UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUMMARY GEOLOGIC REPORT FOR THE SOUTH ATLANTIC OUTER CONTINENTAL SHELF (OCS) PLANNING AREA (A SUPPLEMENT TO U.S. GEOLOGICAL SURVEY OPEN FILE REPORT 83-186)

by

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Open-File Report 84-476

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

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INTRODUCTION

This report presents summary maps of the geologic structures, sediment thickness, geologic hazards and constraints to exploration and development, and hard mineral geology within the area designated by the U.S. Department of Interior, Minerals Management Service as the South Atlantic Outer Continental Shelf (OCS) Planning Area. The report is intended to supplement U.S. Geological Survey (USGS) Open-File Report 83-186 (Dillon, 1983) which discusses the Oil and Gas Lease Sale 90 area and presents many cross sections and illustrations of features herein discussed. The maps accompanying this report consist of two sets of five, superimposable 1:1,000,000 scale compilations that cover all but the southern extremity of the planning area, which lies along the South Florida coast. Set A covers the northern half of the Planning Area, set B covers most of the southern half of the Planning Area. The maps overlap the area between lat 32^{o} and 33^{o}N. The maps are labeled: 1) Structural Features; 2) Sediment Thickness; 3) Thickness of Neogene Sediments; 4) Geologic Hazards and Constraints; and 5) Hard Minerals. They were complied from the published literature referenced on the maps and from unpublished analyses by the author of U.S. Geological Survey common-depth-point (CDP) and high-resolution seismic-reflection profiles collected by the U.S. Geological Survey between 1977 and 1980 (Figures 1 and 2).

The maps included herein should be considered status reports; additions to our data base and improvements in our analysis techniques are continual. The maps are diagrammatic by intent, but accurately present a regional overview of margin geology as it is currently understood.

The South Atlantic OCS Planning Area includes the area from Raleigh Bay just south of Cape Hatteras to Miami, Florida. Because the Planning Area boundaries were defined before the proclamation (March 10, 1983) that established the U.S. Exclusive Economic Zone (EEZ) (Rowland and others, 1983), some boundaries extend beyond the EEZ. The EEZ boundary (illustrated on each plate) should be considered the seaward limit of exploration or production activities, as this is the boundary of the national domain.

GEOLOGIC FRAMEWORK

Structural contours on the post-rift unconformity or basement surface are shown on the Structural Features maps (Plates 1a and 1b). Most areas of the Continental Shelf within the Planning Area are underlain by shallow continental basement at a depth of less than 3 km. Farther offshore, generally under the Continental Slope, basement depth increases abruptly along a hinge zone (at about 3 km depth) into the two major margin basins, the Blake Plateau Basin and the Carolina Trough (Figure 3). The Carolina Trough generally underlies the Slope and upper Rise east of North and South Carolina, while the Blake Plateau Basin underlies the southern Blake Plateau off Georgia and northern Florida. These offshore basins contain up to 13 km of Jurassic- to Holocene-age sediment (see Sediment Thickness maps, Plates 2a and 2b). West of the basins, a minor sag in the shallow basement, the Southeast Georgia Embayment, separates the gently eastward sloping basement of the Florida and Carolina Platforms in Georgia and offshore.

The eastern part of the Planning Area includes the Continental Rise off

North and South Carolina. Here, basement is oceanic crust that shallows towards the east. A seaward-thinning wedge of sediment of chiefly Neogene age (see Figure 3 and Neogene Thickness maps) overlies the oceanic crust (sediment mapped as Neogene includes the late Oligocene through Holocene). The total sediment wedge, including both Neogene and older strata, is about 6 km thick under the rise at the eastern edge of the Carolina Trough, but thins to just over 1 km at the eastern extremity of the Planning Area.

The Blake Plateau Basin and Carolina Trough areas are believed to overlie the thinned and stretched rift-stage or transitional crust at the edge of the continental crust (Figures 4 and 5). Their landward margins are quite linear and aligned northeasterly, normal to the direction of ocean opening. The basins are the result of subsidence accompanying cooling and sediment loading of thinned and stretched crust following continental separation of North America and Africa. The basins are separated by a northwest-trending basement high and they are offset along the extention of a deep-sea fracture zone (Blake Spur Fracture Zone).

A stratigraphic framework has been devised for both basins, chiefly based on interpretation of seismic-reflection profile data using seismic stratigraphic techniques tied to offshore and onshore wells (see Dillon, 1983; Paull and Dillon, 1982). The rapid early subsidence of the Blake Plateau Basin and Carolina Trough is reflected in the thick section of Jurassic strata inferred to be present (Figures 4 and 5). The lower section of each basin is interpreted to consist primarily of continental to shallow-water marginal marine deposits. These grade upward into carbonate platform deposits that formed landward of reefs or carbonate banks that grew near the present Continental Slope off North Carolina and near the Blake Escarpment off Georgia in Late Jurassic and Early Cretaceous time. Although the shoreline migrated back and forth across the western edge of the basins in response to eustacy and subsidence, marine sediment did not lap far across the present shelf (platform) until the close of the Early Cretaceous.

By the end of Early Cretaceous time, reef growth ceased at the Blake Escarpment along the seaward edge of the Blake Plateau Basin, and sedimentation shifted westward, accompanying rising sea level and continued margin subsidence. This resulted in the accumulation of deep-water deposits across the basin areas and the accumulation of chalks and marls on the platform areas and in the Southeast Georgia Embayment. When Gulf Stream flow through the Straits of Florida was initiated in the early Eocene, it cut off the sediment supply from the continent to the former shelf. The Florida-Hatteras Shelf developed landward of the current, while the shelf seaward of the current became sediment starved. Continued subsidence and a lack of sediment east of the Gulf Stream resulted in the deep-water shelf, the Blake Plateau.

