U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

SUMMARY OF ENVIRONMENTAL GEOLOGIC STUDIES IN THE MID-ATLANTIC OUTER CONTINENTAL SHELF AREA-- RESULTS OF 1978-1979 FIELD SEASONS

By

James M. Robb

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AA551-MU8-21 and AA551-MU9-4

Open-File Report 83-353

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ABSTRACT

Because of the need for knowledge of an offshore area that is undergoing exploration for oil and gas resources, since 1975 the U.S. Bureau of Land Management (BLM) has funded studies of the environmental characteristics of the Mid-Atlantic Outer Continental Shelf. This volume briefly summarizes a final report to the BLM on the results of U.S. Geological Survey investigations stemming from data acquired during 1978 and 1979. The parent final report contains complete accounts of those investigations. The subjects of the studies range from the geologic effects of water currents and their capabilities of erosion and transportation, to delineation of potentially hazardous geologic characteristics of the area. Nine specific studies address the complexities of water currents, the nature of materials suspended in the sea waters, rates of mixing-in of material deposited on the bottom, and the sites of probable deposition of such materials, as well as sites and mechanisms of possible submarine landsliding or unstable bottom (engineering characteristics) of the Continental Slope and shelf.

INTRODUCTION

This is a summary of a final report submitted by the U.S. Geological Survey (USGS) to the U.S. Bureau of Land Management (BLM). The complete final report, entitled, "Environmental Geologic Studies in the Mid-Atlantic Outer Continental Shelf Area -- Results of 1978-1979 Field Seasons," edited by James Robb (1982) is a separate volume released through the U.S. National Technical Information Service (NTIS) as report PB 83-147934. The studies that are reported in that volume, summarized here, were funded under two Memoranda of Understanding between the USGS and the BLM: AA551-MU8-21, covering the period October 1977 through September 1978, and AA551-MU9-4, covering the period from October 1978 through September 1979. The work included gathering of basic data at sea and subsequent laboratory and office analysis and interpretation.

Since 1975, the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) have been working to assess environmental conditions of the Outer Continental Shelf of the Mid-Atlantic United States as they affect or would be affected by the activities of offshore exploration and exploitation of oil and gas resources. The Outer Continental Shelf Lands Act of 1953 established federal jurisdiction over the OCS areas and charged the Secretary of the Interior with responsibility for the administration of the mineral exploration and development of these lands. The Bureau of Land Management, under the National Environmental Policy Act of 1969, is compiling and evaluating information relating to the environmental effects of drilling and of possible oil and gas production.

The Mid-Atlantic Outer Continental Shelf, as subdivided into lease blocks, extends from about 36^{o}N to about 40^{o}N latitude, or from a little north of Cape Hatteras to a little south of Long Island. To date, the greatest exploratory interest for hydrocarbons has been directed to the northern part of this region, in the sedimentary basin known as the Baltimore Canyon Trough. Attention was initially focussed on the Continental Shelf where water depths are less than about 130 m. Tracts on the Continental Shelf were leased in two sales, Sale 40 in August 1976 and Sale 49 in February 1979. Sale 59 in December 1981 leased tracts in water as deep as 2,100 m on the Continental Slope (fig. 1).

