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Atlantic OCS Resource and Leasing Potential

by

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Abstract

Thick marine sedimentary sections and geologic structures favorable for the accumulation of petroleum are indicated in Georges Bank basin, the Baltimore Canyon trough, and the Southeast Georgia embayment. Undiscovered recoverable resources of petroleum on the Atlantic OCS are estimated to be 10 billion to 20 billion barrels of oil and 55 trillion to 110 trillion cubic feet of gas. Such estimates carry a high degree of uncertainty. Preliminary results suggest that the most favorable areas for leasing are under the deeper waters of the shelf.

Introduction

Regional geological and geophysical studies are being conducted by the U.S. Geological Survey on the United States Atlantic OCS (Outer Continental Shelf). The objectives of these studies are to determine the general structural framework, depositional environments, and stratigraphy of the Atlantic Continental Shelf and Slope and to asses it's petroleum resource potential.

The first part of this paper will review the geology of the United States Atlantic OCS. The Atlantic OCS is underlain by a series of deep sedimentary basins separated by arches or platforms where the sedimentary

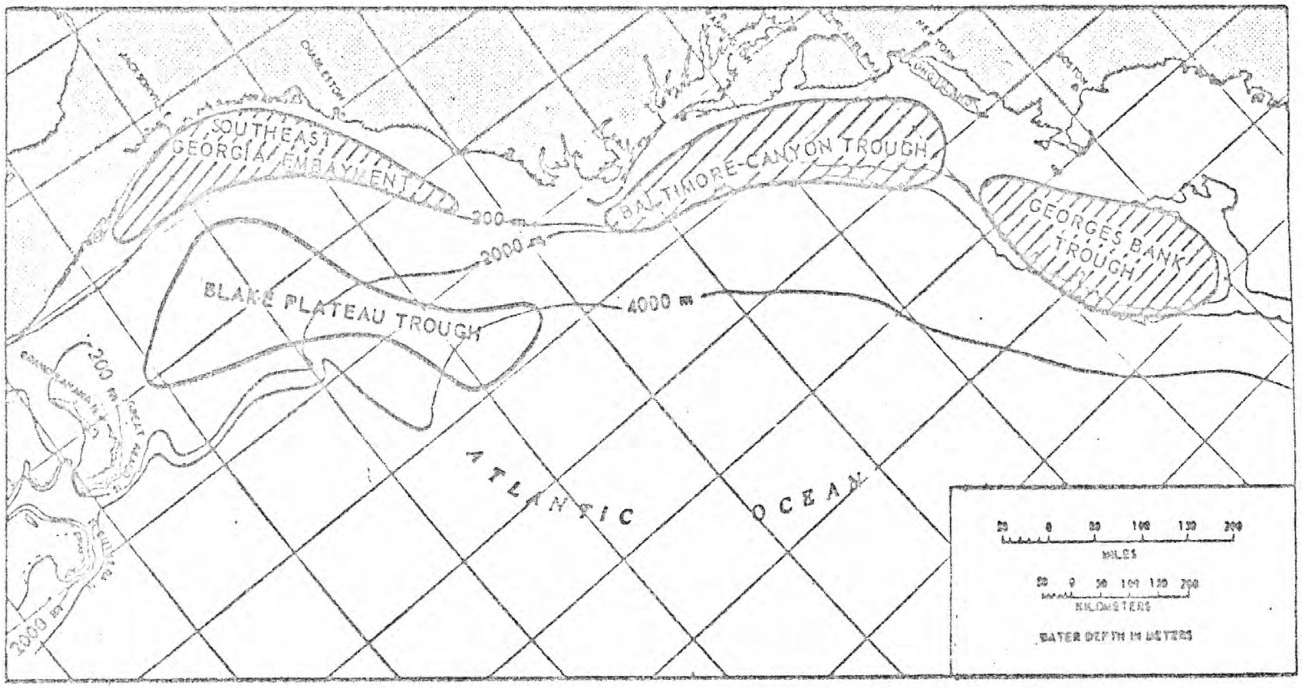

Figure 1. -- Map of United States continental margin showing outline of sedimentary basins.

cover is relatively thin. Three such basins occur offshore of eastern United States -- the Georges Bank basin, the Baltimore Canyon trough, and the Southeast Georgia embayment, shown as hachured areas in Figure 1. Georges Bank basin is southeast of the New England Coast, the Baltimore Canyon trough extends from about twenty miles south of Long Island, New York to North Carolina, and the Southeast Georgia embayment extends from South Carolina to Cape Canaveral, Florida. Emphasis first will be placed on relating the thickness, depositional environments, and distribution of the sedimentary strata in these basins to potential hydrocarbon source beds and reservoir rocks and the types of potential oil and gas bearing geologic structures.

Next, estimates of the oil and gas resource potentials will be given for the U.S. Atlantic shelf area from the shore line to water depths of 200 m (meters). The petroleum resource potential of the deeper water areas (e.g., greater than 200 m) on the Atlantic Continental Margin has been recognized by many scientific investigators. In particular, the Blake Plateau trough eastward of the Southeast Georgia embayment (fig. 1) has been studied by Emery and Uchupi (1972), Maher (1971), and many other scientists. Petroleum and mineral resource potential studies of these deep water areas are also being conducted by the U.S. Geological Survey. The shelf area is receiving first priority, however, because it may be some years before drilling and production technology is fully operational and readily available for the deep water areas.

The last section of this paper will discuss the areas of the Atlantic OCS which appear most favorable for leasing.

Previous Investigations

The existence of major sedimentary basins beneath the continental shelf of eastern North America was postulated by Drake and others (1959). They indicated that a basement ridge near the shelf edge separated basins beneath the shelf from outer basins beneath the continental slope. Taylor and others (1968) mapped a zone of high magnetic intensity near the shelf-slope break. This trend, usually referred to as the "East Coast Anomaly" or "Slope Anomaly" and shown on figure 2, extends along the edge of the shelf; it coincides generally with the ridge proposed by Drake and others in 1963. Maher (1971) described the stratigraphy of the Atlantic Coastal Plain and provided comparisons of gravity and magnetic trends along the shelf edge. Spivak and Shelburne (1971) discussed the petroleum potential of the Atlantic Coastal Plain and Continental Margin. Emery and Uchupi (1972) provided new insight into the geologic history of the Atlantic OCS and suggested that the sedimentary section beneath the shelf was considerably thicker than previously recognized.

