UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Play Analysis of Undiscovered Oil and Gas Resources on Onshore Federal Lands, Phase I: Atlantic Coastal Plain

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ABSTRACT

Three oil and gas plays within the Atlantic Coastal Plain province have been studied to be included in an assessment of undiscovered oil and gas resources on Federal lands: Triassic(?) clastic rocks, Upper Jurassic(?)-Cenozoic clastic rocks, and Lower Cretaceous-Cenozoic carbonate rocks. Within these three plays Federal lands encompass approximately 1,700 mi^2 (4,480 km^2), 5,000 mi^2 (12,950 km^2), and 3,600 mi^2 (9,325 km^2), respectively. The Triassic(?) play consists of a series of buried rift basins beneath the coastal plain. This play has a high exploration risk owing to its sparse well and geophysical data. No source rocks have been documented and only one hydrocarbon show has been reported. Good source rocks are also lacking in the Upper Jurassic(?)-Cenozoic clastic and Lower Cretaceous-Cenozoic carbonate plays, although potential reservoir rocks, traps, and seals may be present. The lack of good source rocks together with the relatively small Federal acreage indicate a low oil and gas potential for the Federal land within these plays.

INTRODUCTION

The United States Geological Survey (USGS) play analysis program was established to evaluate the amount of undiscovered oil and gas of Federal lands in the United States. A play, as used in this assessment, is a group of confirmed or hypothetical hydrocarbon accumulations that have similar geologic characteristics such as source rocks, reservoir rocks, traps, and geologic history. The amount of Federal acreage in each play was determined, and the resource potential of this acreage was then estimated. If any of these plays is considered significant, it will be included in a more detailed study in Phase II of the program.

Previous Work

The USGS has made appraisals of undiscovered oil and gas resources previous to this play analysis program (Miller and others, 1975; Dolton and others, 1981). These studies include estimates of all undiscovered, conventional oil and gas resources in the United States using a direct subjective assessment method. The play analysis method has recently been used for specific areas of the United States (Mast and others, 1980; Bird, 1984). A number of studies review the methodology of play analysis (Baker and others, 1984; White and Gehman, 1979; White, 1981; Lee and Wang, 1983a, 1983b), and the reader is referred to these studies for a complete discussion of play analysis.

A number of studies have assessed the petroleum potential of the Atlantic Coastal Plain, and I have relied heavily on some of them: Johnston and others, 1959; Maher, 1971; Rouse, 1971; Spivak and Shelbourne, 1971; Stafford, 1974; Olson and Glowacz, 1977; and Zieglar, 1983.

Present Study

This report is a summary of the petroleum geology of the Atlantic Coastal Plain that was studied for Phase I. The geology of the province is described, the amount and location of Federal lands is reviewed, and three plays are analyzed. Each play is defined by potential source rocks, reservoir rocks, traps, seals, and reservoirs.

LOCATION AND REGIONAL GEOLOGY

The Atlantic Coastal Plain, as used in this study in other USGS resource assessments (Varnes and others, 1981), includes an area of approximately 383,400 mi^2 (993,000 km^2), from Georgia to Long Island, New York (fig. 1). Approximately 1 percent of this area, 5,000 mi^2 (12,950 km^2), consists of land that the Federal government owns as surface and (or) mineral rights (plates 1 through 3). Most of the Federal acreage is relatively small scattered parcels (less than 100 mi^2 (260 km^2) but some areas encompass up to 800 mi^2 (2,070 km^2). National wildlife refuges, military installations, seashores, parks, monuments, and forests comprise the Federal lands in this province.

The coastal plain is an area of seaward-thickening and dipping sedimentary rocks between the Atlantic Ocean and Piedmont province of the Appalachian Mountains. The sedimentary rocks overlie igneous and metamorphic basement rocks of Paleozoic and Precambrian age. Post-Paleozoic warping of the basement rocks resulted in a series of embayments and arches along the coast (fig. 1).

Triassic(?) through Cenozoic clastic and carbonate rocks comprise the sedimentary sequence above the basement. The sequence ranges in thickness from 0 feet at the western edge of the coastal plain to a little more than 10,000 ft (3,048 m) at Cape Hatteras, North Carolina.

Triassic(?) red beds and intrusive igneous rocks are confined to a series of buried rift basins. The extent of these basins is incompletely known. Some have been delineated from geophysical studies, and some are only approximately located on the basis of well data. Upper Jurassic(?)-Cenozoic clastic rocks are present throughout the entire region, and Cretaceous-Cenozoic carbonate rocks are restricted to the southern portion of the coastal plain. Plate 4 is a cross section showing the distribution of sedimentary rocks and showing the basement configuration along the Atlantic Coastal Plain.

OIL AND GAS PLAYS

Each of the three sedimentary sequences (Triassic(?) clastic rocks, Upper Jurassic(?)-Cenozoic clastic rocks, and Cretaceous-Cenozoic carbonate rocks) have distinct characteristics that allow them to be separated into three distinct plays. The geographic distribution of the plays are shown in plates 1 through 3.

