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Summary of Geologic Framework and Petroleum Potential of the Atlantic Coast

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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 400,000 to 450,000 square miles, more than three-fourths of which is covered to depths of 600 feet 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 seaward far enough 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 an area of more than 100,000 square miles between the crystalline piedmont of the Appalachian System and mean low-tide from southern Florida to the tip of Long Island plus a few small offshore islands and the Cape Cod Peninsula.

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.

References and illustrations at end of paper.

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

Both gravity and magnetic anomalies along the Atlantic Coast reflect primarily 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 Bouguer gravity anomalies extend diagonally across the region from southwest to northeast (as shown on the Bouguer Anomaly Map of the United States, U. S. Geol. Survey, 1964). 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, southwesterly magnetic anomalies trend roughly parallel to the Appalachian Mountain System and the Shelf edge (Drake, Heirtzler, and Hirshman, 1963, fig.

4). Interruption of these trends along the 40th parallel, about 50 miles south of New York, by a linear anomaly, suggests 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 (King, 1959, p. 2853). One large anomaly, known as the slope anomaly, parallels the Shelf edge north of Cape Fear and seemingly represents a basement ridge located previously by seismic methods. Recently the suggestion has been made that the basement ridge along the Atlantic 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. 1360).

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 a mile inland to as much as 120 feet a mile near the ocean. A marked 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, Baltimore Canyon trough, and Georges Bank trough (see fig. 2).

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 dominantly marine carbonates in the subsurface and exceed 15,000 feet in thickness in the Florida Keys and Bahama Islands.

The oldest rock recovered from the sea bottom along the Atlantic Coast has come from the Paleozoic granite pinnacles at a depth of about 5 fathoms on Cashes Ledge near the middle of the Gulf of Maine. Cretaceous rocks of Taylor and Navarro age have been dredged from the east walls of Oceanographer and Gilbert Canyons off Georges Bank (Stetson, 1936, p. 347, 349) and rocks of Woodbine age from the Blake escarpment opposite Cape Kennedy (Ericson, Ewing, and Heezen, 1952, p. 503, 504). 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. Short cores and dredgings of Tertiary rocks, mostly late Eocene (Jackson) and younger in age, have been recovered at more than three dozen localities, concentrated for the most part between Georges Bank and the Hudson Canyon, and in the Blake Plateau-Bahama Banks region (ibid., p. 501-506). 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 (Shepard, Trefethen, and Cohee, 1934, p. 294).

Shoals, artesian submarine springs, and underwater photographs have provided some stratigraphic and structural information about the upper strata of the Shelf. Lower Miocene rocks are reported to crop out on the fishing banks known as "Black Rocks" off the coast of North and South Carolina (Pearse and Williams, 1951, p. 133-161). An oceanic spring in the Ocala Limestone of late Eocene age has been charted about $2\frac{1}{2}$ miles east of Crescent Beach near St. Augustine, Florida (Stringfield and Cooper, 1951, p. 61). Others have been reported along the east coast near Cape Kennedy. An interesting limestone outcrop of unknown age has been photographed at a depth of 6,000 feet in the Tongue of the Ocean of the Bahama Islands (Busby, 1962, pl. 2).

A test hole has been drilled on the Shelf in 54 feet of water about 10 miles off Savannah, Georgia (McCollum and Herrick, 1964, p. C61). The test hole, which stopped in the Ocala Limestone of late Eocene age, revealed that rather uniform thicknesses of Oligocene, lower Miocene, and middle Miocene strata extend from shore seaward for at least 10 miles, that the upper Miocene rocks and the Pleistocene and Recent deposits decrease in thickness seaward, and that only the Oligocene rocks exhibit a pronounced facies change--one from carbonates to clastics in a seaward direction.

Test holes located 27 to 221 miles off Jacksonville, Florida, 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 (JOIDES, 1965). The Eocene, Oligocene, and Miocene beds appear to be prograded seaward beneath the outer Shelf and upper slope, absent from the lower slope, and greatly thinned on the Plateau. The absence of Eocene, Oligocene, Miocene, and post-Miocene deposits from the lower slope corresponds rather closely to the axis of maximum velocity of the Gulf Stream. This lends support to the theory that sometime during early Tertiary time the Gulf Stream began flowing through the Straits of Florida, the Stream's velocity prevented sedimentation on the ancient shelf except near the coast, and the ancient shelf subsided slowly to form the Blake Plateau (Shepard, 1959, p. 116-117).