The Carolina Trough differs from the Blake Plateau basin in that it accumulated a thick evaporite sequence in its early history. Subsequent loading of the evaporites in the western part of the trough squeezed salt into a line of diapirs that now underlie the lower Slope and upper Rise (Structural Features map, Plates 1a and 1b). Twenty-seven diapirs have been mapped by seismic-reflection and sidescan-sonar methods (Popenoe and others, 1982; Dillon and others, 1982) and are shown on the Structural Features maps together with the large growth fault and antithetic faults that have compensated for subsidence related to the salt withdrawal. South of the growth fault between lat 31° and 32° N; a major listric normal fault cuts the Continental Slope. This fault differs from the fault to the north in that it is not a growth fault and it flattens at a shallower depth.

PETROLEUM GEOLOGY

Carolina and Florida Platforms, Southeast Georgia Embayment.

Most areas of the Florida-Hatteras Shelf overlie shallow crust of the Florida and Carolina Platforms. Here, sediments that are of marine origin are less than 3 km thick are younger than Early Cretaceous. On the basis of this thin sedimentary section, and that the deeper, more thermally mature sediments chiefly are a continental to marginal marine facies (which are poor source beds) (Scholle, 1979), the most easily drilled areas underlying the shelf have limited petroleum potential. If petroleum or gas is present under the Shelf areas, it has probably migrated updip from the deeper, marine, and more thermally mature basin areas.

Six dry exploration holes have been drilled in the Southeast Georgia Embayment (see Sediment Thickness map, Plates 2a and 2b) apparently on basement-relief-related structures (Crutcher, 1983). Our data on the character, age, and thermal maturity of the sediment underlying the shelf comes chiefly from two wells: the COST GE-1 well (Plate 1b) in the Southeast Georgia Embayment (Scholle, 1979), and the Esso Hatteras Light well No. 1 (Plate 1a) drilled at the tip of Cape Hatteras (Spangler, 1950). The wells indicate that good reservoir rocks are present; however, the deeper, more thermally mature strata are mainly continental to marginal marine and are poor source rocks. The richest potential source rocks penetrated by the GE-1 well were Upper Cretaceous chalks and marls (Miller and others, 1979). Unfortunately, these rocks are thermally immature as they are buried at depths of less than 1000 m under the shelf and are barely covered or are exposed on the Blake Plateau.

Temperature measurements at the COST GE-1 and Hatteras Light No. 1 wells indicate a geothermal gradient of less than 1°F/100 ft of depth. The liquid petroleum window is considered to have a lower limit of 150°F (66°C) and an upper limit of 270°-300°F (132°-149°C) (Robbins, 1979). The well data indicate that thermally mature sediments should occur at about 4 km depth, but they could occur shallower than that if geothermal gradients were higher in the past.

Structures under the shelf that could act as potential petroleum traps include updip pinchouts, low-relief anticlinal structures such as the Cape Fear Arch, drapes over basement relief (see Dillon, 1983; Crutcher, 1983), and minor reef structures (Plate 4b).

Blake Plateau Basin and Carolina Trough

The Blake Plateau Basin and Carolina Trough have the highest petroleum potential within the Planning Area on the basis of their thick sedimentary sections, deeply buried marine sections, and abundance of potential traps. Unfortunately, the offshore basins are in deep water where there are strong currents (the Gulf Stream and Western Boundary Undercurrent).

The two basins have not yet been drilled to any depth, but thermally mature sediments would be expected below 3.5-4 km sediment depth. The key to the petroleum potential of the basins is the presence of organic-rich source beds within the deeper sedimentary section. Seismic stratigraphic analyses suggest that most of the deeper sediments are shallow-water marine, which perhaps have better source-bed potential than the dominantly continental rocks found at thermal-maturity depths present beneath the shelf. In addition, the Carolina Trough contains both shelf, slope, and upper rise facies--depositional environments favorable for the production and preservation of marine, petroleum-generating organic matter (Dow, 1978).

Many potential traps exist in the basin areas. The most obvious are associated with salt domes in the Carolina Trough (Plates 1a and 1b), but these lie in deep water (±3000 m). Most of the leased blocks lie in the shallower water of the Outer Continental Shelf, Slope, or northern Blake Plateau along the major growth fault caused by salt-related subsidence (Plate 1a). Other potential traps in the Carolina Trough could include structures or pinchouts associated with the Early Cretaceous shelf edge (Plates 1a and 1b). However, the possibility exists that any petroleum that might have been trapped along the buried shelf edge may have escaped during the deep-sea erosion of the Slope in late Oligocene time (A_u unconformity) (Dillon, 1983).

Two other large structures that may have petroleum trapping potential are the large basement high that separates the Blake Plateau Basin from the Carolina Trough (Plates 1a and 1b) and an anticline along the eastern margin of the Carolina Trough that was created by structural subsidence of the trough axis and depositional dips beneath the outer paleoshelf (Dillon, 1983).

