ASSESSMENT OF THE GEOLOGIC INFORMATION OF NY STATE'S COASTAL ZONE AND CONTINENTAL SHELF AND ITS SIGNIFICANCE TO PETROLEUM EXPLORATION AND DEVELOPMENT

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VOLUME I

ASSESSMENT OF THE GEOLOGIC INFORMATION OF NEW YORK STATE'S COASTAL ZONE AND CONTINENTAL SHELF AND ITS SIGNIFICANCE TO PETROLEUM EXPLORATION AND DEVELOPMENT

Prepared for the
New York State Science Service - Geological Survey
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PREFACE

The rapidly increasing needs for domestic petroleum resources by the United States have placed heavy pressures to explore the continental margin of eastern North America's offshore region. Economic successes in other similar regions of the submerged portions of continental margins have spurred very intensive geologic study and economic analysis of the Atlantic coastal margin of the United States by the major energy companies and by the U.S. Department of the Interior. To date, several billions of dollars have been invested there in what can be termed only preliminary assessment of its economic potential for the simple reason that no petroleum reserves have been actually identified there. However, the intensity of the geologic examination of the region in terms of cost and time to industry and to the Federal government is indicative of the positive evidence gathered thus far that makes the continental margin of eastern United States a highly favorable target for extensive petroleum investigation.

During the decade in which the Atlantic continental margin of the United States has been under intensive investigation as a prospective petroleum producing region, two diametrically opposed situations have developed in the United States. The first is the political and economic causes of shifts in the availability of inexpensive petroleum causing a reducing domestic reserve and an increased reliance on petroleum imports. The second is the increasing ability of both private organizations and governmental agencies to slow or prevent the economic development of any region because of real or potential hazards which might be inflicted on the surrounding environment as a result of the exploitation of the petroleum resources.

An example of the strengths of these two forces has been seen during late 1976 and early 1977. Major oil companies paid $1.1 billion dollars to the Department of the Interior in August 1976 for the rights to lease certain designated tracts of offshore area on the continental shelf east of New Jersey. In February 1977 a Federal judge in New York voided this $1.1 billion sale basing his decision upon evidence that the leasing had occurred without full compliance to the National Environmental Policy Act.

Thus, all sides of the exploration venture come into play-economics, national needs, technological and environmental safety along with projected estimates of the positive and negative influences such ventures might produce for the coastal states and communities bordering the Atlantic continental margin. This means that each state having a coastal zone is an active participant in weighing the divergent

and often conflicting factors in condoning or objecting to the rights of the Federal government to lease offshore areas for petroleum exploration purposes. It is therefore encumbent upon all parties involved in this complex decision-making process to have available the full range of fundamental information which needs to be incorporated into a rational choice of the best long-term use of the ocean resources with maximum environmental safeguards.

This report includes a comprehensive coverage of the available information, research and practical experience which exists for the New York State continental margin. That region extends seaward from the beaches, tidal wetlands and river mouths to the relatively deep marine seabed where it is presently feasible to apply the technology of offshore drilling in search of petroleum reservoirs. Two principal topics are encompassed in this report. First, the geology of the continental margin which extends from the unconsolidated surficial sediments on the seafloor downward through the sedimentary layers which have formed since the earliest stages of development of the eastern North American continental margin. Second, the circulation of waters which cover the continental margin. This latter topic therefore includes surface and deep water currents as well as tides and waves. These two topics must be coupled because materials of the seafloor along the continental margin are influenced by the dynamics of water movements. Any influences upon these bottom sediments by man's activities on the seafloor or any introduction of polluting substances into the water column itself results in transfers and redistributions of inert or harmful material by the dynamic circulation patterns of the continental margin's marine waters.

Thus, a major task by governmental agencies in judging suitability of areas for offshore petroleum exploration must be based upon both a knowledge of the seabed geology and the overlying circulation dynamics. Both influence the safety of any exploration site and cause possible widespread redistribution of pollutants added to the water column from the exploration site. In spite of the fact that this report includes titles of published and unpublished studies relevant to New York's continental shelf and adjoining areas, this listing is not complete and the data on this region is only beginning to become available. During the coming few years, new information and dramatically different interpretations concerning this vast unexplored region will emerge at such an explosive rate that this report will very quickly be dated in perspective to the exponential growth in the fundamental knowledge which inevitably is to occur.

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INTRODUCTION

Organization and User's Guide

This report contains a summary of the geologic properties and economic potential of the continental shelf bordering New York State. Included are discussions of origins of the continental margin, the specific surface features which are characteristic of that portion of continental shelf bordering New York and the ways in which the natural geologic setting and its on-going processes can influence offshore exploration. This portion of the report stresses the fact that any predictions of the outcomes of man-made influences upon the continental shelf can be understood and controlled only by means of a thorough knowledge of the shelf and its associated processes as they occur in their natural geologic setting.

Included is an assessment of adequacy of the present geologic knowledge about the continental shelf. Based on this assessment, a number of gaps in data fundamental to understanding shelf processes and to predicting the outcomes of man's influence on that environment are identified. All of these areas of needed information become priority items which can lead toward an intelligent management of the potentially large economic resources which lie along New York's outer continental shelf.

This report includes a bibliography of papers pertinent to an understanding of the continental shelf of the middle and north Atlantic region of eastern United States. These references occur in two forms. Volume II of this report contains an alphabetized listing of about 850 published and unpublished papers pertinent to the area of study. Secondly, bibliographic data has been included at the end of each topic section of the geologic information portion of this report. Following each subject listed there is given the title and author of all pertinent papers and reports. These are not set up in the usual format of bibliographic citations for reasons of usefulness and limitations of duplication. The article title is cited along with author and date of publication. This permits a rapid scanning of all subjects related to each section of the report to determine which papers are needed for immediate use. Once the pertinent titles are selected, the listed author(s) and date give immediate access to the alphabetized bibliography in Volume II where full source information is given for each reference.

In the Appendix of this report is a listing of all public and private organizations engaged in research or in funding research on the continental margin of eastern United States. Included are lists of individuals and their institutional affiliation and their funding and/or equipment support. This

summary is probably the most complete listing of available expertise, and agencies supporting that expertise in studies of the continental margin of eastern United States. This portion of the report is especially useful because more unpublished quantitative research may be underway at the present time concerning the continental shelf, its geology, and the dynamics influencing that region than all of the useful, quantitative studies listed in the bibliography (Volume II).

Participants in Report Preparation and Acknowledgements

J. Douglas Glaeser was responsible for the organization of the report, format, the bulk of the bibliography and those other chapters covering the Identification and Assessment of Geologic Information of New York State's coastal zone and continental shelf, as well as the section on funding agencies and organizations participating in research in the study area. The original illustrations included in Glaeser's chapters are by Daniel D. Hart. Philip C. Smith was responsible for the sections on Geologic Development of New York Continental Shelf (IV), Seismicity of the Continental Margin (V) and portions of those sections concerning petroleum and geological hazards of shelf exploration.

John Myers contributed materially to this report in his thorough organization of unpublished information concerning the study area. He also carried out many of the tasks of gathering scattered information and doing calculations which act as supporting data.

The study was accomplished under the direction of William B. Rogers, New York State Geological Survey, who somehow found the patience to be both administrative overseer and constructive critic throughout the development, preparation and completion of this report. He carried out this dual function with a wealth of understanding and humor which kept all the participants reasonably sane for the duration. Federal funding was made possible for this study as an integral contribution to the State's Outer Continental Shelf Study Program managed by the New York State Department of Environmental Resources through the New York State Department of State's Coastal Zone Management Program.

Summary of Report Contents with Assessments and Evaluations of Existing and Needed Geologic Information

Because there is a vast amount of new quantitative data being developed by both Federal and private research agencies, it is thought that most major gaps of information concerning

the New York continental shelf have been specifically identified within the body of this report. The emphasis has focused on the question of adequacy of knowledge concerning process-response systems of the continental shelf. It has been a theme of this report to underscore the process-response systems for one very important reason: that is, when any change is made in the shelf environment, whether it be construction of a drilling platform or an oil spill, the response which will follow these man-made changes can only be understood in the light of the natural processes already acting there or which have been active within the continental margin in the geologic past. Each of the sections of this report dealing with specific geologic aspects of the continental margin or the physical processes influencing that region (such as shelf water circulation, slumping, beach development and erosion, etc.) has indicated what needs to be known about that particular topic prior to shelf exploration. A review of these has been extracted from each section and summarized below.

Problems Concerning Shelf Surface Features

An understanding of the depositional processes and mechanisms that built and continue to modify the physiographic surface features of the outer continental shelf are of major importance to management of man's activities in the coastal zone and on the continental shelf. Although the distribution of major shelf features is known from detailed bathymetric maps already available, the origins of some of these features are not well understood. Features that need further research for adequate management are briefly discussed below.

Shelf valleys that cross the continental shelf, buried shelf valleys and the nearly ubiquitous ridge and swale topography are features created and modified perhaps by both present and past depositional processes. Sorting out the degree to which present shelf circulation and sediment movement affects these features is important to the overall understanding of the shelf system.

Early studies of ridge and swale topography attributed its origin to fluvial or glacio-fluvial processes. Newer interpretations hold that ridge and swale topography is not a relict feature on the shelf surface but rather a product of the dynamic changes in the shoreface - inner shelf region occurring in response to present-day hydraulic conditions.

Shelf valleys have been discussed in some papers primarily concerned with shelf sediment characteristics, where "drainage networks" on the shelf have been related to shelf valleys.

Another more recent interpretation of these "drainage networks" is that they are merely the low areas of the ridge and swale topography and unrelated to shelf valleys.

Buried shelf valleys are another feature of the shelf surface that need to be known in considerable detail prior to construction of drilling platforms. Buried shelf valleys are former fluvial channels that were eroded into the shelf surface when it was exposed during lower stands of sea level and later filled with material that is unconsolidated and, in places, slumped toward and/or down the fluvial channel axis. These areas of slumped unconsolidated sediment represent significant engineering hazards. Identification of potential slump zones is essential prior to selection of drill sites. Neither the slumping nor the trace of the buried shelf valleys is discernible from bathymetric maps. Shallow seismic profiling reveals their presence beneath the infilled sediment surface. Buried shelf valleys are depositional areas on the shelf surface, hence they could be good sites for burial of pipelines because here pipelines should not be affected by scour.

The problem of sediment mobility, in general, is not well understood in terms of shelf sediment dynamics. The linear shoals making up the ridges of the ubiquitous ridge and swale topography have not been monitored in terms of the currents which influence them. Thus, we have no quantitative link between sediments and the forces which move them. The dynamics of linear shoals are just beginning to be understood. The principle research on this topic is underway at the Atlantic Oceanographic and Meteorologic Laboratory of NOAA in Miami. Any site to be used for petroleum exploration on the shelf surface must be accurately located with respect to these linear shoals. This can be done on the detailed bathymetry shown on Stearns' (1967) charts of the New York bight region. Because of the scale of these ridges (a few kilometers in length, heights up to 10 m), a single map cannot be incorporated in this report showing the areal distribution of these features.

Part of the resolution of problems involving linear features on the shelf surface relates to distinction between remnant structures formed during lower sea-level thought to be strand line features and those which are responding to the dynamic conditions of the shelf surface today. Duane and others (1972) emphasize the fact that linear shoals represent neither subaerial superstructures nor submarine foundations of barrier islands. Instead, they interpret these linear features as "daughter" forms adjusting to the prevailing hydraulic processes on the shelf today.

Another problem involving surficial sediments of the shelf is the need for detailed maps showing sediment types and textures

in terms of their areal distribution. The presently available maps (Williams and Duane, 1974; Charnell and others, 1975) lack a direct link to shelf surface topography, which is necessary to judge the suitability of drilling sites. The result of on-going research at Virginia Institute of Marine Sciences funded by the Bureau of Land Management indicates direct links among shelf surface morphology, wave refraction, sediment types and mobility as well as variations in the inhabiting organisms.

Related to these studies of surface sediment mobility and distribution is a re-evaluation of the uppermost zone of unconsolidated sediment comprising the Pleistocene-Holocene stratigraphic section. Three types of data are being gathered and/or in the process of evaluation. The first comes from continuous seismic reflection profiles. The second, from the 1976 Atlantic Margin Coring Project. The third, from studies of the New York bight by the National Oceanographic and Meteorologic Administration and by the Coastal Engineering Research Center of the Corps of Engineers.

The physical character of submarine canyon heads which incise the outer shelf margin requires further study. Studies of canyon heads are very few and limited in scope. Those examined reveal a "badlands" topography in which two types of slumps occur. The first type are those where slump crests are parallel to the slope and occur in relatively undissected intercanyon areas. They may form small wave-like slump trains. The second type of slumps are those formed at right angles to the first. Slump features of both types imply an active substrate in the heads of submarine canyons. Evolution of this type of relief involves sideward movement into the canyon axis where the slumped sediment is being actively dissected to form younger gullies. Older erosional canyon heads may have been partially buried, although such deposition may be only temporary. A number of lease tracts of the north and mid-Atlantic areas are located at heads of submarine canyons, thus, the processes operating these are of immediate interest.

The increase in slope which occurs beyond the shelf break gives evidence of active sediment mass movement in places. The irregular distribution of erosional and depositional areas within canyon heads all signal caution in terms of exploration in these sites. Slump block detachment represents one of the most serious engineering problems in the areas of canyon heads as well as on the continental slope in general.

The beaches and barrier islands marking the landward edge of the shelf have an intimate association with continental shelf materials and processes. There are no regional studies of the beaches (barrier islands) bordering the New York bight. Sand types, sources, transport rates, downdrift compositional

changes, etc., all are responses to the wave and current regimes. Understanding material transfers and rates of change in the barrier island systems within specific coastal compartments would provide the major key to understanding the extent and intensity of influence which pollutants such as sewage or oil spills would have on the beaches of the region. In addition, knowledge of rates of change in barrier island migration would permit intelligent long-term planning of the important recreational facilities.

Because of the known correlation between some components of beach materials and sediment types on the shelf (Pilkey and Field, 1972), the first step in evaluating any possible unconsolidated sediment resource such as offshore heavy metal placer deposits is an analysis of the beaches themselves.

One important area of sand accumulation within the barrier island system is the tidal delta. Tidal deltas formed just landward or seaward of inlets between barrier islands are important sites of sand storage and represent one dynamic part of the continuous development and regeneration of barrier islands. The removal of such sand bodies for navigation purposes modifies the sand balance which helps maintain and regenerate portions of barrier islands. Tidal deltas can represent the only remaining sand sources in areas where major storms have removed both beach and dune sand to the offshore.

A second dynamic environment situated on the landward edge of the continental shelf is the estuary, an area of sediment accumulation from both rivers and across-shelf transfers. The physical processes and geologic materials of the Hudson River estuary are very poorly known, In terms of the dynamics of estuarine circulation, it is one of the least well understood estuaries in the United States. Because estuaries are sediment and pollutant traps for materials carried landward from the shelf <u>and</u> from river drainage, both modeling and process-response studies of the system as a whole are obviously essential.

Crucial Problems Involving Circulation of Shelf Waters

Because the pathways and fates of any pollutants which might be introduced into the water column on the continental shelf are governed by the circulation dynamics of the region, prediction of pollutant distribution will be based largely on knowledge of the complex shelf circulation systems. There are three major areas of study which need further work before pathways and fates of pollutants, including oil spills, can be understood. First, surface circulation of shelf water varies both seasonally and with the passage of meteorologic highs and lows across the shelf. There is limited evidence that the middle Atlantic bight may respond as a unit to major storms passing seaward. The National Oceanographic and

Meteorologic Administration is presently preparing an historical summary funded by the Bureau of Land Management which is to summarize and interpret the available historical information on the physical oceanography and meteorologic data for the middle Atlantic region. A summary of the goals of this contract is given in the text of this report.

Part of this area requiring further study is the use of computer modeling to predict spill trajectories. Present results of use of computer models to predict pollutant distributions has not matched the actual movement themselves.

A second area requiring further extensive investigation involves the seasonal variation in water mixing related to differences in the position of the thermocline. Existing evidence suggests that under certain seasonal conditions polluted river water mixes well with shelf waters, while in other seasons polluted river water floats as a surface plume over the shelf water. Related to these mixing variations are the different effects pollutants may have on organisms and the different ways pollutants are transferred to the shelf sediment. The rates of supply and concentrations of pollutants result in a number of changes in the geological, biological and chemical properties of the shelf environment.

A third area where much information needs to be assimilated and synthesized involves water mass exchanges between the shelf and continental slope. Both down slope and across-shelf movements of suspended material are known to occur. There is some evidence that suspended particles near the base of the shelf water column have a net movement landward, particularly into estuary mouths. Thus, pollutants introduced near the shelf break do not necessarily move seaward.

An understanding of physical oceanography is necessary to the understanding of movement patterns of all shelf materials, whether suspended debris or bed-load deposits. Both the New York Department of Environmental Conservation and the New York State Geological Survey should make a concerted effort to jointly hire as a consultant a physical oceanographer who has a feeling for the geologic, biologic and physical implications of shelf circulation and wave dynamics. The immediately apparent impacts of offshore exploration invariably are related to fouling of recreational and fishing areas. A physical oceanographer monitoring activities of immediate concern to the State would be able to explain the facts as a problem develops, or, ideally identify a potential problem before it occurs.

One important question which needs to be answered concerns the distances from the shoreline where pollutants might be introduced which would result in inevitable delivery of pollutants to the coast. Pollutant distribution clearly is linked to

circulation dynamics, shelf topography and shelf sediment properties. Understanding fates of oil spills is in part linked to decay rates produced by bacteria, effects of drainage distribution, shelf surface topography, and sediments which may have an ability to trap pollutants.

A final problem involving the shelf and its geology is seismic (earthquake) risk. Few epicenters are known in the mid or north Atlantic shelf. This is partly the result of difficulties that onshore seismographs have in focusing on offshore earthquakes unless they are large or near shore. The present evidence for the outer continental shelf of New York suggests that the region is one of moderate seismic risk.

It is also appropriate to list some major undertakings which clearly are needed as the pressures continue to stimulate the economic development of the continental margin of eastern United States. All of these relate to improving the utilization of resources which New York State already has and to which the State has direct access in contrast to offshore drilling which combines Federal and petroleum company controls.

A strong effort should be made to integrate the coastal plain stratigraphy and its ground-water characteristics to the related rocks of the continental shelf. Fresh waters known to exist beneath the shelf may represent better sources of water for the New York City-Long Island region than the presently proposed use of Hudson River water as a supply to supplement present sources during projected shortfalls of the coming decade.

A second major economic resource of the continental shelf adjacent to New York's coastal zone is sand and gravel. For appraisal of these resources, detailed surface sediment distribution maps are needed which should include thickness of unconsolidated sediments, grain-size distributions, sorting, roundness and sediment composition.

Heavy metals may also be present in economic concentrations on the continental shelf. Data on their distribution can be derived directly from sediment-type distribution maps.

As part of the integration of coastal plain and offshore stratigraphy, there should be attention given to the possible stratigraphic associations with which sedimentary uranium can be associated. The three principal types of sedimentary associations do occur beneath the shelf surface, i.e., fluvial, near shore marine and black shales containing sedimentary derivatives from weathered volcanic debris. This potential uranium resource is not likely to be of immediate economic interest, but its possible presence should be kept in mind.

One final recommendation concludes this summary of assessments and recommendations section. There is, at present, no association of middle Atlantic states to act as a coordinator for information and research in the New York bight. Because the shelf circulation patterns of the middle Atlantic region affect these states in a common way, a strong interstate agency staffed by competent scientists seems highly advisable. Such associations already exist for the southeastern states of Virginia to Florida (Coastal Plains Center for Marine Development Services) and for the New England states (New England Marine Advisory Service). Even if funding is not sufficient to support research, this proposed Middle Atlantic States Association should be staffed adequately to compile and keep abreast of research on the continental shelf of the middle Atlantic Region. It is within groups such as these that planning for pipeline corridors to the on-shore region, for example, can be developed and executed.

I. THE CONTINENTAL MARGIN

I.A. Physiographic Provinces

The margin of the continent which lies adjacent to and seaward of New York State beneath the waters of the western north and middle Atlantic ocean represents a set of major physical features of extraordinary economic and environmental importance. There are three principal physiographic provinces which constitute the continental margin -- continental shelf, continental slope and continental rise. The coastal plain, although a minor to absent feature of New York State's coast line, can be considered as that portion of the continental shelf which is presently above sea level.

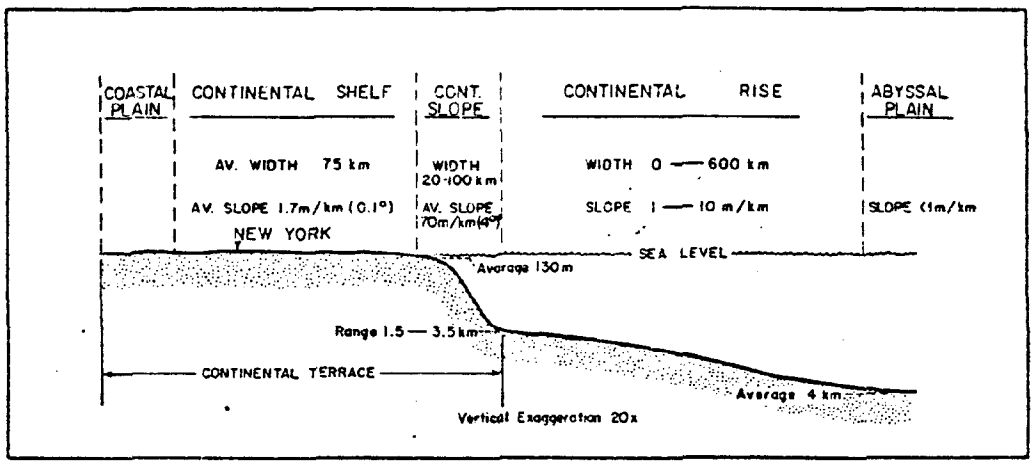
Figure 1 illustrates the cross sectional aspect of the continental margin. Although the surface gradient and width varies from place to place, the average values shown in Figure 1 are reasonable for New York's continental margin.

Physiographic Province	Av. Width (km)	Av. Gradient
continental shelf	75	1.7m/km
continental slope	20-100	70m/km
continental rise	0-600	1-10m/km

The term, continental terrace, shown in Figure 1, is not currently used to designate the combined physiographic provinces of coastal plain, continental shelf and continental slope.

A more "realistic" aerial view of the continental margin adjoining New York is shown in Figure 2. Because of the compressed nature of the block diagram in terms of horizontal versus vertical scale, the gradients of all the physiographic provinces of the continental margin are exaggerated, especially that of the continental slope. It is important to compare Figure 2 to Figure 1 to recognize that the "precipitous" appearance of the continental slope in Figure 2 is a graphic exaggeration of the average gradient of only about 70m/km (about 4°) shown in Figure 1.

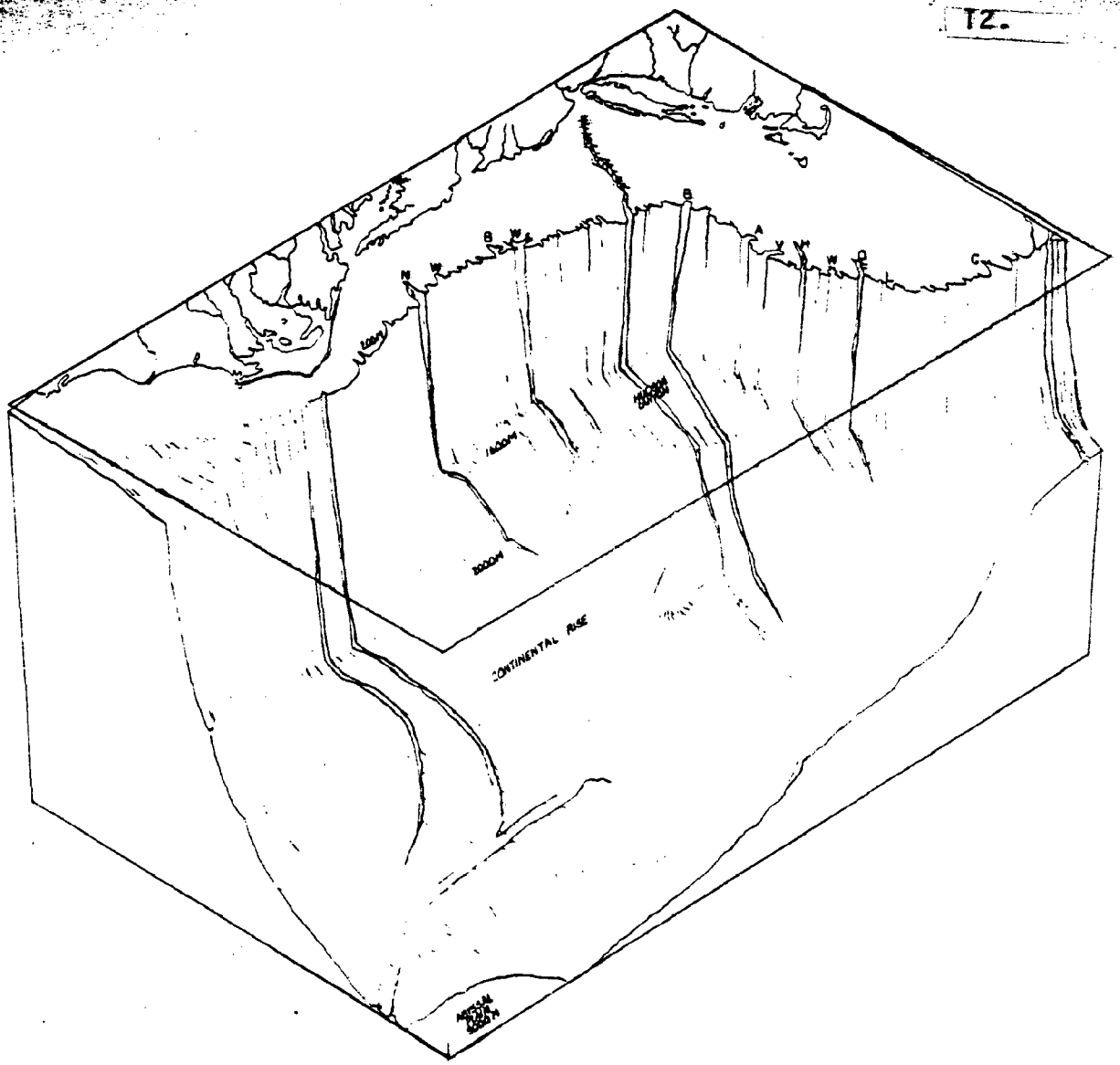
Each of the three portions of New York's continental margin is designated a physiographic province on the Earth's surface -- that is, the geologic structure of each province is distinctive. Thus, the rocks beneath its surface have characteristics which distinguish them from adjoining provinces. The



Idealized diagram of the principal elements of a continental margin.

(From Drake, C. L., and Burk, C. A., 1974, Geological Significance of Continental Margins, fig. 9, p. 8)

FIGURE 1



Physiographic diagram of the continental margin, eastern United States. Vertical dimension greatly exaggerated.

Key to Canyon Names, South to North
N = Norfolk; W = Washington; B = Baltimore; W = Wilmington; Hudson; B = Block; A = Atlantis; V = Veach; H = Hydrographer; W = Welker; O = Oceanographer; L = Lydonia; C = Corsair

FIGURE 2

surface of each physiographic province thus responds to surface processes in ways which distinctively "shape" the surface giving it a definable topographic form which can be recognized from topographic maps or bathymetric charts.

I. The Continental Margin

Shallow structure of the continental margin, Curray, J.R., 1969b.

Atlantic margin of North America (abstr.), Drake, C.L., 1963.

Continental margins, Drake, C.L., 1969.

Geology of the continental margin off eastern United States, Emery, K.O., 1965.

East coast offshore symposium, Baffin Bay to the Bahamas, Emmerich, H.H., ed., 1974.

Eastern continental margin of the United States, Part 2, Hales, A.L., 1970.

The face of the deep, Heezen, B.C. and C. Hollister, 1971.

Continental margins of eastern Canada and Baffin Bay, Keen, C.E. and Keen, M.J., 1974.

The continental margin of eastern Canada, Keen, M.J. and J.E. Blanchard, 1966.

Continental margin of eastern Canada, Keen, M.J., B.D. Loncarevic and G.N. Ewing, 1970.

Preliminary geologic report on the U.S. northern Atlantic continental margin (abstr.), Minard, J.P. and others, 1973.

Preliminary report on geology along Atlantic continental margin of northeastern United States, Minard, J.P., W.J. Perry, E.G.A. Weed, E.C. Rhodehamel, E.I. Robbins and R.B. Mixon, 1974.

Geology of the Atlantic and Gulf coastal province of North America, Murray, G.E., 1961.

The continental margin of the northwest Atlantic Ocean, a geophysical study, Rabinowitz, P.D., 1973.

Oceanographic atlas of the North Atlantic Ocean, Sec. V, Marine Geology, U.S. Naval Oceanographic Office, 1965.

A keyword-indexed bibliography of the marine environment in the New York bight and adjacent estuaries, Ali, J.A., 1973.

I.A. Physiographic Provinces

Atlantic-type continental margins, Heezen, B.C., 1974.

The North Atlantic text to accompany the physiographic diagram of the North Atlantic, Part I of the floors of the oceans, Heezen, B.C., Tharp, M. and Ewing, W.M., 1959.

Seismic reflection observations on the Atlantic continental shelf, slope and rise southeast of New England, Hoskins, H., 1967.

Submarine physiography of the U.S. Continental margins, Jordan, G.F., 1962b.

Topography of the Gulf of Maine, field season of 1940, Murray, H.W., 1947.

The characteristics of the Atlantic sea bottom off the coast of the United States, Pourtales, L.F., 1872.

Glaciation on the continental margin off New England, Pratt, R.M., and Schlee, J., 1969.

Eastern Atlantic continental margins-various structural and morphologic types, Renard, V., and Mascle, J., 1974.

Canyons off the New England coast, Shepard, F.P., 1934.

Submarine Geology, Shepard, F.P., 1973.

Submarine topography of Eastern Channel, Gulf of Maine, Torphy, S.R., and J.M. Zeigler, 1957.

Maps showing relation of land and submarine topography, Nova Scotia to Florida, Uchupi, E., 1965a.

Atlantic continental shelf and slope of the United States -- Physiography, Uchupi, E., 1968.

Map showing relation of land and submarine topography Nova Scotia to Florida, Uchupi, E., 1965.

Bathymetric chart, Bay of Fundy to Gulf of Saint Lawrence, Uchupi, E., 1969b.

Bathymetric chart, Newfoundland shelf, Uchupi, E., 1970b.

Aeromagnetic map Atlantic continental margin, U.S.G.S., 1976.

I.A. (continued)

The fishing banks between Cape Cod and Newfoundland, Upham, W., 1894.

Topographic influences on the path of the Gulf Stream, Warren, B.A., 1963.

I.A.

1. Continental Shelf 2. Continental Slope

Seismic-refraction profiles in the submerged Atlantic Coastal Plain near Ambrose Lightship (N.Y.), Carlson, R.O. and M.V. Brown, 1955.

The stratigraphy of the continental shelf east of New Jersey (abstr.), Chelminski, P. and Fray, C.I., 1966.

History of continental shelves. In The New Concepts of Continental Margin Sedimentation, Curray, J.R., 1969.

Basement beneath the emerged Atlantic coastal plain between New York and Georgia, Dietrich, R.V., 1960.

Geophysical investigations of the emerged and submerged Atlantic Coastal Plain, Part 9, Gulf of Maine, Drake, C.L., Worzel, J.L., and Beckman, W.C., 1954.

Characteristics of continental shelves and slopes, Emery, K.O., 1965.

Joint program of U.S.G.S. and W.H.O.I. for continental shelf and slope. In Summary of investigations conducted in 1964, Emery, K.O., 1965.

The Atlantic Continental Shelf and Slope, a program for study, Emery, K.O. and Schlee, J.S., 1963.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 4, Ewing, M., 1940.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 3, Barnegat Bay, N.J. Section, Ewing, M., Woolard, G.P. and Vine, A.C., 1939.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part IV, Cape May, N.J. Section, Ewing, M., Woollard, G.P. and Vine, A.C., 1940.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 5, Woods Hole, New York, and Cape May sections, Ewing, M., Wongel, J.L., Steenland, N.C. and Press, F., 1950.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 1, Methods and results, Ewing, M., Crary, A.P. and Rutherford, H.M., 1973.

I.A. 1. and 2. (continued)

Cretaceous-Cenozoic development of the continental shelf south of New England, Garrison, L.E., 1967.

Developments of continental shelf south of New England, Garrison, L.E., 1970.

The submerged coastal plain and old land of New England, Johnson, D.W. and Stolfus, M.A., 1924.

Evidence of Pleistocene events in the structure of the continental shelf off the northeastern United States, Knott, S.T. and Hoskins, H., 1968.

Summary of geology of Atlantic Coastal Plain, LeGrand, H.E., 1961.

Geology of the sea-bottom in the approaches to New York Bay, Linderkohl, A., 1885.

Physiographic features on the outer shelf and upper slope, Atlantic continental margin, southeastern U.S., MacIntyre, I.G. and J.D. Milliman, 1970.

Geologic framework and petroleum potential of the Atlantic Coastal Plain and continental shelf, Maher, J.C., 1971.

Geologic framework and petroleum potential of the Atlantic Coastal Plain and continental shelf, Maher, J.C. and E.R. Applin, 1971.

A preliminary report on U.S. Geological Survey geophysical studies of the Atlantic Outer Continental Shelf (abstr.), Mattick, R.E. and others, 1973.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 2, Miller, B.J., 1937.

Study of outer continental shelf lands of the U.S., V. IV (appendices), Nossaman, Waters, Scott, Krueger and Riordan, Consultants, 1969.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 7, continental shelf, continental slope and continental rise south of Nova Scotia, Officer, C.A., and M. Ewing, 1954.

The glaciated shelf off northeastern United States, Oldale, R.N. and Uchupi, E., 1970.

I.A. 1. and 2. (continued)

Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part VI, The Long Island Area, Oliver, J.E. and Drake, C.L., 1951.

Atlantic continental shelf and slope of the United States physiography and sediments of the deep-sea basin, Pratt, R.M., 1968.

Relief and bottom deposits at Georges Bank and Banquereau, Rvachev, V.D., 1964.

Topographic relief and bottom sediments of the Georges and Banquereau Banks, Rvachev, V.D., 1965.

Atlantic continental shelf and slopes of the United States--Nineteenth Century Exploration, Schoff, T.J.M., 1968.

The Long Island Sound sub-bottom topography in the area between 73°00' W and 73°30' W, Smith, M.C., 1963.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

Bathymetric charts Cape Cod to Maryland, Stearns, F., and L.E. Garrison, 1967.

Submergence of the New Jersey coast, Stuiver, M., and Daddario, J.J., 1963.

Topography and structure of the shelf and slope, Uchupi, E., 1965c.

Library research project, mid-Atlantic outer continental shelf, U.S. Bureau of Land Management, 1972.

Bathymetric maps of the Atlantic continental shelf and slope from Delaware to outer Cape Cod, U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

Shelfbreak physiography between Wilmington and Norfolk canyons, Wear, C.M., and others, 1974.

Geomorphology and sediments of the inner New York Bight continental shelf, Williams, S.J. and Duane, D.B., 1974.

I.A. 1. and 2. (continued)

Sub-bottom study of Long Island South (abstr.), Drake, C.L. and Smith, M.C., 1964.

Study of continental shelf and slope on the coasts of Long Island, N.Y. and N.J., Friedman, G.M., 1966.

Microtopography of five small areas of the continental shelf by side-scanning sonar, Sanders, J.E. and others, 1969.

I.A. 3. Continental Rise

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part X, continental slope and continental rise south of Grand Banks, Bentley, C.R., and J.L. Worzel, 1956.

Lateral echo sounding of the ocean bottom on the continental rise, Clay, C.S. and others, 1964.

The continental rise off eastern North America, Emery, K.O., and others, 1969.

Continental rise off eastern North America, Emery, K.O., and others, 1970.

Shaping of the continental rise by deep geostrophic contour currents, Heezen, B.C., and others, 1966.

The shaping and sediment stratification of the continental rise (abstr.), Heezen, B.C. and E.D. Schneider, 1968.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 7, continental shelf, continental slope, and continental rise south of Nova Scotia, Officer, C.B., Jr. and Ewing, M., 1954.

Linear "lower continental rise hills" off Cape Hatteras, Rona, P.A., 1969b.

Bathymetry of the continental rise off Cape Hatteras, Rona, P.A., and others, 1967.

Lower continental rise east of Middle Atlantic States, Stanley, D.J., H. Sheng, and C.P. Pedraza, 1971.

I.B. Boundaries of Study Area

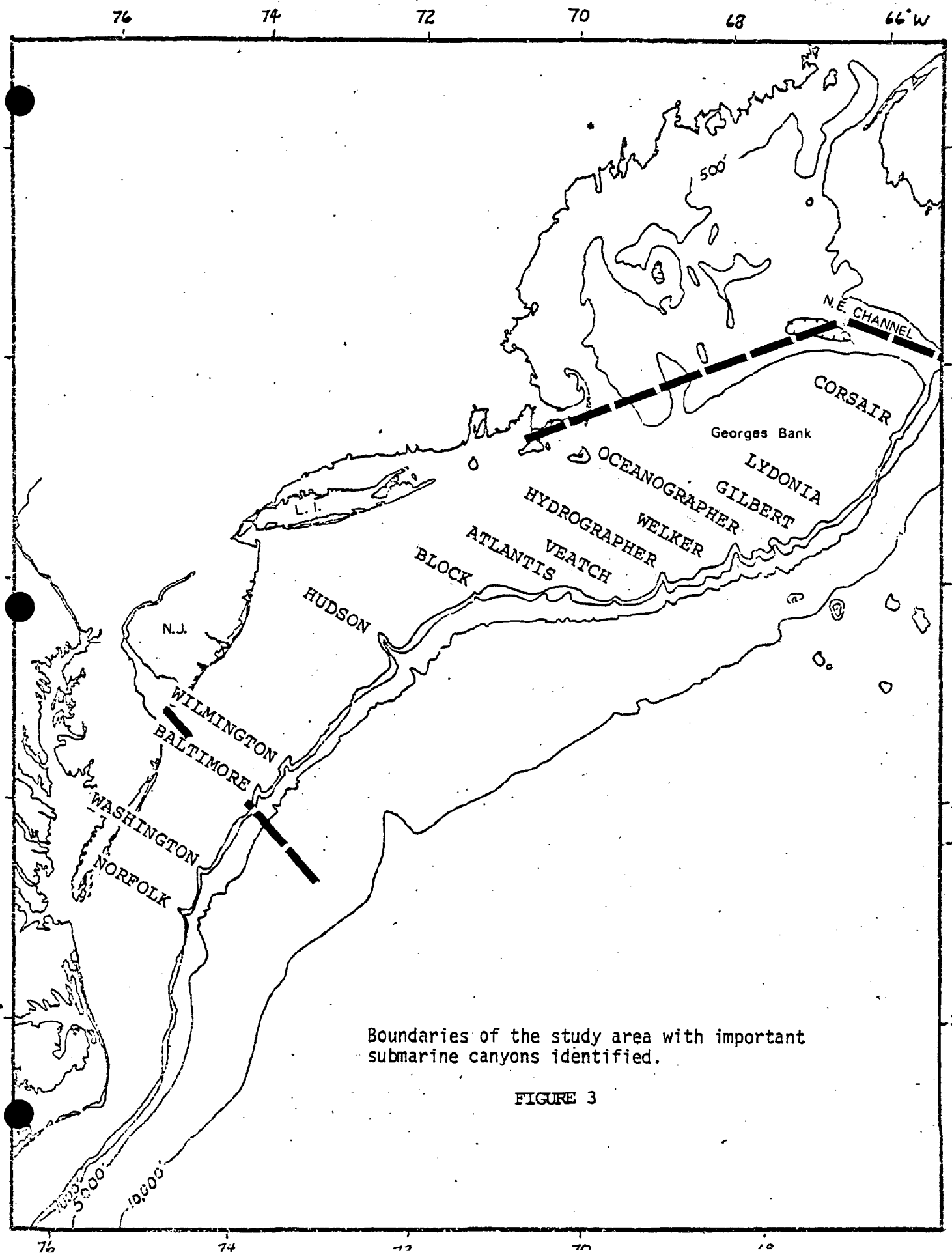
In the remainder of this text, the discussion of the continental margin cannot be confined to seaward projections of New York State's legal boundaries. Instead, the discussion will be more encompassing of the natural geologic features and physiographic provinces which comprise that region adjacent to New York State which lie below sea level. This region encompasses that portion of the continental margin, the southern boundary of which is the southeastern projection of a line extending seaward of the Delaware River estuary and the northern boundary of which is a line projected seaward along the southern coastline of Massachusetts through the "elbow" of Cape Cod. This area is shown in Figure 3 and heavy dashed lines define the southern and northern limits of the study area. Note that the northern limit is defined by Northeast Channel extending toward the continental shelf edge from the Gulf of Maine. The southern limit is roughly coincident with the Baltimore Canyon which incises the continental slope southeast of the Delaware River estuary.

The seaward limit of the study area lies at the boundary between the continental rise and the generally flat surface of the abyssal plain (Figures 1 and 2). This boundary is roughly coincident with the outer limit of the margin of continental crust. A relatively thin sedimentary sequence of the abyssal plain lies upon oceanic crust. Landward, the limit of the study area is defined by several features. The extensive chain of beaches which extend along the coast of southern Long Island and of New Jersey represent barrier islands which form one landward boundary to the area under study. However, tidal inlets between these barrier islands and the marine and brackish water lagoons behind the barrier islands are part of the marine system of coastal zone. A third feature along the coast also represents a landward boundary of marine conditions of New York's continental margin. This third feature is represented by the rivers including the Hudson whose lower reaches are influenced by tidal fluctuations and thus salt water conditions. Thus, in any discussion which follows concerning the coastal zone, these three boundary areas are included:

1. Barrier islands

2. Tidal inlets and back barrier lagoons

3. Estuaries - river mouths subjected to tidal fluctuations and salt water conditions.



Boundaries of the study area with important submarine canyons identified.

FIGURE 3

I.B. Boundaries of Study Area

Penetration of salt water and its effect on tidal areas of the United States of America, Baehr, J.C., 1953.

Annotated bibliography on the geologic, hydraulic and engineering aspects of tidal inlets, Barwis, John H., 1976.

Distinction of shoreline environments on New Jersey, Biederman, E.W., 1962.

Coastal geomorphology of Connecticut, Bloom, A.L., 1967.

Sea level rise as a cause of shore erosion, Bruun, P., 1962.

Coastal processes and beach erosion, Caldwell, J.M., 1966.

Physical processes in coastal waters, Carter, H.H., 1969.

These fragile outposts -- a geological look at Cape Cod, Martha's Vineyard, and Nantucket, Chamberlain, B., 1964.

Summary of marine activities of the coastal plains region Coastal Plains Center for Marine Development Services, 1976.

National shoreline study, regional inventory report, North Atlantic region, Corps of Engineers, 1971.

Color aerial stereograms of selected coastal areas of the United States, Crarat, H.R., and Glaser, R., 1971.

Classification of coastal environments of the world, Part I, Dolan, R., and others, 1972.

Estuaries and lagoons in relationship to continental shelves, Emery, K.O., 1967.

A computer simulation model of sedimentation in a salt wedge estuary, Farmer, D.G., 1971.

Origin of barrier island chain shorelines, middle Atlantic states, Fisher, J.J., 1968a.

Barrier island formation, Fisher, J.J., 1968b.

Coastal plain geology of southern Maryland, Glaeser, J.D., 1968.

I.B. (continued)

Global distribution of barrier islands in terms of tectonic setting, Glaeser, J.D. (in press).

Geomorphology and sedimentation of some New England estuaries, Hayes, M.O., 1971.

Barrier island formation, Hoyt, J.H., 1967.

Barrier island formation, Hoyt, J.H., 1968.

On the tectonic and morphologic classification of coasts, Inman, D.L. and C.E. Nordstrom, 1971.

Environmental framework of coastal plain estuaries, Nelson, B.W., 1972.

The estuarine environment, Estuaries and estuarine sedimentation, Schubel, J.R. and others, 1971.

Barrier Islands, Schwartz, M.L., 1973.

Barrier Island genesis, Evidence from the Middle Atlantic shelf of North America, Swift, D.J.P., 1975a.

History of New Jersey coastline, Wicker, C.F., 1951.

Sub-bottom study of Long Island Sound (abstr.), Drake, C.L. and Smith, M.C., 1964.

I.C. Origins and General Geologic History of Atlantic Physiographic Provinces

The Atlantic continental margin represents a major structural boundary in the crust and upper mantle. The transition from oceanic crust to continental crust occurs within this zone. Modern tectonic interpretations of basement structure of the Atlantic continental margin describe a rifted and block-faulted zone where great thicknesses of shallow water sediments accumulated in gradually subsiding basins (Sheridan, 1974). Figures 4, 5, and 6 illustrate this rifting and sediment-infilling process.

The shelf prograded during the Tertiary in a complex pattern of deltaic sedimentation in the Baltimore Canyon Trough area and as a marine sequence in the Georges Bank area (Garrison, 1970). A depositional regression during the Oligocene and a glacio-eustatic sea level lowering during the Pleistocene exposed the shelf, permitting its erosion. Detrius moved across the shelf in rivers, then down submarine canyons to be deposited at the base of the slope to form the continental rise.

Various attempts have been made to explain the origin and structure of the margin (Sheridan, 1974; Mayhew, 1974; Mattick et al, 1974; Ballard and Uchupi, 1975; Schlee, et al, 1976). These people generally agree that the basement configuration of the continental margin is a result of the separation of the North American and Africa-Europe plates, according to the model of plate tectonics (see discussion on plate tectonic theory). Suggested dates for this plate separation have ranged from Permian (Emery, et al, 1970) to Jurassic, or later (Hallam, 1971). It is thought (Olson, 1974; Talwani et al, 1965) that the injection of low density mantle material initiated the rifting and uplift of the continental crust (Figures 6A and B). As the Atlantic opened it resembled the present-day Red Sea in structure (Figures 6C and 7A) during Jurassic time.

With continued separation, eroded material from both parting continental masses was carried to the newly developing and widening marine area. Thick wedges of sediment build out along the continental margins forming the two principal sedimentary accumulations of the continental shelf and continental rise. The base of the continental slope, itself, is generally thought to be the boundary between low density continental crust and higher density oceanic crust. However, it too has been influenced by the sediment build out from the shoreline and the juncture between continental and ocean crust is deeply buried beneath the base of the present continental slope (Emery and Uchupi, 1972, p. 53). As new crust accreted at the mid-ocean edge, the continental margins moved away from the spreading center and gradually subsided (Figures 6C and 5).

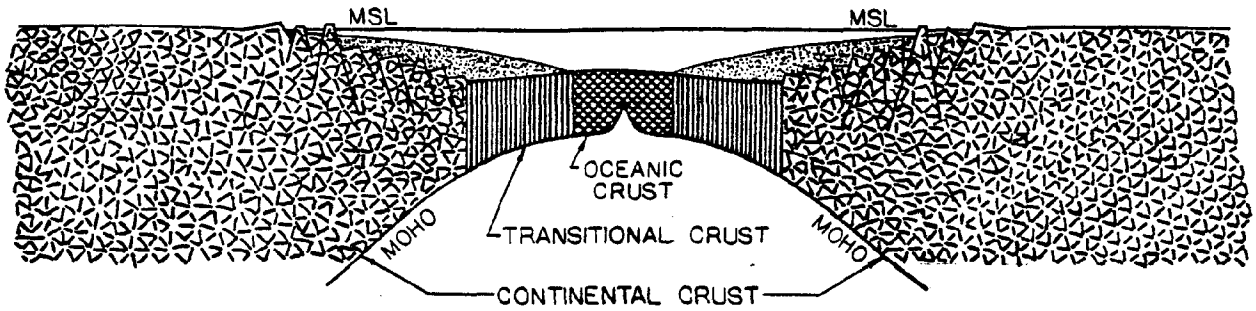


FIGURE 4. Idealized cross section of rifted continental crust that has separated into two continental blocks. New oceanic crust forms along the rifting and spreading zone and sediment drapes onto the continental margins.

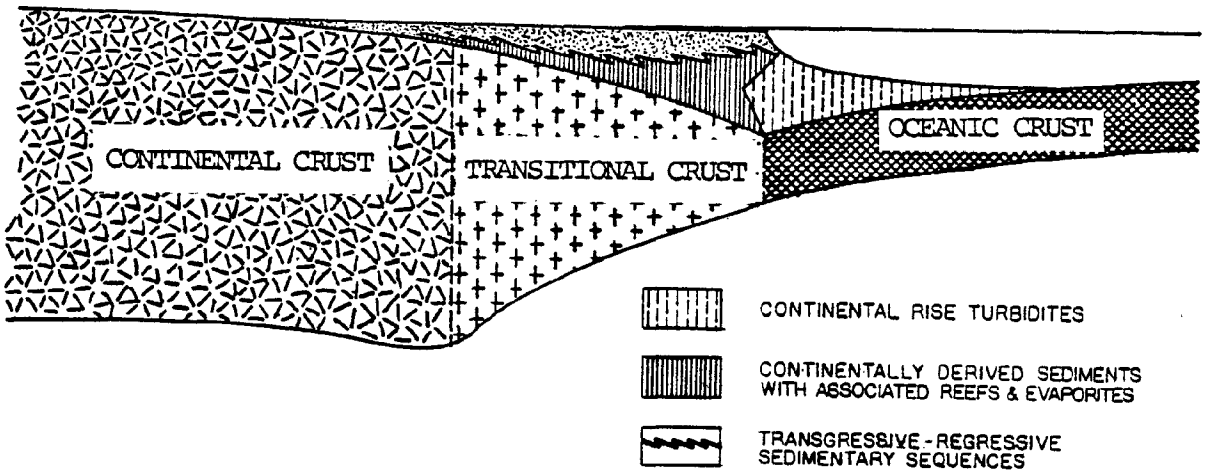


FIGURE 5. Idealized cross section of a transgressive-regressive sedimentary wedge outbuilding on a continental margin.

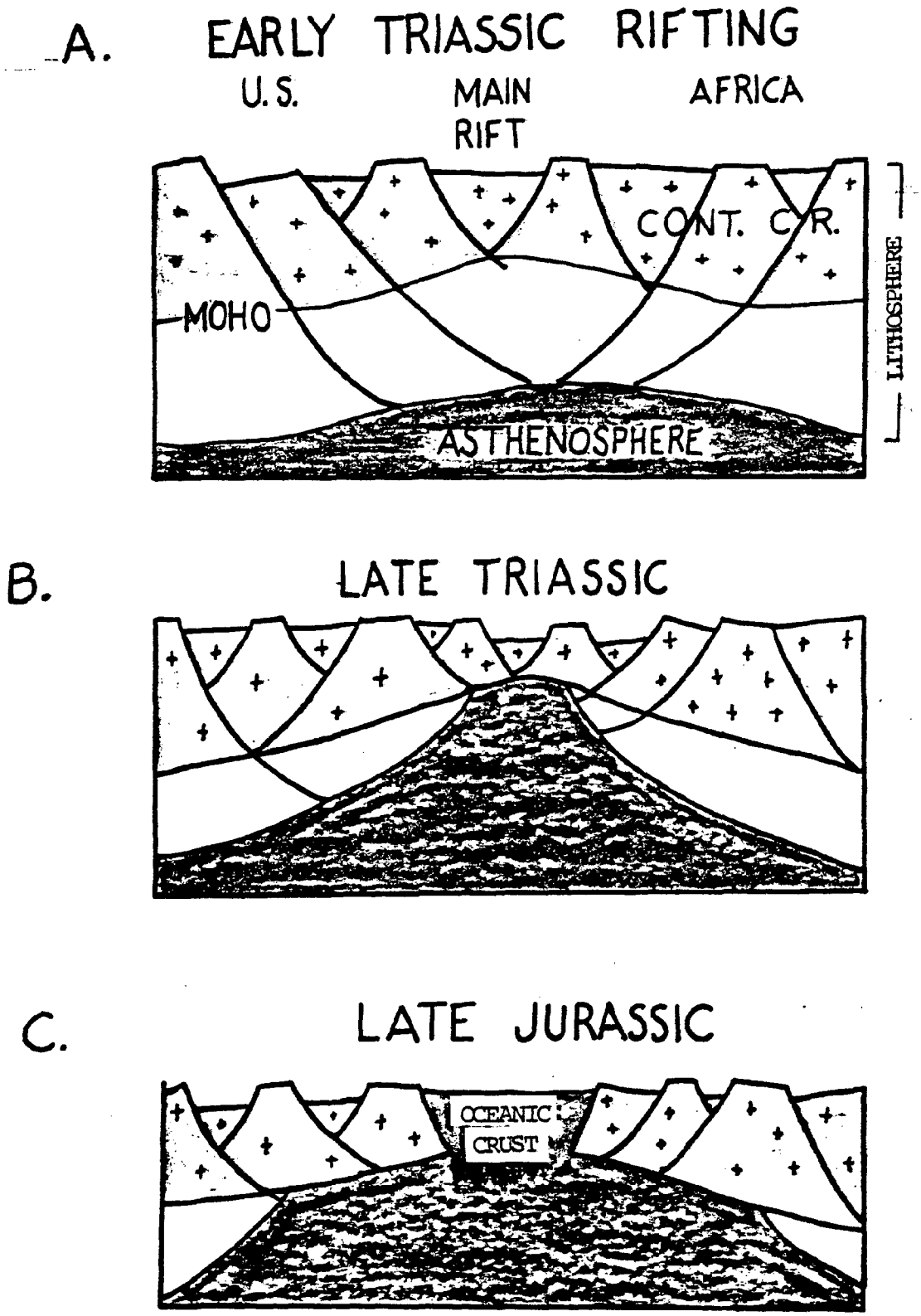


FIGURE 6. Idealized sequential cross section of uplift, rifting and spreading of continental crust and development of new oceanic crust, eastern United States.

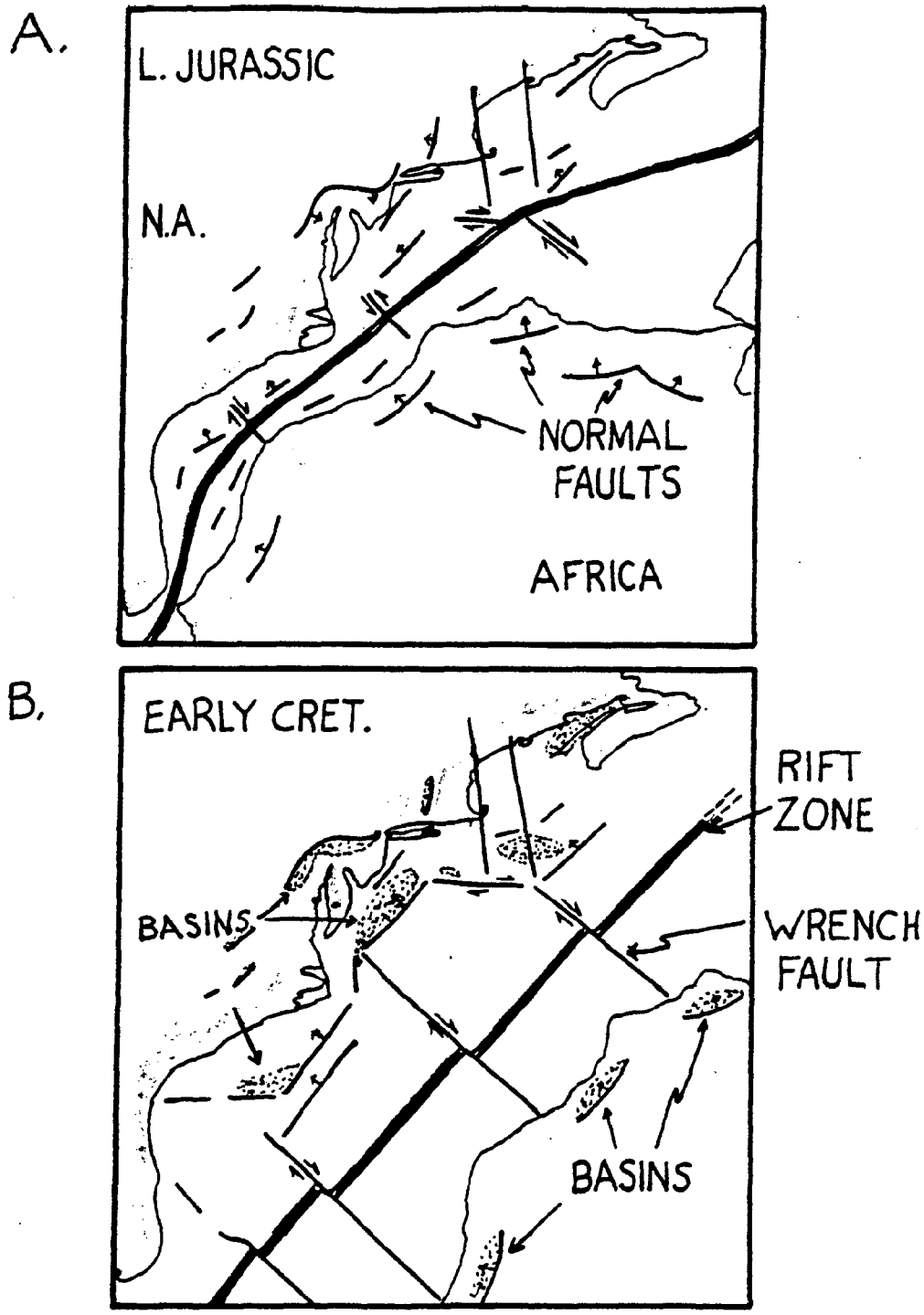


FIGURE 7. Basin formation as a result of faluting, rifting and seafloor spreading, eastern United States.

During the early stages of continental margin development, fracturing of crustal material resulted in a complex sequence of basins in the low areas between zones and fracture. Consequently, numerous filled basins (Figure 7B) lie beneath the more simple seaward-extending lenses and wedges of younger sediment which subsequently have built out over them. Thus the upper few kilometers of sedimentary material of the continental margin is far less complex geologically than the deeper, older sedimentary materials deposited during the early stages of continent margin formation (Heezen, 1974, p. 23).

During the Cretaceous, sediments spilled over the "basement ridge" that formed a sediment barrier at the shelf edge. Through the remainder of the Cretaceous and Tertiary the shelf developed, building up during transgressions and building out during regressions of the sea. Schlee and others (1976) give a detailed description of the development of the continental margin of northeastern United States.

Below are the references from the bibliography (Volume II) which described the continental margin, its physiography, boundary areas as well as its origin and general geologic background. General references are listed first, and specific references to the major subdivisions of New York's continental margin are subdivided as continental shelf, continental slope and continental rise.

I.C. Origins and General Geologic History of Atlantic Physiographic Provinces

Regional geology of eastern Canada offshore, Austin, G.H., 1973.

Structure of the Lower Continental Rise Hills of the western North Atlantic, Ballard, J.A., 1966.

The nature of Triassic continental rift structures in the Gulf of Maine, Ballard, R.D., 1974.

Carboniferous and Triassic rifting, a preliminary outline of the tectonic history of the Gulf of Maine, Ballard, R.D. and E. Uchupi, 1972.

Geology -- the Gulf of Maine, Ballard, R.D. and Uchupi, E., 1974.

Triassic rift structure in Gulf of Maine, Ballard, R.D., and Uchupi, E., 1975.

Mesozoic and Cenozoic history of the Grand Banks of Newfoundland, Bartlett, G.A. and L. Smith, 1971.

Seismic evidence for a thick section of sedimentary rock on the Atlantic outer continental shelf and slope of the United States (abstr.), Behrendt, J.C. and others, 1974.

Geophysical observations on sediments and basement structure underlying Sable Island, Nova Scotia, Berger, J. and others, 1965.

Geophysical observations on the sediments and basement structure underlying Sable Island, Blanchard and others, 1965.

Evolution of young continental margins and formation of shelf basins, Bott, M.H.P., 1971.

Buried ridges within continental margins, Burk, C.A., 1968.

Geology of continental margins, Burk, C.A. and Drake, C.L., 1974.

Plate tectonics and hydrocarbon accumulation, Dickinson, W.R. and Yarborough, H., 1976.

Basement beneath the emerged Atlantic coastal plain between New York and Georgia, Dietrich, R.V., 1960.

I.C. (continued)

Origin of continental slopes, Dietz, R.S., 1964.

Origin of abrupt change in slope at the continental shelf margin, Dietz, R.S. and Menard, H.W., Jr., 1951.

Continental margins and geosynclines, The east coast of North America north of Cape Hatteras, Drake, C.L., and others, 1959.

The continental margin of the eastern United States, Drake, C.L., and others, 1968.

Geology of the continental margin off eastern United States, Emery, K.O., 1965.

Atlantic continental shelf and slope of the United States, geologic background, Emery, K.O., 1966.

Continental margins of the world, Emery, K.O., 1970.

Continental rise off eastern North America, Emery, K.O., and others, 1970.

Ages of horizon A and the Oldest Atlantic sediments, Ewing, J. and others, 1966.

Cretaceous-Cenozoic development of the continental shelf south of New England, Garrison, L.E., 1967.

Developments of continental shelf south of New England, Garrison, L.E., 1970.

Late Mesozoic-Cenozoic tectonic effects of the Atlantic Coastal margin, Gibson, T.G., 1970.

Atlantic sediments, erosion rates, and the evolution of the continental shelf, Gilluly, J., 1964.

Mesozoic geology and the opening of the North Atlantic, Hallam, A., 1971.

Atlantic-type continental margins, Heezen, B.C., 1974.

Continental margins of eastern Canada and Baffin Bay, Keen, C.E. and Keen, M.J., 1974.

The continental margin of eastern Canada, Keen, M.J. and J.E. Blanchard, 1966.

Continental margin of eastern Canada, Keen, M.J. and others, 1970.

I.C. (continued)

The significance of a group of aeromagnetic profiles off the eastern coast of North America, King, E.R. and others, 1961.

Evidence of Pleistocene events in the structure of the continental shelf off the northeastern United States, Knott, S.T., and Hoskins, H., 1968.

Seismic profile showing Cenozoic development of the New England continental margin, Krause, D.C. and others, 1966.

Summary of geology of Atlantic Coastal Plain, LeGrand, H.E., 1961.

Sea-floor spreading and structural evolution of south Red Sea, Lowell, J.D., and Genick, G.J., 1972.

Geologic framework and petroleum potential of the Atlantic Coastal plain and continental shelf, Maher, J.C., 1971.

Pattern of Triassic-Jurassic diabase dikes around the North Atlantic in the context of predrift position of the continents, May, P.R., 1973.

"Basement" to east coast continental margin of North America, Mayhew, M.A., 1974a.

Geophysics of Atlantic North American, Mayhew, M.A., 1974b.

Preliminary geologic report on the U.S. northern Atlantic continental margin (abstr.), Minard, J.P. and others, 1973.

Preliminary report on geology along Atlantic continental margin of northeastern United States, Minard, J.P. and others, 1974.

Geology of the Atlantic and Gulf coastal province of North America, Murray, G.E., 1961.

Post Triassic tectonic movements in the central and southern Appalachians as recorded by sediments of the Atlantic coastal plain, Owens, J.P., 1970.

Continuous deep sea salt layer along North Atlantic related to early phase of rifting, Pautot, G.J.M. and others, 1970.

I.C. (continued)

Relations between rates of sediment accumulation on continental shelves, sea floor spreading, and eustacy inferred from the central North Atlantic, Rona, P.A., 1973.

Regional geologic framework off northeastern United States, Schlee, J., and others, 1976.

The evolution of the continental margins and possible long term economic resources, Schneider, E.D., 1969.

Significance of submerged deltas in the interpretation of the continental shelves, Shepard, F.P., 1928.

Sedimentary basins of the Atlantic margin of North America, Sheridan, R.E., 1976.

Geologic history of basement fault motions in the Baltimore Canyon trough correlated with North Atlantic sea-floor spreading (abstr.), Sheridan, R.E. and Brown, P.M., 1975.

Upper Cretaceous marine transgression in northern Delaware, Spoljaric, N., 1972.

Lower continental rise east of Middle Atlantic States, Stanley, D.J. and others, 1971.

Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America, Swift, D.J.P., and others, 1972.

Distribution and geologic structure of Triassic rocks in the Bay of Fundy and the northeastern part of the Gulf of Maine, Tagg, A.R. and E. Uchupi, 1966.

Crustal structure of the mid-ocean ridges, two computed models from gravity and seismic refraction data, Talwani, M. and LePichon, X. and Ewing, M., 1965.

Geologic implications of aeromagnetic data for the eastern continental margin of the United States, Taylor, P.T.I. and others, 1968.

Basins of the Gulf of Maine, Uchupi, E., 1965.

Topography and structure of the shelf and slope, Uchupi, E., 1965c.

Structural framework of the Gulf of Maine, Uchupi, E., 1968.

I.C. (continued)

Topography and structure of Cashes Ledge, Gulf of Maine, Uchupi, E., 1966.

Structure of the continental margin off the Atlantic coast of the United States, Uchupi, E. and Emery, K.O., 1967.

Generalized pre-Pleistocene geologic map of the northern United States Atlantic continental margin, Weed, E.G.A. and others, 1974.

The ancient continental margin of eastern North America, Williams, H. and Stevens, R.K., 1974.

Appalachian curvature, wrench-faulting, and offshore structures, Woodward, H.P. and Drake, C.L., 1963.

A magnetic map of the Long Island Sound and the southward continuation of geologic units in Connecticut, Zurflueh, E.G., 1962.

II. MAJOR SURFACE FEATURES OF THE CONTINENTAL SHELF

The first chapter described the continental margin and specifically the origin of the continental shelf in terms of the broad, regional characteristics of that physiographic province. Figure 8 (Rogers, et al, 1973) shows these characteristics. In the present chapter, a number of distinctive surface features are described which together are unique to continental shelves of the type bordering the eastern United States. These features are important not only because they reveal some of the geologic history of the past described in Chapter I and the processes of that region described in Chapter III, but also they represent distinctive differences in the overall "terrain" of the shelf which bear directly upon questions of suitability for use of specific sites for economic exploration.

The information presented below is largely descriptive. Chapter III deals with processes influencing the continental shelf and must be linked to this descriptive section. As will be evident when both sections are examined there is an intimate association between the processes and the features themselves. The processes are influenced by the surface features and, in some cases, the features are undergoing modification by the processes.

Listed below are those references which deal with the major surface features of the continental shelf on a regional basis.

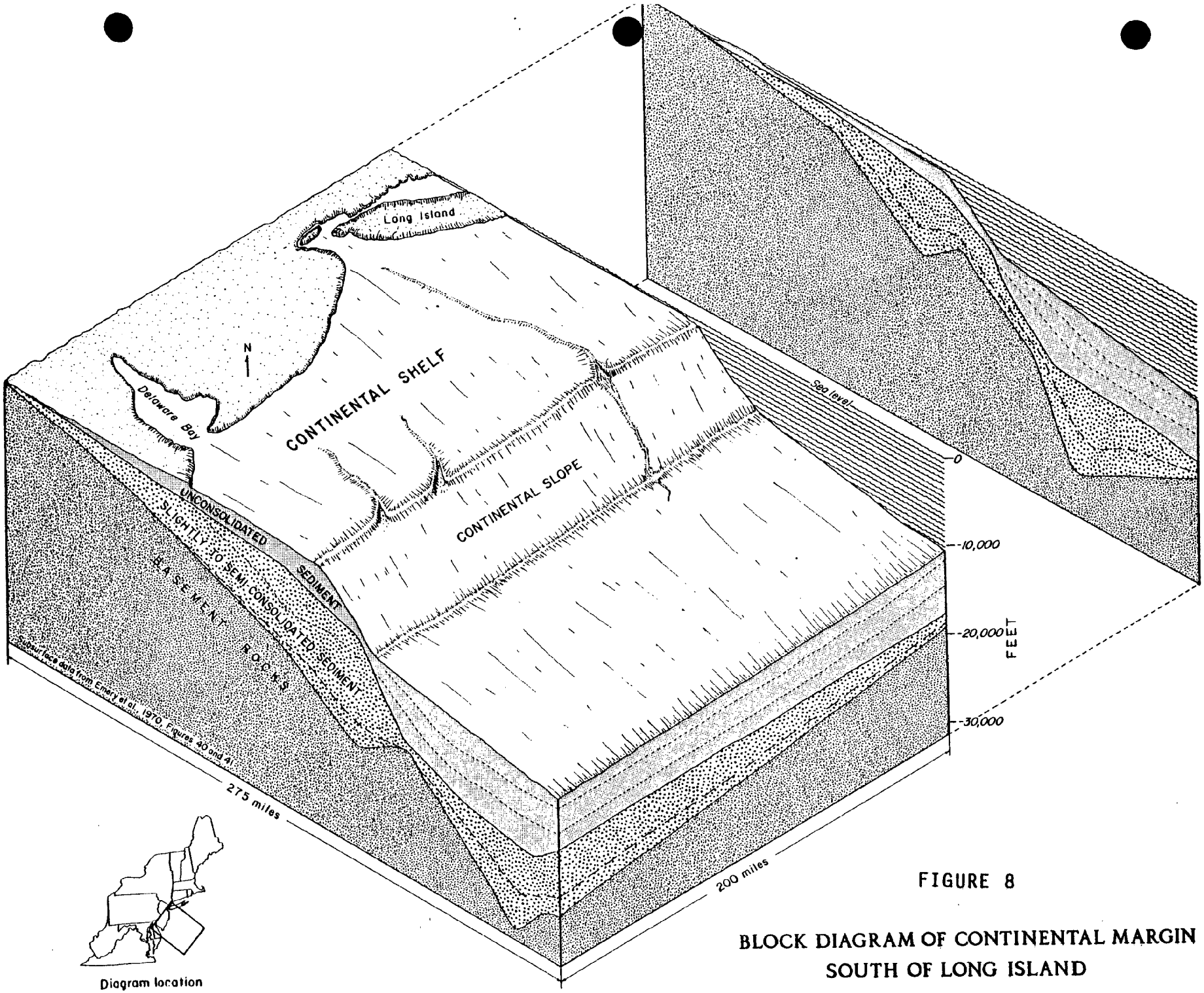


FIGURE 8

BLOCK DIAGRAM OF CONTINENTAL MARGIN SOUTH OF LONG ISLAND

II. Major Surface Features of the Continental Shelf

A keyword-indexed bibliography of the marine environment in the New York Bight and adjacent estuaries, Ali, J.A., 1973.

Characteristics of continental shelves and slopes, Emery, K.O., 1965.

Joint program of the U.S.G.S. and W.H.O.I. for continental shelf and slope, in Summary of investigations conducted in 1964, Emery, K.O., 1965.

The Atlantic continental margin of the U.S. during the past 70 million years, Emery, K.O., 1967.

Geology of Long Island, N.Y., Fuller, M.L., 1914.

The floors of the Oceans, 1., Heezen, B.C., M. Tharp, and M. Ewing, 1959.

Submarine physiography of the U.S. continental margins, Jordan, G.F., 1962b.

Interpretation of high-resolution echo-sounding techniques and their use in bathymetry, marine geophysics, and biology, Knott, S.T., and Hersey, J.B., 1956.

Sediments and geomorphology of the continental shelf off southern New England, Garrison, L.E., and McMaster, R.I., 1966.

Fathometer survey and foundation investigation Ambrose Light Station, New York Harbor entrance; and Fathometer survey and foundation investigation Scotland Light Station, New York Harbor entrance, McCleland engineers, 1963.

Probable Holocene transgressive effects on geomorphic features of the continental shelf off New Jersey, United States, McClennen, C.E. and R. L. McMaster, 1971.

Quantitative method for describing the regional topography of the ocean floor, McDonald, M.G. and E.S. Katz, 1969.

Study of outer continental shelf lands of the U.S., V. IV. (appendices), Nossaman, Waters, Scott, Krueger and Riordan, consultants, 1969.

Sediments and morphology of the continental shelf off southeast Virginia, Payne, L.H., 1970.

II. (continued)

Atlantic continental shelf and slope of the United States physiography and sediments of the deep-sea basin, Pratt, R.M., 1968.

Eastern Atlantic continental margins - various structural and morphologic types, Renard, V. and Mascle, J., 1974.

Topographic relief and bottom sediments of the Georges and Banquereau Banks, Rvachev, V.D., 1965.

Atlantic continental shelf and slopes of the United States - Nineteenth Century Exploration, Schoff, T.J.M., 1968.

Submarine Geology, Shepard, F.F., 1973.

The Long Island Sound sub-bottom topography in the area between 73°00' W and 73°30' W, Smith, M.C., 1963.

Subsurface morphology of Long Island Sound, Block Island Sound, Rhode Island Sound, and Buzzards Bay, Tagg, A.R. and Uchupi, E., 1967.

Maps showing relation to land and submarine topography, Nova Scotia to Florida, Uchupi, E., 1965a.

Topography and structure of the shelf and slope, Uchupi, E., 1965c.

Atlantic continental shelf and slope of the United States - Physiography, Uchupi, E., 1968.

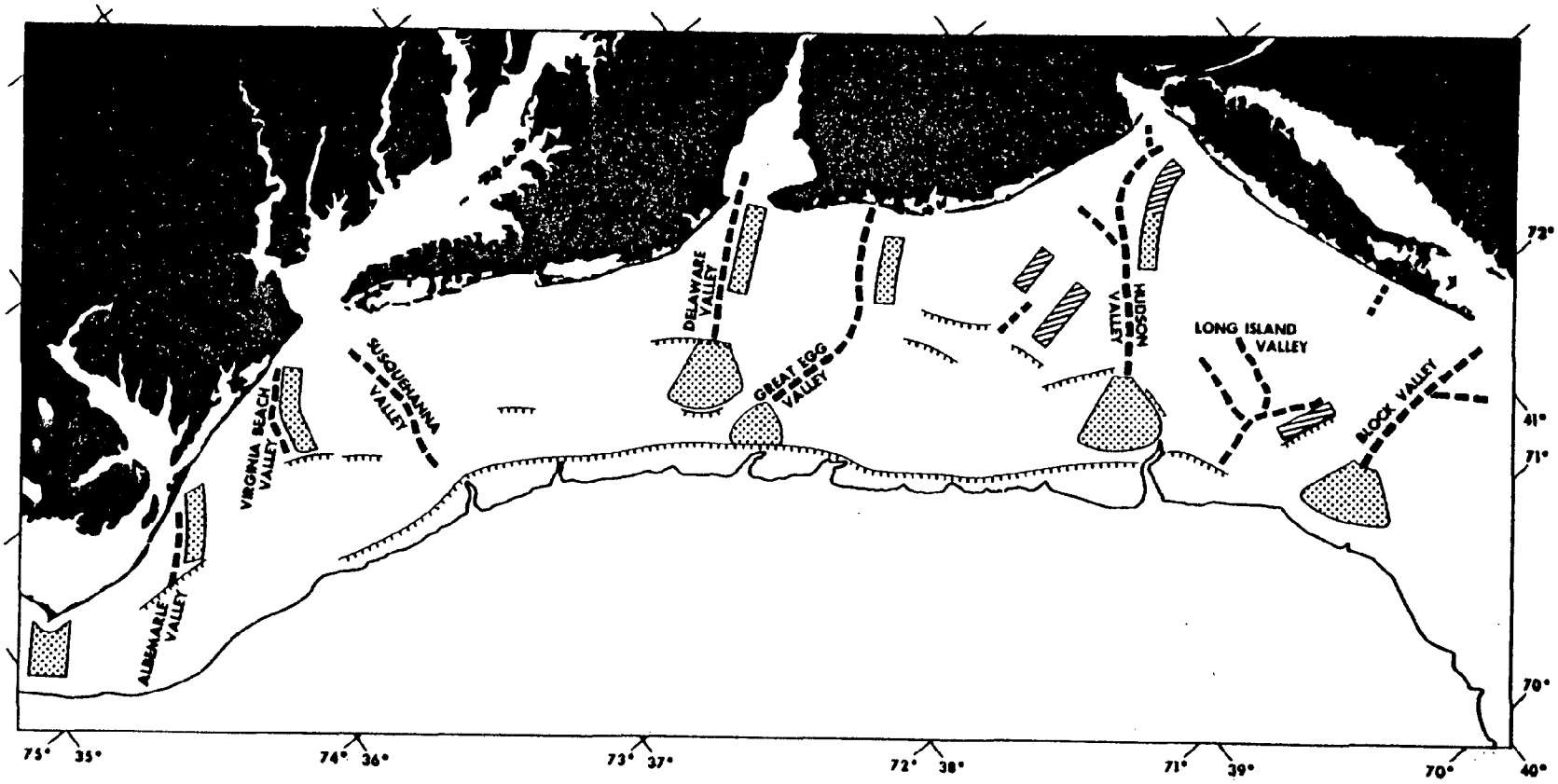
II.A. Shelf Valleys

Examination of the bathymetric charts of the New York bight (Stearns, 1967) shows four distinctive valleys which cross the continental shelf (Figure 9). The most obvious of the four is the Hudson shelf valley, a broad seaward-widening notch which can be traced from the mouth of the Hudson River to the head of the Hudson Canyon at the continental shelf-slope boundary. The second most prominent shelf valley is the Delaware, a seaward continuation from the coastal plain of the Delaware River valley. Two other shelf valleys are somewhat less prominent. The Block Island shelf valley which extends southward between Block Island and Montauk Point at the eastern tip of Long Island is a more broadly defined feature than the Hudson shelf valley. In addition, it cannot be traced directly into the coastline although its contours can be traced to within the 10 fathom isobath. The fourth shelf valley is the Great Egg Harbor off the sourtheastern New Jersey coastline. It is thought to represent an earlier drainage path of the Schuylkill River which formerly flowed across this portion of New Jersey prior to following its present path into the Delaware River at Philadelphia. Near Great Egg Harbor Inlet this shelf valley is not evident. In fact, the isobaths near shore are convex seaward suggesting a sediment build-up in that area. This convex feature is probably a shoal-retreat massif which developed during sea-level rise as the ancestral mouth of the former Schuylkill River along the New Jersey coastline was drowned. Development of these sediment build-ups (shoal-retreat massifs) are described later in this section.

Shelf valleys of the New York bight portion of the continental shelf are the largest single set of features which are evident on the detailed bathymetric charts of Stearns (1967). The following tables give some indication of the size and scale of shelf valleys in terms of the width and gradient characteristics of the Hudson shelf valley:

Width	
Apex	5¼ km
Mid-area	24 km
Near canyon head	37½ km
Gradient of Shelf Valley Walls	
Apex	4 to 7m/km
Mid-area	3m/km
Near canyon head	1m/km

FIGURE 9



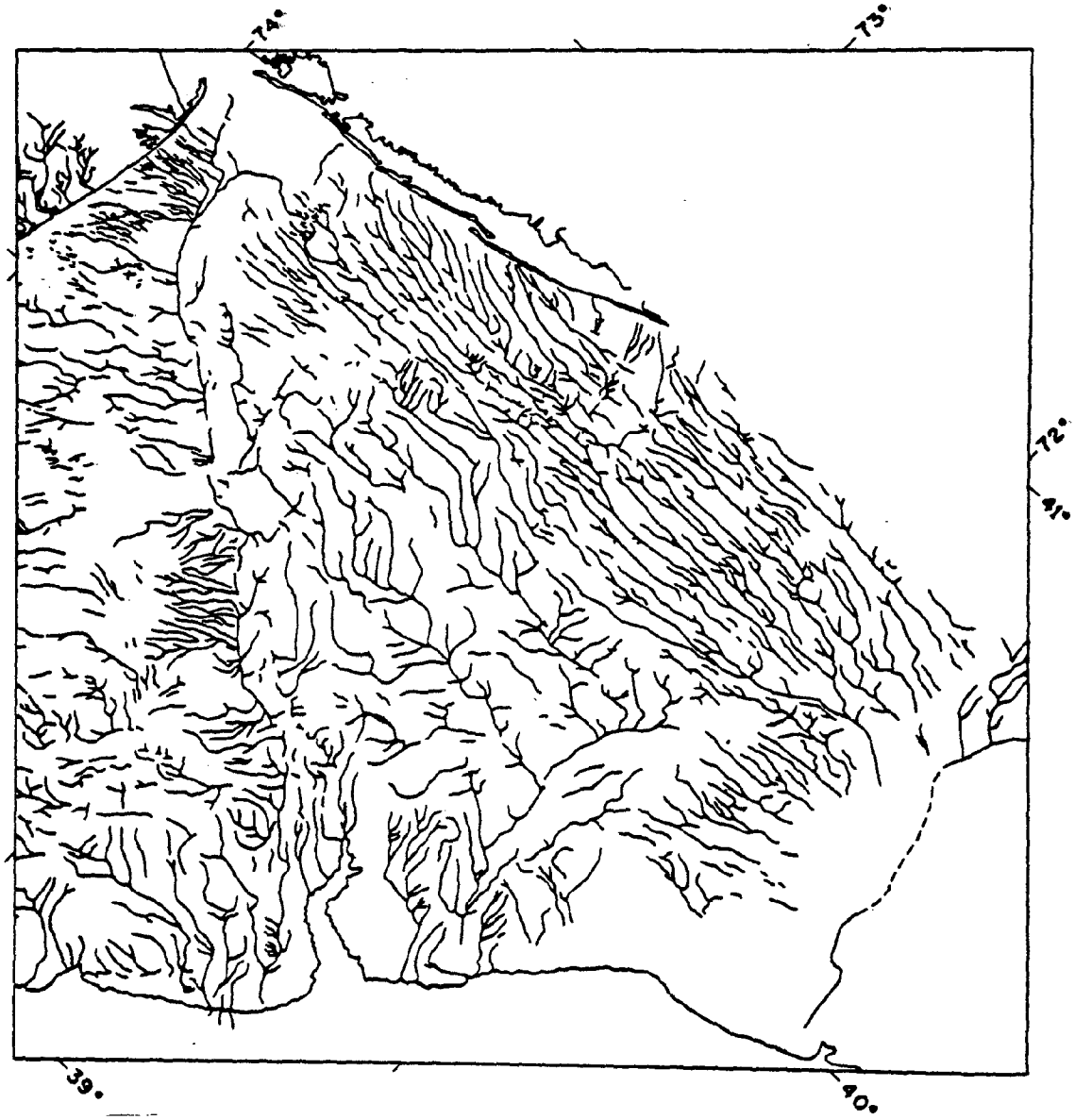
Major morphological elements of the middle Atlantic bight. Dashed lines are shelf valleys. Hachured lines are scarps. Stippled areas are highs of probable constructional origin, including shoal-retreat massifs and stillstand deltas. Diagonally ruled areas are areas of probable erosional orgin, including cuestas.

(From Swift, D., et al, 1972, Shelf Sediment Transport: Process and Pattern, fig. 193, p. 505)

These values show the lack of precipitous slopes within the Hudson shelf valley which is the most sharply defined of the four principal shelf valleys described above. Although values have not been determined from Stearns' (1967) charts, the other three principal shelf valleys are more gently inclined features.

There are three other shelf valleys which are discernible in the contour features of Stearns' (1967) bathymetric charts. These shelf valleys can be traced from the canyon heads landward to within the 35 fathom isobath. These shelf valleys link with the canyon heads of the Veatch, Hydrographer and Atlantis Canyons. These three shelf valleys lie east-northeast of Block canyon and thus cross the Georges Bank region of the study area.

