GENERALIZED PRE-PLEISTOCENE GEOLOGIC MAP OF THE NORTHERN UNITED STATES ATLANTIC CONTINENTAL MARGIN

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INTRODUCTION

Scientific research on the United States Atlantic continental margin has increased rapidly during the last decade encouraged by growing economic and environmental interest. This map shows the distribution and outcropping of older rocks beneath sediments of Quaternary age from Georges Bank to Cape Hatteras. The delineation of Tertiary and Cretaceous rocks, especially on the slope, provides a base to which new data on the age and distribution of rock units may be added as it becomes available.

DESCRIPTION OF AREA

The Atlantic continental margin from Georges Bank to Cape Hatteras, an area of approximately 324,000 sq km (125,000 sq mi), is composed of a seaward-thickening wedge of sediments overlying a crystalline basement. The emerged Coastal Plain covers about 143,000 sq km (55,000 sq mi), and the Continental Shelf and Slope encompasses about 181,000 sq km (70,000 sq mi).

The Continental Shelf, extending to approximately 200 m (660 ft) below sea level, is a broad platform with a seaward slope of less than 1°. Quaternary coarse-grained sands and gravels ranging in thickness from 10 to 60 m (33 to 200 ft) overlie older sediments in most places on the shelf. The width of the shelf ranges from about 30 km (18 mi) off North Carolina to nearly 200 km (120 mi) off New Jersey and Massachusetts.

The Continental Slope, extending from approximately 200 to 2,000 m (660 to 6,600 ft) below sea level, has a gradient ranging from 2° to 6° and is cut by many submarine canyons. Although the slope is chiefly covered by younger fine-grained silts and clays, rocks of Tertiary and Cretaceous age crop out in the canyons and along the slope at depths ranging from 500 to 2,200 m (1,600 to 7,200 ft). The width of the slope ranges from 20 to 50 km (12 to 30 mi).

REGIONAL STRUCTURE

The regional structure of the emerged Coastal Plain is a seaward-dipping and seaward-thickening monoclinal wedge of sediments, gently warped into minor folds locally. Under the shelf and slope the wedge appears to thicken greatly and has major structures at depth.

The stratigraphic trends along the inner edge of the Coastal Plain approximate those of the Appalachian Mountains. From New England across Long Island the trend is about S.70°W. From New Jersey to near Baltimore, Md., the trend is more to the south, about S.45° W. From Baltimore south, the trend is nearly south through Virginia and North Carolina. Although the regional trend is rather uniform, there are many local irregularities, which are especially noticeable near the inner edge of the Coastal Plain, where they commonly result from irregularities of the basement surface. Nearer the coast, stratigraphic trends diverge from those at the inner edge of the Coastal Plain.

Regional dips are gentle at the surface and towards the sea, that is, south, southeast, and east. They typically range from about 3 to 10 m/km (10 to 33 ft/mi). Dips locally may be two to three times this normal amount, generally where associated with local warping.

RESOURCE POTENTIAL

On the basis of currently available data, the mineral resource potential of the United States Atlantic Continental Shelf and Slope north of Cape Hatteras may be large. The volume of sediments is about 580,000 cu km (140,000 cu mi). Assuming that these sediments contain petroleum reservoirs, and using the Spivak and Shelburne (1971) sediment-volume method of resource estimations, the petroleum resource potential could be as much as 2 billion metric tons (15 billion barrels) of oil and 2 trillion cu m (70 trillion cu ft) of gas. These approximations are speculative, and much more information must be obtained by drilling and other exploratory methods to permit a more realistic evaluation of the Atlantic continental margin resources.

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SOURCES OF DATA

Data from many sources—listed on the map, in the tables, and among the references cited in the bibliography—were collated to prepare the geologic map.

To create a usable working model, projections of stratigraphic horizons were made from known information from selected land wells to outcrops or drill holes situated sparsely along the Continental Slope, and tentative correlations were made along the slope from one known locality to the next. Specific data are few, and details of structure are not known. No data are available to confirm the occurrence of continuous outcrops along the slope. Older rocks are known only in the canyons and from drill holes, and beds of late Tertiary age may be draped over the Continental Shelf edge. Along the slope and in the canyons, prograding and massive slumping, as well as erosion, may distort the outcrop boundaries. It is reasonable, however, to hypothesize that Cretaceous and lower Tertiary sediments extend across the shelf to the slope, even if covered in most places by upper Tertiary sediments.