Recent papers by Schultz and Grover (1974), Minard and others (1974), Mattick and others (1974), Perry and others (1974), Behrendt and others (1974), Weed and others (1973), and W. S. Olson (1974) have been published on the structure, stratigraphy and geologic history of the U.S. Atlantic Coastal Plain and Continental Margin. These papers, with additional data cited elsewhere, were used in preparing this paper.

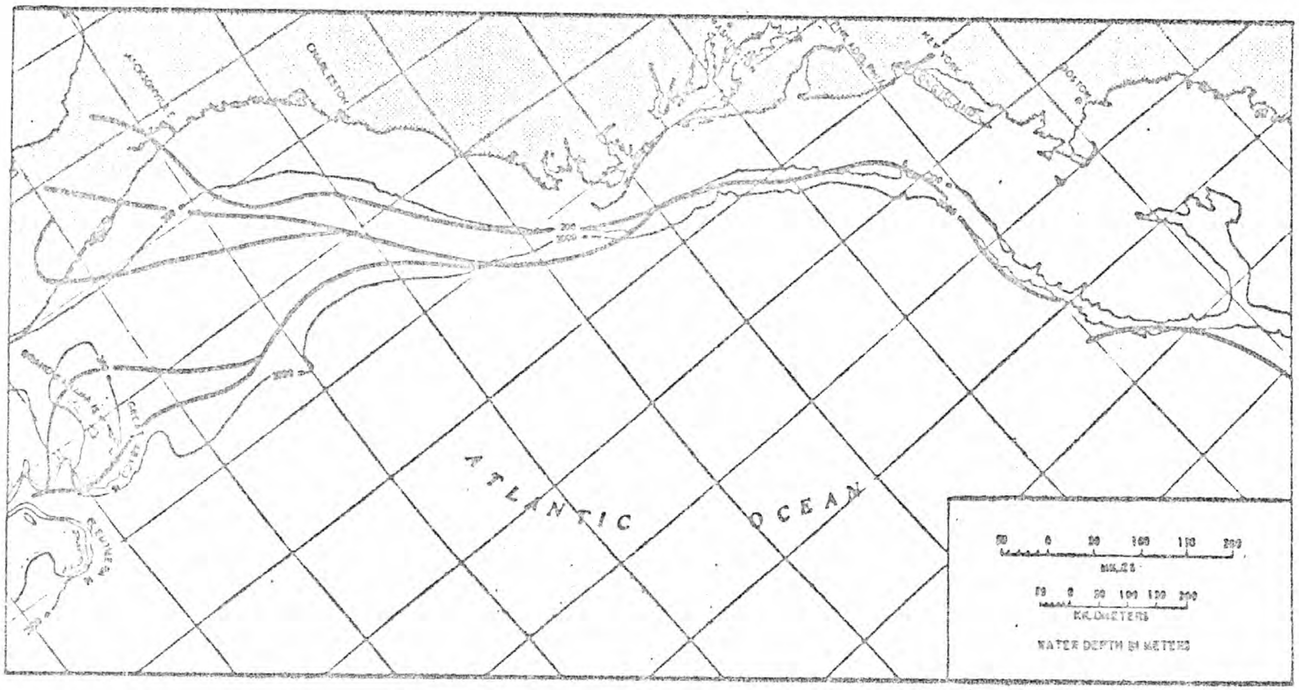

Figure 2. -- Map of United States continental margin showing the trend of the East Coast Magnetic anomaly.

Geological Framework

During the past 20 years, oil and gas exploratory holes and water wells have been drilled throughout the Atlantic Coastal Plain of the eastern seaboard. Samples and logs from the deep wells near the edge of the coastal plain have supplied valuable data used to project the stratigraphy beneath the shelf, and to correlate seismic reflection and refraction horizons. Core and grab samples from the slope are particularly valuable to this study.

In addition, about 40 exploratory wells have been drilled on the Nova Scotia Shelf, north of Georges Bank basin. Thickness and facies changes observed in the stratigraphic units drilled by these tests have been reported by McIver (1974). Some of the stratigraphic units penetrated in these wells can be projected into the Georges Bank basin.

Georges Bank Basin

Georges Bank basin is an elliptically shaped trough about 400 km (kilometers) long and 180 km wide (fig. 3). The axis of the basin is about 300 km east of Boston, Massachusetts. The Yarmouth arch, a broad basement ridge, bounds the basin on the northeast. The southwestern limit of the basin is the Long Island platform, a basement high that extends westward into New Jersey.

Figure 3 also shows the location of diagrammatic cross section A-A', which will illustrate the generalized structure, stratigraphy, and geologic history of Georges Bank basin. This section is based upon the interpretation of a regional Common Depth Point (CDP) seismic reflection survey conducted by the U.S. Geological Survey in 1973.