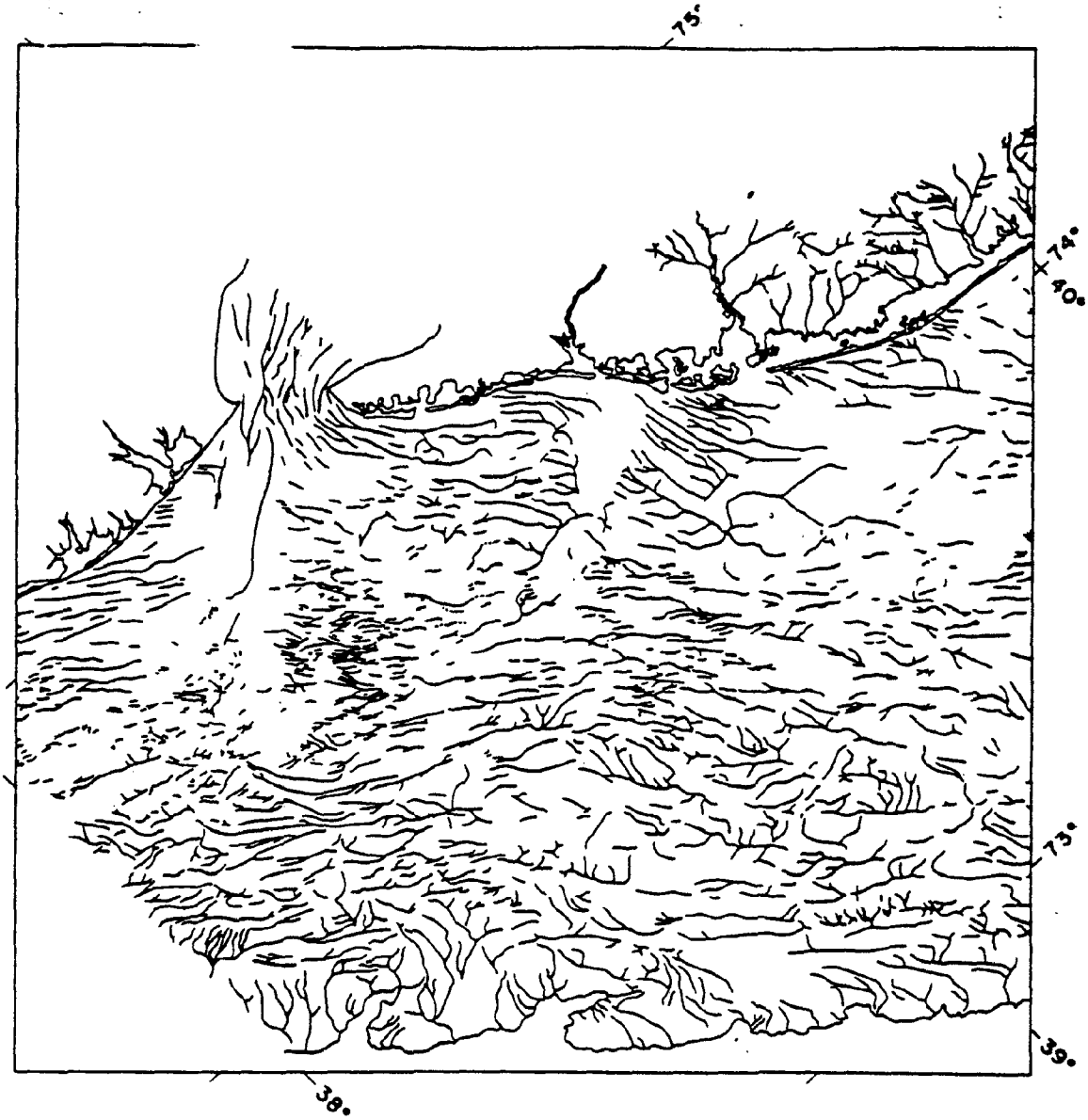
The bathymetric charts of Stearns (1967) and other similar charts listed among the references below represent the best overall view of shelf valleys. There are no detailed studies of one entire shelf valley. References listed below, therefore, represent specific data pertinent to certain aspects or portions fo the shelf valleys. These references (II.A.) plus those in the preceding section (II), which include descriptions of shelf valleys, give a basic coverage of available information. Some review of these ancient drainage patterns across the continental shelf are also to be found in papers dealing mainly with shelf sediment distribution and properties. One example is McKinney and Friedman (1970). Figures 10 and 11 show linear lows defining swales mapped on the Long Island and New Jersey shelf.



Pattern of linear lows on the Long Island shelf. Based on Stearns (1967).

(From Swift, D., et al, 1972, Shelf Sediment Transport: Process and Pattern, fig.194, p. 506)

FIGURE 10



Pattern of linear lows on the New Jersey shelf. Based on Stearns (1967).

(From Swift, D., et al, 1972, Shelf Sediment Transport: Process and Pattern, fig. 195, p. 507)

FIGURE 11

II.A. (continued)

1. Buried Shelf Valleys

An inventory of buried and partially buried shelf valleys in the middle Atlantic bight is shown in Figure 9. In simplest terms, buried shelf valleys are sediment-filled or partially filled shelf valleys. They represent significant features of the shelf surface for two reasons.

First, the material filling former fluvial channels incising the shelf surface is unconsolidated and, in places, slumped toward and/or down the channel axis. Thus, although lacking topographic expression on the present-day shelf surface, these infilled valleys can represent engineering hazards if a drilling rig were placed on or near the buried valley margins.

Second, because they are infilled with sediment, they are depositional, not erosional sites. Thus, buried shelf valleys might be feasible sites where pipe lines might be laid in such a way that the pipe lines would neither cause nor be affected by bottom-current scour.

Within the study area, there are a number of buried shelf valleys. The evidence for connection between the Delaware River and the Wilmington submarine canyon is presented in Knebel and others (1976) and in Twichell, Knebel and Folger (1977). The ancestral shelf valley is 3 km to 8 km wide with relief of 10 m to 30 m. None of this ancestral relief is reflected in the the present shelf surface materials. Seismic profiles also identify the buried shelf valley of the Great Egg Channel which intersects the ancestral Delaware River Valley at water depths of about 50 m. At the confluence, the Great Egg Channel is 30 m to 50 m shallower than the ancestral Delaware River valley. It is thought that the Great Egg Channel was the former lower course of the Schuylkill River which ran at some earlier time southeastward across New Jersey. Later events caused it to join the Delaware at Philadelphia. Knebel and others (1976) present eleven seismic profiles normal to the ancestral Delaware shelf valley which reveal considerable valley-margin slumping. Most importantly, neither the slumping nor the trace of the buried shelf valley is discernible in present-day bathymetry of the shelf surface. To use a simple analogy, the valleys have been "drifted" over by sediment as snow might fill and conceal stream channels on land producing a uniform topograhic surface.

The Hudson shelf valley is the best defined of all the incised features of the middle Atlantic bight. Portions of it are partially infilled with alluvial or reworked sediments deposited during the post-Holocene transgression. A less prominent, partially buried shelf valley, the Highland channel appears to connect with the Hudson shelf valley at depths of 90 feet. It

is thought to be an extension of the Raritan River which flowed across at least part of the shelf during Late Pleistocene prior to the northward growth by littoral processes of Sandy Hook. Extensive seismic profile data are given in Charnell and others (1975, p. 22-32) which pertain to specific areas with the inner apex of the New York bight. Bathymetry of that area in 1945 is given on pages 33 and 34 of that report along with topographic modifications resulting from use of dump sites there.

A less prominent and less extensive group of drowned and buried shelf valleys are reported in McMaster and Ashraf (1973a and 1973b). They identify seven post-Jurassic drainage systems on the southern New England shelf which flowed south. Their data are based on four seismic reflection profiles made off eastern Connecticut, Long Island, Rhode Island and southern Massachusetts. They also indicate in these profiles the broad Block channel which crosses the shelf and terminates on the outer shelf by the Block delta. They suggest the Block channel acted as a major trunk channel to the subsidiary valleys. McKinney and Friedman (1970) have described and analyzed similar types of drainage patterns on the Long Island shelf.

The subleties in the topographic patterns on which the drainage network interpretation are based differ significantly from the major buried shelf valleys described above. Some re-appraisal of these features in Duane and others (1972, p. 491) suggests that some of these "ancestral valleys" may be topographic forms responding to the prevailing hydraulic regime (i.e., ridge and swale topography, linear shoals, etc.).

II.A. Shelf Valleys

Bottom currents in the Hudson Canyon, Kelling, G.H., D. Lambert, G. Rower, and N. Staresinic, 1973.

Mineralogic composition of sand-sized sediment on the outer margin off the Mid-Atlantic States: assessment of the influence of the ancestral Hudson and other fluvial systems, Kelling, G., Sheng, H., and Stanley, D.J., 1975.

Drowned and buried valleys on the southern New England continental shelf, McMaster, R.C. and Ashraf, A., 1973.

Subbottom basement drainage system of inner continental shelf off southern New England, McMaster, R.L. and Ashraf, A., 1973.

Bottom environmental oceanographic data report, Hudson Canyon area, 1967, Oser, R.K., 1969.

Significance of submerged deltas in the interpretation of the continental shelves, Shepard, F.P., 1928.

Bathymetric charts Cape Cod to Maryland, Stearns, F. and L.E. Garrison, 1967.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:125,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Sterne, F., 1969.

Delaware shelf valley, estuary retreat path, not drowned river valley, Swift, D.J.P., 1973.

Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod, U.S. Coast & Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

Delaware River, Evidence for its former extension to Wilmington submarine canyon, Twichell, D.C., Knebel, H.J. and Folger, D.W., 1977.

II.A.1. (continued)

Final report on data reduction for CERC New Jersey offshore sand inventory program, Alpine Geophysical Assoc. Inc. 1969.

Western North Atlantic ocean, topography, rocks, structure, water, life and sediments, Emery, K.O. and Uchupi, E., 1972.

Baltimore canyon trough area hazards, Knebel, H.J. and others, 1976.

Drowned and buried valleys on the southern New England continental shelf, McMaster, R.L. and Ashraf, A., 1973.

Geomorphology and sediments of the inner New York Bight continental shelf, Williams, S.J. and Duane, D.B., 1974.

axis and the slumped sediment is now being actively dissected forming younger gullies. Those authors suggest that older erosional canyon heads have been partially buried although this deposition may be temporary.

A number of lease sites in both the Baltimore Canyon trough and Georges Bank basin are beyond the shelf-break and lie on both intercanyon and canyon-heads sites. The increase in slope beyond the shelf-break, the gradients of the canyon heads listed above, the evidence of active sediment mass movement and the irregular distribution of erosional and depositional areas within the canyon heads all signal caution in preparing for any type of exploration in these locations. Slump-block detachment represents the most serious engineering problem requiring solution through detailed geophysical site exploration along with substrate drill tests. The second area of concern is the inferences made in Section III concerning water-mass exchanges between the shelf and slope. Both down-slope and landward across-shelf movements of suspended material are known to occur. Thus, any pollutant introduced to waters near canyon heads or anywhere along the shelf-break do not necessarily move seaward.

II.B. Heads of Canyons

The shape of submarine canyon heads revealed by Asdic, Belderson, R.H. and A.H. Stride, 1969.

Origin of continental slopes, Dietz, R.S., 1964

Canyons off the New England coast, Shepard, F.P., 1934.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:125,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

Bathymetric charts Cape Cod to Maryland, Stearns, F. and L.E. Garrison, 1967.

Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod, U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

Atlantic submarine valleys of the United States, Veatch, A.C. and Smith, P.A., 1939.

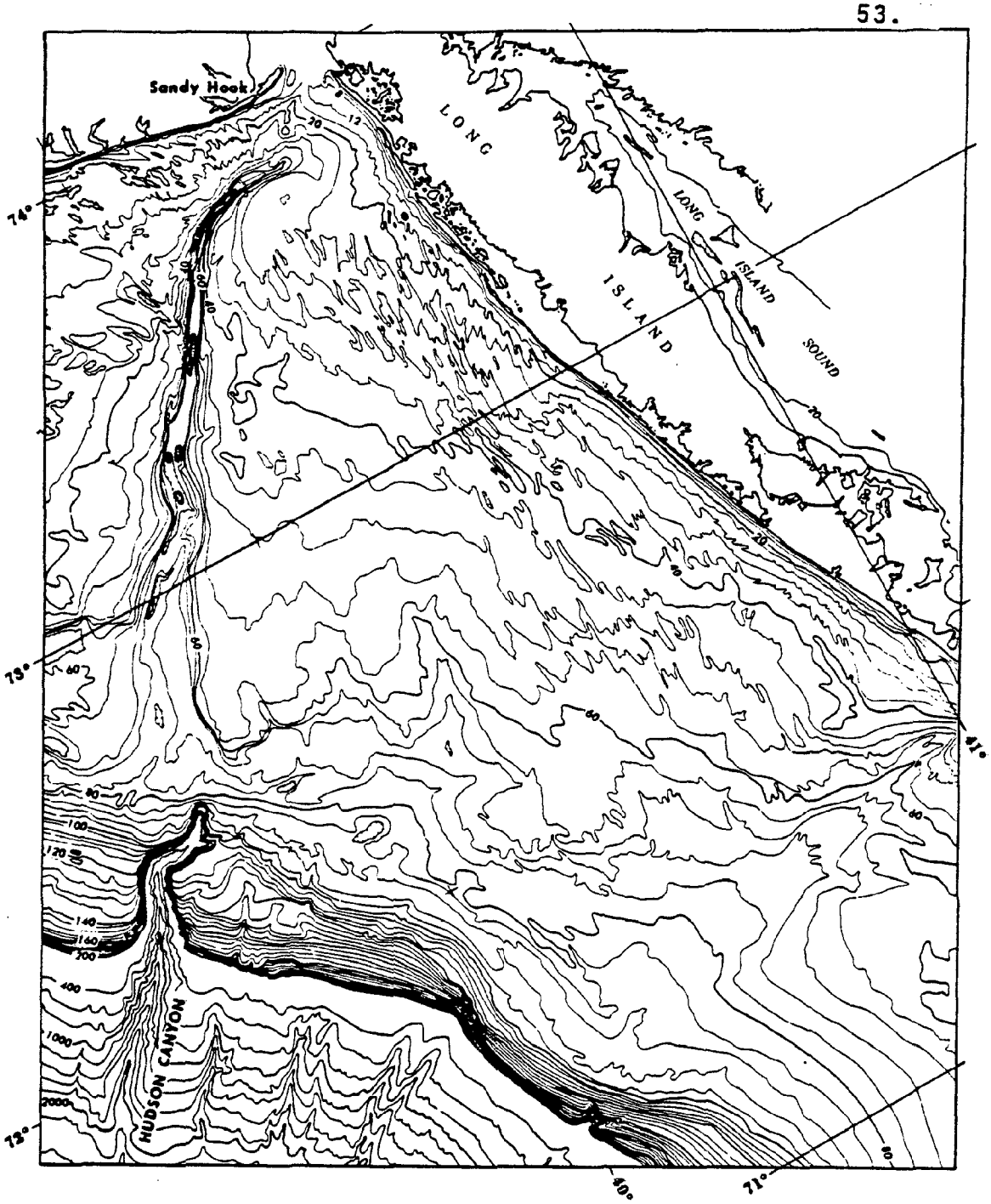
II.C. Ridge and Swale Topography

The general term, ridge and swale topography, is used throughout this report for a family of topographic features common to the shelf surface. All of the features are made of unconsolidated sediments on the shelf surface and influenced by currents, storm generated waves and tidal flow. The ridge and swale topography is readily seen in bathymetric charts of Stearns (1967) and Uchupi (1968) and examples are reproduced in Figures 12 and 13. These and earlier maps show the ridges and swales in shallow water merging at an angle with the shoreline. As described later in section IV.B.3, this hummocky surficial topography is generated by the action of shoreline retreat with resulting sediment transfer and accumulation on the inner shelf. These large shelf surface "bedforms" are responding to present-day hydraulic conditions.

Previous investigators, namely Veatch and Smith (1939), Shepard (1963), Emery (1966), and Garrison and McMaster (1966), have interpreted these topographic features as former positions of shoreline, perhaps representing successive sequences of submerged barrier islands. Present interpretations by Swift (1975), Field and Duane (1976), and Swift, Kofoed, Saulsbury and Sears (1972) relate these forms to an "equilibrium" profile developed by shoreface retreat and transfer of material eroded from the shoreface to the inner shelf. Some terms which appear in the literature which refer to ridge and swale topography are linear shoals, sand ridges, sand waves and shoal-retreat massifs.

Switt (1976, p. 255) divides the inner shelf seaward of the breakpoint bar (which is defined by the breaker line) into two morphologic zones. The first is the shoreface, a relatively steep zone extending to a depth of 12 m to 20 m. The upper slope of the shoreface may be as steep as 1:10 and seaward it may be as gentle as 1:200. Beyond the shoreface is the floor of the inner shelf. The upper shoreface corresponds to the hydraulic zone of shoaling waves to an average depth of 10 m. The lower shoreface and inner shelf receive some effects from shoaling waves but their slopes, sediment textures and bedforms are essentially a response to unidirectional shelf currents.

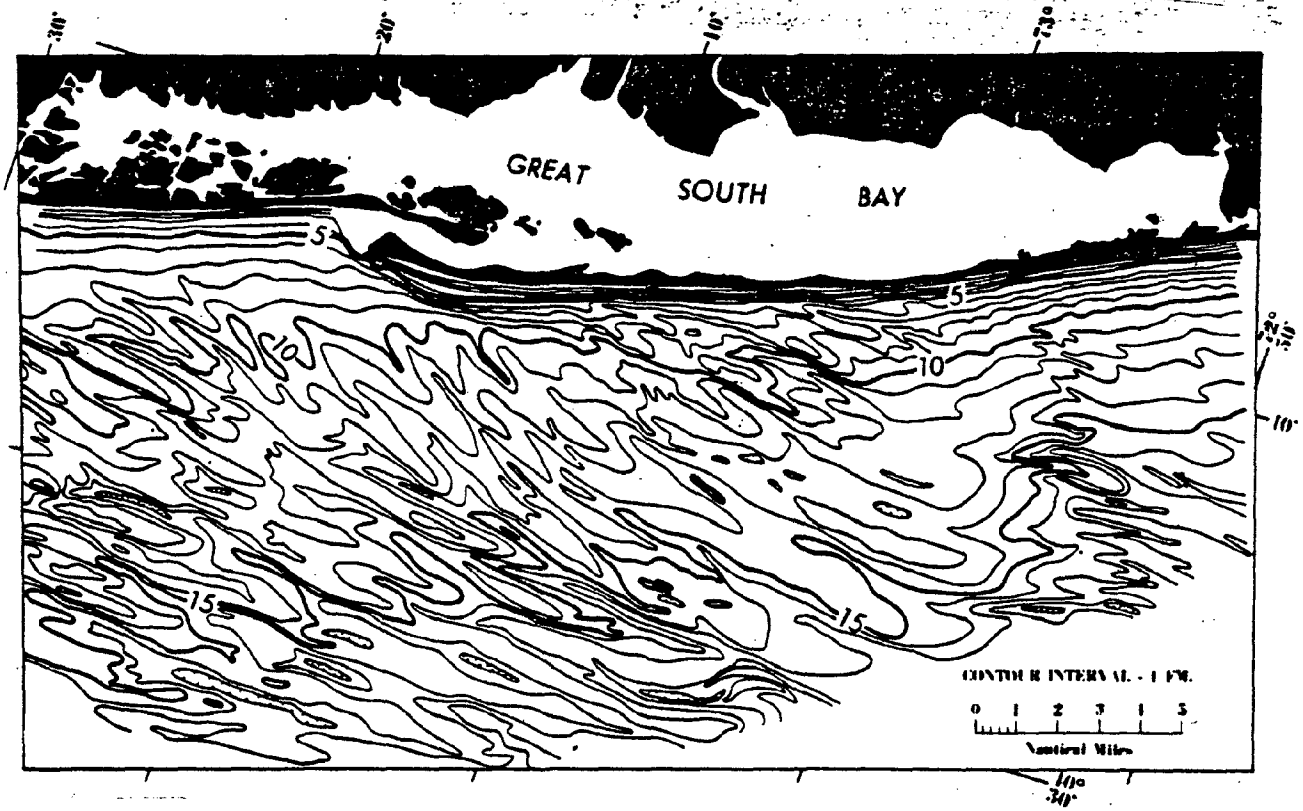
Duane and others (1972) have identified two broad categories of shoals, linear and arcuate. The arcuate forms are associated with either estuary inlets or capes. Some linear shoals are connected at one end to the shoreface (Figure 13). Others form fields of shoals on the shelf surface. Duane and others (ibid., p. 455) define linear shoals as positive features having at least 3 m of relief between the crest and surrounding shelf surface. Those which are shoreface-connected are outlined by, and landward of the base of the shoreface (roughly the 10 m isobath). These linear shoals are known on other shelves, but



Topography of the northern portion of the middle Atlantic Bight showing northeast trending bathymetric fabric off New Jersey and the southeast trending fabric south of Long Island. Contour interval is 4 m. From Uchupi (1968).

(From Swift, D., et al, 1972, Shelf Sediment Transport: Process and Pattern, fig. 171, p. 450)

FIGURE 12



Fire Island shoreface ridge system, south shore of Long Island, New York.

(From Swift, D., et al, 1972, Shelf Sediment Transport: Process and Pattern, fig. 191, p. 492)

FIGURE 13

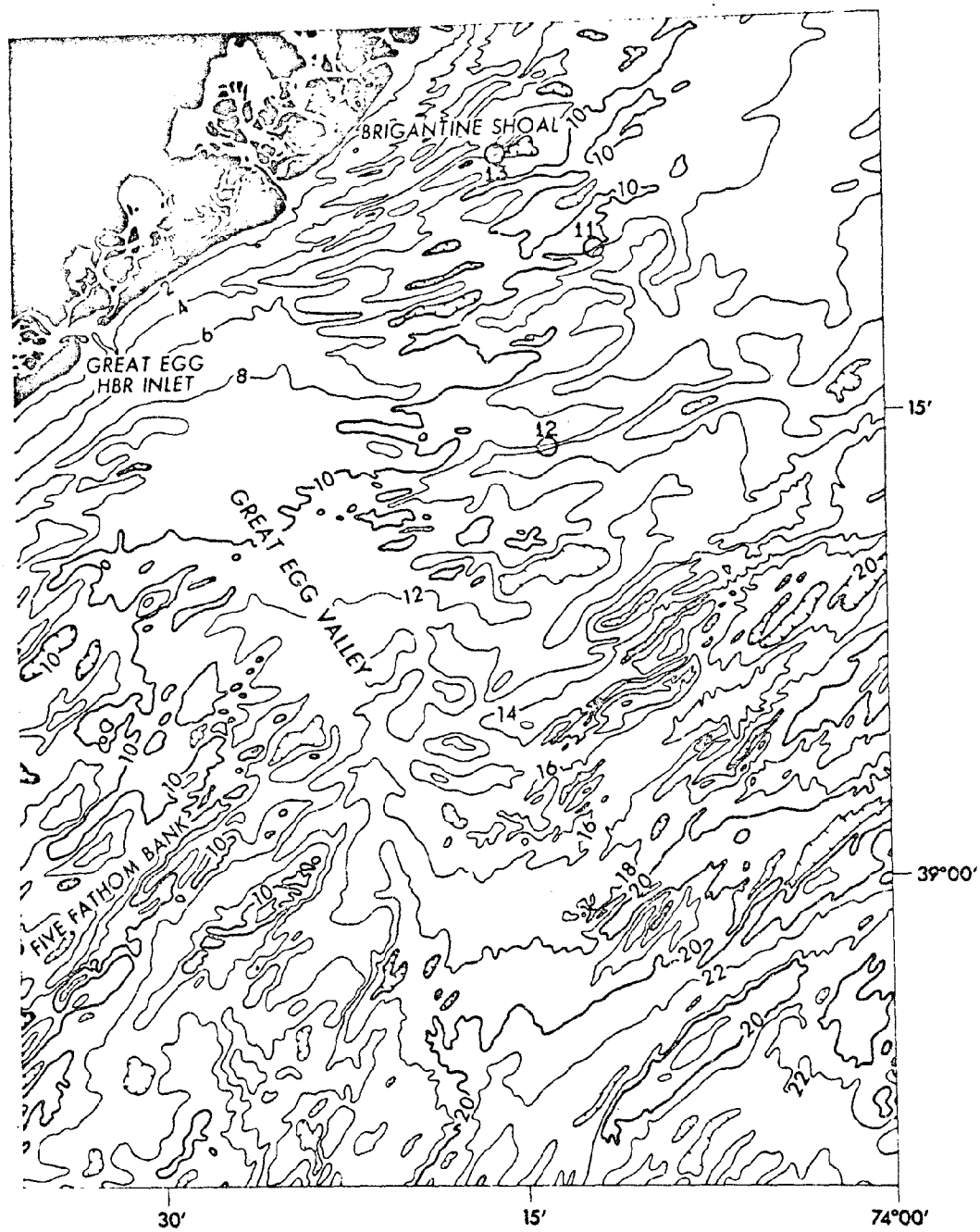
are particularly common to the Atlantic shelf of eastern United States south of Long Island.

The following description of the general characteristics of linear shoals from Duane and others (1972, p. 455-460) is based on observations of those shoals having lengths of at least 100 m and 10 m of relief. All such linear shoals from northern New Jersey southward form a small acute angle with the coastline and nearly all shoals open northward (Figure 14). Seismic reflections show them to be plano-convex features resting upon a nearly horizontal stratum. Sediment of the shoal itself is dominantly silicate sand in contrast to the underlying sonic reflector which shows areal differences in lithology.

Distribution of shoals in terms of water depth shows two distinctive groups; one at 20 to 30 ft. depths; the other at 40 to 55 ft. depths. A third group may be present in water depths of about 80 ft. The bulk of the geologic data available on these shoals comes from the middle Atlantic bight (Cape Hatteras to Cape Cod). The area can be zoned into four coastal compartments (Figure 15). There is an eroding headland at the northeast end of each compartment. Because of the prevailing northeastern wave approach, recurved and cuspate barrier spits have formed north of the headlands and seaward. Convex barrier arcs (a spit and succession of barrier islands) have formed to the southwest and south. The Long Island and New Jersey coastal compartments terminate with arcuate shoals which are convex seaward and are associated with estuarine inlets lying to the north sides of the inlet mouths. In Delaware Bay, this area is called Overfall Shoal. The inlet-associated shoal off the western end of Long Island shows tidal built ridges that curve northeastward and merge with the inner shelf ridge and swale topography (Figure 12).

The northern portion of New Jersey's inner-shelf and shoreface is steep, regular and relatively narrow (2100 ft. average width). The linear shoal fields lie about 2.5 nautical miles off the coastline with the exception of the one off Shrewsbury Rock which extends from the shoreface to 6.5 nautical miles seaward where it terminates at the Hudson shelf valley. Shoal relief is 3 to 11 m and they occur in waters depths of 10 to 20 m. All are oriented northeast making a 30-degree angle with the coast in the Barnegat area and 30-85-degrees in the Ashbury Park-Long Branch sector of the coast. Shoals are nearly symmetrical, but where asymmetry is observed, the steep sides are on the southern flanks except where shoreface connected shoals occur. In those, the northern inshore flanks are steeper.

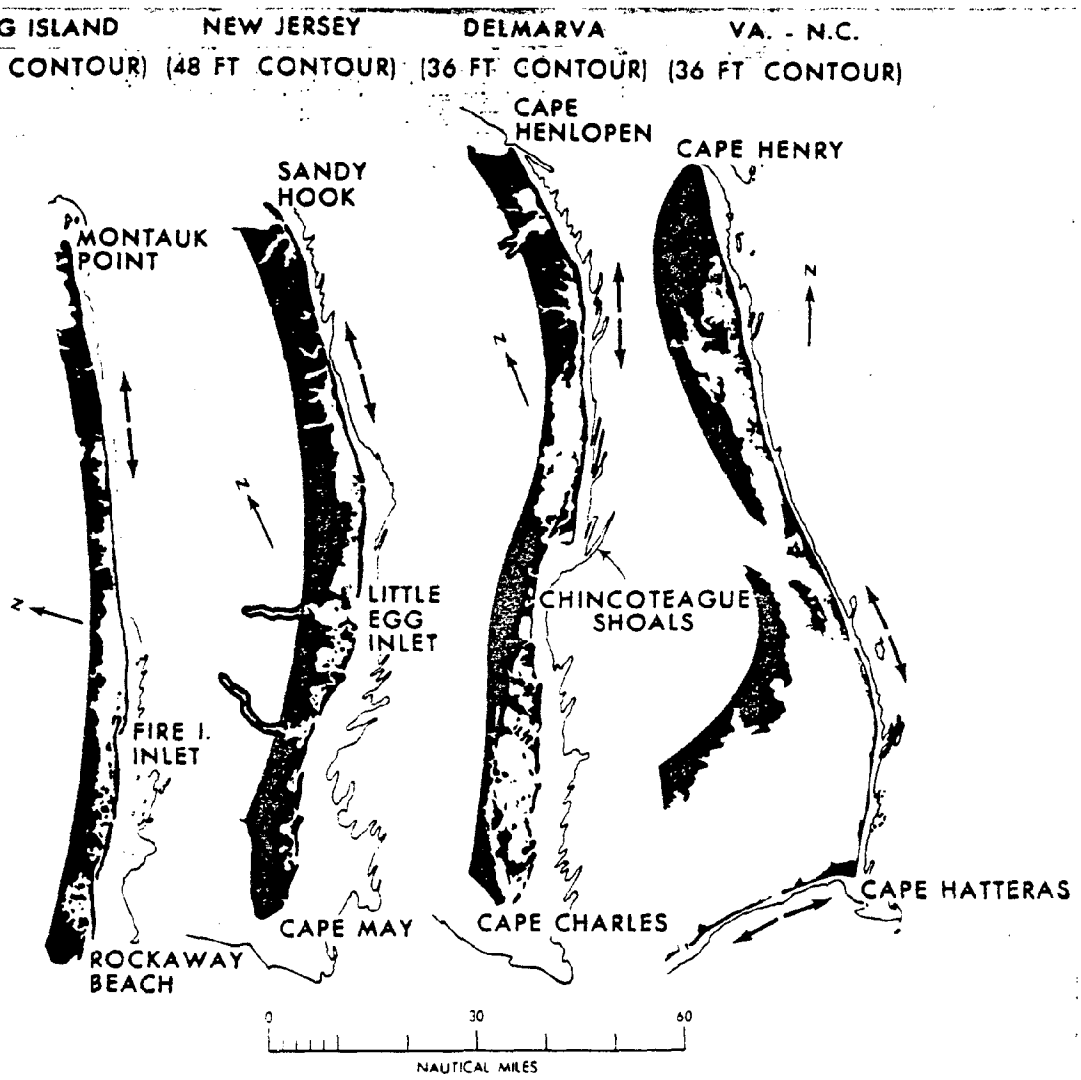
Samples from these shoals show a dominance of medium grained, polished, well-sorted quartzose sand, in places covered by a thin veneer of coarse, poorly-sorted iron-stained and pitted quartz and glauconite overlying a substrate of fine-grained sands,



Bathymetry of a portion of the New Jersey shelf. Contour interval 2 fathoms. From Stearns (1967). See source map, USCGS bathymetric map 0807N-55 for 1-fathom resolution. Numbered circles are submersible stations.

(From Swift, D., et al, 1972, Shelf Sediment Transport: Process and Pattern, fig. 221, p. 546)

FIGURE 14



Coastal compartments and shoreface-ridge systems of the Middle Atlantic Bight, as defined by the 60 ft contour off Long Island, the 48 ft contour off New Jersey, and 36 ft contour off the Delaware-Maryland-Virginia compartment and the Virginia-North Carolina compartment. Arrows indicate major littoral drift directions.

(From Swift, D., et al 1972, Shelf Sediment Transport: Process and Pattern, fig. 177, p. 461)

FIGURE 15

silts and clays. This textured boundary coincides roughly with the uppermost sonic reflector.

From Barnegat to Cape May the linear shoals are longer and more abundant and they form a 20- to 60-degree angle with the shore. Maintaining a northeast and east-northeast orientation regardless of change in shoreline orientation. Shoal crests, flanks and troughs are all mainly well-sorted, polished, medium-grained quartz sand. Beneath the upper sonic reflector, core samples are very coarse gravelly sand containing broken shell fragments. Duane and others (1972, p. 465) suggest that this material is lag deposit resulting from marine reworking. Barnegat represents a nodal point for littoral drift directions; to the north and to the south from Barnegat.

The consistency between orientations of both shoreface-connected and isolated shoals of the inner shelf and their common orientation to shoreline regardless of shoreline orientation changes suggests, that during sea-level rise, the shoreline has maintained the same orientation it has today. Some previous studies have related ridge and swale topography to fluvial or glacial and fluvial processes (Garrison and McMaster, 1966; Knott and Hoskins, 1962; McKinney and Friedman, 1970). The pertinent studies cited in section IV.B.3 describing the controls on these features suggests that further attention needs to be focused in the direction taken by Duane and others (1972) and Swift, Kofoed, Saulsbury and Sears (1972); namely, that ridge and swale topography is not a relict shelf feature but rather a product of the dynamic changes in the shoreface-inner shelf region produced by a transgressing sea. Thus these dominant morphologic features of the middle Atlantic bight are forming in response to present-day hydraulic conditions.

II.C. Ridges and Swale Topography

Linear shoals on the Atlantic inner continental shelf, Florida to Long Island, Duane, D.B., Field, M.E., Meishruger, E.S., Swift, D.J.R., and Williams, S.J., 1972.

Observations on the hydraulic regime of the ridge and swale topography of the inner Virginia shelf, Holliday, B.W., 1971.

Origin of cape and shoals along the southeastern coast of the United States, Hoyt, J.H., and Henry, V.J., 1971.

Depositional ridges in the North Atlantic, Johnson, G.L., and E.D. Schneider, 1969.

Large submarine and waves, Jordan, G.F., 1962a.

Rhythmic linear sand bodies caused by tidal currents, Off, T., 1963.

Holocene shoestring sand on inner continental shelf off Long Island, New York, Sanders, J.E. and Kumar, N., 1975.

Anatomy of a shoreface connected ridge system on the New Jersey shelf, Stahl, L., J. Koczan and D. Swift, 1974.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:125,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

Bathymetric charts Cape Cod to Maryland, Stearns, F. and L.E. Garrison, 1967.

Underwater sand ridges on Georges Shoal, in R.L. Miller, ed., Stewart, H.B., Jr. and G.F. Jordan, 1964.

Ridge development as revealed by sub-bottom profiles on the central New Jersey shelf, Stubblefield, W.L. and D.J.P. Swift, 1976.

Ridge and swale topography of the middle Atlantic Bight, North America, Swift, D.J.P. and others, 1973.

II.C. (continued)

Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod, U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

Anatomy of a shoreface ridge system, False Cape, Virginia, Swift, D.J.P., B.W. Holliday, N.F. Avignone, and G. Shideler, 1972a.

II.D. Remnants of Lower Sea-Level Stands

In the references listed at the end of this section are physiographic features associated with the continental shelf, such as strand plains, beach ridges and escarpments. The discussion which follows does not treat these specific features because as suggested above, the present trend of research in shelf surface dynamics implies that these features may be products of existing shelf processes. Even into the early 1970's a number of topographic features and the sediments comprising them were thought to be relicts of former strand line positions. Research is now in a state of flux toward interpreting these shelf features as responses to dynamic shelf processes.

One of the clearest descriptions of the process of shoreface retreat is given in Charnell and others (1975). The sea advanced to its present position as the glacial ice sheets melted. Low-lying coasts, such as that of the New York bight where sand and clay were the predominant sediment, tend to take on a characteristic submarine profile, concave upward, consisting of a relatively steep shoreface (gradient changing from 1:10 to 1:200) descending to depths of 12 m to 20 m at 2 km to 5 km offshore. Here, the shoreface merges with the inner shelf floor with seaward gradients of less than 1:200. This submarine profile of shoreface and inner shelf is maintained by wave and wind driven currents. During post-glacial sea-level rise, the profile retreated landward by wave erosion of the shoreface. Sediments eroded from the retreating shoreface were deposited seaward on the shelf as a relatively clean sand blanket. The rate of sea-level rise slowed appreciably between 7,000 and 4,000 years B.P. and with this decrease, the New York bight has assumed its present configuration. Sandy Hook has grown northward into the harbor mouth and Rockaway spit has extended westward.

It is possible to appreciate the rapidity of the present transition in thinking by recalling that in 1968, Emery published a classic paper on relict sediments on continental shelves of the world. Relict sediments are defined as those deposits not in equilibrium with the prevailing hydraulic processes. For example, glacial tills found in several meters of sea water are obviously not the product of the prevailing fluid processes. These products of an earlier environment have characteristic petrography, textures, fauna and, in some cases, topographic form. However, Swift, Stanley and Curray (1971) called attention to the fact that these materials, although products of former environments, are responding to present hydraulic conditions and are in the process of attaining an equilibrium with them. Thus, these sediments are in a process of transition to a new equilibrium. The term "palimsest" sediment, was suggested for these materials. Palimsest sediments exhibit physical and, perhaps biological, attributes

of an earlier depositional environment, in addition to the attributes of the later prevailing environment. Once all of the evidence of the previous conditions have been erased, the shelf materials can be considered to be modern autochthonous sediments.

In summarizing the present changes in thinking concerning topographic features, particularly linear shoals which were thought to be static relicts, Duane and others (1972, p. 494) restate they hypothesis that linear shoals represent Holocene barrier retreat across the shelf. However, they emphasize the dynamic rather than static aspects of this process. They suggest that the shoals represent neither the subaerial superstructure nor the submarine foundations of barriers. Instead, they interpret the shoals as independent and distinct daughter forms adjusting to the prevailing hydraulic processes. Their evidence that the persistent orientation of the shoals mimics present day shoreline substantiates the case the the Holocene coastal retreat has maintained essentially the same orientation it has today.

II.D. Remnants of Lower Sea-Level Stand

1. Beach Ridges

A submerged Holocene shoreline near Block Island, Rhode Island, McMaster, R.L., 1967.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:250,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

Bathymetric charts Cape Cod to Maryland, Stearns, F., and L.E. Garrison, 1967.

Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod, U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

2. Escarpments

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:250,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

Bathymetric charts Cape Cod to Maryland, Stearns, F. and L.E. Garrison, 1967.

Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod, U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

3. Shoal-retreat massifs

Constructional shelf topography, Diamond Shoals, North Carolina, Hunt, R.E., Swift, D.J.P. and Palmer, H., 1977.

Large-scale current lineations on the central New Jersey shelf, McKinney, T.F., W.L. Stubblefield and D.J.P. Swift, 1974.

COASTAL ZONE
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II.D. (continued)

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:250,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

Delaware shelf valley, estuary retreat path, not drowned river valley, Swift, D.J.P., 1973.

Tidal sand ridges and shoal retreat massifs, Swift, D.J.P., 1975.

Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod, U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967.

4. Relict Sediments

Relict sediments on continental shelves of the world, Emery, K.O., 1968.

Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast, Swift, D.J.P., Dill, C.E., Jr., McHome, J., 1971.

Textural differentiation in the shoreface during erosional retreat of an unconsolidated coast, Cape Henry to Cape Hatteras, western north Atlantic shelf, Swift, D.J.P., and others, 1971.

Relict sediments on continental shelves, a reconsideration, Swift, D.J.P., Stanley, D.J. and Curray, J.R., 1971.

Shelf edge carbonates, anomalies to conventional ideas relating Quaternary climates and sea levels, Sanders, J.E. and others, 1970.

III. PROCESSES INFLUENCING SURFACE OF THE CONTINENTAL SHELF

III.A. Inner Shelf and Coastal Zone (Shoreface)

The principle process affecting the inner shelf and coastal zone is the movement of waves. Waves are mainly a product of movement of surface water by the frictional drag of wind. The frictional transfer of the wind energy to the water surface produces shear stress. In addition to winds, there are three other causes of waves of far less significance than the wind which affect the inner shelf coastal zone. These are: waves caused by tides; waves caused density variations in water masses; and waves caused by the Earth's rotation.

Waves are the dominant feature of the surface of the ocean. Most of the energy involved in wave movement ultimately reaches the coastal zone where it is expended by breaking waves in the surf zone. The amount of energy dissipated by waves breaking on the shoreline is enormous. The amount of energy along 400 km of a beach would be equivalent to that produced from an average-size nuclear power plant. More specifically, 1 m in height in the surf zone dissipates energy approximately equivalent to 3 kw per meter of shoreline. This energy is being expended constantly as waves of various heights, sizes, various energy levels are continually reaching the shoreline. Thus, the coastline is constantly being modified by wave energy.

In order to understand the basic effects of waves as they approach the inner shelf and the coastal zone, and the way in which they influence the shoreface, one needs to know something about the geometry of an ideal wave as shown in Figure 16A. The ideal wave can be described by its length and its height, and by the direction of propagation. The latter corresponds to the direction of the wind that generated the wave. In addition to the length and height, and the direction of propagation, there are two other important aspects of waves which can be used to characterize them as they approach the shore. First, the wave period, which is the time (measured in seconds) for two successive wave crests to pass a fixed point, and the second is wave velocity (or celerity). The velocity of the wave is equal to wave length over wave period. By measuring the period and the length of the wave, one can determine celerity or velocity.

Figure 16B shows some aspects of ideal wave motion. In deep water, a wave moves in the direction of propagation but the water itself remains in the same location. Only the wave form travels; the water does not. It simply moves up and down. For example, in deep water, a boat or a bobbing cork, simply rides the wave form as it passes, moving upwards as the crest expands and downward as the trough approaches, and up with the next crest, etc. The water surface itself is doing this as well.

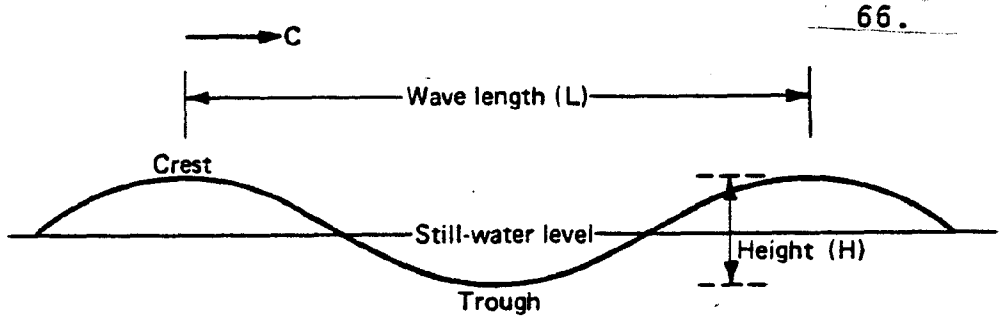


FIGURE 16A. IDEAL WAVE. Component parts are crest, trough, wave length (L), wave height (H).

Propagation direction and speed shown by ⟶C.
Velocity (V) or Celerity (C)= L/T
Wave base = 1/2 L
Wave steepness = H/L

FIGURE 16B.

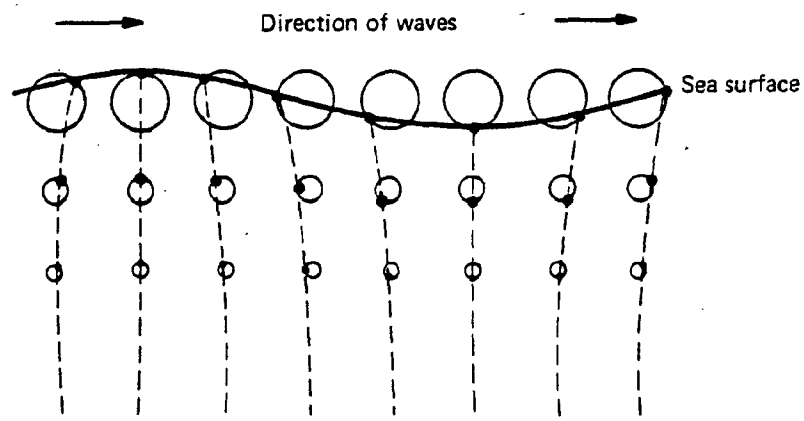
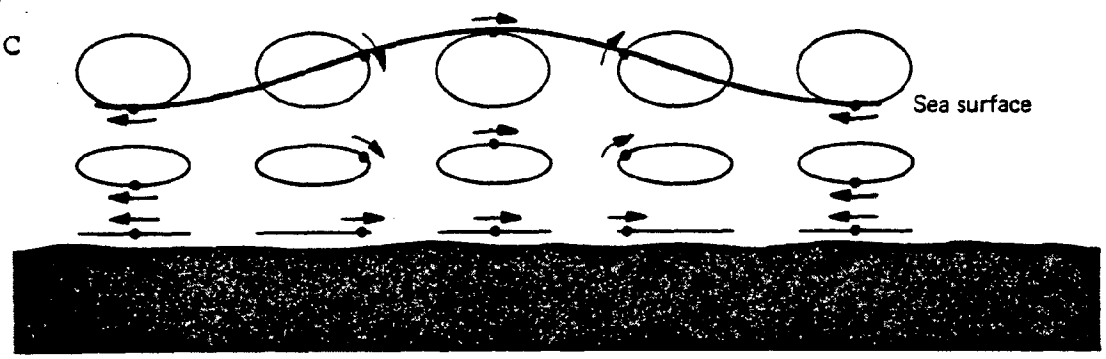


FIGURE 16C



The motion of water particles as a wave passes are circular in deep water (B); and flattened ellipses in shallow water (C). The depth of wave disturbance is approximately 1/2 L.

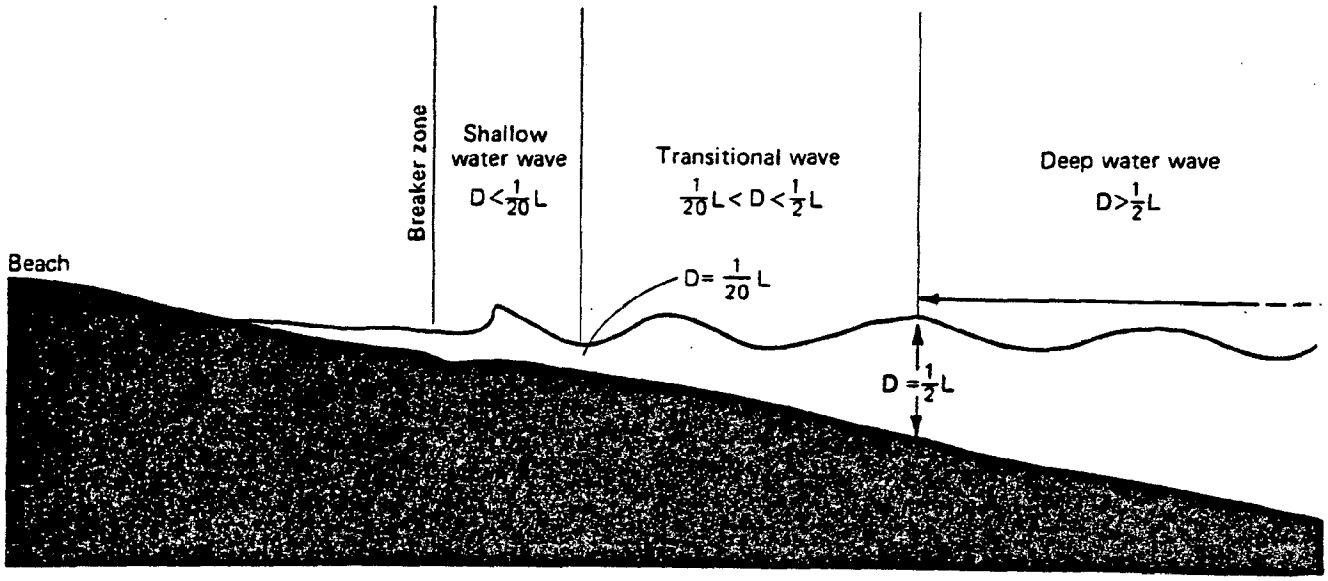
(From Anikouchine, W. A., and Sternberg, R. W., 1973, The World Ocean, fig. 8-1, p. 119 and fig. 8-7, p. 125.)

The wave form is the only thing that is passing some fixed point. In Figure 16B it is evident that any water particle at the sea surface is describing a circular orbit. The diameter of that circular orbit is the wave height. The passage of the wave form causes the water particles to move in these orbits, but the effects of the movement diminish downward exponentially from the water surface (Figure 16B). The fact that the water motion diminishes downward exponentially means that there is a lower limit at which the water itself actually has any orbital movement at all. As indicated in Figure 16C, this depth is about one-half of the wave length. That is, wave motion does not affect the sea bottom at depths greater than one-half the length of the wave. In water depths greater than one-half wave length, a passing wave does not affect bottom sediment or bottom material and conversely, the bottom is not producing frictional drag as the wave passes overhead. Therefore, in the open ocean, surface waves do not "feel" the bottom. As the waves move towards the shore, wave motion very significantly affects the continental shelf, especially the inner shelf and coastal zone. Thus, by knowing the wave length, it is possible to predict at what depths waves will begin to affect bottom material and conversely at what depths the bottom will have a frictional drag on the wave itself as it passes overhead. This depth where waves "feel" bottom is called wave base.

Surface water waves in water depths which are less than one-half wave length produce a frictional drag on the bottom and move sediments. Sediment that is being moved by wave motion is carried in the direction of wave propagation. Because the shelf surface becomes shallower towards the shore, there must be a depth, even when there are very small waves, where water depths are less than one-half wave length in which the wave begins to affect or "feel" the bottom and begin to move sediments. Thus, under any wave conditions, one can determine at what depth the wave is "feeling" bottom.

Figure 17 shows a second modification as they reach shallow water. Where water depth is less than one-half wave length, the wave begins to slow down. As this occurs, the wave length decreases. The wave height, however, remains essentially the same. As the wave length decreases with respect to wave height, there is a relative increase in steepness of the wave. Wave steepness is defined as the ratio of wave height to wave length. Thus, waves steepen as they approach the shoreline. They become unstable and break. The point at which wave steepness creates instability in the wave form occurs approximately when the ratio of wave height to wave length becomes greater than one-seventh. When H/L becomes greater than one-seventh, the wave curls because it is unstable and breaks down over its own crest in a shoreward direction. Thus, from the breaker line through the surf and swash zone the wave form degenerates and dissipates its energy along the shore.

In shallow water the characteristics of a wave change with respect to the water depth.



Wave Steepness = H/L
Waves become unstable and break when the steepness exceeds 1/7

(From Anikouchine, W. A., and Sternberg, R. W., 1973, fig. 8-3, p. 120)

FIGURE 17

III. PROCESSES INFLUENCING SURFACE OF CONTINENTAL SHELF

Sediment transport by waves and currents, Abou-Seida, M.M., 1964.

Water movement within the apex of the New York Bight during summer and fall of 1973, Charnell, R.L. and Mayer, D.A. (in press, 1974).

Continental shelf sedimentation, Swift, D.J.P., 1974.

Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America, Swift, D.J.P. and others, 1972.

Shelf sediment transport, a probability model, Swift, D.J.P. and others, 1972.

Shelf sediment transport, process and pattern, Swift, D.J.P. and others, 1972.

A socio-economic and environmental inventory of the North Atlantic region, Sandy Hook to Bay of Fundy, Trigom, 1974.

Library research project, mid-Atlantic outer continental shelf (reconnaissance), U.S. Bureau of Land Management, 1972.

A keyword-indexed bibliography of the marine environment in the New York Bight and adjacent estuaries, Ali, J.A., 1973.

Chemical changes in interstitial waters from continental shelf sediments, Friedman, G.M., et al, 1968.

Paraecology of benthonic foraminifera and associated micro-organisms of the continental shelf off Long Island, New York, Gevirtz, J.L. and others, 1971.

III.A. Inner Shelf and Coastal Zone (Shoreface)

Distinction of shoreline environments on New Jersey, Biederman, E.W., 1962.

Coastal geomorphology of Connecticut, Bloom, A.L., 1967.

Bedform development and distribution pattern, Parker and Essex Estuaries, Mass., Boothroyd, J.D., and Hubbard, D.K., 1972.

Physical processes in coastal waters, Carter, H.H., 1969.

Bay, inlet and nearshore marine sedimentation, Beach Haven-Little Egg Inlet region, N.J., Charlesworth, L.J., Jr., 1968.

Summary and analysis of physical oceanography data from the New York Bight apex collected during 1969-70, Charnell, R.L. and Hansen, D.V., 1974.

Utility of ERTA - 1 for coastal ocean observation, Charnell, R.L., Jr. and others, 1974.

Summary of marine activities of the coastal plains region, Coastal Plains Center for Marine Development Services, 1976.

Source of the sands on the south shore of Long Island and the coast of N.J., Colony, R.J., 1932.

Classification of coastal environments of the world, Part I, Dolan, R. and others, 1972.

A study of New Jersey and northern New England coastal waters, Duane, D.B., 1969.

Marine sedimentary environments in the vicinity of the Norwalk Islands, Connecticut (abstr.), Ellis, C.W., 1960.

Estuaries and lagoons in relationship to continental shelves, Emery, K.O., 1967.

Wave estimates for coastal regions, Harris, D.L., 1972.

Relationship between coastal climate and bottom sediment type on the inner continental shelf, Hayes, M.O., 1967.

III.A. (continued)

Geomorphology and sedimentation of some New England estuaries, Hayes, M.O., 1971.

Storms as modifying agents in the coastal environment, Hayes, M.O. and Boothroyd, J.C., 1969.

The physical oceanography of Narragansett Bay, Hicks, S.D., 1959.

Hurricane modification of the offshore bar of Long Island, N.Y., Howard, A.D., 1939.

Origin of capes and shoals along the southeastern coast of the U.S., Hoyt, J.H. and Henry, V.J., 1971.

Constructional shelf topography, Diamond Shoals, N.C., Hunt, R.E. and others, 1977.

On the tectonic and morphologic classification of coasts, Inman, D.L. and C.E. Nordstrom, 1971.

Estuary and coastline hydrodynamics, N.Y., Johnson, J.W. and P.S. Engleson, 1966, in A.J. Ippen, ed.

A guide to the geology of Delaware's coastal environments, Kraft, J.C., 1971b.

Transportation of sand grains along the Atlantic shore of Long Island, N.Y., Krinsley, D. and others, 1964.

Coastal sands of the eastern U.S., McCarthy, G.R., 1931.

Petrography and genesis of recent sediments in Narragansett Bay and Rhode Island Sound, Rhode Island, McMaster, R.L., 1962.

Coastal morphology and processes in relation to the development of submarine sand ridges off Bethany Beach, Delaware, Moody, D.W., 1964.

Principles of physical oceanography, Englewood Cliffs, N.J., Neumann, G. and W.J. Pierson, Jr., 1966.

Characteristics of sedimentary environments in Moriches Bay, Nichols, M.M., 1964.

Correlation of shoreline type with offshore bottom conditions, Price, W.A., 1955.

III.A. (continued)

Coastal zone geology and its relationship to water pollution problems, Sanders, J.E., 1970.

Anatomy of a shoreface connected ridge system on the New Jersey shelf, Stahl, L.J. and others, 1974.

The new concepts of continental margin sedimentation, Stanley, D.J., ed., 1969.

Marine sediment transport and environmental management, Stanley, D.J. and Swift, D.J.P., 1976.

Marine erosion of glacial deposits in Massachusetts Bay, Stetson, H.C., 1935.

Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast, Swift, D.J.P. and others, 1971.

Shelf sediment transport, process and pattern, Swift, D.J.P. and others, 1972.

Estuarine and littoral depositional patterns in the surficial sand sheet, central and southern Atlantic shelf of North America, Swift, D.J.P. and Sears, P., 1974.

History of New Jersey coastline, Wicker, C.F., 1951.

Memorandum on dredging work in Ambrose Channel, Wigmore, H.L., 1909.

Erosion of the cliffs of outer Cape Cod, tables and graphs, Zeigler, J.M. and others, 1964.

Marine sedimentary environments in the vicinity of the Norwalk Islands, Connecticut, Ellis, C.W., 1962.

Chemical changes in interstitial waters from sediments of lagoonal, deltaic, river estuary and saltwater marsh and cove environments, Friedman, G.M. and Gavish, E., 1970.

Chemical changes in interstitial waters from lagoonal, estuarine, tidal marsh and deltaic environments, Friedman, G.M. and Gavish, E., 1970.

Chemical and oxidation reduction potential studies of the Long Island Sound sediments, Kaplin, Stephen, Jr., 1961.

III.A. (continued)

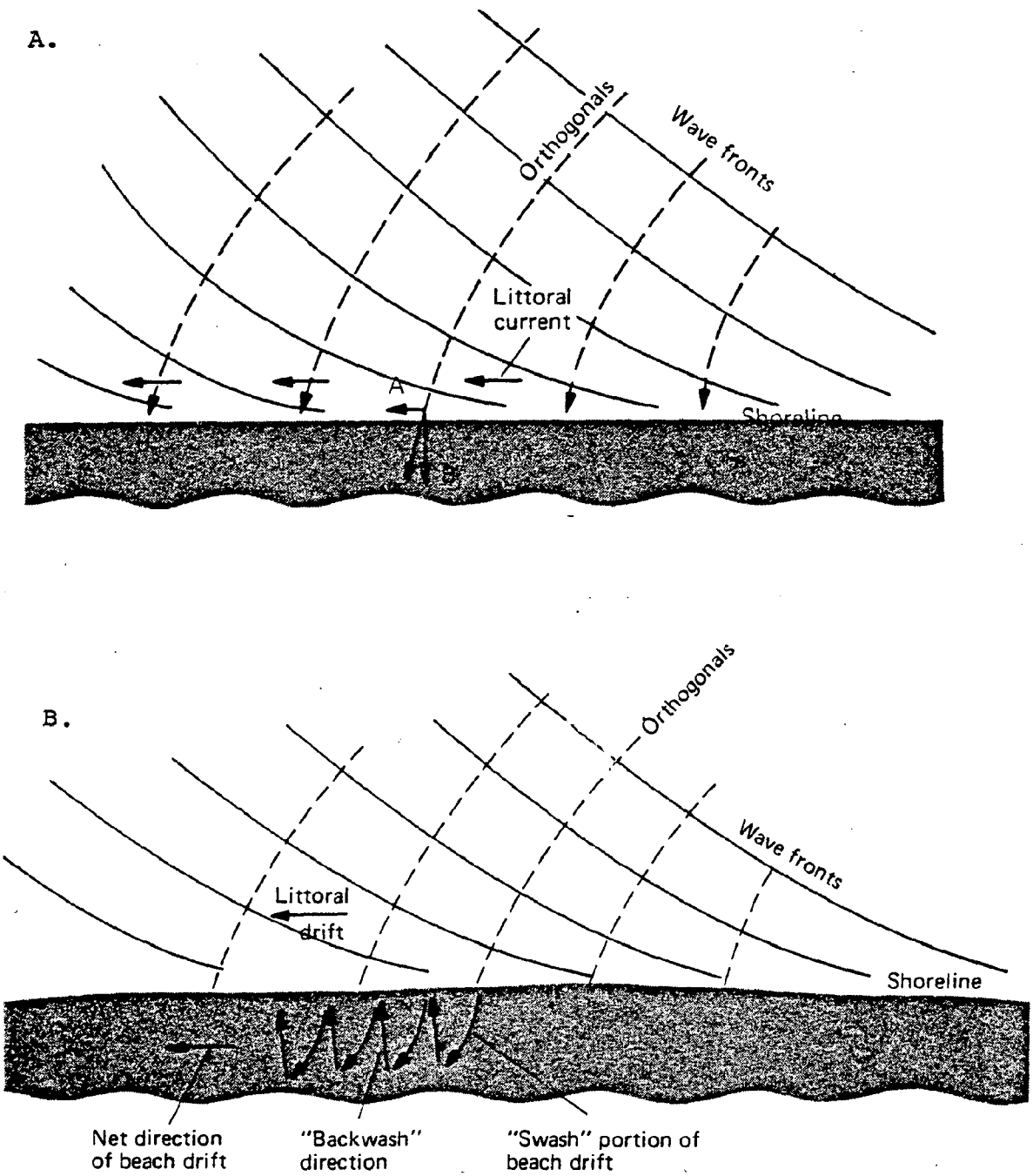
Resumé of investigations of the marine geology in the environs of Long Island, New York, Rogers, W.B., 1970.

III.A.I. Beach Development and Erosion

An understanding of the beach development and erosion requires a knowledge of wave movement in shallow water. There are several factors that need to be known in order to predict what will occur on beaches by wave action in shallow water. Knowing the propagation direction of the wave and the slope of the inner shelf surface permit prediction of what happens to waves as they approach the shore. Figure 18 shows the movement of waves toward a shoreline and indicates the changes that occur as the waves approach the shore. Waves usually approach at some angle to the shore; that is, the direction of propagation is not usually perpendicular to the shoreline. As indicated in Figure 18, the leading end of the wave, which first reaches water less than one-half wave length in depth begins to slow down (Figure 17). As this portion of the wave is slowing down the remainder of the wave, which is still in deeper water, is not slowing, but is continuing at its original velocity. This produces a bending or refraction of the wave which tends to align the wave crest toward the shoreline, but waves still rarely strike the beach head on (Figure 18). Once the wave reaches water depths of less than one-half wave length, movement of bottom sediment can occur. This movement is in the direction of wave propagation. Particles carried up the beach fall by the swash of a breaking wave move in the direction of wave propagation. The backwash of water on the beach surface moves directly down the beach slope, and may carry sediment with it back into the surf zone (Figure 18). Here the sediment is moved again by the next incoming refracted wave onto the beach face. The net result of this movement by waves approaching the shoreline at an angle is the transport of sediment along the shoreline, a process called longshore drift (Figure 18). The current set up by the angular approach of waves to the shore is called the longshore or littoral current.

From these relationships of wave angle approach toward the shoreline and the resulting movement of sediment along the beach, it is possible to predict for any coastline made up of sand-sized material, the nature of the beach development in terms of its growth and erosion. Figure 19 presents three diagrams showing the changes in any coastline which can be predicted given the wave propagation direction, depth at which the waves begin to feel bottom, and the refraction angle produced as the wave slows down. Figure 19A shows an irregular coastline. It also shows wave orthogonals which are lines drawn at right angles to the wave crests, i.e., in the direction of wave propagation. The amount of energy in a wave between two orthogonals is constant. Thus, as orthogonals converge or diverge with change in direction of wave propagation, the wave energy is concentrated or dispersed. It is principally the result of wave energy convergence on headlands of irregular shorelines that causes maximum erosion to take place there. In the intervening areas where the orthogonals diverge, the energy of the wave is less concentrated and less erosion occurs. Also, it is in this area of wave-energy divergence that the sediment accumulates which has been eroded from the headlands. Ultimately, any coastline which is irregular in shape will tend to become straight as the rocky or semi-consolidated

Direction of littoral currents resulting from waves breaking at an angle to the shore.



Sediment movement along the beach occurs in the surf zone as littoral drift and on the beach face as beach drift.

(From Anikouchine W. A., and Sternberg, R. W., 1973, fig. 10-4, p. 162 and fig. 10-10, p. 168)

FIGURE 18

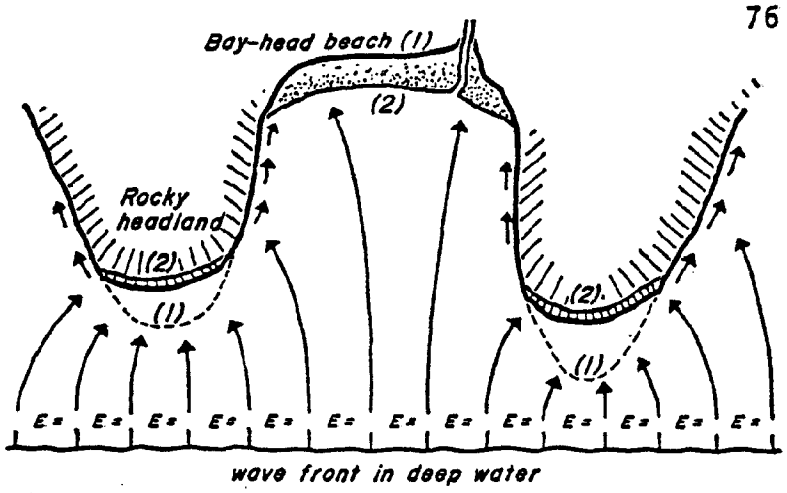


FIGURE 19A. Zones of equal wave energy in deep water are concentrated by wave refraction so that headlands are attacked. E = energy. Amount of wave energy between orthogonals remains constant.

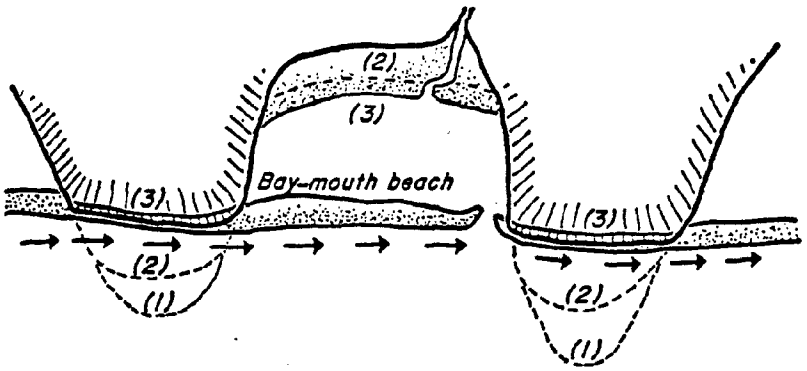


FIGURE 19B. Eventually headlands are cut back and furnish enough sand to build a straight continuous beach.

(Figures 19A and B from Bascom, W., 1964, Waves and Beaches, fig. 6, p. 17)

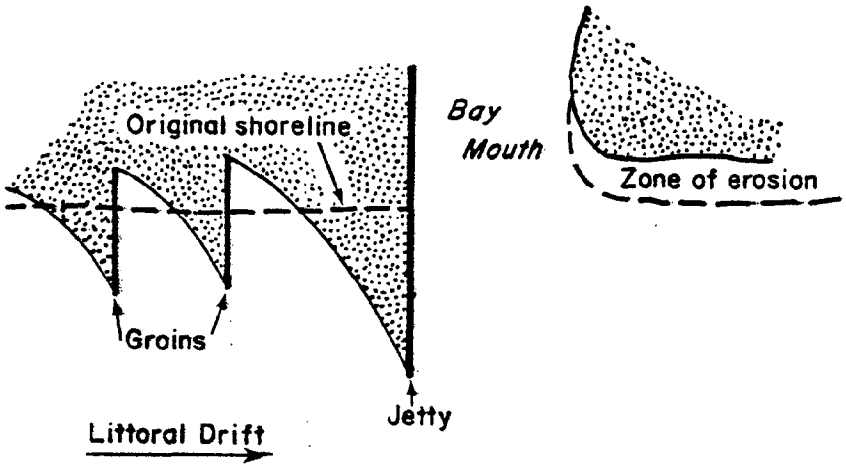


FIGURE 19C. Groins and jetties trap sand on their updrift sides, cause erosion on their downdrift sides. The Local beach is stablized, but the downdrift beach erodes because its supply of sand is diminished.

FIGURE 19. Effects of wave attack and littoral drift on

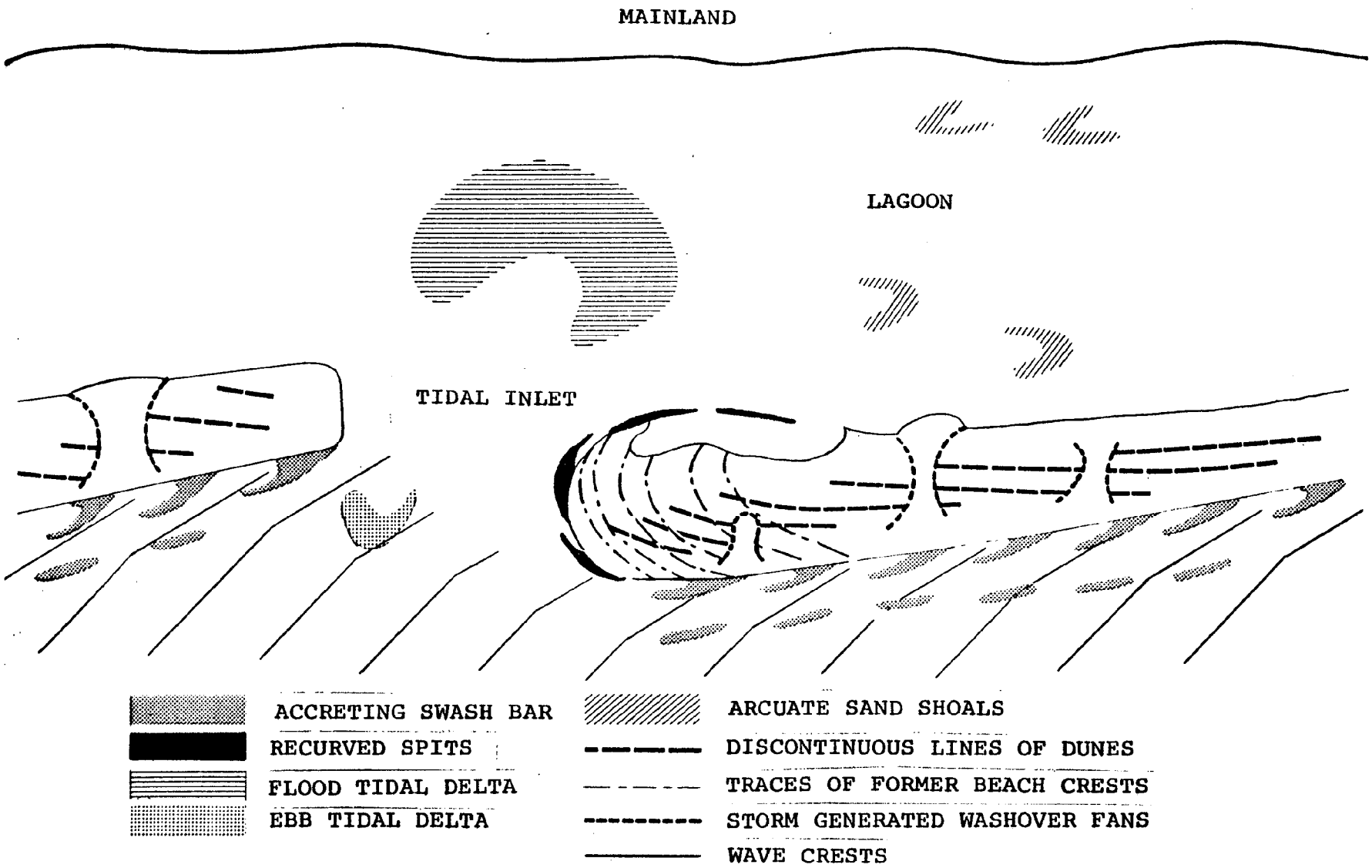


FIGURE 20 Idealized barrier island system.

headland areas become eroded back and the intervening areas between the headlands fill with sediment. Figure 19B shows a more or less straight shoreline and position of bays along that shoreline. This diagram shows what happens to the material carried in the longshore current. As the longshore current approaches the bay, sand extends out from the edge of the beach into the bay to form a spit. Commonly, the tidal exchange in and out of the bay or inlet will prevent the spit from spanning the bay mouth entirely. These tidal currents will cause the spit to curve, usually in a landward direction towards the tidal inlet forming a recurved spit. In some of the older literature this recurved spit is called a hook or a sandy hook.

In situations where the tidal exchange in and out of the bay or tidal inlet is not great, it is possible for sand to extend completely across the bay sealing it off, although this is not typical. Figure 19C shows a straight sandy shoreline, and added to it are some of man's engineering features, including jetties, groins and sea-walls. The development of jetties and groins interfers with the longshore current and thus creates starvation of sand in the downdrift direction along the beach. Small accumulations of sand do develop on the updrift side of each jetty or groin as shown in Figure 19C. However, the sand is trapped there and cannot move in the longshore current and, therefore, cannot continue to add to the downdrift end of the beach. The result of these kinds of engineering structures invariably results in starvation of the beach down current from them. With joints or jetties, the overall pattern of movement of the entire beach in the direction of the longshore current is interrupted and the ultimate result is erosion of the beach.

Because most of the beaches bordering the Atlantic continental shelf of the eastern United States are on barrier islands, the dynamics of beach development and the balance which exists between sand supply and wave action can be extrapolated to apply to barrier islands. There are some added characteristics for barrier islands, however, that need to be examined. Figure 20 shows an idealized example of a barrier island system. There are four important features to note in that diagram. First, the orientation of the barrier islands with respect to average approach direction; second, the presence of a tidal inlet between the barrier islands; third, the development of sand accumulations at the downdrift end of each of the barrier islands; and, fourth, the presence of one or more tidal deltas. Tidal deltas may occur either just behind the barrier island inside the tidal inlet or seaward of the tidal inlet in front of the barrier island. Those that occur behind the barrier island landward of the inlet are called flood-tidal deltas. If the dominant velocity during tidal exchange is in the flood-tide direction, there is a tendency for sand to accumulate inside the tidal inlet creating a flood-tidal

delta. Where the dominant tidal energy is out of the tidal inlet, an ebb-tidal delta may form seaward of the inlet mouth. The bulk of the sand which supplies the tidal deltas is a result of sediment being transported in the longshore current. Sand in the flood-tidal delta has moved along the beach in a longshore current direction, moved around the recurved spit and has been carried by the flood-tidal current into the lagoonal area behind the barrier island itself. These tidal deltas become, therefore, important sites of sand storage and represent part of the dynamic system which permits continued development and regeneration of barrier islands. Unfortunately, build-ups of sand in tidal deltas creates a problem for commercial shipping and pleasure boating because of infilling of the inlet channel. It has been a practice of the U.S. Army Corps of Engineers to remove this sand forming at least part of the tidal delta. Removal of the sand invariably upsets the sand balance which maintains the barrier island system. Present practice in dredging tidal inlets where tidal deltas have developed is to remove the sand and place it back into the littoral drift system on the updrift side of the next barrier island. Thus, there is a replenishment of sand from one barrier island to the next.

III.A.1. Beach Development and Erosion

Final report on data reduction for CERC New Jersey offshore sand inventory program, Alpine Geophysical Assoc. Inc., 1969.

Report on beach erosion at Manasquan Inlet, N.J. and adjacent beaches, Anonymous, 1938.

Observations to determine the cause of the increase of Sandy Hook, for the commissioner on harbor encroachment of New York, Bache, A.D., 1856.

Report on jetties, Blackman, B., 1938.

Sea level rise as a cause of shore erosion, Bruun, P., 1962.

Coastal processes and beach erosion, Caldwell, J.M., 1966.

Atlantic coast of Long Island, N.Y., Fire Island Inlet and westerly to Jones Inlet, Corps of Engineers, 1963.

Atlantic coast of Long Island, Fire Island Inlet and shore westerly to Jones Inlet, Corps of Engineers, 1970.

National shoreline study, regional inventory report, North Atlantic region, Corps of Engineers, 1971.

Coastal process and near-shore sand bars, Davis, R.A. and W.T. Fox, 1972.

Comparison of ridge and tunnel systems in tidal and non-tidal environments, Davis, R.A. and others, 1972.

Layout of outer protective works, maintenance of depth in harbors, on sandy shores and before mouths of estuaries, Dent, E.J., 1935.

Wave-base marine profile of equilibrium, and wave-built terraces -- A critical appraisal, Dietz, R.S., 1936b.

Causes of recent increased erosion along U.S. shorelines, El-Ashry, M.T., 1971.

Beach profile changes on western Long Island, Everts, C.H., 1973.

III.A.1. (continued)

Beach erosion studies of southern New Jersey, Gessler, E.E., 1952.

Comparison of ecological and geomorphic interactions between altered and unaltered barrier island systems in North Carolina, Godfrey, P.L.J. and Godfrey, M.M., 1973.

Test of nourishment of the shore by offshore deposition of sand, Long Branch, N.J., Hall, J.V. and Herron, W.J., 1950.

Restudy of test-shore nourishment by offshore deposition of sand, Long Branch, N.J., Harris, R.L., 1954.

Littoral movements of the New Jersey coast, with remarks on beach protection and jetty reaction, Haupt, L.M., 1890.

Hurricanes as geological agents, Hayes, M.O., 1967.

Offset coastal inlets, Hayes, M.O. and others, 1970.

Sand deposition in the Chatham Harbor estuary and on the neighboring beaches, Cape Cod, Mass., Hine, A.C., 1972.

The New England-Acadian shoreline, Johnson, D.W., 1925.

Estuary and coastline hydrodynamics, N.Y., Johnson, J.W. and P.S. Engleson, 1966, in A.J. Ippen, ed.

Offset tidal inlets, Long Island, N.Y., Kaczorowski, R.T., 1972.

Probable causes of shoreline recession and advance on the south shore of eastern Long Island, McCormick, C.L., 1973.

Recent geomorphic history of Plum Island, Mass. and adjacent coasts, McIntire, W.G. and Morgan, J.P., 1963.

Petrography and genesis of New Jersey beach sands, McMaster, R.L., 1954.

III.A.1. (continued)

Problems involved in coast erosion, Patton, R.S., 1924.

Moriches Inlet, a problem in beach evolution, Patton, R.S., 1931.

Tidal inlets and washover fans, Pierce, J.W., 1970.

Development of the New Jersey shore, Rankin, J.K., 1952.

Washover erosion-important process in creating bays of digitate spit, Democrat Point, Fire Island, L.I., New York (abstr.), Sanders, J.E. and Kumar, N., 1971.

Sand transfer, beach control and inlet improvements, Fire Island Inlet to Jones Beach, N.Y., Saville, T., 1960.

Sand transport along a model sandy beach by wave action, Schinohara, K. and others, 1958.

Coastal erosion and transgressive stratigraphy, Swift, D.J.P., 1968.

Geomorphology of the south shore of Long Island, N.Y., Taney, N.B., 1961.

Littoral materials of the south shore of Long Island, N.Y., Taney, N.M., 1961.

Long Island hurricane rehabilitation, Shymecock Inlet created by 1938 storm, left open and stabilized for Nassau County use, Tuthill, H.T., 1944.

Shore protection manual, U.S. Army, 1973.

Beach erosion at Jocob Riis Park, L.I., N.Y., U.S. Army Beach Erosion Board, Corps of Engineers, 1936.

Beach erosion at Manasquan Inlet, N.J. and adjacent beaches, U.S. Army Beach Erosion Board, Corps of Engineers, 1936.

South shore, state of Rhode Island beach erosion control study, U.S. Army Beach Erosion Board, Corps of Engineers, 1949.

III.A.1. (continued)

Annual Reports of the Chief of Engineers, U.S. Army Corps of Engineers, 1885-1930.

Fire Island inlet and shore westerly to Jones Inlet, U.S. Army Corps of Engineers, 1955.

Study on use of hopper dredge for beach nourishment, U.S. Army Corps of Engineers, 1967.

National shoreline study report, U.S. Army Corps of Engineers, 1971.

Preliminary examination of Chatham New Harbor, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1894.

Westport River, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1938.

Scituate Harbor, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1938.

Newbury Port Harbor, Massachusetts, U.S. Army Engineer District, Boston, Corps of Engineers, 1940.

East Point Judith, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1889.

Survey of inner harbor at Point Judith Pond, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1897.

Point Judith Harbor of Refuge, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1908.

Point Judith Pond, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1916.

Point Judith Harbor of Refuge, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1917.

Harbors of Refuge at Point Judith, Block Island and Great Salt Pond, and adjacent waters, etc., U.S. Army Engineer District, New York, Corps of Engineers, 1903.

III.A.1. (continued)

East Rockaway (Debs) Inlet, New York, U.S. Army Engineer District, New York, Corps of Engineers, 1929.

Shark River, New Jersey, U.S. Army Engineer District, New York, Corps of Engineers, 1939.

Jones Inlet, New York, U.S. Army Engineer District, N.Y., Corps of Engineers, 1941.

Fire Island Inlet, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1948.

Shore of New Jersey from Sandy Hook to Barnegat Inlet, beach erosion control study, U.S. Army Engineer District, New York, Corps of Engineers, 1955.

Fire Island Inlet to Jones Inlet, L.I., N.Y., cooperative beach erosion control study, U.S. Army Engineer District, N.Y., Corps of Engineers, 1956.

Atlantic coast of Long Island, N.Y., Fire Island Inlet to Montauk Point, Cooperative beach erosion control and interim hurricane study (survey), U.S. Army Engineer District, N.Y., Corps of Engineers, 1958.

Moriches and Shinnecock Inlets, L.I., N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1959.

Raritan Bay and Sandy Hook Bay, New Jersey, cooperative beach erosion control and study (survey), U.S. Army Engineer District, N.Y., Corps of Engineers, 1960.

South Shore of Long Island from Fire Island Inlet to Montauk Point, N.Y., beach erosion control study and hurricane survey, U.S. Army Engineer District, N.Y., Corps of Engineers, 1960.

Atlantic coast of Long Island, Fire Island Inlet and shore westerly to Jones Inlet, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1965.

III.A.1. (continued)

Jones Inlet to Montauk Point, N.Y. (remaining areas), U.S. Army Engineer District, N.Y., Corps of Engineers, 1967.

Shark River, N.J., U.S. Army Engineer District, Phila., Corps of Engineers, 1890.

Barnegat Inlet, N.J., U.S. Army Engineer District, Phila., Corps of Engineers, 1936.

Manasquan River, N.J., U.S. Army Engineer District, Phila., Corps of Engineers, 1941.

Barnegat Inlet, N.J., U.S. Army Engineer District, Phila., Corps of Engineers, 1945.

Absecon Inlet, N.J., U.S. Army Engineer District, Phila., Corps of Engineers, 1946.

Atlantic City, N.J., beach erosion control study, U.S. Army Engineer District, Phila., Corps of Engineers, 1950.

Cold Spring Inlet (Cape May Harbor), N.J., U.S. Army Engineer District, Phila., Corps of Engineers, 1953.

Ocean City, N.J., beach erosion control study, U.S. Army Engineer District, Phila., Corps of Engineers, 1953.

New Jersey Coastal inlets and beaches - Great Egg Harbor Inlet to Stone Harbor, U.S. Army Engineer District, Phila., Corps of Engineers, 1969.

Chatham (Stage) Harbor, Mass., U.S. Army Engineer District, Providence, Corps of Engineers, 1941.

Harbor of Refuge at Point Judith and Point Judith Pond, Rhode Island, U.S. Army Engineer Division, New England, Corps of Engineers, 1947.

Plum Island, Mass., beach erosion control study, U.S. Army Engineer Division, New England, Corps of Engineers, 1953.

Point Judith, Rhode Island, U.S. Army Engineer, Division, New England, Corps of Engineers, 1962.

III.A.1. (continued)

Edgartown Harbor, Martha's Vineyard, Mass., U.S. Army Engineer Division, New England, Corps of Engineers, 1970.

Model study of plans for elimination of shoaling in Absecon Inlet, N.J., U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, 1943.

Barnegat Inlet, N.J., U.S. Army Shore Protection Board, Corps of Engineers, 1933.

Behavior of beach fill and borrow area at Sherwood Island State Park, Westport, Conn., Vesper, W.H., 1967.

Report of changes in the shoreline and beaches at Martha's Vineyard, as derived from comparisons of recent with former surveys, Whiting, H.L., 1886.

Growth and migration of digitate spits (April - September, 1971), at Democrat Point, Fire Island, New York - An example of a naturally occurring modifying landfill system, Wolff, M.P., 1972.

Geometry and development of spit-bar shorelines at Horseshoe Cove, Sandy Hook, N.J., Yasso, W.E., 1964.

Use of fluorescent tracers to determine foreshore sediment transport, Sandy Hook, N.J., Yasso, W.E., 1964.

The age and development of the Provincelands Hook Outer Cape Cod, Mass., Zeigler, J.M. and others, 1964.

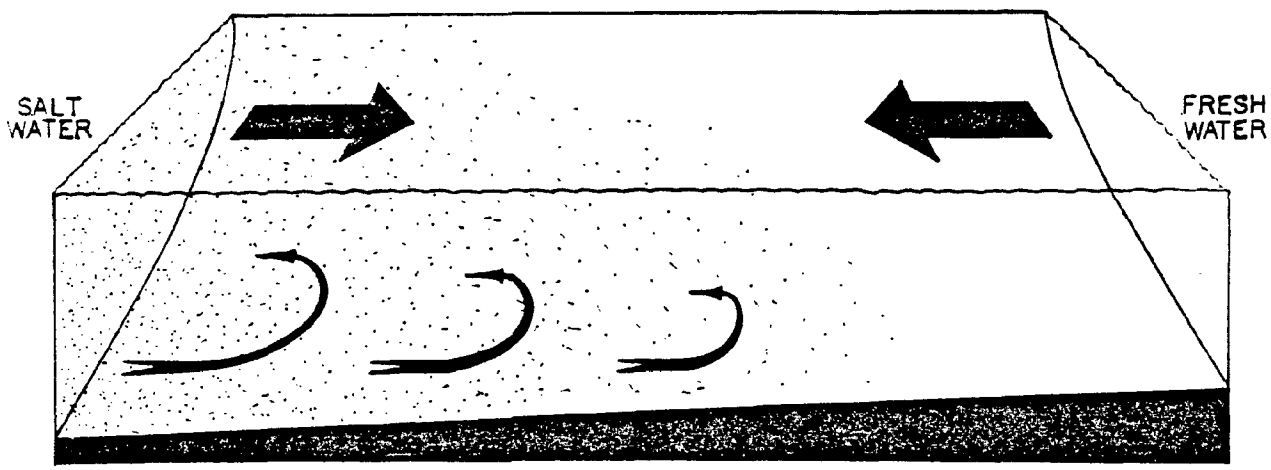
The sediments of the south shore of Long Island Sound, Lloyde Point to Crane Neck Point, Krebs, O.A., 1962.

III.A.2. Dynamics of Tidal Inlets and Estuaries

Tidal inlets are channels between barrier islands where there is tidal exchange between the open ocean and the lagoon behind the barrier. Estuaries, on the other hand, are in a very general way, defined as drowned river mouths. The Hudson River is the most important estuary in the study area. Because estuaries are drowned river mouths, it means that there is a mixture of sea water and fresh so that the upstream limits of the estuary and the dynamics within the estuary itself are largely controlled by the ways in which the salt and fresh water are distributed. The dynamics of estuaries depend on the difference in density of river and ocean water, tidal movement in the river mouth, as well as the flow of the river itself. Thus, a very complex dynamic system is developed. Probably the best summary of estuarine dynamics is given in Schubel (1971) in the American Geologic Institute Short Course on Estuarine Environments. The paper in that volume by Pritchard is outstanding in its definition of the characteristics of estuaries in terms of the dynamics resulting from the salt-fresh water mixtures. In that same volume, there is also a paper by Hayes (1971) in which he discusses the geomorphology of tidal inlets and the dynamics of tidal inlets. Most of the literature cited at the end of this section on tidal inlets relates to the work which the Corps of Engineers has undertaken over the past many decades. It is one of the principal missions of the Corps of Engineers to provide access to harbors and to maintain tidal inlet channels. Therefore, one of their principal functions has been to remove sediments which have accumulated at the downdrift ends of beaches, particularly barrier islands, and in the tidal inlets. The bulk of their operations has been essentially to remove or to modify tidal deltas, especially flood tidal deltas which, if allowed to develop naturally, can fill the tidal inlet and choke off any avenue to harbors in the mainland area. The nature of sand deposition within the tidal inlet, or within estuaries themselves, is well described in two papers by Hine (1972 and 1973). Those papers are perhaps the clearest descriptions of the dynamics of sand infilling and the development of tidal deltas associated with an inlet mouth. A number of other papers on this subject were written and developed under the direction of Hayes, at the University of Massachusetts, and now at the Universtty of South Carolina. Hayes' Coastal Research Group has done extensive studies on the dynamics, the bedform characteristics, and the migration patterns which occur in tidal deltas, and probably represents the best sources of information on this subject. Barwis (1976) has compiled a complete annotated bibliography of all tidal inlets in the United States so that all the literature which relates to any specific tidal inlet can be found in that report.