Common to both the Carolina Trough and the Blake Plateau Basin are structural or stratigraphic traps caused by basement relief, updip pinchouts, ancient strand lines or other shore-related features, and ancient patch reefs. In the outer Blake Plateau Basin, the regional landward dip of strata would probably result in a seaward migration of hydrocarbons that could be trapped in the reef or carbonate bank structures of the outer Blake Plateau, but these features occur outside of the EEZ.

Continental Rise and Abyssal Plain

Although sediment deposited on the Continental Rise is favorable for the production and preservation of marine organic matter (Dow, 1978), the sediment old enough and buried deeply enough for thermal maturity is not only under deep water(±3 km), it is also under a thick section of young Neogene strata (Plates 3a and 3b). Because the strata with petroleum potential are deeply buried, the Continental Rise is less attractive for drilling and recovery of petroleum than the basin areas. Drilling in the deep ocean has shown that large areas are underlain by sequences of black, organic-rich Early to middle Cretaceous shales (Arthur and Schlanger, 1979) which would provide good source rocks, if buried long enough and deeply enough for thermal maturity. These strata under the Rise, however, would be beneath over 3 km of water and 2 km of young Neogene strata, and thus would be a very deep target.

Free gas trapped beneath the frozen gas hydrate and clathrate layer that underlies much of the deeper water of the planning area (Plates 4a and 4b), particularly under the Blake Outer Ridge, may be a potential gas resource (Tucholke and others, 1977; Dillon and others, 1980; Dillon, 1983). Little is known at the present time of the resource potential or recoverability of this gas. The gas also could be a hazard to exploration activities, however, as discussed below.

GEOLOGIC HAZARDS AND CONSTRAINTS

Our knowledge of the geologic hazards and constraints to petroleum exploration and production within the Planning Area is summarized on Plates 4a and 4b. These maps are based on a 20-km grid of high-resolution geophysical data (Figure 2) collected by the U.S. Geological Survey in cooperation with the Bureau of Land Management (now Minerals Management Service) between 1977 and 1980 (Ball and others, 1980; Pinet and others, 1981a; Popenoe and others, 1981; Popenoe and others, 1982).

Geologic hazards are defined as features and conditions that pose a high degree of risk to oil and gas activities. In this area hazards are chiefly of two types: those posed by bottom instability, such as mass movement on the Continental Slope, and those posed by shallow, high-pressure gas pockets that may exist beneath the frozen bottom layer (clathrate) of the deep sea. By contrast, geologic constraints pose less risk, or no risk, to exploration or production if proper engineering and environmental principals are followed. Features such as shallow faults, buried stream channels whose variable load-bearing properties may constrain rig placement, shallow subsurface solution or karst which may constitute a rig support hazard, sand waves or other areas of bottom sediment movement or scour are geologic constraints. Ecologically important features such as live-bottom or reef areas may also act as constraints to rig placement.

Plates 4a and 4b show that sediment instability of the Continental Slope in the form of both slumps and canyons occurs chiefly north of 33^{o} latitude, although a few minor slumps are also present on the Florida-Hatteras slope to the south. Slumping is particularly conspicuous along the slope segment above the salt diapirs on the eastern margin of the Carolina Trough, where both subsidence of the trough due to sediment loading and salt movement and possible instability caused by the clathrate layer have caused past slope failure (Popenoe and others, 1982; Carpenter, 1981). A very large slump scar more than 40 km wide occurs on the lower slope encircling three large breached salt diapirs near long. 76^{o}W., lat 33^{o}N. The scar is characterized by a steep scarp of 60- to 80-m relief that truncates bedding on the lower slope, and a series of rotational listric faults upslope (Popenoe and others, 1982; Dillon, 1983). As these faults offset the sea floor, they should be considered presently active. The slope is more stable between lat 33^{o} and 32^{o} N., because it is less steep (3^{o}-5^{o}) above the Blake Outer Ridge. South of 32^{o} N. the slope steepens and is cut by a large listric fault which has offset the mid- to lower-slope sediment (Pinet and others, 1981a).

Although the hazards associated with the breaching of shallow pockets of gas trapped beneath the frozen clathrate layer (Hazards and Constraints map, Plates 4a and 4b) are unknown, they may be similar to those posed by gas pockets below permafrost, which has caused the loss of several rigs on the Mackenzie delta of Alaska (Popenoe and others, 1982).

The Hazards and Constraints maps (Plates 4a and 4b) show the location and trend of a number of shallow faults within the Planning Area. These faults pose a danger only if they are actively moving (as is the main growth fault on the outer Blake Plateau), in which case they could shear the casing within wells, or if penetrated unexpectedly during drilling and not cased, when they could serve as an avenue for the escape of high-pressure gas to the sea floor, perhaps causing a blowout and potential rig loss.

Constraints to the siting of rigs and pipeline facilities are posed by shallow subsurface karst, live-bottom areas, areas of rapidly variable rig support capabilities such as buried channels, areas of mobile bottom sediments such as sand wave fields, and areas of bottom scour. Where our profiles have crossed these features, they are shown on the Hazards and Constraints maps (Plates 4a and 4b). Our maps indicate only the regional distribution of these features, and a site-specific high-resolution survey should be performed in any lease-block area prior to rig siting.

Plate 4b shows the location of the buried Late Cretaceous and Paleocene reef off northern Florida. Seismic records show that the top of this reef contains numerous sink holes, indicating limestone solution cavities and karstification (Dillon, 1983). Behind the reefs the subsurface is also highly riddled with sink holes, and these beds form the well-known "Boulder Zone" onshore. In at least two cases, (Crescent Beach Spring and Red Snapper Sink) these sink holes have breached the sea floor. Although our seismic data are limited in this area, they clearly show a rig support hazard posed by other buried solution cavities.