The subsurface correlations of the Mesozoic and Cenozoic rocks beneath the Coastal Plain have been traced along eight cross sections (Maher, 1965). One cross 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 others 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 present in the basement in northern Florida.

Triassic(?) rocks, which consist of red arkose, sandstone, shale, tuff, and basalt flows, in places intruded by diabase, are present in down-faulted basins in the basement. Rocks of Late Jurassic or Early Cretaceous (Neocomian) age are present beneath southern Florida (Applin and Applin, 1965, p. 18). 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, North Carolina, 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 (ibid., fig. 11). Northward along the coast, the rocks wedge out on the Peninsular arch, 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 (Maher, 1965, pl. 2).

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.

Tertiary rocks and thin Quaternary deposits are present along the 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 mostly sandstone and limy shale along the northern half.

Upper Jurassic and Lower Cretaceous rocks offer the most promising prospects for oil and gas production in the Atlantic coastal region. Their combined thickness probably exceeds 5,000 feet offshore in the Baltimore Canyon trough, in the Southeast Georgia embayment, and beneath the Blake Plateau and Bahama Islands. 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 (Roberts and Vernon, 1961, p. 218; Puri and Banks, 1959; Kornfeld, 1965, p. 173).

Upper Cretaceous rocks have good possibilities for oil and gas production beneath the Continental Shelf, but 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, the beds are buried sufficiently beneath the Tertiary rocks to provide ample opportunity for the accumulation of petroleum. Potential reservoirs are thick and numerous in the Upper Cretaceous rocks of the Coastal Plain and 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, although they are less promising for large accumulations of petroleum than the Jurassic and Cretaceous rocks. They probably are 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; they crop out in part along the 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.

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.

Bibliography

American Geophysical Union (G. P. Woollard, chm.) and U. S. Geological Survey (H. R. Joesting, Coordinator), 1964, Bouguer gravity anomaly map of the United States (exclusive of Alaska and Hawaii): Am. Geophys. Union Spec. Comm. Geophys. and Geol. Study of Continents and U. S. Geol. Survey, scale 1:2,500,000.

Applin, P. L., and Applin, E. R., 1965, The Comanche Series and associated rocks in the subsurface in central and south Florida: U. S. Geol. Survey Prof. Paper 447, 86 p.

Busby, R. F., 1962, Subaerial features on the floor of the Tongue of the Ocean, Bahamas: U. S. Navy Hydrog. Office Tech. Rept. 108, 84 p.

Drake, C. L., Heirtzler, J., and Hirshman, J., 1963, Magnetic anomalies off eastern North America: Jour. Geophys. Research, v. 68, no. 18, p. 5259-5275.

Ericson, D. B., Ewing, Maurice, and Heezen, B. C., 1952, Turbidity currents and sediments in North Atlantic: Am. Assoc. Petroleum Geologists Bull., v. 36, no. 3, p. 489-511.

King, E. R., 1959, Regional magnetic map of Florida: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 12, p. 2844-2854.

Kornfeld, J. A., 1965, Sunoco-Felda discovery puts South Florida in the spotlight: World Oil, v. 160, no. 6, p. 172-176.

McCollum, M. J., and Herrick, S. M., 1964, Offshore extension of the upper Eocene to Recent stratigraphic sequence in southeastern Georgia: U. S. Geol. Survey Prof. Paper 501-C, p. C61-C63.

Maher, J. C., 1965, Correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic Coast: Tulsa, Okla., Am. Assoc. Petr. Geologists Spec. Pub., 18 p., 9 pls., 1 table.

Pearse, A. S., and Williams, L. G., 1951, The biota of the reef off the Carolinas: Elisha Mitchell Sci. Soc. [Chapel Hill, N. C.] Jour., v. 67, no. 1, p. 133-161.

Puri, H. S., and Banks, J. E., 1959, Structural features of the Sunniland oil field, Collier County, Florida: Gulf Coast Assoc. Geol. Socs. Trans., v. 9, p. 121-130.

Roberts, W. L., and Vernon, R. O., 1961, Florida -- more extensive drilling might uncover big oil and gas-producing areas: Oil and Gas Jour., v. 59, no. 11, p. 215-219.

Shepard, F. P., 1959, The earth beneath the sea: Baltimore, Md., The Johns Hopkins Press, 275 p.

