement ridge mapped at the edge of the continental shelf off New England by Drake, Ewing, and Sutton (1959, p. 176, fig. 29). Somewhat earlier, a brackish ground-water anomaly on the Cape Fear arch, a few miles inland from Wilmington, N.C., had been cited by LeGrand (1955, p. 2020) as deserving attention "if oil-prospecting becomes more active on the Atlantic Coast."

Richards (1963, p. 151, 152) in discussing the oil prospects off the New Jersey shore mentioned Five Fathom Bank, about 10 miles off Cape May, and several landward shoals as likely places for an oil test. These locations were selected for their convenience in drilling operations rather than for geological considerations of a local nature.

Most recently, Emery (1965c, p. C159 and fig. 1) has stated that suitable petroleum-bearing structures may be associated with the seaward extension of the Cape Fear arch, the basement ridge at the edge of the continental shelf off New England, and a "major strike-slip fault" just southeast of New York City. The latter is the transverse fault deduced by Drake, Heirtzler, and Hirshman (1963, p. 5270) from magnetic anomalies in the basement rocks. (See pl. 8.)

All the published suggestions for areas in which to conduct exploration operations for petroleum seem to have merit. However, the Bahama platform, the seaward extension of the Cape Fear arch, the long basement ridge at the edge of the continental shelf off New England, and the Southeast Georgia embayment appear to this writer to be the areas most favorable for initial operations in waters controlled by the United States. The outer shelf in Canadian waters off Nova Scotia and Newfoundland offers equally good possibilities, but with the exception of the possible extension of the outer shelf basement ridge near Sable Island, no basis exists for comparing different parts of this huge area that includes the Grand Banks extending 120 miles from land.

In summary, more stratigraphic and seismic data on the older rocks are needed before additional areas for exploration can be suggested. However, the probabilities for discovery of commercial accumulations of petroleum in the Atlantic coastal region seem to favor rocks classed herein as Upper Jurassic or Lower Cretaceous (Neocomian) and Lower Cretaceous in stratigraphic or combination traps beneath the continental shelf.

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TABLE 1

TABLE 1.—*Records of selected wells along the Atlantic coast*

[Est, estimated]