The inner Blake Plateau is swept by strong Gulf Stream-related currents. The position of the scour track made by these currents on the bottom is shown on the Geologic Hazards maps, as is the position of major areas of deep-water reef mounds that are nourished by the currents. The outer shelf is periodically swept by strong Gulf Stream eddies, which could cause scour around rig support structures.

HARD-MINERALS GEOLOGY

The Hard Minerals maps (Plates 5a and 5b) show the location of the two major hard-minerals resources present within the area: phosphorite and manganese. They do not show the location of sand and gravel deposits or heavy minerals placers as very little is known of the distribution of these commodities. Sand resources of the inner Continental Shelf from south of Cape Fear to Cape Lookout have been studied by the Corps of Engineers (Meisburger, 1977), however, those studies cover only a small area. The major large sand deposits occur in Diamond, Cape Lookout, Frying Pan, and Cape Romain Shoals (Plate 4a). The present maps of phosphorite and manganese were derived largely from two sources, Manheim and others (1982) and Popenoe and others (1984). I have modified the phosphorite and manganese pavement boundaries of Manheim and others (1982) on the basis of outcrop geology mapped by high-resolution seismic reflection data (Paull and others, 1980; Pinet and others, 1981b; Popenoe, 1984) because there is a high degree of correlation between outcrop geology and phosphate and manganese occurrence.

Phosphorite in the Planning Area occurs chiefly within sedimentary deposits of early-to-middle Miocene age, although phosphate-rich upper Miocene and lower Pliocene strata are also found. The offshore beds are seaward extensions of the onshore Miocene-age Pungo River and Hawthorn Formations and

Pliocene-age Yorktown Formation of eastern North Carolina, South Carolina, Georgia, Florida and southern Virginia. These beds are commercially mined in the Aurora Basin along the Pamlico River of North Carolina and in South Carolina and Georgia. The maps show both the outcrop areas of these units on the shelf and their thickness.

The phosphate occurs primarily as phosphorite sand and gravel interbedded with dolomite and limestone. Typically, the phosphate occurs in a series of layered sequences that are gravelly near their base, grading upward into muddy phosphatic sand containing minor amounts of dolomite, and capped by burrowed, moldic, sandy phosphatic dolomite. These sequences reflect cyclic deposition in repetitive eustatic sea-level advances and retreats, in which the beds were laid down dominantly in a shallow-water to outer-shelf environment (Riggs, 1984). Average concentrations of phosphate (P_2O_5)in the Pungo River Formation of North Carolina range from 36 percent in the lower part to 39 percent in the middle and 33 percent in the upper part (Snyder and others, 1982a).

Offshore, phosphate-rich early-to-middle Miocene-age beds underlie and crop out on the shelf in Onslow Bay (Pilkey and Luternauer, 1967; Snyder and others, 1982b; Popenoe, 1984), where they fill a deep Oligocene basin area (Popenoe, 1984). These same beds crop out extensively along the Florida-Hatteras Slope farther offshore (Paull and others, 1980; Popenoe, 1984). Miocene beds underlie a large area of the shelf south of Cape Fear, where they are a major subsurface unit in the Southeast Geologic Embayment and are an extension of the onshore phosphate-rich Hawthorn Formation. The area in which the Miocene crops out or is near the surface under the shelf is shown, as is the thickness of the strata (Plates 5a and 5b). Off Georgia and South Carolina, the Miocene forms a cap to the onshore Paleocene-Eocene aquifer system; therefore, care must be exercised in the mining of these beds to prevent aquifer contamination by mining operations.

Although the genesis of phosphorite is controversial (Sheldon, 1981), in this area the enrichment of phosphate is believed to be associated with Miocene biological productivity driven by the upwelling of nutrient-rich bottom waters, caused by the deflection of the Gulf Stream by the shoaling bottom of the northern Blake Plateau and by deflection off an ancient barrier, the Cape Lookout High (Manheim and others, 1982; Snyder and others, 1982b; Popenoe, 1984). The richest deposits occur where upwelling conditions are most pronounced at present (Janowitz and Pietrafesa, 1984), or where they can be demonstrated to have been active in the past (Manheim and others, 1982; Riggs, 1984; Popenoe, 1984). Briefly, upwelling of nutrient rich waters causes biological enrichment of surface waters. Phosphate-enriched mud settles to the bottom as fecal pellets from higher food-chain organisms and becomes diagenetically altered at the sediment-water interface. This mud is later winnowed and reworked by mechanical processes (currents, exposure, etc.) where the fine-grained components are washed away and apatite pelletal sand and diagenetically cemented phosphate gravel are concentrated. With exposure time, and further mechanical reworking and chemical alteration, these gravels may become cemented into pavements such as those that occur on the northern Blake Plateau.

Cemented slabs and a pavement-like layer of phosphorite caps the surface of the Blake Plateau in 600 to 800 m water depth between lat 30° and 32°N. These deposits lie in the area of maximum bottom scour by the Gulf Stream and are a cemented residual lag-gravel winnowed from formerly present phosphate-rich late Oligocene- to early Miocene-age sediments. The phosphorite pavements are probably not a resource per se; however, they form the surface on which manganese has precipitated from the sea water. Their mining would be difficult, as they are extremely hard and recovery has been limited to broken slabs around the periphery of pavement zones. The deposits form continuous pavements which extend many kilometers, broken only by deep erosion pits cut by both limestone solution and bottom currents.