The available literature on estuaries and tidal inlets is very complex. The bulk of the information relating to the dynamics of estuaries is described in mathematical terms, and it is very difficult to give a simplistic picture of how an estuary works. A diagram is included in the text (Figure 21) which shows, in a simple way, the types of movement of sea and fresh water within the estuary itself. In addition to the paper cited above, Schubel (1971), a second volume gives a more general view of estuaries, especially those of the coastal plain of the eastern United States (Nelson, 1972). The present state of the art in estuary dynamics would suggest that the dynamic models which now exist to describe estuarine systems, are based mainly on a very small number of well-studied estuaries. We may be at a stage now that an understanding of estuary dynamics is biased by this small number of samples. Interestingly, there have been very few studies, and none of them on a large scale, on the Hudson River estuary. It is probably one of the most poorly understood estuarine systems in the United States. This is rather surprising in view of the fact that it is adjacent to the nations largest cities. The dynamics of this estuary needs to be thoroughly understood because of the enormous amount of waste material which is being delivered to that estuary every day.

ESTUARINE CIRCULATION



Fresh water tends to flow over and float on the denser salt water. Mixing occurs in the boundary zone between the two waters. Seaward flow of the fresh river water shapes the saltwater wedge.

FIGURE 21

III.A.2. Dynamics of tidal inlets and estuaries

Shark River Inlet sand bypassing project, Angas, W.M., 1960.

Report on beach erosion at Manasquan Inlet, N.J. and adjacent beaches, Anonymous, 1938.

Tidal inlet problems along the New England coast, Arpin, O.E., 1970.

Penetration of salt water and its effect on tidal areas of the U.S. of America, Baehr, J.C., 1953.

Annotated bibliography on the geologic, hydraulic and engineering aspects of tidal inlets, Barwis, J.H., 1976.

Channel improvement, Fire Island Inlet, N.Y., Bobb, W.H. and Boland, R.A., 1969.

Response characteristics of tidal inlet, A case study, Byrne, R.J. and others, in press.

Sedimentological study of an active part of a modern tidal delta, Moriches Inlet, L.I., N.Y., Caldwell, D.M., 1972a.

Sedimentation in Harbors, Caldwell, J.M., 1950.

Bay, inlet and nearshore marine sedimentation, Charlesworth, L.J., Jr., 1968.

Sedimentation at Beach Haven - Little Egg Inlet, N.J., Charlesworth, L.J. and Briggs, L.I., 1968.

Atlantic coast of Long Island, Fire Island Inlet and shore westerly to Jones Inlet, Corps of Engineers, 1970.

Holocene sediments of the Parker River estuary, Daboll, J.M., 1969.

Layout of outer protective works, maintenance of depth in harbors, on sandy shores and before mouths of estuaries, Dent, E.J., 1935.

The improvement of the channel at the entrance to the harbor of N.Y., Edwards, J., 1891.

A computer simulation model of sedimentation in a salt wedge estuary, Farmer, D.G., 1971.

III.A.2. (continued)

Texture and organic carbon content of bottom sediments in some estuaries of the U.S., Folger, D.W., 1972.

Characteristics of estuarine sediments of the U.S., Folger, D.W., 1972.

Case history of Fire Island Inlet, N.Y., Gofsergeff, S., 1952.

The influence of waves on the origin and development of the offset coastal inlets of the southern Delmarva Peninsula, Virginia, Goldsmith, U. and others, in press.

Fire Island Inlet, Haupt, L.M., 1889.

Harbor bar improvements, Haupt, L.M., 1889.

Geomorphology and sedimentation of some New England estuaries, Hayes, M.O., 1971.

Sedimentation in estuaries with reference to the Merrimack and Parker Rivers, Mass., Hayes, M.O. and McCormick, C.L., 1967.

Offset coastal inlets, Hayes, M.O. and others, 1970.

Sand deposition in the Chatham Harbor estuary and on the neighboring beaches, Cape Cod, Mass., Hine, A.C., 1972.

Bedform distribution and migration patterns on tidal deltas in the Chatham Harbor estuary, Cape Cod, Mass., Hine, A.C., 1973.

Movement of deep-water estuarine bedforms in the lower Parker River estuary, Plum Island, Mass., Hubbard, D.K., 1971.

The morphology and hydrodynamics of the Merrimack ebb-tidal delta, Hubbard, D.K., 1973.

Hydrography tides and tidal flushing of Great South Bay - South Oyster Bay, L.I., Ichiye, T., 1968.

Tidal prison - inlet area relationships, Jarrett, J.T., 1976.

Environmental characteristics of Raritan Bay, a polluted estuary, Jeffries, H.P., 1962.

III.A.2. (continued)

Barnegat Inlet, a problem and a solution, Johnson, J.A., 1969.

Estuary and coastline hydrodynamics, N.Y., Johnson, J.W. and P.S. Engleson, 1966, in A.J. Ippen, ed.

Offset tidal inlets, L.I., N.Y., Kaczorowski, R.T., 1972.

A study of the current structure in the Sandy Hook Rockaway Point transect, Kao, A., 1975.

A formula for the calculation of tidal discharge through an inlet, Keulegan, G.H. and Hall, J.V., Jr., 1950.

Sand body created by migration of Fire Island Inlet, N.Y., (abstr.), Kumar, N., 1972.

A study of Barnegat Inlet, Lucke, J.B., 1934,

Sand waves and tidal channels in the entrance to Chesapeake Bay, Ludwick, J.C., 1970.

The Hudson River estuary, McCrone, A.W., 1966.

Landward transport of bottom sediments in estuaries of the Atlantic Coastal Plain, Meade, R.H., 1969.

Transport and deposition of sediments in estuaries, Meade, R.H., 1972.

Natural flushing ability in tidal inlets, Mota-Oliveira, I.B., 1970.

Source of detrital minerals in estuaries of the Atlantic coastal plain, Neiheisel, J., 1973.

Notes on tidal inlets on sandy shores, Obrien, M.P., 1976.

Lower Hudson River siltation, Pannzio, F.L., 1965.

Tidal sonomena in the harbor of N.Y., Parsons, H. de B., 1913.

Moriches Inlet, a problem in beach evolution, Patton, R.S., 1931.

III.A.2. (continued)

Tidal inlets and washover fans, Pierce, J.W., 1970.

Sediment transport and sedimentation in the marine environment, Postman, H., 1967.

The analysis of tidal phenomena in narrow embayments, Redfield, A.C., 1950.

Report on tidal entrances, Reynolds, K.C., 1951.

Navigation channel improvements, Barnegat Inlet, N.J., Sager, R.A. and Hollyfield, N.W., 1974.

Sand transfer, beach control and inlet improvements, Fire Island Inlet to Jones Beach, N.Y., Saville, T., 1960.

The estuarine environment, estuaries and estuarine sedimentation, Schubel, J.R. and others, 1971.

The geological history of harbors, Shaler, N.S., 1893.

Spread of buoyant jets at the free surface, Sharp, J.J., 1969.

Hydraulic model studies of tidal waterways problems, Simmons, H.B. and Lindner, C.P., 1965.

Estuarine and littoral depositional patterns in the surficial sand sheet, central and southern Atlantic shelf of North America, Swift, D.J.P. and Sears, P., 1974.

Annual Reports of the Chief of Engineers, U.S. Army Corps of Engineers, 1885-1930.

Fire Island Inlet and shore westerly to Jones Inlet, U.S. Army Corps of Engineers, 1955.

Study on use of hopper dredge for beach nourishment, U.S. Army Corps of Engineers, 1967.

National shoreline study report, U.S. Army Corps of Engineers, 1971.

Preliminary examination of Chatham New Harbor, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1894.

III.A.2. (continued)

Westport River, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1938.

Scituate Harbor, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1938.

Newbury Port Harbor, Mass., U.S. Army Engineer District, Boston, Corps of Engineers, 1940.

East Point Judith, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1889.

Survey of inner harbor at Point Judith Pond, Rhode Island, U.S. Army Engineer District, Newport Corps of Engineers, 1897.

Point Judith Harbor of Refuge, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1908.

Point Judith Pond, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1916.

Point Judith Harbor of Refuge, Rhode Island, U.S. Army Engineer District, Newport, Corps of Engineers, 1917.

Harbors of Refuge at Point Judith, Block Island and Great Salt Pond, and adjacent waters, etc., U.S. Army Engineer District, N.Y., Corps of Engineers, 1903.

East Rockaway (Debs) Inlet, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1929.

Shark River, N.J., U.S. Army Engineer District, N.Y., Corps of Engineers, 1939.

Jones Inlet, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1941.

Fire Island Inlet, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1948.

Shore of New Jersey from Sandy Hook to Barnegat Inlet, beach erosion control study, U.S. Army Engineer District, N.Y., Corps of Engineers, 1955.

III.A.2. (continued)

Fire Island Inlet to Jones Inlet, L.I., N.Y. cooperative beach erosion study, U.S. Army Engineer District, N.Y., Corps of Engineers, 1956.

Atlantic coast of L.I., N.Y., Fire Island Inlet to Montauk Point, cooperative beach erosion control and interim hurricane study (survey), U.S. Army Engineer District, N.Y., Corps of Engineers, 1958.

Moriches and Shinnecock Inlets, L.I., N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1959.

Raritan Bay and Sandy Hook Bay, N.J., cooperative beach erosion control and interim hurrican study (survey), U.S. Army Engineer District, N.Y., Corps of Engineers, 1960.

South Shore of Long Island from Fire Island Inlet to Montauk Point, N.Y., beach erosion control study and hurricane survey, U.S. Army Engineer District, N.Y., Corps of Engineers, 1960.

Atlantic coast of L.I., Fire Island Inlet and shore westerly to Jones Inlet, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1965.

Atlantic Coast of New York City from East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, N.Y., U.S. Army Engineer District, N.Y., Corps of Engineers, 1965.

Jones Inlet to Montauk Point, N.Y. (remaining areas), U.S. Army Engineer District, N.Y., Corps of Engineers, 1967.

Shark River, N.J., U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1890.

Barnegat Inlet, N.J., U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1936.

Manasquan River, N.J., U.S. Army Engineer Distict, Philadelphia, Corps of Engineers, 1941.

Barnegat Inlet, N.J., U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1945.

Absecon Inlet, N.J., U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1946.

III.A.2. (continued)

Atlantic City, N.J., Beach erosion control study, U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1950.

Cold Spring Inlet (Cape May Harbor), New Jersey, U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1953.

Ocean City, N.J., beach erosion control study, U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1953.

New Jersey coastal inlets and beaches - Great Egg Harbor Inlet to Stone Harbor, U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1969.

Chatham (Stage) Harbor, Mass., U.S. Army Engineer District, Providence, Corps of Engineers, 1941.

Harbor of Refuge at Point Judith and Point Judith Pond, Rhode Island, U.S. Army Engineer Division, New England, Corps of Engineers, 1947.

Plum Island, Mass., beach erosion control study, U.S. Army Engineer Division, New England, Corps of Engineers, 1953.

Point Judith, Rhode Island, U.S. Army Engineer Division, New England, Corps of Engineers, 1962.

Edgartown Harbor, Martha's Vineyard, Mass., U.S. Army Engineer Division, New England, Corps of Engineers, 1970.

Model study of plans for elimination of shoaling in Absecon Inlet, N.J., U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, 1943.

Barnegat Inlet, N.J., U.S. Army Shore Protection Board, Corps of Engineers, 1933.

A model for the evolution of linear tidal built sand ridges in Delaware Bay, U.S.A., Weil, C.B., R.D. Moose and R.E. Sheridan, 1974.

Development of alternative dredging program related to the navigation project at Fire Island Inlet, N.Y. and Feeder Beach project for the shore westerly to Jones Inlet, N.Y., Wells, J.E. and Turner, T.M., 1972.

III.A.2. (continued)

Recent changes in the south inlet into Edgartown Harbor, Martha's Vineyard, Whiting, H.L., 1889.

The sediments of the south shore of Long Island Sound, Lloyde Point to Crane Neck Point, Krebs, O.A., 1962.

Oceanography of Long Island Sound, 1952-1954, II, physical oceanography, Riley, G.A., 1956.

Sediments of the Smithtown Bay area Long Island, New York (title not accurate), Schafer, C., 1963?

III.A.3. Barrier Islands and Their Possible Origins

The dynamics of beaches and barrier islands discussed in the previous section on beach development and erosion did not touch upon the fact that there is a controversy concerning barrier island origin. The best accumulation of information relating to this controversy of origin can be found in Schwartz (1973). This volume is a collection of papers from the mid-1800's to about 1970 which have discussed the possible origins of barrier islands.

Before getting into the controversy of barrier island origin, it would be best, first, to define just what barrier islands are. Barrier islands are elongated sand bodies of beach and dune material which lie parallel to the mainland shore separated from the mainland by a bay or a lagoon, or in some cases, by salt marsh. Barrier islands commonly are one to two miles wide and often up to ten miles in length. There are some barrier islands which are as long as 105 miles in length along the coast of the eastern United States. The individual islands themselves are separated by tidal inlets. A group of barrier islands along the coast is usually referred to as a barrier island system and it is this system of barrier islands which protects the low lying coastal plains of the mainland from wave attack. Virtually all of the beaches on the south shore of Long Island, along the New Jersey coast, Delaware, Virginia, North Carolina, and South Carolina are barrier islands. In some places, such as at the east end of Long Island, one end of the barrier system is attached to the mainland or headland and the barrier island itself appears to be a very extensive spit extending from the point of attachment. As these barriers elongate or extend themselves in the direction of longshore current movement, storm waves may wash across any part of the island which is low lying, such as in an area where dunes are very low and where the barrier island is very narrow. It is possible, particularly during hurricanes, for storm waves to wash completely across the barrier island. In many cases when this happens, the area of the island which has been breached by storm waves becomes a channel where the accumulated high tidal waters behind the island will rush seaward forming a new inlet. There are many examples along coasts of the world where new inlets have formed virtually overnight as a result of first storm wash-over and then a return of the high tide waters during ebb through this new channel. Frequently the flood and ebb tide movement through this newly created channel will be of sufficiently high energy that the inlet will remain open. Once this new inlet has formed it means that the part of the island which is in the downdrift direction from it is truly a totally isolated body of sand, not attached to a headland nor to any other part of the mainland. This process of barrier island

growth is elongation and breaching. These new inlets are subject to the same kinds of processes to which all other tidal inlets are subject; that is, tidal deltas will form seaward or landward of the tidal inlet, and, depending upon the dynamics of the current system, the tidal inlet may or may not be kept open for very many years after its formation. Typically, once a tidal inlet exists, man attempts to keep it open. Usually the Corps of Engineers will dredge the sand, and keep the inlet open for the residents on the adjacent mainland. These new inlets often form much shorter routes to the sea, particularly for fishing fleets. Thus, it may be economically wise, or at least expedient, to maintain these new tidal inlets.

The origin of barrier islands, which is a debated issue in the current geologic literature, takes two basic forms. The earliest view held in the middle 1800's concerning barrier island origin stated that waves approaching the shore built bars offshore above wave base. They continued to build, emerging above the water surface and beach and dune ridge systems formed. This is essentially the theory of offshore bar development. The second principal theory of barrier island origin was first discussed by G.K. Gilbert and later examined by D.W. Johnson in the middle 1920's. Gilbert's theory stated that barrier islands form by spit extension on the downdrift end of beaches and later, during storms, overwash and spit breaching isolate that portion of the spit downdrift.

It was not until 1967 that there was any serious re-examination of the basic theories of barrier island origin. During the first half of the 20th century the concept of spit extension dominated and, once that view was championed by D.W. Johnson in the 1920's, it remained the standard theory of explanation of barrier islands. However, in 1967, J.H. Hoyt questioned this theory on the basis of information taken from core examination of sediments near tidal inlets at the ends of barrier islands. In the very simplest terms, Hoyt's idea of barrier island formation is: 1) beaches and dune ridges formed along the mainland itself and are topographically higher than the low lying coastal plain behind it; 2) when sea level rose, the marine waters flooded the low areas behind the beach and dune system, forming a lagoon, and leaving the ridge as a barrier island. He based his hypothesis of barrier island formation, which he called submergence hypothesis, on four sets of observations. First, he found that there was an absence of open marine beach or shallow neritic sediments and fauna landward of present-day barriers which negates the bar-emergence theory. Secondly, he observed the ability of barrier island systems to reform after they have been terminated by an emergence. Thirdly, he noted the absence of a worldwide higher-than-present sea level during the Holocene. Fourth, he based his hypothesis on the development and maintenance of barrier island systems during the rise in sea level during the last 18,000 years. J.J. Fisher (1968) wrote a discussion of Hoyt's (1967) paper in which he disagreed with the basic idea. Fisher cited extensive evidence

of spit extension and the development of barrier islands by simple inlet formation by spit breaching during storms. Essentially, he was returning to the concept of D.W. Johnson. Hoyt (1968) replied to this discussion. This was followed by another paper by Fisher (1968) also cited below in the list of references. This controversy between Hoyt and Fisher essentially brought together some of the basic ideas of barrier islands and their formation and probably generated the stimulus for the compilation of the 40 papers that appeared in Schwartz (1973), the best available review of the literature on barrier islands. This is a collection of reprints of the important papers spanning the period from 1848 to 1972 with explanatory remarks by Schwartz including the controversy generated by Hoyt and Fisher. Another aspect of this book by Schwartz is its inclusion of a number of papers in English by Russian authors.

In the middle 1970's, the discussion of barrier islands took a somwhat different turn. Not in the form of controversy, but in the form of much more extensive observation by the groups at NOAA and at CERC. They began to realize that the sediments which form barrier islands were generated by erosion of the shoreface; that is, the sediments which make up the beaches and dunes of the barrier islands of eastern United States are not sand which comes from river mouths, but instead comes from the sandy part of the inner shelf and shoreface itself.

Swift (1975) showed that the nature of barrier island development was in large part related to the slope of the inner shelf and that the coastal regions of the world which were very low lying were areas where submergence of beach and dune ridges could easily occur. In contrast, he showed that in areas of rather steep shoreface slopes that the only probable mechanism for barrier island development was extension of spits from the mainland. A second paper by Swift (1976) followed that by Field and Duane (1976) in which they examined the Holocene evolution of the inner shelf of the middle Atlantic of the eastern United States. Both the paper by Swift and the paper by Field and Duane are of major importance at a time when the thinking is changing in terms of how barrier islands actually form.

Field and Duane (1976) describe a viable model of barrier island development. Their model as viewed in the light of the inner shelf sedimentary record is as follows:

The barrier island coast is one which alternately erodes and progrades, but ultimately retreats in concert with a fluctuating, but steadily rising, Holocene sea level. Thus, the present barrier islands seen along the eastern coast of the

U.S. have been derived from landward-retreating Holocene barrier islands originating on the shelf far out from the present position from which they occur. This interpretation is based on the following information:

a. The shape and the nature of the surface and subsurface deposits on the inner shelf.

b. The orientation of shelf features.

c. The association of continental shelf shoals with capes, inlets and barrier spits.

d. The relationship of the occurrences, the shape and the lithology of shelf sedimentary bodies is strongly related to the adjacent coastal morphology suggesting complex derivation -- a landward retreat coupled with coastwise migration during marine transgression.

The process can explain the generation of a vertical sedimentary sequence of modern, reworked shelf sands overlying a planed-off Holocene back-barrier and lagoon deposits which in turn overlie Pleistocene fluvial and/or coastal deposits. Surficial shelf sands are separated from the underlying strata by an erosional unconformity. This unconformity is continually being formed as back-barrier sediments are planed off in the shallow marine environment prior to temporary preservation by burial under a migrating sand shoal.

Thus, there is compelling evidence that large barrier island systems evolved during Holocene and the systems were driven upward and landward by the transgressing sea. The evolution of a barrier island system is explained by Fisher's (1967) spit elongation and segmentation. With the initiation of a sea-level rise, the exhumed sea-floor surface, with its varieties of land forms, begins to be modified by the marine processes creating sediment, producing transported sediment and resulting in spit and barrier growth, inlet filling, estuary entrance constriction, dune build-up and overwash. With sea level rise, the coastline is translated shoreward. This process does not imply that one continuous barrier island system has been retreating through time or even that most of the barriers were formed at the same time or the same location on the outer continental shelf surface. The individual barrier segment is simply formed and reformed by the processes described above.

During the period that these two landmark papers were published, Glaeser (in press) examined the distribution of barrier islands on a global scale. The intent of that work was to see what relation might exist among coastlines of various

tectonic types. This examination was based on the paper by Inman and Nordstrom (1971) in which they defined essentially two major types of coastal regions; those related to passive tectonic margins; that is, those which face spreading centers; and those which are related to collision margins. It was immediately obvious that passive margin coastlines contain more barrier islands than collision coastlines, although, up to that point, there had been no measurement on a global scale of their actual distribution with respect to tectonic character of the coast. Glaeser (in press) demonstrated a clear relationship between passive margins and the abundance of barrier islands. The preponderance of barrier islands occur along tectonically passive coasts which have broad coastal plains. The following review of the article by Glaeser is taken from the abstract of the article, "Global Distribution of Barrier Islands in Terms of Tectonic Setting."

Measurements of the global abundance of barrier islands indicate that 49% occur along coastlines of trailing continental margins; 24% along collision plate margins, and 27% along coastlines of marginal seas. Based on 2,619 shelf width measurements, evidence is presented to show that for only trailing margins is shelf gradient related to barrier island abundance. Of those barrier islands situated along trailing margin coasts 75% occur along Amero-trailing margins (average gradient 0.57 meters per km); 19%, along Afro-trailing margins (average gradient 2.4 meters per km); and, 6% along Neo-trailing margins (average gradient 5.9 meters per km). Because sediments supplying barrier islands today are generated mainly on the inner shelf and shoreface in response to both nearshore processes and to rising sea level, barrier islands occur in greatest abundance where broad, low-lying coastal plains lie adjacent to the inner shelf and where both contain abundant unconsolidated detritus. Elsewhere, barrier island occurrence is sparse to absent along very low gradient shelves where the coastal plain-continental shelf sedimentary prism is absent. The tectonic setting of the continental margin is fundamental in controlling factors governing barrier island abundance.

III.A.3. Barrier Islands and Their Possible Origins

Observations to determine the cause of the increase of Sandy Hook, Bache, A.D., 1856.

Submergence effects on a Rhode Island barrier and lagoon and inferences on migration of barriers, Dillon, W.P., 1970.

Post-Pleistocene history of the U.S. inner continental shelf, significance to origin of barrier islands, Field, M.E. and Duane, D.B., 1976.

Origin of barrier island chain shorelines, middle Atlantic states, Fisher, J.J., 1968a.

Barrier island formation, Fisher, J.J., 1968b.

Barrier island and migration, new evidence from N.J., Frank, W.M. and Friedman, G.M., 1971.

Global distribution of barrier islands in terms of tectonic setting, Glaeser, J.D. (in press), Journal of Geology.

Comparison of ecological and geomorphic interactions between altered and unaltered barrier island systems in North Carolina, Godfrey, P.J. and Godfrey, M.M., 1973.

The influence of waves on the origin and development of the offset coastal inlets of the southern Delmarva Peninsula, Virginia, Goldsmith, U., and others, in press.

Barrier island formation, Hoyt, J.H., 1967.

Barrier island formation, Hoyt, J.H., 1968.

Development and migration of barrier islands, northern Gulf of Mexico, Hoyt, J.H., 1970.

Influence of island migration on barrier island sedimentation, Hoyt, J.H. and V.J. Henry, 1967.

Modern and ancient barrier sediments, new interpretations based on stratal sequence in inlet-filling sands and on recognition of nearshore storm deposits, Kumer, N., 1972.

Effects of erosion on barrier-island morphology Fire Island, N.Y., Ruzyla, K., 1973.

III.A.3. (continued)

Barrier islands, Schwartz, M.L., 1973.

Barrier island genesis, Swift, D.J.P., 1975a.

Geomorphology of the south shore of Long Island, N.Y., Taney, N.B., 1961.

Growth and migration of digitate spits (April-September 1971) at Democrat Point, Fire Island, N.Y., Wolff, M.P., 1972.

Post-Pleistocene history of the U.S. inner continental shelf, significance to origin of barrier islands, discussion and reply, Otvos, E.G., Jr., 1977.

III.B. Currents and Circulation Dynamics of the Outer Continental Shelf

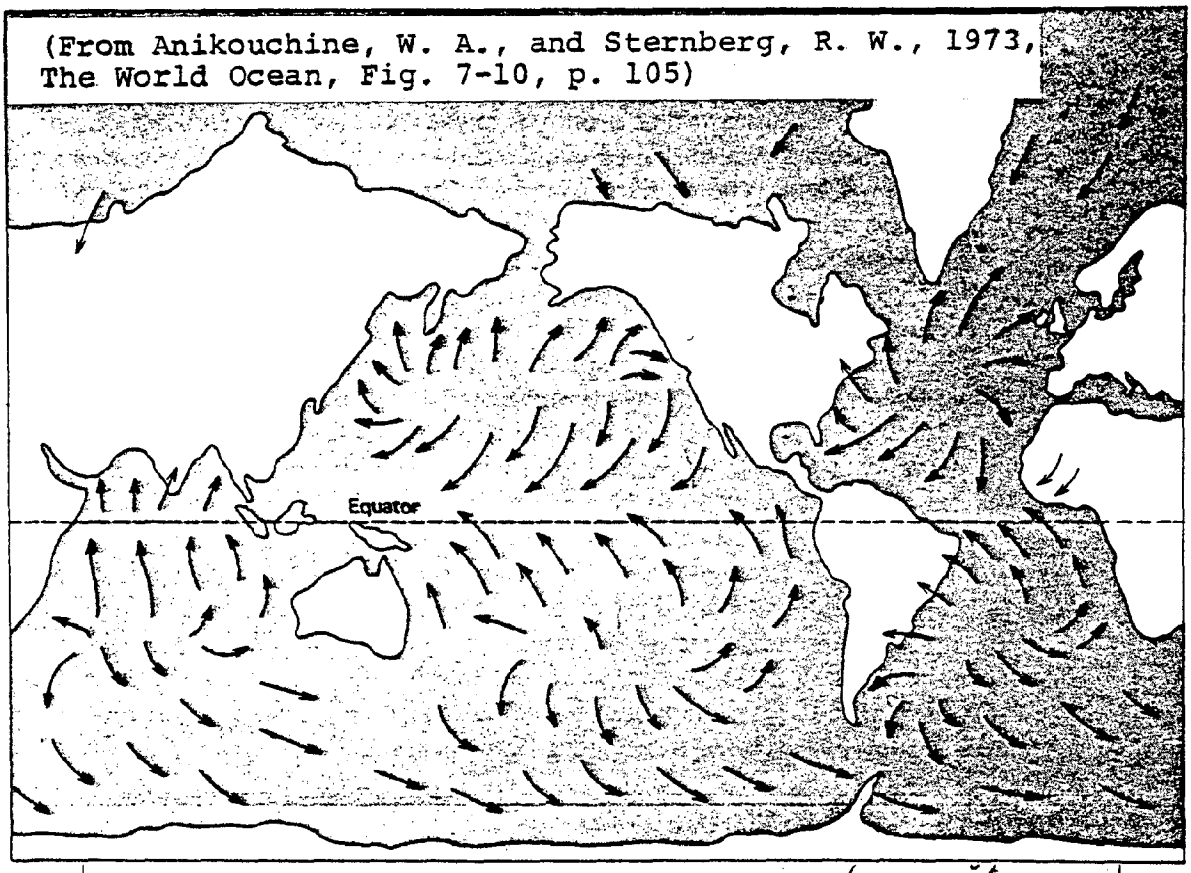
Discussion of circulation dynamics of the outer continental shelf is probably one of the most difficult sections of this report to put together in a quantitative way. The reason for the difficulty is simple. The description of circulation dynamics is based on physical oceanography which is fundamentally a mathematical application to an area of fluid dynamics which most geologists are unable to deal with except in qualitative terms. There is no attempt in the following chapter to give a comprehensive view in quantitative terms of the physical oceanography of the Atlantic continental shelf. We can look at this in a qualitative way, however, to gain some feeling for the problems involved in understanding circulation dynamics of the continental shelf. A qualitative understanding is crucial because most environmental problems which will be faced by states bordering the coastline when there is exploration offshore are related to the circulation system which prevails on the shelf. It is this system which brings pollutants such as oil spills to the shore. This may affect the organisms in the sea, and may transfer pollutants to the sediments and have very long-term effects on geological, chemical and biological factors of the marine environment.

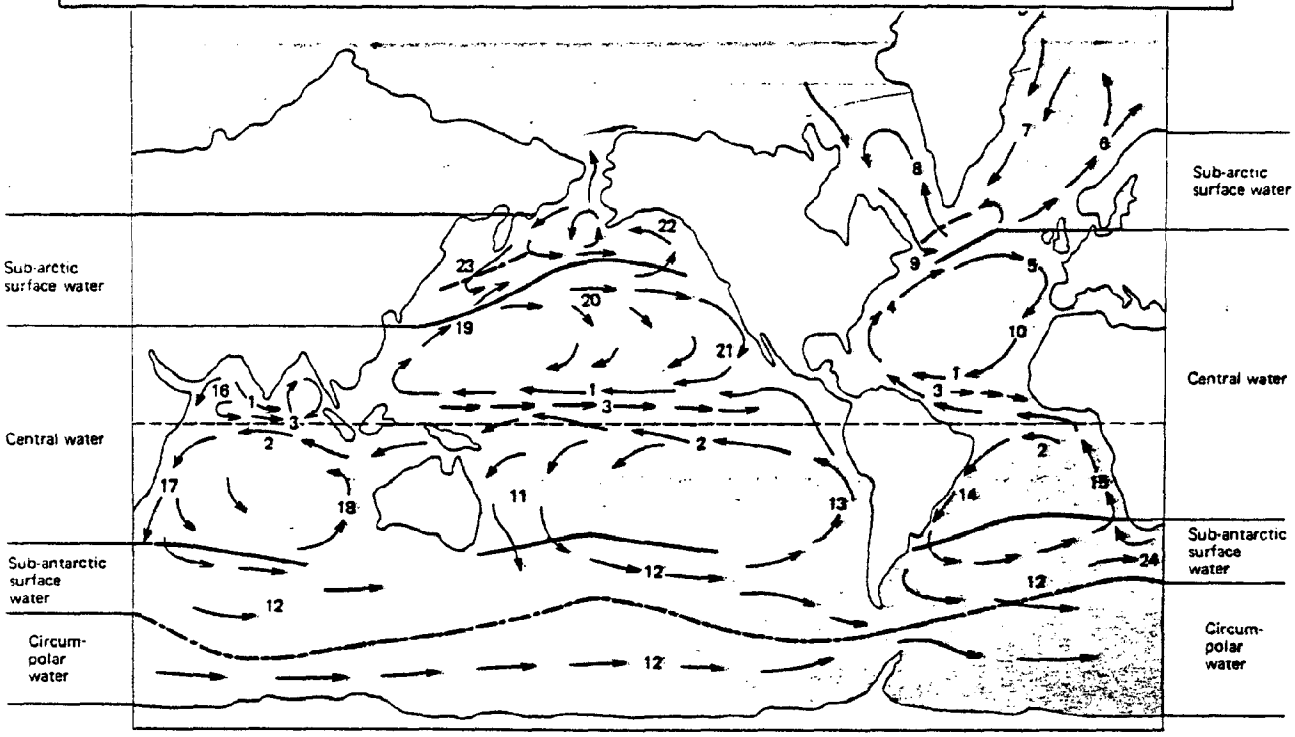
There are two kinds of circulation in the ocean. First is surface water circulation which is a response to atmospheric circulation. The second is geostrophic circulation. Geostrophic circulation is the three dimensional movement of water masses in response to their differences in density. Density differences are controlled by temperature and by salinity variation. Either of these two factors can control movement of geostrophic currents, and in many cases, both control movements of water masses.

The following discussion of surface circulation, which effects the outer continental shelf waters of the mid-Atlantic, begins with a general point. Atmospheric circulation patterns on a global scale cause movements on the ocean surface. Any general text book in atmospheric sciences shows maps indicating that air rising from warm equatorial zones tends to move toward the poles (Figure 22A). As this movement occurs, air masses are deflected by the Coriolis force. The deflection is to the right northern hemisphere and to the left in the southern hemisphere. The winds transfer energy of motion to the water surface by frictional drag. Generally, the speed of the water surface is about 2% of the wind speed. There is a major flow of air, the trade winds, on either side of the equator which move from the eastern side of the Atlantic to the western side of

FIGURE 22A Surface winds over the World Ocean (average for July). (After U.S. Navy Hydrographic Office Publication No. 9, 1958.)

(From Anikouchine, W. A., and Sternberg, R. W., 1973, The World Ocean, Fig. 7-10, p. 105)





1	North Equatorial C.	5	North Atlantic C.	9	Laborador C.	13	Peru C.	17	Mozambique C.	21	California C.
2	South Equatorial C.	6	Norwegian C.	10	Canary C.	14	Brazil C.	18	West Australian C.	22	Aleutian C.
3	Equatorial Counter C.	7	East Greenland C.	11	East Australian C.	15	Benguela C.	19	Kuroshio C.	23	Oyashio C.
4	Gulf Stream C.	8	West Greenland C.	12	Antarctic Circumpolar C. (West Wind Drift)	16	Somali C.	20	North Pacific C.	24	Agulhas C.

FIGURE 22B

Surface currents and surface water of the world ocean. Also included are the major convergences. = sub-tropical convergence (place of origin of Central Water); = arctic, antarctic convergence (place of origin of Intermediate Water). = surface current.

(From Anikouchine, W. A., and Sternberg, R. W., 1973, The World Ocean, Fig. 7-1, p. 97)

FIGURE 22. Surface winds and water currents of the world ocean

the Atlantic parallel to zones of latitude just north and south of the Equator (Figure 22B). As the water currents move in response to the air currents parallel to latitude lines, the waters acquire the temperature of the air along that latitude. However, the presence of continents in the world ocean interrupts this east to west movement of both air and water masses, especially because the continents are elongated in a north-south direction. Thus, the continents cause a deflection of ocean currents in a north or south direction. These deflected currents near the continental margins are called boundary currents. On the western side of ocean basins, and in particular, along the edge of the North American continental margin, the boundary current is very sharply defined. Along the east coast of the United States the boundary current is the Gulf Stream, which carries warm waters in a north and northeasterly direction along the continental margin. South of Cape Hatteras the Gulf Stream is very close to the shelf edge. Off Cape Hatteras, the Gulf Stream is deflected seaward from the shelf break. The Gulf Stream is, in places, on the order of 100 km wide and the depth of transport of the water mass reaches at least 2 km. The speed of movement this boundary current is on the order of 10's of km per day. The significance of this kind of boundary current is: 1) it produces a sharp boundary between shelf and coastal waters and the open ocean waters because it is a discrete water mass itself. This means that nutrients or pollutants or any material in suspension in coastal waters do not mingle easily with open ocean waters. It is for this reason, in part, that the open ocean waters beyond the Gulf Stream are relatively low in nutrients and rather unproductive. Thus, in the middle Atlantic region of the eastern United States, there is a very distinct difference between shelf waters and open ocean waters so that they may be considered separately in discussions of surface circulation patterns.

It is important to discuss geostrophic currents. These currents are a product of density differences of water masses. The surface circulation of water just discussed produces areas of differing temperatures and of different salinities. This occurs by differential evaporation, precipitation, or freezing and melting depending upon location within the ocean environment. The water masses of the ocean are thus stratified by density differences caused by these temperature and salinity variations. This stratification, in a very general way, defines three zones of ocean water -- the surface waters, which are those waters mixed and stirred by atmospheric circulation; an intermediate zone of rather pronounced increases in density downward; and below this, a zone of deep ocean water where there is a relative uniformity of temperature, salinity and, therefore density. In this discussion we do not need to be concerned with deep ocean

water because typically the zone of density change (the intermediate zone) which is called the pycnocline extends to depths of about 2 km which are well below depths of the continental shelf.

The only two water masses that need to be considered on the continental shelf are suface waters and the waters of the pycnocline zone. Each of these water masses has characteristics which can be reviewed in a qualitative way. Surface waters undergo significant seasonal changes in evaporation and precipitation which cause changes in salinity. They also show significant seasonal change in temperature. Surface waters undergo a great deal of vertical mixing by strong winds and waves.

In contrast to the usually well-mixed surface waters, the pycnocline water density increases significantly with depth. In tropical regions the water temperature curve coincides, more or less, with the pycnocline. However, in mid-latitudes, such as the New York bight and off of the edge of the continental shelf of New York, there are large seasonal variations in precipitation and evaporation, and it is the salinity values which change with depth. Thus, in mid-latitude zones, salinity values are the major control of the pycnocline whereas in tropical zones, temperature is the principle control. Deep ocean waters which usually occur below depths of 2 km represent at least 80% of the water of the world's ocean basins.

The following discussion is one example of the importance of seasonal variations of the waters of the New York bight. During periods when temperatures of air and water of the New York bight are lowest, the waters are well mixed over the continental shelf because of winter storms. There is no stratification and essentially the waters over the continental shelf, at least in the inner shelf, are nearly homogeneous because of vertical mixing. In the spring, at the time of peak discharge from the rivers, there is a decrease in salinity, and an increase in temperature. Both changes produce less dense water and cause a stratification of the surface waters of the continental shelf. This surface-water mass of the New York bight is on the order of 10 to 20 meters deep, riding over a more dense, deeper, saltier, cooler underlying water mass. This is particularly significant because a great deal of the waste that is dumped into the Hudson estuary floats as a plume of effluent out over the shelf during these periods of maximum stratification; that is, in the spring and summer seasons. This plume of effluent floats towards the southeast just a few miles off the New Jersey coast. As the fall season approaches, cooling occurs and there is a decrease in the amount of fresh water coming into the New York bight from the adjacent rivers. When this occurs, the

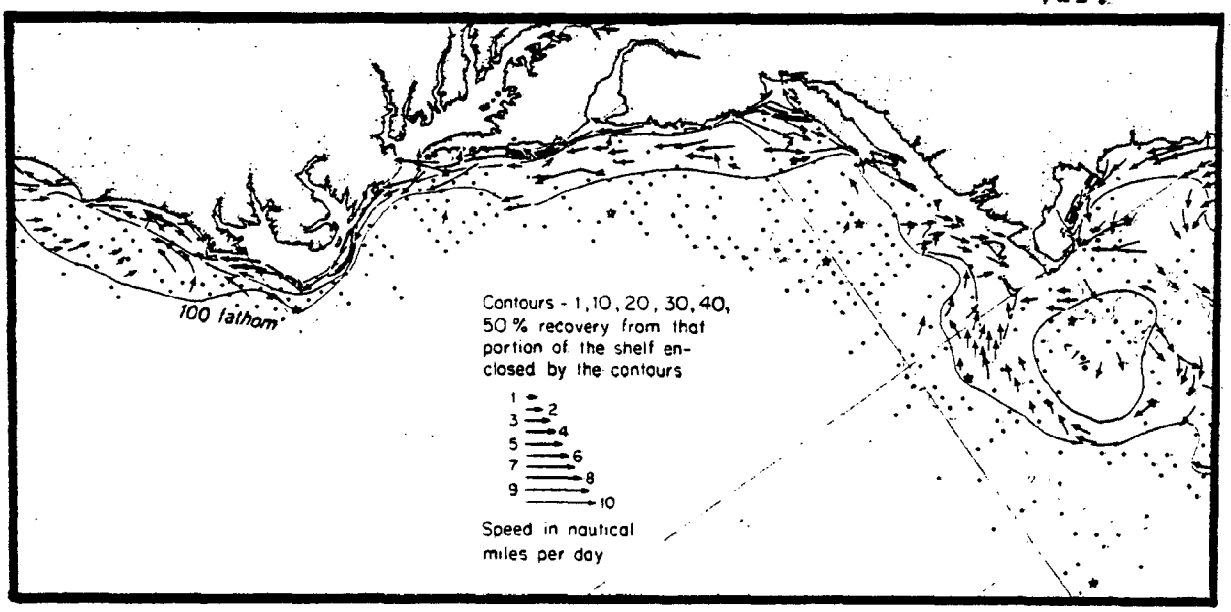


FIGURE 23A

1.6 Inferred surface drift, April, 1960-1970.

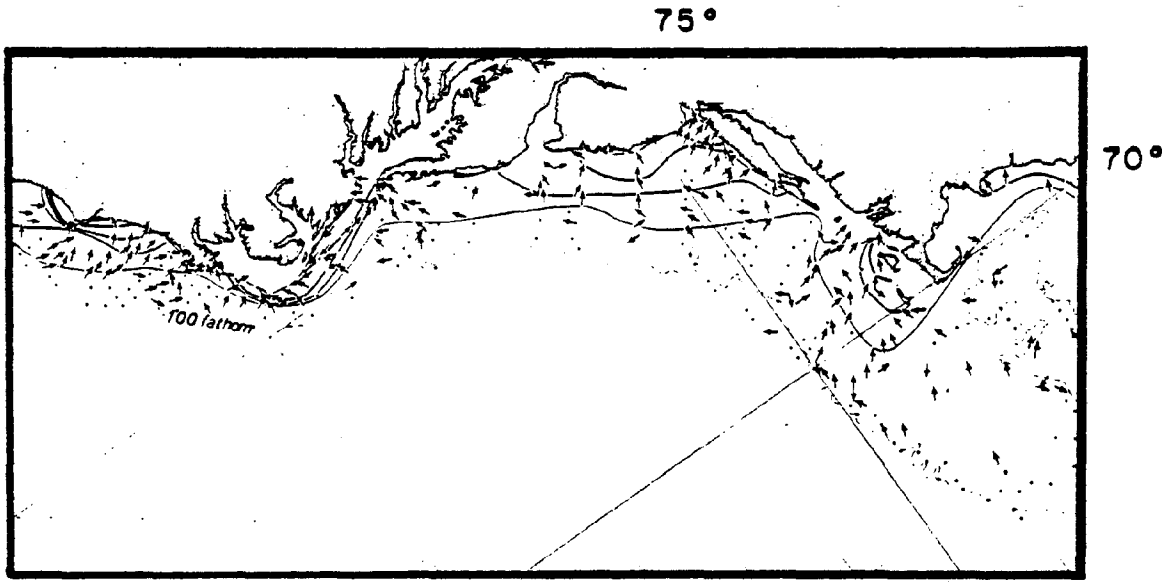


FIGURE 23B

1.18 Inferred bottom drift, April, 1961-1970. Contours define on shore recovery rates of 10, 20, 30, 40, 50 and 60%.

Inferred surface and bottom drift during April on the Mid-Atlantic Shelf.

(From Bumpus, D. F., 1973, A Description of the circulation on the continental shelf of the east coast ot the United States)

FIGURE 23

water masses are no longer stratified and the effluent becomes thoroughly mixed in the shelf waters. Thus, during seasons of non-stratification of shelf waters of the New York bight, there is a greater assimilation of waste products when the waters are well mixed. Thus, if it were possible to govern the amount of material discharged into river systems, one would have some control over the mixing and the assimilation that can occur in a seaward direction by taking advantage of these seasonal variations.

Recent data from current meters near the shelf break gives some evidence that bottom currents move from the shelf edge toward the Hudson estuary. In addition, it has already been shown that wave action, when it affects bottom material, moves the material landward.

Maps of both surface and bottom circulation of shelf waters are shown on Figure 23A and B. These maps show averages of net drift for the month of April during 1960-1970. They cannot be used to predict a specific event at a given site during certain atmospheric conditions in that month, but rather show the general behavior of the water during that time of year.

III.B. Currents and Circulation Dynamics of Outer Continental Shelf

Some mechanisms of oceanic mixing revealed in aerial photographs, Assaf, G. and others, 1971.

Circulation on the New England Continental Shelf, Beardsley, R.C. and Butman, B., 1974.

Surface drift on the Atlantic continental shelf of the U.S., 1960-1967, Bumpus, D.F., 1969.

A description of circulation on the continental shelf of the east coast of the U.S., Bumpus, D.F., 1973.

Surface circulation on the continental shelf of eastern North America between Newfoundland and Florida, Bumpus, D.F. and Lauzier, L.M., 1964.

The effects of waste disposal in the New York Bight, Charnell, R.L., and others, 1972.

Utility of ERTA - 1 for coastal ocean observation, Charnell, R.L., Jr. and others, 1974.

Water movement within the apex of the NY Bight during summer and fall of 1973, Charnell, R.L. and Mayer, D.A., in press, 1974.

Some specific problems in understanding bottom sediment distribution and dispersal on the continental shelf, Creager, J.S. and Sternberg, R.W., 1972.

Wave induced bottom currents on the outer shelf, Ewing, J.A., 1973.

Wind drift surface currents and spread contaminants in shelf waters, Gordon, A.L. and Gerard, R.D., in press.

Circulation of shelf waters off the Chesapeake Bight, Harrison, W. and others, 1967.

New York bight project, water column sampling, Hazelworth, J.B. and others, 1974.

A study of the circulation of the western North Atlantic, Iselin, C.O.D., 1936.

The oceanography of the New York Bight, Ketchum, B.H. and others, 1951.

III.B. (continued)

The accumulation of water over the continental shelf between Cape Cod and Chesapeake Bay, Ketchum, B.H. and Keen, D.J., 1955.

Surface motion of water induced by the wind, Langmuir, I., 1925.

Mass transport in water waves, Longuet-Higgins, M.S., 1953.

Bottom currents near the coast during Hurricane Camille, Murray, S.P., 1970.

Principles of physical oceanography, Neumann, G. and W.J. Pierson, Jr., 1966.

Inferred surface and bottom drift, June 1963 through October 1964, Norcross, J.J. and Stanley, E.M., 1967.

Bottom environmental oceanographic data report, Hudson Canyon area, 1967, Oser, R.K., 1969.

The influence of the continental shelf on the tides of the Atlantic coast of the United States, Redfield, A.C., 1956.

Bottom-water temperatures on the continental shelf off New England, Schopf, T.J.M., 1967.

North Atlantic temperatures at depth of 200 meters, Schroeder, E.H., 1963.

Average surface temperatures of the western North Atlantic, Schroeder, E.H., 1966.

The new concepts of continental margin sedimentation, Stanley, D.J., ed., 1969.

Marine sediment transport and environmental management, Stanley, D.J. and Swift, D.J.P., 1976.

The Gulf stream -- a physical and dynamical description, 2nd ed., Stommel, H., 1965.

An observation of a deep countercurrent in the western North Atlantic, Swallow, J.C. and L.V. Worthington, 1961.

Shelf sediment transport, process and pattern, Swift, D.J.P. and others, 1972.

III.B. (continued)

Oceanographic atlas of the North Atlantic Ocean, Sec. V., Marine Geology, U.S. Naval Oceanographic Office, 1965.

Deep current observations in the western North Atlantic, Volkmann, G., 1962.

Topographic influences on the path of the Gulf Stream, Warren, B.A., 1963.

III.B.I. Indicators of Shelf Circulation

The general discussion above has touched upon some of the indicators of shelf circulation and the example of mixing and assimilation of pollutants is one indicator of shelf circulation dynamics. However, the problem is a much more complex one than the simple movement of pollutants. There are two major sources of information in print which deal with transport of material in shelf waters. The first is a book by Swift, Duane and Pilkey (1972), entitled "Shelf Sediment Transport-Process and Pattern." In that text three major areas of concern are discussed by a number of specialists in the field of shelf sedimentation and shelf circulation dynamics. The first of the three sections in that book deals with water motion and the process of sediment entrainment. The second section deals with patterns of fine sediment dispersal; that is, the movement of sediment in suspension. The third section deals with patterns of coarse sediment dispersal, which is based largely on understanding textural analyses across the shelf sediment.

There is a second major source of information relating to shelf circulation dynamics -- Swift and Stanley (1976),"Marine Sediment and Environmental Management." This text is divided into four parts. The first concerns continental margin circulation; that is, the entire problem of the physical oceanography of the continental shelf and the continental margin. Part two is a discussion of sediment entrainment and transport. The information in this section is significantly more advanced than that found in Swift, Duane and Pilkey (1972). This gives some idea of the rate of growth in the knowledge of shelf sediment processes. The third part of the text by Swift and Stanley discusses the patterns of sedimentation in space and time across the entire shelf region. It considers, for example, intra-coastal sedimentation, nearshore currents, and sediment transport and the resulting beach sediments. It then goes on to consider coastal sedimentation, continental shelf sedimentation, and the sedimentation processes that are going on at the shelf break in canyons, on continental slopes, and at the base of the continental slopes. A fourth section of this text book deals with sedimentation and environmental management. This latter section is an attempt to begin to understand the relationship between man's activities on the shelf and possible consequences to both the environment of the shelf and coastal waters and to the bottom sediments on the shelf surface.

III.B.1. Indicators of Shelf Circulation

Residual shift along the bottom on the continental shelf in the Middle Atlantic Bight area, Bumpus, D.F. 1965.

Preliminary results of coincident current meter and sediment transport observations for wintertime conditions on the Long Island inner shelf, Lavelle, J.W. and others, 1976.

Onshore transportation of continental shelf sediment, Pilkey, O.H. and M.E. Field, 1972.

Summary of sedimentary conditions on the continental shelf off the east coast of U.S., Stetson, H.C., 1939.

Sediment response to hydraulic regime on the central New Jersey shelf, Stubblefield, W.L. and others, 1975.

Implications of sediment dispersed from bottom current measurements, some specific problems in understanding bottom sediment distribution and dispersal on the continental shelf - a discussion of two papers, Swift, D.J.P., 1972.

Relict sediments on continental shelves, Swift, D.J.P. and others, 1971.

Substrate response to hydraulic process, grain-size frequency distributions and bed forms, Swift, D.J.P. and Ludwick, J.C., 1976.

III.B.1.a. Dynamics of Ridge and Swale Topography

The ridge and swale topography discussed in II of this report represents one of the major shelf features in the middle Atlantic bight. The first detailed regional description given of these linear shoals is found in Duane and others, 1972. They indicate that the inner shelf of the Atlantic continental shelf from Long Island southward is characterized by fields of linear shoals which have a northeast orientation. Some of these shoals reach 30 feet in height, have side slopes of 1 to 2 degrees, and are as long as 10 miles. These shoals have been studied from the shoreface area to depths of at least 120 feet by seismic profiling, precision depth profiling, grab sampling, and coring.

Despite the extensive amount of sampling and examination of linear shoals, there has been very little monitoring of the currents influencing ridge and swale topography. In order to find the relationship between the prevailing water currents and the movement of the sediment on them. However, the morphologic data on these linear shoals, as well as the hydraulic data that does exist, suggest that the shoals which are not attached to the shoreface are presently responding to the hydraulic regime of the inner shelf. During periods of storms, the crests of the shoals aggrade and, during fair weather, wave surge seems to degrade them. Swift and others (1972) considered the origin of the ridge and swale topography along with other irregularities on the shelf surface. Their hypothesis states that as sea level rises over an unconsolidated coastal region there is sediment erosion from the shoreface and a transfer seaward. The result is a discontinuous sheet of unconsolidated sediment which is a product of Holocene transgression. The surface of this sand sheet has been molded into at least three major kinds of morphologic units on the shelf surface. In places where the sheet has been generated directly by the erosion of a retreating shoreface as sea level rises ridge and swale topography has formed just off shore. In areas of cuspate forelands, such as Cape Hatteras and other cape regions along the eastern coast of the United States where there is a convergence of longshore drift, there has resulted a series of convex seaward shoals which have formed around these capes. A third type of sediment body which forms off of estuary mouths is the result of the intersection of littoral drift with the reversing motion of estuary tides. This has created shoals associated with the estuary itself.

Seaward of each of these three shoal types are earlier generations of the same shoal types; linear, cuspate or those associated with estuaries. It is this evidence of seaward similarities in the kinds of shoals which has led Field and Duane (1976) to suggest that the present day coastline of the middle Atlantic bight probably is parallel to the one which existed throughout the Holocene since the beginning of sea level

rise approximately 18,000 years ago. Field and Duane (1976) show a series of shoals seaward from each of the major features just described which mimic the shoals which can be seen today in the nearshore area.

The dynamics which control the linear shoals in the ridge and shoal topography is only now being understood. Most research in progress is by the group at NOAA at the Atlantic Oceanographic Marine Laboratory in Miami.

Probably the most important aspect of these features to this report is the need to see the actual physical distribution of the ridge and swale topography prior to any evaluation of lease or exploration sites. It is worth reiterating that the best source of this hydrographic information is Stearns (1967). This publication is a series of 15 bathymetric charts of the continental shelf in the New York bight region. Using these charts along with other publications such as Duane and others (1972), Lavelle and others (1976), and Stubblefield and Swift (1976), linear shoals, cape associated shoals, and shoals associated with estuary mouths can be described in considerable detail. The several diagrams in those papers are probably the best source of information showing the distribution of these ubiquitous topographic features of the middle Atlantic shelf.

Because of the scale and near ubiquity of these features, it is not practical to produce a single small scale map of the areas with ridge and swale topography. A useful tool to determine the topographic type in specific, lease tracts is a transparent overlay with a grid representing tract boundaries at the scale of the Stearns' (1967) charts. This overlay can be keyed to each of the charts by the appropriate latitude and longitude coordinates, and thus one can determine detailed bottom topography in any tract.

III.B.1.a. Dynamics of Ridge and Swale Topography

Migrating sand waves and sand humus, with special reference to investigations carried on in the Danish North Sea Coast, Brunn, P., 1954.

Observations on the hydraulic regime of the ridge and swale topography of the inner Virginia shelf, Holliday, B.W., 1971.

Depositional ridges in the North Atlantic, Johnson, G.L. and E.D. Schneider, 1969.

Stratigraphy of the sedimentary rocks of Delaware, Jordan, R.R., 1962.

Coastal morphology and processes in relation to the development of submarine sand ridges off Bethany Beach, Delaware, Moody, D.W., 1964.

Geomorphology of sand ridge, Smith, J.D., 1969.

Anatomy of a shoreface connected ridge system on the New Jersey shelf, Stahl, L. and others, 1974.

Underwater sand ridges on Georges Shoal, Stewart, H.B., Jr. and G.F. Jordan, 1964.

Ridge development as revealed by sub-bottom profiles on the central New Jersey shelf, Stubblefield, W.L. and D.J.P. Swift, 1976.

Tidal sand ridges and shoal retreat massifs, Swift, D.J.P., 1975.

Shelf sediment transport, process and pattern, Swift, D.J.P.,and others, 1972.

Anatomy of a shoreface ridge system, Swift, D.J.P. and others, 1972a.

Ridge and swale topography of the middle Atlantic Bight, North America, Swift, D.J.P. and others, 1973.

III.B.1.b. Across-Shelf Transfers of Suspended Material

The problem of movement of material across the shelf is only now beginning to be understood. There are three areas of studies which have given indication of across-shelf transfers. The first is the work by Bumpus, 1973, which shows the seasonal circulation patterns of surface shelf waters. His maps show surface and bottom circulation and suggest a net movement towards the shoreline across the shelf for each month. There is no clear information as to how this surface movement towards the shore affects the water masses at depth or how it actually moves sediment, if it moves sediment at all.

There is a second area of study which would suggest that circulation on the shelf does produce a net transfer of material to the shore. The definitive study on this process of shoreward transport of suspended sediment is by Meade (1969). There are two other relevant papers, Meade (1972) and Meade and others (1975). These show that fine suspended sediment is carried into the estuaries from a seaward direction and is trapped there, making a net landward transfer of suspended material. Meade (1969) points out that estuaries are sediment sinks. They trap not only sediments coming across shelf but they also trap a great amount of fine sediment which is coming from the continent by way of the rivers into the estuary. Meade (1969) pointed out that probably as much as 90% of the suspended material carried by rivers remains in the estuaries themselves, very little escaping the estuary to the shelf waters. Thus, there is a two-way delivery system; the river systems carrying the fine sediment to the estuary and the net transfer of fine suspended material toward and into the estuaries.

Some across-shelf transfer may be influenced by the net landward movement of bottom currents. Figure 23 shows average bottom current vectors for the New York shelf region during April. On-going work at Columbia University's Lamont-Doherty Geological Observatory is substantiating this net landward movement of suspended sediment.

There is a third subject which needs to be considered in terms of across-shelf transfers of materials, this is computer modeling. There are a number of computer models which have been devised to predict the movement direction of oil spills or other pollutants in shelf waters. The Marine Science Laboratory, Stony Brook, and M.I.T. have such computer models. Physical oceanographers at a number of other universities have been trying to analyze the direction in which pollutants would move in the water system along continental margins. Smith, Slack and Davis (1976) present an oil spill risk analysis for the mid-Atlantic outer continental shelf lease area. They include data on both oil spill frequencies and spill trajectories for various sites and seasons within the lease area. Travers and Luney (1976) indicate that drilling on the outer continental shelf of eastern United States is preferrable to hazards created by unchecked oil spills from tankers.

Apparently none of these computer models is completely useful in terms of prediction because they have been designed in terms of statistically dominant wind and wave direction, water temperature and so forth. In specific instances, when the models have been applied to the drift direction of a specific spill, the computer model generally has not matched the actual drift direction of the pollutant.

There are two pollution cases which have occurred in the last year which point out the inadequacy of computer models at the present time. The first was floating debris including sewage which affected the beaches of southern Long Island during the late spring of 1976. The debate is still going on as to the source of the pollutant and how it was delivered to the beaches of Long Island. The second relates to the break-up of the tanker, Argo Merchant, during the winter of 1976-1977 in the Nantucket Shoals. From hour to hour and day to day, those who were following the actual movement direction of the oil slick from the Argo Merchant were not able to predict whether the slick would come ashore or whether it would actually wash out to sea. It would appear from both of these examples where computer models have been used to predict the movement direction of pollutants that there is still a great deal to be understood about shelf circulation, especially in terms of surface water movement.

The list of references given below concerning across-shelf transfers of suspended material is rather lengthy, but there are no papers which actually treat the entire mid-Atlantic bight as a single circulation system which apparently it is. There is evidence in some of the work being done at NOAA at the Atlantic Oceanographic Marine Laboratory that the middle Atlantic bight responds as a unit to major storms passing along the middle Atlantic states and out to sea. With the passage of storms and changes of wind direction and resulting changes in circulation patterns, there are significant differences in the nature of surface water movements on the shelf.

The above statement is not based on a complete analysis of information. There is an inter-agency agreement between the Bureau of Land Management and NOAA to produce a summarization and interpretation of historical-physical oceanographic and meteorological information for the middle Atlantic region. This agreement is contract #AA550-IA6-12. The summary of that agreement is given below.

SUMMARY OF BLM CONTRACT #AA550-IA6-12 to NOAA

Physical oceanography and meteorology: complete summary of all available data, Mid-Atlantic area: as far back in time as available.
- Area: coast to 2000 m isobath and 41°N 71°W south to 38°N.
- Analyses of data
  - in terms of subareas
  - defined as maximum size of 1° square over study area.
- To obtain all available data from all possible sources and to analyze data on these parameters:
  1. water column density
  2. lower visibility
  3. wind-velocities and directions
  - Drift data
    - surface, subsurface and bottom
  - Surface temperatures
  - Salinity
  - Oxygen
  - Nutrients
- Time-series extrapolations within areas to be presented as seasonal (and perhaps monthly) charts, plots, etc.
- Most useful oil-spill trajectory and hazards analysis
- Accompanying discussion and conclusions

Study to include short and long-term variations in physical oceanography and meterology
- Circulation patterns
- Spatial magnitude
- Surface and subsurface circulation variations
- Time and space series analysis of meteorological data to determine
  - Temperature magnitudes
  - Durations, and scale of variations
- Extremes in winds and waves
  - Recurrence intervals including force effects of gales, hurricanes on normal circulation
- Stability analysis of water column including depth of seasonal wave agitation penetration
- Effects of pycnocline in protecting water from deep penetration and effects of internal wave phenomenon data interpretation
- Identify and characterize water masses on TS or TO
- Correlations and effects on seasonal circulation

Superstructure isopotential as related to meteorological factors

Recommend designs for physical oceanography and meteorological field studies -- for
1. Improvement of areas of no data
2. Solutions to special problems
3. Contaminant dispersion and dispersal

The details of the inter-agency agreement between the Bureau of Land Management and NOAA which is summarized above is presented in the Appendix of this report from a copy of the contract of the inter-agency agreement between the two Federal agencies.

In summary of this discussion of currents and circulation dynamics, it is important to point out that the present state of the art of studying shelf circulation and shelf dynamics is at a very early stage in terms of understanding just what processes control the movement of suspended and bottom material. At a meeting in Vail, Colorado, in November, 1976, a number of researchers involved in studies of shelf dynamics presented the kinds of problems that need to be solved over the coming years. It was very evident at that meeting that it is premature to synthesize the great amount of isolated data that does exist. It is important to realize that the biggest contribution to understanding the shelf circulation problems will come from the agreement between BLM and NOAA. Until that information is available publicly, there is very little synthesizing of the dynamics of the shelf circulation within the middle Atlantic bight.

III.B.1.b. Across-Shelf Transfers of Suspended Material

Sediment unmixing in the New York Bight area, Cok, A. and others, 1973.

Fluvial sediment discharge to the oceans from the counterminous United States, Curtis, W.F. and others, 1973.

Suspended particulate matter in the New York Bight apex, Drake, D.E., 1974.

Comments on the dispersal of suspended sediment across the continental shelves, Drake, D.E. and others, 1972.

Suspended matter along the continental margin of the North Atlantic basin, Eittram, S. and others, 1969.

Suspended sediment and transport at the shelfbreak and on the slope, Lyall, A.K., 1971.

Suspended matter in surface waters of the Atlantic continental margin from Cape Cod to the Florida Keys, Manheim, F.T. and others, 1970.

Transport and escape of fine-grained sediment from shelf areas, McCave, I.N., 1972.

Landward transport of bottom sediments in estuaries of the Atlantic Coastal Plain, Meade, R.H., 1969.

Sources and sinks of suspended matter on continental shelves, Meade, R.H., 1972.

Suspended matter between Cape Cod and Cape Hatteras, Meade, R.H. and others, 1970.

Sources of suspended matter in waters of the middle Atlantic bight, Meade, R.H. and others, 1975.

Rythmic linear sand bodies caused by tidal currents, Off, T., 1963.

Comments on the dispersal of suspended sediment across the continental shelves, Schubel, J.R. and Akira, O., 1972.

Shelf sediment transport, process and pattern, Swift, D.J.P. and others, 1972.

III.B.1.b. (continued)

An oil spill risk analysis for the mid-Atlantic outer continental shelf, Smith, R.A., Slack, J.R. and Davis, R.K., 1976.

Drilling, tankers, and oil spills on the Atlantic outer continental shelf, Travers, W.B. and Luney, P.R., 1976.

The distribution and abundance of foraminifera in Long Island Sound, Buzas, M.A., 1965.

III.C. Shelf-Break Water-Mass Exchanges with Continental Slope Waters

The physical processes which occur at the shelf-break are much less well understood than currents and circulation dynamics of the continental shelf itself. It is an area where there have been very limited observations made and most of these have been confined to the upper portions of a very few submarine canyons, such as the Hudson submarine canyon. There have been some observations of some physical processes in the Wilmington Canyon, particularly as a result of studies by Stanley and his colleagues. There are a number of references in the listing below to Stanley's work in the Wilmington Canyon. These are pertinent to understanding shelf-break, water-mass exchanges with continental slope waters.

The best summary which exists at the present time is by Southard and Stanley (1976). Their paper addresses itself to shelf-break processes and sedimentation. They focus particularly upon the kind of bottom currents that seem to be distinctive to the shelf edge. They point out that the prevailing view is that the shelf edge is the area in which there is strong turbulence or strong currents which keep fine sediment in suspension, or resuspend fine sediment on a frequent basis. Thus, the fine material which is being supplied from the near-shore area toward the shelf-break is retransported to the continental slope and beyond leaving no permanent depositional record of this material near the shelf-break itself.

Figure 24 is a synthesis of information from Southard and Stanley (1976) showing the distinctive bottom currents which are known to occur, at least from local observations, at the shelf-break. These bottom currents in the vicinity of the break, seem to have a variety of causes and durations. In Figure 24 there is a listing of processes and the duration in which these processes are thought to occur. Southard and Stanley (1976) list a number of processes. These include:

1. passage of surface waves which produce oscillatory motions at the shortest time scale (measured in seconds);

2. barotropic tidal motions which produce currents that vary from semi-diurnal or diurnal periods;

3. wind-driven currents produced by either storms or steadier seasonal wind systems;

4. currents generated by differences in atmospheric pressure caused by passage of storms;

CAUSES OF SHELF-BREAK BOTTOM CURRENTS

PROCESS	DURATION
SURFACE WAVES	SHORT-TERM OSCILLATORY MOTIONS (SECONDS)
BAROTROPIC TIDAL MOTIONS	DIURNAL OR SEMIDIURNAL
WIND-DRIVEN CURRENTS	SEASONAL OR STORM-RELATED
ATMOSPHERIC PRESSURE FLUCTUATIONS	PASSAGE OF STORMS
THERMOHALINE CIRCULATION	SEASONAL & CLIMATIC
INTERNAL WAVES	WIDE RANGE OF PERIODS

(After Southard and Stanley, 1976, Shelf break processes and sedimentation, p. 365)

FIGURE 24

5. various types of thermo-haline circulations, either specific to the shelf or aerially more extensive, but impinging on the shelf as well.

Effects of various kinds of internal waves which can be present, provided that the shelf water is not so well mixed as to destroy the thermocline, may also be important. In other words, some of the current activity at the shelf-break can be a result of differences in density, either thermal differences or salinity differences or a combination of the two.

The summary by Southard and Stanley (1976) seems to confirm the concept that has intuitively been understood by geologists for some time; that is, that the shelf-break zone serves only as a temporary depository for sediments moving from terrigenous sources to ultimate depositional sites in deep marine environments beyond the continental slope. The distribution, the composition, and texture, as well as bedform geometry of surficial sediments near the shelf edge indicate that this is a zone where sediment is frequently set in motion. They point out that one of the most characteristic aspects of the shelf edge, as far as is presently known, is that some of the bottom sediment is continually entrained and shifted on the outermost shelf, ultimately transferred across the shelf edge and on to the upper slope, or into the deep ocean. They suggest that one important mode of such sediment spill-over from the shelf-break is entrainment of bedload moving in a sand stream which may be intercepted by submarine canyons headed in the shelf itself. Generally, a shelf sand stream moves normal to or in an oblique direction off the shelf edge, but there is no need at the present time to consider that movement of sand and mud is restricted to submarine canyons.

There are, of course, a number of observations of spill-overs of sand and gravel into canyon heads, but the distribution of sediment patterns near the shelf-break and on the upper slope seems to suggest that the process of spill-over occurs along vast areas of the shelf-break between canyon heads. In addition to spill-overs which have been observed, Southard and Stanley (1976) point out that there is no reason to rule out the possibilities that bedload movement of sand and the suspension transport of fine sediment in a landward direction from the shelf-break can also occur. The fact that there is current flow both seaward and landward from the shelf-break is a relatively new concept and there are no specific papers dealing with this kind of bi-directional transport except very limited studies at the heads of one or two submarine canyons. Information now becoming available on this two-directional aspect of sediment transfer away from the shelf-break, landward and seaward, suggests at least one important approach in terms of environmental management. It is no longer valid to assume that materials carried to the

shelf-break, particularly to the heads of canyons, will automatically be transferred down-slope to the deep-ocean waters. This evidence suggests that there are currents flowing in both directions. The location and the dynamics of these currents are not well understood and there are very few studies being funded which directly address this problem. The most important point to be made is that across-shelf transfers are not one way.

A review of the papers in Stanley and Swift (1976) points out that, because of the enormous numbers of new observations being made, that there are now a large number of discrepancies between the simplistic models of shelf circulation and the observations themselves and suggests that it will be several years before there is a close correlation between theoretical and computer models of shelf circulation and actual observations of movement processes of shelf waters.

III.C. Shelf-Break Water-Mass Exchanges

Bottom currents in Wilmington submarine canyon, Fenner, P. and others, 1971.

Knoll and sediment drift near Hudson Canyon, Lowri, A., Jr. and B.C. Heezen, 1967.

Suspended sediment and transport at the shelf-break and on the slope, Lyall, A.K. and others, 1971.

Composition of deeper subsurface waters along the Atlantic continental margin, Manheim, F.T. and M.K. Horn, 1968.

Principles of physical oceanography, Neumann, G. and W.J. Pierson, Jr., 1966.

The new concepts of continental margin sedimentation, Stanley, D.J., ed., 1969.

Currents and sediment transport at the Wilmington Canyon shelf-break, as observed by underwater television, Stanley, D.J. and others, 1972.

Marine sediment transport and environmental management, Stanley, D.J. and Swift, D.J.P., 1976.

Current measurements in the Georges Bank canyons, Stetson, H.C., 1937.

Measurements of vertical motion and partition of energy in the New England slope water, Voorhis, A.D., 1968.

How seafloor slides affect offshore, Bea, R.G., 1971.

Turbidity currents and sediments in North Atlantic, Ericson, D.B. and others, 1952.

The role of subaquenous debris flow in generating turbidity currents, Hampton, M.A., 1972.

Turbidity currents and submarine slumps and the 1929 Grand Banks earthquake, Heezen, B.C. and M. Ewing, 1952.

Further evidence for turbidity current following the 1929 Grand Banks earthquake, Heezen, B.C. and others, 1954.

III.C. (continued)

Grand Banks slump, Heezen, B.C. and C.L. Drake, 1964.

Gravity tectonics, turbidity currents and geosynclinal accumulations in the continental margin of eastern North America, Heezen, B.C. and C.L. Drake, 1964b.

Bottom currents in the Hudson Canyon, Keller, G.H. and others, 1973.

Possible quick-clay motion in turbidity currents, Kerr, P.F., 1962.

Slumping on a continental slope at 1°-4°, Lewis, K.B., 1971b.

Sediment gravity flows, Middleton, G.V. and M.A. Hampton, 1973.

Submarine slumps, Moore, D.G., 1961.

Submarine slumping and the initiation of turbidity currents, Morgenstern, N.R., 1967.

Comparing patterns of sedimentation in some modern and ancient submarine canyons, Stanley, D.J., 1967.

Sedimentation in slope and base-of-slope environments (lecture 8), Stanley, D.J., 1969.

Pebbly mud transport in the head of Wilmington Canyon, Stanley, D.J., 1974.

An underwater television survey of the outer continental shelf near Wilmington Canyon, Stanley, D.J. and Fenner, P., 1973.

Photographic investigation of sediment texture, bottom current activity and benthonic organisms in the Wilmington Submarine Canyon, Stanley, D.J. and Kelling, G., 1968.

Sedimentation patterns in the Wilmington Submarine Canyon area, Stanley D.J. and Kelling, G., 1968.

Recent slumping on the continental slope off Sable Island Bank, southeast Canada, Stanley, D.J. and N. Silverberg, 1968.

III.C. (continued)

Recent slumping on the continental slope off Sable Island bank, southeast Canada, Stanley, D.J. and N. Silverberg, 1969.

Photographic investigation of sediment texture, bottom current activity, and benthonic organisms in the Wilmington Submarine Canyon, Stanley, D.J. and G. Kelling, 1969.

Interpretation of a levee-like ridge and associated features, Wilmington Submarine Canyon, eastern United States, Stanley, D.J. and G. Kelling, 1970.

Late Quaternary progradation and sand spillover on the outer continental margin off Nova Scotia, Southeast Canada, Stanley, D.J. and others, 1972b.

Current controlled topography on the continental margin off the eastern United States, Flood, R.D. and Hollister, C.D., 1974.

Shaping of the continental rise by deep geostrophic contour currents, Heezen, B.C. and others, 1966.

The shaping and sediment stratification of the continental rise, Heezen, B.C. and E.D. Schneider, 1968.

Further evidence of contour currents in the Western North Atlantic, Schneider, E.D. and others, 1967.

IV. GEOLOGIC DEVELOPMENT OF THE NEW YORK CONTINENTAL SHELF

A. Geophysical Discussion

The results of the first offshore seismic refraction work, consisting of lines off Virginia and Massachusetts were published in 1937 (Ewing et al, 1937). Miller (1937) published a companion paper "concerned with the geological interpretation" of this data. This work began the geophysical investigation of the Atlantic continental margin.

A long series of refraction studies of the margin between Cape Hatteras and the Gulf of Main followed, and were ultimately synthesized and interpreted by Drake et al (1959). The studies delineated a series of sedimentary basins bounded by a broad basement arch beneath the outer shelf.

Recent magnetic studies support this interpretation; Sheridan (p. 392, 1974) summarizes:

> "Drake et al (1963) reported a prominent positive magnetic anomaly, coincident with the edge of the shelf from Canada to the Florida-Bahamas area. Burk (1968) showed that buried basement ridges were common in continental margins throughout the world. Taylor et al (1968), using newer data mapped in detail the 'east-coast' magnetic anomaly, which parallels the slope from Canada to Cape Hatteras, south of which it bifurcates with a prominent anomaly swinging into land in southern Georgia. Emery et al (1970) show that this anomaly is localized above a buried basement ridge at depths of 6-7 km, with the magnetic properties of oceanic basalts which might well define the structural edge of the eastern North American Continent."

The most recent gravity measurements of the Atlantic margin (Rabinowitz, 1973; Grow et al, 1977) show two parallel belts of positive anomalies, one in the Appalachians, the other at the edge of the continental shelf, commonly called the "shelf edge gravity high." The magnetic slope anomaly lies to the west of the shelf edge gravity high (in general the magnetic slope anomaly does not overlie the continental slope; off the Scotian Shelf it lies far out over the continental rise; off New Jersey it comes well in onto the shelf). Crustal models constructed to fit the gravity data attribute the shelf edge gravity high to a fairly abrupt change in crustal thickness (from thick continental crust to thinner oceanic crust) under the continental slope and upper rise (Mayhew, 1974).

The most recent seismic reflection data has been interpreted (Schlee et al, 1976) as showing a massive reef-like

structure built adjacent to deeply buried fault zones. They infer the presence of a volcanic ridge capped by carbonate deposits. The age of the possible reef deposits appear to be Late Jurassic to Early Cretaceous.

IV. B. Basement Ridge Models

While the various interpretations of the geophysical data agree with a period of uplift, block faulting and subsidence, there are significant differences among the models specifically relating to the nature of the "basement ridge" (Figure 24). The differences among the three principle models are based upon compositional differences of the ridge. They are considered in no particular order of preference.

1. Oceanic Crust Model

This model (Figure 25A is based on interpretation of the east coast slope anomaly, the positive magnetic anomaly that parallels the continental slope from Canada to Cape Hatteras. Sheridan (p. 404, 1974) states: "The transition from continent to ocean occurs under the continental slope and is marked, in places by a ridge of oceanic basement, which produces the east coast magnetic anomaly." The seismic refraction data of Drake et al (1959) tend to support this hypothesis, showing high velocity "basement material" forming a ridge under the shelf edge. Emery et al (1970) explain the source of the magnetic anomaly as a ridge of oceanic crust that formed the initial scar of plate separation and remained attached to the edge of the continental crust as the plates spread apart.

2. Continental Crust Model

Mattick et al (1974) have constructed a model (Figure 25b) based on the magnetic slope anomaly and the shelf edge gravity high. Their model calls for a horst block of continental crust to form the basement ridge.

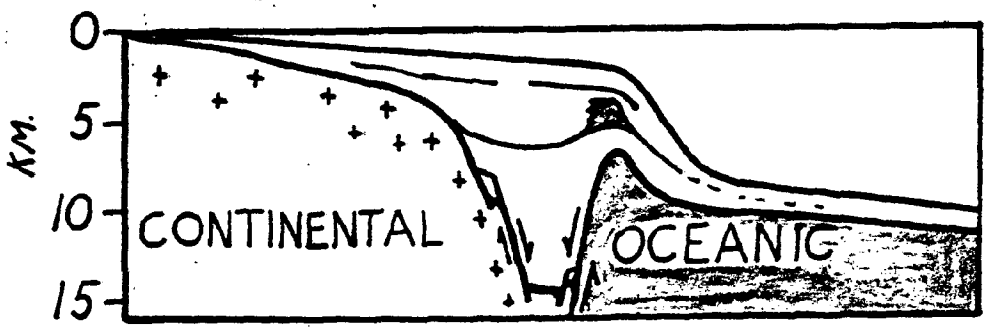
They believe that the Baltimore Canyon Trough subsided as a block-faulted basin in continental rocks. The rifting of the continents provided the initial tensional forces necessary for the formation of the "graben-like" structures of the east coast. The uplift to the west (Palisades disturbance) provided the sediment to fill the basin and enhance basin subsidence, thus keeping the faults active. The shelf edge ridge formed a sediment barrier during the Jurassic. It is possible that reefs grew on this ridge or that it was exposed to erosion before the sediments overran the barrier. This model has appeal in that they attempt to explain the shoreward displacement of the magnetic slope anomaly from the shelf edge gravity high by normal faulting on the shoreward side of the ridge (Mattick et al, 1974).

3. Sedimentary Deposits Model

This model (Figure 25C) interprets seismic reflection profiles to show a ridge of sedimentary deposits rather than

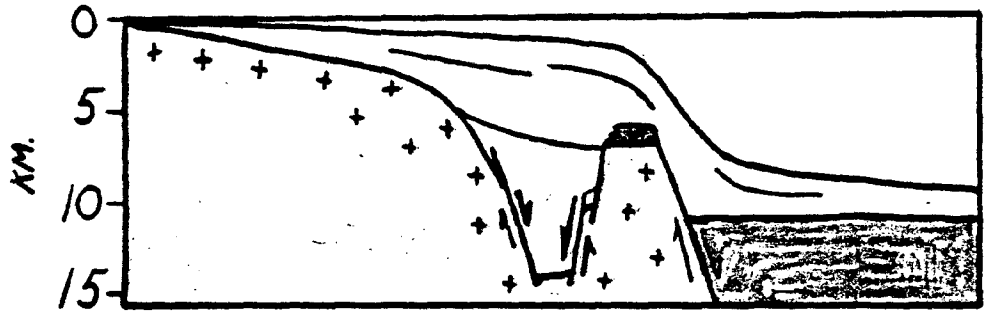
BASEMENT RIDGE MODELS

FIGURE 25A



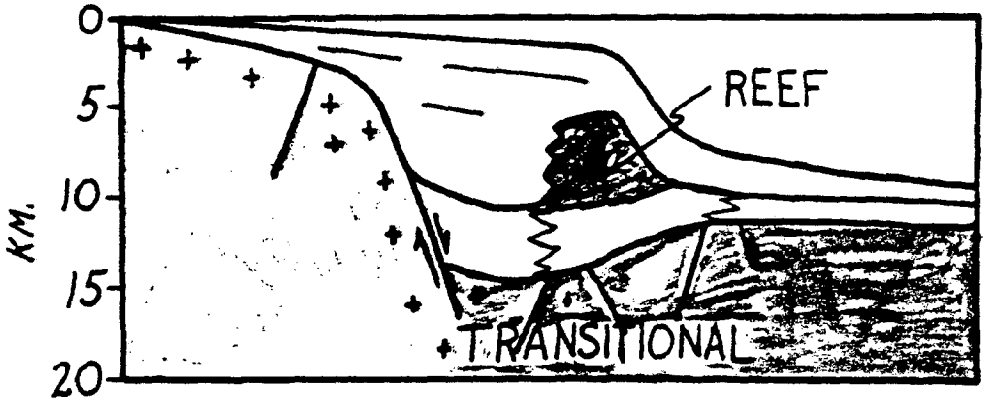
OCEANIC BASEMENT RIDGE

FIGURE 25B



CONTINENTAL CRUST RIDGE

FIGURE 25C



CARBONATE-TRANSITIONAL CRUST

FIGURE 25

crystalline rocks beneath the shelf edge. Schlee et al (1976) believe this ridge is largely carbonate rock. They see evidence of forset beds in "basement ridge" (Figure 13 of Schlee et al, 1976) and no indication of faulting along which the horst (Mattick et al, 1974; Foote et al, 1974) was uplifted. They believe that a deeply buried carbonate platform and reef deposits, Jurassic to Early Cretaceous in age exist atop the block faulted basement and form the "basement ridge." The magnetic slope anomaly may be primarily due to edge effects between continental and ocean crust as suggested by Keen and Keen (1974). If the thick sedimentary section actually forms a ridge, the shelf edge gravity high may be due to a lateral seaward increase in sediment density near the outer shelf.

IV. GEOLOGICAL DEVELOPMENT OF NEW YORK CONTINENTAL SHELF

A. Geophysical Discussion, B. Basement Ridges

Regional geology of eastern Canada offshore, Austin, G.H., 1973.

The nature of Triassic continental rift structures in the Gulf of Maine, Ballard, R.D., 1974.

Preglacial structure of Georges Bank and Northeast Channel, Gulf of Maine, Ballard, R.D. and Sorensen, F.H., 1968,

High sensitivity aeromagnetic survey of the Atlantic margin of the United States (abstr.), Behrendt, J.C., 1975.

Seismic evidence for a thick section of sedimentary rock on the Atlantic continental shelf and slope of the United States (abstr.), Behrendt, J.C. and others, 1974.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part X, Continental slope and continental rise south of Grand Banks, Bentley, C.R. and J.L. Worzel, 1956.

Geophysical observations on sediments and basement structure underlying Sable Island, Nova Scotia, Berger, J. and others, 1965.

Seismic refraction investigations in selected areas of Narragansett Bay, Rhode Island, Birch, W.B. and Dietz, F.T., 1962.

Some seismic profiles onshore and offshore Long Island, N.Y., Black, M. and others, 1959.

Geophysical observations on the sediments and basement structure underlying Sable Island, Nova Scotia, Blanchard, J.E. and others, 1965.

Evolution of young continental margins and formation of shelf basins, Bott, M.H.P., 1971.

Seismic refraction profiles on the continental shelf south of Bellport, L.I., N.Y., Brown, M.V. and others, 1961.

IV. (continued)

Structural and stratigraphic framework, and spatial distribution of permeability of the Atlantic Coastal Plain, North Carolina to New York, Brown, P.M. and others, 1972.

Buried ridges within continental margins, Burk, C.A., 1968.

Basement beneath the emerged Atlantic coastal plain between New York and Georgia, Dietrich, R.V., 1960.

Some geophysical anomalies in the eastern United States, Diment, W.H. and others, 1972.

Geophysical investigations of the emerged and submerged Atlantic Coastal plain, Drake and others, 1954.

Magnetic anomalies off eastern North America, Drake, C.L. and others, 1963.

Appalachian curvature, wrench faulting, and offshore structures, Drake, C.L. and Woodward, H.P., 1963.

Shallow structure of continental shelves and slopes, Emery, K.O., 1968b.

Continental margins of the world, Emery, K.O., 1970.

Geological background Baltimore Canyon Trough, Emery, K.O., 1974.

Structures of Georges Bank, Emery, K.O. and E. Uchupi, 1965.

Western North Atlantic ocean, topography, rocks, structure, water, life and sediments, Emery, K.O. and Uchupi, E., 1972.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 4, Ewing, M., 1940.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 3, Barnegat Bay, N.J. Section, Ewing, M. and others, 1939.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part IV, Cape May, N.J. Section, Ewing, M. and others, 1940.

IV. (continued)

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 5, Woods Hole, N.Y. and Cape May sections, Ewing, M. and others, 1950.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 1, Methods and results, Ewing, M. and others, 1973.

Developments of continental shelf south of New England, Garrison, L.E., 1970.

Late Mesozoic-Cenozoic tectonic effects of the Atlantic Coastal margin, Gibson, T.G., 1970.

Petrology and origin of Potomac and magothy (Cretaceous) sediments, Middle Atlantic coastal plain, Glaeser, J.D., 1969.

Seismotectonic map of the eastern United States, Hadley, J.R. and Devine, J.F., 1974.

Eastern continental margin of the United States, Part 2, Hales, A.L., 1970.

Mesozoic geology and the opening of the North Atlantic, Hallam, A., 1971.

Gravity measurements in the vicinity of Georges Bank, Hendricks, J.D., and Robb, J.M., 1973.

Ocean drilling on the continental margin, Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965.

The significance of a group of aeromagnetic profiles off the eastern coast of North America, King, E.R., and others, 1961.