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			Alabama			
AL–1	Capital Oil & Gas, Gholston 1.	Sec. 18, T. 14 N., R. 22 E., Bullock County.	310	1, 725	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic granite 1,700 ft.
2	Capital Oil & Gas, Pickett 1.	Sec. 22, T. 13 N., R. 21 E., Bullock County.	430	2, 523	do	Electric log available. Top of pre-Mesozoic granite 2,495 ft.
3	W. B. Hinton, Creel 1.	Sec. 14, T. 9 N., R. 26 E., Barbour County.	504	5, 556	Triassic or pre-Mesozoic.	Electric log available. Top of pre-Cretaceous rocks 4,395 ft.
			Bahama Islands			
BA–1	Bahama California Oil Cay Sal 4 well 1.	Lat 23°49′24″ N., long 80°12′24″ W.		18, 906		Offshore. No data released, May 1966.
2	Bahamas Oil Andros Island 1.	Lat 24°52′37.2″ N., long 78°01′54.7″ W., Stafford Creek, Andros Island.	20	14, 585	Lower Cretaceous	Electric log from 6,503 to 10,670 ft only.
3	Harrisville Eleuthera Island 2.	Hatchet Bay, approx lat 25°20′45″ N., long 76°28′30″ W., Eleuthera Island.	123	730	Miocene(?)	No electric log available. Tested salt water 200 to 490 ft in Miocene. Water level 123 ft below surface.
			Delaware			
DL–1	C. R. Casson water well 1.	About 4.5 miles northwest of Newcastle on State Highway 41, Newcastle County.	65	365	Pre-Mesozoic	Top of crystalline rock 352 ft.
2	U.S. Army Fort Dupont water well.	Near Delaware City, Newcastle County.	10	762	Lower Cretaceous	
3	Town of Middletown water well.	Middletown, Newcastle County.	65	1, 478	Pre-Mesozoic(?)	Probably reached bedrock at total depth.
4	Deakyneville test well 1.	About 1.5 miles northeast of Smyrna, Newcastle County.		2, 312	Pre-Mesozoic	Top of pre-Mesozoic rocks 2,290 ft.
5	U.S. Air Force Base test well JE 32–4.	Near Dover, Kent County.	27	1, 422	Upper Cretaceous	
6	Town of Lewes water well.	Lewes, Sussex County	10	1, 080	Miocene	
7	Sun Oil Townsend (Apple Orchard) D–6.	4 miles southeast of Bridgeville, Sussex County.	43	2, 600	Upper Cretaceous	Electric log available.
8	Continental Oil Townsend 1.	4 miles southeast of Bridgeville, Sussex County.	42	3, 012	do	
9	Sun Oil R. Russell 1.	5.2 miles southeast of Bridgeville, Sussex County.	36	2, 674	do	
			Florida			
FL–1	Jeffreys Abbott 1	Sec. 19, T. 3 N., R. 32 W., Escambia County.	202	7, 513	Lower Cretaceous	Electric log available.
2	Zach Brooks Drilling Caldwell-Garvin unit 1.	Sec. 31, T. 2 S., R. 31 W., Escambia County.	33	12, 512	do	Do.
3	Mobil Oil, St. Regis Paper 1.	Sec. 35, T. 4 N., R. 30 W., Santa Rosa County.	120	12, 523	do	Do.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Florida—Continued				
FL-4	Sunnyland Oil, Nowling 1.	Sec. 24, T. 5 N., R. 29 W., Santa Rosa County.	250	6,665	Lower Cretaceous(?).	Electric log available.
5	Humble Oil & Refining, State of Florida lease 833 well 1.	Sec. 17, T. 2 S., R. 28 W., Pensacola Bay, Santa Rosa County.	26	7,505	Lower Cretaceous	Do.
6	Sinclair Oil & Gas Boland 1.	Sec. 7, T. 1 N., R. 27 W., Santa Rosa County.	35	6,950	Lower Cretaceous (?).	Do.
7	Haden McCort 1	Sec. 30?, T. 4 N., R. 24 W., Okaloosa County.	254(?)	6,326	Lower Cretaceous	Do.
8	Hawkins Kelly 1	Sec. 18, T. 2 S., R. 22 W., Cobbs Point, Okaloosa County.	27	6,250	do	No electric log available.
9	Hawkins Coffeein 1	Sec. 12, T. 2 S., R. 21 W. Fourmile Point, Walton County.	14	6,010	do	Do.
10	Sun Oil Belcher 4	Sec. 25, T. 4 N., R. 21 W., Walton County.	244	5,220	Lower Cretaceous	Electric log available.
11	Pan American Petroleum Sealy 1.	Sec. 9, T. 1 S., R. 18 W., Walton County.	111	11,947	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic rhyolite, 11,930 ft.
12	Byers Oil Sealy 1	Sec. 12, T. 2 S., R. 18 W., Walton County.	37	5,475	Lower Cretaceous	Electric log available.
13	Hunt Oil Linton 1	Sec. 30, T. 3 N., R. 17 W., Walton County.	104	6,503	do	Do.
14	Southeastern Exploration Hobbs-Gillis 1.	Sec. 18, T. 6 N., R. 17 W., Holmes County.	159	8,521	do	Do.
15	Breeding Coats 1	Sec. 25, T. 7 N., R. 15 W., Holmes County.	202	4,107	do	Do.
16	Magnolia Petroleum State block 4-B well 1.	Sec. 21, T. 3 S., R. 15 W., Bay County.	7	7,003	do	Do.
17	Temple Oil Moore 1	Sec. 27, T. 1 S., R. 15 W., Bay County.	60	6,021	do	Do.
18	Chipley Oil & Gas Dekle 1.	Sec. 27, T. 4 N., R. 13 W., Washington County.	198	4,912	do	No electric log run.
19	Humble Oil & Refining Tindel 1.	Sec. 8, T. 5 N., R. 11 W., Jackson County.	128	9,245	Paleozoic	Electric log available. Top of Paleozoic sandstone and shale 8,440 ft.
20	Hammond Granberry 1.	Sec. 15, T. 5 N., R. 9 W., Jackson County.	107	5,022	Triassic(?)	No electric log run.
21	Pure Oil International Paper 2.	Sec. 31, T. 1 S., R. 10 W., Calhoun County.	107	5,096	Lower Cretaceous	Electric log available.
21A	Gulf Coast Drilling and Exploration U.S.A. 1.	Sec. 4, T. 5 S., R. 7 W., Liberty County.	49	10,011	do	Do.
22	Pure Oil Hopkins 1	Sec. 22, T. 6 S., R. 9 W., Gulf County.	32	8,708	do	Do.
23	Magnolia Petroleum State block 5-B well 1-A.	Lat 29°41′18″ N., long 85°07′13″ W., Franklin County.	10	7,021	do	Do.
24	California State of Florida lease 224-A well 1.	Sec. 7, T. 9 S., R. 5 W., St. George Sound, Franklin County.	26	7,031	do	Offshore. Electric log available.
25	California State of Florida lease 224-A well 2.	Lat 29°47′03″ N., long 84°22′51″ W., Franklin County.	35	10,566	do	Do.
26	Pure Oil St. Joe Paper 2.	Sec. 34, T. 6 S., R. 4 W., Franklin County.	21	4,787	do	Electric log available.
27	Hughes Oil McDonald 1.	Sec. 6, T. 2 N., R. 5 W., Gadsden County.	296	4,222	do	Do.
28	Oles-Nayler Florida Power 1.	Sec. 35, T. 2 N., R. 3 W., Gadsden County.	177	4,240	do	Do.
29	Central Florida Oil & Gas Rhodes 1.	Sec. 11, T. 2 S., R. 1 E., Leon County.	50	3,755	Upper Cretaceous	No electric log run.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			Florida—Continued			
FL-30	Ravelin-Brown Philips 1.	Sec. 14, T. 3 S., R. 1 E., Wakulla County.	28	5, 766	Triassic(?)	Electric log available.
31	Coastal Petroleum Larsh 1.	Sec. 1, T. 2 S., R. 3 E., Jefferson County.	51	7, 913	do	Electric log available. Top of Triassic(?) red beds and sills 7,909 ft.
32	South State Oil Miller & Gossard 1.	Sec. 17, T. 2 N., R. 5 E., Jefferson County.	220	3, 838	Upper Cretaceous	No electric log available.
33	Hunt Oil Gibson 2	Sec. 6, T. 1 S., R. 10 E., Madison County.	107	5, 385	Paleozoic	Electric log available. Top of igneous rock 4,589 ft. Top of Paleozoic black shale 4,628 ft.
34	Humble Oil & Refining Hodges 1.	Sec. 12, T. 5 S., R. 6 E., Taylor County.	36	6, 254	Triassic(?)	Electric log available. Top of Triassic(?) diabase gabbro 6,153 ft.
35	Gulf Oil Brooks-Scanlon, State block 33 well 1.	Sec. 18, T. 4 S., R. 9 E., Taylor County.	96	5, 243	do	Electric log available. Top of Triassic(?) diabase gabbro 5,200 ft.
36	Gulf Oil Brooks-Scanlon, State block 42 well 1.	Sec. 9, T. 8 S., R. 9 E., Taylor County.	41	5, 517	do	Electric log available. Top of Triassic(?) diabase gabbro 5,438 ft.
37	Gulf Oil Brooks-Scanlon, State block 49 well 1.	Sec. 36, T. 5 S., R. 10 E., Lafayette County.	87	4, 512	Paleozoic	Electric log available. Top of Paleozoic quartzitic sandstone 4,505 ft.
38	Sun Oil Crapps 1	Sec. 25, T. 6 S., R. 12 E., Lafayette County.	70	4, 133	do	Electric log available. Top of Paleozoic quartzitic sandstone and shale 4,030 ft.
39	Stanolind Oil & Gas Perpetual Forest 1.	Sec. 5, T. 11 S., R. 11 E., Dixie County.	33	7, 510	do	Electric log available. Top of Paleozoic quartzitic sandstone 5,228 ft.
40	Sun Oil Adams 1	Sec. 15, T. 9 S., R. 15 E., Gilchrist County.	93	3, 753	do	Electric log available. Top of Paleozoic quartzitic sandstone and shale 3,588 ft.
41	Sun Oil Odom 1	Sec. 31, T. 5 S., R. 15 E., Suwannee County.	73	3, 161	do	Electric log available. Top of Paleozoic black shale 3,040 ft.
42	Fields-Randall Crawley 1.	Sec. 6, T. 2 S., R. 13 E., Suwannee County.	119	3, 833	do	Electric log available.
43	Sun Oil Tillis 1	Sec. 28, T. 2 S., R. 15 E., Suwannee County.	162	3, 572	do	Electric log available. Top of Paleozoic black shale 3,500 ft.
44	Sun Oil Sapp 1-A	Sec. 24, T. 2 S., R. 16 E., Columbia County.	138	3, 311	do	Electric log available. Top of Paleozoic black shale 3,303 ft.
45	Humble Oil & Refining Cone 1.	Sec. 22, T. 1 N., R. 17 E., Columbia County.	141	4, 444	do	Electric log available. Top of Paleozoic black shale 3,482 ft.
46	Hunt Oil Hunt 1	Sec. 21, T. 1 N., R. 20 E., Baker County.	130	3, 349	do	Electric log available. Top of Paleozoic quartzitic sandstone 3,342 ft.
47	Tidewater Associated Oil Wiggins 1.	Sec. 15, T. 6 S., R. 20 E., Bradford County.	141	3, 167	do	Electric log available. Top of Paleozoic quartzitic sandstone and shale 3,167 ft.
48	Tidewater Associated Oil Parker 1.	Sec. 33, T. 7 S., R. 19 E., Alachua County.	168	3, 220	do	Electric log available. Top of Paleozoic quartzitic sandstone and shale 3,170 ft.
49	The Texas Co. Creighton 1.	Sec. 16, T. 11 S., R. 19 E., Alachua County.	77	3, 527	Lower Cretaceous	Electric log available.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			Florida—Continued			
FL–50	Tidewater-Associated Oil Phifer 1.	Sec. 24, T. 9 S., R. 21 E., Alachua County.	132	3, 228	Paleozoic	Electric log available. Top of Paleozoic quartzitic sandstone and shale 3,217 ft.
51	St. Mary's River Oil Hilliard Turpentine 1.	Sec. 19, T. 4 N., R. 24 E., Nassau County.	110	4, 824	do	No electric log run. Top of Paleozoic black shale and diabase 4,636 ft.
52	Humble Oil & Refining Foremost Properties 1.	Sec. 4, T. 6 S., R. 25 E., Clay County.	115	5, 862	do	Electric log available. Top of Paleozoic quartzitic sandstone and shale 3,725 ft.
53	Sun Oil Roberts 1–A.	Sec. 19, T. 9 S., R. 25 E., Putnam County.	206	3, 328	do	Electric log available. Top of Paleozoic quartzitic sandstone 3,320 ft.
54	Sun Oil Westbury 1.	Sec. 37, T. 11 S., R. 26 E., Putnam County.	32	3, 892	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic volcanic rocks 3,873 ft.
55	Humble Oil & Refining Campbell 1.	Sec. 8, T. 11 S., R. 28 E., Flagler County.	31	4, 632	do	Electric log available. Top of pre-Mesozoic volcanic rocks 4,588 ft.
56	Grace Drilling Retail Lumber 1.	Sec. 2, T. 15 S., R. 30 E., Volusia Country.	45	5, 424	do	Electric log available. Top of pre-Mesozoic rhyolite 5,403 ft.
57	Sun Oil Powell Land 1.	Sec. 11, T. 17 S., R. 31 E. Volusia County.	48	5, 958	do	Electric log available. Top of pre-Mesozoic hornblende diorite 5,910 ft.
58	Coastal Petroleum Ragland 1.	Sec. 16, T. 15 S., R. 13 E., Levy County.	14	5, 850	Paleozoic	Electric log available. Top of Paleozoic black shale 5,810 ft.
59	Sun Oil Goethe 1	Sec. 31, T. 14 S., R. 17 E., Levy County.	34	3, 997	do	Electric log available. Top of Paleozoic quartzitic sandstone 3,960 ft.
60	Humble Oil & Refining Robinson 1.	Sec. 19, T. 16 S., R. 17 E., Levy County.	58	4, 609	Lower Cretaceous	Electric log available.
61	J. S. Cosden Lawson 1.	Sec. 25, T. 13 S., R. 20 E., Marion County.	195	4, 334	Paleozoic	No electric log run. Top of Paleozoic quartzitic sandstone 3,660(?) ft.
62	Ocala Oil York 1	Sec. 10, T. 16 S., R. 20 E., Marion County.	80	6, 180	do	No electric log run. Top of Paleozoic quartzitic sandstone 4,100(?) ft.
63	Sun Oil Parker 1	Sec. 24, T. 14 S., R. 22 E., Marion County.	79	3, 845	Lower Ordovician(?).	Electric log available.
64	Sun Oil Camp 1	Sec. 16, T. 16 S., R. 23 E., Marion County.	74	4, 637	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic volcanic rocks 4,615 ft.
65	Dundee Petroleum Bushnell 1.	Sec. 24, T. 20 S., R. 22 E., Sumter County.	77	3, 090	Upper Cretaceous	No electric log available.
66	Ohio Oil Hernasco 1	Sec. 19, T. 23 S., R. 18 E., Hernando County.	47	8, 472	Paleozoic	Electric log available. Top of Paleozoic quartzitic sandstone 7,720 ft.
67	Oil Development of Florida Arnold 1.	Sec. 17, T. 24 S., R. 25 E., Lake County.	120	6, 120	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic granite 6, 103 ft.
68	Warren Petroleum Terry 1.	Sec. 21, T. 23 S., R. 31 E., Orange County.	100	6, 589	do	Electric log available.
69	Hill Oldsmar 1	Sec. 19, T. 28 S., R. 17 E., Hillsborough County.	8	3, 255	Paleocene	No electric log run.
70	Coastal Petroleum Wright 1.	Sec. 7, T. 30 S., R. 17 E., Pinellas County.	13	11, 507	Lower Cretaceous	Electric log available.
71	Humble Oil & Refining Jameson 1.	Sec. 7, T. 31 S., R. 22 E., Hillsborough County.	112	10, 129	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic volcanic rocks 10,010 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Florida—Continued				
FL–72	Pioneer Oil Herscher-Yarnell 1.	Sec. 28, T. 30 S., R. 25 E., Polk County.	88	4,540	Upper Cretaceous	No electric log available.
73	Humble Oil & Refining Carroll 1.	Sec. 10, T. 27 S., R. 34 E., Osceola County.	62	8,049	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic biotite granite 8,035 ft.
74	Humble Oil & Refining Hayman 1.	Sec. 12, T. 31 S., R. 33 E., Osceola County.	86	8,798	do	Electric log available. Top of pre-Mesozoic rhyolite 8,740 ft.
75	Amerada Petroleum Mitchell 1.	Sec. 28, T. 31 S., R. 35 E., Indian River County.	60	9,488	do	Electric log available.
76	Magnolia Petroleum Schroeder-Manatee 1.	Sec. 11, T. 35 S., R. 19 E., Manatee County.	70	11,228	Lower Cretaceous	Do.
77	Humble Oil & Refining Keen 1.	Sec. 23, T. 35 S., R. 23 E., Hardee County.	83	11,934	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic volcanic rocks 11,828 ft.
78	Amerada Petroleum Swenson 1.	Sec. 5, T. 36 S., R. 34 E., Okeechobee County.	54	10,838	do	Electric log available.
79	Amerada Petroleum Cowles Magazine 2.	Sec. 19, T. 36 S., R. 40 E., St. Lucie County.	32	12,748	do	Electric log available. Top of pre-Mesozoic igneous rocks 12,680 ft. Top of Fort Pierce Formation of Late Jurassic or Early Cretaceous age 10,460 ft.
80	Humble Oil & Refining Carlton Estate 1.	Sec. 34, T. 38 S., R. 29 E., Highlands County.	114	12,985	do	Electric log available. Top pre-Mesozoic rhyolite and basalt 12,618 ft.
81	Gulf Oil Vanderbilt 1.	Sec. 35, T. 41 S., R. 21 E., Charlotte County.	22	12,725	Lower Cretaceous	Electric log available.
82	Humble Oil & Refining Lowndes-Treadwell 1–A.	Sec. 17, T. 42 S., R. 23 E., Charlotte County.	20	13,304	do	Do.
83	Amerada Petroleum Lykes Bros. 1.	Sec. 1, T. 41 S., R. 30 E., Glades County.	(?)	10,993	do	Do.
84	Coastal Petroleum Tiedke 1.	Sec. 25, T. 42 S., R. 33 E., Glades County.	14	13,440	Upper Jurassic or Lower Cretaceous.	Electric log available. Top of Fort Pierce Formation of Late Jurassic or Early Cretaceous age 12,933 ft.
85	Amerada Petroleum Southern States lease 34 well 1.	Sec. 34, T. 41 S., R. 39 E., Palm Beach County.	36	11,030	Lower Cretaceous	Electric log available.
86	Humble Oil & Refining Tucson 1.	Sec. 35, T. 43 S., R. 40 E., Palm Beach County.	34	13,375	Upper Jurassic or Lower cretaceous.	Electric log available. Top of Upper Jurassic or Lower Cretaceous rocks 13,180 ft.
87	Humble Oil & Refining State of Florida lease 1004 well 1.	Sec. 2, T. 48 S., R. 35 E., Palm Beach County.	31	12,800	Lower Cretaceous	Oil staining in upper part of Lower Cretaceous.
88	California, State of Florida lease 224–B well 1.	Lat 26°41′07″ N., long 82°19′02″ W., Boca Grande area, Lee County.	39	13,975	do	Electric log run.
89	California, State of Florida lease 224–B well 2.	Lat 26°43′06″ N., long 82°17′12″ W., Boca Grande area, Lee County.		12,600	do	Do.
90	Humble Oil & Refining Kirchoff 1.	Sec. 23, T. 45 S., R. 24 E., Lee County.	24	12,877	do	Electric log available. Oil show at 11,819 to 11,928 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well		Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
No.	Name					
		Florida—Continued				
FL-91	Gulf Refining Consolidated Naval Stores 1.	Sec. 27, T. 45 S., R. 26 E., Lee County.	45	12,865	Lower Cretaceous	Electric log available. Tested 28° API gravity oil at 11,748 to 11,799 ft.
92	Humble Oil & Refining Consolidated Naval Stores 1.	Sec. 16, T. 46 S., R. 27 E., Lee County.	----------	11,893	do	Electric log available.
93	Sun Oil Red Cattle 2.	Sec. 32, T. 45 S., R. 29 E., Felda field, Hendry County.		11,485	do	Electric log run. Oil produced from 11,471 to 11,485 ft.
94	Humble Oil & Refining Gulf Coast Realties 2.	Sec. 30, T. 48 S., R. 30 E., Sunniland field, Collier County.	34	13,512	do	Electric log available. Oil produced from 11,613 to 11,626 ft.
95	Humble Oil & Refining Collier 1.	Sec. 27, T. 50 S., R. 26 E., Collier County.	25	12,516	do	Electric log available.
96	McCord Oil Damoco 1.	Sec. 31, T. 53 S., R 35 E., Dade County.	17	11,885	do	Do.
97	Commonwealth Oil, Wiseheart 1.	SE¼ Sec. 16, T. 54 S., R. 35 E., Forty-Mile Bend field, Dade County.	24	11,557	do	Electric log available. Oil produced from 11,322 to 11,339 ft. Abandoned 1955.
98	Humble Oil & Refining I. I. F. 1.	Sec. 30, T. 55 S., R. 36 E., Dade County.	15	11,794	do	Electric log available.
99	Coastal Petroleum I. I. F. 1.	Sec. 25, T. 55 S., R. 37 E., Dade County.	25	11,520	do	Do.
100	East Coast Oil & Natural Gas Warwick 1.	Sec. 12, T. 55 S., R. 40 E., Dade County.	13	5,535	Paleocene	No electric log.
101	Gulf Oil State Model Land "C" 1.	Lat 25°13′35″, long 80°40′55″, T. 60 S., R. 35 E., Dade County.	12	6,030	Upper Cretaceous	Electric log available.
102	Peninsular Oil & Refining Cory 1.	Sec. 6, T. 55 S., R. 34 E., Monroe County.	14	10,006	Lower Cretaceous	Do.
103	Republic Oil-Robinson State 1.	Sec. 29, T. 59 S., R. 40 E., Monroe County.	23	12,051	Upper Jurassic or Lower Cretaceous.	Electric log available. Top of Fort Pierce Formation of Late Jurassic or Early Cretaceous age 11,878 ft.
104	Sinclair Oil & Gas H. R. Williams 1.	Sec. 24, T. 59 S., R. 40 E., Key Largo, Monroe County.	20	11,968	Upper Jurassic or Lower Cretaceous.	Electric log available.
105	Gulf Oil State of Florida lease 826–G well 1.	Lat 25°0′53″ N., long 81°5′54″ W., Oxfoot Bank, Monroe County.	21	12,631	Lower Cretaceous	Offshore. Electric log available.
106	Coastal Petroleum State of Florida lease 363 well 1.	Sec. 32, T. 62 S., R. 38 E., Plantation Key, Monroe County.	15	7,559	do	Electric log available. Live oil shows at 6,702 ft.
107	Florida East Coast Railway, Marathon 1.	Sec. 10, T. 66 S., R. 32 E., Key Vaca, Monroe County.	----------	2,310	Lower Eocene	No electric log run.
108	California, State of Florida lease 1011 tract 2 well 1.	Sec. 1, T. 67 S., R. 29 E. E., Big Pine Key, Monroe County.	24	6,033	Upper Cretaceous.	Electric log not released, May 1963
109	Gulf Oil State of Florida lease 373 well 1.	Sec. 2, T. 67 S., R. 29 E., Big Pine Key, Monroe County.	23	15,455	Upper Jurassic or Lower Cretaceous.	Electric log available. Top of Fort Pierce Formation of Late Jurassic or Early Cretaceous age 14,340 ft.
110	Gulf Refining State of Florida lease 374 well 1.	Sec. 15, T. 67 S., R. 27 E., Sugar Loaf Key, Monroe County.	23	6,100	Upper Cretaceous	Electric log available.
111	Gulf Oil State of Florida lease 826–Y well 1.	Lat 24°36′59″ N., long 82°02′21″ W., Marquesas Keys, Monroe County.	52	15,475	Upper Jurassic or Lower Cretaceous.	Offshore. Electric log available.
112–A	California State of Florida lease 1011 tract 1 well 2.	Lat 24°32′10″ N., long 82°06′40″ W., Marquesas Keys, Monroe County.	----------	7,723	Upper Cretaceous(?).	Offshore. No data released, May 1963.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Florida—Continued				
FL-112-B	California State of Florida lease 1011 tract 1 well 3.	Lat 24°32′1″ N., long 82°06′31″ W., Marquesas Keys, Monroe County.		12, 850	Lower Cretaceous(?).	Offshore. No data released. May 1963.
113	Gulf Oil O.C.S. State block 28 well 1.	Lat 24°27′00″ N., long 82°21′45″ W., Marquesas Keys, Monroe County.		15, 294		Offshore. No data released, March 1966.
114	California O.C.S. State block 46 well 1.	Lat 24°26′10″ N., long 82°29′37″ W., Marquesas Keys, Monroe County.		7, 871	Upper Cretaceous	Offshore. Twisted off 7,871 ft—abandoned.
115	California O.C.S. State block 44 well 1.	Lat 24°25′17″ N., long 12°36′02″ W., Marquesas Keys, Monroe County.		4, 687	Eocene	Offshore. Twisted off 4,687 ft—abandoned. No data released, May 1963.
116	California Florida State lease 224-B well 3.	Lat 28°05′31. 5″ N., long 82°52′49.9″ W., Honeymoon Island, Pinellas County.		10, 524	Lower Cretaceous	Offshore.
117	Fernandina Beach water well 1.	Fernandina Beach, Nassau County.	10	2, 130	Middle Eocene	
118	JOIDES group site 1.	Lat 30°33.2′ N., long 80°59.5′ W., 27 miles offshore from Jacksonville, Fla.	−90	910	do	Composite of offshore core holes. Gamma log run. Artesian head of 30 to 35 ft. reported in Eocene aquifers.
119	JOIDES group site 2.	Lat 30°20.5′ N., long 80°20′ W., 63.5 miles offshore Jacksonville, Fla.	−136	1, 050	do	Offshore core hole. Gamma and velocity log run.
120	JOIDES group site 5.	Lat 30°22.7′ N., long 80°07.5′ W., 76.5 miles offshore Jacksonville, Fla.	−581	804	Upper Eocene	Composite of offshore core holes. Gamma log run.
121	JOIDES group site 6.	Lat 30°04.8′ N., long 79°14.5 W., 136 miles offshore Jacksonville, Fla.	−2, 710	393	Paleocene	Offshore core hole. No geophysical log run.
122	JOIDES group site 4.	Lat 31°02.5′ N., long 77°43′ W., 221 miles offshore from Brunswick, Ga.	−2, 945	585	do	Composite of offshore core holes. No geophysical log run.
123	JOIDES group site 3.	Lat 28°30′ N., long 77°30.5′ W., 181 miles offshore Cape Kennedy, Fla.	−3, 886	585	Middle Eocene	Composite of offshore core holes. Gamma log run.
		Georgia				
GA-1	Town of Groveton water well 1.	1 mile north of State Highway 12, Groveton, Columbia County.	500	300	Pre-Cretaceous	No electric log run. Top of pre-Cretaceous rocks 135 ft.
2	Georgia Training School water well 1.	Near Gracewood, Richmond County.	136	1, 200	do	No electric log run. Top of pre-Cretaceous schist 305 ft.
3	U.S. Geological Survey test hole 1.	0.25 mile east of McBean-Waynesboro Rd., Burke County.	129	620	do	No electric log available. Top of pre-Cretaceous rocks 602 ft.
4	Three Creeks Oil 2	2.5 miles east of Greens Cut, Burke County.		1, 033	do	No electric log run. Top of pre-Cretaceous crystalline rocks 1,002 ft.
5	U.S. Geological Survey test hole 2.	Wrens, Jefferson County.	445	549	Upper Cretaceous	No electric log available.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			Georgia—Continued			
GA-6	A. F. Lucas & Georgia Petroleum.	3.5 miles southwest of Louisville, Jefferson County.		1,143	Pre-Cretaceous	No electric log run.
7	Middle Georgia Oil & Gas Lillian-B 1.	12 miles northwest of Sandersville, Washington County.		395	do	No electric log run. Top of pre-Cretaceous rocks 395 ft.
8	Town of Sandersville water well 51.	1.4 miles southwest of junction of State Highways 15 and 24 in Sandersville, Washington County.	465	872	do	No electric log run. Top of pre-Cretaceous quartzite and gneiss rocks 871 ft.
9	Strietmann Biscuit water well 1.	1.5 miles east of State Highway 11 in southwest Macon, Bibb County.	364	303	do	No electric log available. Top of pre-Cretaceous rocks 301 ft.
10	U.S. Government Cochran Flying Field 2.	Avondale, 8 miles south of Macon, Bibb County.	358	509	do	No electric log available. Top of pre-Cretaceous rocks 496 ft.