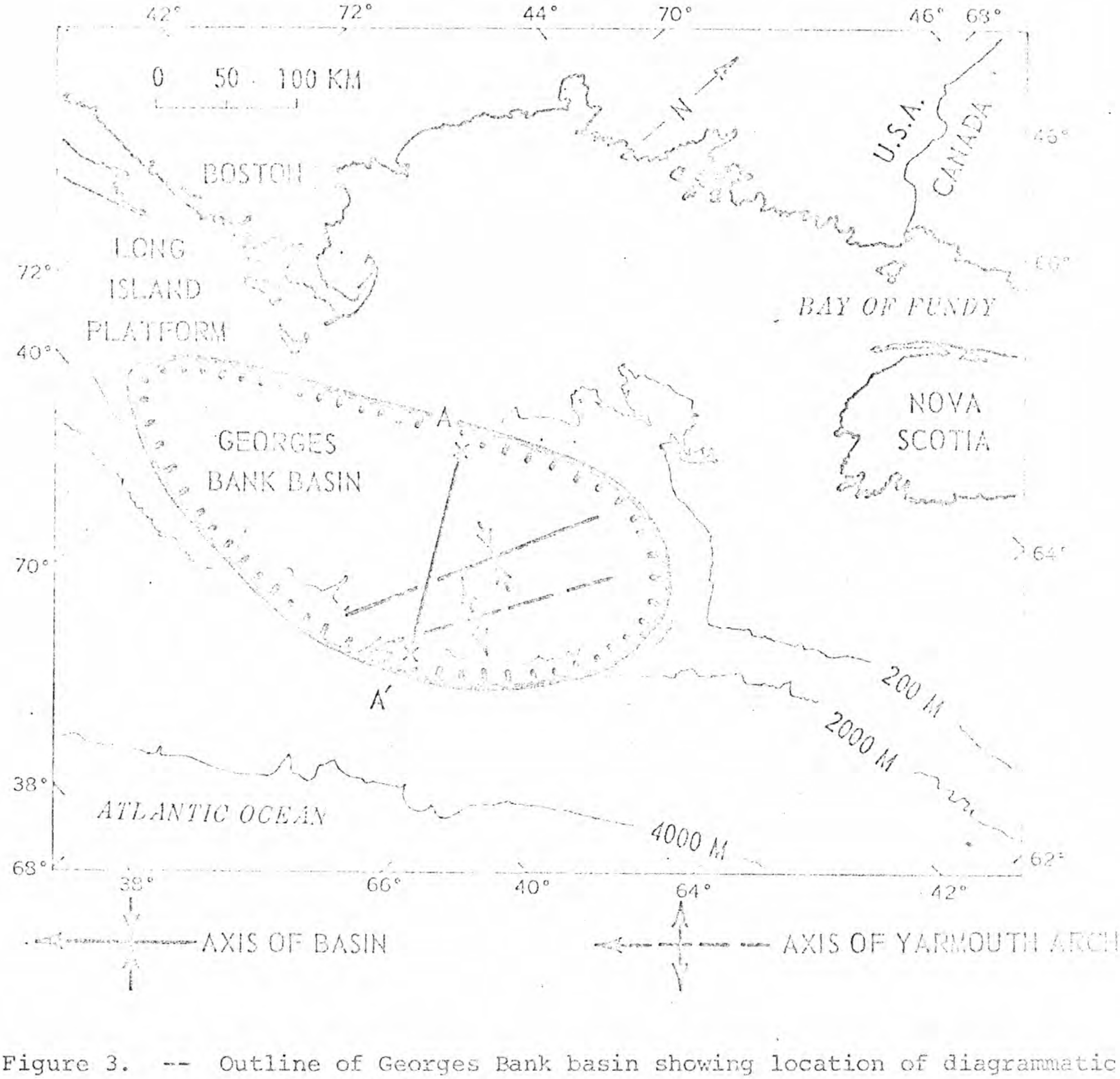

Figure 3. -- Outline of Georges Bank basin showing location of diagrammatic cross section A-A'.

The shoreward, or updip, limit of the basin (fig. 4) is parallel to and beneath the northern edge of Georges Bank. The sedimentary section, consisting of Cenozoic and Mesozoic rocks, dips seaward and increases in thickness from about 750 meters (m) to about 6,000 m to 7,000 m along the basin axis. Mattick and others (1974) have reported that the sedimentary section is 8,000 to 9,000 m thick in the deepest part of the basin.

Schultz and Grover (1974) have suggested that an overall stratigraphic similarity to rocks in the Western Scotian shelf is likely. There may be more than 4,000 m of Lower Cretaceous and Jurassic carbonate rock, marine shale, evaporite and consolidated sandstone. Therefore, ample sedimentary strata suitable for source beds and reservoir rocks are present. The Jurassic units in the basin are probably thicker than the equivalent units on the Western Scotian Shelf.

Upper Cretaceous and Tertiary sandstones and shales more than 3,500 m thick may comprise the upper section of the basin. The Late Cretaceous and Tertiary sediments are believed to represent progradational cycles that poured continent-derived sands and shales across the shelf onto the slope and rise (Schultz and Grover, 1974; Weed and others, 1973).

The CDP seismic reflection data indicate that basement structures include high angle faults, which appear to have directly affected only the basal 1-2 km (kilometers) of sediments, and local basement flexures. The most likely traps for petroleum accumulation then will be anticlines (caused by uplift or differential compaction) over basement highs and horst blocks, and structural closures against faults. Stratigraphic traps formed by updip wedgeouts of Jurassic and Cretaceous strata also could provide substantial petroleum