Shepard, F. P., Trefethen, J. M., and Cohee, G. V., 1934, Origin of Georges Bank: Geol. Soc. America Bull., v. 45, no. 2, p. 281-302.

Stetson, H. C., 1936, Geology and paleontology of the Georges Bank canyons; Part I, Geology: Geol. Soc. America Bull., v. 47, no. 3, p. 339-366.

Stringfield, V. T., and Cooper, H. H., Jr., 1951, Geologic and hydrologic features of an artesian submarine spring east of Florida: Florida Geol. Survey Inv. Rept. No. 7, pt. 2, p. 60-72.

Watkins, J. S., and Geddes, W. H., 1965, Magnetic anomaly and possible orogenic significance of geologic structure of the Atlantic Shelf: Jour. Geophys. Research, v. 70, no. 6, p. 1357-1361.

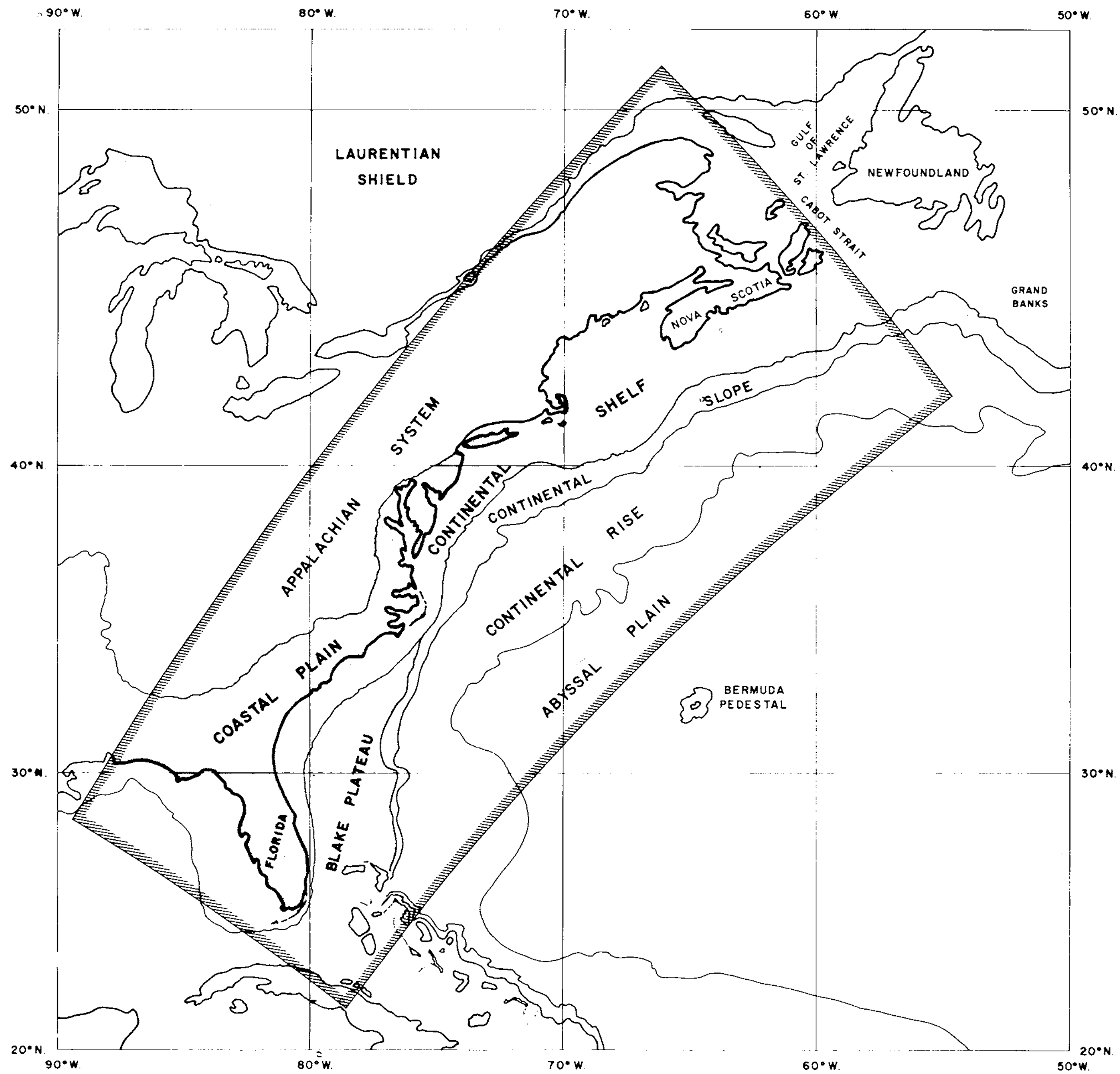

FIG. 1 PHYSIOGRAPHIC PROVINCE MAP OF EASTERN NORTH AMERICA SHOWING AREA DISCUSSED

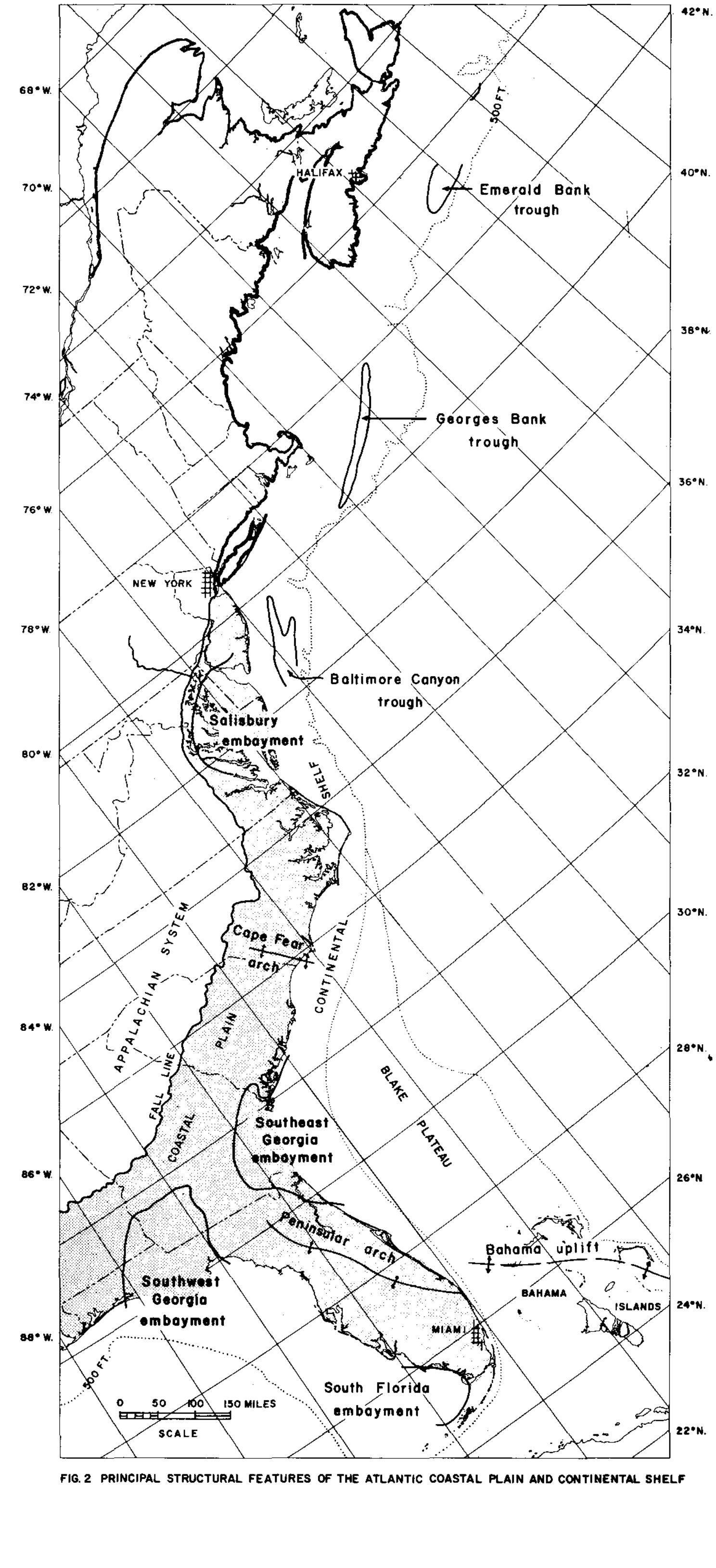

FIG. 2 PRINCIPAL STRUCTURAL FEATURES OF THE ATLANTIC COASTAL PLAIN AND CONTINENTAL SHELF