11	Town of Swainsboro water well 3.	0.9 mile southwest of courthouse, Swainsboro, Emanuel County.	330	873	Middle Eocene	No electric log available.
12	Town of Sylvania water well 3.	Sylvania, Screven County.	202	490	do	Do.
13	Gray Drilling W. M. McRae 1.	0.2 mile northwest of junction of State Highways 1 and 85, 0.5 mile north of main gate, Fort Benning, Muscogee County.	250	445	Pre-Cretaceous	No electric log available. Top of pre-Cretaceous rocks 439 ft.
14	Town of Cusseta water well 1.	0.25 mile south of junction of State Highways 26 and 280, Chattahoochee County.	550	1,205	do	No electric log available. Top of pre-Cretaceous rocks 1,185 ft.
15	Lee Oil & Natural Gas Burgin 1.	Land lot 207, land dist. 31, 4 miles southeast of Buena Vista, Marion County.	600	1,770	do	No electric log available. Top of pre-Cretaceous rocks 1,590 ft.
16	Lee Oil & Natural Gas Winkler 2.	7 miles southwest of Putnam, Marion County.		3,990	Lower Cretaceous(?)	Electric log run but not available.
17	Merica Oil Forhand 1.	Land lot 182, land dist. 1, 3 miles northeast of Ideal, Macon County.	290	2,140	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous schist 2,139 ft.
18	Tricon Minerals Duke 1.	Land lot 44, land dist. 14, 5 miles southwest of Perry, Houston County.	419	1,494	do	No electric log available. Top of pre-Cretaceous gneiss 1,490 ft.
19	Tricon Minerals Gilbert 1.	Land lot 266, land dist. 13, 7 miles southwest of Elko, Houston County.	367	1,698	do	Electric log available. Top of pre-Cretaceous gneiss 1,685 ft.
20	Merica Oil Hill 1	Land lot 74, land dist. 1, 1 mile northwest of Byromville, Dooly County.	371	2,319	do	Electric log available. Top of pre-Cretaceous quartzite 2,317 ft.
21	Georgia-Florida Drilling Walton 1.	Land lot 163, land dist. 6, 9 miles southeast of Vienna, Dooly County.	442	3,748	do	No electric log available. Top of pre-Cretaceous metamorphic rocks 3,512 ft.
22	Ainsworth Tripp 1	Land lot 306, land dist. 21, 4 miles south of Pulaski-Beckley County line, near Hawkinsville, Pulaski County.	280	2,710	Pre-Cretaceous(?)	Electric log run to 2,457 ft available. Top of serpentinized diabase 2,488 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Georgia—Continued				
GA-23	R. O. Leighton Dana 1.	Land lot 280, land dist. 12, near Hawkinsville, Pulaski County.	290	6, 035	Pre-Cretaceous	Electric log available.
24	Calaphor Manufacturing McCain 1.	0.5 mile South of Minter, Laurens County.	280	2, 548	Triassic(?)	Electric log available. Top of Triassic(?) diabase 2,53? ft.
25	Glen Rose Oil Fowler 1.	Land lot 221, Georgia Military Dist. 1386, 6 miles west of Soperton, Treutlen County.	291	2, 125	Upper Cretaceous	No electric log available.
26	McCain & Nicholson J. Gillis & H. Gillis 1.	3 miles east of Soperton, Georgia Military Dist. 1386, Treutlen County.	351	3, 168	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous granite 3,158 ft.
27	Barnwell Drilling J. L. Gillis.	3 miles east of Soperton, Georgia Military Dist. 1386, Treutlen County.		3, 239	do	Electric log available. Top of pre-Cretaceous rocks 3,053 ft.
28	Town of Statesboro water well 3.	Southwest part of Statesboro, Bulloch County.	219	921	Middle Eocene	No electric log available.
29	Flynn-Austin Stephens 1.	Land lot 210, land dist. 17, 9.5 miles southwest of Americus, Sumter County.	431	5, 240	Lower Cretaceous(?).	Do.
30	Town of Dawson water well 3.	East side of Main St., Dawson, Terrell County.	347	1, 028	Upper Cretaceous	Do.
31	Kerr-McGee Pate 1	Land lot 144, land dist. 13, 3 miles northwest of Arabi, Crisp County.	364	5, 008	Lower Cretaceous	Electric log available.
32	Dixie Oil Wilcox 1	7.5 miles southwest of Alamo, Wheeler County.	240	3, 384	do	No electric log run.
33	Parsons & Hoke Spurlin 1.	Land lot 260, land dist. 7, 1 mile south of Scotland, Telfair County.	242	4, 008	do	Electric log available.
34	Paul Parsons Hinson 1.	Land lot 288, land dist. 10, 4 miles northeast of Lumber City, Wheeler County.	205	3, 630	Triassic or lower Cretaceous.	Do.
35	Meadows Development Moses 2.	Near Uvalda, Georgia Military Dist. 1810, Montgomery County.	199	1, 619	Eocene	Do.
36	J. E. Weatherford Wilkes 1.	1 mile north of Higgston, Georgia Military Dist. 1567, Montgomery County.	293	3, 433	Triassic(?)	Electric log available. Top of Triassic(?) diabase 3,415 ft.
37	Tropic Oil & Gas Gibson 1.	6.5 miles southwest of Lyons, Toombs County.	198	3, 681	do	Electric log available. Top of Triassic(?) arkosic sandstone 3,663 ft.
38	Felsenthal-Weatherford Bradley 1.	Land lot 522, land dist. 2, 6 miles northeast of Pine Grove, Appling County.	229	4, 106	do	Electric log available. Top of Triassic basalt 4,095 ft.
39	Savannah Oil Cherokee Hill 1.	2½ miles southwest of Port Wentworth, Chatham County.	21	2, 131	Upper Cretaceous	No electric log run.
40	U.S. Geological Survey test well 1.	Fort Pulaski on Cockspur Island, Chatham County.	8	1, 435	Paleocene	No electric log available.
41	U.S. Army Camp Stewart water well.	1.6 miles northwest of Hinesville Liberty County.	91	816	Upper Eocene	Do.
42	E. B. LaRue Jelks & Rodgers 1.	6 miles southeast of Riceboro, Liberty County.	26	4, 264	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous rhyolite porphyry 4,250 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Georgia—Continued				
GA-43	Sowega Minerals Exploration West 1.	Land lot 328, land dist. 4, 4.2 miles northwest of Edison, Calhoun County.	345	5, 275	Triassic(?)	Electric log available. Top of Triassic(?) diabase 5,190 ft.
44	Sealy Reynolds Lumber 1.	Land lot 2, land dist. 116, 6 miles northeast of Pretoria, Dougherty County.	209	5, 012	Lower Cretaceous	Electric log available.
45	J. R. Sealy Reynolds Lumber 2.	Land lot 374, land dist. 2, 5.4 miles southwest of Pretoria, Dougherty County.	192	5, 310	do	Do.
46	Carpenter Oil Nina McLean 1-A.	Land lot 275, land dist. 1, Coffee County.	193	1, 903	Upper Cretaceous	No electric log available.
47	Carpenter Oil Thurman 1.	Land lot 189, land dist. 1, 1, 3.8 miles southeast of Relee, Coffee County.	317	4, 130	Lower Cretaceous	Electric log available.
48	Carpenter Oil Knight 1.	Land lot 144, land dist. 1, 5 miles northeast of Broxton, Coffee County		4, 151	Pre-Cretaceous(?)	Electric log available. Top of pre-Createceous rocks 4,138 ft.
49	Rowland L. Taylor Knight 1.	Land lot 327, land dist. 6, 6 miles northeast of Douglas, Coffee County.	238	1, 210	Eocene	
50	Operator unknown, Byars 1.	7 miles northwest of Jesup, Wayne County.	175	1, 965	do	No electric log available.
51	Humble Oil Union Bag-Camp Paper 1.	12.5 miles southeast of Jesup, land lot 54, Georgia Military dist. 333, Wayne County.	65	4, 554	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous metamorphic rocks 4,358 ft.
52	California Brunswick Peninsular 1.	Land lot 7, Georgia Military dist. 333, 7.5 miles east of McKinnon, Wayne County.	73	4, 620	do	Electric log available. Top of pre-Cretaceous quartzite 4,570 ft.
53	U.S. Biological Survey water well 4.	Boat landing, west side Blackbeard Island, McIntosh County.	9	711	Upper Eocene	No electric log available.
54	Pan-American Products Adam-McCaskill 1.	Land lot 329, land dist. 4, 2 miles southeast of Offerman, Pierce County.	75	4, 376	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous granite 4,348 ft.
55	W. B. Hinton (Clark) Adams-McCaskill 1.	Land lot 332, land dist. 4, 3 miles northeast of Offerman, Pierce County.	75	4, 355	do	Electric log available. Top of pre-Cretaceous granite 4,345 ft.
56	Humble Oil W. F. Hellem 1.	Land lot 95, land dist. 2, 5.3 miles north of Nahunta, Brantley county.	52	4, 512	Lower Cretaceous	Electric log available.
57	Humble Oil W. C. McDonald 1.	Georgia Military Dist. 1499, southwest of Brunswick, Glynn County.	25	4, 737	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous granite 4,737 ft.
58	Humble Oil Union Bag-Camp Paper ST-1.	Georgia Military Dist. 27, Spring Bluff area, Glynn County.	24	4, 632	Lower Cretaceous	Electric log available.
59	E. B. LaRue Massey 1.	Colonels Island, 5 miles southwest of Brunswick, Glynn County.	20	4, 614	do	Do.
60	State of Georgia Jekyll Island water well 1.	About middle of Jekyll Island, Glynn County.	12	706	Upper Eocene	No electric log available.
61	Mont Warren Chandler 1.	Land lot 406, land dist. 26, 3.5 miles west of Cedar Springs, Early County.	186	7, 320	Pre-Cretaceous	Electric log available. Top of Triassic (?) rocks 5,677 ft. Top of Paleozoic black shale 6,600 ft.
62	Sun Oil Ellis 1	Land lot 341, land dist. 26, Early County.	163	3, 175	Upper Cretaceous	No electric log available.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well		Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
No.	Name					
		Georgia—Continued				
GA-63	Mont Warren Harlow 1.	Land lot 82, land dist. 27, 5 miles east of Donalsonville, Seminole County.	145	3, 572	Lower Cretaceous	Electric log available.
64	Mont Warren Grady Bell 1.	Land lot 61, land dist. 27, 12 miles southeast of Donalsonville, Seminole County.	114	3, 810	do	Do.
65	J. R. Sealy Spindle Top 3 (Seminole Naval Stores).	Land lot 142, land dist. 21, 16 miles southeast of Donalsonville, Seminole County.		7, 620	do	Electric log run.
66	Humble Oil J. R. Sealy 1.	Land lot 42, land dist. 14, 18 miles west of Bainbridge, Seminole County.	96	4, 500	Lower Cretaceous (?).	Electric log available.
67	J. R. Sealy Fee 1	6.5 miles west of Recovery, Decatur County.		3, 007	Upper Cretaceous	No electric log available. Slight gas show reported.
68	Hunt Oil Metcalf 1	Land lot 260, land dist. 21, 5 miles east of Recovery, Decatur County.	104	6, 152	Lower Cretaceous	Electric log available.
69	Hughes and others Martin 1.	Land lot 189, land dist. 15, 4.8 miles north of Bainbridge, Decatur County.	132	3, 718	do	Do.
70	Renwar Oil G. E. Dollar 1.	Land lot 111, land dist. 15, Decatur County.	129	4, 995	do	Do.
71	Calvary Development Scott 1.	Land lot 25, Land dist. 22, 2½ miles southeast of Amsterdam, Decatur County.	277	4, 195	do	Do.
72	Stanolind Oil & Gas Pullen 1.	Land lot 133, land dist. 10, 1 mile south of Cotton, Mitchell County.	338	7, 490	Triassic (?)	Electric log available. Top of Triassic(?) diabase 5,677 ft. Top of Paleozoic rocks 7,486 ft.
73	Adams Drilling Arrington 1.	Land lot 270, land dist. 8, 2 miles southwest of Funston, Colquitt County.	270	4, 910	Lower Cretaceous.	Electric log available.
74	D. E. Hughes Rodgers 1-B.	Land lot 454, land dist. 12, 7 miles west of Morven, Brooks County.	136	3, 850	Upper Cretaceous	Do.
75	Sun Oil Doster-Ladson 1.	Land lot 71, land dist. 7, 5 miles southwest of Kirkland, Atkinson County.	222	4, 296	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous volcanic rocks 4,282 ft.
76	Wiley P. Ballard, Jr., Timber Products 1-B.	Land lot 306, land dist. 7, 8.5 miles northwest of Homerville, Clinch County.	215	4, 232	do	Electric log available. Top of Ordovician(?) rocks 4,010 ft.
77	Hunt Oil Musgrove 2.	Land lot 523, land dist. 12, 5.5 miles southeast of Homerville, Clinch County.	171	3, 513	Upper Cretaceous	
78	Sun Oil Barlow 1	Land lot 373, land dist. 12, 9 miles southwest of of Homerville, Clinch County.	177	3, 847	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous quartzitic sandstone 3,840 ft.
79	Hunt Oil Musgrove 1.	Land lot 198, land dist. 12, 15 miles south of Homerville, Clinch County.	147	4, 088	do	Electric log available. Top of Paleozoic(?) black shale 3 953 ft.
80	Luke Grace Drilling Griffis 1.	Land lot 36, land dist. 13, 8.4 miles northeast of Fargo, Clinch County.	176	4, 588	do	Electric log available. Top of Paleozoic rocks 3,843 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			Georgia—Continued			
GA-81	Humble Oil & Refining Bennett & Langsdale 1.	Land lot 146, land dist. 12, 4 miles northwest of Haylow, Echols County.	181	4,185	Pre-Cretaceous	Electric log available. Top of Paleozoic rocks 4,108 ft.
82	Hunt Oil Superior Pine Products 4.	Land lot 219, land dist. 13, 5 miles northeast of Statenville, Echols County.	156	3,916	do	Electric log available. Top of Paleozoic(?) red silty shale 3,911 ft.
83	Hunt Oil Superior Pine Products 1.	Land lot 364, land dist. 13, 5 miles east of Statenville, Echols County.	148	3,865	do	Electric log available. Top of Paleozoic(?) black shale 3,782 ft.
84	Hunt Oil Superior Pine Products 3.	Land lot 532, land dist. 13, 13 miles southeast of Statenville, Echols County.	143	4,003	do	Electric log available. Top of Paleozoic(?) black shale 3,657 ft.
85	Hunt Oil Superior Pine Products 2.	Land lot 317, land dist. 13, 10 miles southwest of Colon, Echols County.	142	4,062	do	Electric log available. Top of Paleozoic(?) quartzitic sandstone 3,710 ft.
86	Waycross well W-7	6 miles southeast of Ruskin, Ware County.	130	3,045	Upper Cretaceous	No electric log.
87	California Buie 1	4.5 miles northwest of Tarboro, Camden County.	65	4,955	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous volcanic rocks 4,674 ft.
88	U.S. Coast Guard tower site 1.	Lat. 31°56′53.5″ N., long 41°00′00″ W. 10 miles offshore from Savannah, Ga.	−54	161	Upper Eocene	Penetrated 5 ft of Ocala Limestone. Composite of two offshore core holes.
			Maryland			
MD-1	Anne Arundel County Sanitary Commission water well.	1 mile north of Glen Burnie, Anne Arundel County.	35	530	Pre-Mesozoic	Top of pre-Mesozoic granite 52[illegible] ft.
2	Bethlehem Steel water well 10.	Near Sparrows Point, Baltimore County.	10	711	do	Top of pre-Mesozoic granite 658 ft.
3	Chestertown Water Board water well 1.	Chestertown, Kent County.	22	1,135	Lower Cretaceous	
4	City of Centerville water well.	Centerville, Queen Annes County.	59	655	Upper Cretaceous	
5	Maryland Oil and Development oil test Ed-9.	Andrews Air Force Base, Prince Georges County.	240	1,511	Lower Cretaceous	
6	Washington Gas Light Mudd 3.	Near Brandywine, Prince Georges County.	124	1,727	Triassic(?)	Electric log run. Top of Triassic(?) rocks 1,492 ft.
7	Washington Gas Light Thorne 2.	Near Brandywine, Prince Georges County.	65	1,478	Pre-Mesozoic	Electric log run. Top of pre-Mesozoic gneiss 1,430 ft.
8	Washington Gas Light Moore 2.	Near Brandywine, Prince Georges County.	178	1,523	Upper Cretaceous	Electric log run.
9	Coastal Petroleum	Near Pomonkey, Charles County.		492	do	
10	Pan American Refining water well.	Wades Point, Talbot County.	13	1,520	do	
11	Dorchester Water Cambridge CE-3.	Cambridge, Dorchester County.	15	977	do	
12	Ohio Oil Hammond 1.	6 miles east of Salisbury, Wicomico County.	70	5,568	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic quartzite or gneiss 5,498 ft.
13	Socony-Vacuum Oil Bethards 1.	4.5 miles southwest of Berlin, Worcester County.	45	7,178	Triassic(?)	Electric log available. Top of Triassic(?) gabbro 7,130 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Maryland—Continued				
MD–14	Standard Oil of New Jersey Maryland Esso 1.	4.5 miles north of Ocean City, Worcester County.	13	7, 710	Lower Cretaceous	Electric log available.
15	City of Crisfield water well.	Crisfield, Somerset County.		1, 302	Upper Cretaceous	
16	Washington Suburban Sanitary District water well EB–2.	Near Forest Heights, Prince Georges County.	22	630	Lower Cretaceous	
		Massachusetts				
MS–1	W. Manning, water well 1.	Gays Head on Martha's Vineyard, Dukes County.	125	175	Probably Pleistocene.	Tertiary and Cretaceous rocks crop out along coast.
2	Town of Tisbury water well 1.	Northeast part of Martha's Vineyard, Dukes County.	115	262	do	
3	U.S. Coast Guard Coskata Life Saving Station 1.	Northern tip of Nantucket Island, Nantucket County.	10	301	Pleistocene	
4	U.S. Air Force Harwich 1.	8,500 ft N. 86° W. of South and Main Sts., Harwich, Barnstable County.	25	1, 000	Pre-Mesozoic	Top of pre-Mesozoic schist 435 ft.
5	Operator unknown	Holden Pond near Provincetown, Barnstable County.		264	Eocene	Tertiary rocks also reported in shallow wells at Duxbury on mainland.
		New Jersey				
NJ–1	Harold Kuhn water well 1.	Near Fords, Middlesex County.	175	235	Triassic	Top of Triassic red shale 160 ft.
2	Clifford Stultz water well 1.	Cranbury, Middlesex County.	95	263	Pre-Mesozoic	Top of Wissahickon Schist 200 ft.
3	Van Horn Oil Company oil test 1.	Millstone, Somerset County.	100	2, 382	Triassic	Well started in Triassic red shale.
4	New Jersey Highway Authority test hole 1.	Telegraph Hill, Holmdel Township, Monmouth County.	215	1, 039	Pre-Mesozoic	Top of Wissahickon Schist 965 ft.
5	Monmouth Consolidated Water West End Station water well.	Long Branch, Monmouth County.		981	Upper Cretaceous	Electric log run.
6	Monmouth Consolidated Water Whitesville Station water well #1.	Asbury Park, Monmouth County.	30	1, 053	do	Do.
7	New Jersey Oil & Gas Fields Company.	Prospertown, Ocean County.		1, 100	Lower Cretaceous	
8	Hamilton Square Water well 1.	About 4 miles east of Trenton, Mercer County.	100	235	Pre-Mesozoic	Top of Wissahickon Schist 215 ft.
9	Maguire Air Force Base water well 2.	Fort Dix, near Wrightstown, Burlington County.	160	1, 139	do	Top of Wissahickon Schist 1,100 ft.
10	N.J. Oil & Gas Fields and W & K Oil Mathews 2.	Jacksons Mills, Ocean County.	110	5, 022	do	Top of pre-Mesozoic schist 1,336 ft.
11	American Water Works water well.	Lakewood, Ocean County.		638	Upper Cretaceous	Electric log run.
12	Ocean County Water Dept. water well 6.	Mantoloking, Ocean County.		1, 052	do	Do.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			New Jersey—Continued			
NJ-13	Transcontinental Gas Pipeline test hole 19.	About 2 miles northwest of Garden State Parkway, State Highway 530, Ocean County.	39	1, 805	Upper Cretaceous	Electric log run.
14	Transcontinental Gas Pipeline test hole 17.	About 6 miles northwest of Garden State Parkway, State Highway 72, Ocean County.	156	1, 741	do	Do.
14A	Transcontinental Gas Pipeline test hole 13.	About 2.5 miles east of Speedwell, Burlington County.	90	1, 519	do	Do.
15	Town of Beach Haven water well.	Beach Haven, Ocean County.	5	575	Middle Miocene	
16	Transcontinental Gas Pipeline test hole 15.	Near Harrisville, Burlington County.	19	1, 701	Upper Cretaceous	Electric log run.
17	New Jersey water well 15.	Near Barrington, Camden County.		634	do	Do.
18	Borough of Berlin, water well.	Berlin, Camden County.		955	Lower(?) Cretaceous.	Do.
19	President Hotel water well 2.	Atlantic City, Atlantic County.	15	860	Middle Miocene	Do.
20	Borough of Clayton water well 2.	Clayton, Gloucester County.		1, 010	Upper Cretaceous	Do.
21	Town of Salem water well 1.	Near Standpipe in Salem, Salem County.	12	1, 440	Pre-Mesozoic	Top of pre-Mesozoic granite 1,[illegible]76 ft.
22	Town of Bridgeton water well 1.	On Cumberland Ave. in Northern Bridgeton, Cumberland County.	85	1, 651	Upper Cretaceous	See Kasabach and Scudder (1961, p. 54).
23	East Coast Oil	1.5 miles east of Newport, Cumberland County.	15	1, 200	do	
24	Town of Sea Isle City water well.	Sea Isle City, Cape May County.		897	Middle Miocene	Electric log run.
25	Anchor Gas Dickinson 1.	Higbee Beach Road on Cape May, Cape May County.	22	6, 408	Pre-Mesozoic	Electric log run. Top of pre-Mesozoic gneiss 6,344 ft.
26	U.S. Geological Survey Island Beach 1.	South end of Island Beach.	13	3, 891	do	Electric log run. Top of pre-Mesozoic biotite gneiss 3,798 ft.
27	U.S. Geological Survey New Brooklyn Park 1.	Lat 39°42′ N., long 74°57′ W., Camden County.	110	2, 080	do	Electric log run. Top of Paleozoic metamorphic rocks 1,943 ft.
			New York			
NY-1	City of New York Boulevard Station 7.	Emmett and Hylan Blvd., Richmond County, Staten Island.	10	319	Precambrian	Top of Precambrian soapstone 319 ft.
2	Water well K514	Near East New York Kings County, Long Island.	26	560	Pre-Mesozoic	Top of pre-Mesozoic gneiss or schist 466 ft.
3	City of New York Rockaway Beach 2.	Rockway Park Pumping Station, Rockaway Beach, Borough of Queens.	10	1, 049	do	Top of pre-Mesozoic granite rock 991 ft.
4	U.S. Naval Receiving Station water well 1.	Long Beach, Nassau County.	10	1, 471	do	Top of pre-Mesozoic rocks 1,46[illegible] ft.
5	Port Washington Water District water well 2.	Port Washington, Nassau County.	24	369	do	Top of pre-Mesozoic rocks 365 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		New York—Continued				
NY-6	Columbia University (Bellport Coast Guard Station) Schwenke Estate 1-B.	Lat 40°49′ N., Long 72°56′ W., on Fire Island opposite Bellport, Suffolk County.	----------	1, 956	Pre-Mesozoic	Electric log available. Top of pre-Mesozoic rocks 1,915 ft.
7	Brookhaven National Laboratory.	Lat 40°51.5′ N., long 72°53.9′ W., Suffolk County, Long Island.	113	1, 568	do	Electric log run. Top of weathered pre-Mesozoic igneous rock about 1,540 ft.
8	Brookhaven National Laboratory water well 6434.	Lat 40°52.4′ N., long 72°52.3′ W., Suffolk County, Long Island.	85	1, 600	do	Electric log run. Top of pre-Mesozoic igneous rock about 1,493 ft.
9	Water well 189	Near Orient, Suffolk County, Long Island.	5	668	do	Top of pre-Mesozoic gneiss or schist 668 ft.
		North Carolina				
NC-1	City of Murfreesboro water well.	Murfreesboro, Hertford County.	64	432	Upper Cretaceous	
2	Pam-Beau Drilling Basnight 1.	2 miles northwest of Harrellsville, Hertford County.	----------	1, 278	Pre-Cretaceous	No electric log available.
3	State Highway Commission water well.	Gates County Prison Camp, Gates County.	29	615	Upper Cretaceous	
4	DuGrandlee Exploration Foreman 1.	10 miles northeast of Elizabeth City, Camden County.	16	6, 421	Pre-Mesozoic	Top of Triassic(?) rocks 3,520 ft. Top of pre-Mesozoic rocks 4,900 ft. Gas show 3,170 to 4,050 ft.
5	U.S. Navy Harvey Point Seaplane Base 1.	Harvey Point, Perquimans County.	8	77	Upper Miocene	
6	Town of Windsor water well.	Windsor, Bertie County	46	405	Upper Cretaceous	
7	Standard Oil of New Jersey, North Carolina 2.	Pamlico Sound, Dare County	21	6, 410	Lower Cretaceous	Electric log available.
8	Town of Tarboro water well.	Tarboro, Edgecombe County.	50	349	Pre-Cretaceous	Top of pre-Cretaceous rocks 328 ft.
9	Town of Williamston water well.	Williamston, Martin County.	60	500	Upper Cretaceous	
10	Operator unknown, Roper 1.	4 miles northwest of Wenona, Washington County.	----------	2, 223	Lower Cretaceous	
11	Davidson Oil & Development Furbee 1.	2 miles northeast of Wenona, Washington County.	36	2, 660	do	Electric log available.
12	Davidson Oil & Development Rhem 1.	1 mile north of Ponzer, Hyde County.	9	3, 123	do	
13A	Coastal Plains Oil J. M. Ballance 1.	5.9 miles east of State Highway 94 on north side of Lake Mattamuskeet, Hyde County.	[1] 10	2, 005	Upper Cretaceous	No electric log run.
13B	Coastal Plains Oil F. F. Spencer, Jr., 1.	2.4 miles east of State Highway 94 on north side of Lake Mattamuskeet, Hyde County.	[1] 10	1, 635	do	Do.
13C	Coastal Plains Oil David Q. Holton 1.	0.4 mile north of Fairfield Post Office, Hyde County.	[1] 10	2, 005	do	Do.
13D	Coastal Plains Oil J. L. Simmons, Jr., 1.	4.5 miles west of State Highway 94 along north side of Lake Mattamuskeet, Hyde County.	[1] 10	1, 685	do	Do.