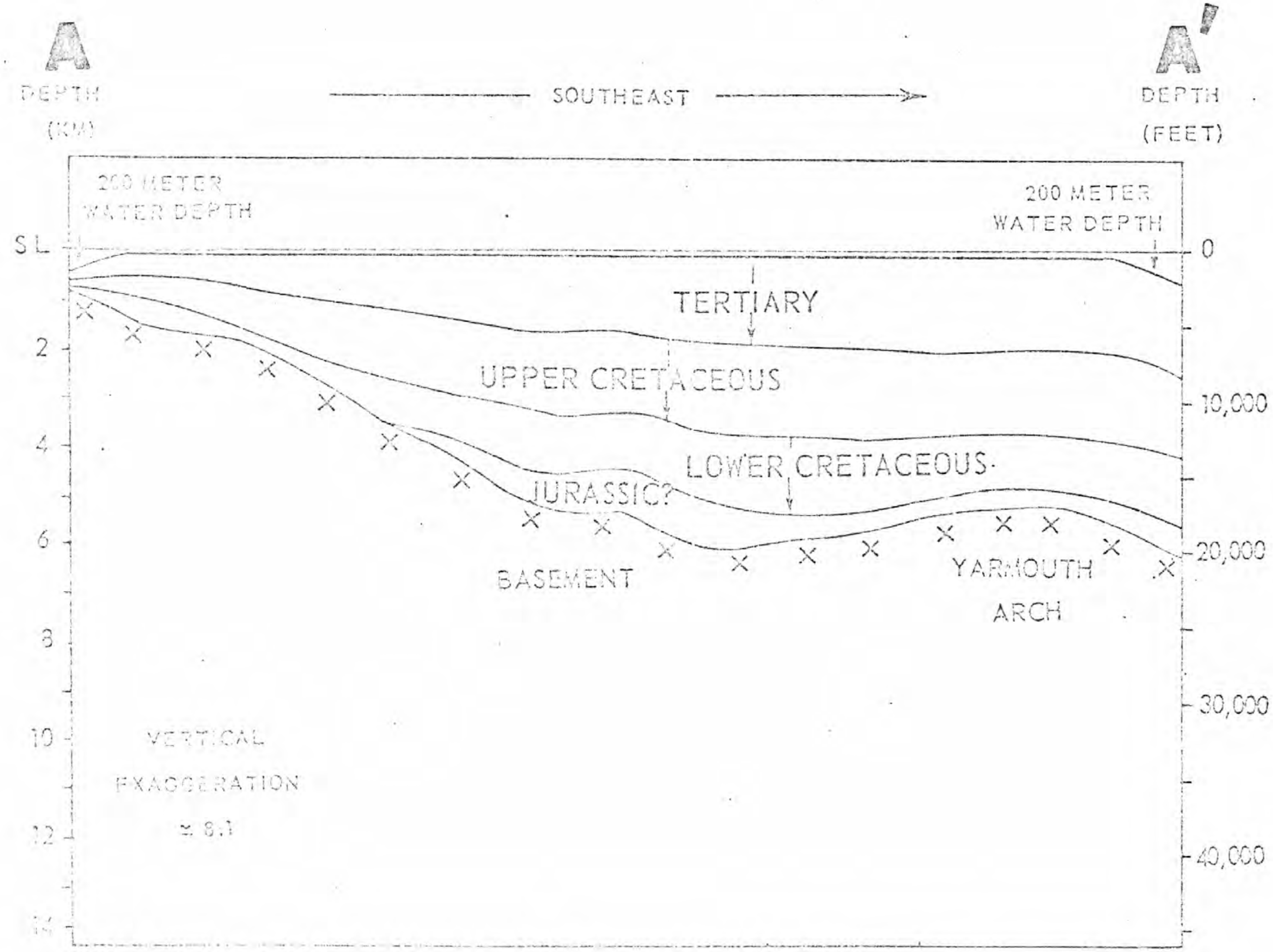

Figure 4. -- Diagrammatic cross section A-A' across Georges Bank basin.

reservoirs. We have no evidence that indicates salt diapirs within Georges Bank basin, an observation consistent with that of Schultz and Grover (1974).

Baltimore Canyon Trough

The Baltimore Canyon trough, the outline of which is shown in figure 5, is a major synclinorium involving the crystalline basement (Kraft and others, 1971, Fig. 7). The trough is bordered on the east by a basement (?) ridge (Drake and others, 1959; Mattick and others, 1974) whose axis is nearly parallel with the shelf edge. The southern end of the basin is controlled by the northern flank of the Cape Fear Arch, located south of Cape Hatteras, and the northeast end of the basin is controlled by the Long Island Platform. The basin is over 600 km long near the shelf edge and is almost 200 km wide off New Jersey.

Figure 5 also shows the location of diagrammatic cross section B-B' (fig. 6) across the basin. CDP seismic reflection data and other geophysical measurements, and onshore geological information were used to construct this section.

As shown in figure 6, the Baltimore Canyon trough is a large, halfgrabenlike structure possibly initiated by tensional forces during separation of the American and European continental plates in Triassic time. Further depression of the trough would have occurred along the controlling faults as more than 13,000 m of sediments, ranging in age from Jurassic to Pleistocene, accumulated in the trough. According to Mattick and others (1974), the trough could contain more than 15,000 m of sediments with

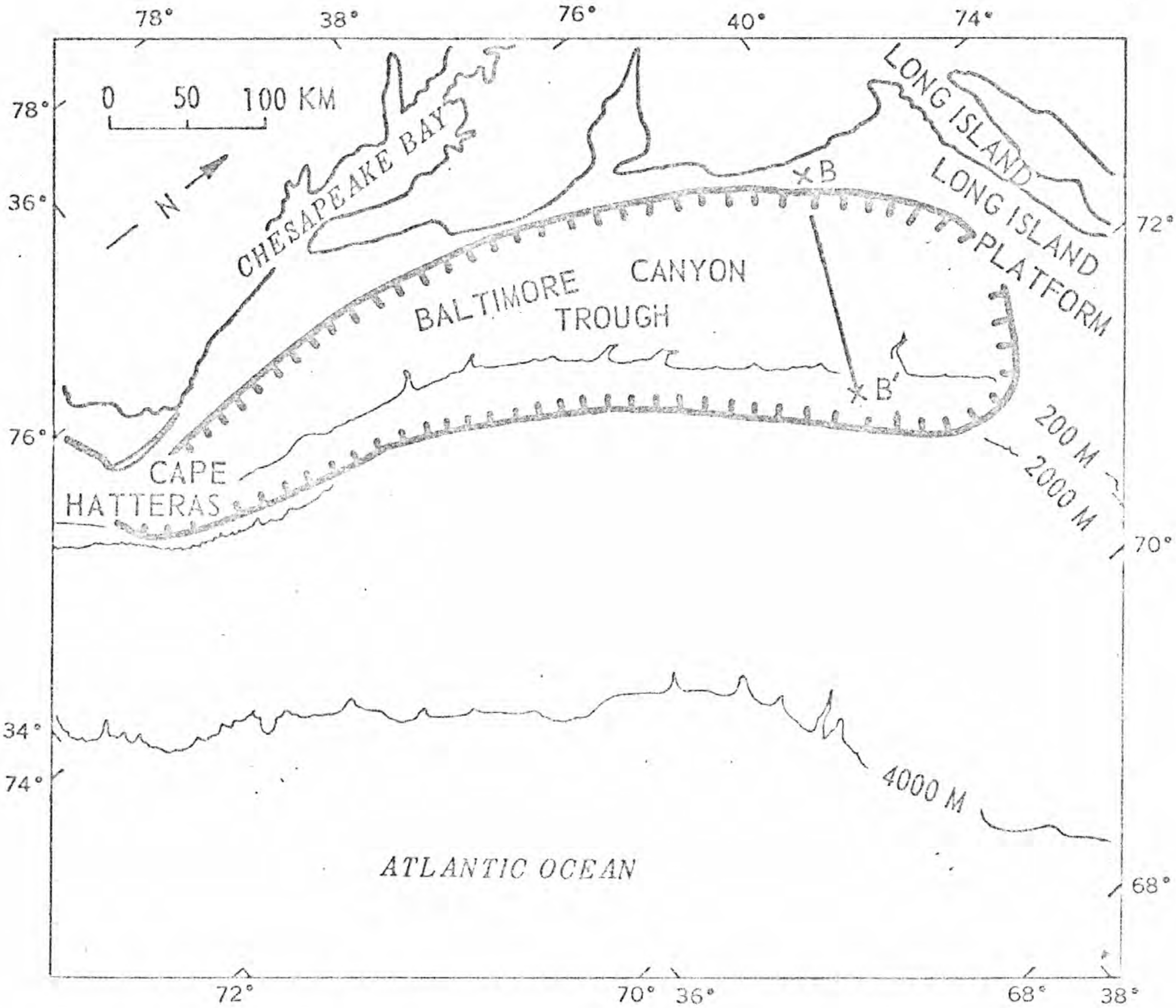

Figure 5. -- Outline of Baltimore Canyon trough showing location of diagrammatic cross section B-B'.