Geologic framework and petroleum potential of the Atlantic Coastal plain and continental shelf, Maher, J.C., 1971.

Geologic framework and petroleum potential of the Atlantic Coastal plain and continental shelf, Maher, J.C. and E.R. Applin, 1971.

A preliminary report on U.S. Geological Survey geophysical studies of the Atlantic Outer Continental Shelf (abstr.), Mattick, R.E. and others, 1973.

IV. (continued)

Structural framework of United States Atlantic outer continental shelf north of Cape Hatteras, Mattick, R.E. and others, 1974.

Pattern of Triassic-Jurassic diabase dikes around the North Atlantic in the context of predrift position of the continents, May, P.R., 1973.

"Basement" to east coast continental margin of North America, Mayhew, M.A., 1974a.

Geophysics of Atlantic North America, Mayhew, M.A., 1974b.

Seismic profiles along the U.S. northeast coast continental margin (abstr.), McGregor, B.A. and others, 1975.

Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part 2, Miller, B.J., 1937.

Preliminary geologic report on the U.S. northern Atlantic continental margin (abstr.), Minard, J.P. and others, 1973.

Preliminary report on geology along Atlantic continental margin of northeastern U.S., Minard, J.P. and others, 1974.

Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 7, Continental shelf, continental slope, and continental rise south of Nova Scotia, Officer, C.A. and M. Ewing, 1954.

Geophysical observations on northern part of Georges Bank and adjacent basins of Gulf of Maine, Oldale, R.N. and others, 1974.

Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part VI, the Long Island Area, Oliver, J.E. and Drake, C.L., 1951.

Structural history and oil potential of offshore area from Cape Hatteras to Bahamas, Olson, W.S., 1974.

Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part 8, Grand Banks and adjacent shelves, Press, F. and Beckman, W.C., 1954.

The continental margin of the northwest Atlantic Ocean, Rabinowitz, P.D., 1973.

IV. (continued)

Eastern Atlantic continental margins -- various structural and morphologic types, Renard, V. and Mascle, J., 1974.

Generalized structure contour maps of the New Jersey coastal plain, Richards, H.G. and others, 1962.

Stratigraphy and structure along a continuous seismic reflection profile from Cape Hatteras, North Carolina to the Bermuda Rise, Rona, P.A. and C.S. Clay, 1967.

Sediments structural framework, petroleum potential, environmental conditions and operational considerations of the United States North Atlantic outer continental shelf, Schlee, J. and others, 1975.

Geology of Georges Bank basin, Schultz, L.K. and R.L. Grover, 1974.

Conceptual model for the block-fault origin of the North American Atlantic Continental Margin Geosyncline, Sheridan, R.E., 1974.

Atlantic continental margin of North America, Sheridan, R.E., 1974.

Sedimentary basins of the Atlantic margin of North America, Sheridan, R.E., 1976.

Geology and Paleontology of Georges Bank Canyons, Part 1, Geology, Stetson, H.C., 1936.

Distribution and geologic structure of Triassic rocks in the Bay of Fundy and the northeastern part of the Gulf of Maine, Tagg, A.R. and Uchupi, E., 1966.

Geologic implications of aeromagnetic data for the eastern continental margin of the U.S., Taylor, P.T.I. and others, 1968.

Topography and structure of the shelf and slope, Uchupi, E., 1965c.

Structural framework of the Gulf of Maine, Uchupi, E., 1966.

Structure of the continental margin off the Atlantic Coast of the U.S., Uchupi, E. and Emery, K.O., 1967.

Regional geologic framework off northeastern United States, Schlee, J. and others, 1976.

IV. (continued)

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the U.S. mid-Atlantic outer continental shelf, U.S. Geological Survey, 1975.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the U.S. North Atlantic OCS, U.S.G.S., 1975.

Aeromagnetic map Atlantic continental margin, U.S.G.S., 1976.

Seismic studies in the region adjacent to the Grand Banks of Newfoundland, Watson, J.A. and Johnson, G.L., 1970.

IV.C. Structural Geology

The pre-Mesozoic basement surface as determined from coastal plain drill holes and offshore geophysics is warped and faulted as a result of large scale tectonic activity. The warping and faulting of the basement is reflected in a series of transverse arches, highs and platforms that have a thin sedimentary cover and basins and embayments that have thick sedimentary sections (Figures 26 and 27).

At the northern end of the study area the Yarmouth Arch bounds Georges Bank Basin on the northeast. This broad basement ridge plunges southward and extends to the edge of the continental shelf (Schultz and Grover, 1974).

To the southwest of Yarmouth Arch, Georges Bank Basin contains up to 8,500 meters of sediments (Mattick et al, 1974). Seismic studies show high-angle faults in the basin, most of which affect only the basal 1500 meters of sediments. The Long Island Platform, a structural high to the south of Rhode Island separates the Baltimore Canyon Trough from Georges Bank Basin (Figure 26).

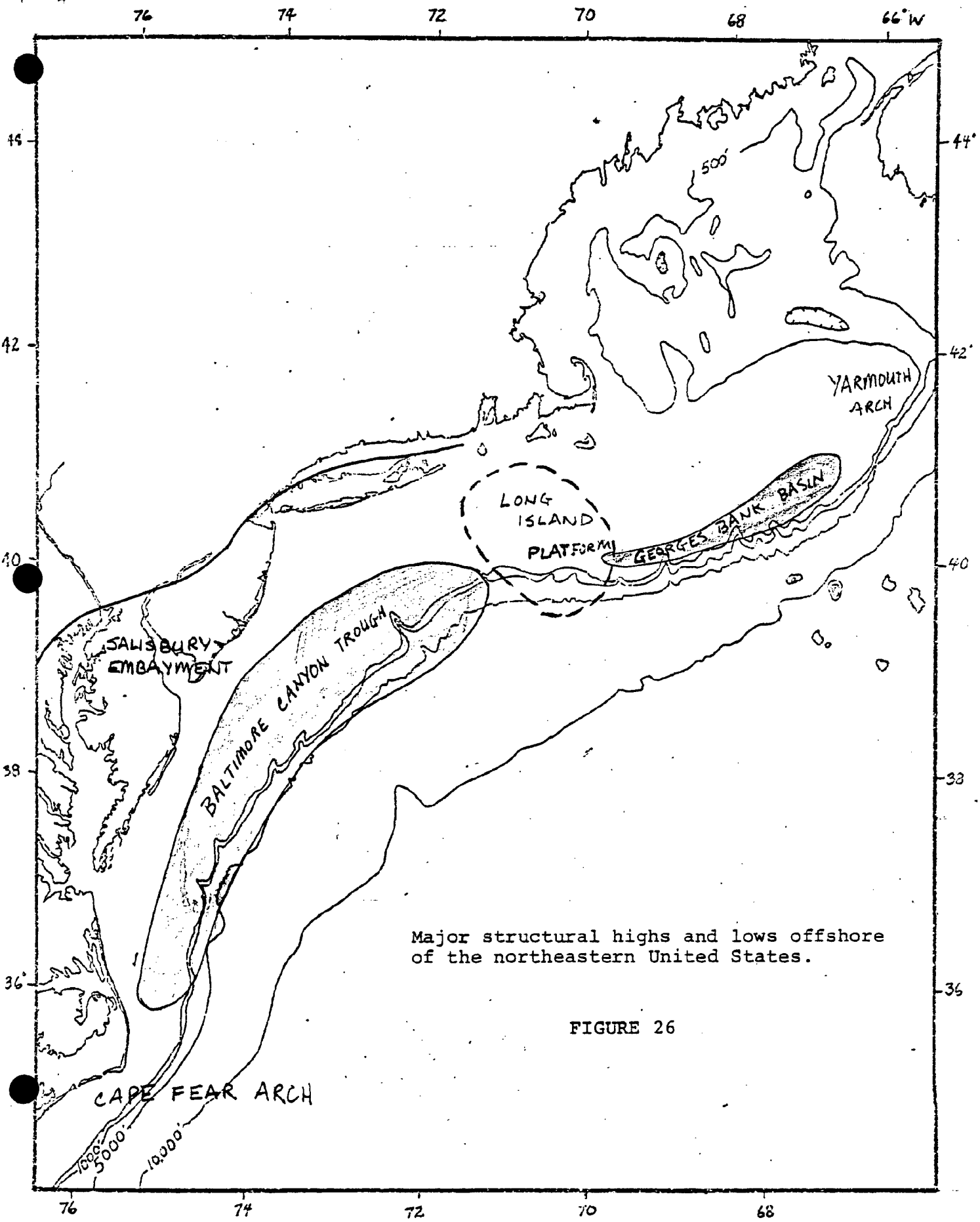
The Baltimore Canyon Trough is a synclinorium in the crystalline basement. The trough is bordered on the east by a postulated basement ridge whose axis is nearly parallel with the shelf edge. The basin is terminated by the Long Island Platform on the north and the Cape Fear arch to the south. To the west, the trough merges with the Salisbury Embayment, the basement low between Washington, D.C. and Ocean City, Maryland (Figure 26).

The trough is over 600 kilometers long near the shelf edge and is almost 200 kilometers wide off New Jersey (USGS, 1975). The basin may contain up to 15 kilometers of Mesozoic and Cenozoic sediments.

Sheridan (1974, 1976) provides a good review of the tectonic framework of the continental margin. Drake (1969) discusses the basement structure as does Burk (1968). Ballard and Uchupi (1972, 1975) discuss the tectonic history of the Gulf of Maine. Keen and Keen (1973) describe the structural history of the Canadian continental margin.

Mattick et al (1974) review the structural framework of the continental margin north of Cape Hatteras and Mayhew (1974) summarizes the geophysics of the continental margin. More recently, Schlee et al (1976) present the results of the USGS seismic reflection survey of the Atlantic outer continental shelf.

The USGS (1976a, b) has reviewed the Baltimore Canyon Trough and Georges Bank Basin and gives a good summary of the structure and geology of both areas.



Major structural highs and lows offshore of the northeastern United States.

FIGURE 26

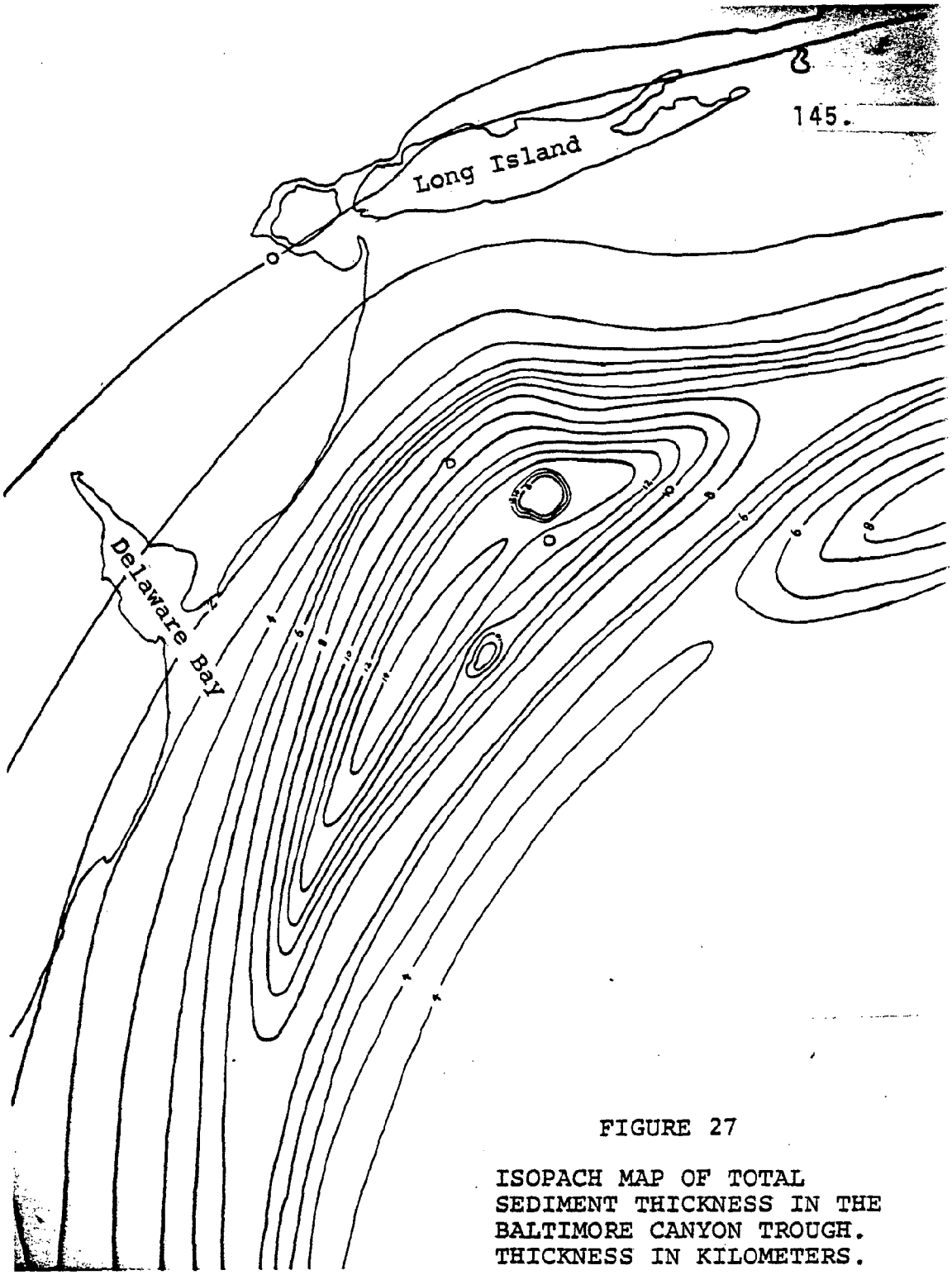


FIGURE 27

ISOPACH MAP OF TOTAL SEDIMENT THICKNESS IN THE BALTIMORE CANYON TROUGH. THICKNESS IN KILOMETERS.

IV.C.1. Faults

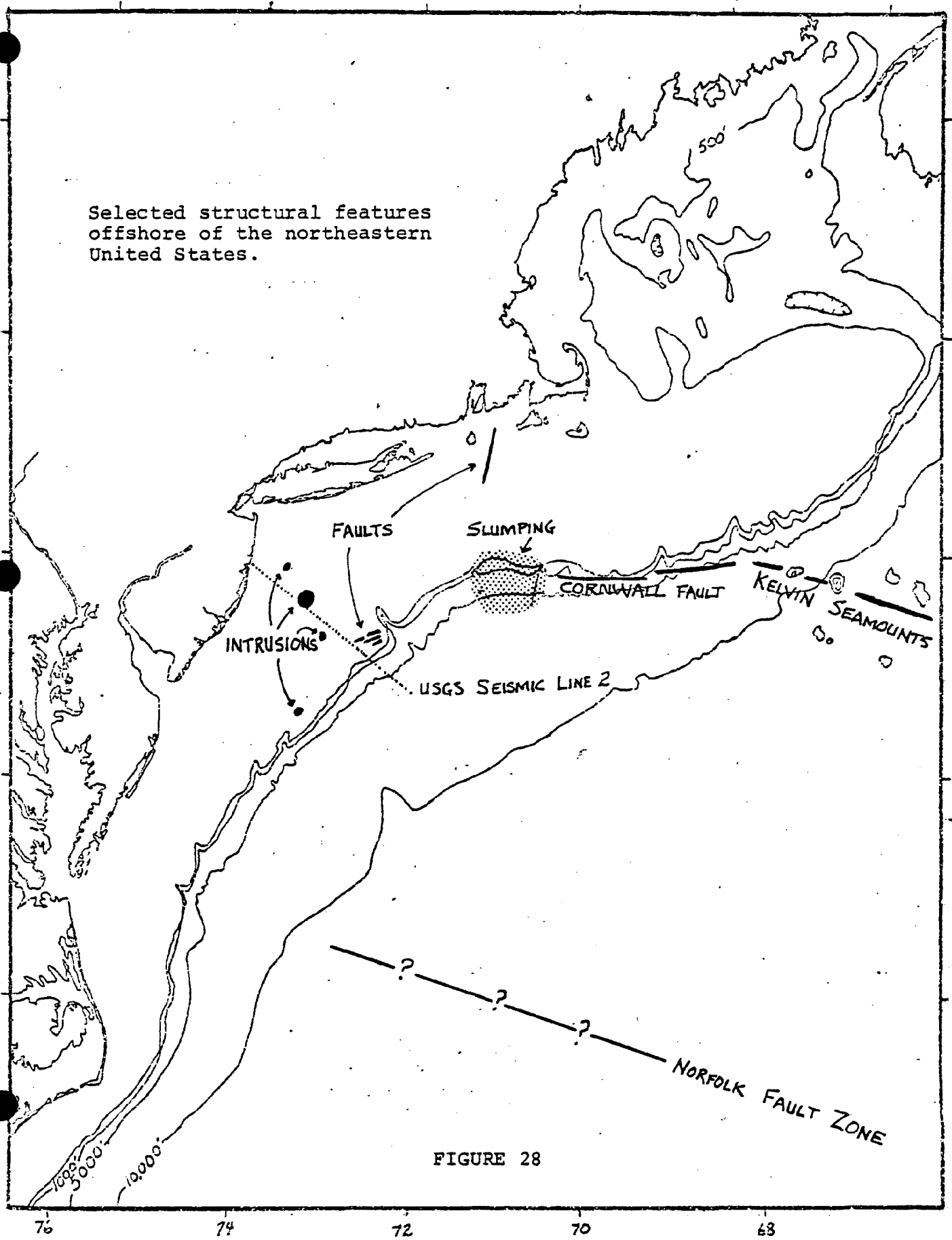
a. Shallow Faults

Detailed geophysical work by the USGS in the Baltimore Canyon Trough area discovered shallow faults near Hudson Canyon and in the sediments near the edge of the continental shelf (Sheridan and Knebel, 1976) as a part of their investigation for potential geologic hazards. They estimate 1.5 meters of throw on the faults which are offset upwards to the southeast. The faults are about 5 kilometers long but one reaches 15 kilometers. Sediments to within 7 meters of the seafloor are offset by the faults, which are 1 to 2 kilometers apart and strike approximately N70E.

Multichannel seismic reflection data indicate that these shallow faults might be a near-surface expression of a deeper fault of Early Cretaceous age which shows a displacement of 96 meters at depth. Because the upper 7 meters of sediment appear to be of recent age, Sheridan and Knebel postulate a Pleistocene or younger age for the faults.

McMaster (1971) reports a north-south trending fault that dips to the east on the continental shelf off Rhode Island, near Block Island. The fault, which is transverse to other structural trends for more than 60 km, appears to be Middle to Later Tertiary in age.

Other shallow faults on the continental shelf are associated with slumping at the shelf edge. Uchupi (1970) shows seismic profiles near Block Canyon with massive slump structures (Figure 28). He believes that the slumping occurred when sea level was near that surface, and is associated with the increased sedimentation during the lower sea level.



Selected structural features offshore of the northeastern United States.

FIGURE 28

IV.C.1.b. Deep Faults

Large scale faulting has been proposed for many areas of the Atlantic coastal margin. Perhaps the largest zone is the Cornwall-Kelvin Fault System (Drake and Woodward, 1965; Sheridan, 1974) which ties the Kelvin Seamount Chain, the re-entrant on the continental shelf southeast of Long Island, and the Cornwall fault zone into a major tectonic feature associated with the opening of the proto-Atlantic Ocean (Figure 28).

A similar zone to the south, the Norfolk fault zone, is also a feature of the rifting of the continents. These faults are not believed to have been active since Mesozoic time (Milliman, 1973).

Large faults are usually ascribed to the borders of the depositional centers under the Atlantic continental margin (Sheridan, 1974). If these faults actually exist there is no reason to believe that they have been active since the Mesozoic (Milliman, 1973).

IV.C.2. Intrusions

The USGS has mapped several intrusive features on the Atlantic coastal plain (USGS, 1974). The largest of these features appears on USGS seismic line 2 (Figure 28). This intrusion is near the center of Baltimore Canyon Trough. A 500 gamma magnetic high is associated with the intrusive feature (Taylor et al, 1968). Mattick et al (1974) believe that the magnetic high indicates an igneous intrusion that may be located in a zone of weakness near the intersection of two faults or fault systems, one parallel to the continental shelf and another oblique to it. The USGS (1975) interprets the feature from the seismic line as follows: Jurassic and Lower Cretaceous beds appear to have been arched several thousand meters over the feature. A prominent unconformity near the Upper-Lower Cretaceous boundary appears to truncate uplifted pre-Upper Cretaceous beds. At least 450 meters of these sediments were removed by erosion. There does not appear to be any significant thinning of Upper Cretaceous and Lower Tertiary beds that would indicated continued movement during this time. On the other hand, the presence of minor faults in the Upper Cretaceous and Lower Tertiary could indicate recurrent upward movement during this time.

Closer to shore on the same seismic line is another intrusive feature. On the magnetic map of Taylor, et al (1968) there is no anomaly associated with this feature. The USGS interprets it as a probable salt diapir. Other evidence for salt domes on the east coast is from the Orpheus Basin near Newfoundland where McIver (1972) reported an 800 m (2600 ft.) bed of relatively pure halite. Emery et al (1970) have suggested salt doming under the continental slope and rise off Nova Scotia.

Sheridan (1975) reports a small domal structure near the shelf edge just north of Wilmington Canyon. Extrapolation of seismic data to nearby DSDP and Caldrill holes indicates that rocks of Miocene age are involved in the doming. A magnetic anomaly is associated with the dome which is centered over the East coast slope anomaly. This suggests a structural control of the dome and Sheridan believes that a Tertiary igneous intrusion is the most likely explanation. If the dome does persist at depth, it would be an interesting petrolem prospect. There has been no positive identification of these intrusive features. The interpretations are based entirely on geophysical evidence.

A combination of seismic and magnetic data provide the basis for interpreting an igneous origin for the large feature seen on the USGS seismic line 2. The large magnetic anomaly associated with the incoherent reflectors on the seismic profile lends support to the igneous hypothesis.

The lack of magnetic anomaly associated with the smaller feature to the northwest leads to the interpretation of a possible salt dome. The character of the seismic reflectors is usually cited in ruling out a pinnacle reef or sedimentary diapir origin.

IV.C. Structural Geology

Regional geology of eastern Canada offshore, Austin, G.H., 1973.

Carboniferous and Triassic rifting, a preliminary outline of the tectonic history of the Gulf of Maine, Ballard, R.D. and E. Uchupi, 1972.

Geology -- the Gulf of Maine, Ballard, R.D. and Uchupi, E., 1974.

Triassic rift structure in Gulf of Maine, Ballard, R.D. and Uchupi, E., 1975.

Appalachian curvature, wrench faulting, and offshore structures, Drake, C.L. and Woodward, H.P., 1963.

Structure of Georges Bank, Emery, K.O. and E. Uchupi, 1965.

Possible late Pleistocene uplift, Chesapeake Bay entrance, Harrison, W.B. and others, 1965.

Seismic reflection observations on the Atlantic continental shelf, slope and rise southeast of New England, Hoskins, H., 1967.

Geophysical investigation of Cape Cod Bay, Mass., using the continuous seismic profiler, Hoskins, H. and others, 1961.

Record of wells in Suffolk County, L.I., N.Y., Johnson, A.H. and others, 1952.

Gravity and magnetic evidence of lithology and structure in the Gulf of Maine region, Kane, M.F. and others, 1972.

Gravity and magnetic evidence of lithology and structure in the Gulf of Maine region, Kane, M.F. and others, 1972.

Possible edge effect to explain magnetic anomalies off eastern seaboard of the U.S., Keen, M.J., 1969.

Subsidence and fracturing on the continental margin of eastern Canada, Keen, M.J. and Keen, C.E., 1973.

The significance of a group of aeromagnetic profiles off the eastern coast of North America, King, E.R. and others, 1961.

IV.C. (continued)

Interpretation of high resolution echo-sounding techniques and their use in bathymetry marine geophysics and biology, Knott, S.T. and Hersey, J.B., 1956.

Evidence of Pleistocene events in the structure of the continental shelf off the northeastern U.S., Knott, S.T. and Hoskins, H., 1968.

A preliminary report on U.S. Geological Survey geophysical studies of the Atlantic Outer Continental Shelf (abstr.), Mattick, R.E. and others, 1973.

Seismic reflection studies in Block Island and Rhode Island Sounds, McMaster, R.L., and others, 1968.

Domes in the Atlantic Coastal Plain east of Trenton, N.J., Minard, J.P. and J.P. Owens, 1966.

Mobil Tetco Sable Island E-48, Morrow, D.L. and others, 1972.

The Georges Bank Petroleum Study, Offshore Oil Task Group, 1973.

Seismic investigations on Cape Cod, Martha's Vineyard and Nantucket and a topographic map of the basement surface from Cape Cod Bay to the Islands, Oldale, R.N., 1969.

Seismic investigations on Cape Cod, Mass., Oldale, R.N. and Tuttle, C.R., 1964.

Geophysical observations on northern part of Georges Bank and adjacent basins of Gulf of Maine, Oldale, R.N. and others, 1974.

Preliminary report on a geophysical study of a dome structure on the Atlantic outer continental shelf east of Delaware, Sheridan, R.E., 1974.

Dome structure, Atlantic OCS east of Delaware, preliminary geophysical report, Sheridan, R.E., 1975.

What is the geology of West Sable structure?, Smith, H.A., 1975.

Distribution and geologic structure of Triassic rocks in the Bay of Fundy and the northeastern part of the Gulf of Maine, Tagg, A.R. and Uchupi, E., 1966.

IV.C. (continued)

Structural framework of the Gulf of Maine, Uchupi, E., 1966.

Topography and structure of Cashes Ledge, Gulf of Maine, Uchupi, E., 1966.

Atlantic continental shelf and slope of the U.S., Uchupi, E., 1970.

Generalized pre-Pleistocene geologic map of the northern U.S. Atlantic continental margin, Weed, E.G.A. and others, 1974.

Sediments and shallow structures of the inner continental shelf off Sandy Hook, N.J., Williams, S.J. and Field, M.E., 1971.

IV.C.1. Faults

Shallow structure of the continental margin, Curray, J.R., 1969b.

Transcurrent faulting along the continental margin of eastern North America (abstr.), Drake, C.L. and others, 1962.

A transverse fault on the continental shelf off Rhode Island, McMaster, R.L., 1971.

Evidence of post-Pleistocene faults on N.J. Atlantic outer continental shelf, Sheridan, R.E. and Knebel, H.J., 1976.

A micro-environmental study of the hydrocarbons of the Long Island Sound sediments, Danker, J.A., 1963.

Correlation of end moraines in southern Rhode Island, Schafer, J.P., 1961.

IV.C.2. Intrusions

Atlantic salt deposits formed by evaporation of water split from the Pacific, Tethys and Southern Oceans (abstr.), Burke, K., 1975.

Pattern of Triassic-Jurassic diabase dikes around the North Atlantic in the context of predrift position of the continents, May, P.R., 1973.

IV.D. Stratigraphy

1. Triassic

A series of basins filled with Triassic rocks underlies parts of the coastal plain. Figure 29 gives a composite section of the Baltimore Canyon Trough area with the Triassic at the base. Most of the basins are bordered by normal faults along one side, usually the west. In outcrop, the Triassic rocks are continental in character, mostly stream, lake and swamp deposits of red arkosic sandstone and shale. Both intrusive and extrusive igneous rocks (tuffs, basalt flows and diabase dikes) are common (Mahar, 1971). 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. Typically, the rocks undergo a facies change across the basin, grading from fanglomerates near the border fault to finer grained floodplain deposits in the center of the basins. The age of these rocks, the Upper Triassic Newark Group, has been determined paleontologically.

Triassic rocks have been reported in deep wells near the seaward edge of the coastal plain and may be present under the continental shelf (Minard et al, 1974). Triassic rocks lying unconformably below Cretaceous have been reported in coastal wells. Brown et al (1972) listed red and brown shales and arkosic sandstones from the E.G. Taylor well in Virginia as Triassic on the basis of lithic correlation with the Newark Group. The USGS (1975) disputes this interpretation, citing a lack of evidence for the necessary 50 million year unconformity to represent Jurassic (i.e., relative consolidation) and palynological data suggests an Early Cretaceous age for the red beds in question.

If these red beds and arkosic sands represent a seaward thickening blanket deposit immediately above the basement and not isolated basin deposits, then the resolution of the age of this stratigraphic interval is important in the understanding of the initial depositional history of the Baltimore Canyon Trough.

Triassic sedimentary rocks were described by Uchupi (1966) and Ballard and Uchupi (1972) in the Gulf of Maine. Ballard and Uchupi (1975) believe that the Triassic section beneath the Gulf of Maine is structurally (half-gravens) and lithically (red bed sequence) similar to the Newark Group rocks on land.

QUATERNARY NON MARINE AND COASTAL UNITS

- GRAY AND GRAY GREEN CLAYS INTERBEDDED WITH VARIABLE SIZE SANDS (COASTAL ENVIRONMENTS) - TOWARD EAST AND SOUTH
- COARSE SANDS AND GRAVELS (FLUVIATILE NON-MARINE) - TOWARD NORTH AND WEST

MIOCENE MARINE UNITS

YORKTOWN	- YELLOW-WHITE SAND AND SILT	ABUNDANTLY FOSSILIFEROUS MARINE MOLLUSCAN FAUNAS
ST. MARY'S	- INTERBEDDED-BLUISH GRAY CLAY, AND GRAY ARGILLACEOUS FINE SANDS	
CHOPTANK	- INTERBEDDED WELL DEFINED SANDY YELLOW-BROWN MOLLUSCAN SHELL BEDS, DENSE GRAY CLAY, & YELLOW-BROWN SAND	
CALVERT	- PLUM POINT MARL - SANDY MOLLUSCAN SHELL BEDS AND MARINE SILTY CLAYS	
	FAIRHAVEN - DIATOMACEOUS EARTH - POORLY SORTED, ARGILLACEOUS, FINE-COARSE SAND	

PALEOCENE-EOCENE MARINE UNITS

---RANCOCAS EQUIV. ---	PINEY POINT:	FINE-MEDIUM-COARSE GLAUCONITIC SANDS, LIGHT GRAY-YELLOWISH GREEN	HIGHLY VARIABLE GLAUCONITIC SANDS AND CLAYS, UNDIFFERENTIATED RANCOCAS TOWARD THE NORTH.
	MARLEMOY:	ARGILLACEOUS SILT AND SAND, DARK GREENISH GRAY	
	MARLBORO:	GRAY-PALE RED CLAY WITH THIN SILT LENSES	
	AQUIA:	FINE-MEDIUM SILTY SAND, DARK GREENISH-GRAY, GLAUCONITIC	
	BRIGHTSEAT:	ARGILLACEOUS, PHOSPHATIC, MICACEOUS FINE SAND, GRAY BROWN	

UPPER CRETACEOUS MARINE UNITS

MONMOUTH:	FINE MICACEOUS GLAUCONITIC QUARTZ SANDS AND GLAUCONITES
MATAWAN:	GLAUCONITIC QUARTZ SANDS AND DARK, MICACEOUS, GLAUCONITIC SANDY CLAY SILTS
MAGOTHY:	ANGULAR WHITE QUARTZ SAND, THINLY INTERBEDDED WITH GRAY-BLACK LIGNITIC SILT AND CLAY, ABUNDANT CARBONACEOUS DEBRIS THROUGHOUT

POTOMAC GROUP

(RAPID LATERAL AND VERTICAL FACIES CHANGE)

UK	RARITAN:	GRAY AND BROWN CLAYS	MARINE
	PATAPSCO:	VARIEGATED (GREEN, YELLOW, GRAY, RED, BROWN & PURPLE) CLAYS (MASSIVE) AND WHITE, YELLOW, & OLIVE GREEN SANDS (FINER & MORE ARGILLACEOUS THAN PATUXENT) WHITE & DK. GRAY LIGNITIC CLAYS, FRESH WATER PELECYPODS & ANGIOSPERMS	
LOWER K	ARUNDEL:	GRAY SILTS & CLAYS, AND LIGNITIC WHITE TO OLIVE GREEN PEBBLY SANDS, DINOSAURS, MINOR TURTLES, CROCODILES, GARS, RARE PELECYPODS	
	PATUXENT:	ORTHOQUARTZITIC AND ARKOSIC MEDIUM-COARSE SANDS AND GRAVELS, POORLY SORTED, ANGULAR & PALE GRAY-TAN INTERBEDDED VARIEGATED CLAYS, ABUNDANT LARGE SCALE CROSS BEDDING, CUT AND FILL, AND CLAY PEBBLE CONGLOMERATES	NON-MARINE

UPPER JURASSIC?

TOP	- SANDY LIMESTONES AND DOLOMITES - QUARTZ SANDS AND GRAY-GREEN SHALES
BASE	- ARKOSE - VARICOLORED RED AND GREEN SHALES

TRIASSIC-NEWARK SERIES?

- REDDISH BROWN-GREEN SHALES
- ARKOSIC, CONGLOMERATIC SANDSTONES

BASEMENT COMPLEX

- SCHIST AND MICA GNEISS
- EPIDOTE AMPHIBOLITE
- GABBRO
- GRANODIORITE

—Composite stratigraphic section found in outcrop and by drill on south and west flanks of Baltimore Canyon trough (modified from Jordan, 1962; Glaser, 1968; Anderson, 1948; Hansen, 1969; and others).

(From Kraft, J. C., et al, 1971, AAPG Bull., v. 55/5, fig.4, p. 663)

FIGURE 29

IV.D.2. Jurassic

Jurassic rocks are not exposed on the Atlantic coastal plain (Maher, 1971). Red beds and arkosic sands dated as Jurassic on the basis of spores and pollen have been reported from the subsurface of New Jersey by Brown et al, (1972). Similar rocks are present in the Salisbury Embayment where Swain and Brown (1972) reported Late Jurassic Ostracoda from deep wells.

McIver (1972) describes a thick section of Lower Jurassic rocks on the Scotian Shelf. A thick section of salt is overlain by other evaporite and dolomite beds more than 300 meters thick. Over these rocks lie sandstone, limestone and marine shales. More than 1500 meters of limestone and sandy shale make up the Upper Jurassic. Schultz and Grover (1974) believe that this section is continuous along strike and project it south to Georges Bank Basin (Figure 30).

To the south, Jurassic rocks have been tentatively identified in the Baltimore Canyon Trough (Figure 30). Pollen and spore analysis from the COST B-2 well done by International Biostratigraphers indicate that the well bottomed in Lower Cretaceous. American/Canadian Stratigraphic Service's examination of the pollen and spores point to an Upper Jurassic age for the lower 400 meters of the well.

Differences aside, no one at this time doubts the presence of at least 3000 meters of pre-Cretaceous Mesozoic sediments in the Baltimore Canyon Trough, based on seismic reflection studies (Schlee, et al, 1976, for example). Without deeper drilling there is no way to tell the Triassic from the Jurassic or to determine the thickness of the Jurassic sediments in the trough.

On the Scotian Shelf, Williams et al (1974) show more than 400 meters of Middle and Late Jurassic from the Shell Naskapi N-30 (Figures 30 and 34). The rocks consist of coarse-grained alluvial plain sands, delta plain shales and thick sections of deeper water carbonate.

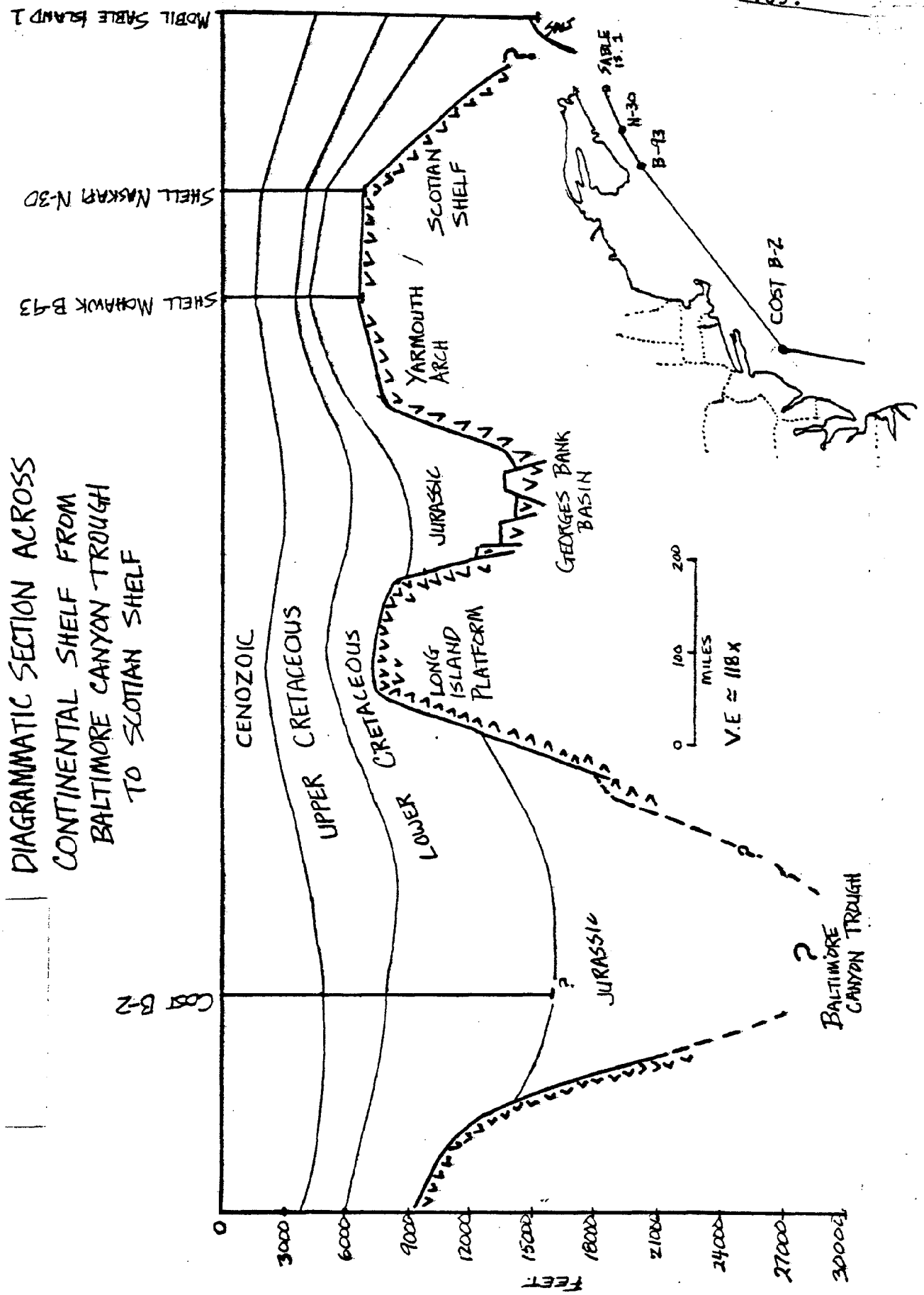

DIAGRAMMATIC SECTION ACROSS
CONTINENTAL SHELF FROM
BALTIMORE CANYON TROUGH
TO SCOTIAN SHELF
MOBIL SABLE ISLAND 1
SHELL NASKAPI N-30
SHELL MOHAWK B-43
COST B-2
CENOZOIC
UPPER CRETACEOUS
LOWER CRETACEOUS
JURASSIC
JURASSIC
YARMOUTH ARCH
SCOTIAN SHELF
GEORGES BANK BASIN
LONG ISLAND PLATFORM
BALTIMORE CANYON TROUGH
SABLE IS. 1
N-30
B-43
COST B-2
0
100
200
MILES
V.E ≈ 118 x
0
3000
6000
9000
12000
15000
18000
21000
24000
27000
30000
FEET

FIGURE 30

IV.D.3. Cretaceous

a. Lower Cretaceous

Perhaps the thickest section of Lower Cretaceous is present in the Baltimore Canyon Trough. The COST B-2 well penetrated more than 2000 meters of Lower Cretaceous sediments (Figure 31). The rocks in the lower part are mostly non-marine or nearshore sandstones and shales with interbedded coal. Higher up in the section calcareous sands and dolomite appear, along with silty shale and lignite.

USGS seismic line 2 (Figure 32) shows the section thinning shoreward from the COST B-2 to about 300 meters of Lower Cretaceous present in the USGS Island Beach 1 well (Figure 31). These interbedded sands and shales are predominantly non-marine in origin. The lower part of the section is missing at the Island Beach #1, but thickens southward in the Salisbury Embayment. To the north the Lower Cretaceous wedges out and is not present beneath Long Island.

Schultz and Grover (1974) have extrapolated well data from the Scotian Shelf to Georges Bank Basin, and hypothesize a sequence of marine and marginal marine shale, siltstone, and calcareous sandstone. Seismic data show a thick section, in excess of 2000 meters generally at a depth of between 1 and 4 kilometers.

On the Scotian Shelf itself, Williams et al (1974) show a Lower Cretaceous section about 500 meters thick in the Shell Naskapi N-30. The basal Mississauga Formation (Figure 33) consists of coarse-grained sands with some coal seams. These beds were deposited in terrestial and nearshore environments. The Naskapi Shale which overlies the Mississauga is predominantly marine and contains some interbedded dolomite. According to McIver (1972) the section is much the same but thicker in the deeper part of the basin to the northeast.

STRATIGRAPHIC CORRELATION FROM USGS ISLAND BEACH 1 TO COST B 2 WELL

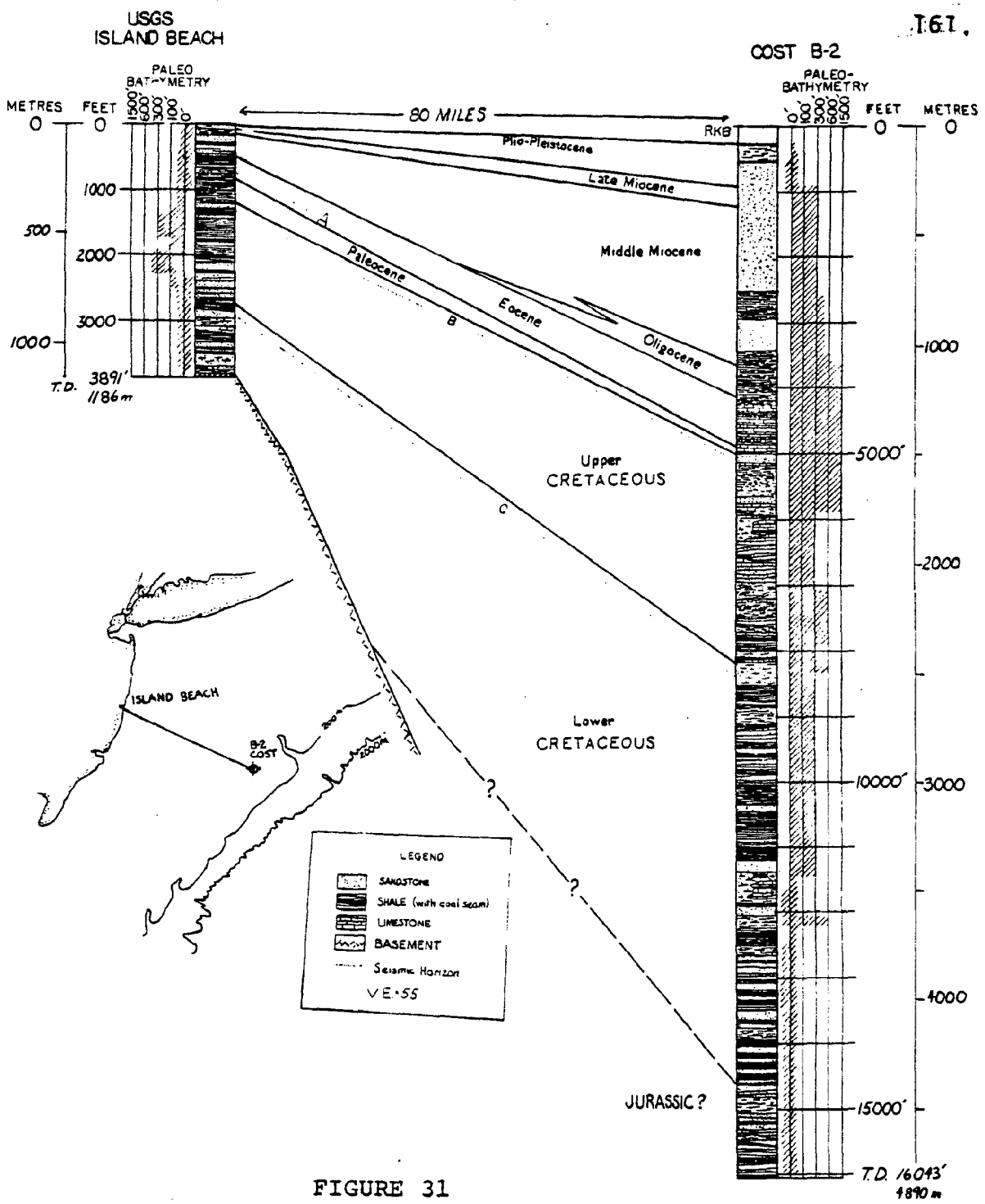


FIGURE 31

CROSS-SECTION BASED ON SEISMIC PROFILE 2 FROM USGS ISLAND BEACH 1 THRU COST B-2 TO EDGE OF CONTINENTAL SHELF

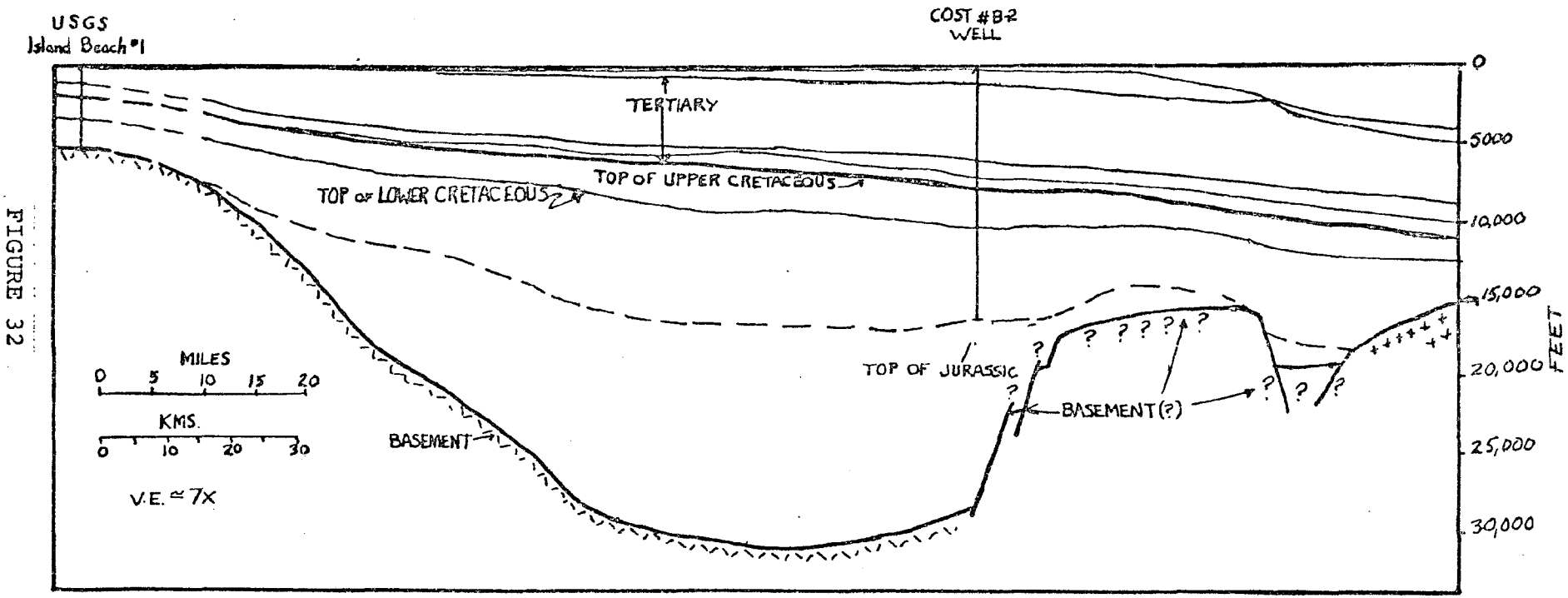


FIGURE 32

Stratigraphic correlation between COST B-2 and Shell N-30.

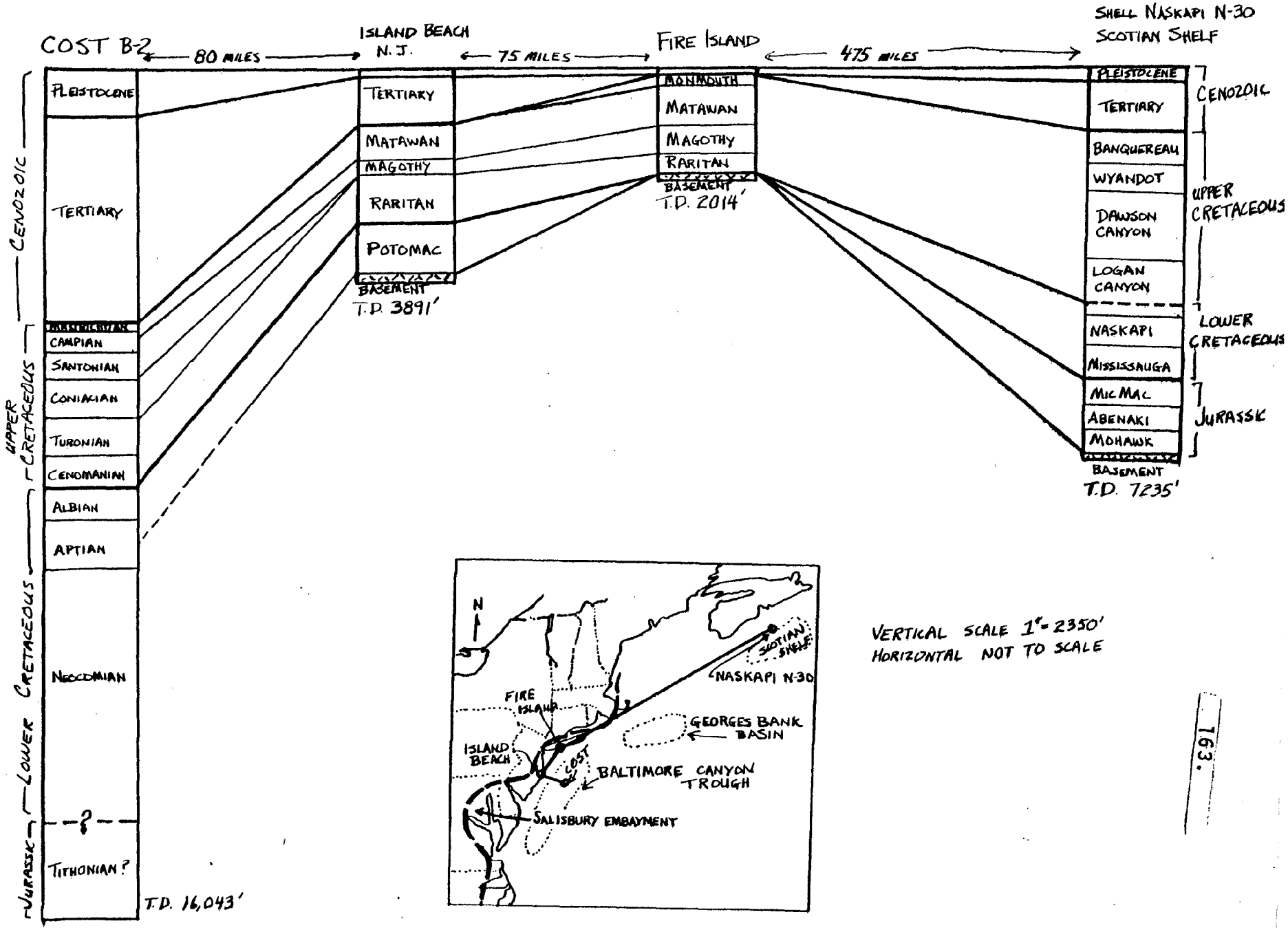


FIGURE 33.

IV.D.3.b. Upper Cretaceous

Under Long Island the Upper Cretaceous is about 600 meters thick (Figure 32) (see Brown et al, 1972 for complete stratigraphy of the Fire Island Well). The section there is complete except for unconformities between the Magothy and Raritan Formations and the Raritan and Basement (Figure 35). The youngest unit beneath the Pleistocene glacial deposits is the Upper Cretaceous Monmouth Group, the Tertiary being absent.

FIGURE 34
LOG OF FIRE ISLAND WELL

Depth below surface (to base of unit)		
-45 m	Pleistocene	glacial deposits
-100 m	Monmouth Group	marine sediments
-250 m	Matawan Group	sands, containing lignite, marine only at top (glauconite and fossils)
-550 m	Magothy Fm.	Predominantly sands - subaqueous river delta deposits; lignite
-612 m	Raritan Fm.	interbedded sand, silt and clay with massive basal sand member, non-marine
-614 m	Basement	mica schist and gneiss

The Magothy and overlying Upper Cretaceous formations thin southward from Long Island along coastal New Jersey, but the Raritan does not. The Raritan appears to be chiefly marine in origin in the Island Beach well because the sediments are finer-grained and more calcareous than those in the subsurface of Long Island. The same is true for the Matawan Group which in New Jersey, is mostly marine silt and clay (Figure 35).

In general, the Upper Cretaceous sediments of the Salisbury Embayment suggest a cyclical sequence of estuarine coastal marsh, and fluvial floodplain sediments constituting several transgressive-regressive phases (Perry et al, 1975).

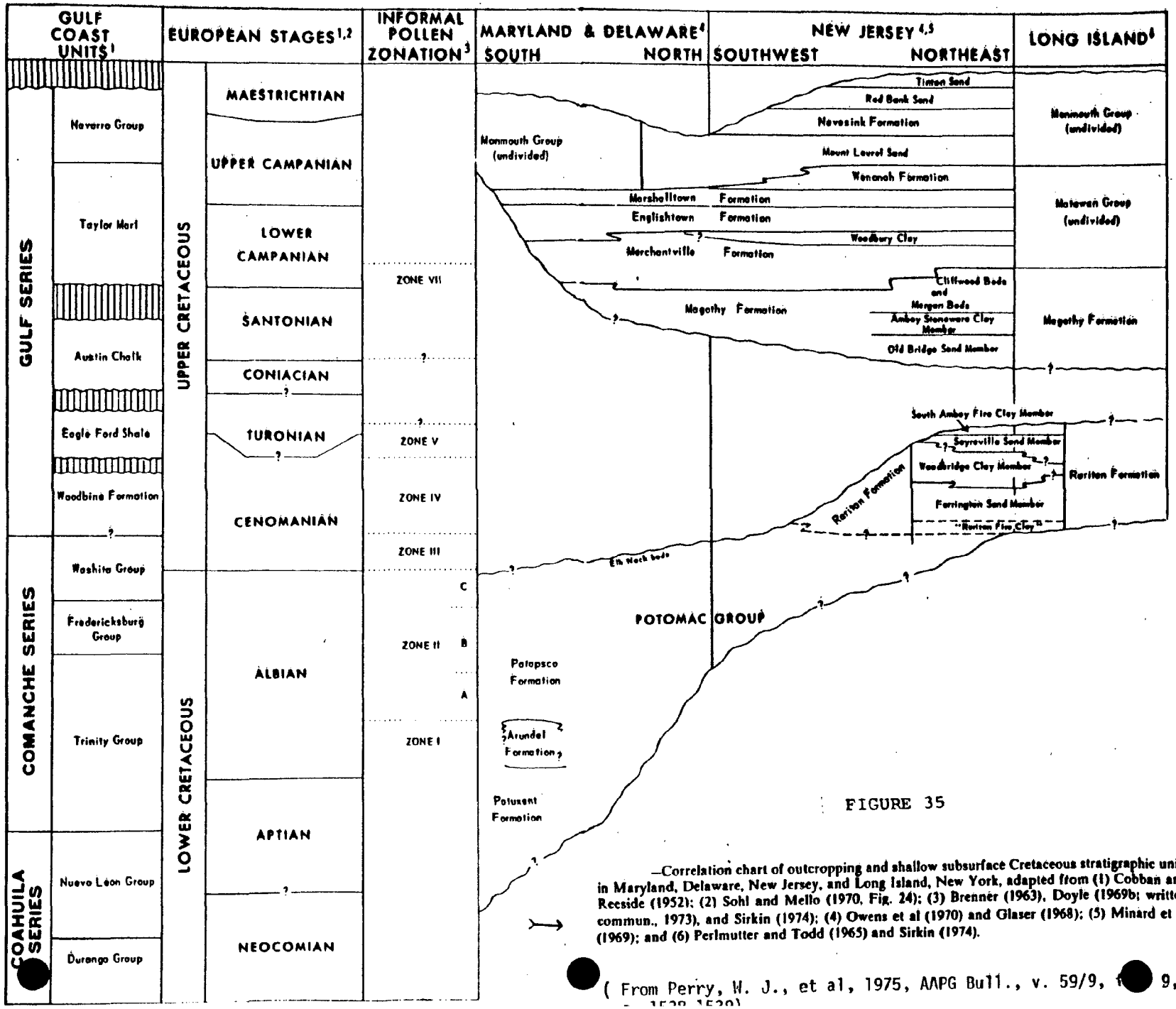


FIGURE 35

—Correlation chart of outcropping and shallow subsurface Cretaceous stratigraphic units in Maryland, Delaware, New Jersey, and Long Island, New York, adapted from (1) Cobban and Reeside (1952); (2) Sohl and Mello (1970, Fig. 24); (3) Brenner (1963), Doyle (1969b; written commun., 1973), and Sirkin (1974); (4) Owens et al (1970) and Glaser (1968); (5) Minard et al (1969); and (6) Perlmutter and Todd (1965) and Sirkin (1974).

(From Perry, W. J., et al, 1975, AAPG Bull., v. 59/9, [illegible] 9, [illegible] 1528-1529)

This is reflected in the COST B-2 well in the Baltimore Canyon Trough, directly offshore of the Salisbury Embayment. The Upper Cretaceous in the COST B-2 well is more than 1000 meters of marine (outer shelf) limestones, calcareous shales and sands interbedded with non-marine sands, shales and lignite. Scholle (1977) describes in detail the fluctuating nature of the depositional environments of these beds.

To the north on the Scotian Shelf the Upper Cretaceous is much thicker than the Lower Cretaceous in that area and almost entirely marine in origin. The sediments consist of interbedded sands and shales with the shales containing a high percentage of carbonate (Williams et al, 1974).

IV.D.4. Cenozoic (pre-Pleistocene)

This section ranges in thickness from a feather edge south of Long Island to 1500 meters of unconsolidated sands, gravels and clays with some limestones on the continental shelf at the COST B-2 well. The pre-Pleistocene section appears just to the south of Long Island and is present in a south and eastward thickening wedge (up to 600 meters in New Jersey). In the other direction this section thins over Georges Bank, where it was removed by the Pleistocene glaciations. It thickens northward again to more than 300 meters of unconsolidated sand and mud on the Scotian Shelf.

Brown et al (1972) is a good compilation and correlation of all the important wells from Cape Hatteras to Long Island. Maher (1972) has a detailed discussion of the stratigraphy of the coastal plain and shelf from Florida to Nova Scotia, relating it to petroleum potential of the area. McIver (1972) and Amoco Canada's (1974 discussion of the exploration results from the Scotian Shelf form the basis of Schultz' and Grover's (1974) inferences about Georges Bank Basin stratigraphy. Both USGS (1975a, b) provide a review of the stratigraphy in Georges Bank Basin and Baltimore Canyon Trough. USGS's (1976) open file on the COST B-2 well gives a detailed stratigraphic section of the top 5000 meters of the BCT and Scholle (1977) provides a more complete analysis of the well data. To the north, Williams et al (1974) gives the stratigraphy of the Shell Maskapi N-30. Perry et al (1975) gives a brief survey of the Atlantic coastal margin, and Weed et al (1974) is an up-to-date geologic map of the coastal plain and shelf.

IV.D. Stratigraphy

Biostratigraphic framework of the Grand Banks, Armstrong, W.E., 1973.

Mesozoic and Cenozoic history of the Grand Banks of Newfoundland, Bartlett, G.A. and L. Smith, 1971.

Seismic evidence for a thick section of sedimentary rock on the Atlantic outer continental shelf and slope of the U.S. (abstr.), Behrendt, J.C. and others, 1974.

Structural and stratigraphic framework, and spatial distribution of permeability of the Atlantic Coastal Plain, North Carolina to New York, Brown, P.M. and others, 1972.

Atlantic salt deposits formed by evaporation of water split from the Pacific, Tethys and Southern Oceans (abstr.), Burke, K., 1975.

The stratigraphy of the continental shelf east of New Jersey (abstr.), Chelminski, P. and Fray, C.I., 1966.

Lost-miocene stratigraphy and morphology, inner coastal plain, southeastern Virginia, Coch, N.K., 1963.

Mobil Tetco Sable Island O-47: well history report, Dawson, W.E., 1972.

Mobil Tetco Thebaud P-84: well history report, de Jonge, B. and others, 1973.

Ages of horizon A and the oldest Atlantic sediments, Ewing, J. and others, 1966.

Regional aspects of deep-sea drilling in the western North Atlantic, Ewing, J.I. and Hollister, C.H., 1972.

Geology of Long Island, N.Y., Fuller, M.L., 1914.

Fossiliferous rocks from submarine canyons off the northeastern U.S., in Geological Survey research 1968, Gibson, T.G. and others, 1968.

Evaluation of geologic and hydrobiologic data from the test-drilling program at Island Beach State Park, New Jersey, Gill, H.E. and others, 1963.

Coastal plain geology of southern Maryland, Glaeser, J.D., 1968.

IV.D. (continued)

Site 108, continental slope, Hollister, C.D. and others, 1972.

Sites 105, 106, 107, 108, Hollister, C.D. and others, 1972.

Seismic reflection observations on the Atlantic continental shelf, slope and rise southeast of New England, Hoskins, H., 1967.

Sedimentary velocities of the western North Atlantic margin, Houtz, R.E., 1964.

Detailed sedimentary velocities from seismic refraction profiles in the western North Atlantic, Houtz, R.E. and Ewing, J., 1963.

Record of wells in Suffolk County, L.I., N.Y., Johnson, A.H. and others, 1952.

Stratigraphy of coastal plain of N.J., Johnson, M.E. and Richards, H.G., 1952.

Ocean drilling on the continental margin, Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965.

Gravity and magnetic evidence of lithology and structure in the Gulf of Maine region, Kane, M.F. and others, 1972.

Geologic and hydrologic data from a test well drilled near Chestertown, Md., Kantrowitz, I.H. and Webb, W.E., 1971.

A geologic cross-section of Delaware showing stratigraphic correlations, distribution and geologic setting with the Atlantic coastal plain - continental shelf geosyncline, Kraft, J.C. and Maisang, M.D., 1968.

Time-stratigraphic units and petroleum entrapment models in Baltimore Canyon Basin of Atlantic Continental Margin geosynclines, Kraft, J.D. and others, 1971.

Lithology of sediments from the western North Atlantic Leg II Deep Sea Drilling Project, Lancelot, Y. and others, 1972.

Summary of geology of Atlantic Coastal Plain, LeGrand, H.E., 1961.

Correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic coast, Maher, J.C., 1965.

IV.D. (continued)

Cenozoic and Mesozoic stratigraphy of the Nova Scotia shelf, McIver, N.L., 1972.

Mobil Tetco Sable Island E-48, Morrow, D.L. and others, 1972.

The Georges Bank Petroleum Study, Offshore Oil Task Group, 1973.

Deep test in Accomack County, Virginia, Onuschak, E.,

Maryland Esso No. 1 well, Standard Oil Co. of N.J., Ocean City, Maryland, description of ditch samples, Overbeck, R.M., 1948.

Continuous deep sea salt layer along North Atlantic margins related to early phase of rifting, Pautot, G.J.M. and others, 1970.

Stratigraphy of the Atlantic continental margin of the U.S. north of Cape Hatteras, a brief survey, Perry, W.J. and others, 1974.

Stratigraphy of the Atlantic continental margin of the U.S. north of Cape Hatteras - brief survey, Perry, W.J. and others, 1975.

Subsurface stratigraphy of Atlantic coastal plain between New Jersey and Georgia, Richards, H.G., 1945.

Studies of the subsurface geology and paleontology of the Atlantic coastal plain, Richards, H.G., 1948.

Stratigraphy of Atlantic coastal plain between Long Island and Georgia - Review, Richards, H.G., 1967.

Invertebrate fossils from cores from the continental shelf off New Jersey, Richards, H.G. and Eberhard, W., 1964.

Stratigraphic section at Island Beach State Park, N.J., Seaber, P.R. and Vecchioli, J., 1963.

Results of subsurface exploration in the mid-island area of western Suffolk County, L.I., N.Y., Soren, J., 1971.

Geology of Atlantic coastal plain in New Jersey, Delaware, Maryland and Virginia, Spangler, W.B. and Peterson, J.J., 1950.

IV.D. (continued)

Geology and paleontology of Georges Bank Canyons, Stetson, H.C., 1936.

The sediments and stratigraphy of the east coast continental margin, Georges Bank to Norfolk Canyon, Stetson, H.C., 1949.

Mapping of geologic formations and aquifers of Long Island, N.Y., Suter, R. and others, 1949.

Lower Cretaceous, Jurassic and Triassic ostracoda from the Atlantic coastal regions, Swain, F.M. and Brown, P.M., 1972.

A seismic record of Mesozoic rocks on Block Island, Rhode Island, Tuttle, C.R. and others, 1961.

Occurrence of fossiliferous Tertiary rocks on the Grand Banks and Georges Bank, Verrill, A.E., 1878.

Generalized pre-Pleistocene geologic map of the northern United States Atlantic continental margin, Weed, E.G.A. and others, 1974.

IV.D. Stratigraphy

1. Triassic, 2. Jurassic, 3. Cretaceous

Cretaceous and Tertiary subsurface geology, Anderson, J.L., 1948.

Geology and paleontology of the Georges Bank Canyons, Part 3, Cretaceous bryozoan from Georges Bank, Bassler, R.S., 1936.

Geology and paleontology of the Georges Bank Canyons, Part 4, Cretaceous and late Tertiary foraminifera, Cushman, J.A., 1936.

Critical analysis of Cretaceous stratigraphy and paleobotany of the Atlantic coastal plain, Dorf, E., 1952.

Cretaceous-Cenozoic development of the continental shelf south of New England, Garrison, L.E., 1967.

Cretaceous deltas in the New Jersey coastal plain (abstr.), Gill, H.E. and others, 1969.

Petrology and origin of Potomac and Magothy (Cretaceous) sediments, middle Atlantic coastal plain, Glaeser, J.D., 1969.

Plant microfossils and age of nonmarine Cretaceous sediments of Maryland and Delaware, Groot, J.J. and Penny, J.S., 1960.

Depositional environments of subsurface Potomac group in southern Maryland, Hansen, H.J., 1969.

Cretaceous-Tertiary boundary in New Jersey, Delaware and eastern Maryland, Minard, J.P. and others, 1969.

Cretaceous deltas in the Northern New Jersey coastal plain, Owens, J.P. and others, 1968.

Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, Field trip no. 2 in Geology of selected areas in N.J. and eastern Penna. and guidebook of excursions, Geol. Soc. Amer. Mtg. Atlantic City, N.J., 1969, Owens, J.P. and N.F. Sohl, 1969.

Stratigraphy of the outcropping post-Magothy Upper Cretaceous formations in Southern New Jersey and Northern Delmarva Peninsula, Delaware and Maryland, Owens, J.P. and others, 1970.

IV.D. (continued)

Correlation and foraminifera of the Monmouth Group (Upper Cretaceous), L.I., N.Y., Perlmutter, N.M. and Todd, R., 1965.

Upper Cretaceous subsurface stratigraphy of Atlantic coastal plain of N.J., Petters, S.W., 1976.

Palynology and stratigraphy of Cretaceous strata in L.I., N.Y. and Block Island, R.I, Sirkin, L.A., 1974.

Biostratigraphic analysis, Sohl, N.F. and Mello, J.F., 1970.

Upper Cretaceous marine transgression in northern Delaware, Spoljaric, N., 1972.

Geology and paleontology of the Georges Bank Canyon, Part 11, Upper Cretaceous fossils from Georges Bank (including species from Banquereau, Nova Scotia), Stephenson, L.W., 1936.

Distribution and geologic structure of Triassic rocks in the Bay of Fundy and the northeastern part of the Gulf of Maine, Tagg, A.R. and Uchupi, E., 1966.

Stratigraphic interpretations of some Cretaceous microfossil floras of the middle Atlantic states, Wolfe, J.A. and Pakiser, H.M., 1971.

IV.D. Stratigraphy

4. Cenozoic (pre-Pleistocene)

Cretaceous and Tertiary subsurface geology (md.), Anderson, J.L., 1948.

Eocene foraminifera from submarine cores off the eastern coast of North America, Cushman, J.A., 1939.

Tertiary fossil dredged off the northeastern coast of North America, Dall, W.H., 1925.

Cretaceous-Cenozoic development of the continental shelf south of New England, Garrison, L.E., 1967.

Eocene and Miocene rocks off the Northeastern Coast of the United States, Gibson, T.G., 1965.

Seismic profile showing Cenozoic development of the New England continental margin, Krause, D.C. and others, 1966.

Pliocene-Miocene strata in a submarine canyon off Nova Scotia (abstr.), Marlowe, J.I. and Bartlett, G.A., 1967.

Cretaceous-Tertiary boundary in N.J., Delaware, and eastern Maryland, Minard, J.P. and others, 1969.

An outcrop of Eocene sediments on the continental slope, Northrop, J.M. and B.C. Heezen, 1951.

Post-Miocene stratigraphy and morphology, outer coastal plain, southeastern Virginia, Oaks, R.Q., Jr., 1964.

Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, Field Trip no. 2, Owens, J.P. and N.F. Sohl, 1969.

Rocks of Eocene age of Fippennies Ledge, Gulf of Maine, Schlee, J. and Chaetham, A.H., 1967.

Seismic reconnaissance of post-Miocene deposits, Middle Atlantic continental shelf - Cape Henry, Virginia to Cape Hatteras, North Carolina, Shidler, G.L. and D.J.P. Swift, 1972.

Discovery of Eocene sediments in subsurface of Cape Cod, Ziegler, J.M. and others, 1960.

IV.D.5. Pleistocene-Holocene

Pleistocene and Holocene sediments form a relatively thin mantle of loose detrital materials across most of the mid and north Atlantic portions of the continental shelf. Sediment thicknesses, texture and compositions are highly variable because of the diverse nature of their source, the mode of deposition on the shelf and the processes which have influenced them after they were first deposited on the shelf. The geologic time scale into which the Pleistocene-Holocene deposits are set is far from standardized for reasons which will be discussed.

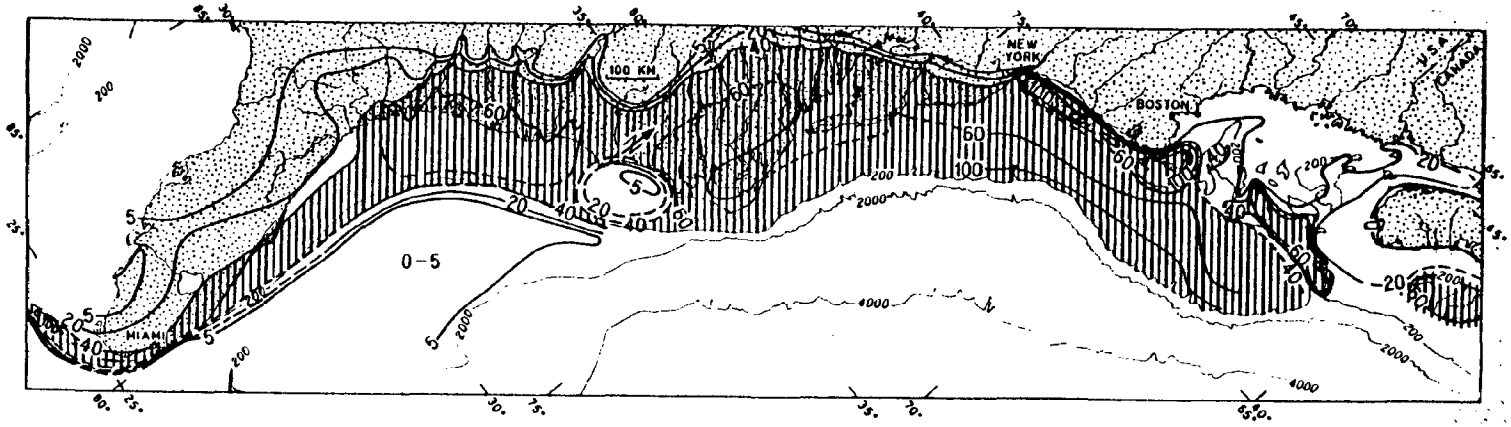
Below is a generally accepted framework of the time-stratigraphic relation of the youngest deposits on the shelf.

ERA	PERIOD		EPOCH	MILLION YEARS BEFORE PRESENT
	Quaternary	TERMS	/Holocene (recently)/	
			/Pleistocene (glacial)/	2-3
Cenozoic		ARCHAIC	Pliocene	12
			Miocene	25
	Tertiary		Oligocene	40
			Eocene	60
			Paleocene	70
Mesozoic	Cretaceous			135

Emery and Uchupi (1972, Fig. 319, p. 414) show a modified map of the thickness distribution of Pleistocene-Holocene sediments which mantle the Atlantic continental shelf of the United States. Their map is reproduced in Figure 36. In the middle Atlantic bight, between Cape Hatteras and the northeast channel along the northern margin of Georges Bank, there is a general pattern of thickening from the coastal zone toward the shelf break. Thicknesses are less than 60 m near the coastal plain whereas they are somewhat greater than 100 m near the shelf break. The glacial deposits underlying Long Island and the Cape Cod region also exceed 100 m in thickness. This isopach map probably can be revised in the near future because of the extensive program of "shallow" coring carried out by the Marine Geology Branch, United States Geological Survey at Woods Hole. A number of holes in the middle Atlantic portion of this drilling program penetrated the lower boundary of Pleistocene deposits.

Placement of the Pleistocene-Holocene deposits within a time-stratigraphic framework has a number of specific problems. The geologic time scale for the Phanerozoic has been defined by interregional boundaries, usually unconformities, with distinctive faunal and/or floral fossil assemblages characterizing the sedimentary sequences between these boundaries. These boundaries usually represent major tectonic events, sea-level and/or climatic

FIGURE 36



-Thickness of Quaternary sediments on Atlantic continental shelf determined from continuous seismic-reflection profiles and drillhole and dredge samples. Contours are in meters, and deposits more than 40m thick are cross-hatched. Modified from Emery and Milliman (1970, Fig. 8).

(From Emery, K. O. and Uchupi, E., 1972, AAPG Mem. 17, fig. 319, p. 414.)

changes and resulting modifications in processes and their intensities. The history of late Cenozoic (Miocene through Holocene) is one basically influenced by climatic fluctuations. The lower and the upper boundaries of the Pleistocene remain unresolved geologic problems at the present time.

The Pliocene-Pleistocene boundary is not resolved for two reasons:

1. The strata of the two epochs are transitional.

2. Two methods are used to define the epoch boundaries:

   a. evolutionary differences in fossil organisms (in this case, differences in planktonic microfossils);

   b. evidence expressing climatic cooling (i.e., glaciation).

From the earliest days (1846) of recognition that glaciation had occurred on the continents of the northern hemisphere to the late 1960's, the epoch, Pleistocene, was equated with the term, glacial epoch. However, in the late 1960's, two important findings in high latitude regions made the equation of Pleistocene=glacial invalid. First, there is evidence of migration of cold water marine fauna and terrestrial flora in lower latitudes. Second, the finding of glacial deposits which have been dated radiometrically at 10 million years (my) before present. For both reasons, glacial climates and glacial deposits in the late Cenozoic cannot be used as a basis for differentiating a Pliocene-Pleistocene boundary.

There is also no agreement upon the Pleistocene-Holocene boundary which initially was conceived as the glacial-post glacial stratigraphic subdivision. One defining criterion for the boundary has been the initiation of autochthonous continental sediments following glaciation. Because of the on-going process of glacier ice retreat, such a boundary is time transgressive. Another criterion which has been utilized is the time fixed by changes in physical features dated around 10,000 years B.P. These indicate the beginning of the Flandrian sea-level rise (recognizable only in borings at the lowest sea-level stands), paleobotanical evidence of temperature increase, the marked on set of aridity and possibly the time extinctions of the big mammals.

Any distinction between Pleistocene and Holocene if linked to glacial-post glacial events is:

1. time transgressive

2. applicable only region by region

3. not applicable in continental regions having no connections with glaciated regions.

Further confounding of the issue are two other important facts. First, the problem is not that the stratigraphic evidence is sparse or obscure, but rather that it is so abundant and reported in such detail. Second, the bulk of the stratigraphic work has been carried out by land-based geologists observing portions of very incomplete and obscure evidence of the entire late Cenozoic patterns of changes. Results of stratigraphic subdivisions, well-entrenched in the literature reportedly by land-based geologists, are not readily comparable to dating of cores taken in the marine environment beginning in the 1960's. No attempt will be made here to examine or unscramble the difficulties in resolving the marine core dates in terms of the generally accepted time-stratigraphic framework presented earlier in this section.

The remainder of this section will deal with what is presently known about the Pleistocene-Holocene continental shelf deposits of the middle Atlantic portion of eastern United States. An understanding of them is crucial from four different points of view:

1. They represent the uppermost, unconsolidated sediments into which any engineering structures, such as drill rigs, must be securely placed.

2. These sediments are responsive to the circulation regimes on the shelf.

3. Pleistocene and Holocene deposits represent the substrate for benthonic marine organisms and represent the feeding, breeding and growth-stage ground for innumerable groups of marine organisms.

4. The deposits are of significant economic importance (see Section VI.E.).

New evaluations of the Pleistocene-Holocene stratigraphic boundary are now underway. Three major sources of data are being gathered, some of which are now available at least in preliminary form.

The first source of data is continuous seismic reflection profiles taken on the continental shelf. As indicated in Emery and Uchupi (1972, p. 415), these profiles commonly show the presence of four or five nearly horizontal, discontinuous acoustic reflectors thought to be sand units deposited subaerially during glacial stages. Beneath them is

an unconformity truncating seaward-dipping pre-Pleistocene Cenozoic strata. The total thickness of these sand units above the unconformity is indicated in the isopach map (Figure 36). Knebel and others (1976) presented the shallow subbottom stratigraphy and structure of the Baltimore Canyon Trough portion of the continental shelf. Using vibracore data in conjunction with detailed seismic reflection surveys, they present detailed isopach maps of subareas on the shelf showing distribution of surficial sand sheets of thicknesses grouped 0-2 m, 2-10 m and 10-20 m. Vibracores of the outer continental shelf indicates that this surficial sand is shelly, poorly sorted and medium to coarse grained. The sand sheet is underlain by muddy, texturally variable materials. This "stratigraphic" boundary coincides with subbottom reflectors which can be traced laterally within the study areas. Where the sand sheet varies in thickness from 1 m to 20 m, thickness correlates closely with bottom morphology (i.e., sand waves and/or ridge and swale topography). In one area, sand waves were observed on top of the sand sheet. It is the type of evidence which further supports the ideas of Swift, Stanley and Curray (1971) and those interpretations in a number of papers in Swift, Duane and Pilkey (1972) that the shelf surface sediments are responding to the prevailing hydraulic regimes.

The second major source of data which will lead, in the near future, to a realistic picture of the Pleistocene-Holocene stratigraphic arrangement on the continental shelf of the middle Atlantic bight, comes from the 1976 Atlantic Margin Coring Project of the U.S. Geological Survey/open-file report 76-844. There are fifteen core sites in the middle Atlantic bight hole sites 6007 through 6021. Of these, fourteen cores did not penetrate below the Pleistocene lower boundary. Early to mid-Cenozoic units were recovered in the remaining holes. Correlations among the holes and with other detailed stratigraphic or seismic information have not been presented.

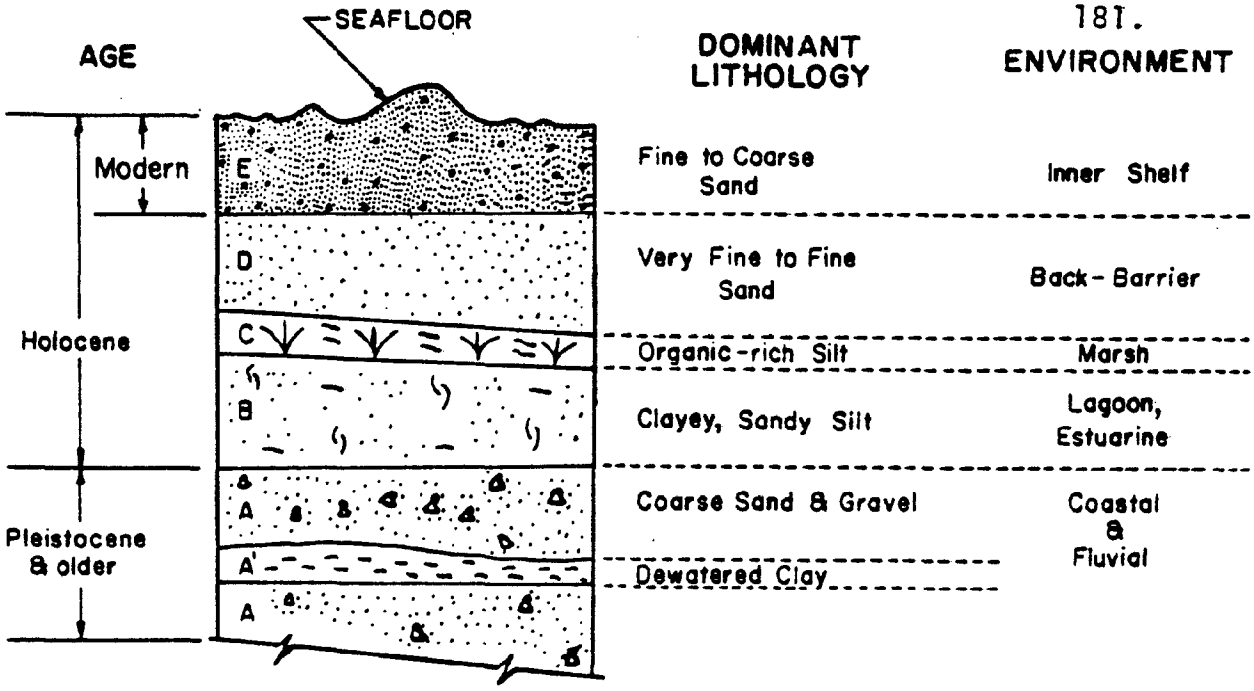
A third major source of data is available through extensive studies of the New York bight region by the National Oceanographic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers Coastal Engineering Research Center (CERC). There are five important published reports from which the remainder of this review of shallow stratigraphy is synthesized. The work of NOAA at the Atlantic Oceanographic and Meteorological Laboratory (AOML) emphasizes sediment distribution and sediment mobility. Among those NOAA geologists most immediately involved in analysis of the data are D.J.P. Swift and George Freeland.

Those reports most useful in the synthesis which follow are:

Duane and others, 1972
Swift, Kofoed, Saulsbury and Sears, 1972
Williams and Duane, 1974
Charnell and others, 1975
Field and Duane, 1976

A generalized vertical Pleistocene-Holocene stratigraphic section of the inner shelf is presented in Field and Duane (Figure 37) showing representative sediment types in vertical sequences determined from hundreds of vibracores. The base is defined by an erosional unconformity separating older strata from surficial sands. Sands and gravels, in places found with an interbedded, dewatered clay are identified as Pleistocene and older fluvial and coastal deposits. This unit is overlain by Holocene clayey sandy silt ranging in thickness from 1 to 5 m which is interpreted as lagoon-estuarine sediment. Above this, a thin (usually less than 1 m) organic-rich silt formed in a marsh deposit. Very fine to fine sands, 1 m to 1.5 m thick, overlie the marsh material. These are thought to be of back barrier origin. The top most inner shelf unit is fine to coarse modern sands 1 m to 5 m thick responding to on-going hydraulic processes of the present day shelf. This generalized model is a logical result of the transgression process continuing since the shelf was previously subject to subaerial erosion during falling sea-level and still-stand. With rising sea-level all portions of the shelf have been subject to processes of shoreface modification and retreat.

Based on the detailed analysis of the surface morphology of the Atlantic inner continental shelf, particularly of the linear shoals (ridge and swale topography), Duane and Field (1976), Duane and others (1972), and Swift, Kofoed, Saulsbury and Sears (1972), the following conceptual model seems to satisfactorily account for the characteristics of the shelf surface. The dominant pattern of linear shoals is thought to be a constructional topography formed at the foot of the shoreface. This constructional topography then undergoes modification in response to the present-day hydraulic regime. This pattern follows the Bruun (1962) model of coastal retreat during rising sea level. The resulting "equilibrium" profile is a product of rising sea-level over unconsolidated material resulting in shoreface erosion equivalent to parallel slope retreat, and a resulting aggradation of the sea floor. The result is the Holocene transgressive sand sheet, a discontinuous mantle of material which is only partly autochthonous because some of its source is Holocene fluvial material. The surface of this sand sheet is molded into three dominant morphologic units:



Generalized vertical section of the shelf in the mid-Atlantic province off barrier island–spit complexes. Units A and B are always present; E, usually present; D, commonly present; and C, rarely present. Thickness of the units is variable, but some approximations can be made for the range of thicknesses within the Holocene section: Unit B, 1 to 5 m; Unit C, <1 m; Unit D, 1 to 1.5 m; Unit E, <1 to 5 m.