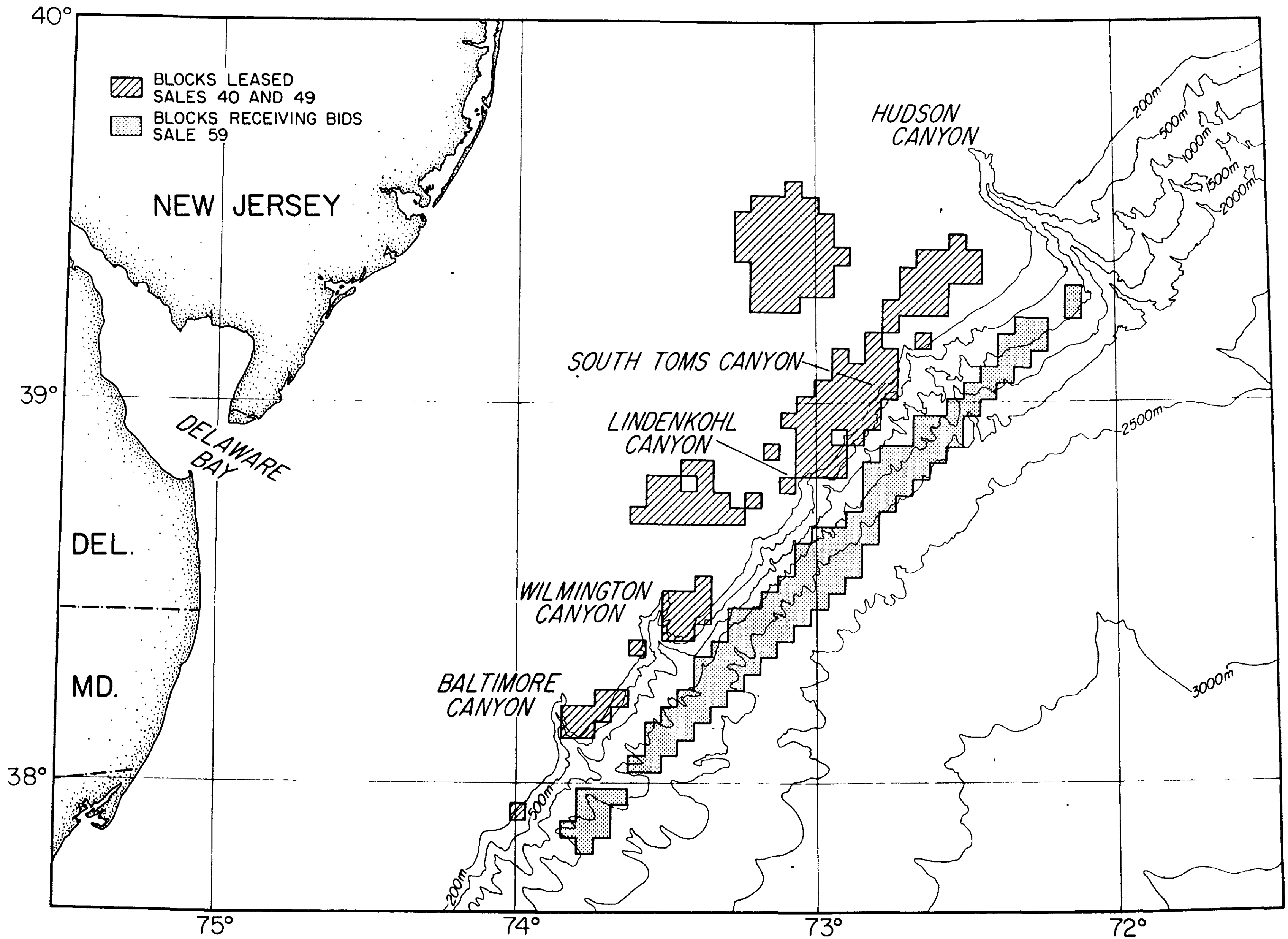


Figure 1. Outer Continental Shelf area ("Baltimore Canyon Trough") offshore New Jersey. Areas of lease blocks shown.

The objectives of the studies reported herein and in the final report have been:

a. To estimate the extent and rate of sediment mobility over the sea bed and to monitor resultant changes in bottom morphology and texture.

b. To identify major processes causing sediment movement and to assess seasonal variability.

c. To complete a study of suspended particulate matter in the water column that was begun under a previous Memorandum of Understanding.

d. To determine the rates and depths of sediment mixing in Sale 40 and Sale 49 lease areas as an aid to predicting the fate of spilled hydrocarbons, drilling chemicals, and drill cuttings.

e. To identify and map areas of slumping or of potential slumping hazard in lease areas on the Continental Slope.

f. To identify and study the effects of processes and mechanisms contributing to sediment instability in offshore lease areas which may lead to inception of slumping and sliding.

g. To assess the geotechnical properties of sediments in the Continental Slope lease areas.

h. To determine potential geologic hazards in nearshore areas.