Locations and depths of dredge samples, by the nature of the sampling techniques, are somewhat imprecise. In general, sampling has been extremely limited, and more than 99 percent of the samples recovered are Quaternary. Less than 100 samples of Tertiary and Cretaceous age have been recovered. Therefore, interpretations based on these samples are necessarily incomplete and include only what we know at present. An absence of samples does not confirm the absence of sediments of a given age. Although well data are more accurate, difficulties and gaps in sample recovery and contamination may be found. Geophysical data indicate that subsurface structures exist, but no drilling has been done yet to confirm interpretations.

Northeast of Long Island on the inner edge of the shelf, Miocene sediments are known at Gay Head (Martha's Vineyard) and Duxbury in Massachusetts. They may have once extended landward over parts of New England. Sediments of Eocene age have been reported from Fippennies Ledge in the Gulf of Maine and in wells on Cape Cod. Eocene beds also may be more extensive than shown.

Interpretation of data is constantly subject to new information and criteria. Even onshore age boundaries are in dispute and under revision in various places. Much work remains to be done, and drilling is needed to recover complete sections.

ROCK UNITS

BASEMENT

The basement, shown on the cross sections but not mapped, crops out adjacent to the inner edge of the Coastal Plain and Triassic basins.

Basement is considered to include the sequence of Precambrian(?) and Paleozoic metamorphic and igneous rocks underlying the Mesozoic and Cenozoic sediments and lies at depths exceeding 10,000 m (33,000 ft) under the shelf.

The basement rocks, as inferred from outcrops on shore, wells along the coast, and a few subsea outcrops in the Gulf of Maine, include granite, gneiss, gabbro, quartzite, schist, and marble. Granite and gneiss seem to be the most common rock types; schist is next in abundance.

TRIASSIC ROCKS

The Triassic rocks, shown on the accompanying figure, underlie relative lowlands or basins trending generally with the north and northeast strike of the older formations. Most basins are bordered by faults, especially along one long side, and at present the rocks dip more steeply than they did when deposited.

The Triassic rocks in outcrop onshore are a heterogeneous mixture of stream, lake, and swamp deposits, plus intrusive and extrusive volcanic rocks. The sedimentary sequence includes typical "red bed" mudstone, shale, siltstone, sandstone, and fanglomerate. Although mostly reddish brown, some beds are gray, yellowish gray, and grayish purple. Sandstones are generally arkosic and somewhat calcareous. Fanglomerate clasts, locally derived, grade from pebbles to boulders as large as 1 m (3 ft) in maximum dimension; the clasts include quartzite, limestone, sandstone, gneiss, granite, schist, slate, and quartz.

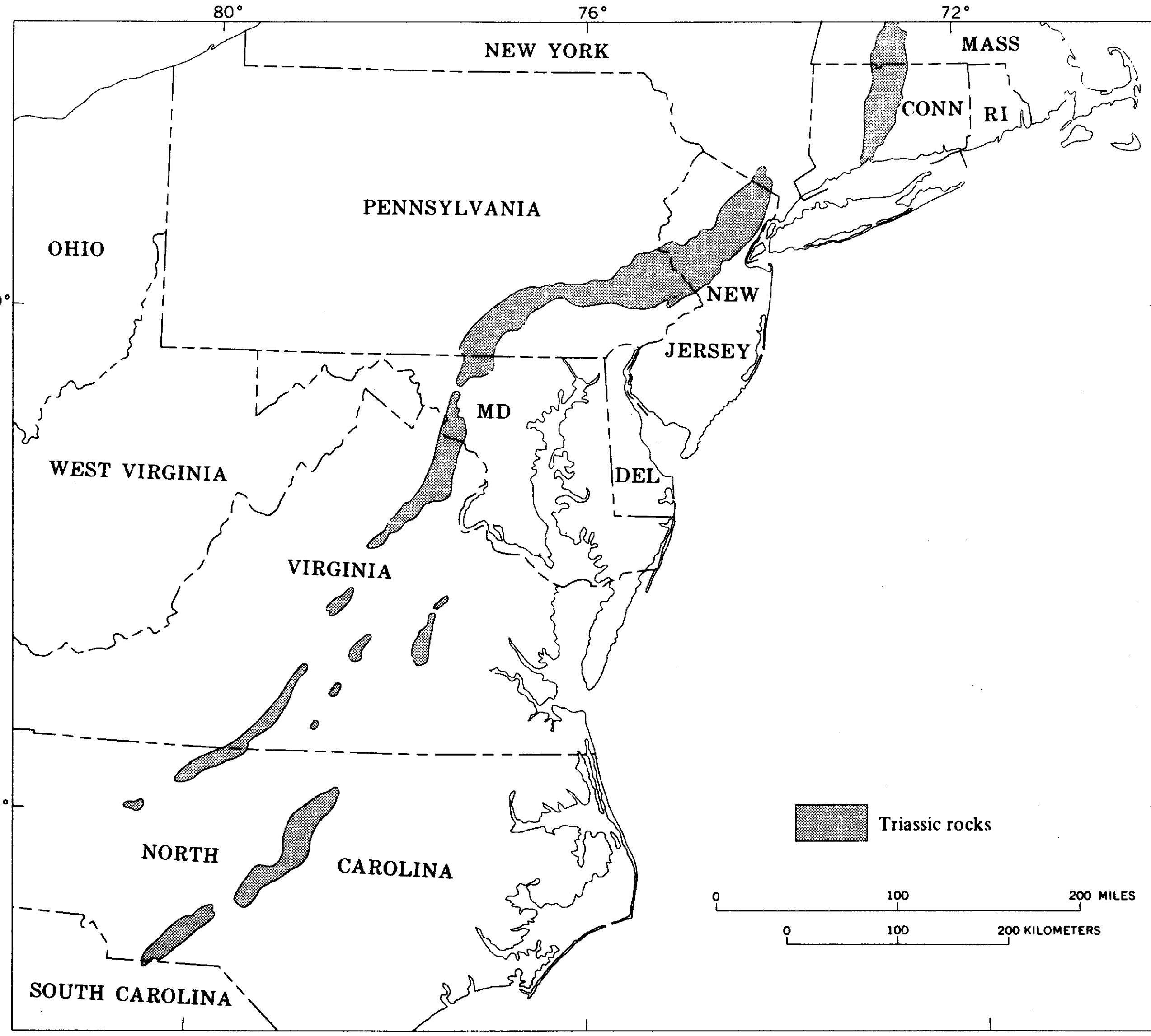
Typically, the less resistant shale, sandstone, and mudstone have been eroded more deeply, and the diabase and basalt now stand as prominent ridges and hills above the sedimentary rocks. These sedimentary rocks, well exposed in many places, are characterized by a thin soil cover, except in certain areas of saprolitized rock locally common on the fanglomerates.