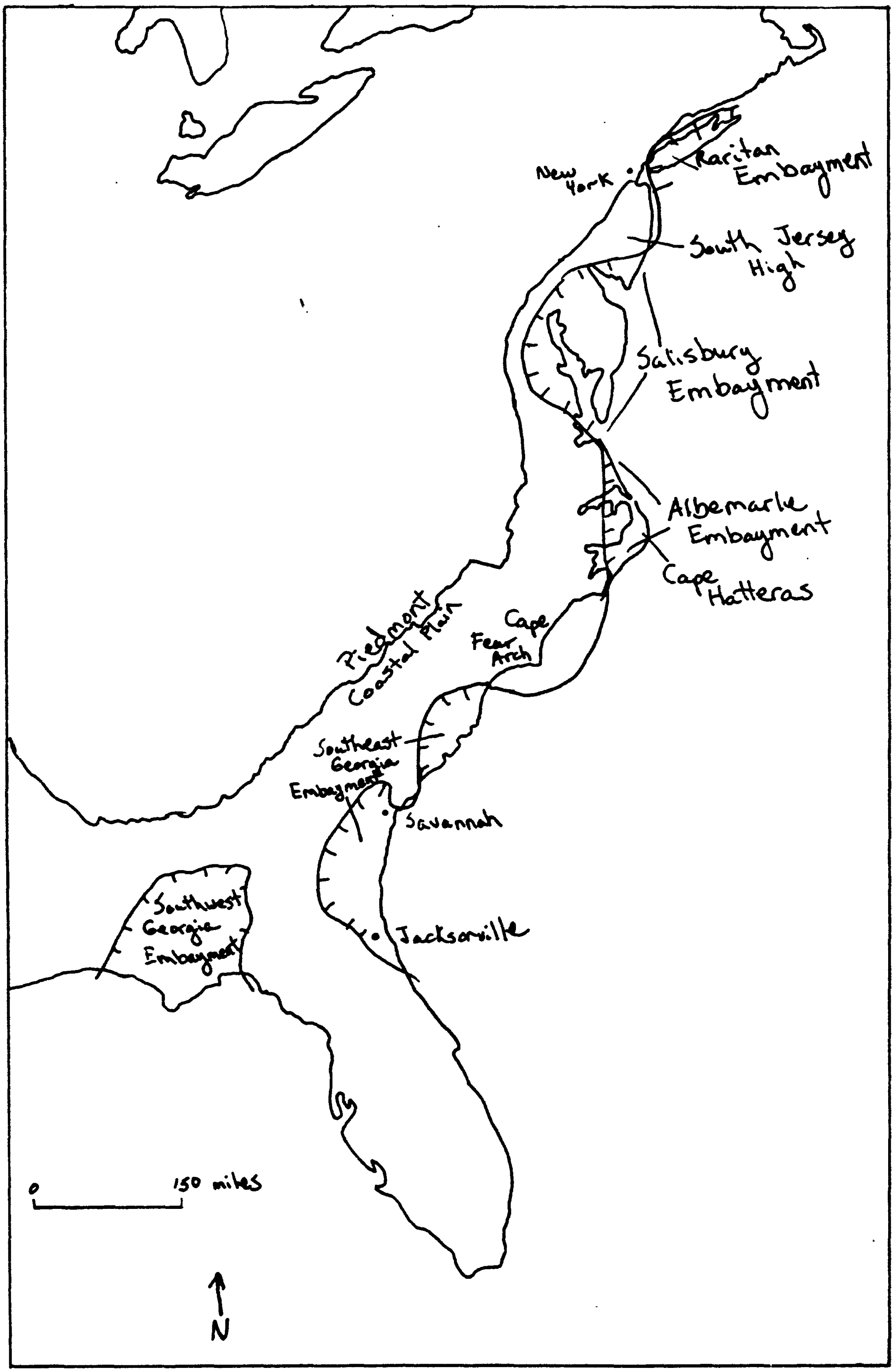

Figure 1 Map showing major structural features of the Atlantic Coastal Plain (from Owens, 1970; Maher, 1971; and Perry and others, 1975).

Triassic(?) Clastic Play

The Triassic(?) play consists of a series of buried rift basins buried beneath the younger rocks and sediments of the coastal plain. The age of the play is uncertain owing to the paucity of fossils, but lithologic similarities with the exposed Triassic basins in the Piedmont province suggest a Triassic age for the coastal plain basins. The Triassic(?) play is speculative because it has only been lightly explored (40 wildcat and stratigraphic test wells). Only three of these wells were drilled on Federal land. The play covers approximately 33,800 mi^2 (87,540 km^2), 1,700 mi^2 (4,480 km^2) of which consist of Federal land.

The South Georgia rift (Popenoe, 1977; Popenoe and Zietz, 1977; Gohn and others, 1978; Chowns, 1979; Daniels and others, 1983) is the largest of the buried Triassic(?) basins. Regional aeromagnetic gravity, seismic-refraction, and well data were used to define this basin. The South Georgia rift trends in a northeasterly direction from the western Florida panhandle and southern Alabama, through central Georgia, to southern South Carolina (fig. 2). Several individual basins may comprise the south Georgia rift. Two of these are the Riddleville and Dunbarton basins (Marine and Siple, 1974; Daniels and Zietz, 1978; Petersen and others, 1984). Other individual basins have not as yet been identified.

Other large Triassic(?) basins, together with scattered occurrences of Triassic(?), rocks comprise the remainder of the Triassic(?) play. The Florence basin in South Carolina (Siple, 1958; Bonini and Woollard, 1960; Daniels and others, 1983) and the Taylorsville basin in Virginia and Maryland (Weems, 1980) may be as large as 550 mi^2 (1,425 km^2) and 300 mi^2 (777 km^2), respectively. Scattered wildcat and stratigraphic-test wells have penetrated Triassic(?) rocks along the remainder of the coastal plain (Brown and others, 1972; Richards, 1954), but distinct basins have not been identified. These wells are spotted on plates 1-3, and small play boundaries with queries are drawn around the well to indicate a possible Triassic(?) play. Some of the Triassic(?) rocks in Maryland that were identified by Brown and others (1972) are now considered to be Late Jurassic(?) or Early Cretaceous in age (Robbins and others, 1975) and are not included on the play maps. Because so little is known about the Triassic(?) sequence under the coastal plain, evaluating its petroleum potential requires using analogs from the better known Triassic rift system exposed in the adjacent Piedmont province (fig. 3).

Lacustrine black shales are the most likely petroleum source rocks in rift basins. Shales from five of the exposed Piedmont basins (Newark, Hartford, Richmond, Danville, and Sanford basins) have a reported total organic carbon content of less than 2 percent to almost 35 percent (table 1) and various indices suggest that they have reached the oil window (Zieglar, 1983). Although other basins have lacustrine shales, they are not volumetrically significant. High (1985) analyzed the lacustrine shales from the Newark, Connecticut, and Deep River basins and concluded that the quality and quantity of organic matter was insufficient to have good source rock potential.