The recovered phosphorite-manganese pavements occur as thin slabs 2 to 5 cm thick which consist largely of ferromanganese oxides and carbonate veins, and thick slabs exceeding 6 to 10 cm where accretionary and replacement ferromanganese oxides surround a phosphorite core (Manheim and others, 1980; 1982). Farther offshore, at water depths between 700 and 1000 m where erosion by bottom currents of the Gulf Stream are less pronounced, large areas of the bottom are overlain by ferromanganese nodules that have precipitated over phosphatic gravel cores. These nodules would be more easily recovered and may constitute a resource, as they are probably the nearest large concentration of manganese and cobalt within U.S. waters. However, the nodules and pavements on the Blake Plateau are substantially lower in metal value than are those of the Pacific. On the basis of manganese, cobalt, and nickel content alone, the nodules are distinctly submarginal as a minable resource, but their proximity to the U.S., their possible use as a catalytic absorber of vanadium and nickel in petroleum refining (Manheim and others, 1982), and their high trace metal values make them more attractive. The nodules vary in size from 3.5 to 10 cm in diameter with a mean diameter slightly less than 6.9 cm (Manheim and others, 1982).

Major metal analyses of the nodules and pavements (Manheim and others, 1980, 1982; Riggs and Manheim, in press) show the following ranges of metals content:

TABLE 1.

<u>% dry weight mean metal content and standard deviation</u>

	Pavement % (S.D.)	Nodules % (S.D.)
Manganese	9.2 (4)	16.3 (4.2)
Nickel	0.38 (.17)	0.62 (.14)
Cobalt	0.14 (.04)	0.33 (0.5)
Copper	0.027 (.003)	0.105 (.027)

In addition, the nodules and pavements contain the following trace metals (Riggs and Manheim, in press).

TABLE 2.

	%	(S.D.)		%	(S.D.)
Titanium	.2	(.14)	Arsenic	0.046	(.071)
Zinc	0.045	(.0005)	Platinum (ppb)	326	(110)
Lead	0.092	(.0169)	Vanadium	0.058	(.015)
Molybdenum	0.036	(.003)	Cerium	0.072	(.070)

Potential manganese resources were estimated by Manheim and others (1982) at between 10 and 100 million tons of dry nodules. More recent data (Riggs and Manheim, in press) suggest the lower value is more correct for nodules, and that the metal resources of the pavement, which is more widespread than thought, could exceed 200 million tons distributed over 14,000 km^2.

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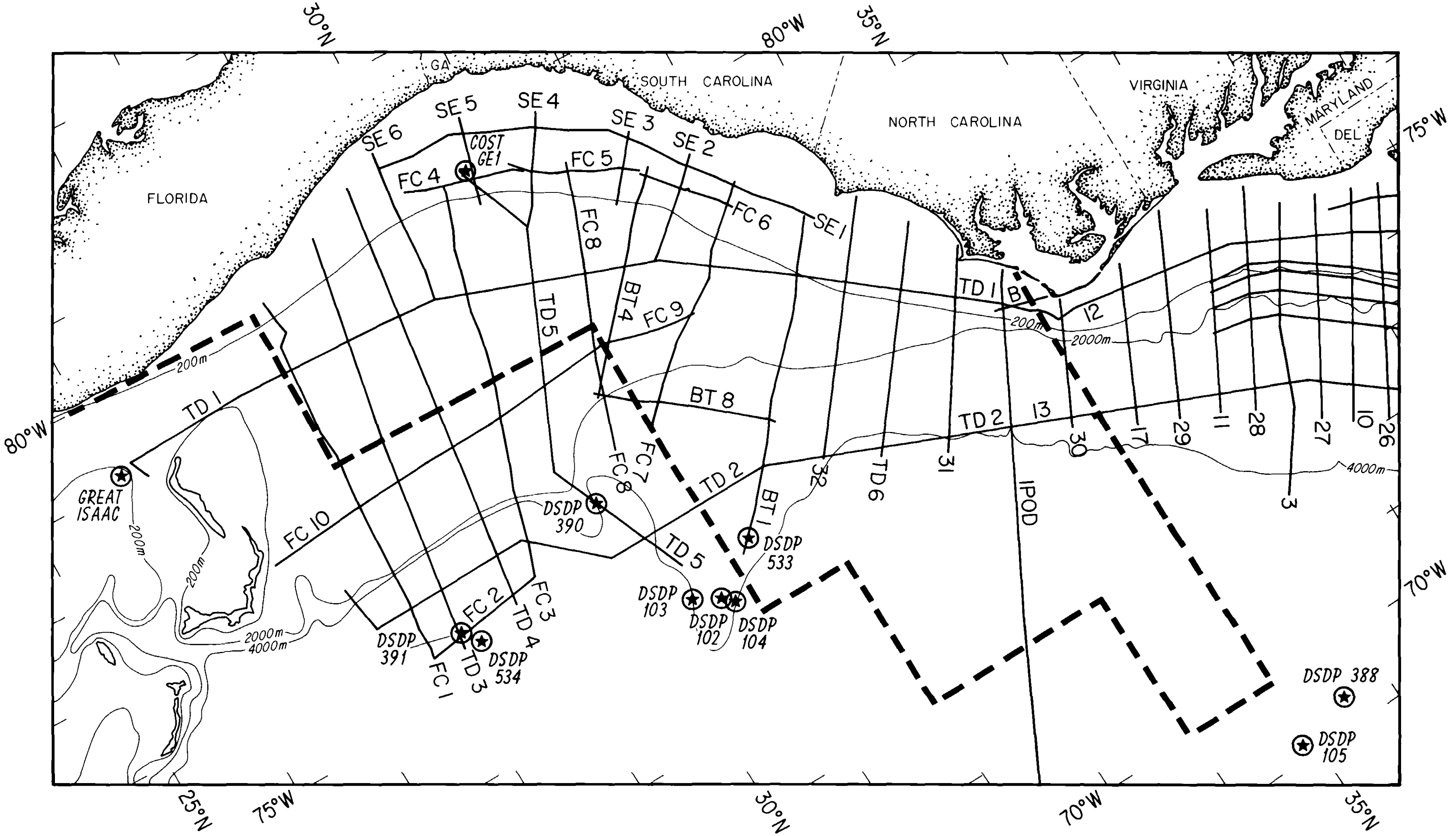