[1] Estimate.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
			North Carolina—Continued			
NC-13E	Coastal Plains Oil J. L. Simmons, Jr., 2.	8.3 miles west of State Highway 94 along north side of Lake Mattamuskeet, Hyde County.	[1] 10	2,005	Upper Cretaceous	No electric log run.
13F	Coastal Plains Oil Walton Williams, 1.	2.3 miles northwest of Swindell Fork and State Highway 264 on southwest side of Lake Mattamuskeet, Hyde County.	[1] 10	2,005	do	Do.
13G	Coastal Plains Oil M. M. Swindell, 1.	2.4 miles northwest of Swindell Fork and State Highway 264 on southeast side of Lake Mattamuskeet, Hyde County.	[1] 10	2,005	do	Do.
14	Standard Oil of New Jersey Hatteras Light 1.	Cape Hatteras, Dare County.	24	10,054	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous granite 9 878 ft.
15	A. B. Williams water well.	9 miles east of Wilson, Wilson County.	123	335	do	Top of pre-Cretaceous rocks 330 ft.
16	Town of Farmville water well.	Farmville, Pitt County	80	472	do	Top of pre-Cretaceous granite 470 ft.
17	Don Langston water well.	2 miles north of Winterville, Pitt County.	63	378	Upper Cretaceous	
18	American Metal test hole.	2.4 miles northeast of Washington, Beaufort County.	30	310	do	
19	Town of LaGrange water well.	LaGrange, Lenoir County.	105	404	Pre-Cretaceous	Top of pre-Cretaceous granite 392 ft.
20	Owner unknown, water well.	5 miles west of Loftins, Lenoir County.	64	120	Upper Cretaceous	
21	Carlton Ward water well.	2 miles northwest of Cove City, Craven County.	46	180	do	
22	Carolina Petroleum Atlas Plywood 1.	2 miles east of Merritt, Pamlico County.	11	3,425	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous granite 3,414 ft.
23	Carolina Petroleum North Carolina Pulp Wood 1.	1 mile southwest of Pamlico, Pamlico County.	11	3,667	do	Electric log available. Top of pre-Cretaceous granite 3,657 ft.
24	Carolina Petroleum Linley 1.	1 mile east of Merritt, Pamlico County.	16	2,897	Lower Cretaceous	Electric log available.
25	Seymour Johnson Air Field water well.	Goldsboro, Wayne County.	64	180	Pre-Cretaceous	Top of pre-Cretaceous rocks 180 ft.
26	Town of Mount Olive water well.	Mount Olive, Wayne County.	155	310	Upper Cretaceous	
27	Town of Calypso water well.	Calypso, Duplin County.	157	215	do	
28	Warsaw Dress water well.	Warsaw, Duplin County.	158	153	do	
29	J. O. Smith water well.	6 miles southwest of Kornegay, Duplin County.	85	111	do	
30	Henry Vann water well 1.	5 miles west of Faison, Sampson County.	166	271	Pre-Cretaceous	Top of pre-Cretaceous schist 245 ft.
31	Town of Roseboro water well.	Roseboro, Sampson County.	134	470	do	Top of pre-Cretaceous granite gneiss 353 ft.
32	Town of Garland water well 2.	Garland, Sampson County.	139	348	Upper Cretaceous	
33	American Mining & Development Corbett 1.	2 miles southeast of Kelly, Bladen County.	23	765	Pre-Cretaceous	Radioactivity log available. Top of pre-Cretaceous rocks 690 ft.
34	American Mining & Development Keith 1.	7 miles north of Acme and 8 miles southwest of Currie, Pender County.	23	730	do	Top of pre-Cretaceous rocks 695 ft.