(From Field, M. E. and Duane, David, 1976, GSA Bull., v. 87, fig. 8, p. 698)

FIGURE 37

1. ridge and swale topography - where the sand sheet has been generated directly from the retreating shoreface,

2. cape-associated shoals - generated off cuspate forelands as a result of littoral drift convergence,

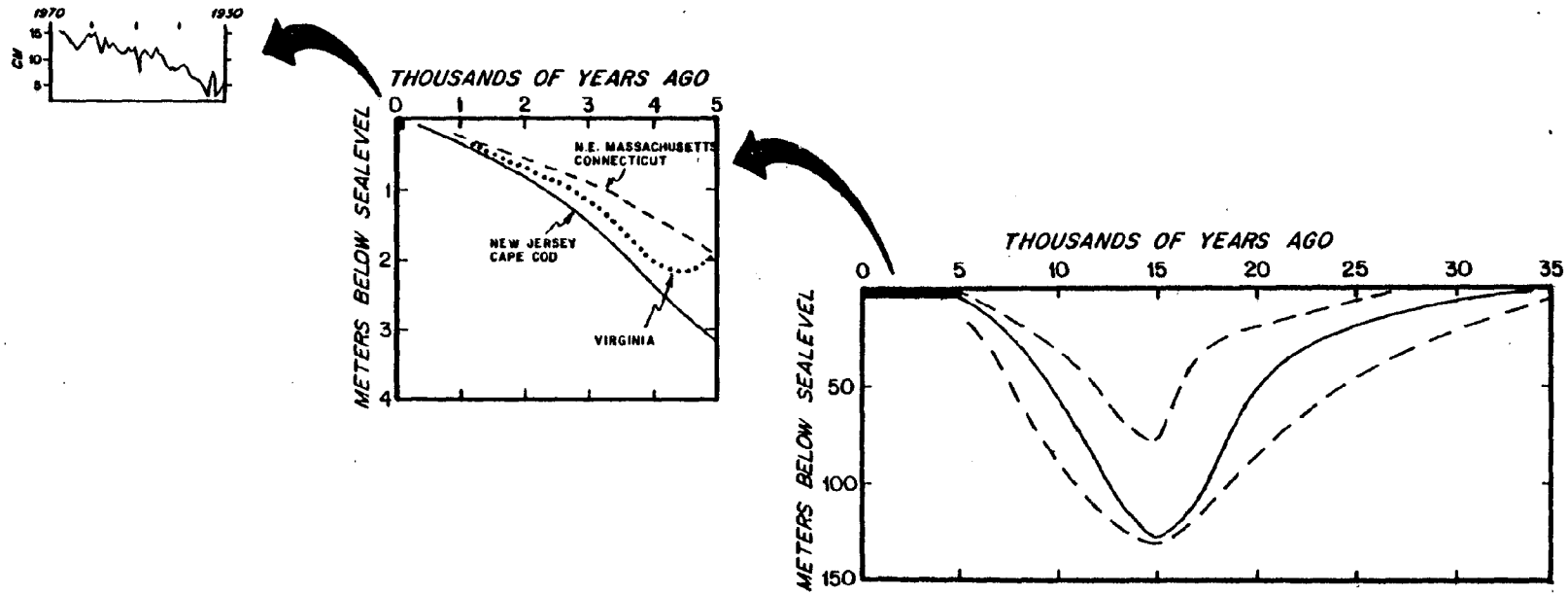
3. inlet-associated shoals - formed off estuary mouths via the intersection of littoral drift and the reversing estuary tide.

Seaward of portions of the inner shelf where these three morphologic units are being formed, are earlier features of the same types. Such evidence clearly substantiates the point emphasized by Field and Duane (1976) that there was a similarity in alignment of shorelines during the passage of Holocene sea-level encroachment across the shelf surface to its present-day position.

One of the results of surficial sediment studies is the development of a detailed lithofacies map of the shelf surface. Two such available maps are given in Williams and Duane (1974, Fig. 14, p. 42), and in Charnell and others (1975, Fig. 2-5, p. 22).

However, these lack the detailed link to topography which is essential in evaluating potential drill sites. Some more extensive, regional information relating surface morphology, sediment types and organisms are reported in the quarterly reviews of BLM-VIMS studies (D. Boesch, M. Champ, H. Kator, V. Goldsmith, all presented reviews January 15, 1977 and summarized in a report to W.B. Rogers as a Summary of the Fifth Quaterly Meeting). The most detailed sediment distribution maps are being compiled by George Freeland (AOML of NOAA at Miami) and have not yet (May, 1977) appeared in print.

There are other models indicating the predictable vertical sequence resulting from a transgressing marine environment. The most detailed are those based on coastal-zone facies arrangements presented by Kraft (1971a), Kraft, Biggs and Halsey (1973), and Kraft and others (1974). More general conceptual models are presented by Fischer (1961) and Swift (1968). Any model of Pleistocene-Holocene stratigraphic arrangements on the Atlantic continental shelf needs to be viewed within the sea-level time curves of Milliman and Emery (1968) (Figure 38).



. Sea levels on the U.S. Atlantic continental margin during the past 35,000 years. The figure on the right shows sea level from 5,000 to 35,000 years ago; the dashed lines show the range of values (after Milliman and Emery, 1968). The middle figure shows the relative rise in Holocene sea level in various areas along the Middle Atlantic Bight (after Newman and Munsart (1968). The figure on the left shows fluctuations in sea level along the Middle Atlantic coast as portrayed in tide gauge records for the past 40 years (after Meade and Emery, 1972).

(From Milliman, J. D., 1973, Coastal and Offshore Enviromental Inventory: Cape Hatteras to Nantucket Shoals, fig. 10.42, p. 10.70)

FIGURE 38

IV.D.5. Pleistocene-Holocene

Late Pleistocene and Holocene sedimentation in the Laurentian Channel, Connolly, J.R., Needham, H.D. and Heezen, B.C., 1967.

Late Quaternary history continental shelves of the U.S., Curray, J.R., Jr., 1965.

Shallow structure of the continental margin, Curray, J.R., 1969b.

Long Island Sound in the Quaternary Era, with observations on the submarine Hudson River Channel, Dana, J.D., 1972.

Relict sediments on continental shelves of the world, Emery, K.O., 1968.

Postglacial subsidence of the New York area, Fairbridge, R.W. and Newman, W.S., 1968.

Post-Pleistocene history of the U.S. inner continental shelf, Field, M.E. and Duane, D.B., 1976.

Stratigraphic record of transgressing seas in light of sedimentation on the Atlantic Coast of N.J., Fisher, A.G., 1961.

Geology of Long Island, N.Y., Fuller, M.L., 1914.

The pollen flora of Quaternary sediments beneath Nantucket Shoals, Groot, C.R. and J.J. Groot, 1964.

Possible late Pleistocene uplift, Chesapeake Bay entrance, Harrison, W.B. and others, 1965.

Preliminary summary of the 1976 Atlantic margin coring project of the USGS, Hathaway, J.C. and others, 1967.

Dispersal patterns of Pleistocene sands on the North Atlantic deep-sea floor, Hubert, J.F., 1962.

The submerged coastal plain and old land of New England, Johnson, D.W., and Stolfus, M.A., 1924.

Stratigraphy of coastal plain of N.Y., Johnson, M.E. and Richards, H.G., 1952.

IV.D.5. (continued)

Late Quaternary sea-level change and crustal rise at Boston, Mass., with notes on the autocompaction of peat, Kaye, C.A. and Barghoorn, E.S., 1964.

Evidence of Pleistocene events in the structure of the continental shelf off the northeastern U.S., Knott, S.T. and Hoskins, H., 1968.

Sedimentary facies patterns and geologic history of a Holocene transgression, Kraft, J.C., 1971a.

Morphology and vertical sedimentary sequence models in Holocene transgressive barrier systems, Kraft, J.C. and others, 1973.

Middle-Late Holocene evolution of the morphology of a drowned estuary system -- the Delaware Bay, Kraft, J.C. and others, 1974.

Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York, MacClintock, P., and Richards, H.G., 1936.

Pleistocene geology of western Cape Cod, Mass., Mather, K.F. and others, 1942.

Probable Holocene transgressive effects on geomorphic features of the continental shelf off New Jersey, U.S., McClennen, C.E. and R.L. McMaster, 1971.

A submerged Holocene shoreline near Block Island, McMaster, R.L. and Garrison, L.E., 1967.

Quaternary geology of N.Y., Muller, E.H., 1965.

Late Quaternary geology of the Hudson River estuary, Newman, W.S. and others, 1969.

The glaciated shelf off northeastern U.S., Oldale, R.N. and Uchupi, E., 1970.

Glaciation on the continental margin off New England, Pratt, R.M. and Schlee, J., 1970.

The Quaternary of New England, Schafer, J.P. and Hartshorn, J.H., 1965.

Reconstruction of late glacial and post-glacial events in Long Island Sound, Schaffel, S., 1971.

IV.D.5. (continued)

Glacial history of the Gulf of Maine (abstr.), Schlee, J.S. and Pratt, R.M., 1966.

Holocene sedimentary environment of the Atlantic inner shelf off Delaware, Sheridan, R.E. and others, 1974.

Late Quaternary stratigraphy of the inner Virginia continental shelf, Shidler, G.L. and others, 1972.

Marine erosion of glacial deposits in Massachusetts Bay, Stetson, H.C., 1935.

Submergence of the N.J. coast, Stuiver, M. and Daddario, J.J., 1963.

Coastal erosion and transgressive stratigraphy, Swift, D.J.P., 1968.

Quaternary sedimentation on the inner Atlantic Shelf between Cape Henry and Cape Hatteras, a preliminary report, Swift, D.J.P. and others, 1970.

Late Pleistocene stratigraphy and paleoecology of the Lower Hudson River Estuary, Weiss, D., 1974.

Foraminifera and origin of the Gardiners clay (Pleistocene), Eastern Long Island, N.Y., Weiss, L., 1954.

Sediments and shallow structures of the inner continental shelf off Sandy Hook, N.J., Williams, S.J. and Field, M.E., 1971.

Post-Pleistocene history of the U.S. inner continental shelf, significance to origin of barrier islands, discussion and reply, Otvos, E.G., Jr., 1977.

V. SEISMICITY OF THE CONTINENTAL MARGIN

The USGS (1975a) has stated (p. 112) that the "seismic risk is moderate on the Atlantic OCS in comparison to the other areas of the United States." An examination of earthquake epicenters (Figure 39) shows very few epicenters in the north and mid-Atlantic outer continental shelf.

Hadley and Devine (1974) state that "no earthquake in the /north Atlantic coastal/ area has had a maximum epicentral intensity greater than Modified Mercalli (MM) IV." This is considered to be below the threshold of damage to structures (USGS, 1975a).

According to Howell (1973) the Continental Shelf has a hazard index of 6.94 ± 1.18 where a hazard index of 7.55 (Mercalli 7) represents substantial damage to structures while an index of 5.4 (Mercalli 5) indicates the threshold of damage.

The Wilmington, Delaware area has had five earthquakes of Mercalli intensity 5 or more and "fault and surface trends lineations suggest that these may be part of an overall tectonic pattern." (USGS, 1975a). The New York City and New Jersey areas have experienced at least four earthquakes of Mercalli intensity 5 or more without significant damage. At least four epicenters have been located on the Continental Slope east of Baltimore Canyon Trough. Few earthquake epicenters have been located offshore due to the difficulty of onshore seismographs in focusing on offshore earthquakes unless they are large or near shore.

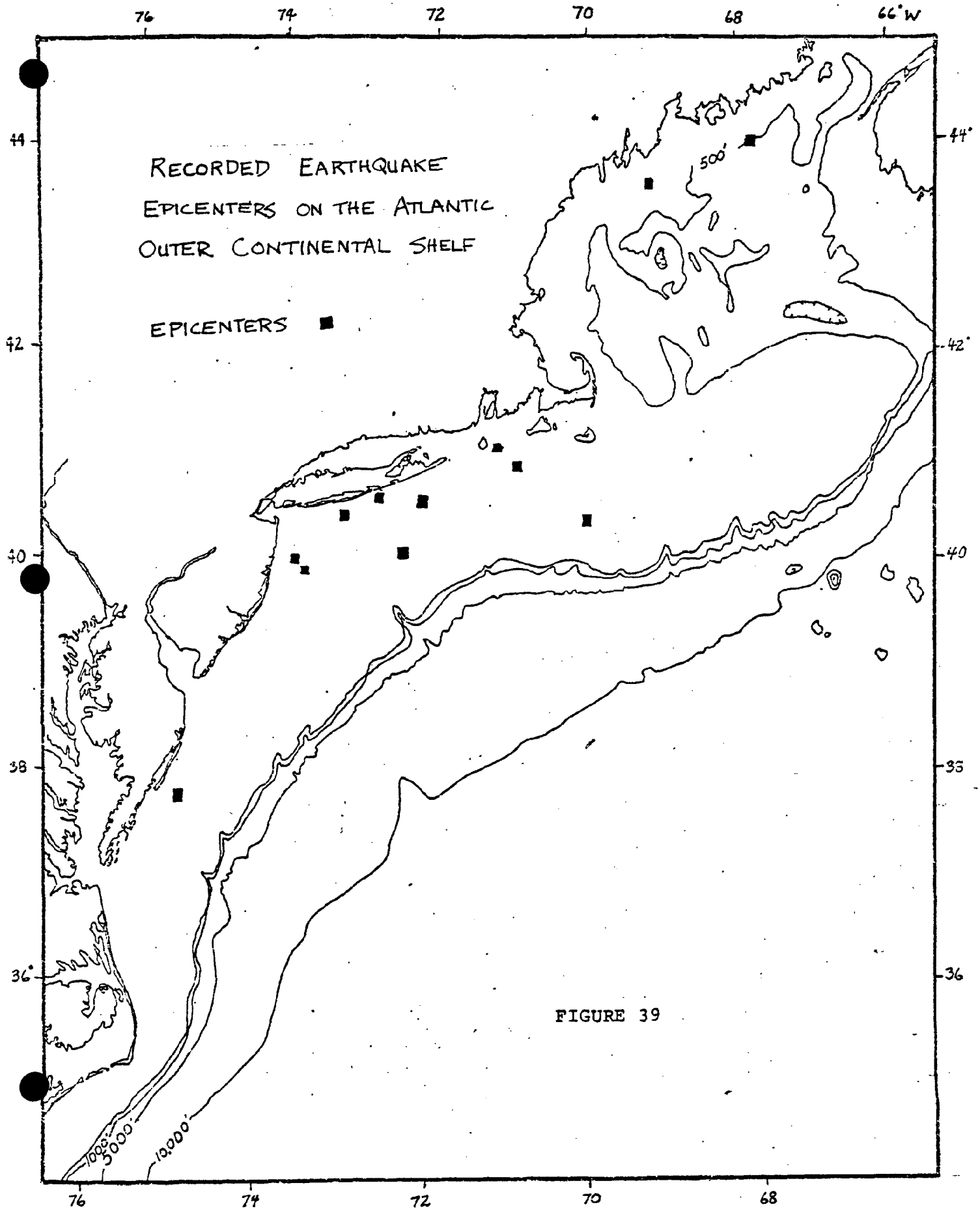

RECORDED EARTHQUAKE
EPICENTERS ON THE ATLANTIC
OUTER CONTINENTAL SHELF
EPICENTERS
76
74
72
70
68
66°W
44
42
40
38
36°
44°
42°
40
35
36
500'
1000'
3000'
10,000'

FIGURE 39

V. SEISMICITY OF THE CONTINENTAL MARGIN

Bouguer gravity anomaly map of the U.S. (exclusive of Alaska and Hawaii), American Geophysical Union and U.S. Geological Survey, 1964.

Some geophysical anomalies in the eastern U.S., Diment, W.H. and others, 1972.

Introduction to geophysical prospecting 3rd ed., Dobrin, M.B., 1976.

Seismotectonic map of the eastern United States, Hadley, J.R. and Devine, J.F., 1974.

Earthquake hazard in the eastern U.S., Howell, B.F., Jr., 1973.

Post-glacial faulting and seismicity in New York and Quebec, Oliver, J.E. and others, 1970.

Seismicity at continental margins, Oliver, J.E. and others, 1974.

Contemporary compressive stress and seismicity in eastern North America, Sbar, M.L. and Sykes, L.R., 1973.

Evidence of post-Pleistocene faults on New Jersey Atlantic outer continental shelf, Sheridan, R.E. and Knebel, H.J., 1976.

Earthquakes of eastern Canada and adjacent areas, 1534-1927, Smith, W.E.T., 1962.

Earthquakes of eastern Canada and adjacent areas, 1928-1959, Smith, W.E.T., 1966.

Engineering geology of the northeast corridor, Washington, D.C. to Boston, Massachusetts, earthquake epicenters, geothermal gradients, and excavations and borings, U.S. Geological Survey, 1967.

Correlation of tectonically deformed shorelines on the southern Atlantic coastal plain, Winker, C.D. and Howard, J.D., 1977.

VI. REASONS FOR ASSUMING NEW YORK SHELF TO BE OF MAJOR ECONOMIC IMPORTANCE

The offshore portion of the Atlantic continental margin of the United States has not been explored to date and thus no firm knowledge exists that oil and gas reserves are even present. The fact that in the July 1976 lease sale #40 of tracts on the continental shelf surface overlying the Baltimore Canyon Trough yielded $1.1 billion of private investment to have drilling rights there, requires a review of the indicators used to assess the petroleum potential of such a region. There are three major considerations used in assessing the petroleum potential which can be reviewed here. A detailed consideration of the petroleum resources potential of continental margins is given in Weeks (1974) which contains an annotated bibliography of recent assessments of the possible extent of petroleum development in continental margins.

Three major considerations used in assessing the petroleum potential of New York State's continental margin are:

1. Direct geophysical and geological evidence from seismic studies and drilling on the continental margin.

2. Comparisons of the eastern Atlantic continental margin with geologically similar regions where petroleum production is underway.

3. Comparisons of the geologic and geophysical data from New York's continental margins with ancient continental margins having similar tectonic and sedimentary histories. An obvious example of this type of comparison lies in the numerous similarities between some geologic portions of the Appalachian basin which are prolific petroleum producers and major geologic units present beneath the surface of New York's continental margin.

The first two considerations above were described in two open-file reports of the United States Geological Survey, reports 75-61 on the mid-Atlantic and 75-353 on the North Atlantic areas.

VI. REASONS FOR ASSUMING NEW YORK SHELF TO BE OF MAJOR ECONOMIC IMPORTANCE

A. Major considerations used in assessing petroleum potential.

Regional geology of eastern Canada offshore, Austin, G.H., 1973.

Oceans, New frontiers in exploration, Beck, R.H. and Lehner, P., 1974.

Review of the subsurface geology and resource potential of southern Delaware, Benson, R.N., 1976.

Evolution of young continental margins and formation of shelf basins, Bott, M.H.P., 1971.

Buried ridges within continental margins, Burk, C.A., 1969.

Geology of continental margins, Burk, C.A. and Drake, C.L., 1974.

OCS oil and gas - an environmental assessment, Council on Environmental Quality, 1974.

Future petroleum provinces of the United States -- their geology and potential, Cram, I.H., ed., 1971.

Canadian offshore mineral resources management, Crosby, D.G., 1974.

Mobil Tetco Sable Island O-47, Dawson, W.E., 1972.

Mobil Tetco Thebaud P-84, de Jonge, B., Prior, D.G. and Harris, R.L., 1973.

Plate tectonics and hydrocarbon accumulation, Dickinson, W.R. and Yarborough, H., 1976.

Joint program of USGS and WHOI for continental shelf and slope. In, Summary of Investigations conducted in 1964, Emery, K.O., 1965.

Continental rises and oil potential, Emery, K.O., 1969.

The Atlantic Continental Shelf and Slope, a program for study, Emery, K.O. and Schlee, J.S., 1963.

VI.A. (continued)

Structure of Georges Bank, Emery, K.O. and E. Uchupi, 1965.

East coast offshore symposium, Baffin Bay to the Bahamas, Emmerich, H.H., ed., 1974.

Regional aspects of deep-sea drilling in the western North Atlantic, Ewing, J.I. and Hollister, C.H., 1972.

Atlantic OCS resource and leasing potential, Foote, R.Q., Mattick, R.E. and Behrendt, J.C., 1974.

Habitat of oil, a symposium containing 56 papers on oil occurrence worldwide, Weeks, L.G., 1958.

Preliminary summary of the 1976 Atlantic margin coring project of the USGS, Hathaway, J.C. and others, 1976.

Site 108, continental slope, Hollister, C.D. and others, 1972.

Sites 105, 106, 107, 108, Hollister, C.D. and others, 1972.

The petroleum potential of the emerged and submerged Atlantic Coastal Plain of the United States, Johnston, J.E., J. Trumbull and G.P. Eaton, 1959.

Lithology of sediments from the western North Atlantic Leg II Deep Sea Drilling Project, Lancelot, Y., Hathaway, J.C. and Hollister, C.D., 1972.

Correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic coast, Maher, J.C., 1965.

Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf, Maher, J.C., 1971.

Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf, Maher, J.C. and E.R. Applin, 1971.

Mineral resources off the Northeastern coast of the United States, Manheim, F.T., 1972.

A preliminary report on U.S. Geological Survey geophysical studies of the Atlantic Outer Continental Shelf, Mattick, R.E. and others, 1973.

VI.A. (continued)

Structural framework of United States Atlantic outer continental shelf north of Cape Hatteras, Mattick, R.E., Foote, R.Q., Weaver, N.L., Crim, M.S., 1974.

Significant possibilities line Atlantic shelf, McCaslin, J.C., 1976.

Oil and gas possibilities on the Atlantic outer continental shelf, McKelvey, V.E., 1969.

World subsea mineral resources, McKelvey, V.E. and Wang, F.F.H., 1969.

Geological estimates of undiscovered recoverable oil and gas resources in the United States, Miller, B.M. and others, 1975.

Preliminary geologic report on the U.S. northern Atlantic continental margin, Minard, J.P. and others, 1973.

Preliminary report on geology along Atlantic continental margin of northeastern United States, Minard, J.P., W.J. Perry, Weed, E.G.A., Rhodehamel, E.C., Robbins, E.I., and R.B. Mixon, 1974.

Mobil Tetco Sable Island E-48, Morrow, D.L., Harris, R.L. and Warden, A.S., 1972.

National Petroleum Council, Committee on U.S. Energy Outlook, 1971.

Study of outer continental shelf lands of the United States, Vol. IV (appendices), Nossaman, Waters, Scott, Krueger and Riordan, Consultants, 1969.

Structural history and oil potential of offshore area from Cape Hatteras to Bahamas, Olson, W.S., 1974.

Maryland Esso No. 1 well, Standard Oil Company of New Jersey, Ocean City, Maryland, description of ditch samples, Overbeck, R.M., 1948.

Continuous deep sea salt layer along North Atlantic margins related to early phase of rifting, Pautot, G.J.M. Auzende, and X. Le Pichon, 1970.

Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras, a brief survey, Perry, W.J., Minard, J.P., Weed, E.G.A., Robbins, E.I., and Rhodehamel, E.C., 1974.

VI.A. (continued)

Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras - brief survey, Perry, W.J. and others, 1975.

Petroleum exploration offshore from New York, Rogers, W.B., Fakundiny, R.H. and Kreidler, W.L., 1973.

Possible future petroleum potential of Atlantic Coastal Plain, Peninsular Florida, and adjacent Continental Shelves - Region II, Rouse, J.T., 1971.

The evolution of the continental margins and possible long term economic resources, Schneider, E.D., 1969.

Atlantic margin looks favorable, Scott, K.R. and Cole, J.M., 1975.

Sedimentary basins of the Atlantic margin of North America, Sheridan, R.E., 1976.

Future hydrocarbon potential of Atlantic coastal province, Spivak, J. and Sheburne, O.B., 1971.

Summary petroleum and selected mineral statistics of 120 countries, including offshore areas, 1973.

Plate tectonics in oil and gas exploration of continental margins, Thompson, T.L., 1976.

An introduction to the geology and mineral resources of the continental shelves of the Americas, Trumbull, J.V.A. and others, 1958.

Library research project, mid-Atlantic outer continental shelf (reconnaissance), U.S. Bureau of Land Management, 1972.

Geological and operational summary, COST #B-2 well, Baltimore Canyon Trough area, mid-Atlantic OCS, U.S.G.S., 1976.

Generalized pre-Pleistocene geologic map of the northern United States continental margin, Weed, E.G.A. and others, 1974.

Petroleum resources potential off continental margins, Weeks, L.G., 1974.

Geology and petroleum potential in and around Gulf of St. Lawrence, Williams, E.P., 1974.

East coast - front or frontier, Wilson, J.R., 1974.

VI.B. Oil and Gas Potential, North Atlantic Georges Bank Basin

Geologic history as related to the basin's petroleum potential:

1. Initial rifting of Mid-Atlantic produced narrow, relatively shallow basins in which water circulation may have been restricted.

2. Data from the Deep Sea Drilling Program (DSDP) indicate that the earliest sediments deposited on oceanic basement are Jurassic shallow water, fossil-bearing carbonates which may have interbeds of evaporites in areas marginal to initial rift zones.

3. As early Atlantic floor continued to sink, carbonate deposition ceased and septic bottom conditions began to form.

4. Thus, dominant deposition was several hundreds of meters of Early Cretaceous black shale and carbonaceous hemipelagic clays caused by both deep water and resulting stagnation. This reducing environment continued from the Lower Cretaceous (Neocomian) to the Upper Cretaceous (Early Cenomanian). Black sapropelic clays also were infilling low areas and irregularities on the deep ocean floor.

5. Toward the end of this time some bottom circulation developed and this is indicated by "normal" deep sea brown sediments resting conformably on the black clays. Southward, evidence of black clays suggest the presence of stronger bottom currents.

6. The top of the sequence described above is marked by an acoustic reflector horizon "A" (earliest Cenomanian). The evidence indicates that increasing bottom circulation developed with the major increase in the areal extent of the North Atlantic Basin beginning in the Late Cretaceous.

The above history of the Western Atlantic can be documented by existing information -- but geologic data on the shelf area encompassing Georges Bank are generally sparse to absent. However, the following presentation of an interpretation of the geology of this area is taken from Schlee and others (1975), U.S.G.S. Open File Report 75-353. Present interpretation from that source is given below.

Triassic opening of the Western North Atlantic initiated block faulting in Georges Bank basin area. These blocks are up to 20 km across with uplift of as much as 2 km vertically. In the down dropped blocks there may be up to 2 km of continentally-derived sediments. This area was also subjected to above normal geothermal temperatures. The first marine deposits may have been Jurassic evaporites and these probably occur in local down-faulted areas. Initial water depths in these basins were shallow, marine waters probably were restricted behind a tectonic dam at the shelf edge, and by the Yarmouth arch to the northeast and the Long Island platform to the southwest. Such restrictions result in the production of evaporite conditions. Seismic evidence shows that younger deposits through late Jurassic draped over continuing block faulted basin margins. Later in Jurassic (Tithonian) and Early Cretaceous (Neocomian), Atlantic deepening occurred and less areal restriction permitted limestones and dolomites to develop over much of the central and the seaward parts of the Georges Bank basin. Shoreward, nearshore marine shales and sandstones probably were deposited. By Neocomian a reduction in the amount and the size of the drape structures indicates that much of the basin-forming activity had ceased by this time and that the basin floor irregularities had filled with sediments.

On some elevated zones near the shelf edge, reefs may have developed. Continuing tilting and foundering of the continental margin would have caused extensive transgressions landward shifting the shoreline westward and reducing terrigenous input into the basin. Seismic data show that carbonate sediments blanketed the regions in earliest Cretaceous but later, in Lower Cretaceous, carbonates were restricted to the southeastern part of the basin along the shelf edge. Along the northwest edge, sand and mud are interlayered. Marine clastics in basin-center possibly interfinger with shelf edge carbonates.

The eastern boundary of the Georges Bank basin, that is, the supposed reef tract, was no longer a sediment barrier in the Cretaceous and perhaps turbidites flowed over the shelf edge and onto the continental rise forming a thick wedge above black clays and carbonate sediments.

The Upper Cretaceous rocks are relatively thin so that Georges Bank basin is filled predominantly with Jurassic and older Cretaceous deposits. In latest Cretaceous and Early Tertiary cyclic deposits of marine sands and shales developed. Normal oceanic circulation was established on the shelf and the slope with oxygenated waters reaching abyssal regions oxydizing organic components, except where rapid burial may have occurred.

A regional erosional unconformity is present across the shelf above Eocene and through Oligocene. Upper Tertiary deposits,

less than 1 km thick, are mainly unconsolidated silts, sands, clays and gravel. Thus, the potential source rocks in the Georges Bank basin are:

1. Carbonaceous Jurassic limestones

2. Organic-rich Lower Cretaceous shale

The potential reservoir rocks in the Georges Bank basin are:

1. Fractured limestone and dolomites -- Jurassic

2. Cretaceous sandstones

3. Shelf edge reefs -- Jurassic and Lower Cretaceous

4. Large structural highs should prevail up into the Jurassic and Lower Cretaceous that have little relief in the Upper Cretaceous.

The Scotian Shelf to the northeast of Georges Bank has been explored by drilling. The two areas have similar tectonic settings. Physical properties of the rocks in the Scotian Shelf area are similar to those in the Georges Bank area as indicated by similar seismic properties of the rocks in the subsurface. This probably indicates that the lithology and the stratigraphy are similar in the Scotian Shelf and in the Georges Bank basin. Of the 45 wells drilled since 1967 in the Scotian Shelf, 6 are small petroleum discoveries. If the analogy of the Georges Bank basin area to the Scotian Shelf is reasonable, both the source and the reservoir beds known to exist on the Scotian Shelf probably exist on the Georges Bank basin.

Potential source and reservoir rocks are as follows:

1. If pre-Triassic rocks which are not metamorphosed exist beneath the Georges Bank basin, depths of those rocks are greater than 13 km.

2. Jurassic rocks occur at depths between 3 and 6 km, with a probable thickness of 2 km, and represent about 1/3 of the total section in the Georges Bank basin. Rock types are limestones and dolomites. The reservoir rocks may be in the northwestern part of the basin where the Jurassic rocks have low velocities and are relatively shallow (less than 3 km). Seismic velocities indicate sandstones and shales. No direct evidence is available for any potential source rocks.

3. Lower Cretaceous rocks are thought to have best petroleum potential. Thicknesses exceed 2 km and depths of these rocks are 1 to 4 km. Potential petroleum resources in reservoir rocks probably are present in the various rock types - marine sandstone, shale and limestone. Downdip, limestone reservoirs may exist. These potential reservoir beds coalesce updip where they are truncated by the regional unconformity along the northern margin of the basin. No evidence exists, at present, of fault traps, but there may be shelf edge reservoirs. The question remains whether any of these shelf edge reservoir rocks connect downslope to the 200 to 300 meter thick organic-rich clay unit which was encountered in DSDP #101 and #105. These holes are 4,000 km apart, which indicates a broad Lower Cretaceous blanket of organic rich clays (sapropel) at the foot of the continental margin of the western North Atlantic.

4. Most Upper Cretaceous and Lower Tertiary (?) rocks probably accumulated in oxidizing conditions, although the rocks present may be good potential reservoirs. Comparison must be made to the Scotian Shelf where 247 m of pay sands are present in the Upper Cretaceous in the Mobil -- Tetco Sable Island E-48 Well. Some Upper Cretacous rocks are exposed downdip on the continental slope Georges Bank.

5. The Upper Tertiary section probably has little potential. It is less than 1 km thick and it is made of unconsolidated silts, sands, clays and gravels.

Potential traps that occur in the Georges Bank basin (based on seismic data) are:

1. Drape structures
2. Fault traps
3. Stratigraphic traps in carbonate sediments
4. Stratigraphic traps associated with facies changes
5. Updip wedgeouts
6. Fracture zones in Triassic basins
7. Unconformities

Estimates of economically recoverable resources in frontier areas are tenuous at best. Different approaches to the problem give results that may differ several fold for a given area. The numbers used in the Draft Environmental Impact Statement for Sale 42 in the Georges Bank area were 0.18 to 0.65 billion barrels of oil and 1.2 to 4.3 trillion cubic feet of gas.

Details of methods of estimating quantities of undiscovered resources are discussed in U.S. Geological Survey Circular 725, "Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States."

VI.B. Oil and Gas Potential, North Atlantic Georges Bank Basin

Oil and the outer continental shelf - The Georges Bank Case, Ahern, W.R., Jr., 1973.

Regional geology of Grand Banks, Amoco Canada Petroleum Co. Ltd., and Imperial Oil Ltd., Offshore Exploration Staffs, 1974.

Preglacial structure of Georges Bank and Northeast Channel, Gulf of Maine, Ballard, R.D. and Sorensen, F.H., 1968.

The native of Triassic continental rift structures in the Gulf of Maine, Ballard, R.D., 1974.

Geology of the Gulf of Maine, Ballard, R.D. and Uchupi, E., 1974.

Triassic rift structure in Gulf of Main, Ballard, R.D. and Uchupi, E., 1975.

Geology and paleontology of the Georges Bank Canyons, Part 3, Cretaceous bryozoan from Georges Bank, Bassler, R.S., 1936.

Geology and paleontology of the Georges Bank Canyons, Cushman, J.A., 1936.

Mobil Tetco Thebaud P-84, de Jonge, B., Prior, D.G., and Harris, R.L., 1973.

Continental margin of eastern Canada, Georges Bank to Kane basin, Keen, M.J., B.D. Loncarevic and G.N. Ewing, 1970.

Preliminary report on geology along Atlantic continental margin of northeastern United States, Minard, J.P., W.J. Perry, E.G.A. Weed, E.C. Rhodehamel, E.I. Robbins, and R.B. Mixon, 1974.

The Georges Bank Petroleum Study, Offshore Oil Task Group, 1973.

Geophysical observations on northern part of Georges Bank and adjacent basins of Gulf of Maine, Oldale, R.N. and others, 1974.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the United States North Atlantic outer continental shelf, Schlee, J. and others, 1975.

VI.B. (continued)

Geology of Georges Bank basin, Schultz, L.K. and R.L. Grover, 1974.

Geology and paleontology of the Georges Bank Canyon, Part 11, Upper Cretaceous fossils from Georges Bank (including species from Banquereau, Nova Scotia), Stephenson, L.W., 1936.

Geology and paleontology of Georges Bank Canyons, Part 1, Geology, Stetson, H.C., 1936.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the U.S. North Atlantic OCS, U.S.G.S., 1975.

Geological and operational summary, COST #B-2 well, Baltimore Canyon Trough area, Mid-Atlantic OCS, U.S.G.S., 1976.

Geological estimates of undiscovered recoverable oil and gas resources in the United States, U.S. Geological Survey Circular 725, Miller, B.M., et al, 1975.

VI.C. Oil and Gas Potential, Mid-Atlantic Baltimore Canyon Trough

In the U.S. Geological Survey (1975) open-file report 75-61, the oil and gas potential of the Mid-Atlantic Baltimore Canyon Trough is assessed. A review of that assessment is given below.

The reasons for optimism concerning the economic potential of the Baltimore Canyon Trough were summarized by Mattick, Weaver, Foote and Grim (1974).

1. The sedimentary thickness is comparable to those thicknesses found in the Gulf and California coasts. The differences lie, however, in the fact that the rocks in the Baltimore Canyon Trough are older. Also, they have higher seismic velocities and, therefore, may have less porosity and thus, less potential as reservoir beds.

2. The structural settings within the Baltimore Canyon Trough appear to be favorable.

According to Weed and others (1974), the mineral resources of the continental shelf and the continental slope north of Cape Hatteras may be enormous. Sediment volumes in that region are about 580,000 cubic km (140,000 cubic mi.). Using the sedimentary-volume method of resource estimation, petroleum resource potential in the Baltimore Canyon Trough could be 15 billion barrels of oil and 70 trillion cubic ft. of gas. Exploration is required to give a more realistic evaluation of the true potential.

DSDP penetrated dark green to black Mesozoic clays southeast of New York which were rich in organic matter and may be a potential source and reservoir bed. These clays have not been identified beneath the continental shelf but the petroleum may have migrated to the shelf area from beds beneath the continental rise via the continental slope where these organic rich clays were found.

The top of the Jurassic section is about 7,000 meters beneath the axis of the Baltimore Canyon Trough. This depth is below the present economic basement, but in the future the Jurassic may become a prospect.

The Lower Cretaceous section beneath the coastal plain is up to 1,600 meters thick and seaward becomes more marine (i.e., deltaic sequences of sands and shales occur shelfward). Rapid sedimentation in nearshore environments favorable to petroleum development is represented in the Early Cretaceous (Cenomanian) transgressive phases which are extensive in the upper and the eastern portions of the Potomac Group in the Salisbury Embayment. Thus, most promise appears to be east of the onshore wells where the Potomac Group thickens and increases in its marine components providing that there are suitable traps.

The Upper Cretaceous section is dominantly marine sands and shales and presumably has fewer reservoir rocks than exist in the materials beneath, although it is considered a prospective horizon. The entire Cretaceous is up to 5,250 meters thick in the center of the Baltimore Canyon Trough.

The Tertiary section reaches a maximum of 2,100 meters thick. It has few structural anomalies and is too shallow and too thin to be highly prospective.

Cretaceous and younger materials are predominately clastic sediments as indicated by the seismic velocity analysis. The onshore well data indicate that this is a thick, deltaic sequence which extends offshore. Potential source and potential reservoir beds probably exist beneath the Mid-Atlantic area. Cretaceous rocks seem to be the most promising as oil and gas prospects, particularly the Lower Cretaceous rocks.

Traps that may be present are of several types:

1. Structural relief over piercement structures, fault blocks and reefs which may be present.

2. Possible reefs.

3. Stratigraphic traps.

Details on the above (1, 2 and 3) can be found on pages 106 and 107 of the U.S. Geological Open-File Report 75-61.

The following estimation of potential petroleum resources is based on the U.S.G.S. Open File Report 75-61, pages 108 and 109. Among the methods of estimating petroleum potential the following have been used commonly.

1. The behavioristic models by M.K. Hubbert and by Charles Moore.

2. Volumetric (and areal) - geologic models by T.A. Hendricks, L.G. Weeks and by Spivak and Shelburne.

3. Combinations of number 1 and number 2 used by the National Petroleum Council and by some oil companies.

In the Middle Atlantic area outlined in the Bureau of Land Management Memorandum number 3301.3 (722) for possible lease sale in reference to the Middle Atlantic area, the following data relating area and sediment thickness have been compiled. First, the total area of the Baltimore Canyon

Trough is 17,373 square miles and, in terms of sediment thickness vs. the areal extent of that sediment thickness, the following data have been given and is presented as a histogram in Figure 40.

1. Where sediment thickness is between 0 and 2 km, this covers an area of 1,149 sq. miles.

2. Where sediment thickness is between 2 and 4 km, that extends over an area of 1,490 sq. miles.

3. In areas where the sediment thickness is between 4 and 6 km, the areal distribution is 3,247 sq. miles.

4. In areas where the sediment thickness is between 6 to 10 km, the areal distribution of that material is 7,312 sq. miles.

5. In areas where sediment thickness exceeds 10 km, the areal distribution of that material is 4,175 sq. miles.

Using the information from Hendricks (1965), the petroleum potential in the Baltimore Canyon Trough is as follows:

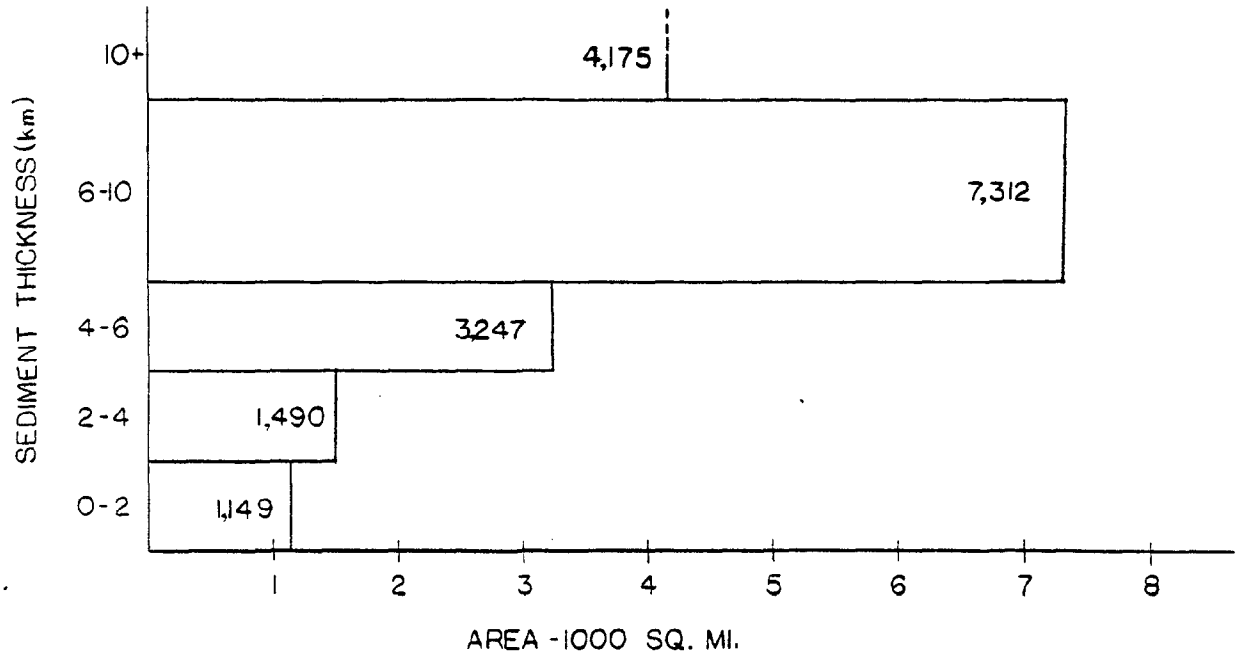
1. Three to five billion barrels of oil, and,

2. Fifteen to twenty-five trillion cu. ft. of gas may be present.

Alternate methods yield different results. For example later U.S.G.S. estimates for the Baltimore Canyon Trough gave the low to high range of 0.40 to 1.40 billion barrels of oil and 2.6 to 9.4 trillion cu. ft. of gas. See Miller, B.M., et al (1975) for a discussion of methods of resource estimates.

There have been only three deep holes drilled thus far on the outer continental shelf off New York. The Cost B-2 well was drilled during 1976 about 146 miles east of Atlantic City, New Jersey, in the Baltimore Canyon Trough. A second well is the G-1, 116 miles east of Nantucket on Georges Bank. Both are deep stratigraphic test wells to help oil companies and the Federal government evaluate areas of potential leasing for petroleum exploration. Thus, the wells are drilled for the purpose of determining the stratigraphic succession, ages and characteristics or rocks present beneath the surface of the Atlantic continental shelf, the acquired data, derived from pooled private financing of the drilling program is, in large measure, available for examination by other governmental agencies and states in order to assess the geology of regions proposed for later intensive exploration for potential petroleum. A third well, the G-3, is now (May, 1977) being drilled.

SEDIMENT THICKNESS VERSUS AREA
BALTIMORE CANYON TROUGH*



*DATA FROM B.L.M. MEMORANDUM 3301.2(722)

FIGURE 40

The following section summarizes the results of the COST B-2 well, drilled in the Baltimore Canyon Trough. A more complete discussion of the results can be found in Scholle (1977) and the Open File report on the well (76-774). Figure 41 shows the COST B-2 well, the thickness of section penetrated compared to total thickness and DSDP hole 108.

The well penetrated almost 5,000 meters of Cenozoic and Mesozoic sediments. Rocks of high organic content are present from 1,000 meters (Miocene) to 2,000 meters (Upper Cretaceous) and 3,000 meters (Lower Cretaceous) to 5,000 meters (Lower Cretaceous) and some of these rocks are capable of generating considerable amounts of hydrocarbons. The temperature may have been too low in much of the section to generate oil, but it should have been high enough for gas formation. Reservoir rocks are abundant, but the reservoir quality of most of the sandstones degrades rapidly at depths greater than 3,500 to 4,000 meters. Seals in the form of shales are present in much of the section.

Scholle (1977) concludes that a higher potential for natural gas is present than for oil because of the lower temperature generated in the sediments. Seaward of the COST B-2 well the sediments probably are more marine in character which would improve the potential for oil generation. Marine sediments with a lower feldspar content than occur in the B-2 section would result in less cementation, hence higher porosity than was found. A section with more shale units at depth than the B-2 section would have a higher petroleum potential as well.

GENERALIZED SECTION OF THE U.S ATLANTIC SHELF, SLOPE AND RISE

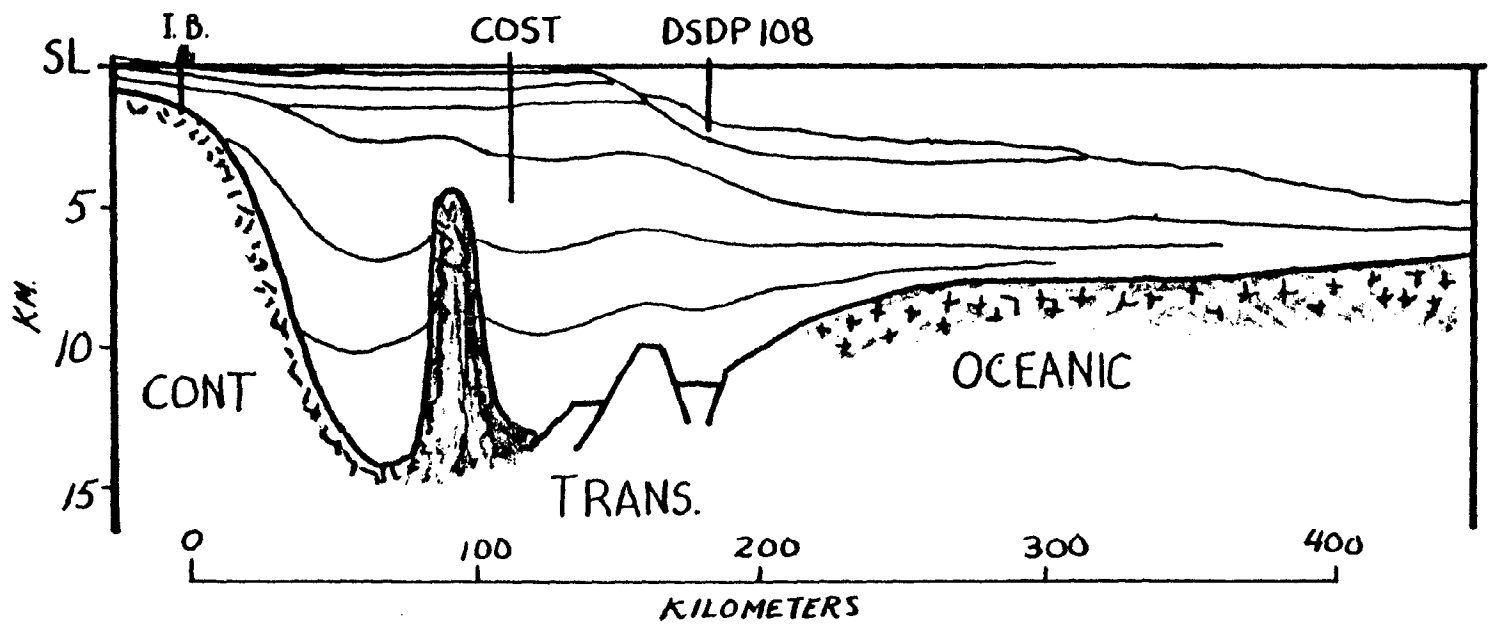


FIGURE 41

VI.C. Oil and Gas Potential, Middle Atlantic Baltimore Canyon Trough

The stratigraphy of the continental shelf east of New Jersey (abstr.), Chelminski, P. and Fray, C.I., 1966.

Geological background Baltimore Canyon trough, Emery, K.O., 1974.

Marine and environmental implications of oil and gas development in the Baltimore Canyon region of the Mid-Atlantic coast, Estuarine Research Federation - OCS Conference and Workshop, 1974.

Baltimore Canyon trough area hazards, Knebel, H.J., et al, 1976.

The responsibilities and environmental programs of the U.S. Geological Survey in the Baltimore Canyon trough area, Knebel, H.J. and Hardin, N.S., 1974.

Time-stratigraphic units and petroleum entrapment models in Baltimore Canyon basin of Atlantic continental margin geosynclines, Kraft, J.C., Sheridan, R.E. and Maisano, M., 1971.

Geological estimates of undiscovered recoverable oil and gas resources in the United States, Miller, et al, 1975.

Geologic history of basement fault motions in the Baltimore Canyon trough correlated with North Atlantic sea-floor spreading (abstr.), Sheridan, R.E. and Brown, P.M., 1975.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the U.S. mid-Atlantic outer continental shelf, U.S. Geological Survey, 1975.

VI.D. Assessment of Petroleum Potential by Comparison with Ancient Continental Margins

The third major means of assessing petroleum potential of the Atlantic continental margin off eastern United States lies in the comparison with ancient continental margins where petroleum production has been a proven resource. There are several geologic facts previously given in this report which are pertinent in this assessment.

First, the continental margin of eastern United States in tectonic terms is a trailing type margin, the type example of the Amero-trailing margin described by Inman and Nordstrom (1971).

Second, the geologic development of a trailing margin included:

a. initial rifting and fragmentation of continental crust,

b. filling of rifted areas with river-derived sediments from the land and on its seaward side the possibilities of both reef development and precipitation of salts resulting from evaporation of marine water influxes,

c. as marine areas between the rifted portions of the spreading continents enlarges, the seaward portion of the trailing continental margin is dominated by marine conditions of sedimentation while the landward part is dominated by continued influx of river-borne detritus from the continent.

The continued development of the trailing margin of the continent is governed by both the rate of influx of landward-derived sediment and the magnitude of sea-level changes along the continent margin. The magnitudes and numbers of shifts in shore-line positions during this build-up of sediment on the continental margin is a chief factor in determining the possible presence and number of both petroleum source beds and petroleum reservoir beds -- where the overall history of sediment accumulation is one in which the land-derived sediments continue building seaward through time. Such sediment sequence is termed a "regressive" sequence. This regression process of seaward building of land-derived sediments established optimal conditions for petroleum source and reservoir beds to occur. Similar regressive sedimentary sequences which developed in the geologic past are important petroleum producers today. The Middle and Upper Devonian deposits of the Central Appalachian basin including New York State yielded the first production of petroleum in the 19th century and continue producing today. Formed under a different tectonic setting, these Devonian rocks represent one important regressive sedimentary sequence and have many important sedimentary counterparts in the deposits of New York State's present-day continental margin. A

review of the ancient continental margin of eastern North America is given in Williams and Stevens (1974). The geologic development of the present continental margin is given in Schlee and others (1976), Mayhew (1974), Ballard and Uchupi (1975), Schultz and Grover (1974), Minard and others (1974) and Mattick and others (1974).

VI.D. Assessment of Petroleum Potential by Comparison with Ancient Continental Margins

Triassic rift structure in Gulf of Maine, Ballard, R.D. and Uchupi, E., 1975.

Plate tectonics and hydrocarbon accumulation, Dickinson, W.R. and Yarborough, H., 1976.

Petroleum and global tectonics, Fischer, A.G. and Judson, S., 1975.

Structural framework of United States outer continental shelf north of Cape Hatteras, Mattick, R.E., et al, 1974.

"Basement" to east coast continental margin of North America, Mayhew, M.A., 1974.

Preliminary report on the geology along Atlantic continental margin of northeastern United States, Minard, J.P., et al, 1974.

Regional geologic framework off northeastern United States, Schlee, J., et al, 1976.

Geology of Georges Bank basin, Schultz, L.K. and Grover, R.L., 1974.

Petroleum resources potential off continental margins, Weeks, L.G., 1974.

The ancient continental margin of eastern North America, Williams, H. and Stevens, R.K., 1974.

VI.E. Other Economic Resources of New York Shelf

Although this report was prepared to organize the geologic information pertinent principally to the potential petroleum exploration of New York's outer continental shelf, other important economic resources exist there as well. A brief assessment of them is given below. It is not idle speculation to point out that some of these economic resources of New York's continental shelf may ultimately be of greater importance to the urban and suburban centers of New York's Coastal region than a petroleum industry. Most particularly, this refers first to the vast resources of sands and gravels necessary for the construction industry which lie just a few miles from New York's shoreline; second, to the potential of fresh artesian waters in the permeable sands which dip from the coastal plain beneath the continental shelf surface. These strata conceivably could be a major water source for the enormous population of southeastern New York State.

The general references pertinent to assessing other economic resources of the New York Shelf are listed below.

VI.E. Other Economic Resources of New York Shelf

Canadian offshore mineral resources management, Crosby, D.G., 1974.

Mineral resources potential of continental margins, Cruickshank, M.J., 1974.

Some potential mineral resources of the Atlantic continental margin, Emery, K.O., 1965.

Manganese iron accumulation in the shallow marine environment, Rhode Island University, Manheim, F.T., 1965.

Mineral resources off the Northeastern coast of the United States, Manheim, F.T., 1972.

Subsea mineral resources and problems related to their development, McKelvey, V.E. and others, 1969.

Potential mineral resources of the U.S. outer continental shelf, Appendix S-A, McKelvey, V.E. and others, 1969.

Atlantic continental shelf and slope of the United States -- physiography and sediments of the deep-sea basin, Pratt, R.M., 1968.

The evolution of the continental margins and possible long-term economic resources, Schneider, E.D., 1969.

Summary petroleum and selected mineral statistics for 120 countries, including offshore areas, U.S. Geological Survey, Prof. Paper 817, 1973.

An introduction to the geology and mineral resources of the continental shelves of the Americas, Trumbull, J.V.A. and others, 1958.

Continental shelf sediments off northeastern United States (abstr.), Trumbull, J.V.A. and others, 1966.

Sediments on the continental margin off eastern United States, Uchupi, E., 1963.

Library research project, mid-Atlantic outer continental shelf (reconnaissance), U.S. Bureau of Land Management, 1972.

Regulations pertaining to mineral leasing, operations, and pipeline on the outer continental shelf as contained in Title 30 and Title 43 of the code of Federal Regulations and the Outer Continental Shelf Lands Act, U.S. Dept. of Interior, 1971.

VI.E. (continued)

Oceanographic atlas of the North Atlantic Ocean, U.S. Naval Oceanographic Office, 1965.

Marine mineral identification survey of coastal Connecticut, Donahue, J.J. and Tucker, F.B., 1970.

VI.E.1. Sands and Gravels

The principal reason for introducing the topic of sand and gravel resources of New York's continental shelf relates to both urban maintenance and suburban sprawl. A principal result of population expansion around urban regions is the rapid shift in availability of raw materials for the construction industry due almost entirely to community zoning regulations. With outward expansion of the metropolitan region comes ever-increasing zoning restrictions on open-pit mining or quarrying for the raw materials of construction -- sand, gravel and limestone, all components of paving, concrete and construction stone. As a result, the present need to transport this raw material from great distances to the metropolitan regions has escalated building costs significantly. To date, there has been no serious effort to acquire the readily available sands and gravels from offshore but the probability is one which needs to be anticipated by state agencies. They clearly can assist the construction industry in outlining feasible target areas and, at the same time, be in a position to demonstrate the types of environmental changes to designated parts of the shelf where sea-bed materials and current patterns might permit the feasibility of surface "strip mining" on the continental shelf surface.

Such a program of outlining "safe" areas for sand and gravel removal is a task for the future. What this report provides is some initial references to reports which give such a study a solid foundation. The geologic information in this report in preceding sections is pertinent:

II. MAJOR SURFACE FEATURES OF CONTINENTAL SHELF

- A. Shelf Valleys
  - 1. Buried Shelf Valleys
- C. Ridge and Swale Topography
- D. Remnants of Lower Sea-Level Stands
  - 1. Beach Ridges
  - 2. Shoal-retreat Massifs

III. PROCESS INFLUENCING SURFACE OF THE CONTINENTAL SHELF

- B. Currents and Circulation Dynamics of the Outer Continental Shelf
  - 1. Indicators of Shelf Circulation
    - a. Dynamics of Ridge and Swale Topography
    - b. Across-Shelf Transfers of Suspended Material

IV. GEOLOGIC DEVELOPMENT OF THE NEW YORK CONTINENTAL SHELF

- D.5. Pleistocene-Holocene

The principal requirement to successfully initiate a study of sand and gravel resources of New York's continental shelf is the preparation of detailed surface sediment distribution maps. Those maps would show sediment properties such as grain size distribution, sorting, roundness and composition. Thickness of surface layers of uniform grain character would be important along with its topographic setting within the shelf surface (for example, within zones of ridge and swale topography or within shelf valleys).

Because of the nature of the link between nearshore sands and compositional properties of inner shelf surficial deposits, it is possible to make a rapid assessment of shelf sediment composition by examining the beach sands along the coast. Pilkey and Field (1972) have shown the validity of this approach whereby beach sand composition can give a "quick and dirty" qualitative assessment of the surficial sand-sized sediments on the shelf.

Below is a list of references which as a group could be used to begin the preparation of such sediment distribution maps useful in locating target sites for sand and gravel "quarrying" offshore.

VI.E.1. Sand and Gravels

A petrographic and petrologic study of some continental shelf sediments, Alexander, A.E., 1934.

Migrating sand waves and sand humps, with special reference to investigations carried on in the Danish North Sea coast, Bruun, P., 1954.

Some specific problems in understanding bottom sediment distribution and dispersal on the continental shelf, Creager, J.S. and Sternberg, R.W., 1972.

Late Quaternary history continental shelves of the United States, Curray, Jr., 1965.

Sediment size distribution profile on the continental shelf off New Jersey, Donohue, J.G. and others, 1966.

Comments on the dispersal of suspended sediment across the continental shelves, Drake, D.E. and others, 1972.

Sand deposits on the continental shelf, a presently exploitable resource, Duane, D.B., 1968.

Upper stratification of Hudson Apron region, Ewing, J.I. and others, 1963.

Sediments and topography of the Gulf of Mexico, Ewing, M. and others, 1958.

Sediment distribution in the oceans, Ewing, M., Carpenter, G. Windisch, C. and Ewing, S., 1973.

Post-Pleistocene history of the United States inner continental shelf, Field, M.E. and Duane, D.B., 1976.

Bottom sediments on the continental shelf of the northeastern United States, Folger, D.W. and others, in press.

Continental shelf sediments off New Jersey, Frank, W.M., 1976.

Continental shelf sediments off New Jersey, Frank, W.M. and Friedman, G.M., 1973.

Sediments and geomorphology of the continental shelf off southern New England, Garrison, L.E. and R.I. McMaster, 1966.

Atlantic sediments, erosion rates, and the evolution of the continental shelf, Gilluly, J., 1964.

VI.E.1. (continued)

Data file, Continental Margin Program, Atlantic coast of the United States, Hathaway, J.C., ed., 1966.

Data file, Continental Margin Program, Atlantic coast of the United States, Hathaway, J.C., ed., 1967.

Data file, Continental Margin Program, Atlantic coast of the U.S., v. 2, Hathaway, J.C., 1971.

Preliminary summary of the 1976 Atlantic margin coring project of the U.S.G.S., Hathaway, J.C. and others, 1976.

Relationship between coastal climate and bottom sediment type on the inner continental shelf, Hayes, M.O., 1967.

Atlantic continental shelf and slope of the United States - Texture of surface sediments from New Jersey to southern Florida, Hollister, C.D., 1973.

Dispersal patterns of Pleistocene sands on the North Atlantic deep-sea floor, Hubert, J.F., 1962.

The continental margin off the Atlantic coast of the United States, Hulsemen, J., 1967.

Relationship between bottom topography and marine sediment properties in an area of submarine gullies, Inderbitzen, A.L. and F. Simpson, 1971.

Mineralogic composition of sand-sized sediment on the outer margin off the Mid-Atlantic States, Kelling, G. and others, 1975.

Sedimentary facies patterns and geologic history of a Holocene transgression, Kraft, J.C., 1971a.

Transportation of sand grains along the Atlantic shore of Long Island, New York, Krinsley, D., Takahashi, T., Silberman, M.L. and Newman, W.S., 1964.

Coastal sands of the eastern United States, McCarthy, G.R., 1931.

Transport and escape of fine-grained sediment from shelf areas, McCave, I.N., 1972.

VI.E.1. (continued)

Probable Holocene transgressive effects on geomorphic features of the continental shelf off New Jersey, McClennen, C.E. and R.L. McMaster, 1971.

Quantitative method for describing the regional topography of the ocean floor, McDonald, M.G. and E.S. Katz, 1969.

Continental shelf sediments of Long Island, N.Y., McKinney, T.F. and Friedman, G.M., 1970.

Petrography and genesis of N.J. beach sands, McMaster, R.L., 1954.

Sediments of Narragansett Bay system and Rhode Island Sound, McMaster, R.L., 1960.

Petrography and genesis of recent sediments in Narragansett Bay and Rhode Island Sound, McMaster, R.L., 1962.

Mineralogy and origin of southern New England shelf sediments, McMaster, R.L. and Garrison, L.E., 1966.

Sub-bottom basement drainage system of inner continental shelf off southern New England, McMaster, R.L. and Ashraf, A., 1973.

Atlantic continental shelf and slope of the United States -- Petrology of the sand fraction of sediments, northern New Jersey to southern Florida, Milliman, J.D., 1972.

Sediments of the continental margin off the eastern United States, Milliman, J.D. and others, 1972.

Coastal morphology and processes in relation to the development of submarine sand ridges off Bethany Beach, Delaware, Moody, D.W., 1964.

Sedimentary framework of continental terrace off Norfolk, Virginia and Newport, Rhode Island, Moore, D.G. and J.R. Curray, 1963.

Bottom sediment studies, Buzzards Bay, Massachusetts, Moore, J.R., III, 1963.

Rythmic linear sand bodies caused by tidal currents, Off, T., 1963.

VI.E.1. (continued)

The glaciated shelf off northeastern United States, Oldale, R.N. and Uchupi, E., 1970.

Sedimentary framework of the western Gulf of Maine and the southeastern Massachusetts offshore area, Oldale, R.N., E. Uchupi and K.E. Prada, 1973.

Sediments and morphology of the continental shelf off southeast Virginia, Payne, L.H., 1970.

Onshore transportation of continental shelf sediment, Pilkey, O.H. and M.E. Field, 1972.

Glaciation on the continental margin off New England, Pratt, R.M. and Schlee, J., 1969.

The sand and gravel industry of the United States of America with special reference to exploiting the deposits offshore the eastern seaboards, Rexworthy, S.R., 1968.

Source and dispersion of surface sediments in the Gulf of Maine-Georges Bank area, Ross, D.A., 1970.

Relief and bottom deposits at Georges Bank and Banquereau. In, Materialy rybokhozyaystvennykh issledevanii severngo basseyna (polarnyi mauchnoissled-vatelskiy i proyektnyi), Rvachev, V.D., 1964.

Topographic relief and bottom sediments of the Georges and Banquereau Banks, Rvachev, V.D., 1965.

Holocene shoestring sand on inner continental shelf off Long Island, Sanders, J.E. and Kumar, N., 1975.

New Jersey offshore gravel deposit, Schlee, J., 1964.

Atlantic continental shelf and slope of the United States -- sediment texture of the northeastern part, Schlee, J., 1973.

Atlantic continental shelf and slope of the U.S. -- Gravels of the northeastern part, Schlee, J. and Pratt, R., 1970.

Bottom sediments on the continental shelf of northeastern United States; Cape Cod to Cape Ann, Mass., Schlee, J., Folger, D.W. and O'Hara, C.J., 1973.

Significance of submerged deltas in the interpretation of the continental shelves, Shepard, F.P., 1928.

VI.E.1. (continued)

Sediments on the continental shelves, Shepard, F.P., 1932.

Continental shelf sediments off the mid-Atlantic states, Shepherd, F.P. and Cohee, G.V., 1936.

Holocene sedimentary environment of the Atlantic inner shelf off Delaware, Sheridan, R.E., C.E. Dill, Jr. and J.C. Kraft, 1974.

Late Quaternary stratigraphy of the inner Virginia continental shelf, Shideler, G.L. and others, 1972.

Geomorphology of a sand ridge, Smith, J.D., 1969.

Anatomy of a shoreface-connected ridge system on the New Jersey shelf, Stahl, L., J. Koczan and D. Swift, 1974.

Atlantic continental shelf and slope of the U.S. -- color of marine sediments, Stanley, D.J., 1969.

Bathymetric charts Cape Cod to Maryland, Stearns, F. and L.E. Garrison, 1967.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:125,000, Stearns, F., 1967.

Bathymetric maps and geomorphology of the middle Atlantic continental shelf, Stearns, F., 1969.

The origin and limits of a zone of rounded quartz sand off the southern New England coast, Stetson, H.C., 1934.

The sediments of the continental shelf off the eastern coast of the United States, Stetson, H.C., 1938.

Summary of sedimentary conditions on the continental shelf off the east coast of United States, Stetson, H.C., 1939.

The sediments and stratigraphy of the east coast continental margin, Georges Bank to Norfolk Canyon, Stetson, H.C., 1949.

Underwater sand ridges on Georges Shoal, Stewart, H.B., Jr. and G.F. Jordan, 1964.

VI.E.1. (continued)

Sediment response to the hydraulic regime on the central New Jersey shelf, Stubblefied, W.L., J.W. Lavelle, T.F. McKinney, and D.J.P. Swift, 1975.

Ridge development as revealed by sub-bottom profiles on the central New Jersey shelf, Stubblefield, W.L. and D.J.P. Swift, 1976.

Submergence of the New Jersey coast, Stuiver, M. and Daddario, J.J., 1963.

Implications of sediment dispersed from bottom current measurement, some specific problems in understanding bottom sediment distribution and dispersal on the continental shelf -- a discussion of two papers, Swift, D.J.P., 1972.

Continental shelf sedimentation, Swift, D.J.P., 1974.

Barrier island genesis, Swift, D.J.P., 1975a.

Tidal sand ridges and shoal retreat massifs, Swift, D.J.P., 1975.

Quaternary sedimentation on the inner Atlantic shelf between Cape Henry and Cape Hatteras, Swift, D.J.P., G.L. Shideler, N.F. Avignone, B.W. Holliday and C.E. Dill, Jr., 1970.

Textural differentiation in the shoreface during erosional retreat of an unconsolidated coast, Cape Henry to Cape Hatteras, western north Atlantic shelf, Swift, D.J.P. and others, 1971.

Relict sediments on continental shelves, a reconsideration, Swift, D.J.P., Stanley, D.J. and Curray, J.R., 1971.

Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America, Swift, D.J.P., Kofoed, J.W., Saulsburg, F.P. and Sears, P., 1972.

Anatomy of a shoreface ridge system, False Cape, Virginia, Swift, D.J.P., B.W. Holliday, N.R. Avignone and G. Shideler, 1972a.

Substrate response to hydraulic process, Swift, D.J.P. and Ludwick, J.C., 1976.

Littoral materials of the south shore of L.I., New York, Taney, N.M., 1961.

VI.E.1. (continued)

Atlantic continental shelf and slope of the U.S. -- sand-sized fraction of bottom sediments, N.J. to Nova Scotia, Trumbull, J.V.A., 1972.

Bottom sediments of Georges Bank, Wigley, R.L., 1961.

Sediments and shallow structures of the inner continental shelf off Sandy Hook, N.J., Williams, S.J. and Field, N.E., 1971.

Sand and gravel on the continental shelf off the northeastern U.S., Schlee, J., 1968.

VI.E.2 Heavy Metals

A direct result of preparing sediment distribution maps for sand and gravel exploration as mentioned above is a map showing the composition of the finer grained, more dense, metallic minerals which inevitably are associated with sand and gravel deposits. Such heavy metal accumulation are called placer deposits and can include a wide variety of economically important heavy metals such as gold, silver, cassiterite, garnet, ilmenite, magnetite and even platinum. Such heavy metals are carried in minute quantities by streams and rivers which have been flowing toward the Atlantic continental margins since its origin in the late Mesozoic. The processes of winnowing by stream flow, currents, tidal and wave action commonly cause local concentrations of the more dense, finer metallic minerals. This concentration process has been particularly active during the shifting sea-level stands across the shelf surface during Pleistocene and post-Pleistocene epochs and is an on-going process on the shelf surface today.

Channel deposits of streams crossing the continental shelf during the Pleistocene lowered sea-level would be immediate targets for potential heavy metal exploration. Buried shelf valleys, ridge and swale topography, ridges and shoals - retreat massifs should undoubtedly contain some quantities of placer deposits of heavy metals. Recognizing such potential sites of this resource could only be a product of second generation detailed maps of shelf surface sediment distribution. Thus, in addition to the references listed above under "Sands and Gravels," the following are papers describing specific heavy mineral types and their distribution on the continental shelf of New York.

VI.E.2. Heavy Metals

Economic placer deposits of the continental shelf, Emery, K.O. and Noakes, L.C., 1968.

Sediment distribution in the oceans, Ewing, M., Carpenter, G. Windisch, C. and Ewing, S., 1973.

Atlantic sediments, erosion rates, and the evolution of the continental shelf, Gilluly, J., 1964.

Data file, continental margin program, Atlantic coast of the United States, Vol. 1, Sample collection data, Hathaway, J.C., ed., 1966.

Data file, continental margin program, Atlantic coast of the United States, Vol. 1, sample collection data, Supplement 1, Hathaway, J.C., ed.,1967.

Data file, continental margin program, Atlantic coast of the U.S., Hathaway, J.C., 1971.

Sub-bottom basement drainage system of inner continental shelf off southern New England, McMaster, R.L. and Ashraf, A., 1973.

Heavy mineral petrology of Wisconsinan and post-glacial deep-sea sands and silts, western North Atlantic, Neal, W.J., 1964.

Heavy mineral assemblages in the nearshore surface sediments of the Gulf of Maine in Geological Survey Research 1967, Ross, D.A., 1967.

Atlantic continental shelf and slope of the U.S. -- heavy minerals of the continental margin from southern Nova Scotia to northern New Jersey., Ross, D.A., 1970.

Significance of submerged deltas in the interpretation of the continental shelves, Shepard, F.P., 1928.

Bathymetric charts Cape Cod to Maryland, Stearns, F. and L.E. Garrison, 1967.

Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Stearns, F., 1967.

Bathymetric maps and geomorphology of the Middle Atlantic continental shelf, Stearns, F., 1969.

VI.E.2. (continued)

Sediment response to the hydraulic regime on the central New Jersey shelf, Stubblefield, W.L., J.W. Lavelle, T.F. McKinney, and D.J.P. Swift, 1975.

Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast, Swift, D.J.P., Dill, C.E., Jr., McHome, J., 1971.

VI.E.3. Uranium

Recovery of sedimentary uranium is not an imminent event although its presence in economic quantities in the sedimentary sequence -- Mesozoic and younger rocks -- beneath the shelf surface is entirely plausible. No direct evidence has yet been sought to substantiate this idea. Three types of sedimentary associations may contain sedimentary uranium ore and numerous economic deposits of these three types have been exploited on land.

a. Uranium accumulation in fluvial deposits of closely associated oxidized and reduced sediments.

b. Uranium accumulations in nearshore deposits where beach sand and lagoonal muds interfinger.

c. Black shales with sedimentary derivatives from weathered volcanic debris.

All three of the above associations occur within the stratigraphic units of Mesozoic and younger deposits within New York's continental margin. Any of the sedimentary associations alone would not "guarantee" the presence of uranium, but would act only as a potential accumulation site where uranium may be carried by groundwater in solution. The boundary between oxidizing and reducing conditions results in precipitation of uraniferous material which might be transported in the groundwater system.

References to sedimentary uranium have not been included in this report. The senior author (Glaeser) has published two abstracts on the subject (not listed in the bibliography) and has exploration experience in this field.

Potential recovery of sedimentary uranium from the continental shelf is not presently feasible economically. However, as future needs for nuclear fuels increase, the shelf may be an important target region for sedimentary uranium exploration. Some general references regarding stratigraphy beneath the shelf surface are essential in an initial phase of determining uranium potential. These are given below.

VI.E.3. Uranium

Deep wells of Maryland, Edwards, J.J., Jr., 1970.

Depositional environments of subsurface Potomac group in southern Maryland, Hansen, H.J., 1969.

Record of wells in Suffolk County, Long Island, New York, Johnson, A.H. and others, 1952.

Stratigraphy of coastal plain of New Jersey, Johnson, M.E. and Richards, H.G., 1952.

A geologic cross-section of Delaware showing stratigraphic correlations, distribution and geologic setting with the Atlantic coastal plain -- continental shelf geosyncline, Kraft, J.C. and Maisang, M.D., 1968.

Summary of geology of Atlantic Coastal Plain, LeGrand, H.E., 1961.

Correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic coast, Maher, J.C., 1965.

Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf, Maher, J.C., 1971.

Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf, Maher, J.C. and E.R. Applin, 1971.

Deep test in Accomack County, Virginia, Onuschak, E., Jr., 1972.

Maryland Esso No. 1 well, Standard Oil Company of New Jersey, Ocean City, Maryland, description of ditch samples, Overbeck, R.M., 1948.

Coastal plain rocks of Harford County, Owens, J.P., 1969.

Post-Triassic tectonic movements in the central and southern Appalachians as recorded by sediments of the Atlantic coastal plain, Owens, J.P., 1970.

Cretaceous deltas in the northern New Jersey coastal plain, Owens, J.P., Minard, J.P., and Sohl, N.F., 1968.

VI.E.3. (continued)

Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, Field trip no. 2. In, Geology of selected areas in New Jersey and eastern Pennsylvania and guidebook of excursions, Owens, J.P. and N.F. Sohl, 1969.

Stratigraphy of the outcropping post-Magothy Upper Cretaceous formations in southern New and northern Delmarva Peninsula, Delaware and Maryland, Owens, J.P. and others, 1970.

Correlation and foraminifera of the Monmouth Group (Upper Cretaceous), Long Island, N.Y., Perlmutter, N.M. and Todd, R., 1965.

Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras, a brief survey, Perry, W.J., Minard, J.P., Weed, E.G.A., Robbins, E.I. and Rhodehamel, E.C., 1974.

Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras - brief survey, Perry, W.J. and others, 1975.

Upper Cretaceous subsurface stratigraphy of Atlantic coastal plain of New Jersey, Petters, S.W., 1976.

Subsurface stratigraphy of Atlantic coastal plain between New Jersey and Georgia, Richards, H.G., 1945.

Studies of the subsurface geology and paleontology of the Atlantic coastal plain, Richards, H.G., 1948.

Stratigraphy of Atlantic coastal plain between Long Island and Georgia - Review, Richards, H.G., 1967.

Significance of submerged deltas in the interpretation of the continental shelves, Shepard, F.P., 1928.

Stratigraphic section at Island Beach State Park, New Jersey, Seaber, P.R. and Vecchioli, J., 1963.

Seismic reconnaissance of post-Miocene deposits, Middle Atlantic continental shelf - Cape Henry, Virginia to Cape Hatteras, North Carolina, Shideler, G.L. and D.J.P. Swift, 1972.

Late Quaternary stratigraphy of the inner Virginia continental shelf, Shideler, G.L., D.J.P. Swift, G.H. Johnson and B.W. Holliday, 1972.

VI.E.3. (continued)

Biostratigraphic analysis, Sohl, N.F. and Mello, J.F., 1970.

Geology of Atlantic coastal plain in New Jersey, Delaware, Maryland, and Virginia, Spangler, W.B. and Peterson, J.J., 1950.

Upper Cretaceous marine transgression in northern Delaware, Spoljaric, N., 1972.

Lower Cretaceous, Jurassic and Triassic ostracoda from the Atlantic coastal regions, Swain, F.M. and Brown, P.M., 1972.

Records of wells in Bronx, New York, Richmond, Kings, Queens, Nassau and Suffolk counties (a series of occasional reports giving factual geological and engineering data compiled about wells and borings on Long Island), U.S. Geological Survey, 1937-59.

Geological and operational summary, COST #B-2 well, Baltimore Canyon trough area, Mid-Atlantic OCS, U.S. Geological Survey, 1976.

Generalized pre-Pleistocene geologic map of the northern United States Atlantic continental margin, Weed, E.G.A. and others, 1974.

Stratigraphic interpretations of some Cretaceous microfossil floras of the middle Atlantic states, Wolfe, J.A. and Pakiser, H.M., 1971.

Discovery of Eocene sediments in subsurface of Cape Cod, Ziegler, J.M. and others, 1960.

VI.E.4. Fresh Artesian Water

A number of reports have been made of fresh water springs and large subsurface zones of fresh water encountered in U.S. Geological Survey drilling programs on the eastern United States continental margins. Such reports are not published but are aside comments on other aspects of the drilling program.

The potential of fresh artesian water in sedimentary units of the continental shelf represents an important potential resource for both coastal cities and sea-based operational platforms. No assessment exists of the extent or importance of fresh water in rocks of the outer continental shelf.

Its presence is logical and predictable. The stratigraphy of the outer continental shelf is in part the down-dip equivalent of Cretaceous and younger strata exposed on the coastal plain. Thus, the coastal plain is the surface recharge zone for a number of permeable (probably sandstone) strata which extend seaward from the coastal zone dipping gently toward the continental margin. Depending upon the thickness, continuity and permeability of such strata known on the coastal plain, vast amounts of fresh water may be stored down-dip within the strata of the outer continental shelf. A greater number of fresh water springs probably exist there which have never been detected or reported. Knowledge of such springs and aquifers could be very important clues to strata continuity and permeability relating not only to direct assessment of fresh water potential but also to fluid transport and hydrocarbon storage capacity of certain strata lying beneath the outer continental shelf surface.

The references to stratigraphic studies which might aid in understanding the distribution of fresh water aquifers are listed below.

VI.E.4. Fresh Artesian Water

Structural and stratigraphic framework and spatial distribution of permeability of the Atlantic Coastal Plain, North Carolina to New York, Brown, P.M., Miller, J.A. and Swain, F.M., 1972.

Deep wells of Maryland, Edwards, J.J., Jr., 1970.

Evaluation of geologic and hydrologic data from the test-drilling program at Island Beach State Park, New Jersey, Gill, H.E., Seaber, P.R., Vecchioli, J., and Anderson, H.R., 1963.

Depositional environments of subsurface Potomac group in southern Maryland, Hansen, H.J., 1969.

Record of wells in Suffolk County, Long Island, New York, Johnson, A.H. and others, 1952.

Geologic and hydrologic data from a test well drilled near Chestertown, Md., Kantrowitz, I.H. and Webb, W.E., 1971.

A geologic cross-section of Delaware showing stratigraphic correlations, distribution and geologic setting with the Atlantic coastal plain - continental shelf geosyncline, Kraft, J.C. and Maisang, M.D., 1968.

Summary of geology of Atlantic Coastal Plain, LeGrand, H.E., 1961.

Correlations of subsurface Mesozic and Cenozoic rocks along the Atlantic coast, Maher, J.C., 1965.

Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf, Maher, J.C., 1971.

Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf, Maher, J.C. and E.R. Applin, 1971.

Deep test in Accomack County, Virginia, Onuschak, E., Jr., 1972.

Maryland Esso No. 1 well, Standard Oil Company of New Jersey, Ocean City, Maryland, description of ditch samples, Overbeck, R.M., 1948.

Coastal plain rocks of Harford County, Owens, J.P., 1969.

VI.E.4. (continued)

Post-Triassic tectonic movements in the central and southern Appalachians as recorded by sediments of the Atlantic coastal plain, Owens, J.P., 1970.

Cretaceous deltas in the Northern New Jersey coastal plain, Owens, J.P., Minard, J.P. and Sohl, N.F., 1968.

Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, Field trip no. 2. In, Geology of selected areas in New Jersey and eastern Pennsylvania and guidebook of excursions, Owens, J.P. and N.F. Sohl, 1969.

Stratigraphy of the outcropping post-Magothy Upper Cretaceous formations in Southern New and Northern Delmarva Peninsula, Delaware and Maryland, Owens, J.P. and others, 1970.

Correlation and foraminifera of the Monmouth Group (Upper Cretaceous), Long Island, N.Y., Perlmutter, N.M. and Todd, R., 1965.

Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras, a brief survey, Perry, W.J., Minard, J.P., Weed, E.G.A., Robbins, E.I., and Rhodehamel, E.C., 1974.

Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras - brief survey, Perry, W.J. and others, 1975.

Upper Cretaceous subsurface stratigraphy of Atlantic coastal plain of New Jersey, Patters, S.W., 1976.

Subsurface stratigraphy of Atlantic coastal plain between New Jersey and Georgia, Richards, H.G., 1945.

Studies of the subsurface geology and paleontology of the Atlantic coastal plain, Richards, H.G., 1948.

Stratigraphy of Atlantic coastal plain between Long Island and Georgia - Review, Richards, H.G., 1967.

Stratigraphic section at Island Beach State Park, New Jersey, Seaber, P.R. and Vecchioli, J., 1963.

Seismic reconnaissance of post-Miocene deposits, Middle Atlantic continental shelf-Cape Henry, Virginia to Cape Hatteras, North Carolina, Shideler, G.L. and D.J.P. Swift, 1972.

VI.E.4. (continued)

Late Quaternary stratigraphy of the inner Virginia continental shelf, Shideler, G.L., D.J.P. Swift, G.H. Johnson, and B.W. Holliday, 1972.

Biostratigraphic analysis, Sohl, N.F. and Mello, J.F. 1970.

Results of subsurface exploration in the mid-island area of western Suffolk County, Long Island, New York, Soren, J., 1971.

Geology of Atlantic coastal plain in New Jersey, Delaware, Maryland and Virginia, Spangler, W.B. and Peterson, J.J., 1950.

Upper Cretaceous marine transgression in northern Delaware, Spoljaric, N., 1972.

Mapping of geologic formations and aquifers of Long Island, New York, Sutter, R., deLaguna, W. and Perlmutter, N.M., 1949.

Lower Cretaceous Jurassic and Triassic ostracoda from the Atlantic coastal regions, Swain, F.M. and Brown, P.M., 1972.

Geological and operational summary, COST #B-2 well, Baltimore Canyon trough area, Mid-Atlantic OCS, U.S. Geological Survey, 1976.

Generalized pre-Pleistocene geologic map of the northern United States Atlantic continental margin, Weed, E.G.A. and others, 1974.

Geomorphology and sediments of the inner New York Bight continental shelf, Williams, S.J. and Duane, D.B., 1974.

Stratigraphic interpretations of some Cretaceous microfossil floras of the middle Atlantic states, Wolfe, J.A. and Pakiser, H.M., 1971.

Discovery of Eocene sediments in subsurface of Cape Cod, Ziegler, J.M. and others, 1960.

Hydrography of Long Island and Block Island Sounds, Riley, G.A., 1952.

VII. GEOLOGIC HAZARDS

According to the USGS (1975a), potential geologic hazards and environmental hazards that may be encountered on the Atlantic outer continental shelf include the following:

1. Slumping (mass movement of sediment);
2. Seismic risk (earthquakes);
3. Shallow hazards (shallow gas, H_2S, surface faults);
4. Overpressures;
5. Movement of oil spills (pollutant dispersal);
6. Erosional-depositional processes;
7. Geochemical balance;
8. Dredging and;
9. Man-made hazards.

Of these, only slumping, earthquakes, shallow hazards, geopressures, movement of oil spills, and erosional-depositional processes will be discussed.

VII.A. Slumping

Slumping (mass movement) is known to have occurred on the continental slope (Ballard, 1966; Uchupi, 1967, 1970; Stanley and Silverberg, 1969). Uchupi (1970) discusses slump features seen on seismic profiles. He believes that the re-entrant between Block and Atlantis Canyons is the result of massive slumping (Figure 28). Strata within the upper continental slope show evidence of folding due to sliding in a seaward direction. The age of the slumping and sliding is probably Pleistocene. During the Pleistocene the shoreline was near the present shelf-break and deposition was directly on the slope. Uchupi (1970) believes that such a drastic increase in deposition triggered the downslope movements.

Stanley and Silverberg (1969) report on recent slumping off Sable Island Bank. Their seismic studies show slump structures disturbing recent sediments on the continental slope.

In the Gulf Coast, Bea (1971) describes the effect of a hurricane induced submarine slide of deltaic muds in more than 300 feet of water. One platform was knocked over and another moved three or four feet at the mudline. This was a special case, not strictly applicable to the Atlantic continental shelf but it illustrates the effects of mass movement on man-made structures.

A number of papers have been written on the mechanical properties of sediments and slope stability. McClelland (1974) gives an up-to-date overview in "Geologic Engineering Properties Related to Construction of Offshore Facilities on the Mid-Atlantic Continental Shelf." Smith (1977) discusses how proper design of offshore platforms can help prevent catastrophies. Finn *et al* (1971) discuss engineering properties of sediments and their geophysical identification from their experience in Alaska. Fisk and McClelland (1959) describe the nearshore sediments of Louisiana and their effect on foundation design.