Figure 1: Tracklines along which multichannel seismic profiles were collected by the U.S. Geological Survey. Heavy dashed line indicates seaward limit of the Planning Area. Bathymetry in meters. Locations of selected drillsites are shown. DSDP - Deep Sea Drilling Project, COST - Continental Offshore Stratigraphic Test, IPOD - International Phase of Ocean Drilling.

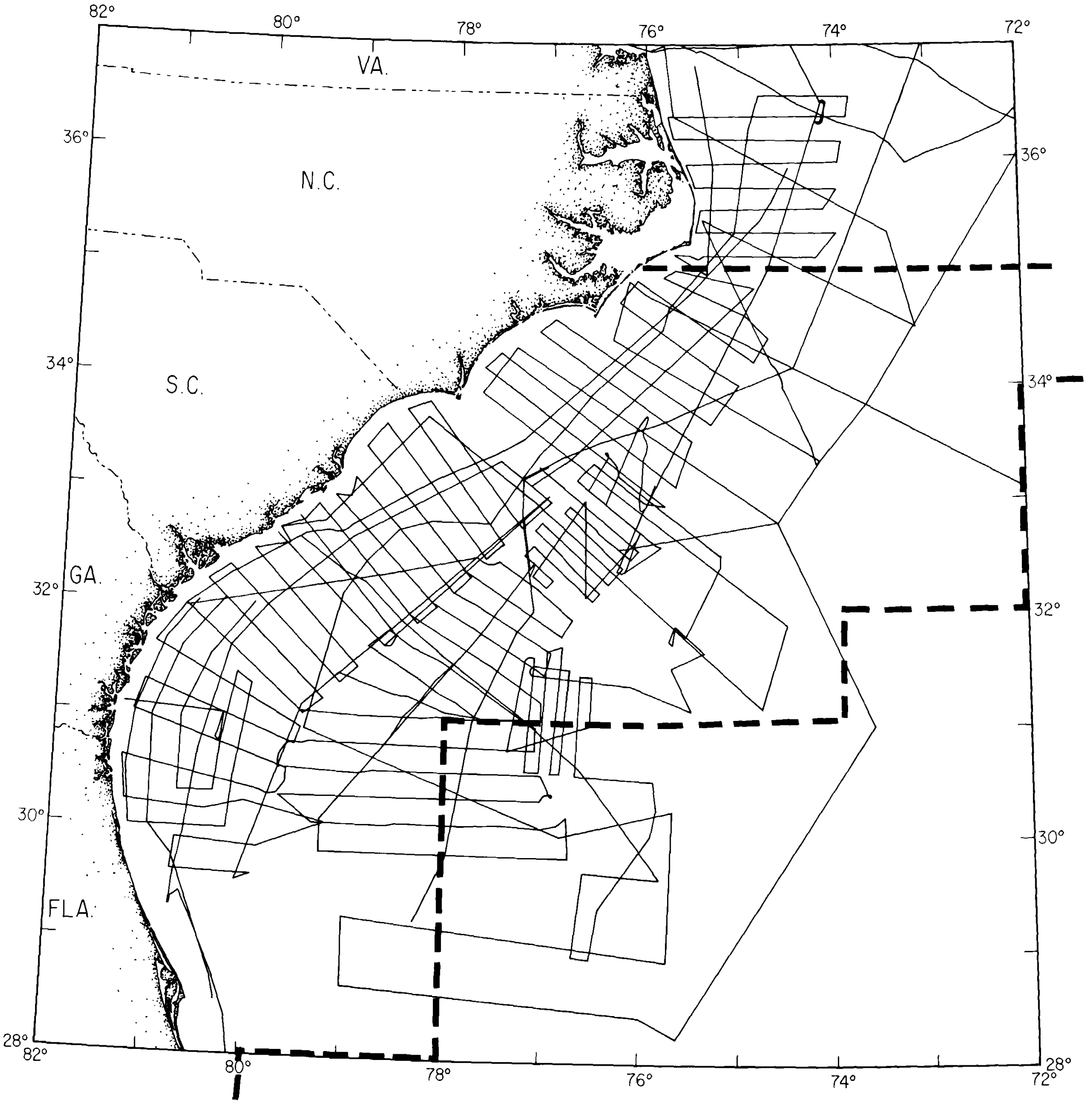

Figure 2: Track chart showing the distribution of U.S. Geological Survey high-resolution seismic-reflection survey data in the Planning Area. Light lines are track lines, heavy dashed lines indicate boundary of Planning Area.