[1] Estimate.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		North Carolina—Continued				
NC-35	Mueller Farms water well.	Rocky Point, Pender County.	35	580	Upper Cretaceous.	
36	Town of Richlands water well.	Richlands, Onslow County.	50	535	do	
37	Peter Henderson Hoffman Forest 1.	Sec. 21, block 4, Hoffman Forest, Onslow County.		1,232	Pre-Cretaceous(?).	Well 2, 2.5 miles to the north, drilled to 1,239 ft. Well 3, 2 miles southeast, drilled to 1,328 ft.
38	Gilbert and Seay Hoffman Forest 1.	10 miles north of Jacksonville, Onslow County.		1,430	do	Well 2 nearby drilled to pre-Cretaceous rocks at 1,335 ft.
39	Burton Drilling Hofmann Forest 1.	Sec. 8, block 10, Hoffman Forest, 5 miles south of Belgrade, Onslow County.	44	1,570	do	Electric log available. Top of basement 1,562 ft.
40	U.S. Government Camp Lejeune water well 1.	1 mile southeast of Jacksonville, Onslow County.	30	567	Upper Cretaceous.	
41	Operator unknown, Cadco 2.	4 miles southwest of Verona, Onslow County.		1,493	Pre-Cretaceous	Top of pre-Cretaceous rocks 1,343 ft.
42	Operator unknown, Cadco 1.	Hollyridge, Onslow County.	30	1,497	do	Top of pre-Cretaceous rocks 1,422 ft.
43	Carolina Petroleum Bryan 1.	2 miles east of Ellis Lake, Craven County.	15	2,435	do	Electric log available. Top of pre-Cretaceous granite 2,408 ft.
44	Great Lakes Drilling Havelock 1.	5 miles west of Havelock, Craven County.	30	2,351	do	Top of pre-Cretaceous granite 2,318 ft.
45	Carolina Petroleum G. Carraway 1.	Merrimon, Carteret County.	15	4,069	do	Electric log available. Top of pre-Cretaceous granite 4,054 ft.
46A	Carolina Petroleum N. Carraway 1.	2 miles south of Merrimon, Carteret County.	15	4,126	do	Electric log available. Top of pre-Cretaceous granite 4,120 ft.
46B	Carolina Petroleum G. Yeatman 1.	2 miles south of Merrimon, Carteret County.	20	4,097	Lower Cretaceous (?).	Electric log available.
47	F. L. Karsten Laughton 1.	3 miles northwest of Morehead City, Carteret County.	17	4,044	Pre-Cretaceous	Electric log available. Slight oil shows(?). Top of pre-Cretaceous granite 4,030 ft.
48	Coastal Plains Oil Huntley-Davis 1.	0.5 mile north of Harkers Island Bridge, Carteret County.		4,975	Pre-Cretaceous (?).	Electric log available. Top of pre-Cretaceous rocks 4,954 ft.
49	Coastal Plains Oil Baylands 1.	2.5 miles north of Atlantic, Carteret County.		5,607	do	Electric log available. Top of pre-Cretaceous rocks 5,561 ft.
50A	Carolina Petroleum Salter 1.	1 mile north of Merrimon, Carteret County.	13	3,963	Pre-Cretaceous	Electric log available. Top of pre-Cretaceous rocks 3,954 ft.
50B	Carolina Petroleum Phillips-State 1.	1.5 miles north of Merrimon, Carteret County.	10	3,964	do	Electric log available. Top of pre-Cretaceous rocks 3,930 ft.
50C	Carolina Petroleum Wallace 1.	West side Jerry Creek, Merrimon Township, Carteret County.	11	4,020	Pre-Cretaceous(?).	Electric log available. Top of pre-Cretaceous (?) 4,016 ft.
51	North Carolina Sanitorium water well 1.	2 miles east of McCain, Hoke County.	510	401	Pre-Cretaceous	Top of pre-Cretaceous schist 380 ft.
52	U.S. Army Maxton Glider School water well 1.	3 miles northwest of Maxton, Scotland County.	208	448	do	Top of pre-Cretaceous schist 363 ft.
53	Carolina Power & Light water well 2.	Lumberton, Robeson County.	165	310	Upper Cretaceous.	
54	Virginia Machine & Well water well.	Tabor City, Columbus County.	105	675	do	