The final report includes an introduction, nine interpretive chapters, and two appendices (table 1). Because the results of this program of studies have been of timely importance to the federal OCS leasing program, most of the chapters contained in the final report were released as open-file reports of the U.S. Geological Survey when individual investigations were completed. The appendices of the report contain cruise reports and much of the basic data upon which the interpretive reports are based. Copies of other data gathered under this program, especially the seismic-reflection profiles, are available to the public from the National Geophysical Data Center, Environmental Data and Information Service (NGDC/EDIS) in Boulder, Colorado; for Open-File Reports of the U.S. Geological Survey describing those data, see "Bibliography: Products of the Program," included with this summary.

References to other reports, scientific publications, maps, and presentations at scientific meetings which were produced during the course of the investigations funded by the Bureau of Land Management are included in that bibliography.

FIELD SURVEYS

Eleven research cruises using eight different vessels were conducted to acquire field data for this program during 1978 and 1979. Those cruises are tabulated in table 2.

Table 1. Contents of final report released as NTIS report PB 83-147934 showing which chapters have been released separately.

CHAPTER 1.	INTRODUCTION AND SUMMARY by James M. Robb
CHAPTER 2.	SEMIDIURNAL BOTTOM PRESSURE AND TIDAL CURRENTS ON GEORGES BANK AND IN THE MID-ATLANTIC BIGHT by John A. Moody and Bradford Butman (U.S. Geological Survey Open-File Report 80-1137)
CHAPTER 3.	OBSERVATIONS OF NEAR-BOTTOM CURRENTS AT THE SHELF BREAK NEAR WILMINGTON CANYON by Bradford Butman, Marlene Noble, and John Moody
CHAPTER 4.	STUDIES OF SUSPENDED MATTER ALONG THE NORTH AND MIDDLE ATLANTIC OUTER CONTINENTAL SHELF by M. H. Bothner, C. M. Parmenter, R. R. Rendigs, B. Butman, L. J. Poppe, and J. D. Milliman (U.S. Geological Survey Open-File Report 82-938)
CHAPTER 5.	^{210}Pb IN SEDIMENT CORES FROM THE ATLANTIC CONTINENTAL SHELF: ESTIMATES OF RATES OF SEDIMENT MIXING by Michael H. Bothner and Peter P. Johnson (U.S. Geological Survey Open-File Report 81-582A Chapter 3 and 81-582B)
CHAPTER 6.	GEOLOGY AND POTENTIAL HAZARDS OF THE CONTINENTAL SLOPE BETWEEN LINDENKOHL AND SOUTH TOMS CANYONS, OFFSHORE MID-ATLANTIC UNITED STATES by James M. Robb, John C. Hampson, Jr., John R. Kirby, and David C. Twichell (U.S. Geological Survey Open-File Report 81-600)
CHAPTER 7.	GEOTECHNICAL PROPERTIES AND SLOPE-STABILITY ANALYSIS OF SURFICIAL SEDIMENTS ON THE BALTIMORE CANYON CONTINENTAL SLOPE by James S. Booth, Richard A. Farrow, and Thomas L. Rice (U.S. Geological Survey Open-File Report 81-733)
CHAPTER 8.	SUMMARY REPORT OF THE RESIDUAL LIGHT HYDROCARBON ANALYSES OF INTERSTITIAL GASES IN PISTON CORE SAMPLES FROM THE NORTH AND MID-ATLANTIC CONTINENTAL SLOPE ENVIRONMENTS by R. E. Miller, D. M. Schultz, H. E. Lerch, D. T. Ligon, and D. K. Owings
CHAPTER 9.	SUBMERSIBLE OBSERVATIONS OF POTENTIAL GEOLOGIC HAZARDS ALONG THE MID-ATLANTIC OUTER CONTINENTAL SHELF AND UPPERMOST SLOPE by Richard A. Slater, David C. Twichell, and James M. Robb (U.S. Geological Survey Open-File Report 81-968)
CHAPTER 10.	SHALLOW SUBBOTTOM STRATA, MIDDLE AND INNER CONTINENTAL SHELF SOUTH OF HUDSON SHELF VALLEY, OFFSHORE EASTERN UNITED STATES by Harley J. Knebel (published in modified form in Geology, v. 7, p. 254-258, 1979, as "Hudson River: Evidence for extensive migration on the Continental Shelf during Pleistocene time")
APPENDIX I.	CRUISE REPORTS
APPENDIX II.	TABULATED DATA