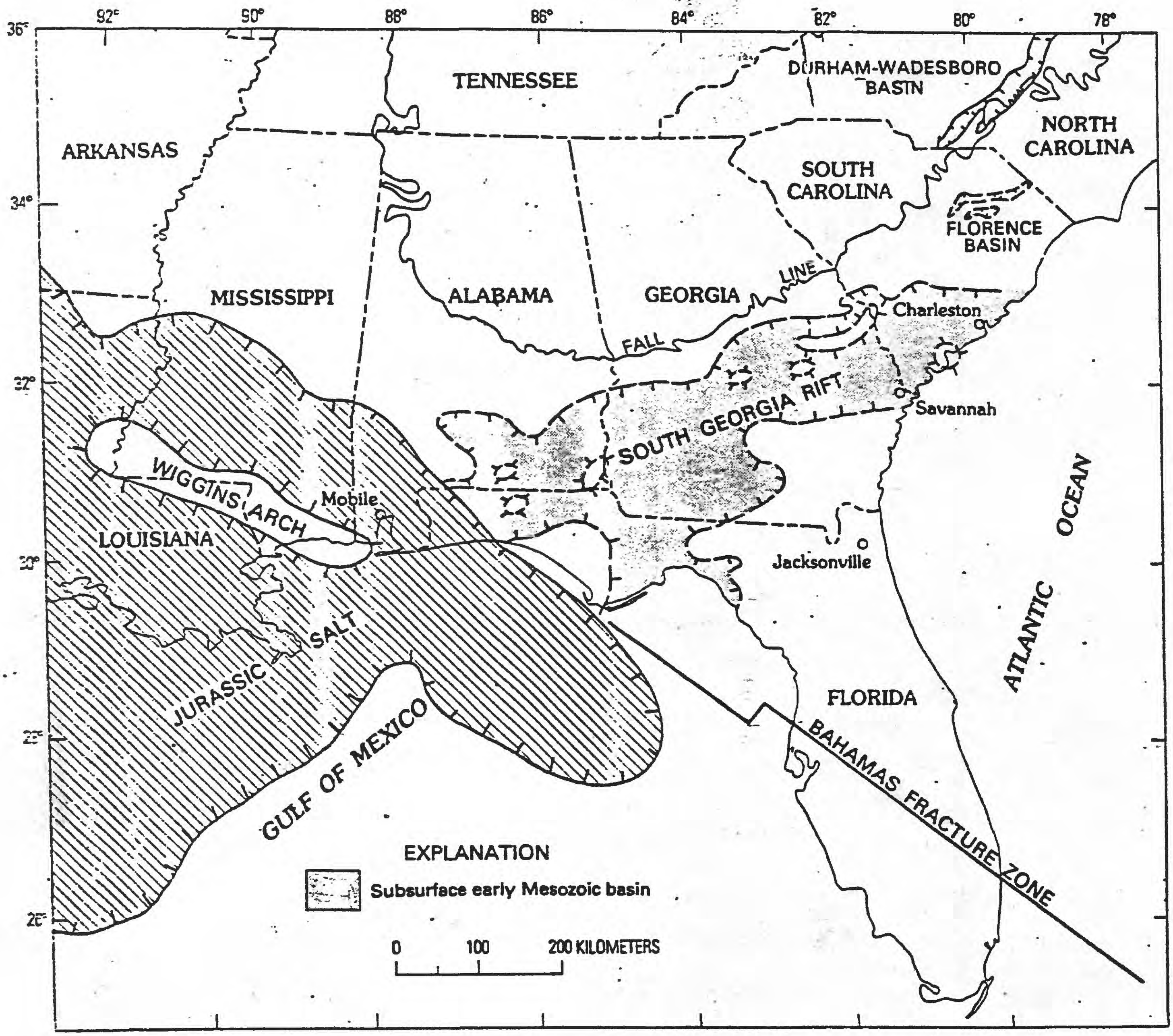

Figure 2.--Map of the South Georgia rift(Daniels and others, 1983).

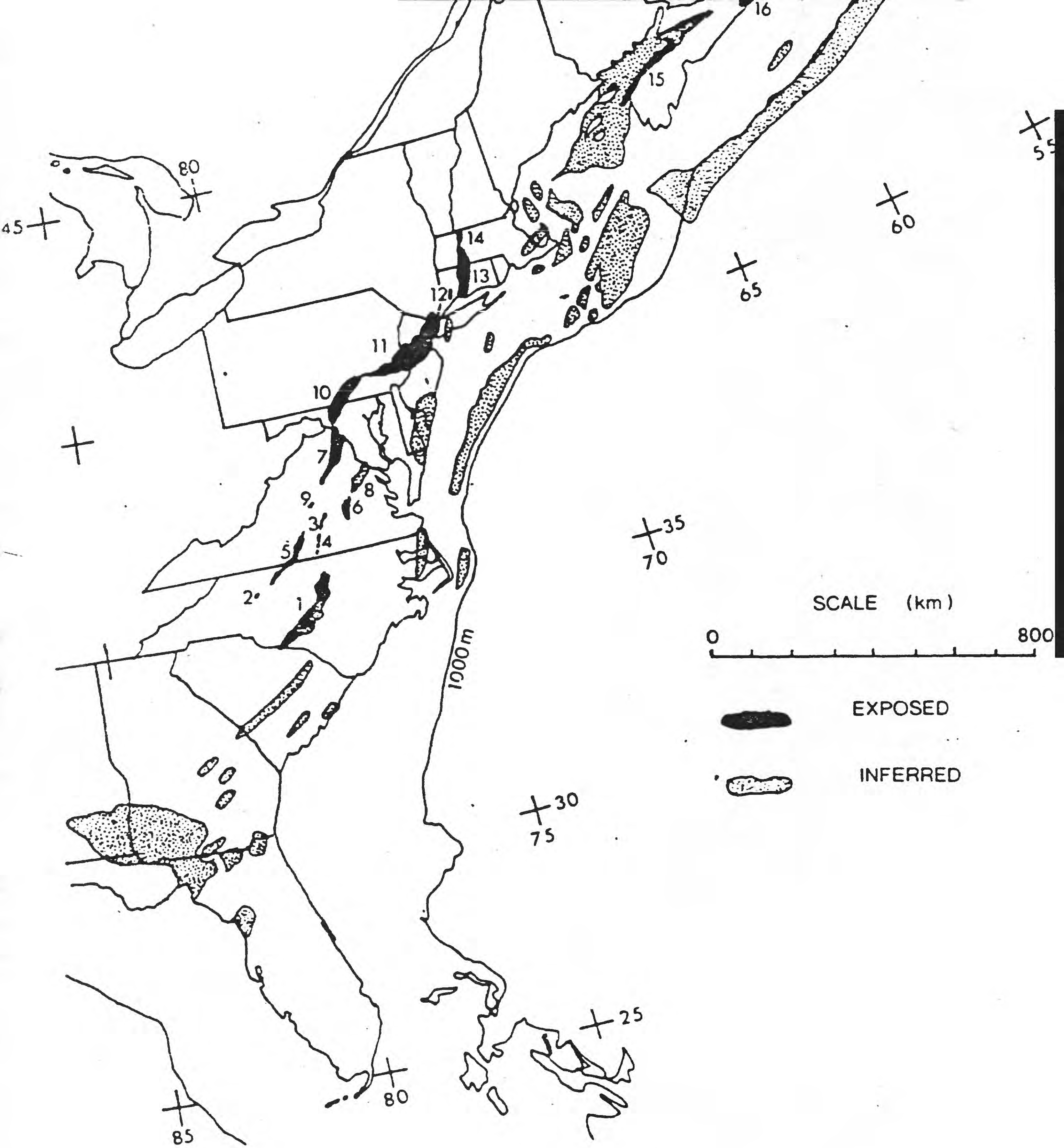

Figure 3 Map showing Triassic rift basins along the Atlantic margin (Olsen,1980).

Table 1.--Total organic content and thermal maturity of potential source rocks in Piedmont Triassic basins (Zieglar, 1983)

Basin	Formation	Total organic carbon	Thermal alteration index	Hydro-carbon window
Newark	Lockatong	<7%	3+	gas-condensate
Hartford	East Berlin	>2%	2.5	oil
Richmond	Vinita Beds	<25%	2.6-3.0	oil
Danville	Cow Branch	<2%	4.0	gas
Sanford	Cumnock	<35%	2.6-3.0	oil

The Taylorsville basin is the only buried coastal plain basin from which lacustrine black shales have been identified, and these shales are present in the exposed portion of the basin. Black shales were not encountered by the test wells. The lack of confirmed source rocks in the coastal plain basins leaves the petroleum potential of the basins suspect. Richards (1954), however, did report gas shows in a suspected Triassic section in Camden County, North Carolina.