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
North Carolina—Continued						
NC-55	Town of Whiteville water well.	Whiteville, Columbus County.	59	260	Upper Cretaceous	
56	Brunswick County Leland Colored High School.	Leland, Brunswick County.	25	300	do	
57	U.S. Army Ammunition Depot water well 6.	Sunny Point, Brunswick County.	35	198	do	
58	U.S. Army Fort Caswell water well.	Fort Caswell, Brunswick County.	11	1,543	Pre-Cretaceous	Top of pre-Cretaceous metamorphic rock 1,540 ft.
59	Clarendon Waterworks Hilton Park 1.	Wilmington, New Hanover County.	9	1,330	do	Top of pre-Cretaceous granite 1,109 ft.
60	Town of Wrightsville Beach stratigraphic test hole.	Wrightsville Beach, New Hanover County.	5	412	Upper Cretaceous	
61	E. I. DuPont de Nemours water well 1.	1.5 miles west of Grifton, Lenoir County.	53	823	Lower Cretaceous	Electric log available.
62	U.S. Geological Survey test hole CR-T2-62.	2.5 miles west of Wilmar, Craven County.	[1] 50	959	Upper Cretaceous	Do.
63A	Coastal Plains Oil Rodman 1.	1.5 miles west of intersection of county roads 1609 and 1619, Beaufort County.	[1] 15	2,012	Lower Cretaceous	Do.
63B	Coastal Plains Oil Rodman 2.	2.5 miles south of Terra Cia, Beaufort County.	[1] 18	2,113	do	Do.
63C	Coastal Plains Oil Ratcliff 1.	1.9 miles east of Townsite Acre, Beaufort County.	[1] 18	1,963	do	Do.
63D	Corstal Plains Oil West Dismal 1.	4.2 miles north of Acre Station, Beaufort County.	[1] 30	1,938	do	Do.
63E	Coastal Plains Oil H. M. Jackson 1.	1.7 miles north of railroad in Pinetown, Beaufort County.	[1] 50	1,526	do	Do.
64	Socony-Mobil Oil State 1.	Lat 35°59.8′ N., long 75°51.8′ W., Albemarle Sound, Dare County.		5,255	Pre-Cretaceous	Electric log run. Top of pre-Cretaceous granite gneiss 5,16[illegible] ft.
65	Socony-Mobil Oil State 2.	Lat 35°27.3′ N., long 75°35′ W., Pamlico Sound, Dare County.		8,382	do	Electric log run. Top of pre-Cretaceous gabbro (?) 8,372 ft.
66	Socony-Mobile Oil State 3.	Lat 35°15′ N., long 75°52′ W., Pamlico Sound, Hyde County.		7,266	do	Electric log run. Top of pre-Cretaceous rock 7,227 ft.
Rhode Island						
RI-1	Block Island Water well 33.	Central southern part Block Island, Town of New Shoreham.	80	165	Pre-Mesozoic(?)	Pleistocene on pre-Mesozoic granite(?); "Rotten granite" reported by Drake, Ewing, and Sutton (1959, p. 152) at 80 ft below sea level in this or nearby well.
2	U.S. Army Corps of Engineers test well 46.	Fort Greene, Ocean Road and Old Point Judith Road.	28	109	Pre-Mesozoic	Pleistocene on pre-Mesozic granite at 95 ft.