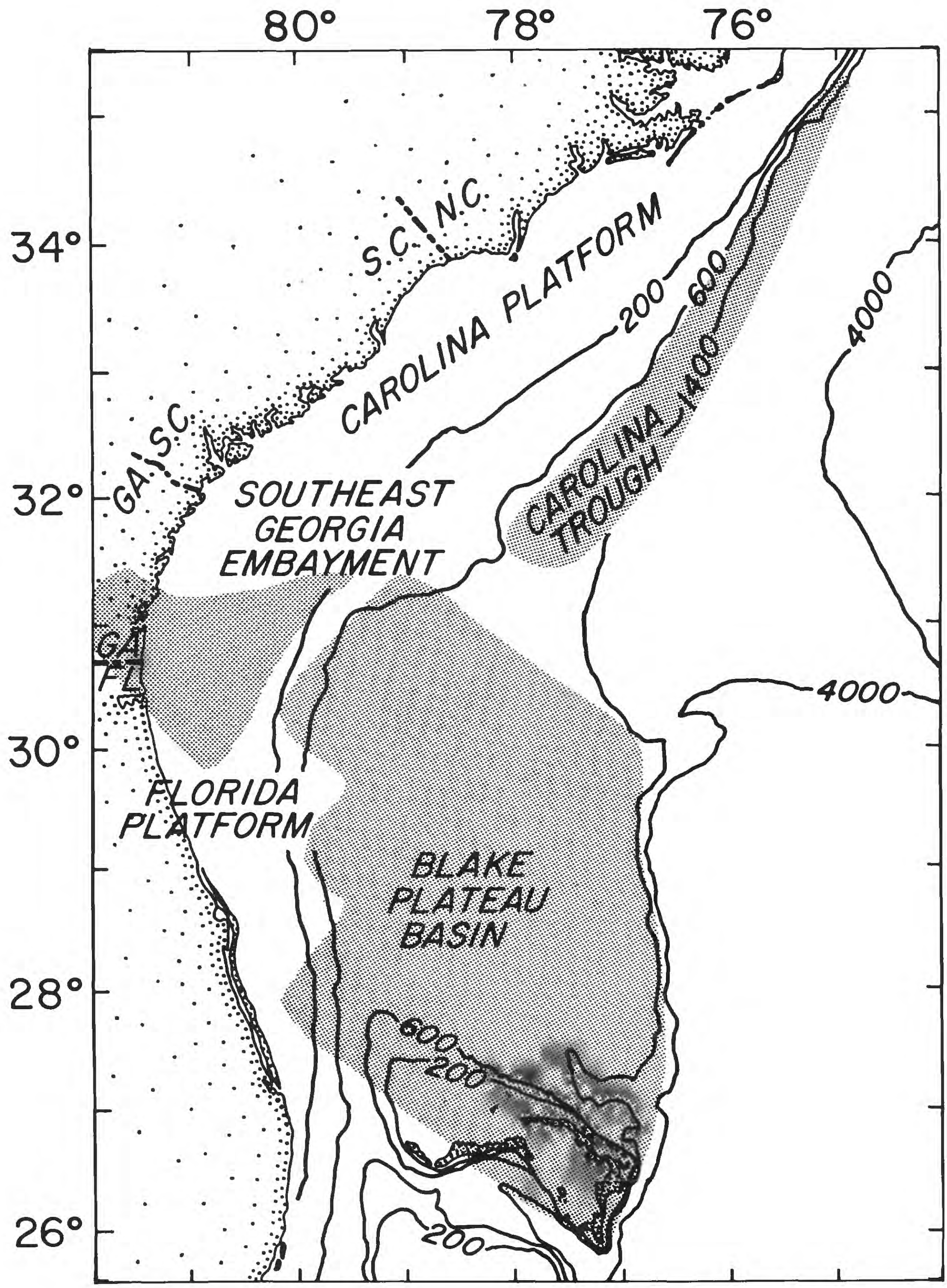

Figure 3: Main basins of the continental margin off the southeastern United States. Bathymetry in meters.