VII.B. Seismic Risk (Earthquakes)

At least four earthquake epicenters have been located on the continental slope to the east of Baltimore Canyon Trough in historic times (USGS, 1975). Since the early 1960's a number of minor earthquakes have been located across New Jersey and the continental shelf. The epicenters of these earthquakes parallel the Cornwall-Kelvin fault zone, but is about 100 kilometers to the south (Milliman, 1973). Any relation between the two is speculative at this time.

In the Georges Bank area, Sbar and Sykes (1973) have projected the Boston-Ottawa seismic trend southeast through the western part of the basin to connect it with the Kelvin Seamount Chain.

The USGS (1976) rates the Georges Bank Basin and Baltimore Canyon Trough as having a moderate seismic hazard in comparison to the rest of the United States.

Few earthquake epicenters have been located offshore because of the difficulty of onshore seismographs in focusing on offshore earthquakes unless they are large or near shore.

The USGS (1974) has published a seismotectonic map of the eastern United States and the Department of Commerce (1973) has compiled the earthquake history of the country. Howell (1973) has rated the earthquake hazard in the eastern United States. In addition, the BLM Environmental Impact Statements give a somewhat cursory examination of the seismic risks.

VII.C. Shallow Hazards

1. Shallow Faults

Sheridan and Knebel (1976) and Knebel *et al* (1976) consider the hazards of the shallow faults they mapped. The evidence of post-Pleistocene activity suggests that the faults have a high potential for future movement. These faults probably present a minor seismic risk that must be considered during operations on this part of the shelf.

McMaster (1971) reported on a shallow transverse fault but it does not appear to be active. The USGS (1975) did not discover any faults in the Georges Bank area, based on 2,200 kilometers of shallow seismic profiles.

VII.C.2. Shallow Gas

Gas at shallow depths can pose a hazard to drilling operations. High resolution seismic surveys and proper drilling procedure are necessary to overcome this problem. In addition hydrogen sulfide (H_2S) is a hazard in the Gulf Coast. No problem with shallow gas of H_2S has been reported from drilling on the Scotian Shelf, or from the COST B-2.

VII.D. Overpressure (Formation Fluid Pressure Greater than Hydrostatic).

Lithostatic pressure has two components: one that results from the weight of the interstitial fluids and the other from the weight of the sedimentary particles. The fluid pressure within the pore spaces of a formation normally is hydrostatic, i.e., it is a function of the density of the fluids filling the pore spaces and depth of the formation below the surface. This implies that pore spaces within the rock column are interconnected and that the pore fluids are free to migrate. As sediments are buried, the increased overburden causes compaction, which reduces pore space and squeezes pore fluids out. Where this fluid flows freely, normal hydrostatic pressure is maintained. Abnormal formation pressure, which may be higher or lower than normal hydrostatic, cannot exist without some restriction to flow to prevent equilization of pressures (Bradley, 1975). Abnormally high formation pressure, called overpressure, can be hazardous to drilling operations if it is not anticipated and allowed for in the design of the drilling program. Penetrating an overpressured formation unexpectedly can cause a blowout that may be difficult to control.

The following characteristics have been associated with overpressured sediments (Hedberg, 1974):

1. Fluid pressures higher than normal calculated hydrostatic pressure.

2. Porosity higher than normal porosity-overburden relations.

3. Density lower than normal density-overburden relation negative gravity anomalies with lower density.

4. Velocity of seismic waves lower than normally expected.

5. Occasionally strong seismic reflection from transition zone, but lack of continuous reflections from within low density layers.

6. Rate of drilling penetration above normal.

7. Increase of temperature above normal.

8. Abnormally low electrical resistivity and high sonic transit time with increased water content as shown on well logs.

9. Lower than normal formation-water salinity.

10. "Trip" gas (gas coming up hole as drill string is removed) and small gas pockets frequently encountered during drilling.

Thus, careful observations in an area generally can detect the existence of overpressure in advance of drilling.

VII.D.1. Major Causes of Overpressure

a. Undercompaction

In many places there is an abrupt change from normal pressure to high pressure, indicating that these zones are isolated from their surroundings by some relatively impermeable zone. Dickey et al (1972) wrote that in Louisiana "the normal pressures are found only in sands completely enclosed in shale, with no permeable connection to the outcrop."

Hedberg (1974) writes of undercompacted shales, in which the shale acts as both the seal and the pressurized zone. He states that the most common cause of the undercompacted shale is simply a rate of sedimentation so high and a permeability so low that expulsion of water is not able to keep up with increasing overburden pressure. Under such conditions, the interstitial water carries a part of the weight of the sediment overburden in addition to the normal hydrostatic pressure. Undercompacted sections may persist for a considerable period of geologic time if the sealing beds develop adequate impermeability. This mechanism appears to be most likely to develop in sections containing abundant montmorillonite clays. Some believe it is the most prevalent cause of overpressure.

VII.D.1.b. Temperature Rise

Heating of the lower part of a sediment pile as it becomes deeply buried may cause overpressure because water has a higher coefficient of expansion than do the mineral grains that form the sediment. As the temperature increases, pore water expands more rapidly than the pore space does, and fluid pressure will increase if the fluid cannot migrate freely. Barker (1972) called this process aquathermal pressuring. Bradley (1972) suggests this may be the most important mechanism that causes overpressure.

VII.D.2. Minor Causes of Overpressure

a. Dewatering of Clays

Interlayer water which is bound to clay has a higher density than the normal fluid because of its closer packing in the bound state. If dehydration occurs, the interlayer water reverts to water of normal density with a concomitant increase in volume. This also may be a cause of low salinity in formation water because clay-bound water is fresh (Powers, 1967; Bradshaw and Bredehoeft, 1968).

VII.D.2.b. Tectonics

A rapid decrease of the overburden by uplift and erosion over a lens of normally pressured but sealed rock will reduce the lithostatic and hydrostatic pressure in the rock surrounding the sealed lens. Fluids within the lens would then be overpressured, if the seal is adequate.

VII.D.2.c. Structural Barriers

Structural barriers to fluid expulsion can develop by tectonic movement. Bradley (1974) states that vertical seals can be formed by fault displacement of less than a foot and that gouge and tear zones can act as barriers.

VII.D.2.d. Thermal Degradation of Petroleum

If oil is heated sufficiently, gas is generated which increases pressure.

VII.D.2.e. Carbonization

Thermal alteration of organic matter (production of petroleum) may increase or decrease pressure, depending on the volume change.

VII.D.2.f. Biogenic Gas Production

Hedberg (1974) emphasized the role of bacterial methane generation in subsurface sedimentary deposits.

VII.D.2.g. Osmosis

The mass transfer of water (solvent) through a semipermeable membrane from fresher water to saltier water can cause abnormal pressure. A shale layer can serve as a membrane for the process. Osmotic pressure equals the back pressure required to stop the osmotic flow. If pore water within a sealed formation is saltier than the pore water in the surrounding rock, osmosis may cause abnormally high pressure and vice versa, if it is fresher. Osmosis is not thought to be a major factor in subsurface pressure systems (Bradley, 1974).

VII.D.2.h. Mineralization

Growth of salt crystals may reduce pore volume thus increase pressure (Levorsen, 1954).

VII.D.2.i. Gypsum-to-anhydrate

Under proper pressure-temperature conditions, the volume of water released in the change from gypsum to anhydrate exceeds the volume decrease in the mineral transformation and produces an excess fluid pressure (Heard and Rubey, 1966).

VII.D.2.j. Permafrost Development - forms an impermeable surface layer trapping any shallow gas.

The primary requirement for abnormal formation pressure, as stated earlier, is a seal. Horizontal seals may be shale or evaporite, while vertical seals may be fault zones or facies changes. Seals may be assumed to be thin with respect to the size of the pressurized zone and pressure changes may be abrupt (Bradley, 1974).

On the other hand, a large transition zone (several thousand feet) may exist around the overpressured zone (Hedberg, 1974). Overpressures that have been recorded are usually between normal hydrostatic pressure ($\approx$ 0.465 psi/ft for saline waters) and approximate rock overburden pressure ($\approx$ 1.0 psi/ft). Hedberg (1974) has reported cases of "super-pressures," (up to 1.5 psi/ft) where the overpressure is greater than geostatic pressure. No satisfactory explanation for this phenomenon exists at this time.

VII.E. Pollutant Distribution in Terms of Circulation Dynamics, Shelf Topography and Sediment Properties

This aspect of geologic hazards is one of the most obvious areas of concern to all groups concerned with or opposed to continental shelf exploration for petroleum. The number of ways to control this hazard is minimal because of the present inability of predictive models to accurately portray travel paths of pollutants in the shelf circulation system. The principal research presently underway is taking place at Virginia Institute of Marine Science where Bureau of Land Management funding is supporting studies in two major fields. One concerns computer modeling studies of induced wave refraction resulting from shelf topography. A second concerns a variety of studies of fates of hydrocarbons in the marine environment. These include rates of hydrocarbon decay via bacterial action, affects of grain size distribution in terms of topography and the associated biotic community assemblages as well as water mass movements.

Interim reports are available, based on the present data and/or the report with draft status expected at Bureau of Land Management (Horowitz) by summer, 1977. Regional studies of pollutant distribution are taking place and the discussion earlier concerning circulation dynamics of the outer continental shelf (III.B.) suggested the present divergence between mathematical computer simulation models and actual drift patterns. A clear problem which demands solution is one involving delivery of pollutants to the coastal zone. Is there a minimal distance from shore for which any pollutant will invariably come ashore? Until the NOAA report on the physical oceanography of the middle Atlantic bight is available (summarized in III. B.) reliance will be placed on the Stony Brook and M.I.T. computer models to predict drift directions of pollutants.

VII. GEOLOGIC HAZARDS

OCS oil and gas - an environmental assessment, Council on Environmental Quality, 1974.

Ocean drilling on the continental margin, Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965.

Subsea mineral resources and problems related to their development, McKelvey, V.E. and others, 1969.

Geologic hazards in the northern Gulf of Alaska (abstr.), Molnia, B.F. and others, 1976.

Mobil Tetco Sable Island E-48, Morrow, D.L. and others, 1972.

Petroleum exploration offshore from New York, Rogers, W.B. and others, 1973.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the United States North Atlantic outer continental shelf, Schlee, J. and others.

A socio-economic and environmental inventory of the North Atlantic region, Trigom, 1974.

Regulations pertaining to mineral leasing, operations, and pipeline on the outer continental shelf as contained in Title 30 and Title 43 of the Code of Federal Regulations and the Outer Continental Shelf Lands Act, U.S. Dept. of Interior, 1971.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the U.S. Mid-Atlantic outer continental shelf, U.S. Geological Survey, 1975.

Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the U.S. North Atlantic OCS, U.S. Geological Survey, 1975.

Geological and operational summary, COST #B-2 well, Baltimore Canyon trough area, Mid-Atlantic OCS, U.S. Geological Survey, 1976.

Baltimore Canyon trough area hazards, Knebel, H.J. and others, 1976.

VII.A. Slumping

Recommended practice for planning, designing and constructing fixed offshore platforms, American Petroleum Institute, 1971.

Effects of explosive loading on the strength of seafloor sands, Dill, R.F., 1967.

Oceanographic information for engineering submarine cable systems, Elmendorf, C.H. and Heezen, B.C., 1957.

Engineering properties of a marine sediment, Finn, W.D.L. and others, 1971.

Geology of continental shelf off Louisiana, its influence on offshore foundation design, Fisk, H.N. and McClelland, C., 1959.

Grand Banks slump, Heezen, B.C. and C.L. Drake, 1964.

Geologic engineering properties related to construction of offshore facilities on the Mid-Atlantic continental shelf, McClelland, B., 1974.

Shear strength and stability of continental slope deposits western Gulf of Mexico, Morelock, J., 1969.

Correlation of shoreline type with offshore bottom conditions, Price, W.A., 1955.

Proper design helps prevent offshore platform catastrophic hazards, Smith, R.S., 1977.

Engineering geology of the northeast corridor, Washington, D.C. to Boston, Mass., earthquake epicenters, geothermal gradients, and excavations and borings, U.S. Geological Survey, 1967.

Engineering geology of the northeast corridor, Washington, D.C., to Boston, Mass., coastal plain and surficial deposits, U.S. Geological Survey, 1967.

The geologic framework of inner New York bight - its influence on positioning offshore engineering structures, Williams, S.J., 1973.

VII.B. Seismic Risk

(see references in Chapter V, Seismicity of the Continental Margin)

VII.C. Shallow Hazards

(See references in Chapter V, Seismicity of the Continental Margin)

Shallow structure of the continental margin, Curray, J.R., 1969b.

Engineering geology of the northeast corridor, Washington, D.C., to Boston, Mass., coastal plain and surficial deposits, U.S. Geological Survey, 1967.

Sediments, structural framework, petroleum potential, environmental conditions, and operational considerations of the U.S. North Atlantic outer continental shelf, Schlee, J. and others, 1975.

Sediments, structural framework, petroleum potential, environmental conditions, and operational considerations of the U.S. North Atlantic OCS, U.S. Geological Survey, 1975.

VII.D. Overpressure (Formation Fluid Pressure Greater than Hydrostatic).

Sediments, structural framework, petroleum potential, environmental conditions, and operational considerations of the U.S. North Atlantic outer continental shelf, Schlee, J. and others, 1975.

Sediments, structural framework, petroleum potential, environmental conditions, and operational considerations of the U.S. North Atlantic OCS, U.S. Geological Survey, 1975.

NOTICE: These references are not included in the bibliography, hence, the complete citations are given here.

Barker, C., 1972. Aquathermal pressuring-role of temperature in development of abnormal-pressure zones: AAPG Bull.,v. 56, no. 10, p. 2068-2071.

Bradley, J.S., 1975. Abnormal formation pressure: AAPG Bull., v. 59, p. 957-973.

Dickey, P.A., Collins, A.G., Fajardo, M., 1972. Chemical composition of deep formation waters in southwestern Louisiana: Amer. Assoc. Petrol. Geol. Bull., v. 56, p. 1530-1570.

Hanshaw, B.B., and Bredehoeft, J.D., 1968. On the maintenance of anomalous fluid pressures, II, Source layer at depth: Geol. Soc. Amer. Bull., v. 79, p. 1107-1122.

Heard, H.C. and Rubey, W.W., 1966. Tectonic implications of gypsum dehydration: G.S.A. v. 77, p. 741-760.

Hedberg, H.D., 1974. Relation of methane generation to undercompacted shales, shale diapirs and mud volcanos: AAPG v. 58, p. 661-673.

Levorsen, A.I., 1954. Geology of Petroleum: San Francisco, W.H. Freeman, 703 p.

Powers, M.C., 1967. Fluid-release mechanisms in compacting marine mud rocks and their importance in oil exploration: AAPG, v. 51, no. 7, p. 1240-54.

VII.E. Pollutant Distribution in Terms of Circulation Dynamics, Shelf Topography and Sediment Properties

Geologic prediction, developing tools and techniques for geophysical identification and classification of sea floor sediments, Barnes, B. et al (1972.

Ocean disposal of waste materials, Buelor, R.W., 1968.

Assessment of ERTA - 1 for coastal ocean observation, Charnell, R.L., Jr., Apel, Manning, W., III, and Quelset, R.H., 1974.

Assessment of offshore dumping, technical background, Charnell, R.L., 1975.

Ocean disposal, Delwing, R.T., 1974.

Ocean dumping in the New York Bight, facts and figures, Environmental Protection Agency, 1973.

Marine and environmental implications of oil and gas development in the Baltimore Canyon region of the Mid-Atlantic coast, Estuarine Research Foundation - OCS Conference and Workshop, 1974.

Wind drift, surface currents and spread of contaminants in shelf waters, Gordon, A.L. and Gerard, R.D., in press.

EPA's view of projected oil drilling on the continental shelf, Green, F., 1976.

Metropolitan region - A major sediment source, Gross, M.G., 1970.

Preliminary analysis of urban waste, N.Y., Metropolitan region, Gross, M.G., 1970.

Analyses of dredged wastes, fly ash and waste chemicals, N.Y. metropolitan region, Gross, M.G., 1970.

Geologic aspects of waste solids and marine waste deposits, N.Y. metropolitan region, Gross, M.G., 1972.

Survey of marine waste deposits, N.Y. metropolitan region, Gross, M.G. and others, 1971.

Movement and effects of spilled oil over the outer continental shelf - inadequacy of existant data for the Baltimore Canyon trough area, Knebel, H.J., 1974.

Ocean dumping in the New York bight, an assessment of environmental studies, Pararas-Carayannis, G., 1973.

VII.E. (continued)

The effects of waste disposal on the N.Y. bight, Pearce, J.B., 1969.

The effects of solid waste disposal on benthic communities in the N.Y. bight, Pearce, J.B., 1970.

Correlation of shoreline type with offshore bottom conditions, Price, W.A., 1955.

An oil spill risk analysis for the mid-Atlantic outer continental shelf lease area, Smith, R.A., Slack, J.R., and Davis, R.K., 1976.

Drilling tankers and oil spills on the Atlantic outer continental shelf, Travers, W.B. and Luney, P.R., 1976.

Volume II Appendix and Bibliography

ASSESSMENT OF THE GEOLOGIC INFORMATION OF NEW YORK STATE'S COASTAL ZONE AND CONTINENTAL SHELF AND ITS SIGNIFICANCE TO PETROLEUM DEVELOPMENT

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Appendix

INVENTORY OF INSTITUTIONS, ORGANIZATIONS, PERSONNEL AND FUNDING AGENCIES ACTIVELY INVOLVED (OR CAPABLE OF STUDIES) IN NEW YORK CONTINENTAL SHELF AND COASTAL ZONE

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Preface

This section has three parts. The first lists, by region, those organizations involved in studies or compiling information from studies in the northern and middle Atlantic regions of eastern United States. All have information or are capable of gathering information concerning New York's continental margin and its coastal zone.

The second portion of this section is a detailed listing of institutions, personnel and equipment in most of the organizations listed in the first part. This second detailed listing gives the bulk of information needed to specify most of the research capability available to the eastern continental margin of the United States. In most cases, the major source of funding support is included.

The third portion of this section lists the principal Federal funding agencies supporting on-going research in the New York shelf region. A review of each agency's function is given along with the name of the individual in charge of continental shelf programs. Where possible, a listing is given of individual grants pertinent to the New York region.

New England - general

New England River Basin Commission
New England Natural Resource Center
New England Marine Advisory Service
John Hutchinson, Coordinator
The New England Center for Continuing Education
15 Garrison Avenue
Durham, New Hampshire 03824
U.S. Army District, Boston, Corps of Engineers
U.S. Army District, Providence, Corps of Engineers
U.S. Geological Survey - at Woods Hole, Mass.

New England States

Connecticut - Univ. of Connecticut, Avery Point, Groton, Conn. - W.F.Bohlen

Maine - Bigelow Laboratories for Ocean Science
West Boothbay Harbor, Maine

The Research Institute of Gulf of Maine (Tregom)
96 Falmouth St.
P.O. Box 2320
South Portland, Maine
(consortium of education and research institutions in Maine)

Massachusetts - Woods Hole Oceanographic Institute
Woods Hole, Mass.

Mass. Institute of Technology - Cambridge
Dept. of Civil Engineering - Ole Madsen
Dept. of Earth & Planetary Sciences - John Southard

Univ. of Mass. - Amherst
Coastal Research Center
Dept. of Geology and Geophysics

Boston College - Chestnut Hill, Mass.
Dept. of Geology and Geophysics
Benns Brenninkmeyer, S.J.

New Hampshire - Univ. of New Hampshire - Durham
Dept. of Earth Sciences - Franz E. Anderson

Rhode Island - Univ. of Rhode Island, School of Oceanography, Kingston

Middle Atlantic States (NY, NJ, PA, DE, MD)

NY Dept of Environmental Conservation
NY State Geological Survey
Marine Sciences Research Center
Stony Brook (NY Sea Grant)
City Univ. Institute of Marine & Atmospheric Sciences (CIMAS)
Lamont-Doherty Geological Observatory
Long Island Univ., Mitchell, Greenvale, NY, Dept. of Marine Science
NY Ocean Science Laboratory
Brookhaven Laboratory - Jon Scott
Rensselaer Polytechnic Institute
Dames & Moore, Cranford, NJ and Washington, D.C.
NJ State Geological Survey
Penna. Marine Science Consortium
Center for Marine & Environmental Science, Lehigh Univ., Bethlehem, Pa., James Parks, Director
Dept. of Geology, Univ. of Delaware
Delaware Geological Survey
Long Island Sound Research Group
US Army District, New York, Corps of Engineers
US Army District, Philadelphia, Corps of Engineers
US Army District, Providence, Corps of Engineers

Southeastern Atlantic States (Virginia - Florida)

Coastal Plains Center for Marine Development Services, Wilmington, N.C.
Virginia Institute Marine Sciences
Inst. of Oceanography, Old Dominion Univ., Norfolk

Duke Univ. Marine Laboratory
Univ. of North Carolina, Marine Science Curriculum
North Carolina State Univ., Raleigh
Univ. of North Carolina, Wilmington

Coastal Research Group, Univ. of S. Carolina

Univ. of Georgia, Athens
Dept. of Geology (Parts formerly at Skidaway)
University of Miami, Division of Marine Geology & Geophysics

Florida State University, Dept. of Oceanography, Tallahassee

Florida Institute of Technology, Dept. of Oceanography & Oceanographic Engineering, Melbourne, Florida

University of South Florida, Dept. of Marine Science, St. Petersburg
University of South Florida, Dept of Geology, Tampa

National Oceanographic and Atmospheric Administration

Atlantic Oceanographic & Meteorological Labs/MIAMI

NAME	Geographical Work Areas	Interest	Support
D.J.D.Swift	Middle Atlantic Bight	Fluid and sediment interaction in the coastal & bottom boundary layer. Influence of local shelf morphology on fluid motion, bed forms, shelf geomorphology.	NOAA/ERL NOAA/MESA ERDA
J.W.Lavelle	Middle Atlantic Bight	Fluid and sediment interaction in coastal and bottom boundary layers. Influence of local shelf morphology on fluid motion.	NOAA/ERL MESA ERDA
Robert A. Young	Middle Atlantic Bight	Fluid and sediment interaction in coastal and bottom boundary layers. Influence of local shelf & morphology on fluid motion, suspended matter transport, erosion & depssit on processes of fine sediments.	NOAA/ERL MESA ERDA
G.F.Freeland	New York Bight	Fluid & sediment interaction in coastal & bottom boundary layer. Influence of local shelf morphology on fluid motions, sedimentology, morphology, morphology & ocean dumping canyon processes, shelf-break processes.	NOAA/ERL MESA ERDA
G.A.Han	Middle Atlantic Bight	Dynamic & kinematic of large scale shelf circulation/coastal boundary layer, transport & diffusion of dissolved & suspended sediments.	NOAA/ERL MESA

(continued from previous page)

NAME	Geographical Work Areas	Interest	Support
Richard Bennett	Middle Atlantic Bight, Mississippi Delta	Mass physical properties of slope and deltaic sediment.	NOAA/ERL
Bonnie McGregor-Stubblefield	Middle Atlantic Bight	Stratigraphy & structure of the shallow continental margin.	NOAA/ERL
John Proni	Middle Atlantic Bight, Great Lakes	Acoustic properties of suspension. Internal waves.	NOAA/ERL Army Corps of Engin.
Donald Hansen	Middle Atlantic Bight	Circulation of shelf water	NOAA/ERL BLM
Donald Atwood	Middle Atlantic Bight,	Inorganic, organic, and nutrient chemistry.	NOAA/ERL
George Berberian	Middle Atlantic Bight, Gulf of Mexico	Nutrient chemistry	NOAA/ERL
Patrick Hatcher	Middle Atlantic Bight	Organic Chemistry	NOAA/ERL

NOAA and AOML/MIAMI (continued)

Ship Support

RESEARCHER - 300 ft. - High Resolution (315 KHZ) Echo sounder, Air Guns, La Coste Gravimeter, Proton Precession Magnetometer, Ewing Piston Corer - 14 Scientists - Miami Based.

R/V George Kelez - 180 Ft., CSTD

Rosette Water Sampler - 6 scientists - New York Based.

R/V Johnson - 45 ft. day boat, New York based.

R/V Virginia Key - 65 ft. "T" Boat (6 scientist) Miami based.

Field Equipment

3.5 KHZ shallow seismic reflection profiler

UNIBOOM " " " "

Side scan sonar system

Box corer

Camera - shipek grab sampler

Underwater cameras

2 Marsh-McBierney E-M current meters, internally recording, tripod mounts

6 EGG-102 savonius rotor current meters, internally recording

Pore-water pressure probes

40 Aandaraa RCM-4 current meters

witness, spar bouys & acoustic releases

5 shallow water bottom pressure gauges

1 Nephelometer - Electromagnetic CM system

Laboratory Equipment

Sedimentology Lab

Rapid Sediment analyses

U.S. Geological Survey

Office of Marine Geology

Atlantic-Gulf of Mexico Branch

Woods Hole, Massachusetts

Type of Inst.: U.S. Government Laboratory

Funding: U.S. Government Funds and from Bureau of Land Management

Personnel

Wm. P. Dillon: Shallow seismic

John Grow: Geophysics

D. Folger: Environmental assessment coordinator, continental shelves. Bottom sediment distribution, suspended matter. Submersible observations.

H. Knobel: Shelf sediment distribution, characteristics, shallow coring.

M. Bothnor: Sediment geochemistry, suspended sediment distribution, coring.

B. Butman: Sediment transport dynamics, shelf dynamics, physical oceanography.

M. Noble: Sediment transport dynamics, shelf dynamics, physical oceanography.

J. Schlee: Deep seismic and sedimentology.

Support Personnel: Approximately fifteen technical staff to support shelf sediment programs additional staff as program require.

Type of Work:

Basic and applied geophysical and geological research. (Sediment characteristics and transport programs at present primarily directed toward environmental assessment of offshore continental shelf regions for petroleum exploration and production). Present programs in North Atlantic Region (Georges Bank), Middle Atlantic Region, (Baltimore Canyon Trough), South Atlantic Region (S.E. Georgia Emboyment), Gulf of Mexico.

Laboratory Support:

Sediment Laboratory, Electronics shop, Sediment transport equipment lab. Limited mechanical shop facilities, SEM.

Institution: University of Connecticut

Marine Sciences Institute

Avery Point, Groton, Connecticut

Type of Institution: State

Investigators: W.F. Bohlon, W.F. Fitzgerald, J. Dowling, R.W. Garvine

Type of Investigations - Studies dealing with suspended sediment transport, sediment geochemistry, sediment inventory and geological structures, and physical investigations of river frontal dynamics.

Facilities: 65' T-Boat equipped for oceanographic studies, shallow coring equipment, seismic profiling systems, sediment laboratory, recirculating flume, current meter arrays and associated data processing facilities.

Source of support: U.S. Army Corps of Engineers, Waterways Experiment Station, NOAA, IDOE, Sea Grant

Institution: Yale University

Department of Geology and Geophysics

New Haven, Connecticut

Type of Institution: Private

Investigators: R.B. Gordon, D. Rhoads, K. Turekian

Type of Investigations: Variety of studies dealing with coastal sedimentations, Biological influences and impacts, and sedimentary geochemistry.

Facilities: Analytical laboratories, current meter arrays. Penetrometer, interface camera. Sampling and standard hydrographic facilities, seismic profiling.

Source of Support: N.S.F., ERDA, U.S. Army Corps, Waterways Experiment Stations.

Woods Hole Oceanographic Inst.
Woods Hole, Mass. 02543

Type of Inst. - private research - (and education)

Type of Work - basic research (and increasing applied res.)

Type of Funding - NSF, ONR, SEA GRANT, private funds, USGS, NOAA

PEOPLE

Geology

David A. Ross (and 1 technician) - sed. petrography, depositmal processes

K.O. Emery - same as above

J.D. Milliman - same as above plus suspended matter studies (3 technicians & 2 students)

Susomu Hinjo - (and technician) - suspended matter studies

Physical Oceanography

Gabe Scanady (and 1 technician) - shelf circulation

Robert Beardsley (and 1 technician) - shelf circulation and current regime

A. Voorhis - circulation of slope water and outer shelf interactions

Engineering Dept. - increasing interest in shelf dynamics

W. Grant - coastal engineering and processes

J. Mavor - oceanographic instrumentation

E.E. Hays - general

Marshall Orr - acoustical analysis of suspended matter

Working primarily with Civil Eng. Dept. of MIT
1. man-made hazards
2. offshore structure
3. oceanographic equipment development

Biology

Gilbert Rowe - (and 1 technician) dump spoils and transport and biological implications

Richard Hoedvich - same as above

Peter Wilke - settling of plankton and seston

Chemistry

Derick Spencer and Peter Brewer - (and 2 technicians) trace element content in suspended matter

Facilities

Ships

R/V KNORR
ATLANTICS II — Mainly large open-ocean ships

R/V Oceanos - 180' ship used also on shelf

R/V Asterias - 45' ship for nearshore work

R/V LULU & DSDR ALVIN - submersible plus several smaller boats

Coring (piston, gravity), curab samplers, current meters, suspended matter sampling, echo sounding (3.5 KHZ & 12 KHZ), shallow seismics, sediment traps

Lab Equipment - complete oceanographic labs.

Support Equipment - SEM, computer center, engineering shops

Harvard University
Cambridge, Massachusetts

Type of Inst.: Educational and Research

Gen. Capacity: Laboratory studies, mathematical modeling

People:

Raymond Siever, Dept. of Geological Sciences: physical processes, geochemistry of sediments.

Engineering Dept.

Equipment

Institution: Massachusetts Institute of Technology

Type of Inst.: Education and Research

General Capability: laboratory experiments, analytical modeling, limited field studies (Programs with WHOI)

People:

John Southerd, Earth and Planetary Sciences; Lab experiments, sed. transport by currents, field study of sed. processes

John Bennett, Earth & Planetary Sciences; numerical modeling of shelf circulation

Ole S. Madsen, Dept. Civil Engineering: coastal engineering, sediment transport and coastal processes, longshore currents and sed. transport

John Edmond, Earth & Planetary Sciences; chemistry of suspended sed. in coastal waters

Byran Pearce, Dept. Civil Engineering; numerical modeling of storm surge physical measurements in coastal waters

Institution: University of Massachusetts

People: Alan W. Niedoroda, Edward Perry, Dayton Carritt, Gregory Webb

Type of Institution: University and Coastal Research Center (Research)

General Capability: Field and analytical studies of continental shelf, shoreface and surf zone sediment dynamics and morphological changes and wave and current studies. (Niedorada) Geochemical studies of fine sediments (Perry), Remote sensing of nearshore water masses (Carritt), Sediment distribution and shelf strategraphy (Webb)

Type of Investigation - Field study of the dynamics of granular sediment transport in the zone from the inner continental shelf to the surf zone. Laboratory studies of sediment transport by waves.

Equipment - Electromagnetic current meters, wave gauges, tripods, signal processing and recording units, twenty-six foot Research Launch NORWOOTUC, skiffs and outboards, sediment traps, automatic Emory tube, sedimentation laboratory, complete machine shop, Smart Terminal with digitizer and plotter, electronic laboratory, twelve meter wave tank, seven meter square wave tank, trucks and jeeps, geochemistry laboratory, remote sensing laboratory, computer CDC7200, salinity, temperature, conductivity probe, depth sounders

Support personnel - Full time machinist/mechanical technician

Sources of support - ONR, NOAA, NSF, Water Resources

Table 1. New England estuaries studied by the Coastal Research Center, Univ. of Massachusetts

Estuary	Location	Publication
Royal River	Maine	unpublished (Timson)
Cousins River	Maine	unpublished (Timson)
Scarboro	Maine	Farrell (1970, 1971a, 1971b, 1971-ms)
Saco	Maine	Farrell (1970, 1971a, 1971b, 1971-ms)
Webhannet	Maine	unpublished (Timson)
Hampton Harbor	New Hampshire	Coastal Research Group (1969) Greer (1971-ms)
Merrimack	North-eastern Mass.	Hartwell (1970); Coastal Research Group (1969); McCormick (1968)
Parker	North-eastern Mass.	DaBoll (1969); Coastal Research Group (1969); Hubbard (1971); Rhodes (1971)
Essex	North-eastern Mass.	Coastal Research Group (1969); Rhodes (1971)
Barnstable Harbor	South-eastern Mass.	Hobbs (1971-ms)
Pleasant Bay	South-eastern Mass.	unpublished (Hine)
Shinnecock, Moriches, Fire Island, and Jones Inlets	Long Island, New York	Kaczorowski (1971) unpublished (Kaczorowski)
Summary articles covering several estuaries.		Hayes, et al (1971); Hayes (1969; Hayes, Boothroyd, and Hine (1970); Boothroyd and Hubbard (1971); Farrell (1971)

Inst.: Boston College
Dept. of Geology and Geophysics
Chestnut Hill, Mass.

People:

Benno Brenninkmeyer and 4 support personnel

Joe Foster and 4 support personnel

David Ray and 4 support personnel

Type of: Educational

Institution: Data Reduction Lab

Type of Work: Nearshore sedimentation processes, Physical oceanography - Modelling, Sed. transport dynamics

Type of Equipment: Field: 2 EM Current Meters, 1 Resistance Wave Staff, 6 Almometers

Lab: Complete sedimentation lab settling tube, Leco Carbon/ Carbonate/Flume

Support: Computor 370-60 Machine Shop, Electronics

Source of Support: ONR, Corp. of Engineers, Air Force (Cambridge)

Institution: Williams College, Department of Geology

People: William T. Fox

Type of Institution: College

Area of Research: Field and computor model studies of beaches and near-shore sediments.

Equipment: Contact Fox

Support: ONR

University of New Hampshire
Durham, New Hampshire

People: Fran E. Anderson
Brown
Wendal

Types of Investigations: Numerical Modeling of Coastal Circulation

Ellikol, Dept. Civil Engineering

Measurements of Suspended Sediments

Continental shelf circulation

Bottom pressure measurements

Source of Support: NSF

Institution: University of Rhode Island
Graduate School of Oceanography
Narragansett, Rhode Island

Type of Institution: State

Investigators: C. Griscom
R. McMaster

Type of Investigations: Variety of studies, geological structure, sediment transport and coastal oceanography

Facilities: 125' Oceanographic Vessel, completely equipped oceanographic facility

Sources of Support: U.S. Army Corps of Engineers, NSF, ETC

Institution: University of Rhode Island
Dept. of Geology
Kingston, Rhode Island

Type of Institution: State

Investigatore: John Boothroyd

Type of Investigations: Coastal Processes

Facilities: None

Source of Support: Unknown

Bigelow Laboratories for Ocean Science

West Boothbay Harbor, Maine

Private marine research laboratory

Located next to State Marine Resource Laboratory in Boothbay Harbor

Previously a part of University of Massachusetts system located outside Gloucester, Massachusetts

People - not defined

Equipment - not defined

Source of Support - Partly by Maine Department of Marine Resource

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University of Maine at Orono

Orono, Maine

Education & Res.

People Novak - sed. dynamics

Equipment - not defined

Source of Support -

Isra Dailing Center

University of Maine

Walpole, Maine

People - not defined

Equipment - not defined

Source of Support -

THE RESEARCH INSTITUTE OF THE GULF OF MAINE (TRIGOM)

- ...an oceanographic consortium of educational and research institutes in Maine dedicated to expanding marine research education and information,
- provides a variety of services to the marine science community through publications, meetings, and seminars on subjects of common interest. In addition, the Institute undertakes its own projects to help the state and region better plan for multiple uses of the coast and to manage its natural resources
- TRIGOM academic membership
  - Bates College
  - Bowdoin College
  - Colby College
  - Cornell University
  - Maine Maritime Academy
  - Nasson College
  - Saint Francis College
  - Southern Maine Vocational Technical Institute
  - U. of Maine @ Farmington
    - @ Orono
    - @ Portland-Gorham
- it does exist and acts as a focal point for such things as symposiums etc. - courses are taught there etc. lending to the fact that although it is part of a consortium it remains itself an entity.
- Director (1970) Donald B. Horton
- a person to contact would be:
  - Ned Shenton 207-773-2981
  - 96 Falmouth St.
  - S. Portland, Maine 04103
- TRIGOM done under contract w/ BLM
  - 08550-CT3-8

Columbia University
Lamont - Doherty Geological Observatory

Pierce Biscay	Radon tracers, geochemistry in NY Bight and Hudson Estuary
Arnold Gordon	Physical oceanography, surface drift patters in NY Bight
James Simpson	Hudson River estuary geochemistry
John Sanders	Sedimentology, Coastal sedimentation

Equipment
R/V Vema, R/V Conrad
3.5KHZ, on-board AA,
current meters, sparker,
Piston Corer, S.E.M.

City University Institute of Marine and Atmospheric Science

Willard Pierson	Satellite studies of wave motion
N. Coch and Dennis Weiss	Hudson River Estuary studies
Eric Posmontier	Hudson River Estuary dynamic models

C.W. Post College

A. Uzzo	Bottom Current studies

SUNY Stony Brook

J.Schubel	Okuba

Brookhaven Laboratory

John Scott	Cobalt Project shelf circulation studies

N.Y. OSL

Rudey Holman	Coastal studies, hydrography

Adelphi University
Garden City, NY 11530

Anthony E. Cok	MESA projects

Monitoring studies, shoreface, benthic ecology, channel transport

55' spindrift - Interocean system, Hydro Winches, Diver Capabilities, Rapid Sed. Analyzer, 5 current meters

Institution: Southampton College

People: Larry McCormick

Type of Institution: College

General Capabilities: Sedimentation on inner continental shelf

Type of Investigation: Sedimentation patterns, morphological changes, field studies

Equipment: Marine station, thirty five foot Research Vessel SHAWNA, numerous smaller vessels, automated Emory tube, sedimentation laboratory, geochemical laboratory, continuous recording pressure wave gauge (CERC), Tide gauge, surveying equipment, S.T.D., depth sounder, coring and grabbing equipment

Support Personnel: Boat Captain, electronics technician

Sources of Support: C.E.R.C.

Institution: Lehigh Univ. (Center for Marine and Environmental Studies - CMES), Bethlehem, Pennsylvania

People: James Parks, Bob Carson, Joseph Kelley, Adrian Richards

Type of Research: Nearshore/inner shelf; inner shelf; back barrier suspended and bottom sediment interaction; geotechnical properties of bottom sediments, Gulf of Maine and southern New Jersey

Equipment: Sedimentology Lab., Research Station (Stone Harbor, N.J.) various grab samplers, covers, Small (30') boats. Generator and pump for filtering suspended sediment, 293 mm diameter filter holder, sediment traps, current meters, collection of local aerial imagery, nephelometer, centrifuges, supercentrifuge, AA cent., mass spec. geotechnical lab (Adrian Richards)

Source of Support: Private foundations (Noyes, Victoria)
Companies - Union Oil Company,
Sea Grant

Pennsylvania Marine Sciences Consortium

Ben Oostdam, (Millersburg State, Millersburg, Pa.) Director, Wallops Island Lab., Va.

Types of Research: Geochemistry, Sedimentology, of Atlantic shelf suspended sediments

Equipment: R/V Annandale

Support: N.S.F.

University of Delaware, Newark, Delaware

Research Topics	Investigators
Continental shelf, coring and seismic studies	R. Sheridan
Coastal sediments, stratigraphy, history of sea level changes	J.C. Kraft
Organic geochemistry age dating	J. Wehmiller
Suspended sediments, geochemistry	R. Gibbs
Geotechnical soils, foundations	T. Inderbitzen
Same	K. Demars
Ocean engineering, sediment transport	R. Dean
Waste disposal	A. Darymple
Wave studies	C.Y. Yang
Remote sensing, ocean fronts	V. Klemas
Physical oceanography, continental shelves	C. Mooens

Equipment

R/V Cape Henolopen
Sub-bottom profiles
Settling tube, SEM, A.A., wave tanks, gas chromatographs, Coulter Counter, transmissometers

Sources of Support: Sea Grant, NOAA, ONR, NSF.

Delaware Geological Survey
Newark, Delaware
Coastal Zone Management

Robert Jordan, State Geologist

Research Topics

Suspended sediments estuarine and coastal studies, high-resolution seismic studies

Equipment

Access to equipment of University of Delaware

University of Maryland

Solomon's Island Laboratory

Offshore Service Vessel

The Johns Hopkins University

Baltimore, Maryland

Chesapeake Bay Institute

Grant Gross, Director

Wm. Borcourt

Estuarine studies, geochemistry

Physical oceanography, continental shelf

Equipment: R/V Ridgeley Warfield

Maryland State Geological Survey

Kenneth Weaver, State Geologist

Owen Bricker - geochemistry

C.Slaughter - high resolution seismic studies, shelf drilling

Equipment: Uniboom, contract seismic studies

Institute of Oceanography

1. Old Dominion Univ. - Norfolk

Educational - Research

J.C. Ludwick Director, Chesapeake Bay, tidal delta morphology and circulation

Wave gage inform from remote tower

Peter Fleigher - slope geology

1. Physical Oceanographic

1- 2 Boats, lab equipment, sed. samplers

2. Va. Inst. of Marine Science

400 people

90 Faculty - research

90 Graduate students

approximately 1/3 in physical Sciences Division

Phys. Sci. and Coastal Engineering Division

a. Geological & chemical Ocean. Dept.

Maynard Nichols - shelf sedimentology

Victor Goldsmith - Wave Refraction Models (Montauk Pt. to Cape Hateras)

- Shelf Bathymetry & Geomorphology

- Longshore wave energy inter-relations with historical shoreline change

- Wave climatology

3 Chemists (Smith, McIntire, and other)

- hydrocarbons

and 5 other faculty

b. Physical Oceanography & Coastal Hydraulics Dept.

- Evon P. Ruzecki Phys. Ocean. Field Work, Modeling, etc.

- Chris Welch

- Satelite Buoy Systems

Full gamut of salinity, BOD, current meters, etc. and 10 other faculty available and trained for shelf studies

VIMS BLM Baseline studies, which include Phys. Oc., sed. characterizations, etc. transend dept. (see Federal Agencies listing for support level).

Equipment

3 Deep-sea ocean vessels

6 boats capable of overnight shelf work

Full sed. lab with WHOI settling tube, etc.

Full electronics, instrument, carpentry, etc. shops

Recirculating flume

50 braincon current meters

6 satellite buoys (with telemetering equipment)

Source of Support

Commonwealth of Va.

Sea Grant

BLM

WES

Water Resources

NASA (Satellite Buoys)

Smithsonian Institute
Washington, D.C.

Sedimentology Laboratory

Jack Pierce	clay minerology, suspended sediments
D.J. Stanley	sediment transport

Westinghouse Ocean Research Laboratory

Donald Wilson	sediment transport, ocean engineering

Equipment
Sediment flume, subbottom profiler, settling tube, coulter counter, transport probe, quadripod

Sources of Support
ERDA, State, Federal, Industrial

New Jersey Marine Science Consortium
Don Zalusky
Glasgow State College
Sedimentology, Paleontology

Princeton University
Geophysics
Fluid Dynamics lab.
Hydraulic modelling

Rutgers University
Littoral drift modelling
Sandy Hook studies

Fairleigh Dickinson University
Robert Dill
Maring geology, sedimentology
Marine Laboratory, St. Croix, U.S. Virgin Islands

Dames and Moore
Harold Palmer
Roger Moose
Tom McKinney
Jim Marlowe
Peter Feldhausen

Area of Studies
  Shelf sediment transport, sedimentology

Equipment
  Geotechnical laboratory, current meters,
  sub-bottom profilers

Sources of Support
  Industrial, federal and state

National Marine Fisheries Service
Sandy Hook Laboratories
Highlands, New Jersey

work has included sediment studies

LONG ISLAND RESEARCH FORUM

- there is an annual meeting concerning L.I. Sound research - an abstract is printed annually
- people to contact:
  (1) John Sanders
  prof. @ Barnard College, CCNY
  adjunct prof. @ RPI
  (2) Mickey Weiss
  project "Oceanology" in Groton, Conn. 203-445-9007
  (3) Don Squires
  director, Sea Grant 518-474-6240
  (4) John Baiardi (Bayardi - pron.)
  director, Ocean Science Labs
  in Montauk, N. Y..... 668-5800 ext. 30

COASTAL ZONE
INFORMATION CENTER

CONTRACTS
MID- and NORTH ATLANTIC

A. MID-ATLANTIC

(1) USGS

sediment characteristics, high resolution seismic reflection data, hydrostatically damped gravity cores, hydrocarbon geochemistry, shelf sediment monitoring system

these data are presented through a series of interim reports; summarizations appear in appendices. Appendices include:

1st report
(1) Shelf sediment monitory system
Description and specifications
(2) Evidence of Post-Pleistocene faults on the New Jersey Atlantic OCS

2nd report
(1) Large sand waves on the Outer Shelf near Wilmington Canyon

3rd report
No Appendix

4th report (up to date)
(1) Thickness and age of the surficial sand sheet, Baltimore Canyon Trough Area
(2) Results of sediment analyses intercalibration

(2) VIMS

physical oceanography, hydrographic data, water column/biological oceanography, marine microbiology, chemical oceanography, geochemistry, benthic community analysis, some meteorology (more complete - NOAA), and geochemistry

these data also presented through a series of interim reports - (6) up to date.

B. NORTH-ATLANTIC

(1) Energy Resources Company, Inc.
185 Alewife Brook Parkway
Cambridge, Mass. 02138

geochemistry, macrofauna chemistry, benthic infauna community analysis, histopathology, microbiology, descriptive chemistry

(2) Raytheon Company
P. O. Box 360
Portsmouth, R.I. 02871

physical oceanography

(3) EG & G
Environmental Consultants Division
151 Bear Hill Road
Waltham, Mass. 02154

physical oceanography

C. NORTH AND MID-ATLANTIC

(1) Center for Natural Areas
Box 98
South Gardiner, Maine 24359

general environmental information: Bay of Fundy to Cape Hatteras

AGENCIES - NEW YORK SHELF FUNDING

A. National Oceanographic and Atmospheric Administration

George Peter
ERL - NOAA
3600 Marine Street
Boulder, Colorado 80302

Geology programs:

MESA (Marine Eco Systems Analysis) includes
AOML (Atlantic Ocean Marine Laboratory)
OCSEAP (Outer Continental Shelf Environment Analysis Program)

Major Objectives of the MESA and OCSEAP Environmental Geology Program

To provide a baseline characterization of the geologic environment in order to evaluate potentially undesirable changes. Inventory and characterization of sediment (grain size engineering properties, pollutants in sediments, etc.) Additional value is to biologists, as habitant information.

To identify regional geologic hazards that might affect exploration development, and/or transportation of petroleum to shore.

Fault structures, slumps, stability relationships, etc.

To develop an understanding of geological transport processes as part of the overall effort to understand the pathways, sinks, and geochemical interactions of pollutants.

Involves interdisciplinary studies, physical oceanography, and chemical oceanography.

NY Bight since 1973
Puget Sount since 1975
OCSEAP since 1975

NOAA conducts research in all areas of marine science - has been a decline in geological emphasis.

NOAA has responsibility for research and monitoring on marine waste disposal and pollution effects under clean water acts - also has responsibilities under coastal programs.

Total F.Y. 1976 - $1.5 - 1.7 X 10^6 per year
New York bight funds through 1981
other areas to be examined where local problems prevail.

Level of Geological Effort by Geographic Area

Area	Funding $ in 1000's	
	FY76	FY77
New York Bight	370	345
Puget Sound	25	75
Alaska	1624	1650
East Coast & Gulf of Mexico*	200	200
	$2219	$2270

MESA New York Bight Geologic Studies
(anticipated through 1981)

Area	INSTITUTION	Type of Study	FY76	FY77
New York Bight	AOML	Substrate inventory	79	
New York Bight	(AOML-MIT)	Resuspension of cohesive sediments	12	
New York Bight	(AOML-U of Chicago)	Suspended sediment transport	59	
New York Bight	U of S Florida	Sources, transport, & reactions of suspended sediments	50	
New York Bight	Yale	Coastal sedimentation history	26	45
New York Bight	AOML	Sludge tracking	64	
New York Bight	AOML	Inner shelf sediment transport experiment (INSTEP)		300
		SUBTOTAL	$370	$345

AOML Geology
(exclusive of MESA)

East Coast of U.S.	NOAA/AOML	Continental margin sedimentation	100	100
Gulf of Mexico	NOAA/AOML	Geotechnical properties of sediments	100	100
		SUBTOTAL	$200	$200

Ship Support - Geology

Area	Program	Ship Days	$Per Year in 1000's
		FY76	FY77
New York Bight (49 days)	MESA	49	77
East Coast & Gulf of Mexico (95 days)	AOML	95	50
	SUBTOTAL	$144	$127

Future functions will be aimed at national trends and demands. Heavy emphasis on New York Bight and Alaska.

B. Energy Research and Development Administration

William Forster
ERDA - Division of Biomedical and
Environmental Programs (301) 353-5323
Washington, D.C. 20545

Based upon the Energy Reorganization Act of 1974 (PL 93-438)

ERDA's purpose is to consolidate energy related functions of the Federal Government in ERDA and NRC in the following areas:

- Develop energy sources
- Meet future energy requirements
- Strengthen the national economic base
- Environmental quality - restore/protect/enhance
- Assure public health/safety
- Coordinate other Federal agencies energy roles
- Establish programs to use research performed by other Federal agencies to minimize adverse environmental effects due to energy activities
- Develop cooperative programs to avoid duplications

ERDA's functions derive from the former Atomic Energy Commission established from the Atomic Energy Act - 1954

AEC was entrusted to regulate/control all aspects of nuclear activity

- Promulgate radiation standards
- Prevent pollution of the seas in amounts that would adversely affect man and his marine resources

Main consideration was "man," the most sensitive part of the system

Emphasis was on fundamental oceanographic studies

- Effects of oceanographic processes on the redistribution accumulation of radioactivity in the biotic/abiotic portions of the marine environment

ERDA has 2% of Federal ocean program monies. Involvement with shelf sediment dynamics wherever energy related activities influence sedimentary environment and vice versa.

Examples: a. Distruption of dynamic stability of shelf environment
b. Pollutants from energy related activities on suspended sediment.

Research and Development needs:
Substrate inventories (regional and intensive transects)
Bed load transport (physical forcing functions)
Physical, geological and bio-chemical interactions

Examples: a. Hydraulic climate for substrate mobility
b. Bottom boundry conditions for physical modeling
c. Maps of bottom sed. characteristics
d. Maps of sed. T/D vectors

Concern is with activity of Benthos in modifying the sed./water interface, which influences the flux of chemical constituents to the water column.

Objectives of ERDA's Biomedical and Environmental Research (BER) Marine Studies

In order to help ERDA attain its mission, as outlined in the Energy Reorganization Act of 1974 (PL 93-438), this marine program's goal is to Assess the Potential Impact of ERA on the Coastal Zone.

The following four objectives are considered essential in the assessment:

1. An understanding of the natural processes that govern the transport and fate of natural materials in this coastal zone.

2. An understanding of the causes of natural variability in this coastal zone.

3. An understanding, in the form of a predictive scheme, of the pathways and rates of passage of materials that cycle through coastal zone ecosystems.

4. Assemble a team of credible oceanographers, who are knowledgeable about objectives 1 through 3, that will be able to address specific situations of environmental impacts from various ERA in these regions.

In-house: Geo-Physical Contractors - $1,290,000

ERDA's Biomedical and Environmental Research (BER) On-Site Geo-Physical Contractors

National Laboratories	P.I.	FY'77 ($K)	FY'78 ($K)	Projects (8)
ORNL	N.Case/ N.Cutshall	$ 75	$ 100	Radio-active isotope sand tracers
ORNL	N.Cutshall	100	110	Nat. RA. in MAB
SRL	D.Hayes	120	130	TU Deposition in Savannah Est.
LLL	R.Spies	140	140	S.Barbara Substrate Alteration from Oil Seeps
LLL	V.Noshkin	350	375	TU Cycling in Enewetak Atoll Sediments
PNL	N.Wogman/ D.Perkins	55	60	In Situ Detection of T.E. on Surficial Sediments
ANL	D.Edgington	250	275	R.A. Deposition in Lk. Mich.
ANL	D. Edgington/ A.Preston (UK)	100	110	TU-Sus. Sed. Interactions in Irish Sea
		$1,240	$1,290	

ERDA's (BER) Off-Site Geo-Physical Contractors

Institution	P.I.	FY'77 ($K)	FY'78 ($K)	Projects (16)
LDOI	W.Broecker	$ 430	$ 430	Transport/Transfer Rates in MAB
LDOI	J.Simpson	75	75	TU Cycling in Hudson River Estuary
SUNY-SB	Okubo	120	120	L/E Diffusion in Long Island Sound
NOAA	D.Swift	150	150	INSTEP
JHU	G.Gross	60	60	TE Cycling in Chesapeake Bay
NCSU	L.Pietrafesa	130	140	P.O. Studies in SAB
SKIO	L.Atkinson/ J.Blanton	160	180	SAB Shelf Processes
UM	T.Lee	180	190	Gulf Stream Intrusions in SAB
TAMU	W.Sackett/ M. Scott	50	75	Dispersion of Miss. Riv. R.A. on Shelf
SIO	C.Winant	120	120	Mixing Processes in Near Shore
OSU	Pak/Zaneveld/ Small	120	125	Particulate Dynamics in CZ
OSU	T.Beasely	100	100	TU Cycling Mechanisms
OCE	D.Jennings	45	45	FE 55 Distributions in Col. River Sed.
U.Wash.	B.Hickey/D.Smith	215	225	P.O./Sed. Transport in NW-CZ
U.Wash	R.Carpenter	60	65	Geochemical Cycling of TE in NW-CZ
U.A.	D.Burrell	60	65	TE/Glacial Flour Interactions
		$2,065	$2,260	

Out-of-house: $2,260,000 - radioactive material availability on shelf.

Future Plans

1. Expand Basic Oceanography Program into Transport, fate and Effects of Specific Energy-Related Pollutants as Energy facilities go on-line for Each Region

   Base programs underway in some regions should provide knowledge on the working of the coastal zone system.

   Specific studies of ERP will be superimposed on this base.

2. Regional Coordinators Established in the field

   SAB - D. Menzel (SKIO)
   GC - T. Treadwell (TAMU)
   MAB - B. Manowitz (BNL)
   PNL - B. Templeton (PNL)

C. National Science Foundation
IDOE (Internation Decade of Ocean Exploration)

Bruce Malfait
IDOE
National Science Foundation
1800 G Street
Washington, D.C. 20550

Ocean Sciences Division of NSF - $55 million
IDOE (International Decade of Ocean Exploration) - head - Fennon Jannings

Areas -
- Environmental quality (Geo. Sec.)
- Environmental Forecasting - role of ocean in modifying climate
- Sea bed assessment - Bruce Malfait
- Living Resources Program - productivity and upwelling
- Submarine geology and geophysics
  - Shelf - $700,000
  - Sediment transport - $250,000
- Physical Oceanography Program - $3.3 million
  - $1 million - continental shelves
  - approx. $0.1 million - benthic boundary

The general organization of the N.S.F is as follows:

The National Science Foundation supports the study of shelf sediment dynamics from the division of oceanography which is located within the Directorate for Astronomical, Atmospheric, Earth and Ocean Sciences. By law the Foundation does no in-house research, a majority of its funds going to the support of research at academic institutions. Funding is justified on the basis of the need to understand the basic physical processes which transport sediment on the margin. Although such an understanding in a justifiable and in its own right, it also provides the basic knowledge needed in more applied research on the continental margins.

The Division of Oceanography is further subdivided into three offices (1) the office of Ship and Facilities, (2) the office for the International Decade of Ocean Exploration (IDOE) and (3) the office of ocean project support. The budget for the Division is approximately 55M dollars which is split roughly equally between the three offices. The office of ship and facilities supports and maintains the platforms from which NSF sponsored research is done. The office for the International Decade of Ocean Exploration supports U.S. participation in the IDOE, a ten year (1970-1980) program of international research to improve more utilization of the ocean and how the ocean influences the global environment. IDOE projects are typically long-term, multi-institutional, multi-disciplinary studies of:

(1) the role of the oceans in global climate, (2) the environment quality and transport of pollutants in the ocean (3) marine processes which may be responsible for the formation of mineral resources and (4) the processes which control ocean productivity. IDOE projects have been typically open ocean studies although some work on coastal currents and continental margin structure has been supported. No work on sediment transport is presently funded from the IDOE office.

The project support office is the traditional source of support for academic oceanography in the U.S. projects supported from this office are typically short term (1 to 2 years), involve a minimum number of investigators (typically at one institution) and under the entire range of problems and processes in oceanography. The office is divided into the four major disciplines of oceanography. Support for sediment transport comes both from the physical oceanography program and the submarine geology and geophysics program.

Physical Oceanography Program

	FY 77	FY 78
Sediment Transport	$ 100,000	$ 200,000
Total Shelf Support	$1,000,000	$1,000,000
Total Budget	$3,500,000	($3,350,000)

Submarine Geology and Geophysics

Sediment Transport	$ 250,000	$ 250,000
Shelf Sediment Studies	$ 700,000	$ 700,000
Total Budget	$6,800,000	$6,800,000

(above figures exclusive of ship-time)

D. U.S. Army Corps of Engineers

Barry Holliday
Office of Dredged Material Research
Waterways Experiment Station
Box 631
Vicksbury, Miss. 39180

Dredged Materials Research Program started in 1973 - $30 million for 5 years.
Sediment transport and water motion structures end March, 1978.

Corps of Engineers has lab
2 labs at WES do sediment work:
1. hydraulics lab
2. models - such as the physical model of NY harbor

190 Contracts - lists available of reports published on status of funded projects.

Most sediment transport work comes under two tasks:
1. Instrumentation - 0.15M
2. Field Studies (described on cover page)
   Other studies - 0.16M
   Base line and monitoring in field studies - costs shown are not necessarily 1 year

Field studies - Sediment transport studies - sedimentation - sites of open water dumping - $864,000.

Sample: Long Island Sound - base line study - monitor disposal mounds - monitor dispersion.

Model of dredged material movements - dispersion
Factors effecting long-term rate
Effects of storms
Cohesive sediment transport studies - for estuaries.
Develop predictive capability

Needs - sediment characterization
Relate sediment on bottom to processes on bottom.
Fates of dumped dredged material criteria development.

Questions raised in this program will need work after 78 - Needs -
1. sediment type versus process moving sed in an area
2. modelling - differsion studies
3. engineering properties
4. bio stability & reworking of deposits
5. instrument needs - reduction of enor range - etc.
6. mixing studies

Requests are being made to continue program - may be thru district office. Districts will document and monitor dumping programs to meet EPA. Contract from WES on demand.

E. Office of Sea Grants

David B. Duane, Assoc. Director
Project Support Programs
Office of Sea Grants
3300 Whitehaven Street, N.W.
Washington, D.C. 20235

Sea Grants of NOAA - $24 million
- Applied research - Education - Marine Advisory Services
- Cost-sharing - for $2 million Federal funds to $1 million non-Federal agency. Matching fund ratio vs. required.
- Funding mainly through university systems -
  - At present - 27 universities
    80 program topics
  - Three types of grants -
    Projects
    Coherants (multidiscipline)
    Institutionals

Local Manager - Swanson - at Stony Brook.

Topics - in shelf sediment dynamics
- Coastal sediment transport and beach stability
- Sediment flux and sediment characterization (many placers and sand-gravels)
- Ocean motion (including mathematical models) open ocean and estuarine circulation. Approximately 20 funded programs

Potentials for future programs
- New legislation permits support of ship time and authorization to do national projects (do not require matching funds)
- These will be larger in interest - regional and multidisciplinary - long-term, 3 to 5 years @ $200 - 500,000 per year.

Listing of Sea Grant Projects relevant to New York State's Outer Continental Shelf and Coastal Zone.

A Listing of Sea Grant Projects
As Of July 1, 1976

(by classification)

**each record in this sea grant report has the following format --

...classification title.... ...classification code
...project title..... SG funding.....
...institution.....grant number...principal investigator...

Effects of mixed petroleum hydrocarbons in marine fishes
$71,500
Woods Hole Oceanographic Institute
04-6-158-44106 J.J.Stegman, D.J.Sabo

Mineral Resources - Other

Evaluation of confining strata associated with principal coastal Georgia aquifer $44,300
University of Georgia
04-6-158-44017 J.R.Wolsey, J.L. Harding

An evaluation of coastal sand and gravel deposits as construction or specialty materials $34,000
University of Georgia
04-6-158-44017 R.G.Hicks, J.L.Harding

Manganese resources $36,678
University of Hawaii
04-6-15844026 J.E.Andrews, M.E.Morgenstein

Developing a management program for offshore sand and gravel mining, marine district, New York
State University of New York
04-6-158-44040 J.R.Schubel

An economic study of marine-oriented activities in the Southern New England marine region $21,991
University of Rhode Island
04-6-158-44085 T.A.Grigalunas

Ocean Law - Coastal

Development of county and local ordinances designed to protect the public interest in Florida's coastal beaches
State University System of Florida $32,800
04-6-158-44055 F.E.Maloney, D.C.Dambly

Site selection for port, waterway and pipeline development in coastal Louisiana: legal, institutional & policy aspects
Louisiana State University A&M College $24,982
04-6-158-44024 M.J.Hershman, K.Midboe

Regulation of offshore technology under extended jurisdiction
$15,000
Massachusetts Institute of Technology
04-6-158-44081 Prof.J.D.Nyhart

Legal aspects of coastal zone management $ 6,324
University of North Carolina
04-6-158-44054 T.J.Schoenbaum

Problems in coastal law $34,369
State University of New York
04-6-158-44040 R.Reis

Legal implications of changes in ocean law for U.S. coastal states $75,000
Texas A&M University
04-6-158-44066 J.Seymour

Ocean Law - International

A legal and institutional response to oil and deep sea mineral exploitation in the Pacific basin $38,385
University of Hawaii
04-6-158-44026 J.P.Craven, V.C.Bloede

Alternative methods for effectuating U.S. ocean policy goals after the Law of the Sea Conference $13,193
Louisiana State University A&M College
04-6-158-44024 H.G.Knight

Law of the Sea Institute $15,971
University of Rhode Island
04-6-158-44085 J.K.Gamble

Recreation - Sports Fisheries

Marine policy and ocean management $10,000
Woods Hole Oceanographic Institute
04-6-158-44106 R.A.Frosch

Seafloor Engineering

Exploration and evaluation of engineering properties of marine soils for foundation design of offshore structures
Massachusetts Institute of Technology $35,000
04-6-158-44081 M.M.Baligh, C.C.Ladd

Vehicles, Vessels, and Platforms

Seaward advancement of industrial societies $23,570
University of Hawaii
04-6-158-44026 J.P.Craven, J.A.Hanson

Materials and Structures

Pipeline survival under ocean wave attack $37,179
University of Hawaii
04-6-158-44026 R.A.Grace

Dynamic analysis of offshore structures
Massachusetts Institute of Technology
04-6-158-44081 J.K.Vandiver

Applications of nonlinear random sea simulations for design of offshore structures $ 7,804
Oregon State University
04-6-158-44094 R.T.Hudspeth

Applications of nonlinear random sea simulations for design of offshore structures $16,396
Oregon State University
04-6-158-44094 R.T.Hudspeth

Degradation of metal-fiber reinforced concrete in a marine environment $13,425
University of Rhode Island
04-6-158-44084 R.Heidersbach

Degradation of metal-fiber reinforced concrete in a marine environment $13,425
University of Rhode Island
04-6-158-44085 R.Heidersbach

Offshore pipelines $20,000
Texas A&M University
04-6-158-44012 V.K.Lou, J.Herbich

Corrosion of metals in marine structures $8,062
University of Wisconsin
04-6-158-44006 Y.A.Chang, P.C.Rosenthal

Coastal Engineering

Coastal engineering assessment of Delaware's beach erosion
University of Delaware $27,800
04-6-158-44025 R.A.Dalrymple, R.G.Dean

Beach erosion control at Indian River inlet $20,000
University of Delaware
04-6-158-44025 R.A.Dalrymple

Nearshore circulation, littoral drift, and the sand budget of Florida $72,400
State University System of Florida
04-6-158-44055 M.Smutz, J.Purpura, T.Chiu. A.

Stabilization of subtidal sediments by transplantation of submerged vegetation $12,187
State University of New York
04-6-158-44040 A.Collidge Churchill, A.Cok

Ocean engineering of shore protection structures$20,100
Virginia Institute of Marine Science
04-6-158-44047 R.J.Byrne, G.Anderson

Electromagnetic measurements of harbor flushing $ 7,672
University of Wisconsin
04-6-158-44006 T.Green

Mechanisms and scales of exchanges between urban-industrial harbor systems and coastal and offshore $29,790
University of Wisconsin
04-6-158-44006 C.H.Mortimer, Lai, Sikdar

Dredging

Disposal of dredged spoil in central Long Island Sound: A management plan $21,121
State University of New York
04-6-158-44040 J.R.Schubel, P.K.Weyl

Trace element recycling from diked dredged disposal
Texas A&M University $14,900
04-6-158-44012 R.J.Scrudato, C.Michey

Predicting erosion of dredge spoil islands by wave processes
Texas A&M University $28,000
04-6-158-44012 C.C.Mathewson, D.Basco

Ocean Engineering - Other

Power from salinity gradients $10,206
University of California
04-6-158-44021 J.D.Isaacs,K.Spiegler,G.Wick

Hydrodynamic and engineering evaluation of an ocean wave energy system $55,700
Massachusetts Institute of Technology
04-6-158-44081 C.C.Mei,A.D.Carmichael

Urban neighborhoods and recreational uses of the coastal zone
State University of New York $ 7,216
04-6-158-44040 Mitchell L. Moss

Institutional structure for coastal management $15,987
State University of New York
04-6-158-44040 J.M.Heikoff

The management of coastal waters $16,572
State University of New York
04-6-158-44040 P.D.Marr

The redevelopment of the urban coastal zone $13,855
State University of New York
04-6-158-44040 M.L.Moss, S.Johnston

Public participation assistance for Pennsylvania coastal zone management program $ 5,200
State University of New York
04-6-158-44040 P.Marr

Port development and operations as an aspect of coastal management programs $67,000
University of Washington
04-5-158-48A M.J.Hershman

Coastal Zone Mgmnt-Natural Sciences & Engineering

Statistical prediction of extreme tides, waves and their potential damage to the Delaware coast
University of Delaware
04-6-158-44025 M.A.Tayfun, C.Y.Yang

Visual quality of New York State's coastal zone $16,524
State University of New York
04-6-158-44040 D.B.Harper

Additional funds for the New York bight environmental atlas series $47,500
State University of New York
04-6-158-44040 J.McAlpine, J.Ginter

Coastal resources center $ 4,837
University of Rhode Island
04-6-158-44085 W.J.Gray

Coastal resources center $ 4,836
University of Rhode Island
04-6-158-44085 W.J.Gray

Remote sensing photogrammetric survey for long-term shoreline erosion inventory, R.I. $ 9,498
University of Rhode Island
04-6-158-44085 J.J.Fisher

Technical aspects of ocean dumping of industrial wastes
Texas A&M University $26,100
04-6-158-44012 R.W.Hann,Jr.

Pollution - Oil Spills

Mode of uptake and rate of release of petroleum hydrocarbons by shellfish in relation to their physiological conditions $22,010
Louisiana State University A&M College
04-6-158-44024 C.L.Ho

Hydrocarbon effects on estuarine carbon flux $23,149
Louisiana State University A&M College
04-6-158-44024 R.E.Turner

Effect of crude oil on nitrogen flux in salt marshes
Louisiana State University A&M College $ 5,847
04-6-158-44024 W.H.Patrick,Jr.

Hydrocarbon concentration in food chains $13,906
Louisiana State University A&M College
04-6-158-44024 T.Whelan III

Water and sediment chemistry $19,510
Louisiana State University A&M College
04-6-158-44024 C.L.Ho

Oil slick control in offshore environments $20,700
Massachusetts Institute of Technology
04-6-158-44081 Dr.J.H.Milgram

Distribution of hydrocarbons in Narragansett Bay sediments
University of Rhode Island $13,486
04-6-158-44085 J.G.Quinn

Monitoring hydrocarbons on and in sea water $11,386
University of Rhode Island
04-6-158-44085 C.W.Brown

Monitoring hydrocarbons on and in sea water $11,387
University of Rhode Island
04-6-158-44085 C.W.Brown

Pollution - Metals

Distribution diversity and toxicological response of resident species, as correlated with changes in the physico-chemical environment of Newark Bay $16,400
New Jersey Marine Sciences Consortium
04-6-158-44076 J.M.McCormick, S.J.K

Distribution of heavy metals and nutrients in the Newark Bay estuary with comparison to that of the Great Egg Harbor estuary
New Jersey Marine Sciences Consortium $ 9,600
04-6-158-44076 Su-Ling Cheng

Pollution - Other

Numerical simulation of the New York bight coastal waters
New Jersey Marine Sciences Consortium $24,800
04-6-158-44076 G.L.Mellor, W.G.Gray, George P

Distribution and diversity of plankton in relation to the physico-chemical environment of the Great Egg Harbor estuary and New Bay estuary $ 5,100
New Jersey Marine Sciences Consortium
04-6-158-44076 D.M.Huey

Effects of persistent pollutants on plankton $54,400
State University of New York/Cornell University
04-6-158-44065 C.F.Wrster,H.B.O'Connors

Sediment dispersal in New Bedford Harbor and Western Buzzards Bay $51,500
Woods Hole Oceanographic Institute
04-6-158-44106 C.P.Summerhayes, G.Lohmann, J

Environmental Models - Physical Processes

Longshore sediment transport $28,800
Massachusetts Institute of Technology
04-6-158-44081 O.S.Madsen

The sea environment of Massachusetts Bay and adjacent waters $60,500
Massachusetts Institute of Technology
04-6-158-44081 J.J.Connor,B.R.Pearce

Calibration and field verification of numerical models for circulation and dispersion in Biscayne Bay $41,200
University of Miami
04-6-158-44104 J.D.Wang

Analytical modeling of coastal zone areas $19,866
University of Rhode Island
04-6-158-44085 F.M.White, M.Spaulding

Development of an integrated three-dimensional hydrodynamic, salinity and temperature model $13,571
University of Rhode Island
04-6-158-44085 M.Spaulding

Analytical modeling of coastal zone areas $19,867
University of Rhode Island
04-6-158-44085 F.M.White,M.Spaulding

Stability of a small coastal inlet $ 5,600
Woods Hole Oceanographic Institute
04-6-158-44106 J.A.Moody

The geologic structure,evolution and destruction of coastal barriers and adjacent wetlands
University of Delaware
04-6-158-44025 J.C.Kraft

Applied Chemical Oceanography

Interdisciplinary study of pollution in Newark Bay estuary: Pollutant transport patterns in tidal marshes as delineated by the sulfate-chlorinity $ 7,300
New Jersey Marine Sciences Consortium
04-6-158-44076 A.L.Meyerson, G.W.Luther

Applied Physical Oceanography

Physical criteria for coastal planning $88,814
University of California
04-6-158-44021 D.L.Inman,C.D.Winant

Estuarine hydrography - data compilation $14,000
University of Georgia
04-6-158-44017 J.D.Howard

Study of the rate of renewal of Newark Bay water through tidal exchange and fresh water inflow $14,900
New Jersey Marine Sciences Consortium
04-6-158-44076 R.I.Hires, C.J.Henry

Three-dimensional study of modern estuarine deposits in the Narragansett Bay system, Rhode Island and southern Mass.
University of Rhode Island $ 7,630
04-6-158-44085 R.L.McMaster

Three-dimensional study of modern estuarine deposits in the Narragansett Bay system, Rhode Island and southern Mass.
University of Rhode Island $ 7,630
04-6-158--4085 R.L.McMaster

Synthesis and application of ocean wave refraction data
Virginia Institute of Marine Science $42,600
04-6-158-44047 V.Goldsmith,R.J.Byrne

Course Development

Coastal law traineeships $14,000
State University of New York
04-6-158-44040 J.H.Judd, R.Reis

Sea grant traineeships - New York Sea Grant Institute
State University of New York $166,500
04-6-158-44040 J.H.Judd

Public service legislative studies by students and their professors $ 3,200
04-6-158-44040 S.Chapman

Traineeships in engineering and marine technology
State University of New York $33,000
04-6-158-44040 J.H.Judd

Doctoral stipends for studies of marine industries
State University of New York $ 1,000
04-6-158-44040 J.H.Judd

Extension Agent Services

Sea grant advisory services program $47,500
University of Connecticut
04-6-158-44079 G.S.Geer,L.Stewart

Marine advisory services $112,600
University of Delaware
04-6-158-44025 C.Thoroughgood

Advisory services: Development, operation, and management
Massachusetts Institute of Technology $85,400
04-6-158-44081 E.R.Pariser

Marine industry advisory service (MIDAS) $90,000
Massachusetts Institute of Technology
04-6-158-44081 N.Doelling

MITSG/CES marine extension service $28,200
Massachusetts Institute of Technology
04-6-158-44081 E.R.Pariser, J.H.Noyes

Marine advisory service $129,855
University of Rhode Island
04-6-158-44085 W.J.Gray

Advisory services - extension agents and publications
Virginia Institute of Marine Science $129,600
04-6-158-44047 R.D.Anderson, F.Biggs

Applied engineering advisory program $ 9,170
Virginia Polytechnical Institute
04-6-158-44068 W.H.Mashburn, C.Shoemaker

Public Education Programs

Continuation of the services provided by the National Sea Grant Depository $70,400
University of Rhode Island/Sea Grand Depository
04-6-158-44018 P.K.Weedman

New England marine advisory service $43,300
University of New Hampshire
04-6-158-44070 J.K.Hutchinson

New Jersey marine advisory service $25,500
New Jersey Marine Sciences Consortium
04-6-158-44076 Dr.N.Psuty

Program Planning

Program planning $20,000
New Jersey Marine Sciences Consortium
04-6-158-44076 L.A.Walford

Program management - New York Sea Grant program $38,556
State University of New York
04-6-158-44040 D.F.Squires

Program Administration

Program management $26,300
New Jersey Marine Sciences Consortium
04-6-158-44076 L.A.Walford

Program management $40,625
University of Rhode Island
04-6-158-44085 N.Rorholm, W.Gray

Sea grant program administration, planning and coordination
Virginia Institute of Marine Science $64,500
04-6-158-44047 W.J.Hargis,Jr., Roger D.A

Program management and development $94,700
Woods Hole Oceanographic Institute
04-6-158-44106 D.F.Bumpus

Program Logistic Support

Communications and publications $31,965
State University of New York
04-6-158-44040 J.McAlpine Hopkins

New Applications Development

Application of conceptual study of international marine technology sharing: alternatives $30,000
Massachusetts Institute of Technology
04-5-158-51 J.T.Kildow

New Initiatives - New York Sea Grant Institute $36,117
State University of New York
04-6-158-44040 D.F.Squires

Program development $46,056
University of Rhode Island
04-6-158-44085 N.Rorholm

F. Bureau of Land Management

Robert Beauchamp
(for Frank Monastero)
Bureau of Land Management
Department of Interior
18th and C Streets, N.W.
Washington, D.C. 20240

Establish base line levels of environment
Division of Minerals and Environmental Assessment in OCS - $50 million with half to Alaska program through NOAA
Regional offices - New York, New Orleans, Los Angeles and Alaska
Types of contracts in Atlantic retion -

1. North Atlantic - Georges Bank
   A. Energy Resources Co. - $3 million - Bio/chem base line study - contracts with P.I.'s in universities bacteria - mesofauna, chemical/taxonomic, (no fish) NOAA, Georges Bank, Trace metals/hydrocarbons.
   B. U.S.G.S. $1 million - Geophysical studies - slumping, earthquake effects, recent faulting, sediment transport (Brad Butman), suspended sediment flux (John Milliman), stations-submersibles (Folger).
   C. Physical oceanography - EG&G ($600,000 thought work) and Raytheon ($3.6 million - instrumentation). Seven meter stations - three on each frontal zone
2. Mid-Atlantic Region - categories similar to those in North Atlantic.
   A. Bio/wave climate model - VIMS, $2.7 million.
   B. U.S.G.S. - Hydrocarbons and tract metals in sediments - $1.2 million
   C. Buoys - NOAA/MESA
   D. NOAA/EDS/CETDDA - P.I. is E. Rasmussen. Historical summation and interpretation of physical oceanography and meteorology for mid-Atlantic region - $150,000. Details of results of this contract given in section F-1, pages F2 thru F8.
   E. Fish (historical) - NOAA/NMES

Future Programs to be Considered:

1. Potential oil and gas resources of upper slope.
2. Pipe line corridor studies from OCS to Coastal Zone.

INTERAGENCY AGREEMENT

Between

The Bureau of Land Management

U.S. Department of the Interior

And

The National Oceanic and Atmospheric Administration

U.S. Department of Commerce

For

The Summarization and Interpretation of
Historical Physical Oceanographic and
Meteorological Information for the Mid-Atlantic Region

AA550-IA6-12

Background: The Bureau of Land Management (BLM) under its Outer Continental Shelf (OCS) environmental studies program requires a summarization and interpretation of historical physical oceanographic and meteorological information for the Mid-Atlantic region, in order to preliminarily describe baseline environmental conditions and effectively plan future efforts to fill data gaps.

The National Oceanic and Atmospheric Administration (NOAA-EDS) acts as a repository for marine and climatological data collected from national and international programs.

The Center for Experimental Design and Data Analysis (NOAA-EDS/CEDDA) possesses unique interdisciplinary capabilities in oceanography and meteorology to effectuate such studies.

Purpose: The purpose of this Interagency Agreement is to provide the terms and conditions under which the National Oceanographic and Atmospheric Administration, (Environmental Data Service) agrees to the summarization and interpretation of historical meteorological and physical oceanographic data necessary to describe and/or characterize the Mid-Atlantic region between the coast and the 2,000 meter isopath, and terminated on the northeast at 41°N - 71°W and on the south at 38°N, for the purpose of developing offshore environmental hazard and trajectory predictions.

The Bureau of Land Management, United States Department of the Interior agrees to fund $82,000.00 through June 30, 1976. Additional funding for the fifth quarter of FY 1976 - $38,000.00 and FY 1977 - $30,000.00 will be made upon the availability of funds.

Work Statement:

A. Methodology:

1. Divide the Mid-Atlantic area into sub-areas to be determined after examination of the availability and quality of historic data, and the spatial variation of the parameters to be described. Sub-areas will in no case be larger than one-degree squares.

2. Obtain data from available Federal sources such as NODC, NCC, etc., and from other selected institutional files, including such appropriate parameters as wind velocity and direction; low extremes of visibility; wave height; water column density profiles; empiric draft values (surface, subsurface, and bottom currents); surface temperature, salinity, oxygen, and nutrients.

3. When appropriate, obtain data from additional fixed recording sites, both on shore and at sea, to generate time series extrapolations within the sub-areas of interest.

4. Present the data to BLM in a format, such as monthly or seasonal tabluation, histogram, chart, graph, contour plot, etc., most useable for oil spill trajectory modelling and hazard evaluation.

B. Interpretive Conclusions and Recommendations:

1. Accompany graphic and table presentations with interpretive discussion and conclusions pertaining to the short and long term variability of meteorologic and oceanographic parameters. Among the material discussed will be:

a. Circulation patterns (seasonal or monthly depending on data accuracy), including the spatial magnitude and variability of surface and subsurface currents and of surface winds.

b. Time/space series analysis of subsurface current meter data to determine the temporal magnitude, duration, and scales of the variability.

c. Extreme wind and wave recurrence intervals, including the forcing effects of the passage of hurricanes and gales on the regional circulation.

d. Stability analysis of the water column, including the depth of seasonal wave agitation penetration; the effect of the pycnoline in protecting the water column from deep penetration; and the effect of internal wave phenomena on data interpretation.

e. Identify and characterize water masses by T-S or T-O_2 correlations and effects on the seasonal circulation pattern.

f. Meteorologic factors relating to superstructure icing potential.

2. Recommend design of future meteorologic and future physical oceanographic field studies for the purpose of improving:

a. Areas of sparse or non-existent data.

b. Contaminant dispression and dispersal.

c. Solutions to special problems.

C. Reports

1. Quarterly Progress Reports. The Contractor shall require the Principal Investigator (PI) employed hereunder to prepare and submit three (3) copies of quarterly reports describing all work accomplished during the preceding quarter by that PI. One (1) copy shall be sent to the Chief Scientist, Branch of Mineral Assessment; one (1) copy to the COAR and one (1) copy to the New York OCS field office. The quarterly reports will start the first quarter after this Interagency Agreement is signed by the last signatory. The reports shall include, but shall not be limited to, a quantitative summary, analyses started, analyses completed, observations made, and significance of findings. Uniform reporting methods, developed by the Contractor, shall be used by the PI for this report. One (1) copy of the cover letter for each report shall be sent to the Contracting Officer upon submission of each report.

2. Format of the Draft Final Report

The format for the report shall be developed and submitted to the BLM for review and approval within ninety (90) days of the contract award date and may be changed from time to time by the mutual agreement of the parties involved.

3. Draft Final Report

The Contractor shall prepare and submit five (5) copies of a draft final report setting forth all methodology, techniques, analyses, interpretations, characterizations and recommendations employed or generated in the fulfillment of the contract requirements within fifteen (15) months of the contract award date. The report shall contain the products of Item 2, Interpretive Conclusions and Recommendations. One (1) copy shall be sent to the Chief Scientist; two (2) copies to the COAR and two (2) copies sent to the New York OCS field office.

The Bureau of Land Management shall review the Draft Report, notify the Contractor of the required corrections, changes, or additions within (30) days after receipt of these draft reports.

4. Final Report

Fifty (50) copies will be printed and delivered to BLM within thirty (30) days after receipt of the BLM comments.

Performance and Deliveries: It is agreed that the period of performance for this Interagency Agreement is fifteen (15) months from the date of the last signatory. The reports and delivery dates are contained in section C1. reports.

Special Provisions.

1. NOAA shall be responsible for all subcontractors or delegations of work elements in the fulfillment of this Interagency Agreement.

2. Dr. Thomas S. Austin, Director, Environmental Data Service is designated herein as the responsible individual for NOAA/EDS activities under this Interagency Agreement, and will act as the coordinator between NOAA/EDS and the Bureau of Land Management under this Interagency Agreement. Dr. Gene Rasmussen is designated herein as the Principal Investigator (PI) for this Interagency Agreement. The Enviornmental Data Service of NOAA is designated herein as the lead organization for this Interagency Agreement.

3. All proposed changes shall be agreed upon by NOAA and BLM prior to implementation and shall be further approved in writing by the BLM Designated Officer.

4. It is also agreed that:

a. The BLM Designated Officer may, at any time, after consultation with NOAA by written order designated or indicated to be a change order, make any change in the work within the general scope of the Interagency Agreement, including but not limited to changes

(1) in the specifications;
(2) in the method or manner of performance of the work;
(3) in the place of inspection, delivery, or acceptance.

b. Any other written order from the Designated Officer, which causes any such change, shall be treated as a change order under this clause, provided that NOAA gives the Contracting Officer notice stating the date, circumstances, and source of the order and that NOAA regards the order as a change order.

c. Except as herein provided, no order, statement, or conduct of the Designated Officer shall be treated as a change under this clause or entitle NOAA to an equitable adjustment hereunder.

d. If any change under this clause causes an increase or decrease in NOAA's cost of, or the time required for, the performance of any part of the work under this Interagency Agreement whether or not changed by any order, an equitable adjustment shall be made and the Interagency Agreement modified in writing accordingly.

e. NOAA will respond with an assessment of the impacts of directed changes on the adequacy of the technical program within 14 days. If NOAA intends to assert a claim for an equitable adjustment under this clause, they must within 30 days after receipt of written change order under a. above, or the furnishing of a written notice under b. above, submit to the Designated Officer a written statement setting forth the general nature and monetary extent of such a claim, unless this period is extended by the BLM. The statement of claim hereunder may be included in the notice under b. above.

f. The BLM shall, prior to the issuance of change orders hereunder, notify the appropriate NOAA program office of the scope and extent of all change orders and shall discuss the impact of such changes on the overall effort. In the event the BLM issues a change under the provisions of this clause which cannot be accomplished by NOAA because of manpower ceilings, funding, or other causes beyond NOAA's control, NOAA shall immediately notify the Designated Officer that the change cannot be accepted and the reasons therefor.

5. Data

a. Data and information obtained under the terms of this agreement, and copies thereof, shall be available through free access from appropriate data centers to any interested party. Freedom of information will be adhered to under the broadest interpretation of the principles. BLM will be provided with copies of all data requested as soon as practicable, and will have access to original data upon demand.

b. Publication.

(1) All analyses or interpretation of the data pertaining to this effort made by NOAA may be published freely upon prior written approval from the BLM.

(2) BLM reserves the right to conduct an independent analysis of the effort performed by NOAA, and to publish this analysis.

(3) NOAA may use data resulting from this effort to meet internal mission requirements as necessary.

6. News Releases. Each agency shall apprise the other, prior to the issuance of releases to the news media, of findings or conclusions accruing as a result of effort conducted hereunder.

Inspection. The BLM, through any authorized representatives, has the right at all reasonable times, to inspect, or otherwise evaluate the work performed or being performed hereunder and the premises in which it is being performed. If any inspection, or evaluation is made by the BLM on the premises of the NOAA, subcontractor, or other Federal participants, the NOAA shall provide and shall require his subcontractors to provide all reasonable facilities and assistance for the safety and convenience of the BLM representatives in the performance of their duties. All inspections and evaluations shall be performed in such a manner as will not unduly delay the work.