[1] Estimate.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well		Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
No.	Name					
			South Carolina			
SC-1	Town of Hartsville water well.	Hartsville, Darlington County.	170	432	Pre-Cretaceous	Top of pre-Cretaceous schist 428 ft.
2	Town of Dillon water well.	Dillon, Dillon County	114	595	do	Top of pre-Cretaceous rhyolite breccia 594 ft.
3	Town of Florence water well.	Florence, Florence County.	142	715	Triassic(?)	Top of Triassic(?) olivine diabase 710 ft.
4	Town of Marion water well.	Marion, Marion County	68	1, 244	Pre-Cretaceous	No electric log available. Top of pre-Cretaceous schist 700 ft.
5	Palmetto Drilling Allsbrook 1.	1 mile north of Allsbrook, Horry County.	107	1, 150	do	No electric log available. Top if pre-Cretaceous rocks 1,150 ft.
6	Pioneer Oil Smart 1.	12 miles southwest of Conway, Horry County.	31	1, 429	do	Electric log available. Top of pre-Cretaceous rocks 1,400 ft.
7	A. B. Cruse Drilling Fannie Collins 1.	12 miles southwest of Conway, Horry County.	15	1, 440	Upper Cretaceous	
8	Southern States Drilling Williams 1.	28 miles north of Georgetown, Georgetown County.	46	1, 397	do	No electric log available.
9	Town of Georgetown water well.	Georgetown, Georgetown County.	15	1, 870	do	Do.
10	Southern States Drilling oil test.	Near Rhems, Williamsburg County.	40	825	do	Do.
11	Town of Sumter water well.	Sumter, Sumter County.	162	784	Pre-Cretaceous	No electric log available. Top of pre-Cretaceous granite 782 ft.
12	Survey Drilling oil test.	5 miles southwest of Aiken, Aiken County.	315	492	do	Top of pre-Cretaceous granite 450 ft.
13	Town of Aiken water well 266.	1 mile south of center of Aiken, Aiken County.	480	519	do	Top of pre-Cretaceous rocks 519 ft. Electric log run.
14	Oil test	Between Perry and Wagner, Aiken County.	450	1, 000	do	Top of pre-Cretaceous granite 642 ft.
15	U.S. Government Savannah River Project water well.	Savannah River area, Aiken County.	----------	1, 185	do	Top of pre-Cretaceous schist 999 ft.
16	Town of Vance water well.	26 miles southeast of Orangeburg, Orangeburg County.	131	839	Upper Cretaceous	No electric log available.
17	U.S. Government Intransit Depot water well.	Moncks Corners, Berkeley County.	53	177	Eocene	Do.
18	Oil test	Near Summerville, Dorchester County.	71	2, 470	Pre-Cretaceous	Top of pre-Cretaceous diabase 2,450 ft.
19	Town of Walterboro water well 3.	Walterboro, Colleton County.	65	1, 500	Upper Cretaceous	
20	Charleston Consolidated Railway & Lighting water well 1.	Charleston, Charleston County.	10	2, 015	do	
21	U.S. Government water well 2.	Parris Island Marine Base, Beaufort County.	18	3, 450	Lower Cretaceous	Electric log available.
			Virginia			
VA-1	Spotsylvania County water well.	1 mile southwest of Fredericksburg Spotsylvania County.	----------	263	Pre-Mesozoic	Top of pre-Mesozoic granite 229 ft.
2	U.S. Navy Proving Ground water well.	Dahlgren, King George County.	20	780	Upper Cretaceous	
3	Town of Dogue water well.	Dogue King, George County.	----------	385	do	
4	Town of Colonial Beach water well.	Colonial Beach, Westmoreland County.	----------	654	do	