Potential reservoir rocks consist of sandstones from various depositional environments: marginal lake environments, alluvial fans, and fluvial-deltaic environments (fig. 4). Sandstones from the exposed Piedmont basins have porosity values up to 17-25 percent (Zieglar, 1983), permeability values have not been reported. Sandstones in the buried Dunbarton basin, however, only have a porosity of 8 percent; permeability was also low, less than .02 mD, (Marine, 1974). Porosity and permeability data from other buried basins are not available.

Rift basins afford many trapping mechanisms: anticlinal structures, faults, unconformities, and stratigraphic pinchouts. Numerous folds are present in the Newark basin. If similar structures are present in the buried basins, then the crests of the anticlines could provide traps for hydrocarbons. Faults, also abundant in the Newark and Dunbarton basins, could be potential traps. Unconformity traps are another probable trap type. A Cretaceous-Triassic(?) unconformity is indicated by wells that drilled through the Cretaceous section directly into the Triassic(?) red beds. Although they have not been documented, stratigraphic pinchouts are probably present. Facies changes within rift-basin sequences are common (fig. 4) and can be expected in the coastal plain basins. Shale and mudstone are abundant in both the Piedmont and coastal plain Triassic(?) sequence and they are potential reservoir seals.

Because of the number of uncertainties concerning the Triassic(?) clastic play, its petroleum potential is difficult to estimate. The play has a high exploration risk owing to its sparse well and geophysical data. None of the 45 wells encountered lacustrine source rocks, low porosity and permeability values of the sandstones have been documented, and only one hydrocarbon show was reported. These factors, together with the relatively small amount of Federal acreage, indicates a low potential for the play on Federal land.

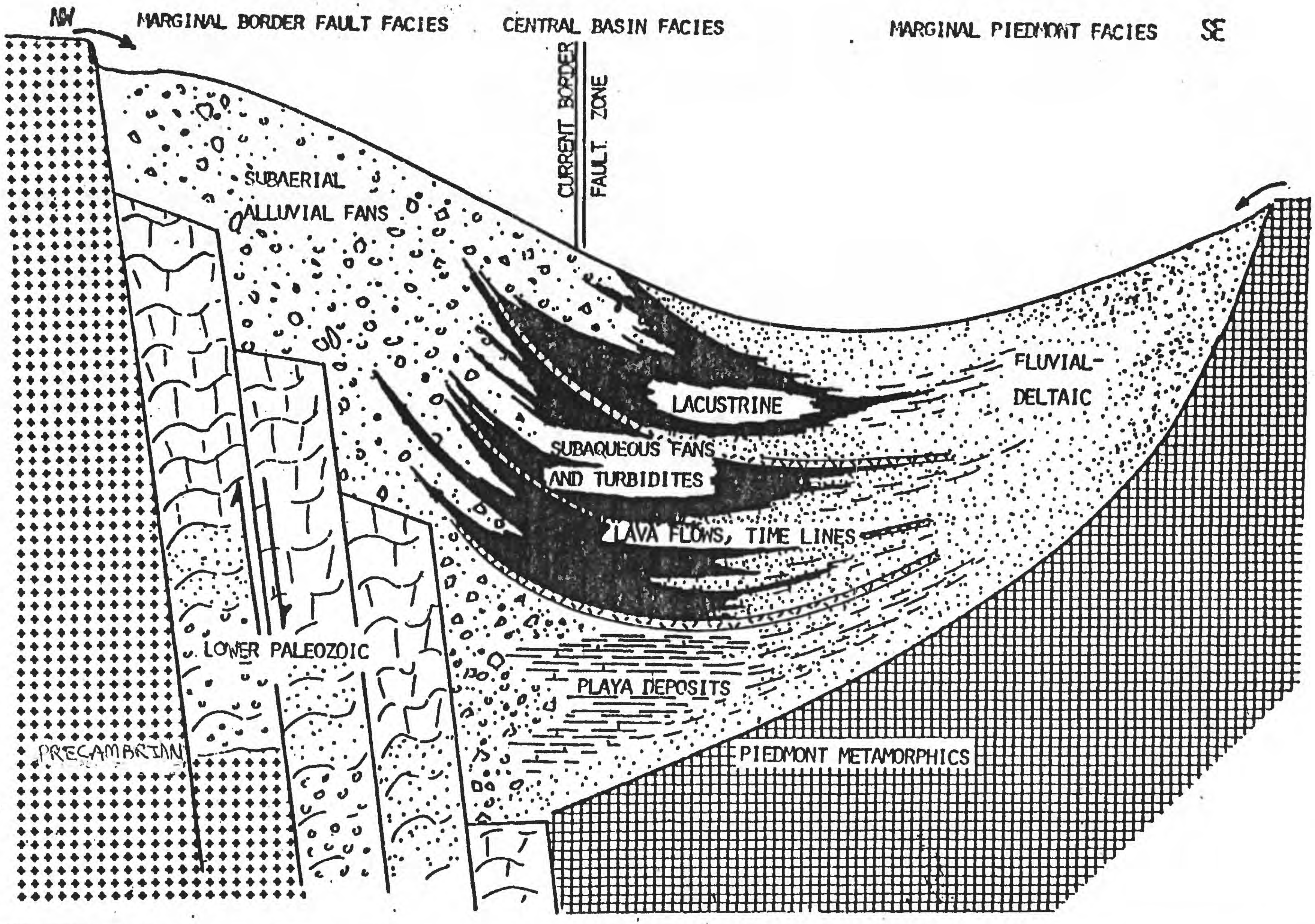

Figure 4.--Schematic cross section showing facies distributions in the Newark-type rift basins (Manspeizer, 1981).

Upper Jurassic(?)-Cenozoic Clastic Play

This clastic play encompasses the entire Atlantic Coastal Plain province and includes rocks ranging in age from Upper Jurassic(?) to Cenozoic. The clastic sequence is 0-10,000 ft (0-3,048 m) below the surface, but most of the sandstones are less than 6,500 ft deep (1,980 m). Federal lands consist of approximately 5,000 mi^2 (12,950 km^2) within the play. Most of the parcels are less than 100 mi^2 (260 km^2), but some are up to 800 mi^2 (2,070 km^2). About 350 dry holes have been drilled in the play, and about 20 of these were drilled on Federal land.