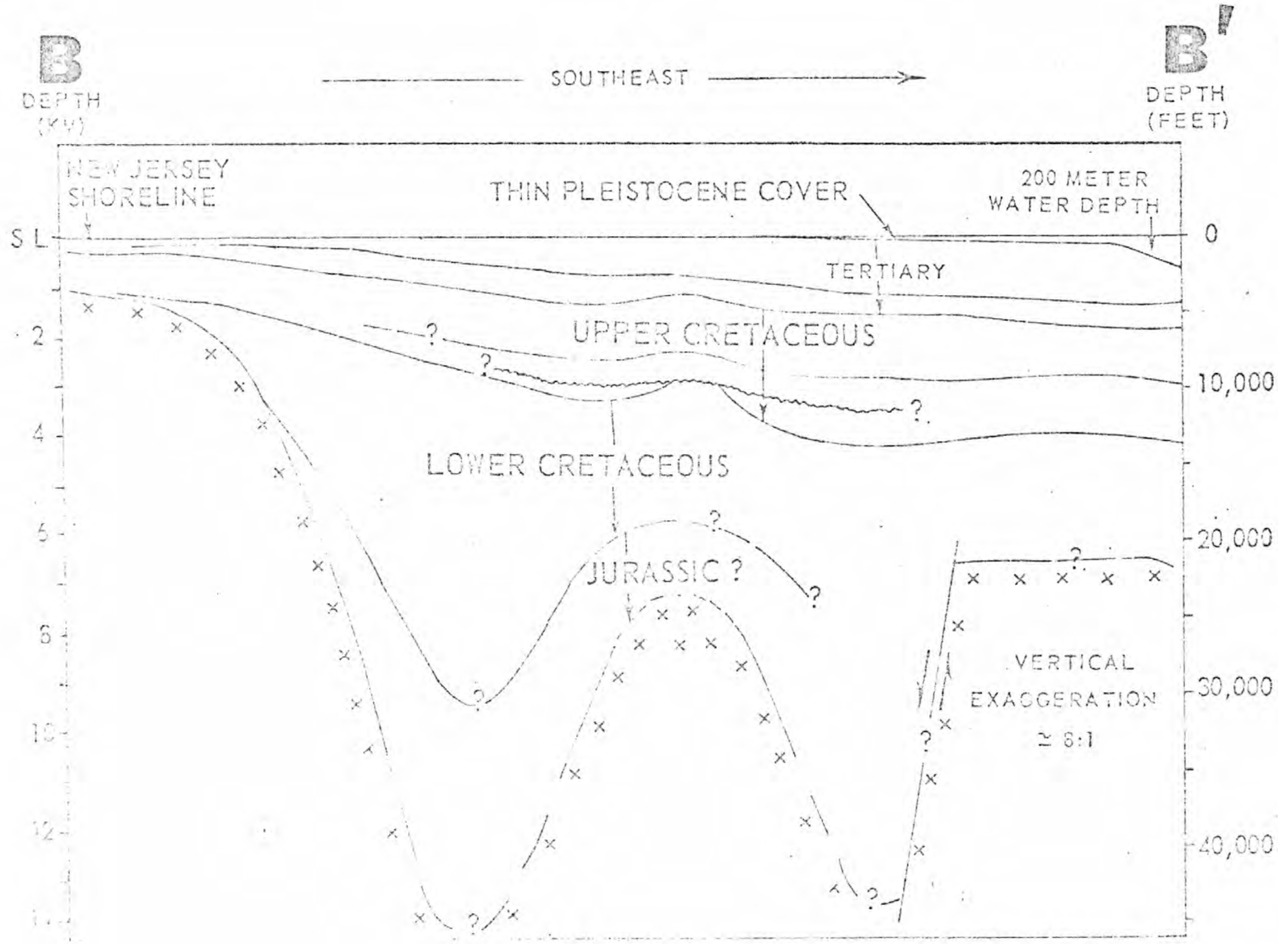

Figure 6. -- Diagrammatic cross section B-B' across Baltimore Canyon trough.

Paleozoic and Triassic marine sediments near the base of the section. This is slightly more than suggested by Emery and Uchupi (1972). The deepest part of the basin appears to be about 160 km off the New Jersey coast.

Although the age of the basal sedimentary rocks is uncertain, it is likely that Jurassic rocks will be found to be present. About 300 m of marine Jurassic limestones and clastic rocks are present in the basal portion of the Esso-Hatteras Light well on Cape Hatteras, North Carolina (Perry and others, 1974).

Lower and lower Upper Cretaceous deltaic sediments were deposited by a large river system(s) along the Atlantic Coastal Plain. These sediments are overlain unconformably by a thinner sequence of chiefly marine sediments (Minard and others, 1974, p. 1173). In New Jersey and under Long Island, a relatively complete Upper Cretaceous section is present. This Upper Cretaceous section is largely marine but also contains deltaic sediments (Minard and others, 1974, p. 1173). Projection seaward suggests that the Cretaceous sediments may be as much as 8,000 m to 9,000 m thick along the axis of the basin.

A potential source bed of Mesozoic age has been found by the Deep Sea Drilling Program (DSDP). More than 100 m of dark green to black Mesozoic clays, rich in organic material, were encountered in DSDP Hole 105 off the Continental Slope southeast of New York (Hollister and others, 1972).

Based upon the above data, potential hydrocarbon source beds of Jurassic and Cretaceous age may be present in the Baltimore Canyon trough. Potential reservoir rocks in these sequences may also exist.