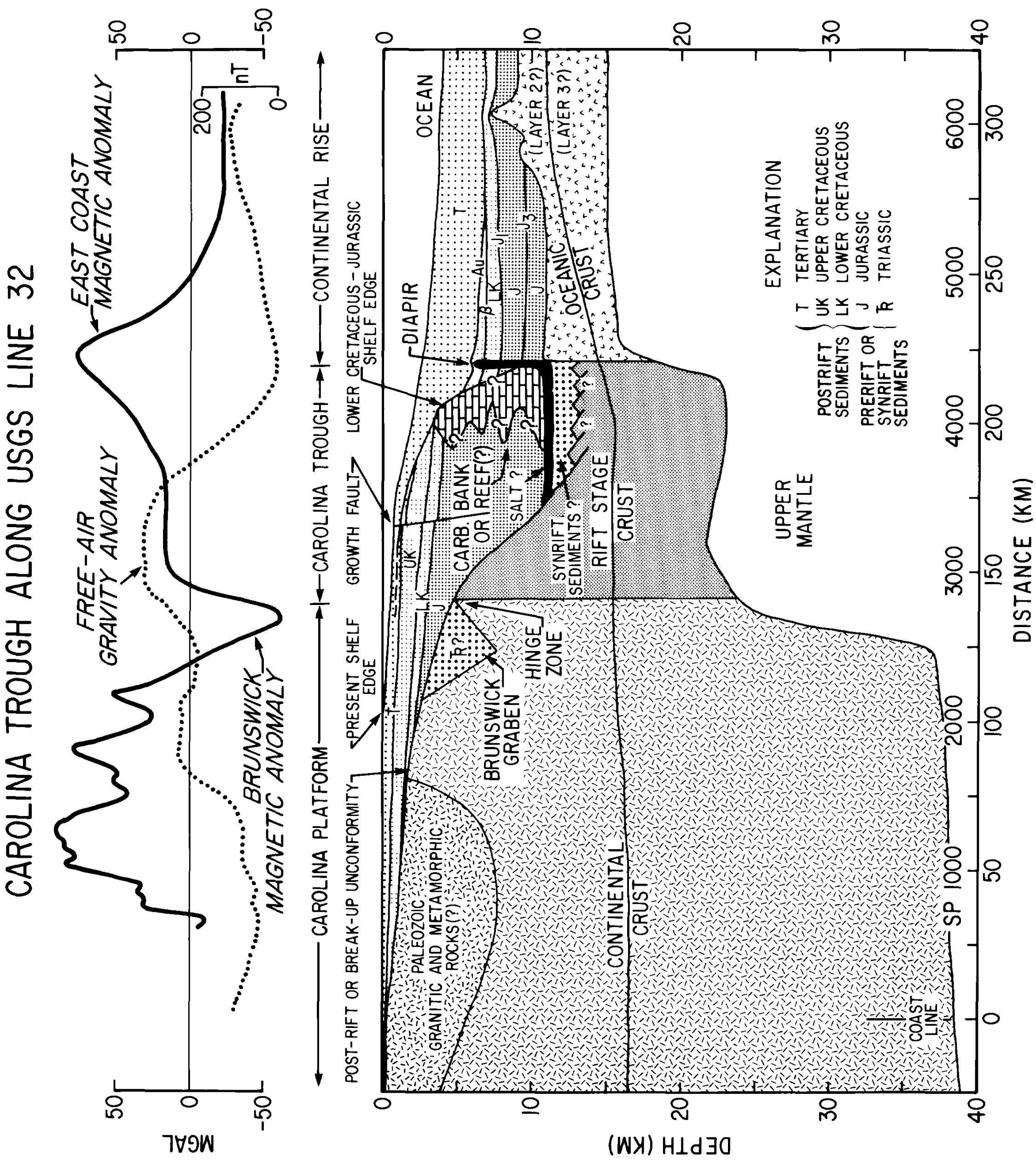

Figure 4: Crustal interpretation across the Carolina Trough along USGS line 32 (from Hutchinson and others, 1983). The salt is inferred to have been deposited in late synrift sediments in the bottom of the Carolina Trough and then to have been squeezed laterally to the southeast until encountering the landward edge of oceanic crust (Dillon and others, 1983). The sediment labeled "T" are post late Oligocene in age and comprise the Neogene wedge shown on the Neogene thickness maps. For location see Figure 1.

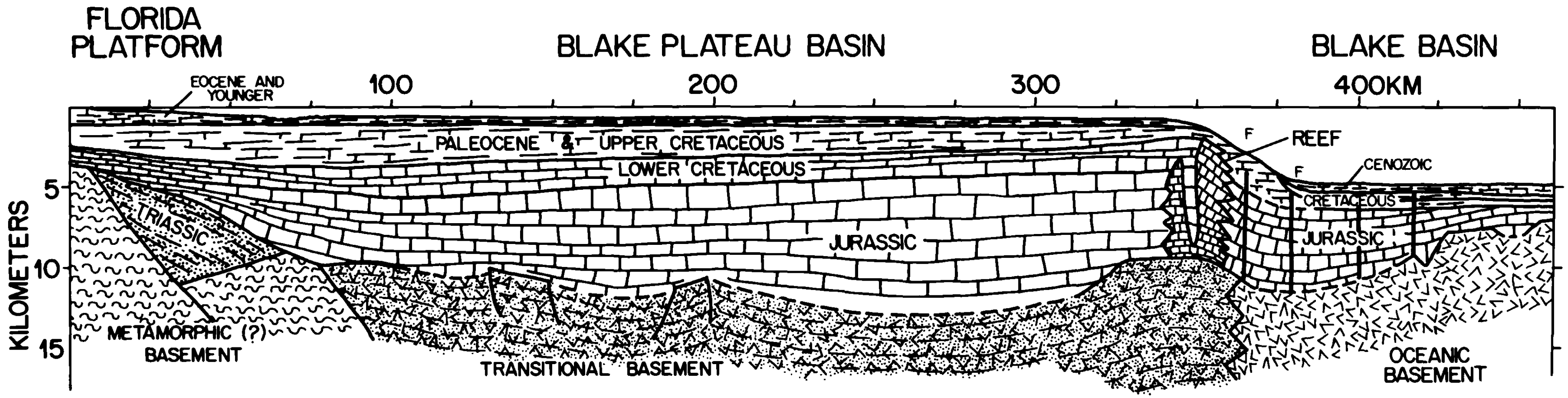

Figure 5: Composite geologic section across the Blake Plateau Basin along multichannel seismic line FC-3 (Grow, 1981). The Jurassic reef shown at the Blake Escarpment is diagrammatic. Location of seismic line FC-3 is shown on Figure 1.