Possible, but unlikely, source rocks for this play are marine shale, marl, and limestone that are scattered throughout the sequence. Of the 350 wildcat wells, only about 10 have reported hydrocarbon shows. Surface oil seeps have been reported in Georgia and North Carolina (Maher, 1971), but these are rare occurrences. Marsh gas was produced for 2 years in Wicomico County, Maryland. This gas came from Pleistocene or Pliocene alluvium associated with a 100-foot-deep buried swamp (Maher, 1971), and it is not a significant occurrence. Brown and others' (1979) source-rock study of 13 wells indicates that although the section contains sufficient organic matter for petroleum generation, the rocks are thermally immature. This agrees with preliminary source-rock studies of the adjacent offshore area. Smith and others (1981) showed that burial of this section below 11,500 ft (3,505 m) is required for petroleum generation. Because the onshore sequence is shallower than 11,500 ft (3,505 m), it is unlikely that the sequence was sufficiently heated. Perhaps the Triassic(?) section is a source for the clastic play, but Triassic(?) source rocks have not as yet been documented beneath the coastal plain.

Potential sandstone reservoirs are abundant in the coastal plain. In outcrop, these sandstones have porosity values as high as 45 percent (Maher, 1971). Upper Cretaceous and Tertiary sandstones are major fresh-water aquifers in the coastal plain, suggesting high porosity and permeability values for these rocks.

The clastic sequence has not been affected by major tectonic movements and so structures are limited to local faults and gentle folds. These structural features may be potential traps, but detailed studies are needed to delineate them. Stratigraphic traps are more likely to occur. Pinchouts, lateral lithologic variations, and unconformities are common in the clastic sequence, and each of these is a potential trap. The sandstone beds were deposited in a variety of depositional environments, from nearshore to deltaic, alluvial, and other nonmarine environments (figs. 5, 6). Stratigraphic pinchouts and lateral lithologic variations between the different facies provides possible traps. Unconformities are common throughout the Upper Jurassic(?)-Cenozoic sequence (Jordan and Smith, 1983) and afford trapping possibilities. As in the Triassic(?) clastic play, shales and clays are the most likely seals to the reservoirs.

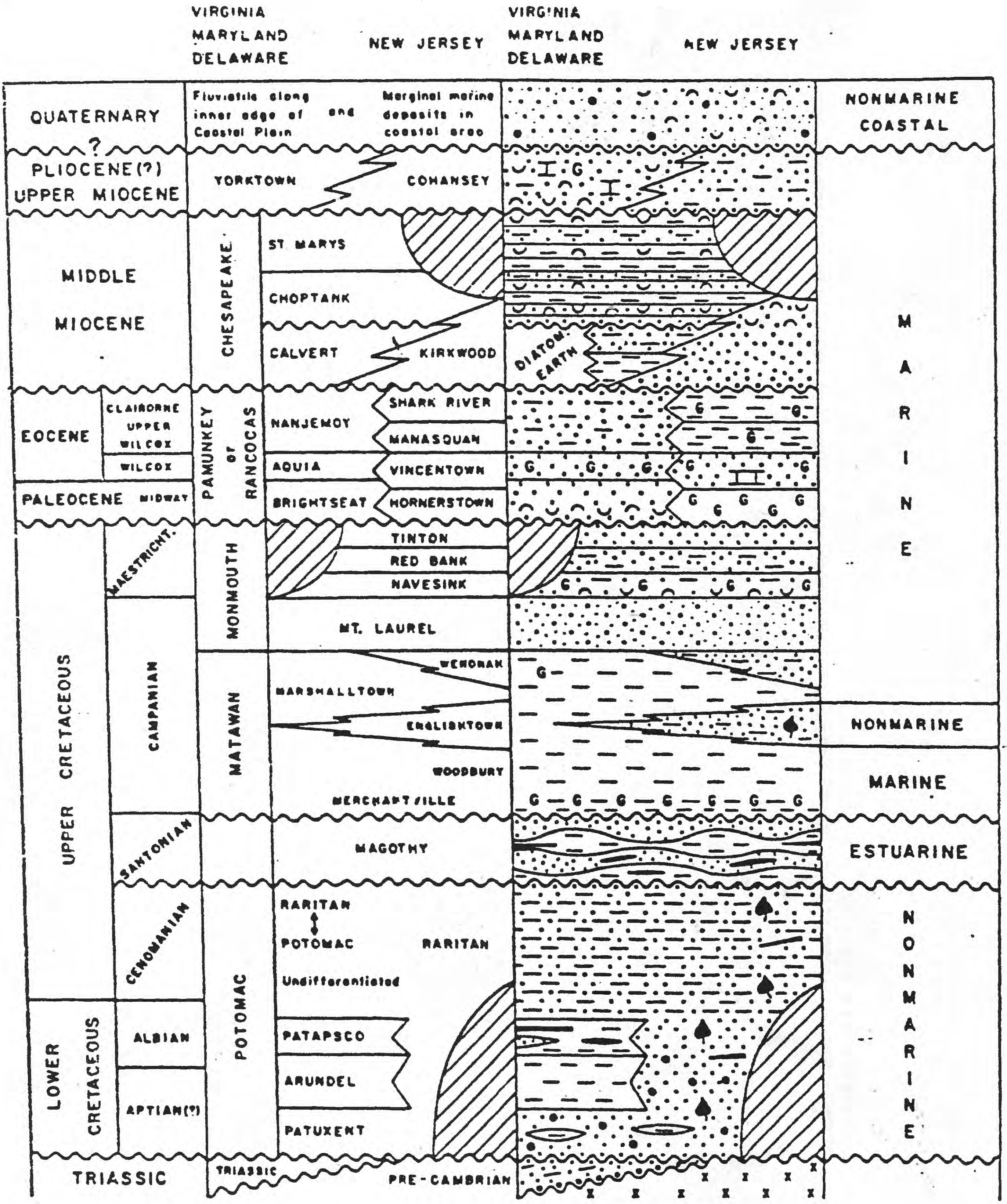

Figure 5 Schematic diagram of Mesozoic-Cenozoic rocks of the northern Atlantic Coastal Plain (Kraft and others, 1971).