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Virginia—Continued				
VA-5	Westmoreland State Park water well.	Westmoreland State Park, Westmoreland County.	----------	631	Upper Cretaceous	
6	E. Henneson water well.	Oak Grove, Westmoreland County.	180	530	do	
7	Port Royal Tomato Cannery water well.	Port Royal, Caroline County.	----------	240	Lower Eocene	
8	Town of Bowling Green water well 23.	Bowling Green, Caroline County.	215	1,550	Pre-Mesozoic	Top of pre-Mesozoic granite 1,160 ft.
9	Town of Warsaw water well.	Warsaw, Richmond County.	----------	653	Upper Cretaceous	
10	Benford Trice water well.	St. Stephens Church, King and Queen County.	----------	470	do	
11	A. R. Beane water well.	Lancaster, Lancaster County.	----------	438	Lower Eocene	
12	T. A. Treakle water well.	Palmer, Lancaster County.	----------	740	Upper Cretaceous	
13	Peaks Industrial School water well.	1 mile southeast of Peaks, Hanover County.	190	240	Lower Eocene	
14	V. E. Portwood water well.	6 miles northeast of Mechanicsville, Hanover County.	----------	350	Lower Cretaceous	
15	Roberts Drilling Hugh Townsend 1.	18 miles northeast of Richmond and 3 miles southwest of Manquin, King William County.	37	3,278	Pre-Mesozoic	Red clastic rocks 834–2,609 ft. Igneous and metamorphic fragments abundant 2,083–2,609 ft. Schist, quartzite and gneiss below 2,609 ft (top of pre-Mesozoic rocks).
16	W. S. Reynolds water well.	Cohoke, King William County.	----------	555	Upper Cretaceous	
17	Chesapeake West Point 1.	West Point, King William County.	30	1,689	Triassic(?)	Top of Triassic(?) rocks 1,284 ft.
18	Elkins Oil & Gas Marchant and Minter 1.	Mathews, Mathews County.	15	2,325	Pre-Mesozoic	Top of pre-Mesozoic granite 2,307 ft.
19	Tidewater Oil & Gas Johr 1.	Approx. lat 37°30′ N., long 77°15′ W., Henrico County.	145	860(?)		
20	V. R. Shepherd water well.	5 miles southeast Highland Springs, Henrico County.	----------	236	Lower Eocene	
21	Riverview Farm water well.	Malvern Hill, Charles City County.	42	204	do	
22	Charles City School water well.	Charles City, Charles City County.	----------	205	Upper Cretaceous	
23	U.S. Navy Mine Depot water well.	2 miles northwest of Yorktown, York County.	80	620	do	
24	Pennsylvania Railroad Co. water well.	Cape Charles, Northampton County.	20	1,810	Lower Cretaceous	
25	Disputanta School for Colored water well.	Disputanta, Prince George County.	114	219	do	
26	City of Newport News water supply well 1.	3 miles south of Bacons Castle, Surry County.	97	1,060	do	
27	Newport News Gas	Newport News, Warwick County.	----------	1,065	Upper Cretaceous	
28	U.S. Army Fort Monroe water well.	Fort Monroe, Elizabeth County.	10	2,255	Pre-Mesozoic	Top of pre-Mesozoic granite 2,246 ft.

TABLE 1.—*Records of selected wells along the Atlantic coast*—Continued

Well No.	Well Name	Location	Alt (feet)	Total depth (feet)	Oldest rocks reported	Notes
		Virginia—Continued				
VA-29	Town of Wakefield water well.	Wakefield, Sussex County.	----------	399	Upper Cretaceous	
30	Monogram Farm water well.	Driver, Nansemond County.	20	540	Lower Cretaceous	
31	Nestle Company water well.	1 mile north of Suffolk, Nansemond County.	----------	1,006	do	
32	Town of Whaleyville water well.	Whaleyville, Nansemond County.	----------	320	Lower Eocene	
33	Town of Franklin water well.	Franklin, Southampton County.	----------	601	Lower Cretaceous	
34	Town of Norfolk water well.	5 miles east of Norfolk, Princess Anne County.	12	1,740	do	