The volcanic rocks are chiefly diabase and basalt. The diabase includes intrusive sills, dikes, and masses, whereas most basalt occurs as extrusive flows. Soil cover generally is thicker and more clayey on the volcanic than on the sedimentary rocks.

Triassic rocks are reported in deep wells near the seaward edge of the Coastal Plain (table 3) and may be present elsewhere under the Coastal Plain and Continental Shelf sediments, particularly as extensions of the exposed basins, but none have yet been recovered offshore. The boundaries for the Triassic rocks shown in the Gulf of Maine on the geologic map were compiled from seismic work by Ballard and Uchupi (1972).

JURASSIC (?)

Jurassic rocks are not exposed on the Coastal Plain. However, sedimentary rocks of possible Jurassic age are shown on the cross section (*A–A′*) because studies of wells in coastal North Carolina (Brown and others, 1972) reported dense finely crystalline limestone underlain by conglomeratic sandstone and reddish-brown to green shale and sandy mudstone, all of Jurassic(?) age. The sandstone is feldspathic and is partly stained by hematite. Similar sandstone, shale, and mudstone are present above the basement surface in several wells in the outer Salisbury Embayment; they occur at depths of more than 1,500 m (5,000 ft) below sea level. Late Jurassic ostracodes have been reported from these rocks by Swain and Brown (1972). A thick Jurassic section was penetrated by drilling on the Nova Scotia Shelf (McIver, 1972).



Triassic basins in eastern United States.

LOWER CRETACEOUS

Most Lower Cretaceous deposits in the Coastal Plain north of Cape Hatteras are of continental origin and are mostly unconsolidated gravel, sand, and clay. Lower beds generally are coarser, and upper beds contain more clay layers and fine sand. Sand typically is light gray but may be stained yellow or brown by iron oxide. Clay ranges in color from light gray through brown, purplish, and pink to dark gray. Crossbedding is common and of the type that suggests stream deposition. Carbonaceous and sideritic swamp clay is present locally within the sequence. Lateral continuity of beds is poor; coarse basal gravel grades laterally into clay, and upper sand and clay beds contain lenses of gravel. Locally, iron-oxide cementation, particularly in coarser beds, has resulted in indurated layers. The Lower Cretaceous sediments average 460 m (1,500 ft) in thickness in Maryland west of Chesapeake Bay near the inner edge of the Coastal Plain. Near the seaward edge of the Coastal Plain, east of Chesapeake Bay, the sediments average 1,500 m (5,000 ft) in thickness. Under the outer shelf they may be several thousand meters (more than 10,000 ft) thick. None of these sediments are known to crop out in the submarine canyons or on the slope.