Under the outer shelf off New Jersey, the Tertiary section is about 1,070 m thick (Garrison, 1970), and deltaic sedimentation apparently continued in the Tertiary. Garrison (1970) has postulated two major Cenozoic regressions (p. 122-123). The first during Oligocene time, was characterized by the growth of deltas which rapidly built the shelf outward. An increase in the rate of subsidence accompanied this outgrowth which extended the shelf at least 100 km seaward. The second regression, during Pleistocene glaciation, resulted in deposition of some material at the edge of the shelf, but most was carried into the ocean basin (Garrison, 1970). Potential petroleum source beds and reservoir rocks in the Tertiary strata should exist. However, because of the depositional cycles, the most favorable areas for possible Tertiary oil and gas accumulations may be on the Continental Slope and under the deeper waters toward the Continental Rise.

Major deep seated intrusions, such as shown in the diagrammatic section (fig. 6), may have caused the development of significant structural closures in the overlying sedimentary beds (Mattick and others, 1974, p. 1187). The existence of a postulated deep-seated basement ridge in the vicinity of the outer edge of the shelf also could result in the development of structural highs in the overlying section as a result of differential compaction or continued movement of the basement blocks.

Areas of uplift, either local or along the basement ridge as discussed above, if exposed to favorable shallow-water and favorable climatic conditions, could have provided marine environments suitable for the development of platform, fringing, and/or patch reefs.

Onshore well data and offshore geophysical data suggest that Jurassic and some Cretaceous stratigraphic units wedge out updip along much of the coastal plain. Therefore, stratigraphic traps are possible along much of the shoreward side of Baltimore Canyon trough.

Southeast Georgia Embayment

The Southeast Georgia embayment, shown in outline in figure 7, is an arcuate basin extending from the Cape Fear arch offshore South Carolina to the Peninsular Arch, at Cape Canaveral, Florida. The basin is over 600 km long at the edge of the shelf and is about 150 km wide off the southeastern coast of Georgia. Figure 7 also shows the location of diagrammatic cross section, C-C', from northern Florida across Blake Plateau to the deep sea floor.

Section C-C' (fig. 8), based upon papers by J. C. Maher (1971) and Emery and Uchupi (1972), shows the subsurface relationship of the Southeast Georgia embayment to Blake Plateau. Maher (1971) has shown that there is about 6,000 m of Cretaceous and Tertiary sedimentary rocks under the southeast Georgia coast. The basement ridge at the edge of the shelf does not appear to have as great an influence on the distribution and thickness of sediments under the shelf as previously noted for the Baltimore Canyon trough. However, it is likely that up to 4,000 m of Cretaceous sediments are present.

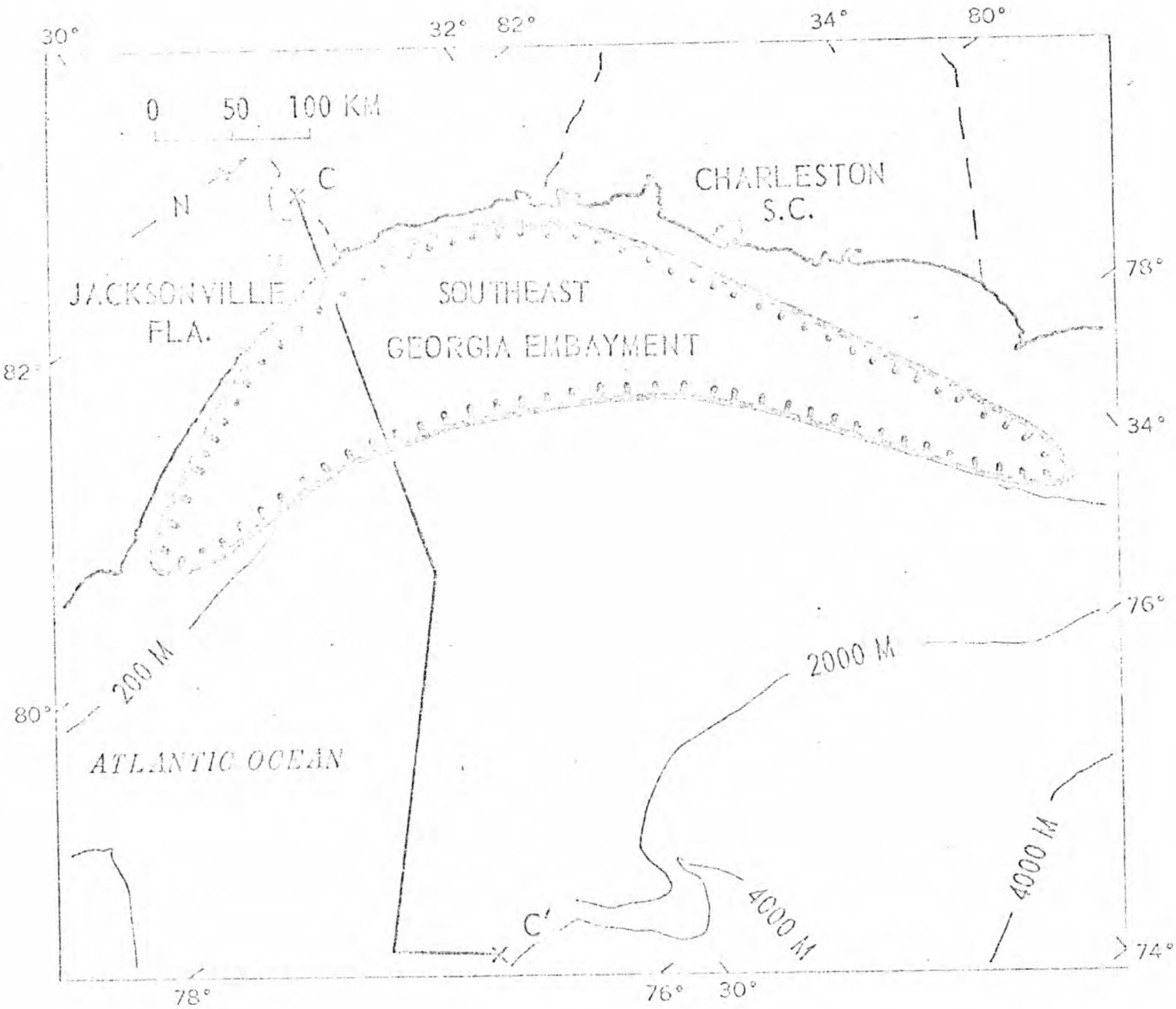

Figure 7. -- Outline of Southeast Georgia embayment.