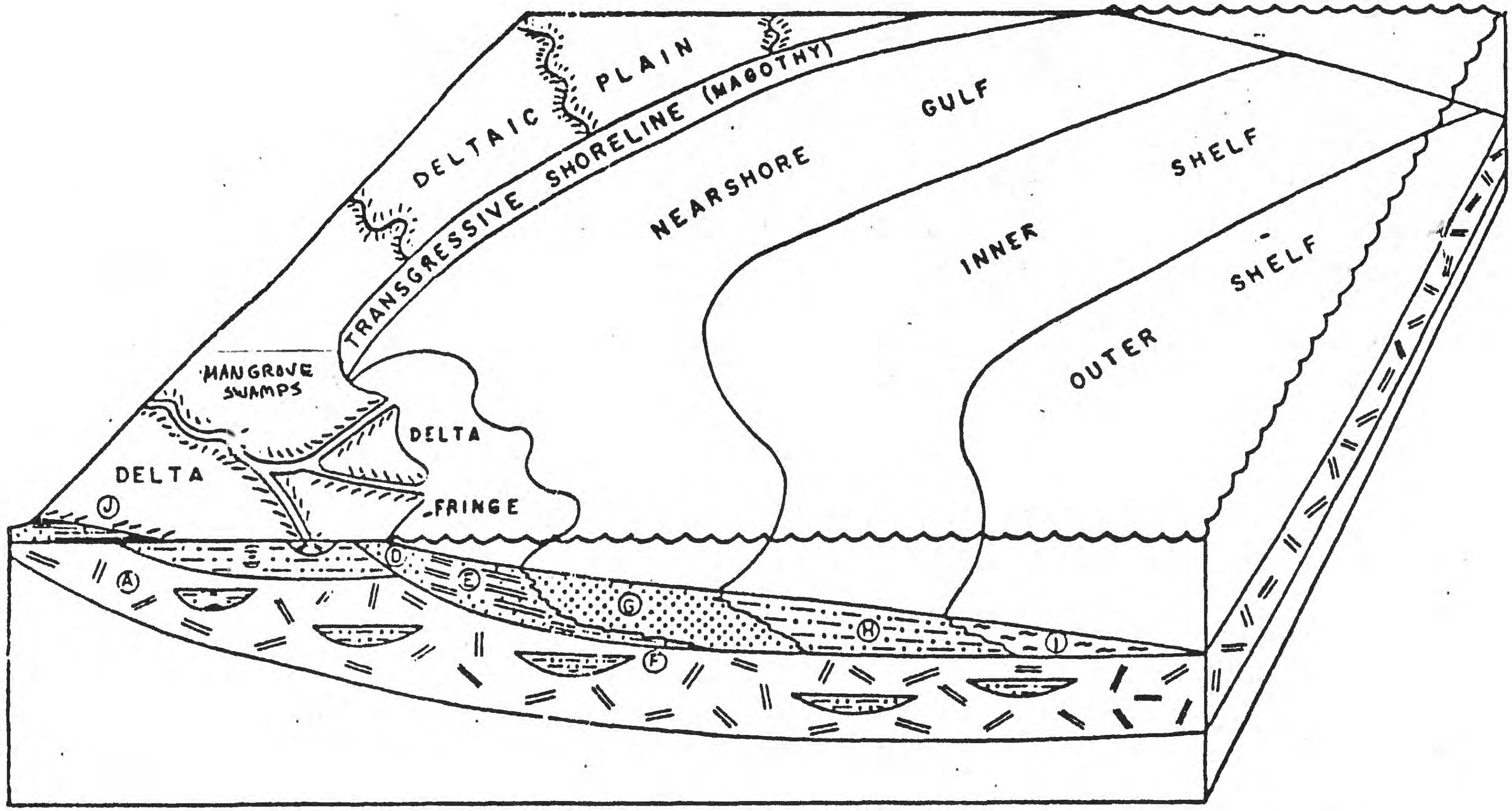

Figure 6 Diagram showing Cretaceous-Tertiary depositional environments in the New Jersey Coastal Plain. A. channel-fill point bar; B. overbank mangrove swamps; C. overbank flood basin; D. beach; E. topset delta; F. bottomset delta; G. nearshore gulf; H. inner shelf; I, outer shelf; J. overbank natural levee (Kraft and others, 1971).

Although potential reservoir rocks, traps, and seals are present, the lack of good source rocks in the region indicates a poor petroleum potential for the Federal acreage.

Lower Cretaceous-Cenozoic Carbonate Play

The carbonate play encompases about half of the coastal plain from Georgia to North Carolina (plates 1 and 2); no significant carbonate rocks are present north of North Carolina. Federal lands comprise approximately 3,600 mi^2 (9,325 km^2) of the total 51,800 mi^2 (13,430 km^2) play. The carbonate rocks range in age from Lower Cretaceous to Cenozoic, and are interbedded with clastic rocks of the same age (plate 4).

Potential source rocks are the same as those for the Upper Jurassic(?)-Cenozoic clastic play (interbedded marine marls and shales and Triassic lacustrine shales) and their presence is doubtful. No hydrocarbons shows have been reported from these rocks.

Potential carbonate reservoirs are fossiliferous and oolitic grainstones. No porosity or permeability studies of these limestone are available, but some of the Tertiary limestones are fresh-water aquifers, suggesting good porosity and permeability (Maher, 1971). Age-equivalent limestones in the offshore area have porosity values generally below 30 percent and permeability values below 5 millidarcies (Simonis, 1979). The depth of the potential reservoirs ranges between 0 and 6,500 ft (1,980 m) below the surface, but most of them are less than 3,500 ft (1,066 m) deep.

Potential traps and seals are similar to those in the Upper Jurassic(?)-Cenozoic clastic play. Clastic-carbonate lithofacies changes (fig. 7) and unconformities are the most likely trap types. The lack of good source rocks, however, indicates a low petroleum potential for this play.

SUMMARY

Although the three plays comprise a large area, the amount of Federal land within each of the plays is relatively small. Except for a few parcels, each piece of Federal land is also small. The Triassic(?) play is a high exploration risk owing to the number of unknown parameters, and the clastic and carbonate plays have a low petroleum potential owing to the lack of good source rocks. These factors combine to indicate an overall low potential for oil and gas on Federal land in the Atlantic Coastal Plain.