Administrative.

1. The BLM shall transfer to the NOAA funds in the amount specified herein upon receipt of a properly submitted Form 1081. Billing should be directed to the Bureau of Land Management, Division of Finance (520), 18th & C Streets, N.W., Washington, D.C. 20240.

2. Nothing contained in this agreement shall abrogate the statutory responsibility or authority of either agency signatory to this Interagency Agreement.

3. The BLM officer designated the authority and responsibility for signing this Interagency Agreement and Changes hereto is Mr. Fred M. Galinsky, Contracting Officer, Bureau of Land Management (551), Washington, D.C. 20240, telephone (FTS) (202) 343-5766. Acceptance of all supplies/services delivered or performed hereunder will be made by the Contracting Officer.

4. Dr. Robert Beauchamp, BLM, Branch of Marine Environmental Assessment, Code 732, Washington, D.C., is designated as the Contracting Officer's Authorized Representative (COAR) for purposes of inspecting the effort accomplished under this Interagency Agreement to assure compliance with the work statement, delivery requirements and specifications. The COAR is authorized to clarify, review, and approve work which is clearly within the scope of this Interagency Agreement in any way.

U.S. Department of Commerce National Oceanographic and Atmospheric Adminstration Enviromental Data Service	U.S. Department of the Interior Bureau of Land Management
Mr. J. W. Townsend, Jr. Associate Administrator	George L. Turcott Associate Director
Date	Date

G. U.S.G.S.

Robert Roland
U.S. Geological Survey
12201 Sunrise Valley Drive
Mail Stop 915
Reston, Virginia 22092

Topographic Division
Nat. Ocean Survey maps integrating coastal and offshore

Conservation Division
O.C.S. tract selection and leasing
Statutory Responsibility

Geologic Division

Earthquakes research and predicted seismicity in OCS lease areas

Energy related off shore oil and gas
Marine Geology - Environmental and Resource Problems
35 professionals in Atlantic and Gulf regions.

Research cooperation outside U.S.G.S.
Grants and unsolicited Research Proposals
RFP contracts
Personal contracts - short term: example; invitation
Topical studies
Dynamics
Coastal
Storm effects

Future Projects
Engineering properties of marine sediments
Continental shelf coring program
Coastal Zone program
Deep-ocean mining - 1978 is $2.3 million
Upper continental slope - petroleum potential
Seeking funds from ERDA - probable high amounts of funding after 1980.

H. Office of Naval Research, Geography Programs

Dennis M. Conlon
Geography Program
Office of Naval Research (code 462)
Arlington, Cirginia 22217

Objective

The objective of the research effort of Geography Programs is to develop the capability to make real-time assessments and short-term predictions of nearshore environmental conditions for any given coastal area of the world.

This program definition limits the scope of our interests in many important respects. "Short-term" is taken by us to mean a few hours to a few days; studies of long-term (say, years to decades) erosional behavior of coastal sites do not therefore fall within our task area.

The use of the term "nearshore" indicates that philosophically our research is centered on or near the surf zone. In practical terms, this means that the research that we fund should ultimately have a significant bearing on the behavior of the surf or near-surf zone region. We specify wide nature of the tasks of the U.S. Navy. This specification results in two general program principles. First, we avoid "site-specific" studies; i.e., those studies in which state-of-the-art research is applied in an effort to understand a particular (albeit largely unknown) coastal setting. Second, we avoid any studies involving the effects of man-made coastal structures, since such studies are not optimal in providing basic new understandings of coastal processes.

Apart from these provisos, proposals are judged on two basic points: (1) consistency with the program, and (2) scientific merit. Both points are equal in importance, but program consistency is a bit more equal.

Program Structure

In order to accomplish the broad research objective stated above, we fund research in three major areas: Coastal Dynamics, Coastal Remote Sensing, and Systematic Geography.

Greatest emphasis of our program is placed on studies of coastal dynamic processes in which attempts are made to determine what environmental parameters and combinations of parameters must be measured to describe and define a particular coastal phenomenon and relate it to a space-time framework.

The Systematic Geography project recognizes the need for new data structures to assure that only significant data are quickly and accurately entered into an appropriate inshore data base system. Also, we must assure that the full information content of all recorded data formats is properly synthesized and stored for rapid recall, and display in forms most useful to various levels of command.

The third task, Coastal Remote Sensing, is concerned with acquiring rapid and reliable environmental measurements by remote sensing techniques. Adequate environmental data are needed regularly and on short notice for updating data bases and these data must be available for any geographic area of the world within which Naval and Marine Corps operations might take place.

For the purposes of this workshop, I will hereafter limit my remarks to a description of the Coastal Dynamics sub-program.

Coastal Dynamics Research

The objective of the coastal dynamics program is to achieve a basic physical understanding of the coastal shallow water environment. In particular, the goal is to understand the processes and predict the changes in parameters that can adversely affect operations in coastal waters.

The coastal dynamics research effort is broken down into three principal areas of investigation:

A. Coastal Form and Interaction
B. Shelf and Nearshore Transformation
C. Coastal Class Studies

Each principal area has several important subareas of research.

A. Coastal Forms and Interactions

Research Objective: To achieve the capability to rapidly assess and accurately model physical phenomena occurring near the shore boundary.

Research in this area is concentrated primarily on beach and surf zone processes. Major subareas of investigation include (with examples):

a. Breaking Waves

Determination of depth at which waves will break, and mode of breaking (spilling, plunging, etc.). Prediction of breaker characteristics along a given stretch of coast. Modeling of mechanisms of energy dissipation at point of breaking.

b. Longshore Currents

Determination of three-dimensional velocity fields for various breaker conditions, including both the steady-state and time-dependent cases.

c. Sediment Transport

Field investigations directed at quantifying the onshore-offshore mode of sediment transport in relation to the longshore mode.

d. Beach and Bottom Dynamics

Application of the concept of equilibrium beach profiles to the problem of gross beach change prediction. Studies of wave energy dissipation over bottoms of varying geometry.

e. Nearshore Modeling

Develcpment of a state-of-the-art nearshore computer model.

B. Shelf and Nearshore Transformations

Research Objective: To achieve an understanding of the processes and variations of offshore energy conditions; application of research results to the providing of critical input conditions for nearshore environmental models.

In the area of Coastal Form and Interaction, emphasis was placed on an understanding of coastal phenomena characterized by length scales of hundreds of meters in the longshore and offshore directions. Research in Shelf and Nearshore Interaction centers on environmental conditions offshore and how such conditions provide the forcing functions for nearshore models. Major subareas of investigation include:

a. Wave Transformation

Given the deep water wave conditions, determining how wave parameters vary under the combined effects of shoaling, refraction, non-linear interactions, energy dissipation, etc.

b. Wave Current Interaction

Measurement and modeling of the effects of currents on wave spectral characteristics.

c. Tides, Tidal Currents

Modeling of shelf and nearshore currents and water level variations, given the tide at the continental shelf break and the wind field acting over shelf waters.

d. Mesoscale Processes

Determination of atmospheric variations in the presence of the coastal boundary.

Research Objective and Types of Studies Funded:
To achieve the capability of making rapid assessments of arbitrary coastal environments in terms of dominant driving forces, major processes, and predominant forms.

This research is essential to the application of the results of the research efforts heretofore mentioned to real world cases. Specifically, it must be known, for any coast, what methods must be used for environmental assessments, and the conditions under which various predictive models can be applied with success.

Within the past eighteen months, field efforts have been undertaken in the following types of coastal environments:

a. Muddy Coast (Surinam)

b. Shallow Bank Shelf (Nicaragua)

c. High Energy Barred Coast (Brazil)

d. Tide Dominated Coast (England)

e. Shallow Semi-Enclosed Sea (Persian Gulf)

The coastal research effort of Geography Programs emphasizes two main points: short-term predictions and world wide flexibility. The interests of Geography Programs are quite broad and many scientific disciplines are encompassed. The foregoing remarks must therefore be regarded only as an introduction to our effort. Finally, we do not solicit research; rather, we welcome proposals by which we can improve our research program.

OTHER NATIONAL FUNDING AGENCIES
RECEIVING OR DELEGATING FUNDS

Environmental Protection Agency

U.S. Fish and Wildlife Service
National Marine Fisheries Service

Office of Naval Research
Especially Geography Branch

U.S. Army District, New York Corps of Engineers

U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Virginia

List of Existing and Proposed Agency Reports of General Scope

Below are listed existing reports or proposed documents which are not a part of the commonly cited or published information. Those now available from national agencies (BLM, NOAA-MESA) are listed by author in the bibliographic index.

Existing documents

Trigom 1974. A socio-economic and environmental inventory of the North Atlantic Region (Bay of Fundy to Sandy Hook, N.J.)

URI 1973. A coastal and environmental inventory, Cape Hatteras to Nantucket Shoals.

MESA New York Bight Atlas Monograph Series. Plans for 32 volumes. Ten are now ready. The rest are in manuscript.

Proposed documents

MESA New York Bight Atlas. This is underway but is several years from completion. It is designed to integrate the knowledge from the various disciplines of the monograph series to show how the various aspects of the marine environment interact and respond.

NERBC/RALI project. Siting of onshore facilities. This is expected to be completed within a year. (June 77)

BLM contract for updating the summary environmental data from Bay of Fundy to Cape Hatteras. Data from the various disciplines to be integrated. Designed to complement the existing Trigom summary. To be completed 8 months after contract award.

NOAA-BLM. Summary and interpretation of historical, physical, oceanographic and meterologic information for the Mid-Atlantic region. Coast to 200m. depth. Will interpret the existing available data and recommend future meterologic and physical oceanograhic studies, to be completed in 1977.

MESA. New York Bight Project. Working on the degradation of pollutants and the effects the products of the degradation have on the system.

Hope to provide answers to physical and geological transformations of pollutants and to begin to evaluate the chemical impact especially in terms of effects on organisms and man.

BIBLIOGRAPHY

ASSESSMENT OF GEOLOGIC INFORMATION OF NEW YORK STATE'S COASTAL ZONE AND CONTINENTAL SHELF AND ITS SIGNIFICANCE TO PETROLEUM DEVELOPMENT

by

J. Douglas Glaeser and Philip C. Smith

Abou-Seida, M.M., 1964, Sediment transport by waves and currents: Univ. Calif., Hydr. Engr. Lab., Rept. HEL 2-7, Berkeley.

Ahern, W.R., Jr., 1973, Oil and the outer continental shelf-The Georges Bank Case: Cambridge, Mass., Ballinger Pub. Co., 129 pp.

Alexander, A.E., 1934, A petrographic and petrologic study of some continental shelf sediments: Jour. Sed. Petrol. v. 4, no. 1, p. 12-22.

Ali, J.A., 1973, A keyword-indexed bibliography of the marine environment in the New York bight and adjacent estuaries: Marine Sciences Res. Center, SUNY at Stony Brook, Stony Brook, N.Y. 721 pp.

Alpine Geophysical Associates, Inc., 1969. Final report on data reduction for CERC New Jersey offshore sand inventory program: Alpine Geophysical Associates, Inc., Norwood, N.J.

American Geophysical Union and U.S. Geological Survey, 1964, Bouguer gravity anomaly map of the U.S. (exclusive of Alaska and Hawaii): U.S. Geol. Survey, scale 1:2,5000,000, 2 sheets.

American Petroleum Institute, 1971, Recommended practice for planning, designing and constructing fixed offshore platforms: API RP 2A, Jan. 1971.

Amoco Canada Petroleum Company Ltd. and Imperial Oil Ltd., Offshore Exploration Staffs, 1974, Regional geology of Grand Banks: American Assoc. of Petrol. Geol., Vol. 58, pp. 1109-1123.

Anderson, J.L., 1948, Cretaceous and Tertiary subsurface geology (md.): Md. Dept. of Geology, Mines and Water Resources Bull. 2, p. 1-113, 126-151, 385-441 (description of wells).

Angas, W.M., 1960, Shark River Inlet sand bypassing project: Jour. Waterways and Harbors, D.W., Proc. Am. Soc. Civil Engin. No. W.W.3, p. 29-47 (Discussion W.W.2, p. 153-157, 1961)

Anikouchine, W.A., and Sternberg, R.W., 1973. The world ocean. Prentice Hall, Englewood Cliffs, N.J. 338 p.

Anonymous, 1938, Report on beach erosion at Manasquan Inlet, New Jersey and adjacent beaches: Shore and Beach, vol. 6, no. 1, p. 13-18.

Armstrong, W.E., Creath, W.B., Kidson, E.J., Sanderson, G.A., Upshaw, C.F., Craig, J., Gradstein, F.M., Van Hint, J., Jenkins, W.A.N., Pocock, S.A.J., Staplin, F.L. and Salek, J.A., 1973, Biostratigraphic framework of the Grand Banks: Am. Assoc. Pet. Geol. East Coast Offshore Symp., Tech. Prog. 5.

Arpin, O.E., 1970, Tidal inlet problems along the New England coast: Conf. Coastal Engr., 12th, Proc. vol. 2, no. 74, p. 1171-1185.

Assaf, G., R. Gerard, and A.L. Gordon, 1971, Some mechanisms of oceanic mixing revealed in aerial photographs, J. Geophys. Res., 76(27): 6550-6572.

Austin, G.H., 1973, Regional geology of eastern Canada offshore: American Assoc. Pet. Geol. Bull. v. 57, p. 1250-1275.

Bache, A.D., 1856, Observations to determine the cause of the increase of Sandy Hook, for the commissioner on harbor encroachment of New York: U.S. Coastal and Geodetic Survey Rept. 1856, app. 38, Washington, p. 263-264.

Baehr, J.C., 1953, Penetration of salt water and its effect on tidal areas of the United States of America: Proc. 18th, Intern. Nav. Congr., Sec II, Communications, p. 81-107.

Ballard, J.A., 1966, Structure of the Lower Continental Rise Hills of the western North Atlantic. Geophysics, 31, 506-523.

Ballard, R.D., 1974, The nature of Triassic continental rift structures in the Gulf of Maine: Woods Hole Oceanogr. Inst. Rep. no. 74-71, 96 p.

Ballard, R.D., and Sorensen, F.H., 1968, Preglacial structure of Georges Bank and Northeast Channel, Gulf of Maine: American Assoc. Petrol. Gal. Bull. vol. 52, no. 3, p. 494-500.

Ballard, R.D., and E. Uchupi, 1972, Carboniferous and Triassic rifting: a preliminary outline of the tectonic history of the Gulf of Maine: Geol. Soc. America Bull., v. 83, p. 2285-2301

Ballard, R.D., and Uchupi, E., 1974, Geology the Gulf of Maine: American Assoc. of Petrol. Geol. v. 58, no. 6, pt. 2, p. 1156-1158.

Ballard, R.D. and Uchupi, E., 1975, Triassic rift structure in Gulf of Maine: American Assoc. of Petrol. Geology Bull., vol. 59, no. 7, p. 1041-1072.

Barnes, B., et al, 1972, Geologicprediction: Developing tools and techniques for the geophysical identification and classification of sea floor sediments: Tech. Rept. ERL 224-MMTC-2, NOAA, Rockville, Md.

Bartlett, G.A., and L. Smith, 1971, Mesozoic and Cenozoic history of the Grand Banks of Newfoundland: Canadian Jour. Earth Sci., v. 8, p. 65-84.

Barwis, John H., 1976. Annotated bibliography on the geologic, hydraulic and engineering aspects of tital inlets: Dept. of Army, Corps of Engineers, GITI Report 4, 333 pp.

Bascom, W., 1964. Waves and beaches. Anchor Books, Doubleday and Co., Garden City, N.Y. 267 p.

Bassler, R.S., 1936, Geology and paleontology of the Georges Bank canyons; part 3. Cretaceous bryozoan from Georges Bank: Geol. Soc. America Bull., v.47, no.3, p. 411-412.

Bea, R.G., 1971, How sea floor slides affect offshore: Oil and Gas Jour., v. 69, no. 48, p. 88-92.

Beardsley, R.C. and Butman, B., 1974, Circulation on the New England Continental Shelf: Response to strong winter storms. Geophys. Res. Lett. v.1, p. 181-184.

Beck, R.H., and Lehner, P., 1974, Oceans, New frontiers in exploration: AAPG, v. 58, no. 3, p. 376-395.

Behrendt, J. C., 1975, High sensitivity aeromagnetic survey of the Atlantic margin of the United States (Abstr.): EOS (Am. Geophysical Union Trans.), vol. 56: 356.

Behrendt, J.C., Schlee, J., and Foote, R.Q.,1974, Seismic evidence for a thick section of sedimentary rock on the Atlantic outer continental shelf and slope of the United States (Abstr.): E.O.S. (Am. Geophysical Union Trans.), v. 55, p. 278.

Belderson, R.H. and A.H. Stride, 1969, The shape of submarine canyon heads revealed by Asdic. Deep-Sea Res., 16, 103-104.

Benson, R.N., 1976, Review of the subsurface geology and resource potential of southern Delaware: Delaware Geol. Survey open file report.

Bentley, C.R., and J.L. Worzel, 1956, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Pt. X, Continental slope and continental rise south of Grand Banks: Geol. Soc. America Bull., v. 67, p. 1-18.

Berger, J., Blanchard, J.E., Keen, M.J., McAllister, R.E., and Tsong, C.F., 1965, Geophysical observations on sediments and basement structure underlying Sable Island, Nova Scotia: AAPG, v. 49, no. 7, p. 959-965.

Biederman, E.W., 1962, Distinction of shoreline environments on New Jersey: Jour. Sed. Petrol., v. 32, no. 2, p. 181-200.

Birch, W.B., and Dietz, F.T., 1962, Seismic refraction investigations in selected areas of Narragansett Bay, Rhose Island: Jour. Geophys. Research, v. 67, no. 7, p. 2813-2821.

Blackman, B., 1938, Report on jetties: Report to Shore Protection Board, OCE, U.S. Army Corps on Engineers, Coastal Engin. Research Center, Ft. Belvoir, Va., 125 pp.

Blaik, M.J. Northrop, and C.S. Clay, 1959, Some seismic profiles onshore and offshore Long Island, New York: Jour. Geophys. Research, v. 64, no. 2, p. 231-239.

Blanchard, J.E., Keen, M.J., McAllister, R.E., and Tsong, C.F., 1965, Geophysical observations on the sediments and basement structure underlying Sable Island, Nova Scotia: AAPG, v. 49, p. 959-965

Bloom, A. L., 1967, Coastal geomorphology of Connecticut: Cornell Univ. Dept. of Geol. Sci. Final Report to Office Navel Res. (contract nonr.-401[45], Task no. NR388-065), Ithaca, N.Y.

Bobb, W.H. and Boland, R.A., 1969, Channel improvement, Fire Island Inlet, New York: U.S. Army Engineer, Waterways Experiment Station, Corps of Engineers, Tech. Rept. No. H-69-16, Vicksburg, 33 pp., Billistr., 206 pp.

Boothroyd, J.C., and Hubbard, D.K., 1972, Bedform development and distribution pattern, Parker and Essex Estuaries, Mass.: Coastal Res. Center, Dept. of Geol., Univ. Mass., Amherst, 79 pp. (also published as U.S. Army Coastal Engr. Res. Center, miscell paper, 1-74, Ft. Belvou, Va., 1974, 39pp.)

Bott, M.H.P., 1971, Evolution of young continental margins and formation of shelf basins: Tectonophysics, v. 11, p.319-327.

Brown, M.V., J. Northrop, R. Frassetto, and L.H. Grabner, 1961, Seismic refraction profiles on the continental shelf south of Bellport, Long Island, New York: Geol. Soc. America Bull., v. 72, No. 11, p. 1693-1705.

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

Bruun, P., 1954, Migrating sand waves and sand humps, with special reference to investigations carried on in the Danish North Sea coast, Conf. Coastal Eng., 5th Proc., 460-468.

Bruun, P., 1962, Sea level rise as a cause of shore erosion: Jour. Waterways Harbors Div. Am. Soc. Civil Engrs., v. 88, p. 117-130.

Buelor, R.W., 1968, Ocean disposal of waste materials, in Transections national symposium on ocean sciences and engineering of the Atlantic shelf: Philadelphia, Pa., Delaware Valley Section, Marine Technology Society.

Bumpus, D.F., 1965, Residual drift along the bottom on the continental shelf in the Middle Atlantic Bight area: Limnology and Oceanography, v. 10, supp. no. 2, p. R50-R53.

Bumpus, D.F., 1969, Surface drift on the Atlantic continental shelf of the United States, 1960-1967: Woods Hole Inst. Ref. 69-18, 100 p.

Bumpus, D. F., 1973, A description of circulation on the Continental Shelf of the east coast of the United States: Prof. Oceanography, vol. 6, pp. 116-157.

Bumpus, D.F. and Lauzier, L.M., 1964, Surface circulation on the continental shelf of eastern North America between Newfoundland and Florida: Am. Geog. Soc. Serial Atlas Marine Environment, Folio 7.

Burbank, W.S., 1920, The petrology of the sediment of the Gulf of Maine and Bay of Fundy: U.S. Geol. Survey open-file report, 74 p.

Burk, C.A., 1968, Buried ridges within continental margins: Trans. N.Y. Acad. Sci., ser.II, v. 30, p. 397-405.

Burk, C.A., and Drake, C.L., 1974, Geology of continental margins. Springer-Verlaf, New York, 1009 pp.

Burke, Kevin, 1975, Atlantic salt deposits formed by evaporation of water spilt from the Pacific, Tethys and Southern Oceans (abs.): EOS, no. T121, p. 457.

Buzas, M.A., 1965, The distribution and abundance of Foraminifera in Long Island Sound: Smithsonian Misc. Colln, v. 149, no. 1, p. 1-89.

Byrne, R.J., P. Bullock, and D.G. Tyler (in press a), Response characteristics of a tidal inlet: A case study. In M.O. Hayes, ed., Second International Estuarine Conference Proc. Myrtle Beach, S.C., Oct. 15-18, 1973, New York, Academic Press.

Caldwell, J.M., 1950, Sedimentation in harbors: Trask, P.D., ed., Applied sedimentation, John Wiley and Sons, New York, P. 291-299.

Caldwell, J.M., 1966, Coastal processes and beach erosion: Jour. of Soc. Civil Engineers, v. 53, no. 2, p. 142-157.

Caldwell, D.M., 1972a, Sedimentological study of an active part of a modern tidal delta, Moriches Inlet, Long Island, New York: Unpub. Masters Thesis, Columbia Univ, New York, 70 pp.

Carlson, R.O., and M.V. Brown, 1955, Seismic-refraction profiles in the submerged Atlantic Coastal Plain near Ambrose Lightship (N.Y.): Geol. Soc. America Bull., v. 66, no. 8, p. 969-976.

Carmody, D.J., Pearce, J.B., and Yasso, W.E., 1973, Trace metals in sediments of New York Bight: Marine Pollut. Bull., v. 4, p. 132-135.

Carter, H. H., 1969. Physical Processes in coastal waters: in, Background on coastal wastes management, vol. V, pp. VI-16, National Academy of Engineering, Washington, D.C.

Chamberlain, Barbara B., 1964, These fragile outposts -- a geological look at Cape Cod, Martha's Vineyard, and Nantucket: Garden City, NY, Natural History Press, 327 p.

Charlesworth, L. J., Jr., 1968, Bay, inlet and nearshore marine sedimentation: Beach Haven-Little Egg Inlet region, New Jersey: Ph.D. dissertation, Univ. of Michigan, Ann Arbor.

Charlesworth, L.J., and Briggs, L.I., 1968, Sedimentation at Beach Haven--Little Egg Inlet, New Jersey (abstr.): Geol. Soc. America Special Paper 101, p. 433.

Charnell, R.L., 1975, Assessment of offshore dumping: Technical background: Physical Oceanogr., Geo. Oceanogr., and Chemical Oceanography: NOAA Technical Memorandum ERL MESA 1

Charnell, R.L., Hansen, D.V., Wicklund, R.I., 1972, The affects of waste disposal in the New York Bight: NMFS, chapter 6, final report to the U.S. Corps of Engineers, Nat. Mar. Fisheries Service, Sandy Hook Laboratory, Highland, N.J., 31 pp.

Charnell, R. L. and Hansen, D. V., 1974: Summary and analysis of physical oceanography data from the New York Bight apex collected during 1969-70: Mesa Report 74-3, , Washington, D.C., U.S. Govt. Printing Office, 44 pp.

Charnell, R.L. Jr., Apel, Manning, W.III and Quelset, R.H., 1974, Utility of ERTS - 1 for coastal ocean observation: the New York Bight example, Marine Technology Soc. J. v. 8, p. 42-47.

Charnell, R. L. and Mayer, D. A. (in press, 1974): Water movement within the apex of the New York Bight during summer and fall of 1973, Tech. memo, National Oceanic and Atmospheric Admin., Boulder, Colorado

Chelminski, P. and Fray, C.I., 1966, The stratigraphy of the continental shelf east of New Jersey (abstr.): Am. Geophys. Union Trans., v. 47, no. 1, p. 120.

Clay, C.S., John Ess, and Irving Weisman, 1964, Lateral echo sounding of the ocean bottom on the continental rise: Jour. Geophys. Research, v. 69, p. 3823-3835.

Coastal Plains Center for Marine Development Services, 1976, Summary of marine activities of the coastal plains region. Annual report of current research and advisory service activities and projects of the major marine and coastal organizations in the region. Region includes: Virginia, North Carolina, South Carolina, Georgia and Florida.

Coch, N.K., 1963, Post-Miocene stratigraphy and morphology, inner coastal plain, southeastern Virginia: U.S. Office of Naval Research Technical Report 6, 97 pp.

Cok, A. and others, 1973, Sediment unmixing in the New York Bight area: Abstracts with Programs, Geol. Soc. America v. 5, no. 2, p. 150.

Colony, R.J., 1932, Source of the sands on the south shore of Long Island and the coast of New Jersey: Jour. Sed. Petrol., v. 2, no. 3, p. 150-159.

Conolly, J.R., Needham, H.D., and Heezen, B.C., 1967, Late Pleistocene and Holocene sedimentation in the Laurention Channel: Jour. Geology, v. 75, p. 131-147.

Corps. of Engineers, 1963, Atlantic coast of Long Island, N.Y., Fire Island Inlet and westerly to Jones Inlet: Review report on beach erosion control cooperative study, U.S. Army Engineer District, New York, 31 pp and appendices.

Corps of Engineers, 1970, Atlantic coast of Long Island, Fire Island Inlet and shore westerly to Jones Inlet: New York beach erosion control and navigation project, General design memorandum, Dept. of Army, N.Y. District, Corps of Engineers, 28 pp.

Corps of Engineers, 1971, National shoreline study, regional inventory report, North Atlantic region: U.S. Army Engineer district, Corps of Engineers, N.Y. 120 pp.

Council on Environmental Quality, 1974, OCS oil and gas - an environmental assessment: A report to the President by the Council on Environmental Quality: U.S. Govt. Printing Office, Washington, D.C., Stock No. 4000-00322, v. 1, 214 p.

Cram, I.H., ed., 1971, Future petroleum provinces of the United States--their geology and potential: AAPG, Mem.15, v.1&2.

Crarat, H.R., and Glaser, R., 1971, Color aerial stereograms of selected coastal areas of the United States: Nat. Ocean Survey, 93 pp.

Creager, J.S., and Sternberg, R.W., 1972, Some specific problems in understanding bottom sediment distribution and dispersal on the continental shelf: in, Swift, D.J.P., Duane, D.B., and Pillsey, O.H., eds., Shelf sediment transport: Process and Patterns: Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 347-362.

Crosby, D.G., 1974, Canadian offshore mineral resources management: AAPG, v. 58, no. 6, pt.II, p. 1059-1064.

Cruickshank, M.J., 1974, Mineral resources potential of continental margins: in, Burk, C.A., and Drake, C.L., eds., The geology of continental margins, Springer-Verlag, New York, p. 965-1001.

Curray, Jr., 1965, Late Quaternary history continental shelves of the United States: in H.E. Wright, Jr., and I.G. Frey, eds., The Quaternary of the United States, Princeton Univ. Press, Princeton, N.J., p. 723-735.

Curray, J.R., 1969b, Shallow structure of the continental margin. In D.J. Stanley, ed., The New Concepts of Continental Margin Sedimentation. Washington, D.C.: Am. Geol. Inst., pp. JC-XII-1 to JC-XII-22.

Curray, J.R., 1969, History of continental shelves. In The New Concepts of Continental Margin Sedimentation, Washington, D.C., Am. Geol. Inst. pp. JC-6-1 to JC-6-18.

Curtis, W.F., Culbertson, J.K., and Chase, E.B., 1973, Fluvial sediment discharge to the oceans from the counterminous United States: USGS circ 670, 17 pp.

Cushman, J.A., 1936, Geology and Paleontology of the Georges Bank Canyons: Pt. 4, Cretaceous and late Tertiary Foraminifera: Geol. Soc. America Bull. v. 47, p. 413-440.

Cushman, J.A., 1939, Eocene Foraminifera from submarine cores off the eastern coast of North America: Cushman Lab. Foram. Research Contr., v. 15, pt. 3, p. 49-76.

Daboll, J.M., 1969, Holocene sediments of the Parker River estuary: Coastal Environments, N.E. Mass. and New Hampshire, Field Trip Guidebook Eastern Section, Soc. Econ. Paleont. and Min. Mag. 9-11, p. 337-355.

Also- Thesis - Coastal Research Group, Dept. of Geol., Univ. Mass, Amherst, 138 pp.

Dall, W.H., 1925, Tertiary fossil dredged off the northeastern coast of North America: Am. Jour. Sci. 5th ser., v. 10, p. 213-218.

Dana, J.D., 1972, Long Island Sound in the Quaternary Era, with observations on the submarine Hudson River Channel: The American Jour. Sci., 3rd ser., v. 60, no. 24, p. 426-437.

Danker, J.A., 1963, A micro-environmental study of the hydrocarbons of the Long Island Sound sediments: Unpubl. Master's thesis, New York University.

Davis, R.A. and W.T. Fox, 1972, Coastal process and near-shore sand bars. J. Sediment. Petrol, 42: 401-412.

Davis, R.A., W.T. Fox, M.O. Hayes, and J.C. Boothroyd, 1972, Comparison of ridge and runnel systems in tidal and non-tidal environments. J. Sediment. Petrol., 32: 413-421.

Dawson, W.E., 1972, Mobil Tetco Sable Island O-47: Well History Report, Mobil Oil, 61 p.

de Jonge, B., Prior, D.G., and Harris, R.L., 1973, Mobil Tetco Thebaud P-84: Well history report, Mobil Oil, 63 p.

Delwing, R.T., 1974, Ocean disposal: in, Ocean dumping in the New York Bight: Environmental Protection Agency briefing report, p. 19-29.

Dent, E.J., 1935, Layout of outer protective works, maintenance of depth in harbors, on sandy shores and before mouths of estuaries: Proc. 16th Intern. Conf. on Nav., Sec. II-I, paper no. 69.

Dickinson, W.R. and Yarborough, H., 1976, Plate tectonics and hydrocarbon accumulation: Short Course, AAPG Continuing Education Committee and AAPG Research Committee, May 23, 1976, New Orleans, La., 66 pp.

Dietrich, R.V., 1960, Basement beneath the emerged Atlantic coastal plain between New York and Georgia: Southeastern Geology, Vol. 1, no. 4, p. 121-131.

Dietz, R.S., 1964, Origin of continental slopes: Am. Scientist, v. 52, no. 1, p. 50-69.

Dietz, R.S., 1931b, Wave base, marine profile of equilibrium, and wave-built terraces--a critical appraisal: Geol. Soc. America Bull., v. 74, p. 971-990.

Dietz, R.S., 1963b, Wave-base, marine profile of equilibrium, and wave-built terraces--A critical appraisal: Geol. Soc. America Bull., v. 74, no. 8, p. 971-990.

Dietz, R.S., and Menard, H.W., Jr., 1951, Origin of abrupt change in slope at the continental shelf margin: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 9, p. 1994-2016.

Dill, R.F., 1967, Effects of explosive loading on the strength of seafloor sands. In A.F. Richards, ed., Marine Geotechnique, Urbana, University of Illinois Press, pp. 291-299.

Dillon, W. P., 1970: Submergence effects on a Rhode Island barrier and lagoon and inferences on migration of barriers: Jour. Geol., vol. 78, pp. 94-106.

Dillon, W.P. and H.B. Zimmerman, 1970, Erosion by biological activity in two New England submarine canyons. J. Sediment. Petrol., 40, 542-547.

Diment, W.H., Urban, T.C., and Revetta, F.A., 1972, Some geophysical anomalies in the eastern United States, in Robertson, E.C., ed., The nature of the solid earth: New York, McGraw-Hill, p. 544-574.

Dobrin, M.B., 1976, Introduction to geophysical prospecting 3rd.ed: McGraw-Hill, 1121 Ave Am., N.Y.

Dolan, R., and others, 1972, Classification of coastal environments of the world, Part I: The Americas: Washington, D.C., Office of Naval Research, 163 pp.

Donahue, J.J. and Tucker, F.B., 1970, Marine mineral identification survey of coastal Connecticut: Connecticut Research Commission, 385 pp.

Donn, W.L., Farrand, W.R., and Ewing, Maurice, 1962, Pleistocene ice volumes and sea-level lowering: Jour. Geology, v. 70, no. 2, p. 206-214.

Donner, Joakim, 1964, Pleistocene geology of eastern Long Island, New York: Am. Jour. Sci., v. 262, no. 3, p. 355-376.

Donohue, J.G., Allen, R.C., and Heezen, B.C., 1966, Sediment size distribution profile on the continental shelf off New Jersey: Sedimentology, v. 7, p. 155-159.

Dorf, E., 1952, Critical analysis of Cretaceous stratigraphy and paleobotany of the Atlantic coastal plain: American Assoc. Petrol. Geol. Bull., v. 36, p. 2161-2184.

Drake, C.L., 1963, Atlantic margin of North America (abstr): American Assoc. Petrol. Geol. v. 47, p. 335.

Drake, C.L., 1969, Continental margins, in The earth's crust and upper mantle: Am. Geophys. Univ. Geophys. Mon. 13, p. 549-556.

Drake, C.L., Worzel, J.L., and Beckman, W.C., 1954, Geophysical investigations of the emerged and submerged Atlantic Coastal plain, part 9, Gulf of Maine: Geol. Soc. America Bull., v. 65, p. 957-970.

Drake, C.L., Erving, M. and Sutton, G.H., 1959, Continental margins and geosynclines: The east coast of North America north of Cape Hatteras, in Ahrens, L.H., and others, eds., Physics and Chemistry of the earth, v. 3, London, Pergamon Press, p. 110-198.

Drake, C.L., Heirtzler, J. and Hirshman, J., 1962, Transcurrent faulting along the continental margin of eastern North America (abstr): Trans. Am. Geophys. Union, v.43, no. 4, p. 434.

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

Drake, C.L., and Woodward, H.P., 1963, Appalachian curvature, wrench faulting, and offshore structures: New York Acad. Sci. Trans. ser. 2, v. 26, no. 1, p. 48-63.

Drake, C.L. and Smith, M.C., 1964, Sub bottom study of Long Island South (abs): Geol. Soc. America Ann. Mtg. Progr. p. 49-50.

Drake, C.L. and Burk, C.A., 1974, Geological significance of continental margins: in Burk, C.A. and Drake, C.L. eds., The geology of continental margins, Springer-Verlag, New York, p. 3-10.

Drake, C.L., Ewing, J.I., and Stockard, H., 1968, The continental margin of the eastern United States: Canadian Jour of Earth Sci., v. 5, p. 993-1010.

Drake, D.E., 1974, Suspended particulate matter in the New York Bight apex: Sept - Nov 1973: NOAA Technical Report ERL 318-MESA 1.

Drake, D.E., R.L. Kolpack and P.J. Fischer, 1972, Comments on the dispersal of suspended sediment across the continental shelves. In D.J. P. Swift, D.B. Duane and O.H. Pilkey, eds., Shelf Sediment Transport, Process and Pattern, Stroudsburg, Pa., Dowden, Hutchinson & Ross, pp. 307-332.

Duane, D.B., 1968, Sand deposits on the continental shelf, a presently exploitable resource: Marine Technology Society Regional Meeting, p. 289-297, Trans. National Symposium Ocean Sci. and Engineering Atlantic Shelf, Phila., Pa., March.

Duane, D.B., 1969, A study of New Jersey and northern New England coastal waters: Shore and Beach, v. 37, no. 2, p. 12-16.

Duane, D. B., Field, M. E., Meisburger, E.S., Swift, D.J.P., and Williams, S. J., 1972: Linear shoals on the Atlantic inner continental shelf, Florida to Long Island: in D.J.R. Swift, D. B. Duane and O. H. Pilker, eds., Shelf Sediment Transport Process and Pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., pp. 447-498.

Dunn, G., and Miller, B., 1960, Atlantic hurricanes: Louisiana State Univ. Press, Baton Rouge, 326 p.

Edwards, J., 1891, The improvement of the channel at the entrance to the harbor of New York: Trans. Am. Soc. Civil Eng., v. 25, p. 573-614.

Edwards, J.J., Jr., 1970, Deep wells of Maryland: Maryland Geol. Survey Basic Data Report 5, 9 pp.

Eittreim, S., Ewing, M., and Thorndike, E.M., 1969, Suspended matter along the continental margin of the North American basin: Deep-sea Res., v. 16, p. 613-624.

Eittreim, S. and M. Ewing, 1972, Suspended particulate matter in the deep waters of the North American Basin. In A.L. Gordon, ed., Studies in Physical Oceanography, Vol. 2, New York, Gordon & Breach, pp. 123-168.

El-Ashry, M.T., 1971, Causes of recent increased erosion along United States shorelines: Geol. Soc. America Bull., v. 82, p. 2033-2038.

Ellis, C.W., 1960, Marine sedimentary environments in the vicinity of the Norwalk Islands, Connecticut (abstr.): Geol. Soc. America Bull., v. 71, no. 12, pt. 2, p. 1857-1858.

Ellis, C.W., 1962, Marine sedimentary environments in the vicinity of the Norwalk Islands, Connecticut: Conn. Geol. Nat. Hist. Surv. Bull. 94, 89 p.

Ellis, T.G., 1873, The causes of the formation of bars at the mouth of rivers, as shown in an examination of the Connecticut River: Trans. Am. Soc.Civil. Eng., v. 2, p. 313.

Elmendorf, C.H., and Heezen, B.C., 1957, Oceanographic information for engineering submarine cable systems: Bell System Tech. Jour. v. 36, no. 5, p. 1047-1093.

Emery, K.O., 1965, Characteristics of continental shelves and slopes. Am. Assoc. Pet. Geol. Bull., 49, 1379-1384.

Emery, K.O., 1965, Geology of the continental margin off eastern United States: in, Submarine Geology and Geophysics, Whittard, W.F., and Bradshaw, R., eds., Butterworths, London, p. 1-20.

Emery, K.O., 1965, Some potential mineral resources of the Atlantic continental margin: U.S. Geol. Survey Prof. Paper, 525-C, p. C157-C160.

Emery, K.O., 1966, Atlantic continental shelf and slope of the United States, geologic background: U.S. Geol. Survey Prof. Paper 529A, 23 pp.

Emery, K.O., 1967, Estuaries and lagoons in relationship to continental shelves: in, Estuaries, Larff, G.H., ed., Washington, D.C., American Assoc. Advancement of Science., Publ. No. 83, p. 9-11

Emery, K.O., 1967, The Atlantic continental margin of the United States during the past 70 million years: Geol. Assoc. Canada Special Paper 4, p. 53-70.

Emery, K.O., 1967, Atlantic Continental Shelf and Slope of the United States--Geologic background: U.S. Geol. Survey Prof. Paper 529-A, 23 p.

Emery, K.O., 1968, Relict sediments on continental shelves of the world: American Assoc. Petrol. Geol. v. 52, p. 445-464.

Emery, K.O., 1968b, Shallow structure of continental shelves and slopes. Southeast. Geol., 9, 173-194.

Emery, K.O., 1969, Continental rises and oil potential. Oil Gas J., 67, 231-243.

Emery, K.O., 1970, Continental margins of the world. In The Geology of the East Atlantic Continental Margin. 1. ICSU-SCOR Working Party 31 Symposium, Cambridge, Rep. 70/13, pp. 7-29.

Emery, K.O., 1974, Geological background Baltimore Canyon trough, in Marine environmental implications of offshore oil and gas development in the Baltimore Canyon region of the Mid-Atlantic coast, ERF Paper 75-1, p. 207-208.

Emery, K.O., E. Uchupi, J.D. Phillips, C.O. Bowin, E.T. Bunce, and S.T. Knott, 1970, continental rise off eastern North America. Am. Assoc. Pet. Geol. Bull., 54, 44-108.

Emery, K.O., and Schlee, J.S., 1963, The Atlantic Continental Shelf and Slope, a program for study: U.S. Geol. Survey Circ. 481, 11 p.

Emery, K.O., 1965, Joint program of U.S.G.S. and W.H.O.I. for continental shelf and slope, in Summary of investigations conducted in 1964: Woods Hole Oceanog. Inst. Ref. 65-13, pp. 67-68.

teeth from the Atlantic Continental Shelf: Science, V. 156, p. 1477-1481.

Emery, K.O., and R.L. Edwards, 1966, Archaeological potential of the Atlantic continental shelf: Am. Antiquity, v. 31, p. 733-737.

Emery, K.O., and Garrison, L.E., 1967, Sea-level 7,000 to 20,000 years ago: Science, v. 157, p. 684-687.

Emery, K.O., and Noakes, L.C., 1968, Economic glacer deposits of the continental shelf: UN Econ. Comm. Asia Far East Comm. Coord. Joint Prosp. Mineral Resources Asian Offshore Areas Tech. Bull, v. 1, p. 95-111.

Emery, K.O. and D.A. Ross, 1968, The topography and sediments of a small area of the continental slope south of Martha's Vineyard. Deep-Sea Res., 15, 415-422.

Emery, K.O., and Uchupi, Elazar, 1965, Structure of Georges Bank: Marine Geology, v. 3, no. 6, p. 349-358.

Emery, K. O. and Uchupi, E., 1972: Western North Atlantic ocean; topography, rocks, structure; water, life and sediments. Am. Assoc. Petrol. Geologists, Memoir 17, 532 pp.

Emery, K.O., Uchupi, Elazar, Phillips, J.D., Bowin, C.O., Bunce, E.T., and Knott, S.T., 1969, The continental rise off eastern North America: Am. Assoc. Petroleum Geologists Bull., v. 54.

Emery, K.O., Wigley, R.L., Bartlett, A.S., Rubin, Meyer, and Barghoorn, E.S., 1967, Freshwater peat on the continental shelf: Science, v. 158, p. 1301-1307.

Emery, K.O., R.L. Wigley, and Meyer Rubin, 1965, A submerged peat deposit off the Atlantic coast of the United States: Limnology and Oceanography, Supp. to v. 10, p. 97-102.

Emery, K.O., Wigley, R.I., and Rubin, Meyer, 1965, A peat deposit on Georges Bank: Limnology and Oceanography Supplement v. 10, p. 97-102.

Emmerich, H.H., ed., 1974, East coast offshore symposium, Baffin Bay to the Bahamas: American Assoc. Petrol. Geol. Bull., v. 58, p. 1055-1239.

Environmental Protection Agency, 1973, Ocean dumping in the New York Bight: facts and figures: Envir. Protection Agency, Region II.

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

Ericson, D.B., and others, 1961, Atlantic deep-sea sediment cores: Geol. Soc. America Bull., v. 72, p. 193-286.

Estuarine Research Federation - OCS Conference and workshop, 1974, Marine and environmental implications of oil and gas development in the Baltimore Canyon region of the Mid-Atlantic coast: College Park, Md. 504 pp.

Everts, C.H., 1973, Beach profile changes on western Long Island: in Coates, D.R., ed., Coastal Geomorphology Publications in Geomorphology, S.U.N.Y., Binghamton, N.Y., p. 279-301.

Ewing, J.A., 1973, Wave-induced bottom currents on the outer shelf. Mar. Geol. 15, M31-M35.

Ewing, John, J. Antoine, and Maurice Ewing, 1960, Geophysical measurements in the western Caribbean Sea and in the Gulf of Mexico: Jour. Geophys. Research, v. 65, p. 4087-4126.

Ewing, J.I. and Hollister, C.H., 1972, Regional aspects of deep-sea drilling in the western North Atlantic: Deep-Sea Drilling Project Initial Report, v. 11, p. 951-973.

Ewing, John, Luskin, Bernard, Roberts, Archie, and Hirshman, Julius, 1960, Sub-bottom reflection measurements on the continental shelf, Burmuda Banks, West Indies Arc, and in the West Atlantic basins: Jour. Geophys. Research, v. 65, p. 2849-2859.

Ewing, J.I., Pichon, X.L., and Ewing, M., 1963, Upper stratification of Hudson Apron region: Jour. of Geophys. Research, v. 68, n. 23, p. 6303-6316.

Ewing, John, Worzel, J.L., Ewing, Maurice, and Windisch, Charles, 1966, Ages of horizon A and the oldest Atlantic sediments: Science, v. 154, no. 3753, p. 1125-1132.

Ewing, M., 1940, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 4: Cape May, N.J., Sections: Geol, Soc. America Bull., v. 51, p. 1821-1840.

Ewing, M., Carpenter, G., Windisch, C., and Ewing, S., 1973, Sediment distribution in the oceans: the Atlantic GSA Bull., v. 84, p. 71-88.

Ewing, M., Crary, A.P., and Rutherford, H.M., 1973, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 1, Methods and results: Geol. Soc. America Bull., v. 48, p. 753-802.

Ewing, Maurice, D.B. Ericson, and B.C. Heexen, 1958, Sediments and topography of the Gulf of Mexico, in L.G. Weeks, ed., Habitat of oil: Am. Assoc. Petroleum Geologists, p. 995-1053, see fig. 2.

Ewing, M., Wongel, J.L., Steenland, N.C., and Press, F., 1950, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Part 5, Woods Hole, New York and Cape May sections: Geol. Soc. America Bull., v. 61, p. 877-892.

Ewing, W.M., G.P. Woollard, and A.C. Vine, 1939, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Pt. 3, Barnegat Bay, New Jersey section: Geol. Soc. America Bull., v. 50, no. 2, p. 257-296.

Ewing, W.M., G.P. Woollard, and A.C. Vine, 1940, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Pt. 4, Cape May, New Jersey section: Geol. Soc. America Bull., v. 51, no. 12, pt. 1, p. 1821-1840.

Ewing, W.M., J.L. Worzel, N.C. Steenland, and F. Press, 1950, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Pt. 5, Woods Hole, New York, and Cape May sections: Geol. Soc. America Bull., v. 61, no. 9, p. 877-892.

Fairbridge, R.W., and Newman, W.S., 1968, Postglacial subsidence of the New York area: Geomorph., v. 3, p. 296-317.

Farmer, D.G., 1971, A computer simulation model of sedimentation in a salt wedge estuary. Mar. Geol. 10: 133-143.

Fenner, P., Kelling, G., and Stanley, D.J., 1971, Bottom currents in Wilmington submarine canyon: Nature, Physical Science, v. 229, p. 52-54.

Field, M.E. and Duane, D.B., 1976, Post-Pleistocene history of the United States inner continental shelf: s gnificance to origin of barrier islands: Geol. Soc. America Bull. v.87, p. 691-702.

Finn, W.D.L., Byrne, P.M. and Emery, J.J., 1971, Engineering properties of a marine sediment in Proceedings of the international symposium on the engineering properties of sea floor sails and their geophysical identification: p. 110-120.

Fischer, A.G. and Judson, S., 1975, Petroleum and global tectonics: Princeton University Press, Princeton, N.J. 322 pp.

Fisher, A.G., 1961, Stratigraphic record of transgressing seas in light of sedimentation on the Atlantic Coast of New Jersey: American Assoc. of Petrol. Geol. Bull. v. 45, p. 1656-1666.

Fisher, J.J., 1968a, Origin of barrier island chain shorelines, middle Atlantic states: Geol. Soc. America Spec. Paper 115, Abs. for 1967, p. 66-67.

Fisher, J.J., 1968b, Barrier island formation: Discussion: Geol. Soc. America Bull., v. 79, p. 1421-1426.

Fisk, H.N. and McClelland, C., 1959, Geology of continental shelf off Louisiana, it's influence on offshore foundation design: GSA Bull., v.70, p. 1369-1394.

Flood, R.D. and Hollister, C.D., 1974, Current-controlled topography on the continental margin off the eastern United States: in, Burk, C.A., and Drake, C.L., eds., The geology of continental margins, Springer-Verlag, New York, p. 197-205.

Flowers, B.S., 1976, Overview of exploration geophysics--Recent breakthrough and challenging new problems: AAPG v. 60, no. 1, p. 3-11.

Folger, D.W., 1972, Texture and organic carbon content of bottom sediments in some estuaries of the United States, in Nelson, B.W., ed., Environmental framework of coastal plain estuaries: Geol. Soc. American Mem. 133, p. 391-409 (1973).

Folger, D.W., 1972, Characteristics of estuarine sediments of the United States: U.S. Geol. Survey Prof, P 742, 94 pp.

Folger, D.W., O'Hara, C.J., and Robt. J.W., in Press, Bottom sediments on the continental shelf of the northeastern United States; Cape Ann, Mass. to Casco Bay, Maine: U.S. Geol. Survey Misc. Geol. Invest. Map I-839.

Foote, R.Q., Mattick, R.E., and Behrendt, J.C., 1974, Atlantic OCS resource and leasing potential: U.S. Geol. Survey open-file report 74-348, 33 pp.

Fox, P.J., B.C. Heezen, and A.M. Harian, 1968, Abyssal anti-dunes: Nature, v. 220, p. 470-472.

Frank, W.M., 1976, Continental shelf sediments off New Jersey: Ph.D. Thesis, Rensselear Polytech Inst. 84 p.

Frank, W.M. and Friedman, G.M., 1971, Barrier Island and migration: New evidence from New Jersey: in Abstract volume, Second National Coastal and Shallow Water Conference, Univ. Press, Univ. of Southern Calif., Los Angeles, 327 pp.

Frank, W.M. and G.M. Friedman, 1973, Continental shelf sediments off New Jersey. J. Sediment. Petrol., 43, 224-237.

Friedman, G.M., 1966, Study of continental shelf and slope on the coasts of Long Island, NY and New Jersey: Maritime Sediments, v. 2, no. 1, p. 21-22.

Friedman, G.M. and Gavish, E., 1970, Chemical changes in interstitial waters from sediments of lagoonal, deltaic, river estuary and saltwater marsh and cove environments: Jour. Sed. Petr., v. 40, p. 930-953.

Friedman, G.M., et al, 1968, Chemical changes in interstitial waters from continental shelf sediments: Jour. Sed. Petrology, v. 38, p. 1313-1319.

Friedman, G.M. and Gavish, E., 1970, Chemical changes in interstitial waters from lagoonal, estuarine, tidal marsh and deltaic environments: Geol. Soc. Amer., Abstracts with Programs, v. 2, p. 20-21.

Fuller, M.L., 1914, Geology of Long Island, New York: U.S. Geol. Survey, Prof. Paper 82, 231 pp.

Garrison, L.E., 1967, Cretaceous-Cenozoic development of the continental shelf south of New England: Providence, Univ. Rhode Island, Ph.D. thesis, unpub., 100 p.

Garrison, L. E., 1970. Developments of continental shelf south of New England: American Assoc. Petrol. Geol. Bull., vol. 54, pp. 109-124.

Garrison, L.E., and R.I. McMaster, 1966, Sediments and geomorphology of the continental shelf off southern New England: Marine Geology, v. 4, p. 273-289.

Gaul, R.D., 1961, Observations on internal waves near Hudson Canyon. J. Geophys. Res., 66, 3821-3830.

Gessler, E.E., 1952, Beach erosion studies of southern New, Jersey: Shore and Beach, v. 20, no. 2, p. 3-7.

Gevirtz, J.L., Park, R.A. and Friedman, G.M., 1971 , Paraecology of benthonic foraminifera and associated microorganisms of the continental shelf off Long Island, New York: Jour. Paleo., v. 45, p. 153-177

Gibson, T.G., 1965, Eocene and Miocene rocks off the Northeastern Coast of the United States: Deep-Sea Research, v. 12, p. 975-981.

Gibson, T.G., 1970, Late Mesozoic-Cenozoic tectonic effects of the Atlantic Coastal margin: Geol. Soc. America Bull., v. 81, p. 1813-1822.

Gibson, T.G., J.E. Hazel, and J.F. Mello, 1968, Fossiliferous rocks from submarine canyons off the northeastern United States, in Geological Survey research 1968: U.S. Geol. Survey Prof. Paper 600-D, p. D222-D230.

Gill, H.E., Seaber, P.R., Vecchioli, J., and Anderson, H.R., 1963, Evaluation of geologic and hydrologic data from the test-drilling program at Island Beach State Park, New Jersey: N.J. Rept. Conservation and Economic Devel. Div. Water Policy and Water Supply Resources, circ. 12, 25 pp.

Gill, H.E., Sirkin, L.A., and Doyle, J.A., 1969, Cretaceons deltas in the New Jersey coastal plain (Abstr.): Geol. Soc. America, Abstracts with Programs, v. 1, part 7, p. 79.

Gilluly, J., 1964, Atlantic sediments, erosion rates, and the evolution of the continental shelf: some speculations: Geol. Soc. America Bull., v. 75, p. 483-492.

Glaeser J.D., 1968, Coastal plain geology of southern Maryland: Maryland Geol. Survey Guidebook no. 1, 56 pp.

Glaeser, J.D., 1969, Petrology and origin of Potomac and agothy (retaceo s) sediments, middle Atlantic coastal plain: Maryland Geol. Survey Rept. Inv. no. 11, 102 pp.

Glaeser, J.D.(in press), Global distribution of barrier islands in terms of tectonic setting: Jour. of Geology (submitted April, 1977).

Godfrey, P.J., and Godfrey, M.M., 1973, Comparison of ecological and geomorphic interactions between altered and unaltered barrier island systems in North Carolina, in Coates, D., ed., Coastal geomorphology: Binghamton, N.Y., State Univ. New York, Pubs. in Geomorphology, p. 239-258.

Gofsergeff, S., 1952, Case history of Fire Island Inlet, New York: Conf. Coastal Engin., 3rd, Proc. Chap. 23, p. 272.

Goldsmith, V., R.J. Byrne, A.H. Sallenger, and R. Driecker (in press), The influence of waves on the origin and development of the offset coastal inlets of the southern Delmarva Peninsula, Virginia. In M.O. Hayes, ed., Second International Estuarine Conference Proceedings, Myrtle Beach, South Carolina, Oct. 15-18, 1973, New York, Academic Press.

Gordon, A.L., and Gerard, R.D., in press, Wind drift surface currents and spread of contaminants in shelf waters: U.S. Coast Guard Res. Develop. Center, Groton, Conn., Rept. DOTCG 23339-A.

Green, F., 1976, EPA's view of projected oil drilling on the continental shelf: Sea Technol., v. 17, no. 10, p. 11-13.

Grim, M.S., Drake, C.L., Heirtzler, J.P., 1970, Sub-bottom study of Long Island Sound: GSA Bull., v. 81, p. 649-666.

Groot, C.R., and J.J. Groot, 1964, The pollen flora of Quaternary sediments beneath Nantucket Shoals: Am. Jour. Sci., v. 262, p. 488-493.

Groot, J.J., and Penny, J.S., 1960, Plant microfossils and age of nonmarine Cretaceons sediments of Maryland and Delaware: Micropaleontology, v. 6, no. 2, p. 225-236.

Gross, M.G., 1970, Metropolitan region - A major sediment source: Water Resources Research, v. 6, p. 927-931.

Gross, M.G., 1970, Preliminary analysis of urban waste, New York metropolitan region: Marine Science Research Center, Tech. Report 5, State University of New York, Stony Brook, 35 pp., also in Congressional Record, v. 116, no. 31, p. S2885-2890.

Gross, M.G., 1970, Analyses of dredged wastes, fly ash and waste chemicals, New York metropolitan region: Marine Science Research Center, Tech. Report 7, State Univ. of New York, Stony Brook, 33 pp.

Gross, M.G., 1972, Geologic aspects of waste solids and marine waste deposits, New York metropolitan region: Geol. Soc. Am. Bull. v. 83, p. 3163-3176.

Gross, M.G., Black, J.A., Kalm, R.J., Schramal, Jr., and Smith, R.N., 1971, Survey of marine waste deposits, New York metropolitan region: Marine Science Research Center, Tech. Report 8, State Univ. of New York, Stony Brook, 72 pp.

Habitat of oil: a symposium containing 56 papers on oil occurrence worldwide: Am. Assoc. Petr. Geol., 1958, 1384p.

Hadley, J.R., and Devine, J.F., 1974, Seismotectonic map of the eastern United States: U.S. Geol. Survey Map MF-620, 3 sheets and text.

Hahn, Jan, ed., 1963, Thresher search: Oceanus, v. 9, no. 4, p. 16-17.

Hales, A.L., 1970, Eastern continental margin of the United States, Part 2: A review, in A.E. Maxwell, ed., The sea: ideas and observations on progress in the study of the seas, v. 4, pt. 2, New York Wiley Interscience, p. 311-320.

Hall, J.V., and Herron, W.J., 1950, Test of nourishment of the shore by offshore deposition of sand, Long Branch, New Jersey: Dept. of the Army Corps of Engineers, Beach Erosion Board, Tech. Mem. 17, 32 pp.

Hallam, A., 1971, Mesozoic geology and the opening of the North Atlantic: Jour. Geol. v. 79, p. 129-157.

Hampton, M.A., 1972, The role of subaqueous debris flow in generating turbidity currents. J. Sediment. Petrol., 42, 775-793.

Hansen, H.J., 1969, Depositional environments of subsurface Potomac group in southern Maryland: American Assoc. Petrol. Geol. v. 53, p. 1923-1937.

Harris, D.L., 1972, Wave estimates for coastal regions in Swift, D.J.P., Duane, D.B., and Pilkey, O.H., eds., Shelf sediment transport, Process and Pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 99-126.

Harris, R.L., 1954, Restudy of test-shore nourishment by off-shore deposition of sand, Long Branch, New Jersey: Dept. of Army Corps of Engineers, Beach Erosion Board. Tech. Mem. 62, 18 pp.

Harrison, W.B., Malloy, R.J., Rusnak, G.A., and Terasmac, J., 1965, Possible late Pleistocene uplift, Chesapeake Bay entrance: Jour. Geology, v. 73, p. 201-229.

Harrison, W., Norcross, J.J., Pore, N.A., and Stanley, E.M., 1967, Circulation of shelf waters off the Chesapeake Bight: U.S. ESSA Prof. Paper 3, 82 p.

Hathaway, J.C., ed., 1966, Data file, Continental Margin Program, Atlantic coast of the United States, v.1, Sample collection data: Woods Hole Oceanog. Inst. Ref., 66-8, 184 p.

Hathaway, J.C., ed., 1967, Data file, Continental Margin Program, Atlantic coast of the United States, v. 1, Sample collection data, Supplement 1: Woods Hole Oceanog. Inst. Reference No. 67-21, 108 p.

Hathaway, J.C., 1971, Data file, continental margin program, Atlantic coast of the United States, v. 2, sample collections analytical data, Woods Hole Oceanographic Institution Ref. 71-15, U.S. Geol. Survey, Woods Hole, Mass., 496 pp.

Hathaway, J.C., 1972, Regional clay mineral facies in estuaries and continental margin of the United States East Coast, in Nelson, B.W., ed., Environmental framework of coastal plain estuaries: Geol. Soc. America Mem. 133, p. 293-317 (1973).

Hathaway, J.C., 1972, Regional clay mineral facies in the estuaries and continental margin of the United States east coast in Nelson, B.W., ed., Environmental framework of coastal plain estuaries: Geol. Soc. America Mem. 133, p. 293-316.

Hathaway, J.C., Hulsemann, Jobst, Schlee, J.S., and Trumbull, J.V.A., 1965, Sediments of the Gulf of Maine (abs.): Soc. Econ. Paleontologists and Mineralogists, Ann. Meeting, New Orleans.

Hathaway, J.C., Schlee, J.S. Trumbull, J.V.A., and Hulsemann, Jobst, 1965, Sediments of the Gulf of Maine (abs.): Am. Assoc. Petroleum Geologists Bull., v. 49, p. 343-344.

Hathaway, J.C. and others, 1976, Preliminary summary of the 1976 Atlantic margin coring project of the USGS: USGS Open File Report #76-844, 217 p.

Haupt, L.M., 1889, Fire Island Inlet: Jour. Franklin Institute, v. 127, no. 9, p. 249-254.

Haupt, L.M., 1889, Harbor bar improvements: Jour. Franklin Institute, v. 127, p. 19-41, and discussion of the above, v. 128, p. 224-229, 294-297.

Haupt, L.M., 1890, Littoral movements of the New Jersey coast, with remarks on beach protection and jetty reaction: Trans. Am. Soc. Civ. Engr. vol. 23, p. 123-154.

Hayes, M.O., 1967, Relationship between coastal climate and bottom sediment type on the inner continental shelf: Marine Geol. V. 5, p. 111-132.

Hayes, M.O., 1967, Hurricanes as Geological Agents: Case Studies of Hurricanes Carla, 1961, and Cindy, 1963. Texas Bureau of Economic Geol., Report of Investigation 61, 54 pp.

Hayes, M.O., 1971, Geomorphology and sedimentation of some New England estuaries: in Schubel, J.R., convenor, The estuarine environment: estuaries and estuarine sedimentation Short Course Lecture Notes, American Geological Institute, Washington, D.C., P.XII 1-17.

Hayes, M.O. and McCormick, C.L., 1967, Sedimentation in estuaries with reference to the Merrimack and Parker Rivers, Mass., Economic Geol. in Mass., Conf., Amherst, 1966: Proc. Univ. Mass. Grad. School, Amherst, p. 547-558.

Hayes, M.O. and Boothroyd, J.C, 1969, Storms as modifying agents in the coastal environment in Coastal Environments, N.E. Mass and N.H., : Coastal Research Group, Univ. of Mass., Amherst, p. 245-265.

Hayes, M.O., V. Goldsmith, and C.H. Hobbs, 1970, Offset coastal inlets, In 12th Conference Coastal Engineering Proceedings, pp. 1187-1200.

Hazleworth, J.B., and others, 1974, New York bight project, water column sampling, cruises #1-5 of the NOAA ship Ferrel, Aug - Nov 1973: MESA Report no. 2.

Heezen, B.C., 1974, Atlantic-type continental margins: in Burk, C. A., and Drake, C.L., eds., The geology of continental margins, Springer-Verlag, New York, p. 13-24.

Heezen, B.C., and Maurice Ewing, 1952, Turbidity currents and submarine slumps, and the 1929 Grand Banks earthquake: Am. Jour. Sci., v. 250, p. 849-873.

Heezen, B.C., Tharp, M. and Ewing, W.M. 1959, The North Atlantic text to accompany the physiographic diagram of the North Atlantic, Part I of the floors of the oceans: Geol. Soc. America Special Paper 65, 122 pp., see p.41, 18-19, pl.2, figs. 13,29, 31, pl. 20, 27.

Heezen, B.C., and Charles Hollister, 1964, Deep-sea current evidence from abyssal sediments: Marine Geology, v.1, p. 141-174.

Heezen, B.C., D.B. Ericson, and Maruice Ewing, 1954, Further evidence for a turbidity current following the 1929 Grand Banks earthquake: Deep-Sea Research, v.1, p. 193-202.

Heezen, B.C. and C.L. Drake, 1964, Grand Banks slump. Am. Assoc. Pet. Geol. Bull., 481, 221-225.

Heezen, B.C., and C.L. Drake, 1964b, Gravity tectonics, turbidity currents and geosynclinal accumulations in the continental margin of eastern North America: Hobart, Tasmania Univ. Symposium, p. D1-D10.

Heezen, B.C., C.D. Hollister, and W.F. Ruddiman, 1966, Shaping of the continental rise by deep geostrophic contour currents. Science, 152, 502-508.

Heezen, B.C., and E.D. Schneider, 1968, The shaping and sediment stratification of the continental rise (abs.): Washington, D.C., Marine Tech. Soc. Natl. Symposium, Ocean Sciences & Engineering of the Atlantic Shelf Trans., March 19-20, 1968, Philadelphia, Pa., p. 279-280.

Heezen, B.C. and Charles Hollister, 1971, The face of the deep: New York, Oxford Univ. Press, 759 p.

Hendricks, J.D., and Robb, J.M., 1973, Gravity measurements in the vicinity of Georges Bank: Geol. Soc. Am. Bull., v. 84, no. 12, p. 3911-3916.

Hersey, J.B., S.T. Knott, and A.T. Johnston, 1964, Search for the Thresher by photomosaic: U.S. Navy Jour. Underwater Acoustics, v. 14, no. 2, p. 311-318.

Hicks, S.D., 1959, The physical oceanography of Narragansett Bay: Limnology and Oceanography, v. 4, no. 3, p. 316-327.

Hine, A.C., 1972, Sand deposition in the Chatham Harbor estuary and on the neighboring beaches, Cape Cod, Mass.: M.S. Thesis, Univ. of Mass., Amherst, 187 pp.

Hine, A.C., 1973, Bedform distribution and migration patterns on tidal deltas in the Chatham Harbor estuary, Cape Cod, Mass.: Proc. 2nd Intern Estuaring Res. Conf., Columbia, S.C.,

Holliday, B.W., 1971, Observations on the hydraulic regime of the ridge and swale topography of the inner Virginia shelf, Masters Thesis, Old Dominion University, Inst. of Oceanog. Norfolk. Va.

Hollister, C.D., 1967, Sediment distribution and deep circulation in the western North Atlantic (Ph.D. thesis): Columbia Univ., New York, 471 p.

Hollister, C.D., 1973, Atlantic continental shelf and slope of the United States - Texture of surface sediments from New Jersey to southern Florida: U.S. Geol. Sur. 529-M,

Hollister, C.D. and B.C. Heezen, 1972, Geologic effects of ocean 'bottom currents': Western North Atlantic, In. A.L. Gordon, ed., Studies in Physical Oceanography, Vol. 2, New York, Gordon & Breach, pp. 37-66.

Hollister, C.D., Ewing, J.I., Habib, D., Hathaway, J.C., Lancelot, Y., Luterbacher, H., Paulus, F.J., Poag, C.W., Wilcoxun, J.A., Worstell, P., 1972, Site 108, continental slope in Initial reports of the deep sea drilling project, v. II: Washington, D.C., U.S. Geol. P.O., p. 357-364.

Hollister, C.D., and Heezen, B.C., 1972, Geologic effects of ocean bottom currents, Western North Atlantic in Gordon, A.L., ed., Studies in physical oceanography: Gordon and Breach Sci. Pub., New York, p. 37-66.

Hollister, C.D. and others, 1972, Sites 105, 106, 107, 108, in Kaneps, A.G., Sci. Ed., Initial reports of the Deep-Sea Drilling Project, V. I, Washington, D.C., U.S. Govt. Printing Office, p. 351-364.

Hollister, C.D., and Heezen, B.C., 1972, Geologic effects of ocean bottom currents--Western North Atlantic, in Gordon, A.L., ed., Studies in physical oceanography, vol. 2: New York, Gordon & Breach, p. 37-66.

Hoskins, H., 1967, Seismic reflection observations on the Atlantic continental shelf, slope and rise southeast of New England:

Hoskins, Hartley, and Knott, S.T., 1961, Geophysical investigation of Cape Cod Bay, Massachusetts, using the continuous seismic profiler: Jour. Geology, v. 69, no. 3, p. 330-340.

Hough, J.L., 1940, Sediments of Buzzards Bay, Massachusetts: Jour. Sed. Petrology, v. 10, no. 1, p. 19-32.

Hough, J.L., 1942, Sediments of Cape Cod Bay, Massachusetts: Jour. Sed. Petrology, v. 12, no. 1, p. 10-30.

Houtz, R.E., 1964, Sedimentary velocities of the western North Atlantic margin: Seismol. Soc. America Bull., v. 54, p. 867-895.

Houtz, R.E., and Ewing, J.I., 1963, Detailed sedimentary velocities from seismic refraction profiles in the western North Atlantic: Jour. Geophys. Research, v. 68, no. 18, p. 5233-5258.

Houtz, R.E., and Ewing, J., 1964, Sedimentary velocities of the western North Atlantic margin: Seismol. Soc. America Bull., v. 54, p. 867-895.

Howard, A.D., 1939, Hurricane modification of the offshore bar of Long Island, New York: Geog. Rev. v. 29, p. 400-415.

Howell, B.F., Jr., 1973, Earthquake hazard in the eastern United States: Earth and Mineral Sci., The Pennsylvania State College of Earth and Mineral Sciences, Univ. Park, Penna., v. 42, no. 6, p. 41-45.

Howie, R.D., 1970, Oil and gas exploration--Atlantic coast of Canada: Am. Assoc. Petroleum Geologists Bull., v. 54, no. 11, p. 1989-2006.

Hoyt, J.H., 1967, Barrier island formation: Geol. Soc. America Bull., v. 78, p. 1125-1136.

Hoyt, J.H., 1968, Barrier island formation: Reply: Geol. Soc. America Bull., v. 79, p. 1427-1432.

Hoyt, J.H., 1970, Development and migration of barrier islands, northern Gulf of Mexico, discussion, Geol. Soc. Am. Bull., 81: 3779-3782

Hoyt, J.H. and V.J. Henry, 1967, Influence of island migration on barrier island sedimentation, Geol. Soc. Am. Bull, 78: 77-86.

Hoyt, J.H., and Henry, V.J., 1971, Origin of capes and shoals along the southeastern coast of the United States: Geol. Soc. America Bull., v. 82, p. 59-66.

Hubbard, D.K., 1971, Movement of deep-water estuarine bedforms in the lower Parker River estuary, Plum Island, Mass: Unpub. Senior Honors Thesis, Coastal Res. Center, Dept. of Geol. Univ. Mass., Amherst, 70 pp.

Hubbard, D.K., 1973, The morphology and hydrodynamics of the Merrimack ebb-tidal delta: Proc. 2nd Intern Estuarine Res. Conference, Columbia, S.C.,

Hubert, J.F., 1962, Dispersal patterns of Pleistocene sands on the North Atlantic deep-sea floor: Science, v. 136, no. 3514, p. 383-384.

Hulsemen, J., 1967, The continental margin off the Atlantic coast of the United States: Carbonate in sediments, Nova Scotia to Hudson Canyon: Sedimentology, v. 8, p. 121-145.

Hunt, R.E., Swift, D.J.P. and Palmer, H., 1977, Constructional shelf topography, Diamond Shoals, North Carolina: Geol. Soc. America Bull., v. 88, p. 299-311.

Hurley, R.J., 1964b, Bathymetric data from the search for USS "Thresher": Internat. Hydrog. Rev., v. 41, no. 2, p. 43-52.

Ichiye, T. 1968, Hydrography tides and tidal flushing of Great South Bay - South Oyster Bay, Long Island: Trans. Nat. Symp. on Ocean Sci. and Engr. of the Atlantic Shelf, March 19-20, Philadelphia, p. 15-62.

Inderbitzen, A.L. and F. Simpson, 1971, Relationship between bottom topography and marine sediment properties in an area of submarine gullies. J. Sediment. Petrol., 41, 1126-1133.

Inman, D.L. and C.E. Nordstrom, 1971, On the tectonic and morphologic classification of coasts. J. Geol. 79, 1-21.

Iselin, C. O'D., 1936, A study of the circulation of the western North Atlantic: Massachusetts Inst. Technology and Woods Hole Oceanog. Inst. Papers in Physical Oceanography and Meteorology, v. 4, 101 p.

Jarrett, J.T., 1976, Tidal prism - inlet area relationships: Dept. of the Army, Corps of Engineers, CERC and WES, GITI Report 3, 32 pp.

Jeffries, H.P., 1962, Environmental characteristics of Raritan Bay, a polluted estuary: Limnology and Oceanography, v.7, no. 1, p. 21-31.

Johnson, A.H., and others, 1952, Record of wells in Suffolk County, Long Island, New York: New York State Water Power and Control Commission Bull. G.W. 31, 137 pp.

Johnson, D.W., and Stolfus, M.A., 1924, The submerged coastal plain and old land of New England: Science, new ser., v. 59, no. 1526, p. 291-293.

Johnson, M.E., and Richards, H.G., 1952, Stratigraphy of coastal plain of New Jersey: American Assoc. Petrol. Geol. Bull. v. 36, no. 11, p. 2150-2160.

Johnson, G.L., and E.D. Schneider, 1969, Depositional ridges in the North Atlantic: Earth and Planet. Sci. Letters, v. 6, p. 416-422.

Johnson, J.A., 1969, Barnegat Inlet, a problem and a solution: Shore and Beach, v. 37, no. 2, p. 17-20.

Johnson, J.W. and P.S. Engleson, 1966, In. A.J. Ippen, ed. Estuary and Coastline Hydrodynamics, New York: McGraw Hill, pp. 404-492.

Johnson, D.W., 1925, The New England-Acadian shoreline: New York, John Wiley & Sons, 608 p., see p. 265-314.

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

Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965, Ocean drilling on the continental margin: Science, v. 150, no. 3697, p. 709-716.

Jordan, G.F., 1962a, Large submarine sand waves: Science, v. 136, p. 839-848.

Jordan, G.F., 1962b, Submarine physiography of the U.S. continental margins: U.S. Dept of Commerce, Coast and Geodetic Survey, Tech. Bull. No. 18, p. 1-28.

Jordan, R.R., 1962, Stratigraphy of the sedimentary rocks of Delaware: Delaware Geological Survey, Bull. 9, 51 pp.

Kaczorowski, R.T., 1972, Offset tidal inlets, Long Island, New York: unpub. M.S. thesis, Univ. Mass., Amherst, 151 pp.

Kane, M.F. and others, 1972, Gravity and magnetic evidence of lithology and structure in the Gulf of Maine region: U.S.G.S. Prof. Paper 726B, 22 pp.

Kantrowitz, I.H. and Webb, W.E., 1971, Geologic and hydrologic data from a test well drilled near Chestertown, Md.: U.S. Geol. Sur. Water Res. Division, Open-File Report, 18 pp.

Kao, A., 1975: A study of the current structure in the Sandy Hook-Rockaway Point transect: M.S. research paper, Marine Sciences Research Center, SUNY, Stony Brook.

Kaplin, Stephen, Jr., 1961, Chemical and oxidation reduction potential studies of the Long Island Sound sediments: Unpub. Masters thesis, New York University.

Katz, Samuel, and Ewing, Maurice, 1956, Seismic refraction measurements in the Atlantic Ocean; Part VII, Atlantic Ocean basin west of Bermuda: Geol. Soc. America Bull., v. 67, no. 4, p. 475-510.

Kaye, C.A., and Barghoorn, E.S., 1964, Late Quaternary sea-level change and crustal rise at Boston, Massachusetts, with notes on the autocompaction of peat: Geol. Soc. Am. Bull., v. 75, no. 2, p. 63-80.

Kaye, C.A., 1964, Outline of Pleistocene geology of Martha's Vineyard, Massachusetts: U.S. Geol. Survey Prof. Paper 501-C, p.C134-C139.

Kaye, C.A., 1964, The Pleistocene geology of Martha's Vineyard, Mass.: Friends of the Pleistocene 27th Ann. Reunion, Martha's Vineyard, Mass., May 1964, Itinerary 9 pp.

Keen, C.E. and Keen, M.J., 1974, Continental margins of eastern Canada and Baffin Bay: in Burk, C.A. and Drake, C.L., eds., Geology of Continental Margins, Springer-Verlag, N.Y., p. 375-380.

Keen, M.J., and J.E. Blanchard, 1966, The continental margin of eastern Canada: Canada Geol. Survey Paper 66-15, p. 9-18.

Keen, M.J., 1969, Possible edge effect to explain magnetic anomalies off eastern seaboard of the United States: Nature, v. 222, p. 72-74.

Keen, M.J., B.D. Loncarevic and G. N. Ewing, 1970, Continental margin of eastern Canada: Georges Bank to Kane basin: The Sea, V. 4, p. 251-292.

Keen, M.J. and Keen, C.E., 1973, Subsidence and fracturing on the continental margin of eastern Canada: Geol. Survey Canada, pap. 71-23.

Kelling, G.H., D. Lambert, G. Rower, and N. Staresinic, 1973, Bottom currents in the Hudson Canyon. Science, 180, 181-183.

Kelling, G., H. Sheng, and D.J. Stanley, 1975, Minerologic comps-sition of sand-sized sediment on the outer margin off the Mid-Atlantic States: Assessment of the influence of the ancestral Hudson and other fluvial systems. Geol. Soc. Am. Bull., 86, 853-862.

Kelling, G., and Stanley, D.J., 1970, Morphology and structure of the Wilmington and Baltimore submarine canyons, eastern United States: Jour. Geology, v. 78, p. 637-660.

Kerr, P.F., 1962, Possible quick-clay motion in turbidity currents: Science, v. 137, no. 3528, p. 420-421.

Ketchum, B. H., Redfield, A. C. and Ayers, J. C., 1951. The oceanography of the New York Bight: Pap. Phys. Oceanography and Meteorology, vol. 12, pp. 4-46. Also in Physical Oceanographic Meteorology, M.I.T.-W.H.O.I., vol. 12, no. 1.

Ketchum, B.H., and Keen, D.J., 1955, The accumulation of water over the continental shelf between Cape Cod and Chesapeake Bay: Deep. Sea Research supp to V.3 (Bigelow Volume) P. 346-357.

Keulegan, G.H. and Hall, J.V., Jr., 1950, A formula for the calculation of tidal discharge through an inlet: U.S. Army, Corps of Engineers, Beach Erosion Board, Bull. 4, p. 15-29, Washington, D.C.

King, E.R., Zietz, I., and Dempsey, W.J., 1961, The significance of a group of aeromagnetic profiles off the eastern coast of North America: U.S. Geol. Survey Prof. Paper 424-D, p. D299-303.

Knebel, H.J., 1974, Movement and effects of spilled oil over the outer continental shelf - inadequacy of existant data for the Baltimore Canyon Trough area: U.S. Geol. Sur. circ. no. 702, p. 1-17.

Knebel, H.J., and Hardin, N.S., 1974, The responsibilities and environmental programs of the U.S. Geological Survey in the Baltimore Canyon trough area: in Marine environmental implications of off-shore oil and gas development in the Baltimore Canyon region of the mid-Atlantic coast - Estuarine Research Federation Outer Continental Shelf Conference and Workshop Proc. College Park, Univ. Maryland, p. 7-17.

Knebel, H.J. and others, 1976, Baltimore canyon trough area hazards: U.S. Geological Survey Misc. Field Studies, MF 828.

Knott, S.T., 1965, Navigation techniques used in the Thresher search: Jour. Inst. Navigation, v. 12, p. 1-10.

Knott, S.T., and Hersey, J.B., 1956, Interpretation of high-resolution echo-sounding techniques and their use in bathymetry, marine geophysics, and biology: Deep-Sea Research, v. 4, no. 1, p. 36-44.

Knott, S.T., and Hoskins, H., 1968, Evidence of Pleistocene events in the structure of the continental shelf off the northeastern United States: Marine Geology, v. 6, p. 5-43.

Kraft, J.C., 1971a, Sedimentary facies patterns and geologic history of a Holocene transgression: Geol. Soc. America Bull., v. 82, p. 2131-2158.

Kraft, J.C, 1971b, A guide to the geology of Delaware's coastal environments: Publ. 26L039, 220pp., College of Marine Studies, Univ. of Delaware, Newark, Del.

Kraft, J.C, and Maisano, M.D., 1968, A geologic cross-section of Delaware showing stratigraphic correlations, distribution and geologic setting with the Atlantic coastal plain - continental shelf geosyncline: Newark, Del., Univ. of Delaware Water Resources Center, 1 sheet.

Kraft, J.C., Sheridan, R.E. and Maisano, M., 1971, Time-stratigraphic units and petroleum entrapment models in Baltimore Canyon basin of Atlantic continental margin geosynclines: Amer. Assoc. Petrol. Geol., v. 55, no. 5, p. 658-679.

Kraft, J.C, Biggs, R.B. and Halsey, S.D., 1973, Morphology and vertical sedimentary sequence models in Holocene transgressive barrier systems: in, Coates, D.R., ed., Coastal geomorphology, Publications in Geomorphology, S.U.N.Y., Binghampton, N.Y., p. 321-354.

Kraft, J.C., R.E. Sheridan, R.D. Moose, R.N. Strom, and C.B. Weil, 1974, Middle-Late Holocene evolution of the morphology of a drowned estuary system--the Delaware Bay. In International Symposium on Interrelationships of Estuarine and Continental Shelf Sedimentation. Inst. Geol. du Bassin D'Aquitaine, July 9-14, 1973, pp. 297-306.

Krause, D.C., and others, 1966, Seismic profile showing Cenozoic development of the New England continental margin: Jour. Geophys. Res., v. 71, no. 18, p. 4327.

Krebs, O.A., 1962, The sediments of the south shore of Long Island Sound, Lloyde Point to Crane Neck Point: Unpub. Masters thesis, New York University.

Krinsley, David, Takahashi, Taro, Silberman, M.L., and Newman, W.S., 1964, Transportation of sand grains along the Atlantic shore of Long Island, New York: Marine Geology, v. 2, nos. 1-2, p. 100-120.

Kumar, N., 1972, Modern and ancient barrier sediments; new interpretations based on stratal sequence in inlet-filling sands and on recognition of nearshore storm deposits: Ph.D. thesis, Dept. Geol., Columbia Univ., N.Y., 180 pp., Published as Annals NY Acad. Sci., v. 220, Art.5, 95pp, 1973.

Kumar, N., 1972, Sand body created by migration of Fire Island Inlet, New York (abstr.): American Assoc. Petrol. Geol., v. 56, no. 3, p. 634.

Kumar, N. and J.E. Sanders, 1970, Are basal transgressive sands chiefly inlet filling sands? Marit. Sediments, 6, 12-14.

Kumar, N., and Sanders, J.E., 1970, Geologic implication of migration of Fire Island Inlet: Geol. Soc. Amer. Programs with Abstracts, v.2, no. 1, p. 27.

Lancelot, Y., Hathaway, J.C., and Hollister, C.D., 1972, 31, Lithology of sediments from the western North Atlantic Leg II Deep Sea Drilling Project, in Kaneps, A.G., sci. ed., Initial reports of the Deep Sea Drilling Project, Volume XI: Washington, D.C., U.S. Govt. Printing Office, p. 901-949.

Langmuir, I., 1925, Surface motion of water induced by the wind, Science, 87: 119-123.

Lavelle, J.W., Gadd, P.E., Han, G.C., Mayer, D.A., Stubblefield, W.L., Swift, D.J.P., R.L. Charnell, H.B. Brashear, F.N. Case, K.W. Haff, and C.W. Kunselman, 1976, Preliminary results of coinsident current meter and sediment transport observations for wintertime conditions on the Long Island inner shelf: Geophysical Res. Letters, v.3, no.2, p. 97-100.

LeGrand, H.E., 1961, Summary of geology of Atlantic Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v.45, no.9, p.1557-1571.

Lewis, K.B., 1971b, Slumping on a continental slope at 1°-4°. Sedimentology, 16, 97-110.

Lidz, L., 1963, Sedimentology of Nantucket Bay, Mass. (Abstr.), American Assoc. Petrol. Geologists, Bull., v. 47, no. 9, p. 1772-1773.

Linderkohl, A., 1885. Geology of the sea-bottom in the approaches to New York Bay. The American Jour. Science, vol. 24, no. 174, pp. 475-480.

Livingstone, D.A., 1964, The pollen flora of submarine sediments from Nantucket Shoals: Am. Jour. Sci. v. 262, no. 4, p. 479-487.

Longuet-Higgins, M.S., 1953, Mass transport in water waves, Phil. Trans. Roy. Soc. London, 245: 535-581.

Lowell, J.D., and Genick, G.J., 1972, Sea-floor spreading and structural evolution of south Red Sea: American Assoc. Petrol. Geol. V. 56, P. 247-259.

Lowrie, Allen, Jr., and B.C. Heezen, 1967, Knoll and sediment drift near Hudson Canyon: Science, v. 157, p. 1552-1553.

Lucke, J.B., 1934, A study of Barnegat Inlet: Shore and Beach, v. 2, no. 2, p. 45-94.

Lyall, A.K., D.J. Stanley, H.N. Giles, and A. Fisher, 1971, Suspended sediment and transport at the shelfbreak and on the slope. Mar. Technol. Soc. J., 5(1), 15-26.

Ludwick, J.C., 1970, Sand waves and tidal channels in the entrance to Chesapeake Bay: Ottawa, Old Dominion Univ. Inst. Oceanog. Tech. Rept. 1, 7p. (multilithed).

Lyall, A.K., D.J. Stanley, H.N. Giles, and A. Fisher, 1971, Suspended sediment and transport at the shelfbreak and on the slope. Mar. Technol. Soc. J., 5(1), 15-26.

MacClintock, P., and Richards, H.G., 1936, Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York: Geol. Soc. America Bull. V. 47, no. 3, p. 289-337.