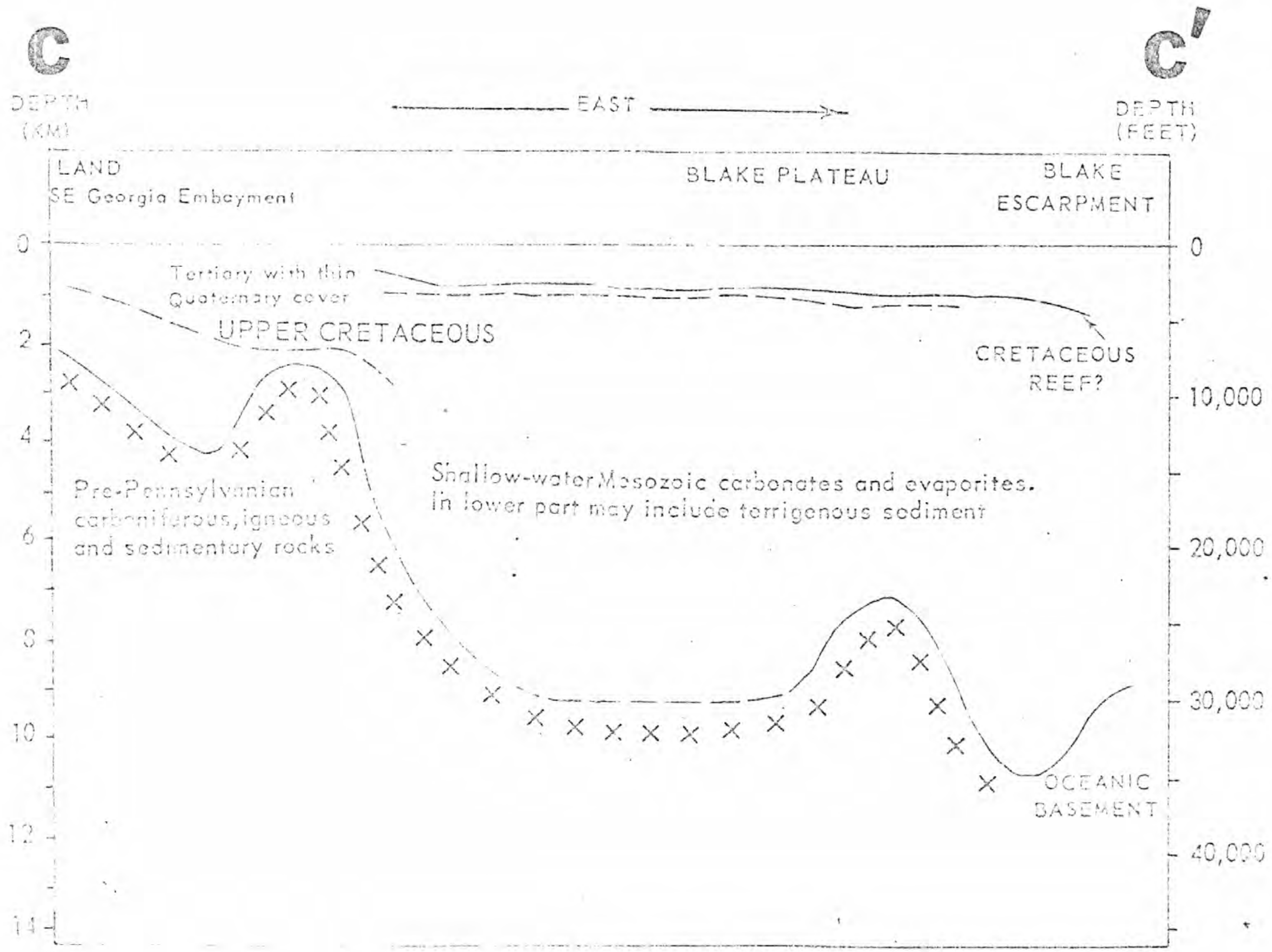

Figure 8. -- Diagrammatic cross section C-C' across Southeast Georgia embayment and Blake Plateau.

According to W. S. Olson (1974), this province was uplifted during Early Triassic time, which caused a series of rift valleys to develop with trends roughly parallel with the present Continental Rise. Emery and Uchupi (1972) have suggested that Mesozoic terrigenous continental deposits similar to those in Triassic basins of northeastern North America may overlie basement on Blake Plateau trough. During Jurassic time, the area began to founder as a result of downward flexing of the crust toward the ocean as a new miogeosyncline formed. Slow subsidence permitted the growth of great Mesozoic carbonate banks and reefs (W. S. Olson, 1974). Shallow-water carbonate and evaporite deposits then accumulated in the lagoons behind the reefs at the outer edge of the plateau.

The downwarping to the southeast appears to have continued into the Cenozoic. Drill cores from Joint Oceanographic Institutions Deep Exploration Surveys (JOIDES) indicate that the upper section consists of Cenozoic deep-water carbonate oozes, phosphorite, and manganese oxide (Emery and Uchupi, 1972). Emery and Uchupi (1972) have shown that the Cenozoic strata are very thin and that certain numerous erosional features resemble the features on the present surface.

The Southeast Georgia embayment-Blake Plateau areas are between a carbonate platform and a mainly clastic depositional province at and north of Cape Hatteras. Transitions in the depositional environment of the strata are likely to include rocks with favorable petroleum source beds and reservoir properties.

Block faulting in basement rocks could provide favorable sites for development of reefs or structural closures in the overlying section as a result of renewed uplift or differential compaction respectively.

Petroleum Potential

From the foregoing, it would seem that there may be petroleum accumulations in numerous places beneath the U. S. Atlantic OCS. However, to date, no deep exploratory wells have been drilled that might provide a realistic basis for estimating the petroleum resource potential. Therefore, a theoretical method must be used.

Mallory (1974) has classified the existing schools of thought of estimating petroleum resources into three categories, and discussed the major proponents of each. These are: (1) Behavioristic models used by M. King Hubbert and Charles Moore; (2) Volumetric-geologic models constructed by Thomas A. Hendricks, Lewis G. Weeks, and Spivak and Shelburne; and, (3) Combinations of the above two classes used by the National Petroleum Council and some oil companies.

The behavioristic model is a graph of the rate at which discoveries have been made as a function of time. The area under the curve can then be used to estimate the quantities of hydrocarbons that will be produced.