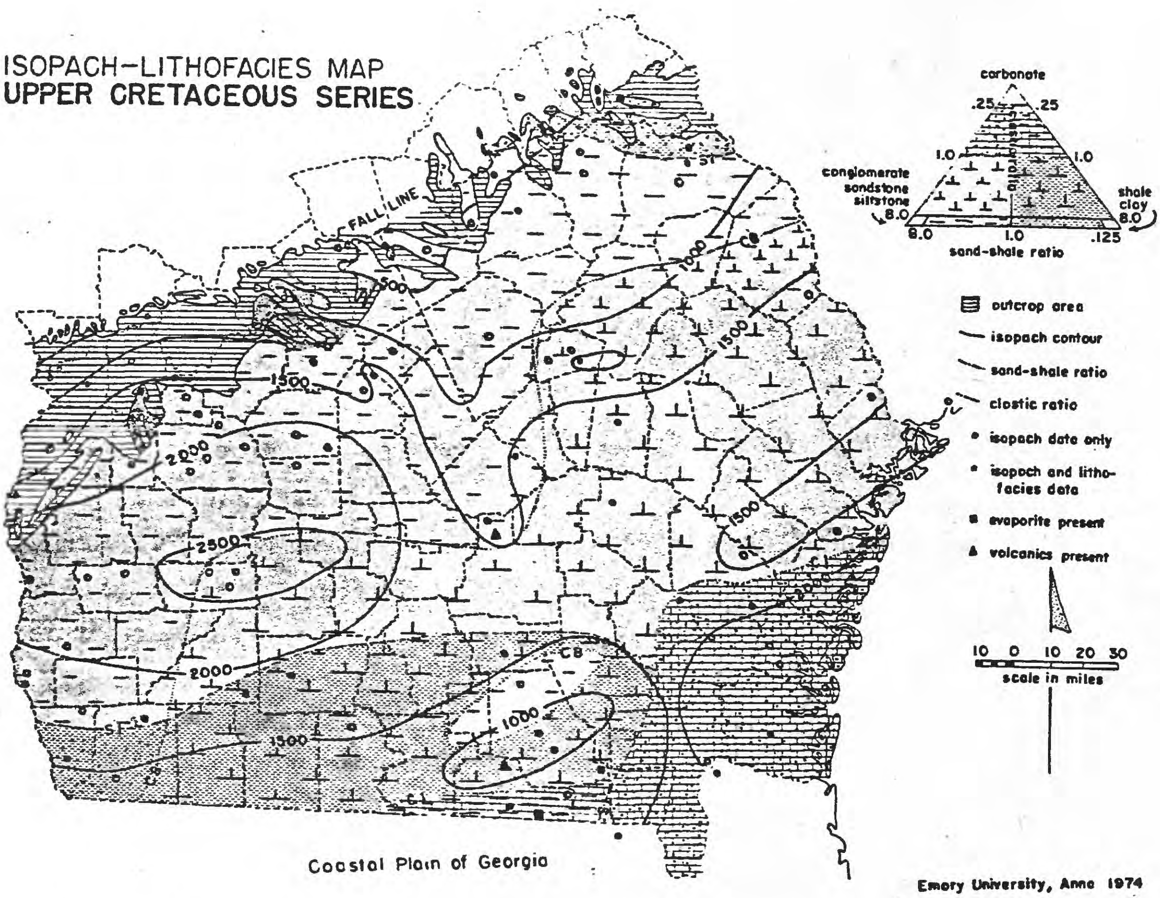

Figure 7 Map showing clastic-carbonate facies changes in the Georgia Coastal Plain (Cramer, 1974).

SELECTED BIBLIOGRAPHY

American Petroleum Institute, 1983a, Federal land status-southeastern states: American Petroleum Institute, scale 1:1,500,000, 1 map sheet.

_____1983b, Federal land status-northeastern states: American Petroleum Institute, scale 1:1,500,000, 1 map sheet.

Bain, G. L., 1973, Feasibility study of east coast Triassic basins for waste storage: U.S. Geological Survey Open-File Report 73-15, 113 p.

Baker, R. A., Gehman, H. M., James, W. R., and White, D. A., 1984, Geologic field number and size assessments of oil and gas plays: American Association of Petroleum Geologists Bulletin, v. 68, no. 4, p. 426-437.

Bird, K. J., 1984, A comparison of the play-analysis technique as applied in hydrocarbon resource assessments of the Artic National Wildlife Refuge: U.S. Geological Survey Open-File Report 84-78, 18 p.

Bonini, W. E., and Woollard, G. P., 1960, Subsurface geology of North Carolina-South Carolina Coastal Plain from seismic data: American Association of Petroleum Geologists Bulletin, v. 44, no. 3, p. 298-391.

Brown, P. M., Miller, J. A., and Swain, F. M., 1972, Structural and stratigraphic framework and spatial distribution of permeability of Atlantic Coastal Plain, North Carolina to New York: U.S. Geological Survey Professional Paper 796, 79 p.

Brown, S. W., Cernock, P. J., and Haykus, J. A., 1979, Regional hydrocarbon source-rock evaluation of Atlantic Coastal Plain adjacent to Georgia embayment (abs): American Association of Petroleum Geologists Bulletin, v. 63, no. 3, p. 425.

Chowns, T. M., 1979, Pre-Cretaceous rocks beneath the Georgia Coastal Plain (abs.), in Arden, D. D., Beck, B. F., and Morrow, Eleanore, eds., 2nd symposium on the geology of the Southeastern Coastal Plain, proceedings: Georgia Geologic Survey Information Circular 53, p. 196.

Cramer, H. R., 1974, Isopach and lithofacies analysis of the Cretaceous and Cenozoic rocks of the coastal plain of Georgia, in Stafford, L. P., compiler, Symposium on the petroleum geology of the Georgia Coastal Plain: Georgia Geologic Survey Bulletin 87, p. 21-44.

Daniels, D. L., and Zietz, Isidore, 1978, Geologic interpretation of aeromagnetic maps of the coastal plain region of South Carolina and parts of North Carolina and Georgia: U.S. Geological Survey Open-File Report 78-261, 62 p.

Daniels, D. L., Zietz, Isidore, and Popenoe, Peter, 1983, Distribution of subsurface lower Mesozoic rocks in the southeastern United States, as interpreted from regional aeromagnetic and gravity maps, in Gohn, G. S., ed., Studies related to the Charleston, South Carolina earthquake of 1886-tectonics and seismicity: U.S. Geological Survey Professional Paper 1313-K, p. K-1-K-24.

Dolton, G. L., Carlson, K. H., Charpentier, R. R., Coury, A. B., Crovelli, R. A., Frezon, S. E., Khan, A. S., Lister, J. H., McMullin, R. H., Pike, R. S., Powers, R. B., Scott, E. W., and Varnes, K. L., 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: U.S. Geological Survey Circular 860, 87 p.

Gohn, G. S., Ackermann, H. D., Campbell, D. L., Dillon, W. P., Gottfried, David, Phillips, J. D., and Popenoe, Peter, 1978, Buried Early Mesozoic graben in the southeastern United States (abs.): Los Alamos Scientific Laboratory, 1978 International Symposium on the Rio Grande Rift, Program and abstracts, p. 39.

High, L. R., 1985, Evaluation of potential hydrocarbon sources in lacustrine facies of Newark Supergroup, Eastern United States (abs.): American Association of Petroleum Geologists Bulletin, v. 69, no. 3, p. 265.

Johnston, J. E., Trumbull, James, and Eaton, G. P., 1959, The petroleum potential of the emerged and submerged Atlantic Coastal Plain of the United States: World Petroleum Congress, 5th, New York 1959, Proceedings, sec. 1, p. 435-445.

Jordan, R. R., and Smith, R. V., 1983, Atlantic Coastal Plain correlation chart: American Association of Petroleum Geologists, COSUNA Project, Tulsa.

Kraft, J. C., Sheridan, R. E., and Maisano, Marilyn, 1971, Time-stratigraphic units and petroleum entrapment models in Baltimore Canyon basin of Atlantic Continental margin geosynclines: American Association of Petroleum Geologists Bulletin, v. 55, no. 5, p. 658-679.

Lee, P. J., and Wang, P. C. C., 1983a, Probabilistic formulation of a method for the evaluation of petroleum resources: Journal of the International Society for Mathematical Geology, v. 15, no. 1, p. 163-181.