MacIntyre, I.G. and J.D. Milliman, 1970, Physiographic features on the outer shelf and upper slope, Atlantic continental margin, southeastern United States. Geol. Soc. Am. Bull., 81, 2577-2598.

MacKenzie, M.G., 1967, Environments of deposition on an offshore barrier sandbar, Moriches Inlet, Long Island, N.Y.: Tulane Studies Geology, v. 5, no. 2, p. 67-80.

Maher, J.C., 1965, Correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic coast: Am. Assoc. Petroleum Geologists, Cross Section Pub. 3, 18 p.

Maher, J.C., 1971, Geologic framework and petroleum potential of the Atlantic Coastal plain and continental shelf: U.S. Geol. Sur. Prof. Paper 659, 98 pp.

Maher, J.C. and E.R. Applin, 1971, Geologic framework and petroleum potential of the Atlantic coastal plain and continental shelf: U.S. Geol. Survey Prof. Paper 659, 98 p.

Malloy, R.J. and Harbison, R.N., 1966, Marine geology of the north eastern Gulf of Maine: U.S. Coast and Geodetic Survey Tech. Bull. no. 28, 15 p.

Manheim, F.T., 1965, Manganese iron accumulation in the shallow marine environment: Rhode Island Univ. Narragansett Marine Lab., Occasional Pub. 3-1965, p. 217-276.

Manheim, F.T., 1972, Mineral resources off the Northeastern coast of the United States: U.S. Geol. Survey, circ. 669, 28 pp.

Manheim, F.T., and M.K. Horn, 1968, Composition of deeper subsurface waters along the Atlantic continental margin: Southeastern Geology, v. 9, no. 4, p. 215-236.

Manheim, F.T., Meade, R.H., and Bonet, G.C., 1970, Suspended matter in surface waters of the Atlantic continental margin from Cape Cod to the Florida Keys: Science, v.167, p.371-376.

Marlowe, J.I. and Bartlett, G.A., 1967, Pliocene-Miocene strata in a submarine canyon off Nova Scotia (Abstr): Geol. Soc. America Special Paper 115, p. 487.

Mather, K.F., Goldthwait, R.P., and Thiesmeyer, L.R., 1942, Pleistocene geology of western Cape Cod, Massachusetts: Geol. Soc. America Bull., v. 53, no. 8, p. 1127-1174.

Mattick, R.E. and others, 1973, A preliminary report on U.S. Geological Survey geophysical studies of the Atlantic Outer Continental shelf (abstr.): American Assoc. Petrol. Geol. Easter- Section Tech. Program., Atlantic City, April 1973, Program p. 9.

Mattick, R.E., Foote, R.Q., Weaver, N.L., Grim, M.S., 1974, Structural framework of United States Atlantic outer continental shelf north of Cape Hatteras: American Assoc. Petrol. Geol. Bull., v.58, p. 1179-1190.

May, P.R., 1973, Pattern of Triassic-Jurassic diabase dikes around the North Atlantic in the context of predrift position of the continents: Geol. Soc. America Bull., v. 82, p. 1285-1292.

Mayhew, M.A., 1974a, "Basement" to east coast continental margin of North America: American Assoc. Petrol. Geol. Bull., v.58, p. 1069-1088.

Mayhew, M.A., 1974b, Geophysics of Atlantic North American: in Burk, C.A. and Drake, C.L., Geology of continental margins: New York, Springer-Verlag, p. 409-428.

McCarthy, G.R., 1931, Coastal sands of the eastern United States: Am. Jour. Sci., 5th ser., v. 22, p. 35-50.

McCaslin, J.C., 1976, Significant possibilities line Atlantic shelf: Oil and Gas Jour. v. 74, no. 37, p. 111-114.

McCave, I.N., 1972, Transport and escape of fine-grained sediment from shelf areas. In D.J.P. Swift, D.B. Duane, and O.H. Pilkey, eds., Shelf Sediment Transport: Process and Pattern. Stroudsburg, Pa., Dowden, Hutchinson & Ross, pp. 225-248.

McClelland engineers, 1963. Fathometer survey and foundation investigation Ambrose Light Station, New York Harbor entrance; and Fathometer survey and foundation investigation Scotland Light Station, New York Harbor entrance, Report no. 63-162-1, McClelland Engineers, Houston, Texas.

McClelland, B., 1974, Geologic engineering properties related to construction of offshore facilities on the Mid-Atlantic continental shelf in Marine environmental implications of offshore oil and gas development in the Baltimore Canyon region of the Mid-Atlantic coast: ERF Pap 75-1, p. 217-242.

McClennon, C. E., 1973. New Jersey continental shelf near bottom current meter records and recent sediment activity. vol. 43, pp. 371-380.

McClennen, C.F., 1973, New Jersey continental shelf near bottom current meter records and recent sediment activity: Jour. Sediment. Petrology, v. 43, p. 371-380.

McClennen, C.E. and R.L. McMaster, 1971, Probable Holocene transgressive effects on geomorphic features of the continental shelf off New Jersey, United States. Marit. Sediments, 7, 69-72.

McCormick, C.L., 1973, Probable causes of shoreline recession and advance on the south shore of eastern Long Island: in Coates, D.R., ed., Coastal Geomorphology, Publications in Geomorphology, SUNY, Binghampton, N.Y. p. 63-71.

McCrone, A.W., 1966, The Hudson River estuary: Hydrology sediments and pollution: Geogr. Rev., v. 56, p. 175-189.

McCrone, A.W., 1966a, Sediments from Long Island Sound (New York) -- Physical and chemical properties reviewed: Jour. Sed. Petrology, v. 36, no. 1, p. 234-236.

McCrone, A.W., Ellis, B.F., and Charmatz, R., 1961, Preliminary observations on Long Island Sound sediments: New York Acad. Sci. Trans., ser. 2, v. 24, no. 2, p. 119-129.

McCrone, A.W. and Schafer, C., 1966, Geochemical and sedimentary environments of foraminifera in the Hudson River estuary, New York: Micropaleontology, v. 12, p. 505-509.

McDonald, M.G., and E.S. Katz, 1969, Quantitative method for describing the regional topography of the ocean floor: Jour. Geophys. Research, v. 74, p. 2597-2606.

McGregor, B.A., Keller, G.H. and Bennett, R.H., 1975, Seismic profiles along the U.S. northeast coast continental margin (abstr.): EOS (Am G U Trans) vol. 56, no. 6, p. 382.

McIntire, W.G., and Morgan, J.P., 1963, Recent geomorphic history of Plum Island, Massachusetts and adjacent coasts: Coastal Studies Series 8, Louisiana State Univ. Press, Baton Rouge, 44 pp.

McIver, N.L., 1972, Cenozoic and Mesozoic stratigraphy of the Nova Scotia shelf: Canadian Jour. Earth Sci., v. 9, no. 1, p. 54-70.

McKelvey, V.E., Oil and gas possibilities on the Atlantic outer continental shelf: Interstate Oil Compact Comm., Comm. Bull., v. 16, no. 2, p. 15-22.

McKelvey, V.E. and others, 1969, Subsea mineral resources and problems related to their development: U.S. Geol. Survey circular 619, 26 pp.

McKelvey, V.E., and others, 1969, Potential mineral resources of the United States outer continental shelf, Appendix S-A, in Public Land Law Review Commission, v.4, (appendices): U.S. Dept. of Commerce, PB 188-717, P.5A1-5A117.

McKelvey, V.E. and Wang, F.F.H., 1969, World subsea mineral resources: U.S. Geol. Survey Misc. Ceol. Inv. Map I-632, 4 sheets, 17 pp.

McKinney, T.F. and Friedman, G.M., 1970, Continental shelf sediments of Long Island, New York: Jour. Sed. Petr., v. 40, p. 213-248.

McKinney, T.F., W.L. Stubblefield, and D.J.P. Swift, 1974, Large-scale current lineations on the central New Jersey shelf. Investigations by side scan sonar. Mar. Geol. 17, 79-102.

McMaster, R.L., 1954, Petrography and Genesis of New Jersey beach sands: State of NJ Dept. of Conservation and Economic Development, Geol. Surv. Bull. 63, 239 pp.

McMaster, R.L., 1960, Sediments of Narragansett Bay system and Rhode Island Sound, Rhode Island: Jour. Sed. Petrology, v. 30, no. 2, p. 249-274.

McMaster, R.L., 1962, Petrography and genesis of recent sediments in Narragansett Bay and Rhode Island Sound, Rhode Island: Jour. Sed. Petrology, v. 32, no. 3, p. 484-501.

McMaster, R.L., 1971, A transverse fault on the continental shelf off Rhode Island: Geol. Soc. America Bull. v. 82, p. 2001=2004.

McMaster, R.L., and Garrison, L.E., 1966, Mineralogy and origin of southern New England shelf sediments: Jour. Sed. Petrology, v. 36, no. 4, p. 1131-1142.

McMaster, R. L. and Garrison, L. E., 1967. A submerged Holocene shoreline near Block Island, Rhode Island. Marine Geol., vol. 75, pp. 335-340.

McMaster, R.L., LaChance, T.D. and Garrison, L.E., 1968, Seismic-reflection studies in Block Island and Rhode Island Sounds: American Assoc. Petrol. Geol. Bull. v. 52, no. 3, p. 465-474.

McMaster, R. L. and Ashraf, A., 1973. Drowned and buried valleys on the southern New England continental shelf. Marine Geology, vol. 17, pp. 79-103.

McMaster, R.L., and Ashraf, A., 1973, Subbottom basement drainage system of inner continental shelf off southern New England: Geol. Soc. America Bull., v. 84, p. 187-190.

Meade, R.H., 1969, Landward transport of bottom sediments in estuaries of the Atlantic Coastal Plain: Jour. Geol. Petrol., v. 39, p. 222-234.

Meade, R.H., 1972, Transport and deposition of sediments in estuaries, in, Nelson, B.W., ed., Environmental framework of coastal plain estuaries, Geol. Soc. American Memoir 133, p. 91-120.

Meade, R.H., 1972, Sources and sinks of suspended matter on continental shelves: in, Swift, D.J.P., Duane, D.B., and Pilkey, O.H., eds., Shelf sediment transport: Process and Pattern, Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 249-262.

Meade, R.H. and Emery. K.O., 1971, Sea-level as affected by river runoff, eastern United States: Science v. 173, p. 425-428.

Meade, R.H., Sachs, P.L., Manheim, F.T. and Spencer, D.W., 1970, Suspended matter between Cape Cod and Cape Hatteras: in, Summary of investigations conducted in 1969: Ref. 70-11, 47-49, Woods Hole Oceanographic Institution.

Meade, R.H., Sachs, P.L., Manheim, F.T., Hathaway, J.C., Spencer, D.W., 1975, Sources of suspended matter in waters of the middle Atlantic bight: Jour. Sed. Petr., v. 45, no. 1, p. 171-188.

Menard, H.W., 1955, Deep=sea channels, topography, and sedimentation: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 236-255.

Merrill, A.S., Emery, K.O., and Rubin, Meyer, 1965, Ancient oyster shells on the Atlantic continental shelf: Science, v. 147, p. 398-400.

Middle Atlantic Coastal Fisheries Center, 1972, The effects of waste disposal in the New York bight: Final report to the U.S. Army Corps of Engineers, Nat. Marine Fisheries Service, Sandy Hook Laboratories, Highland, N.J.

Middleton, G.V. and M.A. Hampton, 1973, Sediment gravity flows: Mechanics of flow and deposition. In G.V. Middleton and A. H. Bouma, eds., Turbidites and Deep-Water Sedimentation. SEPM Pacific Section Short Course, Anaheim, pp. 1-38.

Miller, B.J., 1937, Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part 2: Geological significance of the geophysical data: Geol. Soc. America Bull., v. 48, p. 803-812.

Miller, B.M., and others, 1975, Geological estimates of undiscovered recoverable oil and gas resources in the United States: U.S. Geol. Survey Circ. 725, 78 p.

Miller, J.F., and Frederick, R.H., 1969, The precipitation regime of Long Island, New York: U.S. Geol. Surv. Prof. Paper 627-A, 21 p.

Milliman, J.D., 1972, Atlantic continental shelf and slope of the United States - Petrology of the sand fraction of sediments, northern New Jersey to southern Florida: U.S. Geol. Survey Prof. Paper 529J, 40 pp.

Milliman, J.D., 1973. in Coastal and offshore and environmental inventory, Cape Hatteras to Nantucket shoals, complement volume, Saila, S.B., ed.: Univ. Rhode Island. Marine Publ. Ser. 3, pp. 10-1-10-91.

Milliman, J.D. and Emery, K.O., 1968, Sea-level changes during the past 35,000 years: Science, v. 162, p.1121-1123.

Milliman, J.D., O.H. Pilkey, and D.A. Ross, 1972, Sediments of the continental margin off the eastern United States. Geol. Soc. Am. Bull., 83, 1315-1334.

Milne, John, 1897, Sub-oceanic changes: Geog. Journal, v. 10, p. 129-146, 259-289.

Minard, J.P., 1969, Geology of the Sandy Hook Quadrangle in Monmouth County, New Jersey, U.S. Geol. Survey Bull. 1276, 43 pp.

Minard, J.P., and J.P. Owens, 1966, Domes in the Atlantic Coastal Plain east of Trenton, New Jersey, in Geological Survey Research 1966: U.S. Geol. Survey Prof. Paper 550-B, p. B16-B19.

Minard, J.P. and others, 1969, Cretaceous-Tertiary boundary in New Jersey, Delaware and eastern Maryland: U.S. Geol. Survey Bull., 1274-H, P.H1-H33.

Minard, J.P. and others, 1973, Preliminary geologic report on the U.S. northern Atlantic continental margin (abstr): American Assoc. Petrol. Geol. Eastern Section Tech. Program, Atlantic City, April, 1973, Program p. 8.

Minard, J.P., W.J. Perry, E.G.A. Weed, E.C. Rhodehamel, E.I. Robbins, and R.B. Mixon, 1974, Preliminary report on geology along Atlantic continental margin of northeastern United States: Am. Assoc. Petroleum Geologists Bull, v. 58, no. 6, p. 1169-1178.

Molnia, B.F., Carlson, P.R. and Bruns, T.R., 1976, Geologic hazards in the northern Gulf of Alaska (abstr.): GSA Abstr. Prog., v.8, no.3, (Cordillerian Section, 72, ann. meet.), p. 396-397.

Moody, D.W., 1964, Coastal morphology and processes in relation to the development of submarine sand ridges off Bethany Beach, Delaware: doctoral dissert. Johns Hopkins Univ., 167 p.

Moore, D.G., 1961, Submarine slumps: Jour. Sed. Pet., v.31, p. 343-357.

Moore, D.G. and J.R. Curray, 1963, Sedimentary framework of continental terrace off Norfolk, Virginia and Newport, Rhode Island, Am. Assoc. Pet. Geol. Bull., 47, 2051-2054.

Moore, J.R., III, 1963, Bottom sediment studies, Buzzards Bay, Massachusetts: Jour. Sed. Petrology, v. 33, no. 3, p. 511-558.

Morelock, Jack, 1969, Shear strength and stability of continental slope deposits western Gulf of Mexico: Jour. Geophys. Res., v. 74, p. 465-482.

Morgenstern, N.R., 1967, Submarine slumping and the intnation of turbidity currents, in Marine geotechnique, ed., A. Richards, p. 189-220, U. of Ill. Press, Urbana.

Morrow, D.L., Harris, R.L., and Warden, A.S., 1972, Mobil Tetco Sable Island E-48: Well History Report, Mobil Oil, 61 p.

Mota-Oliveira, I.B., 1970, Natural flushing ability in tidal inlets, Proc. 12th Coastal Eng. Conf., Washington, D.C., pp. 1827-1845.

Muller, E.H., 1965, Quaternary geology of New York, in Wright, H.E., Jr., and Frey, D.G., eds., The Quaternary of the United States: Princeton, N.J., Princeton Univ. Press, p. 99-112.

Murray, G.E., 1961, Geology of the Atlantic and Gulf coastal province of North America: New York, Harper and Brothers, 692 pp.

Murray, H.W., 1947, Topography of the Gulf of Maine, field season of 1940: Geol. Soc. America Bull., v. 58, no. 2, p. 153-196.

Murray, S.P., 1970, Bottom currents near the coast during Hurricane Camille, J. Geophys. Res., 75: 4579-4582.

National Petroleum Council, Committee on U.S. Energy Outlook, 1971, U.S. energy outlook: Washington, D.C., v. 1., 75 p., v. 2, 195 p.

National Research Council, Division of Earth Sciences, 1959, Glacial map of the United States east of the Rocky Mountains: New York, Geol. Soc. America, 2 sheets, scale 1:1,750,000 (1 inch=about 28 miles).

Neal, W.J., 1964, Heavy mineral petrology of Wisconsin and post-glacial deep-sea sands and silts, western North Atlantic: Columbia, Mo., Missouri Univ. M.S. thesis, 164 p.

Neiheisel, J., 1973, Source of detrital minerals in estuaries of the Atlantic coastal plain (Ph.D. dissert.): Atlanta, Georgia Inst. Technology, 111p.

Nelson, B.W., 1972, Environmental framework of coastal plain estuaries: Geol. Soc. America Memoir 133, 619 pp.

Neumann, G. and W.J. Pierson, Jr., 1966, Principles of Physical Oceanography, Englewood Cliffs, N.J., Prentice Hall, 545 pp.

Newman, W.S., D.H. Thurber, H.S. Zeiss, Allan Rokach, and Lillian Musich, 1969, Late Quaternary geology of the Hudson River estuary: a preliminary report: New York Acad. Sci. Trans., ser. 2, v. 31, p. 548-570.

Nichols, M.M., 1964, Characteristics of sedimentary environments in Moriches Bay: Chap. 16 in Papers in Marine Geology, Shepard Commemorative vol., Macmillan Co., N.Y., p. 313-383.

Norcross, J.J., and Stanley, E.M., 1967, Inferred surface and bottom drift, June 1963 through October 1964, in Harrison, W., Norcross, J.J., Pore, N.A., and Stanley, E.M., Circulation of shelf water of the Chesapeake Bight: U.S. ESSA Prof. Paper 3, p. 11-42.

Northrup, J., 1951, Ocean bottom photographs of the neritic and bathyal environments south of Cape Cod, Mass.: Geol. Soc. America Bull. Vol. 62, p. 1381-1383.

Northrop, J.M. and B. C. Heezen, 1951. An outcrop of Eocene sediments on the continental slope: Jour. Geology, v. 59, p. 396-399.

Northrop, John, Frosch, R.A., Frassetto, R., and Zeigler, J.M., 1959, The Bermuda-New England seamount chain: Internat. Oceanog. Cong. Am. Assoc. Adv. Sci., preprint, p. 48-49.

Northrop, John, Frosh, R.A., and Frassetto, Roberto, 1962, Bermuda-New England seamount arc: Geol. Soc. America Bull, v. 73, no. 5, p. 587-593.

Nossaman, Waters, Scott, Krueger and Riordan, consultants, 1969, Study of outer continental shelf lands of the United States, v. IV (appendices): Public Land Law Review Commission, U.S. Dept. Inter. - Bur. and Management Pub., p. 5A1-5-77.

Oaks, R.Q.Jr., 1964, Post-Miocene stratigraphy and morphology, outer coastal plain, southeastern Virginia: Office of Naval Research, Tech Report 5, 240 pp.

O'Brien, M.P., 1976, Notes on tidal inlets on sandy shores: US Army, Corps of Engineers, CERC GITI Report 5, 26 pp.

Off, T., 1963, Rythmic linear sand bodies caused by tidal currents: American Assoc. Petrol. Geol. Bull. v. 47, p. 324-341.

Officer, C. B., Jr., and M. Ewing, 1954, Geophysical investigations in the emerged and submerged Atlantic Coastal Plain, Pt. 7, Continental shelf, continental slope, and continental rise south of Nova Scotia: Geol. Soc. America Bull., v. 65, p. 653-670.

Offshore Oil Task Group, 1973, The Georges Bank Petroleum Study: Sea Grant Project Office, Massachusetts Inst. of Tech., 3 vols., Rept. no. 73-5.

Oldale, R.N., and Uchupi, E., 1970, The glaciated shelf off northeastern United States: U.S. Geol. Survey Prof. Paper 700-B, p. B167-B173.

Oldale, R.N., E. Uchupi, and K. E. Prada, 1973, Sedimentary framework of the western Gulf of Maine and the southeastern Massachusetts offshore area: U.S. Geol. Survey Prof. Paper 757, 10p.

Oldale, R.N., 1969, Seismic investigations on Cape Cod, Martha's Vineyard, and Nantucket and a topographic map of the basement surface from Cape Cod Bay to the Islands: U.S. Geol. Survey Prof. Paper 650-B, p. B122-127.

Oldale, R.N., and Tuttle, C.R., 1964, Seismic investigations on Cape Cod, Massachusetts: U.S. Geol. Survey Prof. Paper 475-D, p. D-118-122.

Oldale, R. N. and others, 1974. Geophysical observations on northern part of Georges Bank and adjacent basins of Gulf of Maine. American Assoc. Petrol. Geol. Bull., vol. 58, pp. 2411-2427.

Oliver, J.E. and Drake, C.L., 1951, Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part VI, The Long Island area: Geol. Soc. America v. 62, p. 1287-1296.

Oliver, J.E., Johnson, T., Dorman, J., 1970, Postglacial faulting and seismicity in New York and Quebec: Canadian Jour. Earth Sci., v. 7, p. 579-590.

Oliver, J.E., Isecks, B.L., and Barazangi, M., 1974, Seismicity at continental margins: in, Burk, C.A., and Drake, C.L., eds., The geology of continental margins, Springer-Verlag, New York, p. 85-92.

Olson, W.S., 1974, Structural history and oil potential of offshore area from Cape Hatteras to Bahamas: AAPG, v. 58, no. 6, pt. II, p. 1191-1200.

Onuschak, E., Jr., 1972, Deep test in Accomack County, Virginia: Charlottesville, Va., Virginia Minerals, v. 18, no. 1, p 1-4.

Oser, R.K., 1969, Bottom environmental oceanographic data report, Hudson Canyon area, 1967: Informal Report no. 69-8, U.S. Naval Oceanographic Office, Washington, D.C.

Otvos, E., G., Jr., 1977, Post-Pleistocene history of the United States inner continental shelf: Significance to origin of barrier islands: Discussion and Reply: Discussion (Otvos), Geol. Soc. America Bull. Vol. 88, p. 734-735, Reply (Field and Duane) p. 735-736.

Overbeck, R.M., 1948, Maryland Esso No.1 well, Standard Oil Company of New Jersey, Ocean City, Maryland, description of ditch samples: in Anderson, J.L., Cretaceo s and Tertiary subsurface geology (Md.); Maryland Dept. of Geology, Mines and Water Resources Bull.2, p. 428-440.

Owens, J.P., 1969, Coastal plain rocks of Harford County in The geology of Harford County: Baltimore, Md., Maryland Geol. Survey, P. 77-103, 123-127.

Owens, J.P., 1970, Post Triassic tectonic 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., and Weaver, K.N., eds., Studies of Appalachian geology, central and southern: New York, Interscience Publishers, p. 417-427.

Owen, D.M., and K.O. Emery, and L.D. Hoadley, 1967, Effects of tidal currents on the sea floor shown by underwater time-lapse photography, in J.B. Hersey, ed., Deep-sea photography: Baltimore, Johns Hopkins Press, p. 159-166.

Owens, J.P., Minard, J.P., and Sohl, N.F., 1968, Cretaceous deltas in the Northern New Jersey coastal plain: in Finks, R.M., ed., Guidebook to field excursions, N.Y. State Geological Assoc., 40th Ann Mtg., Flushing, N.Y., May, 1968, p. 31-48.

Owens, J.P., and N.F. Sohl, 1969, Shelf and deltaic paleoenvironments in the Cretaceous-Tertiary formations of the New Jersey Coastal Plain, Field trip no. 2 in Geology of selected areas in New Jersey and eastern Pennsylvania and guidebook of excursions, Geol. Soc. America, Ann. Mtg. Atlantic City, New Jersey, 1969: New Brunswick, New Jersey, Rutgers Univ. Press, p. 235-278.

Owens, J.P. and others, 1970, Stratigraphy of the outcropping Post-Magothy Upper Cretaceous formations in Southern New and Northern Delmarva Peninsula, Delaware and Maryland: U.S. Geol. Survey Prof. Paper 674, 60 pp.

Pann F.L., 1965, Lower Hudson River siltation: in, Proceedings of the Federal inter-agency sedimentation conference: Agricultural Research Service, Misc. Pub. 970, p. 512-550.

Pararas-Carayannis, G., 1973, Ocean dumping in the New York bight: An assessment of environmental studies: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Tech. Mem. 39, pp.

Parker, F.L., 1948, Foraminifera of the continental shelf from the Gulf of Maine to Maryland: Harvard Univ. Mus. Comp. Zoology Bull., v. 100, p. 211-241.

Parker, F.L., 1952b, Foraminiferal distribution in the Long Island-Buzzards Bay area: Harvard Univ. Mus. Comp. Zoology Bull., v. 106, no.10, p. 428-473.

Parsons, H. de B., 1913, Tidal phenomena in the harbor of New York: Pro. Am. Soc. Civil Eng., v. 39, p. 653-767.

Patton, R.S., 1924, Problems involved in coast erosion: Milit. Eng., v. 16, no. 90, p. 458-463.

Patton, R.S., 1931, Moriches Inlet: A problem in beach evolution: Geogr. Rev., v. 21, p. 627-632.

Pautot, G.J.M. Auzende, and X. Le Pichon, 1970, Continuous deep sea salt layer along North Atlantic margins related to early phase of rifting: Nature, v. 227, no. 5256, p. 351-354.

Payne, L. H., 1970. Sediments and morphology of the continental shelf off southeast Virginia. Ph.D. thesis, Colubmia Univ., New York, 70 pp.

Pearce, J.B., 1969, The effects of waste disposal on the New York bight, Interim Report for Jan. 1, 1970: Sandy Hook Marine Laboratory, U.S. Bureau of Sport Fisheries and Wildlife, Sandy Hook, N.J., 103 p.

Pearce, J.B., 1970, The effects of solid waste disposal on benthic communities in the New York bight: Food and Agriculture Organization of the United Nations Technical Conference on Marine Pollution and its effects on Living Resources and Fishing, Dec. 9-18, 1970, Rome, Italy, Paper FIR: MP/70/E-99.

Perlmutter, N.M., and Todd, R., 1965, Correlation and foarninifera of the Monmouth Group (Upper Cretaceous), Long Island, N.Y.: U.S. Geol. Survey Prof. Paper 483-I, PI1-I24.

Perry, W.J., Minard, J.P., Weed, E.G.A., Robbins, E.I., and Rhodehamel, E.C., 1974, Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras, a brief survey: U.S. Geol. Survey Open File Rept. 1974, 51 p.

Also in: American Assoc. Petrol. Geol. Bull. v.59, p.1529-1548.

Perry, W.J. and others, 1975, Stratigraphy of the Atlantic continental margin of the United States north of Cape Hatteras - brief survey: American Assoc. of Petrol. Geol. Bull. v. 59, p. 1529-1548.

Petters, S.W., 1976, Upper Cretaceous subsurface stratigraphy of Atlantic coastal plain of New Jersey: AAPG, v. 60, p. 87-107.

Pierce, J.W., 1970, Tidal inlets and washover fans: Jour. Geology, v. 78, p. 230-234.

Pilkey, O.H. and M.E. Field, 1972, Onshore transportation of continental shelf sediment: Atlantic southeastern United States. In Shelf Sediment Transport: Process and Pattern, Stroudsburg, Pa., Dowden, Hutchinson & Ross, pp. 424-446.

Postma , H., 1967, Sediment transport and sedimentation in the marine environment, In. G.H. Lauff, ed., Estuaries, Washington, D.C., Am. Assoc. Adv. Sci., pp. 158-180.

Pourtales, L.F., 1872, The characteristics of the Atlantic sea bottom off the coast of the United States: U.S. Coast and Geodetic Survey Rept. Superintendent *** for 1869, app. 11, p. 220-225.

Pratt, R.M., 1967, The seaward extension of submarine canyons off the northeast coast of the United States: Deep-Sea Research, v. 14, no. 4, p. 409-420.

Pratt, R.M., 1968, Atlantic continental shelf and slope of the United States physiography and sediments of the deep-sea basin: U.S. Geological Survey Prof. Paper 529-B, 44pp.

Pratt, R.M., and Schlee, John, 1970, Glaciation on the continental margin off New England: Geol. Soc. America Bull., v. 80, p. 2335-2341.

Press, F. and Beckmann, W.C., 1954, Geophysical investigations in the emerged and submerged Atlantic coastal plain, Part 8; Grand Banks and adjacent shelves: Geol. Soc. America Bull., v. 65, p. 299-314.

Price, W.A., 1955, Correlation of Shoreline Type with Offshore bottom conditions, Dept. of Oceanography, Texas A&M University, Project 65: 75-107.

Rabinowitz, P.D., 1973, The continental margin of the northwest Atlantic Ocean: A geophysical study: Ph.D. thesis, Columbia Univ.

Rainnie, W.O., Jr. and C.L. Buchanan, 1969, Recovery of the DSRV 'Alvin': Ocean Industry, v. 4, no. 11, p. 61-63, no. 12, p. 69-70.

Rankin, J.K., 1952, Development of the New Jersey shore: Confer. Coastal Engr., 3rd., Proc., P. 306-317.

Redfield, A.C, 1950, The analysis of tidal phenomena in narrow embayments: Mass. Instit. of Tech. and Woods Hole Oceanographic Inst., Papers in Phys. Oceanogr. and Meteorology, v. 11, no. 4.

Redfield, A. C., 1956. The influence of the continental shelf on the tides of the Atlantic coast of the United States. Jour. Marine Research, vol. 17, pp. 432-448.

Renard, V. and Mascle, J., 1974, Eastern Atlantic continental margins-various structural and morphologic types: in, Burk, C.A., and Drake, C.L., eds., The geology of continental margins, Springer-Verlag, New York, p. 285-291.

Rexworthy, S.R., 1968, The sand and gravel industry of the United States of America with special reference to exploiting the deposits offshore the eastern seabords: Unpub. rept. for Ocean Mining Aktiengesell., 48 p.

Reynolds, K.C., 1951, Report on tidal entrances: U.S. Army Beach Erosion Board, Unpubl. Rept., 18 pp.

Richards, H.G., 1945, Subsurface stratigraphy of Atlantic coastal plain between New Jersey and Georgia: American Assoc. of Petrol. Geol., v. 29, p. 858-995.

Richards, H.G., 1948, Studies of the subsurface geology and Paleontology of the Atlantic coastal plain: Acad. Nat. Sci., Phila., Proc., v. 100, p. 39-76.

Richards, H.G., Olmstead, F.H. and Rukle, J.L., 1962, Generalized structure contour maps of the New Jersey coastal plain: New Jersey Geol. Survey Geol. Rept. Ser., no. 4, 38 pp.

Richards, H.G., 1967, Stratigraphy of Atlantic coastal plain between Long Island and Georgia - Review: American Assoc. Petrol. Geol. Bull. v. 51, p. 2400-2429.

Richards, H.G., and Eberhard Werner, 1964, Invertebrate fossils from cores from the continental shelf off New Jersey: Acad. Nat. Sci. Philadelphia, Notulae Naturae, no. 372, p. 1-7.

Richards, A.F., Palmer, H.D. and Perlow, M., 1975, Review of continental shelf marine geotechnics; distribution of soils, measurement of properties and environmental hazards: Mar. Geotechnology, v. I, no. I, p. 33-67.

Riley, G.A., 1952, Hydrography of Long Island and Block Island Sounds: Bingham Oceanographic Collection Bull. 12, p. 5-39, Peabody Museum, Yale University.

Riley, G.A., 1956, Oceanography of Long Island Sound: 1952-1954, II, physical oceanography: Bingham Oceanographic Collection, Bull. 15, p. 15-46, Peabody Museum, Yale University.

Roberson, M.I., 1964, Continuous seismic profiler survey of Oceanographer, Gilbert, and Lydonia submarine canyons, Georges Bank: Jour. Geophys. Research, v. 69, no. 22, p. 4771-4789.

Rockwell, C., 1961, Recent sedimentation in Great South Bay, Long Island, New York (Abstr.): Special Paper 68, Geol. Soc. America, p. 254.

Rogers, W.B., 1970, Resume of investigations of the marine geology in the environs of Long Island, New York: New York State Geological Surv., State Museum and Sci. Serv., Open File Report, 11 pp.

Rogers, W.B., Fakundiny, R.M. and Kreidler, W.L., 1973, Petroleum exploration offshore from New York: N.Y. State Museum and Science Service, circular 46, 25 pp.

Rona, P.A., 1965, Middle Atlantic continental slope of the United States; deposition and erosion: American Assoc. Petrol. Geol. Bull., v. 53, p. 1453-1465.

Rona, P.A., 1969b, Linear "lower continental rise hills" off Cape Hatteras: Jour. Sed. Petrology, v. 39, p. 1132-1141.

Rona, P.A., 1973, Relations between rates of sediment accumulation on continental shelves, sea floor spreading, and estuary inferred from the central North Atlantic: Geol. Soc. America Bull, v. 84, p. 2851-2872.

Rona, P.A., E.D. Schneider, and B.C. Heezen, 1967, Bathymetry of the continental rise off Cape Hatteras: Deep-Sea Research, v. 14, p. 625-633.

Rona, P.A., and C.S. Clay, 1967, Stratigraphy and structure along a continuous seismic reflection profile from Cape Hatteras, North Carolina to the Bermuda Rise: Jour. Geophys. Research, v. 72, p. 2107-2130.

Ross, D.A., 1967, Heavy mineral assemblages in the nearshore surface sediments of the Gulf of Maine in Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575-C, p. C77-C80.

Ross, D.A., 1968b, Geological observations from Alvin: Woods Hole Oceanog. Inst. Ref. No. 69-13, p. 71-72.

Ross, D.A., 1969, Heavy minerals of the continental margin from southern Nova Scotia to northern New Jersey: U.S. Geol. Surv. Prof. Paper 529-G, in press.

Ross, D.A., 1970, Source and dispersion of surface sediments in the Gulf of Maine-Georges Bank area: Jour. Sed. Petrology.

Ross, D.A., 1970, Atlantic continental shelf and slope of the United States-heavy minerals of the continental margin from southern Nova Scotia to northern New Jersey: U.S. Geol. Survey Prof. Paper 529-G, 40 pp.

Rouse, J.T., 1971, Possible future petroleum potential of Atlantic Coastal Plain, Peninsular Florida, and adjacent Continental Shelves-Region 11, in Cram, I.H., Sr. ed., Future petroleum provinces of the United States-their geology and potential: Am. Assoc. Petroleum Geologists Mem. 15, v. 2,p. 1291-1294.

Ruzyla, K., 1973, Effects of erosion on barrier-island morphology Fire Island, New York: in Coates, D.R., ed., Coastal Geomorphology, Publications in Geomorphology, SUNY, Binghamton, N.Y., p. 219-237.

Rvachev, V.D., 1964, Relief and bottom deposits at Georges Bank and Banquereau, in Materialy rybokhozyaystvennykh issledevanii severngo basseyna (polarnyi mauchnoissledevatelskiy i proyektnyi): Murmansk, Inst. Morskogo Rybnogo Khozyaystva i Okconografii "Pinro," v. 2, no. 2, p. 78-87.

Rvachev, V.D., 1965, Topographic relief and bottom sediments of the Georges and Banquereau Banks (translated from 1964 Russian pub. by E.R. Hopel): Canada Defence Research Board Directorate Sci. Inf. Services Rept. T 436 R, 7 p.

Sager, R.A., and Hollyfield, N.W., 1974, Navigation Channel improvements, Barnegat Inlet, New Jersey: U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Tech. Rept. H-74-1, Vicksburg, Mass., 44 pp.

Sanders, J.E., 1970, Coastal zone geology and its relationship to water pollution problems: in Johnson, A.A., ed., Water pollution in the greater New York area: Gordon and Breach, New York, p. 23-35.

Sanders, J.E., and others, 1969, Microtopograph of five small areas of the continental shelf by side-scanning sonar: Geol. Soc. Amer. Bull., v. 80, p. 561-572, 8 figs. 7 pls.

Sanders, J.E. and others, 1970, Shelf edge carbonates: Anomolies to conventional ideas relating Quaternary climates and sea levels: in Abstracts with programs for 1970, pt. 1, Northeast Sect., Geol. Soc. American, p. 34.

Sanders, J.E., and Kumar, N., 1971, Washover erosion-important process in creating bays of digitate spit, Democrat Point, Fire Island, L.I., New York (abstr.): Geol. Soc. America, N.E. Section, Hartford, Conn., p. 53-54.

Sanders, J.E., and Kumar, N., 1975, Holocene shoestring sand on inner continental shelf off Long Island, New York: AAPG, v. 59, no. 9, p. 1549-1961.

Saville, T., 1960, Sand transfer, beach control and inlet improvements, Fire Island Inlet to Jones Beach, New York: Proceedings, 7th Conference Coastal Engineering, p. 785-807.

Sbar, M.L., and Sykes, L.R., 1973, Contemporary compressive stress and seismicity in eastern North America: An example of intra-plate tectonics: Geol. Soc. American Bull., v. 84, p. 1861-1882.

Schafer, Charles, 1963?, Sediments of the Smithtown Bay area Long Island, New York (title not accurate): Unpub. Ph.D. thesis, New York University.

Schafer, J.P., 1961, Correlation of end moraines in southern Rhode Island: U.S. Geol. Surv.Prov. Paper 424-D, p. D68-70.

Schafer, J.P., and Hartshorn, J.H., 1965, The Quaternary of New England, in Wright, H.E., Jr., and Frey, D.G., eds., The Quaternary of the United States: Princeton, N.J., Princeton Univ. Press, p. 113-128.

Schaffel, S., 1971, Reconstruction of late glacial and post-glacial events in Long Island Sound, New York: Ph.D. dissertation, N.Y.U., New York,

Schlee, J., 1964, New Jersey offshore gravel deposit: Pit and Quarry, v. 57, no. 6, p. 80-81, 95.

Schlee, J., 1968, Sand and gravel on the continental shelf off the northeastern United States: U.S. Geol. Surv. Circular 602, 9 p.

Schlee, J., 1973, Atlantic continental shelf and slope of the United States-sediment texture of the northeastern part: U.S. Geol. Survey Prof. Paper 529-L, 68 pp.

Schlee, J.S., and Pratt, R.M., 1966, Glacial history of the Gulf of Maine (abs.): Am. Assoc. Adv. Sci., Ann. Mtg., Sec. E, Geology and Geography, Program, p. 32.

Schlee, J and Chaetham, A.H., 1967, Rocks of Eocene age on Fippennies Ledge, Gulf of Maine: Geol. Soc. America Bull., v. 78, p. 681-684.

Schlee, J. and Pratt, R., 1970. Atlantic continental shelf and slope of the United States - Gravels of the Northeastern Part: U.S. Geological Survey Prof. Paper 529-H, 39 pp.

Schlee, J. Folger, D.W. and O'Hara, C.J., 1973, Bottom sediments on the continental shelf of northeastern United States; Cape Cod to Cape Ann, Massachusetts: U.S. Geol. Survey Misc. Geol. Inv. Map I-746.

Schlee, J. and others, 1975, Sediments structural framework, petroleum potential, environmental conditions and operational considerations of the United States North Atlantic outer continental shelf: U.S. Geol. Survey Open-File Report 75-353, 179 pp.

Schlee, J., and others, 1976, Regional geologic framework off northeastern United States: American Assoc. of Petrol. Geol. Bull. v. 60, p. 926-951.

Schneider, E.D., 1969, The evolution of the continental margins and possible long term economic resources: Soc. Petroleum Engineers AIME, Offshore Technol. Conf., preprints, Houston, Tex., p. 257-264.

Schneider, E.D., Fox, P.J., Hollister, C.D., Needham, H.D., and Heezen, B.C., 1967, Further evidence of contour currents in the Western North Atlantic: Earth and Planetary Sci. Letters, v. 2, p. 351-359.

Schopf, T.J.M., 1968. Atlantic continental shelf and slopes of the United States--Nineteenth Century Exploration. U.S. Geol. Survey, Prof. paper 529-F, 12 pp.

Schopf, T.J.M., 1967, Bottom-water temperatures on the continental shelf off New England, in Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575-D, D192-D197.

Schroeder, E.H., 1963, North Atlantic temperatures at a depth of 200 meters: Am. Geog. Soc., Serial Atlas of the Marine Environment, Folio 2, 11p. 9pls.

Schroeder, E.H., 1966, Average surface temperatures of the western North Atlantic: Bull. Marine Sci., v. 16, no. 2, p. 302-323.

Schubel, J.R., and others, 1971, The estuarine environment: Estuaries and estuarine sedimentation: Am. Geol. Inst. Short Course Lecture Notes, October, 1971, American Geol. Inst., Washington, D.C.

Schubel, J.R., and Akira, O., 1972, Comments on the dispersal of suspended sediment across the continental shelves: in Swift, D.J.P., Duane, D.B. and Pilkey, O.H., eds., Shelf sediment transport: process and pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 333-346.

Schultz, L.K., and R.L. Grover, 1974, Geology of Georges Bank basin: Am. Assoc. Petroleum Geologists Bull., v. 58, no. 6, p.1159-1168.

Schwartz, M.L., 1973, Barrier Islands, Stroudsburg, Pa., Dowden, Hutchinson & Ross, 451 pp.

Scott, K.R. and Cole, J.M., 1975, Atlantic margin looks favorable: Oil and Gas Journal, v. 73, no. 1, p. 95-99.

Seaber, P.R. and Vecchioli, J., 1963, Stratigraphic section at Island Beach State Park, New Jersey: U.S. Geol. Survey Prof. Paper 475B, P.B.102-B.105.

Shaler, N.S., 1893, The geological history of harbors: U.S. Geol. Survey Ann. Report, v. 13, pt. 2, p. 93-209.

Shepard, F.P., 1928, Significance of submerged deltas in the interpretation of the continental shelves: Geol. Soc. America Bull., v. 39, p. 1157-1170.

Shepard, F.P., 1932, Sediments on the continental shelves: Geol. Soc. America Bull. v. 43, p. 1017-1039

Shepard, F.P., 1934, Canyons off the New England coast: Am. Jour. Sci., 5th ser., v. 27, p. 24-36.

Shepard, F.P., 1963, Thirty-five thousand years of sea level, in Essays in marine geology in honor of K.O. Emery: Los Angeles, Calif., California Univ. Press, p. 1-10.

Shepard, F.P., 1965, Submarine canyons explored by Cousteau's Diving Saucer. In W.F. Whittard and R. Bradshaw, eds., Submarine Geol. and Geophysics, London, Butterworths, pp. 303-311.

Shepard, F. P., 1973. Submarine Geology: Harper Row, New York, N.Y., 517 pp. 3rd edition. Describes continental terraces: Gulf of Maine and Georges Bank, pp. 204-209; Nantucket Island to Cape Hatteras, pp. 209-212.

Shepard, F. P. and Cohee, G. V., 1936. Continental shelf sediments off the mid-Atlantic states. Geol. Soc. America Bull., vol. 47, pp. 441-457.

Shepard, F.P. and R.F. Dill, 1965, Submarine Canyons and Other Sea Valleys, Chicago, Rand McNally, 381 pp.

Sheridan, R.E., 1974, Conceptual model for the block-fault origin of the North American Atlantic Continental Margin geosycline: Geology, v. 2, no. 9, p. 465-468.

Sheridan, R.E., 1974, Preliminary report on a geophysical study of a dome structure on the Atlantic outer continental shelf east of Delaware: Geol. Soc. America Abstracts with Programs, v. 6, no. 7, p. 952.

Sheridan, R.E., 1974, Atlantic continental margin of North America: in Burk, C.A. and Drake, C.L., Geology of continental margins: New York, Springer-Verlag, p. 391-407.

Sheridan, R.E., 1975, Dome structure, Atlantic OCS east of Delaware; preliminary Geophysical Report: American Assoc. Petrol., Geologists, v. 59, no. 7, p. 1203-1211.

Sheridan, R.E., 1976, Sedimentary basins of the Atlantic margin of North America: Tectonophysics, v. 36, no. 1-3, p. 113-132.

Sheridan, R.E., C.E. Dill, Jr. and J.C. Kraft, 1974, Holocene sedimentary environment of the Atlantic inner shelf off Delaware. Geol. Soc. Am. Bull, 85, 1319-1328.

Sheridan, R.E. and Brown. P.M., 1975, Geologic history of basement fault motions in the Baltimore Canyon trough correlated with North Atlantic sea-floor spreading (Abstr.): E.O.S. (Am. Geophys. Union Trans.), v. 56, p. 451.

Sheridan, R.E. and Knebel, H.J., 1976, Evidence of post-Pleistocene faults on New Jersey Atlantic outer continental shelf: American Assoc. Petrol. Geologists, v. 60, no. 7, p. 1112-1117.

Shideler, G.L. and D.J.P. Swift, 1972, Seismic reconnaissance of post-Miocene deposits, Middle Atlantic continental shelf-Cape Henry, Virginia to Cape Hatteras, North Carolina. Mar. Geol., 12, 165-185.

Shideler, G.L., D.J.P. Swift, G.H. Johnson, and B.W. Holliday, 1972, Late Quaternary stratigraphy of the inner Virginia continental shelf: A proposed standard section. Geol. Soc. Am. Bull., 83, 1787-1804.

Shinohara, K. and others, 1958, Sand transport along a model sandy beach by wave action: Reports of Res. Inst. for App. Mech., v. 6, no. 21, p. 1-47.

Sharp, J.J., 1969, Spread of buoyant jets at the free surface: Proc. Am. Soc. Civil Eng. Jour. Hydr. Div. No. HY3, p.811-825.

Simmons, H.B. and Lindner, C.P., 1965, Hydraulic model studies of tidal waterway problems: Rept. No. 3, U.S. Army Committee on Tidal Hydraulics, Corps of Engineers., P. IX-1-21.

Sirkin, L.A., 1974, Palynology and stratigraphy of Cretaceous strata in Long Island, N.Y., and Block Island, R.I.: U.S. Geol. Survey Jour. Research v.2, p. 431-440.

Smith, H.A., 1975, What is the geology of West Sable structure?: Oil and Gas Jour., June 2, 1975, p. 170-172.

Smith, J.D., 1969, Geomorphology of a sand ridge. J. Geol., 77, 39-55.

Smith, M.C., 1963, The Long Island Sound sub-bottom topography in the area between 73°00' W and 73°30' W: New York, Columbia Univ., Fac. Pure Sci., unpub. M.S. thesis, 25 p.

Smith, R.A., Slack, J.R. and Davis, R.K., 1976. An oil spill risk analysis for the mid-Atlantic outer continental shelf lease area. U.S. Geol. Survey open-file report 76-451. 24 p.

Smith, R.S., 1977, Proper design helps prevent offshore platform catastrophic hazards: Oil and Gas Jour. v. 75, no. 5, p. 154

Smith, W.E.T., 1962, Earthquakes of eastern Canada and adjacent areas, 1534-1927: Dominion Observatory Ottawa Pubs., v. 26, p. 271.

Smith, W.E.T., 1966, Earthquakes of eastern Canada and adjacent areas, 1928-1959: Dominion Observatory Ottawa Pubs., v. 32, p. 87.

Sohl, N.F. and Mello, J.F., 1970, Biostratigraphic analysis: in Owens, J.P. and others, Stratigraphy of outcropping post-Magothy Upper Cretaceous formations in southern New Jersey and northern Delmarva Peninsula, Delaware and Maryland: U.S. Geol. Survey Prof. Paper f74, p. 28-55.

Soren, J., 1971, Results of subsurface exploration in the mid-island area of western Suffolk County, Long Island, New York: U.S. Geol. Survey, Long Island Water Resources Bull. 1, 60 pp.

Southard, J.B., and Stanley, D.J., 1976. Shelf-break processes and sedimentation: in Stanley, D.J., and Swift, D.J.P., 1976. Marine sediment transport and environmental management. J. Wiley and Sons, N.Y. pp. 351-377.

Spangler, W.B. and Peterson, J.J., 1950, Geology of Atlantic coastal plain in New Jersey, Delaware, Maryland and Virginia: America Assoc. Petrol. Geol. Bull. v. 34, p. 1-99.

Spinner, G.P., 1969, The wildlife wetlands and shellfish areas of the Atlantic coastal zone; Am. Geogr. Soc. Serial Atlas of the Marine Environment, Folio 18.

Spivak, J. and Sheburne, O.B., 1971, Future hydrocarbon potential of Atlantic coastal province: in Cram, I.H., ed., Future petroleum provinces of the United States-their geology and potential: American Assoc. Petrol. Geol. Memoir. 15, v. 2, p. 1295-1310; 1342-1345.

Spoljaric, N., 1972, Upper Cretaceous marine transgression in northern Delaware: Southeastern Geology, v. 14, no. 1, p. 25-37.

Stahl, L., J. Koczan, and D. Swift, 1974, Anatomy of a shoreface-connected ridge system on the New Jersey shelf, Implications for genesis of the shelf surficial sand sheet, Geology, 2: 117-120.

Stanley, D.J., 1967, Comparing patterns of sedimentation in some modern and ancient submarine canyons. Earth Planet. Sci. Lett., 3, 371-380.

Stanley, D.J., 1969, Sedimentation in slope and base-of-slope environments (Lecture8), In D.J. Stanley, ed., The New Concepts of Continental Margin Sedimentation. AGI Short Course Notes, Am. Geol. Inst., Washington, D.C., pp. DJS-8-1 to DJS-8-25.

Stanley, D.J., 1969, Atlantic continental shelf and slope of the United States-color of marine sediments: U.S. Geol. Survey Prof. Paper 529-D, 15 pp.

Stanley, D.J., ed. (1969). The New Concepts of Continental Margin Sedimentation. Washington, D.C., Am. Geol. Inst. 400 pp.

Stanley, D.J., 1974, Pebbly mud transport in the head of Wilmington Canyon. Mar. Geol. 16, M1-M8.

Stanley, D.J. and Fenner, P., 1973 ,An underwater television survey of the outer continental shelf and head of Wilmington Canyon: Contributions to the Earth Sciences, Smithsonian Inst. Press, Washington, D.C.

Stanley, D.J., D.J.P. Swift, and H.G. Richards, 1967, Fossiliferous concretions on Georges Bank. J. Sediment. Petrol., 37, 1070-1083.

Stanley, D.J. and Kelling, G., 1968, Photographic investigation of sediment texture, bottom current activity and benthonic organisms in the Wilmington Submarine Canyon: U.S. Coast Guard Oceanogr. Rept. 22, 95 pp.

Stanley, D.J., and Kelling, G., 1968, Sedimentation patterns in the Wilmington submarine canyon area, in Ocean sciences and engineering of the Atlantic Shelf: Marine Technology Soc., Fourth Ann. MTS Conf. and Exhibit, 1968, Trans., p. 127-142.

Stanley, D.J., H. Sheng, and C.P. Pedraza, 1971, Lower continental rise east of Middle Atlantic States: Predominant dispersal perpendicular to isobaths. Geol. Soc. Am. Bull, 82, 1831-1840.

Stanley, D.J. and N. Silverberg, 1968, Recent slumping on the continental slope off Sable Island Bank, southeast Canada. Earth Planet. Sci. Lett., 6, 123-133.

Stanley, D.J., and Norman Silverberg, 1969, Recent slumping on the continental slope off Sable Island Bank, southeast Canada: Earth Planet. Sci. Letters, v. 6, p. 123-133.

Stanley, D.J. and G. Kelling, 1969, Photographic investigation of sediment texture, bottom current activity, and benthonic organisms in the Wilmington Submarine Canyon. U.S. Coast Guard Oceanogr. Rep., 22, 1-95.

Stanley, D.J. and G. Kelling, 1970, Interpretation of a levee-like ridge and associated features, Wilmington submarine canyon, eastern United States. Geol. Soc. Am. Bull., 81, 3747-3752.

Stanley, D.J., D.J.P. Swift, N. Silverberg, N.P. James, and R.G. Sutton, 1972b, Late Quaternary progradation and sand spillover on the outer continental margin off Nova Scotia, Southeast Canada. Smithsonian Contrib. Earth Sci., 8, 88 pp.

Stanley, D.J., Fenner, P. and Kelling, G., 1972, Currents and sediment transport at the Wilmington Canyon shelfbreak, as observed by underwater television: in Swift, D.J.P., Duane, D.B. and Pilkey, O.H., eds., Shelf sediment transport, process and pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 621-644.

Stanley, D.J. and Swift, D.J.P., 1976, Marine sediment transport and environmental management: John Wiley and Sons, Inc., New York

Stearns, F., 1967, Bathymetric maps of the New York Bight, Atlantic continental shelf of the United States, Scale 1:125000. National Ocean Survey, National Oceanic and Atmospheric Administration, Rockville, Md. (contour interval- 1 fm.)

Stearns, F., 1969. Bathymetric maps and geomorphology of the middle Atlantic continental shelf. Fishery Bulletin, vol. 68, no. 1, pp. 37-66.

Stearns, Franklin, and L.E. Garrison, 1967, Bathymetric charts Cape Cod to Maryland: Washington, D.C., Environmental Science Services Administration and U.S. Bureau Commercial Fisheries, scale 1:125,000, 15 sheets.

Stephenson, L.W., 1936, Geology and paleontology of the Georges Bank canyon. Pt. 11, Upper Cretaceous fossils from Georges Bank (including species from Banquereau, Nova Scotia): Geol. Soc. America Bull., v. 47, p. 367-410.

Stetson, H.C., 1935, Marine erosion of glacial deposits in Massachusetts Bay: Jour. Sed. Petrology, v. 5, no. 1, p. 40-51.

Stetson, H.C., 1936, Geology and Paleontology of Georges Bank Canyons; Part 1, Geology: Geol. Soc. America Bull., v. 47, p. 339-366.

Stetson, H.C., 1937, Current measurements in the Georges Bank canyons: Am. Geophys. Union Trans., 18th Ann. Mtg., July 1937, p. 216-219.

Stetson, H.C., 1934, The origin and limits of a zone of rounded quartz sand off the southern New England coast: Jour. Sed. Petrology, v. 4, no. 3, p. 152-153.

Stetson, H.C., 1938, The sediments of the continental shelf off the eastern coast of the United States: Mass. Instit. of Tech. and Woods Holoe Oceanographic Inst. Papers in Physical Oceanography and Meteorology, v. 5, no. 4, p. 48.

Stetson, H.C., 1939, Summary of sedimentary conditions on the continental shelf off the east coast of United States, in Trask, P.D., ed., Recent marine sediments, a symposium: Tulsa, Am. Assoc. Petroleum Geologists, p. 230-244.

Stetson, H.C., 1949, The sediments and stratigraphy of the east coast continental margin, Georges Bank to Norfolk Canyon: Mass. Inst. Tech. and Woods Hole Oceanog. Inst. Papers Phys. Oceanog. and Meteorology, v. 11, no. 2, 00 pp.

Stewart, H.B., Jr. and G.F. Jordan, 1964, Underwater sand ridges on Georges Shoal, in R.L. Miller, ed., Papers in marine geology, Shepart commemorative volume: New York, Macmillan Co., p. 102-114.

Stommel, Henry, 1965, The Gulf Stream--a physical and dynamical description, 2d ed.: Berkeley, Calif., Univ. California Press, 248 p.

Stubblefield, W.L., J.W. Lavelle, T.F. McKinney, and D.J.P. Swift, 1975, Sediment response to the hydraulic regime on the central New Jersey shelf, J. Sediment Petrol., 45: 337-358.

Stubblefield, W.L. and D.J.P. Swift, 1976, Ridge development as revealed by sub-bottom profiles on the central New Jersey shelf. Mar. Geol, v. 20, p. 315-334.

Stuiver, M., and Daddario, J.J., 1963, Submergence of the New Jersey coast: Science, v. 142, p. 941.

Summary petroleum and selected mineral statistics for 120 countries, including offshore areas: U.S. Geol. Survey Prof. Paper 817, 1973.

Suter, R., deLaguna, W. and Perlmutter, N.M., 1949, Mapping of geologic formations and aquifers of Long Island, New York: N.Y. Dept. of Conservation, Water and Power Commission, Bull. 6, W. 18, 212 pp.

Swain, F.M. and Brown, P.M., 1972, Lower Cretaceous Jurassic (?) and Triassic ostracoda from the Atlantic coastal regions: U.S. Geol. Survey Prof. Paper 795, 55 pp.

Swallow, J.C. and L.V. Worthington, 1961, An observation of a deep countercurrent in the western North Atlantic. Deep-Sea Res., 8, 1-9.

Swanson, R.L., 1977. Status of ocean dumping research in New York bight. Jour. of Waterways, Port, Coastal and Ocean Division. Proc. of ASCE, vol. 103, no. WW1. pp. 19-24.

Swift, D.J.P., 1968, Coastal erosion and transgressive stratigraphy: Jour. Geol. v. 76, p. 444-456.

Swift, D.J.P., 1972, Implications of sediment dispersed from bottom current measurements; some specific problems in understanding bottom sediment distribution and dispersal on the continental shelf-a discussion of two papers: in Swift, D.J.P., Duane, D.B. and Pilkey, O.H., eds., Shelf sediment transport: process and pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 363-371.

Swift, D.J.P., 1973, Delaware shelf valley: estuary retreat path, not drowned river valley: Geol. Soc. America Bull., v. 84, p. 2743-2748.

Swift, D.J.P., 1974, Continental shelf sedimentation, In. C.A. Burke and C.L. Drake, eds., The Geology of Continental Margins. Berlin and New York, Springer-Verlag, pp. 117-135.

Swift, D.J.P., 1975a, Barrier Island genesis: Evidence from the Middle Atlantic Shelf of North America, Sediment, Geol., 14: 1-43.

Swift, D.J.P., 1975. Tidal sand ridges and shoal retreat massifs. Marine Geology, vol. 18, pp. 105-133.

Swift, D.J.P., 1976, Barrier island genesis: Evidence from the central Atlantic shelf: Sed. Geology, vol. 14, p. 1-43.

Swift, D.J.P., G.L. Shideler, N.F. Avignone, B.W. Holliday, and C.E. Dill, Jr., 1970, Quaternary sedimentation on the inner Atlantic shelf between Cape Henry and Cape Hatteras: a preliminary report: Maritime Sediments, v. 6, p. 5-11.

Swift, D.J.P., Dill, C.E., Jr., McHome, J., 1971, Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast: Jour. Sed. Petr., v. 41, p. 683-690.

Swift, D.J.P. and others, 1971, Textural differentiation in the shoreface during erosional retreat of an unconsolidated coast, Cape Henry to Cape Hatteras, western north Atlantic shelf: Sedimentology, V.16, p. 221-250.

Swift, D.J.P., Stanley, D.J. and Curray, J.R., 1971, Relict sediments on continental shelves: a reconsideration: Jour. Geol. v. 79, p. 322-346.

Swift, D.J.P., Kofoed, J. W., Saulsburg, F. P. and Sears, P., 1972. Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America, in Swift, D.J.P., Duane, D. B. and Pilkey O. H. (eds.), Shelf sediment transport: Process and Pattern. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pa., pp. 499-575.

Swift, D.J.P., Ludwick, J.C., and Boehmer, R.W., 1972, Shelf sediment transport: a probability model: in Swift, D.J.P., Duane, D.B. and Pilkey, O.H. eds., Shelf sediment transport process and pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 195-223.

Swift, D.J.P., Duane, D.B. and Pilkey, O.H., eds., 1972, Shelf sediment transport, process and pattern: Dowden, Hutchinson and Ross, Stroudsburg, Pa., 656 pp.

Swift, D.J.P., Duane, D.B. and McKinney, T.F., 1974. Ridge and swale topography of the middle Atlantic Bight, North America: Secular response to the Holocene hydraulic regime. Marine Geol., vol. 15, pp. 227-247.

Swift, D.J.P., B.W. Holliday, N.F. Avignone, and G. Shideler, 1972a, Anatomy of a shoreface ridge system, False Cape, Virginia, Mar. Geol. 12: 59-84.

Swift, D.J.P. and P. Sears, 1974, Estuarine and littoral depositional patterns in the surficial sand sheet, central and southern Atlantic shelf of North America. In International Symposium on Interrelationships of Estuarine and Continental Shelf Sedimentation, Inst. Geol. du Bassin d'Aquitaine, Bordeaux, Mem. 7, pp. 171-189.

Swift, D.J.P. and Ludwick, J.C., 1976, Substrate response to hydraulic process: grain-size frequency distributions and bed forms: in Stanley, D.J. and Swift, D.J.P., Marine sediment transport and environmental management, John Wiley and Sons, Inc., New York, p. 159-196.

Tagg, A.R., and Uchupi, E., 1966, Distribution and geologic structure of Triassic rocks in the Bay of Fundy and the northeastern part of the Gulf of Maine: U.S. Geol. Survey Prof. Paper 550-B, p. B95-B98.

Tagg, A.R., and Uchupi, Elazar, 1967, Subsurface morphology of Long Island Sound, Block Island Sound, Rhode Island Sound, and Buzzards Bay: U.S. Geol. Survey Prof. Paper 575-C, p. C92-96.

Talwani, M. and LePichon, X and Ewing, M., 1965, Crusted structure of the mid-ocean ridges, two computed models from gravity and seismic refraction data: Journal Geo. Physical Rese. V. 70, P. 341-352.

Taney, N. B., 1961. Geomorphology of the south shore of Long Island, New York. Beach Erosion Board Tech. Memo, 128, 50 pp.

Taney, N.M., 1961, Littoral materials of the south shore of Long Island, New York: U.S. Army Corps of Engineers, Beach Erosion Board (now CERC), Tech. Man. 129, 59 pp.

Taylor, P.T.I. Zietz, and I. S. Dennis, 1968, Geologic implications of aeromagnetic data for the eastern continental margin of the United States: Geophysics, v. 33, no. 5, p. 755-780.

Thompson, T.L., 1976, Plate tectonics in oil and gas exploration of continental margins: AAPG, v. 60, no. 9, p. 1463-1501.

Torphy, S.R., and J.M. Zeigler, 1957, Submarine topography of Eastern Channel, Gulf of Maine: Jour. Geology, v.65, p. 433-441.

Travers, W.B. and Luney, P. R., 1976. Drilling tankers, and oil spills on the Atlantic outer continental shelf. Science, vol. 194, no. 4267. pp. 791-796.

Trigom, 1974, A socio-economic and environmental inventory of the North Atlantic region; Sandy Hook to Bay of Fundy: v. 1, Book 1.

Trumbull, J.V.A., 1972, Atlantic continental shelf and slope of the United States-sand-size fraction of bottom sediments, New Jersey to Nova Scotia: U.S. Geol. Survey Prof. Paper 529-K, 45 pp.

Trumbull, J.V.A. and others, 1958, An introduction to the geology and mineral resources of the continental shelves of the Americas: U.S. Geol. Survey Bull. 1067, 92 pp.

Trumbull, J.V.A., Schlee, J.S., Hathaway, J.C., Ross, D.A., and Hulsemann, Jobst, 1966, Continental shelf sediments off northeastern United States (abs.): Am. Assoc. Adv. Sci. Ann. Mtg. Sec. E, Geology and Geography, Program, p. 35.

Trumbull, J.V.A. and M.J. McCamis, 1967, Geological exploration in an East Coast submarine canyon from a research submersible. Science, 158, 370-372.

Trumbull, J.V.A., and J.C. Hathaway, 1968b, Further exploration of Oceanographer Canyon: Woods Hole Oceanog. Inst. Ref. No. 68-37, 57 p. (multilithed).

Tuthill, H.T., 1944, Long Island hurricane rehabilitation: Shinnecock Inlet created by 1938 storm, left. open and stabilized for Nassau County use: Shore and Beach. v. 12, no. 4, p. 16-20.

Tuttle, C.R., W.B. Allen, and G.W. Hahn, 1961, A seismic record of Mesozoic rocks on Block Island, Rhode Island: U.S. Geol. Survey Prof. Paper 424-C, p. C254-C256.

Twichell, D.C., Knebel, H.J. and Folger, D.W., 1977, Delaware River: Evidence for its former extension to Wilmington submarine canyon: Science, v. 195, no. 4277, p. 483-485.

Uchupi, E., 1963, Sediments on the continental margin off eastern United States: USGS Prof Paper 475-C, p.C132-C137.

Uchupi, E., 1965a, Maps showing relation of land and submarine topography, Nova Scotia to Florida: U.S. Geol. Survey, Misc. Geol. Inv. Map 1-451, scale 1:1,000,000, 3 sheets.

Uchupi, E. 1968. Atlantic continental shelf and slope of the United States--Physiography. U.S. Geol. Survey Prof. paper 529-C, 30 pp.

Uchupi, Elazar, 1965, Basins of the Gulf of Maine: U.S. Geol. Survey: Prof. Paper 525-D, p. D175-D177.

Uchupi, E., 1965. Map showing relation of land and submarine topography Nova Scotia to Florida. U.S. Geol. Survey, Miscell. Geol. Investigations Map I-451.

Uchupi, Elazar, 1965c, Topography and structure of the shelf and slope: Woods Hole Oceanog. Inst. Ref. 65-13, p. 84-87.

Uchupi, Elazar, 1966, Topography and structure of Cashes Ledge, Gulf of Maine: Maritime Sediments, v. 2, p. 117-120.

Uchupi, E., 1967b, Slumping on the continental margin southeast of Long Island. Deep-Sea Res., 14, 635-639.

Uchupi, E., 1969b, Bathymetric chart, Bay of Fundy to Gulf of Saint Lawrence: Canadian Hydrographic Service, chart 801, scale 1: 1,000,000, 1 sheet.

Uchupi, E., 1969, Seismic profiling survey of the east coast submarine canyons, Part I: Wilmington, Baltimore, Washington and Norfolk canyons: Deep-Sea Research, v. 15, p. 613-616.

Uchupi, E. , 1970, Atlantic continental shelf and slope of the United States: Shallow Structure, U.S. Geol. Surv. Prof. Paper, 524-1, 44 pp.

Uchupi, E., 1970b, Bathmetric chart, Newfoundland shelf: Canadian Hydrographic Service, chart 802, scale 1:1,000,000, 1 sheet.

Uchupi, E. and Emery, K.O., 1967, Structure of the continental margin off the Atlantic Coast of the United States: American Assoc. of Petrol. Geol. Bull., v. 51, p. 223-234.

University of Rhode Island, 1973. Coastal and offshore environmental inventory, Cape Hatteras to Nantucket shoals. Marine Publ. Ser. 2, Univ. Rhode Island. Chapters 1-8.

University of Rhode Island, 1973. Coastal and offshore environmental inventory, Cape Hatteras to Nantucket shoals, complement volume. Marine Publ. Ser. 3, Unive. Rhode Island. Chapters 9-12.

Upham, Warren, 1894, The fishing banks between Cape Cod and Newfoundland: Am. Jour. Sci. 3rd Ser., v. 47, p. 123-129.

U.S. Army, 1973, Shore protection manual: Ft. Belvoir, Va., U.S. Army Corps Engineers Coastal Eng. Research Center, Vol. 1-111, 1160 p.

U.S. Army Beach Erosion Board, Corps of Engineers, 1936, Beach erosion at Jacob Riis Park, Long Island, New York: House Document no. 397, 74th Congress, 2nd Session.

U.S. Army Beach Erosion Board, Corps of Engineers, 1936, Beach erosion at Manasquan Inlet, New Jersey, and adjacent beaches: House Doc. no. 71, 75th Congress, 1st Session.

U.S. Army Beach Erosion Board, Corps of Engineers, 1949, South shore, state of Rhode Island beach-erosion control study: House Document no. 490, 81st Congress, 2nd Session.

U.S. Army Corps of Engineers, 1885-1930, Annual Reports of the Chief of Engineers: Washington, D.C.

U.S. Army Corps. of Engineers, 1955, Fire Island inlet and shore westerly to Jones Inlet: NY District, Atlantic coast of Long Island, New York, Beach Erosion Control Report on Cooperative Study, 16 pp.

U.S. Army Corps of Engineers, 1967, Study on use of hopper dredge for beach nourishment: U.S. Army Engineer District, Philadelphia, Pa.

U.S. Army Corps of Engineers, 1971, National shoreline study report; Washington, D.C.

U.S. Army Engineer District, Boston, Corps of Engineers, 1894, Preliminary examination of Chatham New Harbor, Massachusetts: House Ex. Doc. no. 69, 53rd Congress, 3rd Session.

U.S. Army Engineer District, Boston, Corps of Engineers, 1938, Westport River, Massachusetts: House Doc. no. 692, 75th Congress, 3rd Session.

U.S. Army Engineer District, Boston, Corps. of Engineers, 1938, Scituate Harbor, Massachusetts: House Doc. no. 556, 75th Congress, 3rd Session.

U.S. Army Engineer District, Boston, Corps of Engineers, 1940, Newbury Port Harbor, Massachusetts: House Doc. no. 703, 76th Congress, 3rd Session.

U.S. Army Engineer District, Newport, Corps of Engineers, 1889, East Point Judith, Rhode Island: House Ex. Doc. no. 66, 51st Congress, 1st Session.

U.S. Army Engineer District, Newport, Corps of Engineers, 1897, Survey of inner harbor at Point Judith, Pond, Rhode Island; House Doc. no 132, 55th Congress, 2nd Session.

U.S. Army Engineer District, Newport, Corps. of Engineers, 1908, Point Judith Harbor of Refuse, Rhode Island: House Doc. no. 911, 60th Congress, 1st Session.

U.S. Army Engineer District, Newport, Corps of Engineers, 1916, Point Judith Pond, Rhode Island: House Doc. No. 788, 64th Congress, 1st Session.

U.S. Army Engineer District, Newport, Corps of Engineers, 1917, Point Judith Harbor of Refuge, Rhode Island: House Doc. No. 2001, 64th Congress, 2nd Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1903, Harbors of Refuse at Point Judith, Block Island and Great Salt Pond, and adjacent waters, etc.: House Doc. No. 60, 58th Congress, 2nd Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1929, East Rockaway (Debs) Inlet, New York: House Document No. 19, 71st Congress, 1st Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1939, Shark River, New Jersey: House Doc. No. 102, 76th Congress, 1st Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1941, Jones Inlet, New York: House Document No. 409, 77th Congress, 1st Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1948, Fire Island Inlet, New York: House Document 762, 80th Congress, 2nd Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1955, Shore of New Jersey from Sandy Hook to Barnagat Inlet, beach erosion control study: House Doc. No. 361, 84th Congress, 2nd Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1956, Fire Island Inlet to Jones Inlet, Long Island, New York cooperative beach erosion control study: House Doc. No. 411, 84th Congress, 2nd Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1958, Atlantic coast of Long Island, New York, Fire Island Inlet to Montauk Point, cooperative beach erosion control and interim hurricane study (survey): 2 vols., Corps of Engineers use only.

U.S. Army Engineer District, New York, Corps of Engineers, 1959, Moriches and Shinnecock Inlets, Long Island, New York: House Doc. 126, 86th Congress, 1st Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1960, Raritan Bay and Sandy Hook Bay, New Jersey; cooperative beach erosion control and interim hurricane study (survey): Corps of Engineers use only.

U.S. Army Engineer District, New York, Corps of Engineers, 1960, South Shore of Long Island from Fire Island Inlet to Montauk Point, New York, beach erosion control study and hurricane survey: House Doc. No. 425, 56th Congress, 2nd Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1965, Atlantic coast of Long Island, Fire Island Inlet and shore westerly to Jones Inlet, New York: House Document No. 115, 89th Congress, 1st Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1965, Atlantic Coast of New York City from East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, New York: House Doc. No. 215, 89th Congress, 1st Session.

U.S. Army Engineer District, New York, Corps of Engineers, 1967, Jones Inlet to Montauk Point, New York (remaining areas): House Doc. 191, 90th Congress, 1st Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1890, Shark River, New Jersey: House Ex. Doc. No. 25, 51st Congress, 2nd Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1936, Barnegat Inlet, New Jersey: House Doc. No. 85, 74th Congress, 2nd Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1941, Manasquan River, New Jersey: House Doc. 356, 77th Congress, 1st Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1945, Barnagat Inlet, New Jersey: House Doc. 358, 79th Congress, 1st Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1946, Absecon Inlet, New Jersey: House Doc. 504, 79th Congress, 2nd Session.

U.S. Army Engineer, District, Philadelphia, Corps of Engineers, 1950, Atlantic City, New Jersey, beach erosion control study: House Doc. No. 538, 81st Congress, 2nd Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1953, Cold Spring Inlet (Cape May Harbor), New Jersey: House Doc. No. 206, 83rd Congress, 1st Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers. 1953. Ocean City. New Jersey. beach erosion control study: House Doc. 184. 83rd Congress, 1st Session.

U.S. Army Engineer District, Philadelphia, Corps of Engineers, 1969, New Jersey Coastal inlets and beaches - Great Egg Harbor Inlet to Stone Harbor: House Doc. No. 160, 91st Congress, 1st Session.

U.S. Army Engineer District, Providence, Corps of Engineers, 1941, Chatham (Stage) Harbor, Massachusetts: House Doc. No. 456, 77th Congress, 1st Session.

U.S. Army Engineer Division, New England, Corps of Engineers, 1947, Harbor of refuge at Point Judith and Point Judith Pond, Rhode Island: Senate Doc. No. 15, 80th Congress, 1st Session.

U.S. Army Engineer Division, New England, Corps of Engineers, 1953, Plum Island, Massachusetts, beach erosion control study: House Doc. No. 243, 83rd Congress, 2nd Session.

U.S. Army Engineer, Division, New England, Corps of Engineers, 1962, Point Judith, Rhode Island: House Doc. 521, 87th Congress, 2nd Session.

U.S. Army Engineer Division, New England, Corps of Engineers, 1970, Edgartown Harbor, Martha's Vineyard, Massachusetts: Senate Doc. No. 108, 91st Congress, 2nd Session.

U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, 1943, Model study of plans for elimination of shoaling in Absecon Inlet, New Jersey: Tech. Memo No. 204-1, 55 pp., Vicksburg, Miss.

U.S. Army Shore Protection Board, Corps of Engineers, 1933, Barnegat Inlet, New Jersey: House Doc. No. 19, 73rd Congress, 2nd Session.

U.S. Bureau of Land Management, 1972, Library research project, mid-Atlantic outer continental shelf(reconnaissance): U.S. Bureau Land Management Open-File Report.

U.S. Coast and Geodetic Survey and U.S. Bureau of Commercial Fisheries, 1967 (Bathymetric maps of the Atlantic Continental Shelf and Slope from Delaware to outer Cape Cod): U.S. Coast and Geodetic Survey, C & GS 0807N-51 through 57, 080N-51 through 55, 0708N-51 through 53, 15 sheets, scale 1:125,000. See Stearns, F., 1967.

U.S. Department of Interior, 1971, Regulations pertaining to mineral leasing, operations, and pipeline on the outer continental shelf as contained in Title 30 and Title 43 of the code of Federal Regulations and the Outer Continental Shelf Lands Act, 90 pp.

U.S. Geological Survey, 1937-59, Records of wells in Bronx, New York, Richmond, Kings, Queens, Nassau and Suffolk counties, (a series of occasional reports giving factual geological and engineering data compiled about wells and borings on Long Island): New York State Water Power and Control Commission Bulls. G.W.3, 11, 13, 17, 18, 31, 32, 39 and 41.

U.S. Geological Survey, 1967, Engineering geology of the northeast corridor, Washington, D.C. to Boston, Massachusetts; earthquake epicenters, geothermal gradients, and excavations and borings: U.S. Geol. Survey Misc. Geol. Inv. Map I-514-C, 2 sheets.

U.S. Geological Survey, 1967, Engineering geology of the northeast corridor, Washington, D.C. to Boston, Mass.: coastal plain and surficial deposits: Miscell. Geologic Investig. Map I-514B, 9 pp, 8 sheets.

U.S. Geological Survey Water Resources Division, Virginia District Office, 1973, (Basic well records): Richmond, Va.

U.S. Geological Survey Water Resources Division, New Jersey District Office, 1973, (Basic records of geophysical logs; computer tabulation): Trenton, N.J., 31 pp.

U.S. Geological Survey Water Resources Division, Maryland District Office, 1973, (Basic well records): Parkville, Md.

U.S. Geological Survey, 1975, Sediments, structural framework petroleum potential, environmental conditions and operational considerations of the United States mid-Atlantic outer continental shelf: U.S. Geol. Survey open file report 75-61, 143 p.

U.S.G.S., 1975, Sediments, structural framework, petroleum potential, environmental conditions and operational considerations of the United States North Atlantic OCS: U.S.G.S. Open File Report #75-353, 179 p. (same as Schlee and others, 1975)

U.S.G.S., 1976, Geological and operational summary, COST #B-2 well, Baltimore Canyon trough area, Mid-Atlantic OCS: Open File Report #76-774, 79 p.

U.S.G.S., 1976, Aeromagnetic map Atlantic continental margin: U.S.G.S. MF 752(A-H) Woods Hole, Mass.

U.S. Naval Oceanographic Office, 1965, Oceanographic atlas of the North Atlantic Ocean, Sec. V., Marine Geology: Washington, U.S. Naval Oceanog. Office, 71 p.

Weed, E.G.A. and others, 1974, Generalized pre-Pleistocene geologic map of the northern United States Atlantic continental margin: U.S. Geol. Survey Misc. Geol. Inv. Series Map I-861, scale 1:1,000,000.

Weeks, L. G., ed., 1958. Habitat of oil. Amer. Assoc. Petroleum Geologists. 1384 p.

Weeks, L.G., 1974, Petroleum resources potential off continental margins: in Burk, C.A. and Drake, C.L., eds., Geology of continental margins, Springer-Verlag, N.Y., p. 953-964.

Weil, C.B.R.D. Moose, and R.E. Sheridan, 1974, A model for the evolution of linear tidal built sand ridges in Delaware Bay, U.S.A. In G. Allen, ed., Estuary and Shelf Sedimentation, A Symposium, University of Bordeaux, July 1973.

Weiss, D., 1974, Late Pleistocene stratigraphy and paleoecology of the Lower Hudson River Estuary: Geol. Soc. America Bull. v. 85, p. 1561-1570.

Weiss, L., 1954, Foraminifera and origin of the Gardiners clay (Pleistocene), Eastern Long Island, N.Y.: U.S. Geol. Survey Professional Paper 254-G, pp.

Wells, J.E. and Turner, T.M., 1972, Development of alternative dredging program related to the navigation project at Fire Island Inlet, New York, and feeder beach project for the shore westerly to Jones Inlet, New York: Ellicot Machine Corp., Baltimore, Md., Rept. submitted to U.S. Army Corps of Engineers, New York District, DACW 51-73-C-0061.

Whiting, H.L., 1886, Report of changes in the shoreline and beaches of Martha's Vineyard, as derived from comparisons of recent with former surveys: Rept. 1886, App. 9, U.S. Coast and Geodetic Survey, p. 263-266.

Whiting, H.L., 1889, Recent changes in the south inlet into Edgartown Harbor, Martha's Vineyard: Report 1889, app. 14, U.S. Coast and Geodetic Survey, p. 459-460.

Wicker, C.F., 1951, History of New Jersey coastline: Proc. First Confer. Coastal Engineering, Berkeley, Calif. p. 299-319.

Veatch, A. C. and Smith, P. A., 1939. Atlantic submarine valleys of the United States: The Congo submarine valley. Geol. Soc. America Special Paper 7, 101 pp.

Verrill, A.E., 1878, Occurence of fossiliferous Tertiary rocks on the Grand Banks and Georges Bank: Am. Jour. Sci., 3rd Ser., v. 16, pp. 323-324.

Vesper, W.H., 1967, Behavior of beach fill and borrow area at Sherwood Island State Park, Westport, Connecticut: U.S. Army Coastal Engineering Research Center, Tech. Memo No. 20, Ft. Belvoir, Va.

Volkmann, G., 1962, Deep current observations in the western North Atlantic. Deep-Sea Res., 9, 493-500.

Voorhis, A.D., 1968, Measurements of vertical motion and the partition of energy in the New England slope water. Deep-Sea Res., 15, 599-608.

Warme, J.E., T.B. Scanland, and N.F. Marshall, 1971, Submarine canyon erosion: Contribution of marine rock burrowers. Science, 173, 1127-1129.

Warren, B.A., 1963, Topographic influences on the path of the Gulf Stream: Tellus, v. 15, p. 167-183.

Warren, D.H., 1968, Transcontinental geophysical survey (35°-39°N) Seismic refraction profiles of the crust and upper mantle from 74° to 87° W longitude: U.S. Geol. Survey Misc. Geol. Inv. Map I-535-D.

Watson, J.A. and Johnson, G.L., 1970, Seismic studies in the region adjacent to the Grand Banks of Newfoundland: Can. Jour. Earth Sci., v. 7, p. 306-316.

Wear, C.M., D.J. Stanley, and J.E. Boula, 1974, Shelfbreak physiography between Wilmington and Norfolk canyons. Mar. Technol. Soc. J., 8, 37-48.

Wigley, R.L., 1961, Bottom sediments of Georges Bank: Jour. Sed. Petrol. v. 31, p. 165-188.

Wigley, R.L., 1968, Can submersible vehicle be used effectively in studies of cold water shelf fisheries?: Fishing News International, v. 7, p. 32-34.

Wigmore, H.L., 1909, Memorandum on dredging work in Ambrose Channel: U.S. Army Prof. Mem., Engineer Bureau, v. 1, p. 57-62.

Williams, E.P., 1974, Geology and petroleum potential in and around Gulf of St. Lawrence: AAPG, v. 58 no. 6, pt II, p. 1137-1155.

Williams, H. and Stevens, R.K., 1974, The ancient continental margin of eastern North America: in, Burk, C.A., and Drake, C.L., eds., The geology of continental margins, Springer-Verlag, New York, p. 781-796.

Williams, S.J., 1973, The geologic framework of inner New York bight - its influence on positioning offshore engineering structures: Geol. Soc. America Abstracts with Programs, v. 5, no. 2, p. 239.

Williams, S.J. and Field, M.E., 1971, Sediments and shallow structures of the inner continental shelf off Sandy Hook, New Jersey: Geol. Soc. America Abstracts with Program, v. 3, no. 1, p. 62.

Williams, S. J. and Duane, D. B., 1974. Geomorphology and sediments of the inner New York Bight continental shelf. U.S. Army Corps of Engineers Coastal Engineering Research Center, Technical Memorandum No. 45, 81 pp.

Wilson, J.E., 1974, East coast - front or frontier: AAPG, v.58, no. 6, pt II, p. 1057-1058.

Winker, C.D. and Howard, J.D., 1977, Correlation of tectonically deformed shorelines on the southern Atlantic coastal plain: Geology, v. 5, no. 2, p. 123-127.

Wolfe, J.A., and Pakiser, H.M., 1971, Stratigraphic interpretations of some Cretaceous microfossil floras of the middle Atlantic states: U.S. Geol. Survey Prof. Paper 750-B, p. B.35-B.47.

Wolff, M.P., 1972, Growth and migration of digitate spits (April - September, 1971) at Democrat Point, Fire Island, New York - An example of a naturally occurring modifying landfill system: Geol. Soc. America. NE Section meeting Abstracts with Programs, v. 4, no. 1, p. 53-54.

Worzel, J.L. and C.L. Drake, 1959, Structure section across the Hudson River at Nyack, N.Y., from seismic observations: New York Acad. Sci. Annals, v. 80, p. 1092-1105.

Yamaguchi, S., Henkel, D.J., 1976, The role of waves on causing submarine landslides: Niigata Univ., Dep. Geol. Mineral, Contrib., No. 4 (Prof. Shoichi Nishida memorial vol.), p. 547-552. (english summary).

Yasso, W.E., 1964, Geometry and development of spit-bar shorelines at Horseshoe Cove, Sandy Hook, New Jersey: Dept. of Geology, Columbia Univ., New York, NY, 166 pp.

Yasso, W.E., 1964, Use of fluorescent tracers to determine foreshore sediment transport, Sandy Hook, New Jersey: Tech Rept. No. 6 of Project N.R. 388-057 (contract no. 266(68), Office of Naval Res., Geogr. Branch), Dept of Geology, Columbia Univ. New York, N.Y.

Ziegler, J.M. and others, 1960, Discovery of Eocene sediments in subsurface of Cape Cod: Science v. 132, no. 3437, p. 1397-1398.

Zeigler, J.M., H.J. Tasha, and G.S. Giese, 1964, Erosion of the cliffs of outer Cape Cod: tables and graphs: Woods Hole Oceanog. Inst. Ref. No. 64-21, 59 p. (multilithed).

Zeigler, J.M., Tuttle, S.D., Tasha, H.J., and Giese, G.S., 1964, The age and development of the Provincelands Hook Outer Cape Cod, Massachusetts: Limnology and Oceanography, v. 10, supp., p. R298-R311.

Zeigler, J.M., Tuttle, S.D., Tasha, Herman, and Giese, G., 1964, Pleistocene geology of outer Cape Cod, Massachusetts: Geol. Soc. America Bull., v. 75, No. 8, p. 705-714.

Zurflueh, E.G., 1962, A magnetic map of the Long Island Sound and the southward continuation of geologic units in Connecticut (abs.): Am. Geophys. Union Trans., v. 43, no. 4, p. 435.

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