The volumetric-geologic model examines the resource base and allocates the proper quantities of a hydrocarbon commodity to past production, known reserves, and expected undiscovered quantities of oil and gas in the recoverable and subeconomic categories. A common practice in this method is to estimate the volume or areal extent of prospective rocks and then assign reasonable quantities of hydrocarbon to these rock volumes or areal distributions. Government agencies frequently use this method and it has proven useful for examing broad geographic areas.. It is essentially geologic in approach and does not depend upon technological, economic, time, industrial performance or political extrapolations to determine quantities.

The combination models vary, but invariably they are based upon a mix of hard data and estimated variables.

It may be informative at this time to review the meanings of Resources and Undiscovered Recoverable Resources. Resources are concentrations of naturally occurring solids, liquids, or gaseous material in or on the earth's crust in such forms that economic extraction is currently or potentially favorable. Undiscovered Recoverable Resources are those quantities that reasonably may be expected to exist in favorable geologic settings, but which have not yet been identified.

On March 26, 1974, the Geological Survey, (U.S. Department of the Interior, 1974) released revised estimates of the nation's crude oil and natural gas liquids, and natural gas. Beneath the U. S. Atlantic Shelf, which covers the area from mean sea level at the shoreline to water depths of 200 m, the undiscovered recoverable resources are estimated to be 10 billion to 20 billion barrels of liquid petroleum (includes crude oil and natural gas liquid) and 55 trillion to 110 trillion cubic feet of natural gas. These estimates are contained in Table 1.

CRUDE OIL AND NATURAL GAS LIQUIDS (BILLIONS OF BARRELS)		NATURAL GAS (TRILLIONS OF CUBIC FEET)	
STATE	FEDERAL	STATE	FEDERAL
2-4	8-16	5-10	50-100
10-20		55-110	

Table 1. -- Estimate of the undiscovered recoverable resources of the United States Atlantic Outer Continental Shelf beneath water depths of less than 200 m.

Since these estimates were made, new geophysical data have been analyzed. While the estimates of the amount of oil and gas that might be recovered in terrain as yet unexplored by the drill are highly speculative, the prospects may be judged somewhat less optimistic than previously estimated. For example, if in our estimates based on areal extent for the Atlantic OCS we had assigned a different Hendricks' category to all prospective areas, the amount of undiscovered recoverable liquid petroleum may be estimated to be as low as 2.5 to 3.0 billion barrels and 10 trillion cubic feet of gas.

Leasing Potential

Following the President's Energy Message of July, 1971, the U. S. Geological Survey accelerated its study of the Atlantic OCS in anticipation of a lease sale. Possibilities of a lease sale did not materialize, however, because of legal claims by twelve of the Atlantic Coast states of jurisdiction over shelf areas up to 80 miles off their coasts.

In August of this year, a special master appointed by the U. S. Supreme Court ruled that the Federal Government - not the states - holds jurisdiction beyond the 3-mile limit. A final ruling by the Supreme Court is expected in the near future.

In April of 1973, the President asked his Council on Environmental Quality (C.E.Q.) to work with the Environmental Protection Agency, in consultation with the National Academy of Sciences and other Federal Agencies to estimate the environmental and economic impact which might result from oil and gas development on the Atlantic OCS and in the Gulf of Alaska. The resultant environmental assessment by C.E.Q. found that the environmental risks of oil and gas production on the Atlantic OCS would be generally lower than in the Gulf of Alaska. The lowest risk areas on the Atlantic OCS, in order of increasing risk, are: eastern Georges Bank, southern Baltimore Canyon, western Georges Bank, and central Baltimore Canyon. Northern Baltimore Canyon and Southeast Georgia embayment were designated as higher risk areas.

The Mid-Atlantic area, specifically the Baltimore Canyon trough area, is presently on schedule for leasing in the latter part of 1975. The other Atlantic OCS areas, Georges Bank trough and Southeast Georgia embayment are being considered as alternatives. However, a lease sale in any one or all of these areas will depend upon a decision of the Supreme Court awarding jurisdiction of the OCS beyond 3 miles to the Federal Government, or in lieu of a decision, an interim agreement between the litigants and satisfactory completion of NEPA requirements for a lease sale.

Conclusions

Regional geological and geophysical studies being conducted by the U. S. Geological Survey on the United States Atlantic OCS indicate that thick marine sedimentary sections and geological structures favorable for the generation and accumulation of petroleum exist within the Georges Bank basin, the Baltimore Canyon trough, and the Southeast Georgia embayment areas. Preliminary results suggest that the areas of greatest petroleum potential on the U. S. Atlantic OCS north of Cape Hatteras, North Carolina, are at least 48 km offshore--out of sight of land.

The most promising traps for petroleum accumulation in the Georges Bank basin area seem to be anticlines caused by uplift or differential compaction, over basement highs and horst blocks, and structural closures against faults. A probable overall stratigraphic similarity between the sedimentary rocks within the Georges Bank basin and those found beneath the Western Scotian shelf, offshore from Canada, suggest that source beds and reservoir beds exist beneath the Georges Bank area.

In the Baltimore Canyon trough area, significant structural closures in Mesozoic beds exist as a result of differential compaction or continued movement of the basement blocks. Additionally, these areas of local uplift could have provided excellent environments for reef development. Onshore geologic data and the results of DSDP Hole 105 drilled off the Continental Slope suggest that potential hydrocarbon source beds and reservoir beds are present within the Baltimore Canyon trough.

Stratigraphic traps formed by updip wedgeouts of Jurassic and Cretaceous strata could provide substantial petroleum reservoirs in both the Georges Bank basin and Baltimore Canyon trough areas.

Relative to the former two areas, little is known about the Southeast Georgia embayment area. It is located between a carbonate platform and a mainly clastic depositional province. Transitions in the depositional environment of the strata are likely to include rocks with favorable petroleum source beds and reservoir properties.

Beneath the U. S. Atlantic Shelf, the undiscovered recoverable resources are estimated to be 10 billion to 20 billion bbls of liquid petroleum and 55 to 110 trillion cubic ft of natural gas. Estimates of resources carry a high degree of uncertainty. In developing estimates of undiscovered resources, we are trying to appraise the unknown, and this is particularly true of the Atlantic Continental Shelf where not a single oil test hole has been drilled.

Future lease sales will depend on economic, legal, and environmental considerations; tentatively, the Secretary of the Interior has proposed that the Mid-Atlantic area (Baltimore Canyon trough area) will be offered for lease in the latter part of 1975.

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