_____ 1983b, Conditional analysis for petroleum resource evaluations: Journal of the International Society for Mathematical Geology, v. 15, no. 2, p. 349-361.

Maher, J. C., 1971, Geologic framework and petroleum potential of the Atlantic Coastal Plain and Continental Shelf: U.S. Geological Survey Professional Paper 659, 98 p.

Manspeizer, Warren, 1981, Early Mesozoic basins of the central Atlantic passive margins, in Bailey, A. W., Watts, A. B., Grow, J. A., Manspeizer, Warren, Beroulli, Daniel, Schreiber, B. C., and Hunt, J. M., eds., Geology of passive continental margins-history, structure, and sedimentologic record (with special emphasis on the Atlantic margin): American Association of Petroleum Geologists Education Course Note Series No. 19, p. 4-1 - 4-60.

Marine, I. W., 1974, Geohydrology of buried Triassic basin at Savannah River Plant, South Carolina: American Association of Petroleum Geologists Bulletin, v. 58, no. 9, p. 1825-1837.

Marine, I. W., and Siple, G. E., 1974, Buried Triassic basin in the central Savannah River area, South Carolina and Georgia: Geological Society of America Bulletin, v. 85, no. 2, p. 311-320.

Mast, R. F., McMullin, R. H., Bird, K. J., and Brosge, W. P., 1980, Resource appraisal of undiscovered oil and gas resources in the William O. Douglas Artic Wildlife Range: U.S. Geological Survey Open-File Report 80-916, 62 p.

Miller, B. M., Thomsen, H. L., Dolton, G. L., Coury, A. B., Hendricks, T. A., Lennartz, F. E., Powers, R. B., Sable, E. G., and Varnes, K. L., 1975, Geological estimates of undiscovered recoverable oil and gas resources in the United States: U.S. Geological Survey Circular 725, 78 p.

Olsen, P. E., 1980, Triassic and Jurassic formations of the Newark Basin, in Manspeizer, Warren ed., Field Studies of New Jersey geology and guide to field trips: 52nd Annual Meeting of the New York Geological Association, p. 2-39.

Olson, N. K., and Glowacz, M. E., 1976, Petroleum geology and oil and gas potential of South Carolina: American Association of Petroleum Geologists Bulletin, v. 61, no. 3, p. 331-343.

Owens, J. P., 1970, Post-Triassic movements in the central and southern Appalachians as recorded by sediments of the Atlantic Coastal Plain, in Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., Weaver, K. N., eds., Studies of Appalachian Geology, central and southern: New York, Interscience Publishers, p. 417-427.

Perry, W. J., Jr., Minard, J. P., Weed, E. G. A., Robbins, E. I., and Rhodehamel, E. C., 1975, Stratigraphy of Atlantic coastal margin of United States north of Cape Hatteras-brief survey: American Association of Petroleum Geologists Bulletin, v. 59, no. 9, p. 1529-1548.

Petersen, T. A., Brown, L. A., Cook, F. A., Kaufman, Sidney, Oliver, J. E., 1984, Structure of the Riddleville basin from COCORP Seismic data and implications for reactivation tectonics: Journal of Geology, v. 92, p. 261-271.

Popenoe, Peter, 1977, A probable major Mesozoic rift system in South Carolina and Georgia (abs.): EOS, American Geophysical Union Transactions, v. 58, no. 6, p. 432.

Popenoe, Peter, and Zietz, Isidore, 1977, The nature of the geophysical basement beneath the coastal plain of South Carolina and northeastern Georgia, in Rankin, D. W., ed., Studies related to the Charleston, South Carolina, earthquake of 1886--a preliminary report: U.S. Geological Survey Professional Paper 1028, p. 119-137.

Richards, H. G., 1954, Subsurface Triassic in eastern North Carolina: American Association of Petroleum Geologists Bulletin, v. 38, no. 12, p. 2564-2565.

Robbins, E. I., Perry, W. J., Jr., and Doyle, J. A., 1975, Palynological and stratigraphic investigations of four deep wells in the Salisbury Embayment of the Atlantic Coastal Plain: U.S. Geological Survey Open-File Report 75-307, 120 p.

Rouse, J. T., 1971, Possible future petroleum potential of Atlantic Coastal Plain, Peninsular Florida, and adjacent continental shelves, in Cram, I. R., Future petroleum provinces of the United States--their geology and potential: American Association of Petroleum Geologists Memoir 15, v. 2, p. 1291-1294.

Simonis, E. K., 1979, Petrophysical summary, in Scholle, P. A., ed., Geological studies of the COST GE-1 well, United States South Atlantic Outer Continental Shelf Area: U.S. Geological Survey Circular 800, p. 37-41.

Siple, G. E., 1958, Stratigraphic data from selected oil tests and water wells in South Carolina Coastal Plain: South Carolina Minerals Industries Laboratory Monthly Bulletin, v. 2, no. 9, p. 62-68.

Smith, M. A., Fiorillo, A. R., and Fry, C. E., 1981, Geochemical framework and source-rock evaluation of Mid-Atlantic OCS (abs.): American Association of Petroleum Geologists Bulletin v. 65, no. 9, p. 1671.

Spivak, J., and Shelburne, O. B., 1971, Future hydrocarbon potential of Atlantic coastal province, in Cram, I. R., Future petroleum provinces of the United States--their geology and potential: American Association of Petroleum Geologists Memoir 15, v. 2, p. 1291-1294.

Stafford, L. P., 1974, Symposium on the petroleum geology of the Georgia Coastal Plain: Georgia Geological Survey Bulletin 87, 191 p.

Varnes, K. L., Coury, A. B., Dolton, G. L., Frezon, S. E., Khan, A. S., Pike, R. S., Powers, R. B., and Scott, E. W., compilers, 1981, Oil and gas resource assessment areas, Geologic Division, 1980, lower 48 United States, Regions 2 through 11, 2A, 6A and 11A: U.S. Gological Survey Open-File Report 81-84C, scale 1:5,000,000, 1 sheet.

Weems, R. E., 1980, Geology of the Taylorsville basin, Hanover County, Virginia: Virginia Division of Mineral Resources 27, Contributions to Virginia Geology IV, Publication 27, p. 23-38.

White, L. P., 1981, A play approach to hydrocarbon resource assessment and evaluation, in Ramsey, J. B., ed., The economics of exploration for energy resources: Greenwich, CT, JAI Press, p. 51-67.

White, L. P., and Gehman, H. M., 1979, Methods of estimating oil and gas resources: American Association of Petroleum Geologists Bulletin, v. 63, no. 12, p. 2183-2192.

Zieglar, D. G., 1983, Hydrocarbon potential of the Newark rift system--eastern North America: Northeastern Geology, v. 5, no. 3/4, p. 200-208.