UPPER CRETACEOUS

Upper Cretaceous sediments are mostly of marine, estuarine, or beach-complex origin; they include cyclic sequences of thin beds of unconsolidated sand, silt, and clay and minor amounts of gravel. Unweathered rocks are shades of greenish gray and greenish black to dark gray. Clean loose sands are light gray. Weathering lightens the dark colors to shades of brown, yellow, and lighter gray. Locally, these sediments are very fossiliferous. A typical cycle is represented by a basal deeper water glauconite sand unit grading up into a nearer shore clayey and silty fine sand unit. This is overlain by a nearshore or beach-complex unit of medium to coarse sand. Although some cycles are complete, erosion has eliminated beds both during and between depositional cycles.

The total section is about 300 m (980 ft) thick near the inner edge of the Coastal Plain and about 800 m (2,600 ft) thick near the seaward edge. Upper Cretaceous sediments may be several thousand meters (more than 10,000 ft) thick under the outer shelf.

Rocks of this age, identified in dredge and grab samples and in cores from drilling holes, are the oldest retrieved from the slope and submarine canyons.

PALEOCENE AND EOCENE

Sediments of Paleocene and Eocene age are glauconite-province sediments, particularly in New Jersey, Delaware, and eastern Maryland. Glauconite content is highest in the lower Paleocene beds, constituting as much as 95 percent of the total sediment in some units. Seaward, southward, and upward, the Paleocene beds tend to be less glauconitic and more quartzose and locally contain limestone layers. The Eocene typically contains clay strata alternating with quartz-glauconite sands. Colors are dominantly dusky green, greenish black, and greenish gray where the sediments are unweathered. In places these sediments are extremely fossiliferous. Toward the southwest, the Eocene sediments tend to be less glauconitic and more clayey and silty and have increasing carbonate content. Near the inner edge of the Coastal Plain, the sediments are about 50 m (160 ft) thick; near the seaward edge, they may reach thicknesses of 220 m (720 ft). Under the outer shelf, these sediments may reach thicknesses of 1,000 m (more than 3,000 ft).

OLIGOCENE

Sediments of Oligocene age include clay, chalk, and calcareous siltstone and sandstone of marine origin. They are missing below the middle Tertiary unconformity near the inner edge of the Coastal Plain. Oligocene sediments, possibly 70 m (230 ft) thick, have been penetrated by wells along coastal North Carolina, where sandy chalk, coarse glauconitic sand, and sandy glauonitic clay are reported to overlie Eocene sediments (Maher, 1971, and unpub. data). Oligocene calcareous clay has been recovered from the Continental Slope east of Cape Hatteras (Fleischer and Fleisher, 1971, and written commun., 1972). Oligocene sediments recovered from the slope to the north include clay and chalk samples recovered in Oceanographer Canyon off Georges Bank during *Alvin* dive 208 (Gibson and others, 1968) and silty clay from The Gully off Nova Scotia (Marlowe and Bartlett, 1967).

MIOCENE AND PLIOCENE

Sediments of Miocene and Pliocene age range from fine sand and silt deposited in the nearshore marine environment to beach-complex, tidal-delta, and barrier-bar sand and some interbedded clay. The lower beds are very fossiliferous in places. In the northeast part of the Coastal Plain, the deposits tend to be mostly quartz sand that contains considerable feldspar in the lower beds and, in places, diatomaceous earth. In New Jersey, the upper beds are the source of the ilmenite and silica sand that are presently being mined. In Virginia, thick beds of limestone are mined for use in the cement industry. Color ranges from light bluish gray through shades of brown to light gray and yellowish gray.

These sediments are about 60 to 70 m (200 to 230 ft) thick in outcrop near the inner edge of the Coastal Plain. Near the seaward edge they are as much as 300 m (980 ft) thick. Near the outer edge of the Continental Shelf they may exceed 1,000 m (3,000 ft) in thickness, especially where prograded on the Continental Slope.

The uppermost Pliocene deposits of the emerged Coastal Plain consist of scattered erosional remnants of stream sand and gravel.

PLEISTOCENE AND HOLOCENE

North of Hudson Canyon, the Pleistocene sediments include sand, gravel, silt, and clay, mainly of glacial origin. South of Hudson Canyon, sand covers most of the shelf. Distribution of sediment by types has been discussed in several papers, including those by Schlee (1973) and Hollister (1973). The Pleistocene and Holocene sediments of the emerged Coastal Plain consist of stream, marsh, and shallow-water marine beds. Thicknesses are variable, ranging from less than 3 m (10 ft) to more than 60 m (200 ft).

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