Table 2. Cruise activity -- data acquisition.

Cruise	Dates	Chief scientist	Days at sea	Number in scientific party	Cores	Grab samples	Tripods deployed/recovered	Current meter moorings deployed/recovered	Sidescan sonar (km)	Seismic profiles (km)	Submersible dives	Bathythermograph/ Expendable bathythermograph (BT/XBT)	Conductivity-temperature-depth (CTD)
Oceanus 38	January 19-26, 1978	Butman	7	10		6	4/2	3/2				96	31
Oceanus 45	May 10-18, 1978	Butman	9	12	10	6	2/4	2/3				80	58
Atlantis II 103	September 28-October 5, 1978	Butman	8	15			5/2	6/2	18			61	33
Gyre 78-G-7	August 19-September 1, 1978	Bothner	13	14	3	4						127	116
State Arrow/ Diaphus 78-1,2	July 30-August 9, 1978	Slater	10	11						564	24		
Columbus Iselin 7807-1	August 18-September 4, 1978	Robb	18	13					22	2,100			
Oceanus 56	March 6-15, 1979	Butman	10	12	2	4	3/6	3/5	145			46	25
Oceanus 67	August 6-13, 1979	Butman	7	12	3		4/1	6/4	296	185		28	23
Oceanus 77	December 13-20, 1979	Butman	8	11			5/2	4/2				49	10
Endeavor 042	August 28-September 23, 1979	Robb/Aaron	25	16	98					100			
Gilliss 7903-4	June 27-July 11, 1979	Robb	14	14					70	1,750			

GENERAL SUMMARY

These and previous studies under BLM/USGS agreements are directed toward characterization of the environments of the OCS -- measurements of day-to-day activity of the sea waters and descriptions of those aspects of the sea floor which can tell us what processes have taken place to create and to modify it.

To date, these studies have measured bottom water activity which varies with geographic area, season, and weather. Material on the bottom at Continental Shelf depths is stirred up by storms from time to time. However, study of subtle components of water movement is necessary to determine where suspended or resuspended matter is transported. Measurements from current meters and arrays of current meters are broken down into various categories. Tidal motions are commonly the strongest components of coastal sea-water motions and cause rotary currents, whose velocity vectors trace out ellipses over diurnal periods. On Georges Bank, where tidal currents are strongest southeast and northwest in the onshore and offshore directions, there is a long-term component of water transport toward the southwest. This transport apparently leads to the deposition in the "mud patch," an area south of Martha's Vineyard, of fine-grained material winnowed from Georges Bank. If fine-grained materials are produced by drilling activities, the mud patch may be the site of their eventual accumulation. The amount of material carried southwest from the mud patch to the Mid-Atlantic shelf is probably slight but is not determined.

Near Wilmington Canyon, on the southern part of the area of greatest exploration interest in the Mid-Atlantic OCS, Gulf Stream rings (eddies shed from the northeast-flowing Gulf Stream) affect the currents of the outer shelf. The major factor affecting flow in that area is wind stress. In the deeper waters seaward of the Continental Shelf break, bottom currents caused by wind stress are much reduced.

Residence times of material suspended near the bottom in a nepheloid layer (turbid near-bottom waters) were found to be about 5 hours on Georges Bank, 1.3 days in the "mud patch" south of Martha's Vineyard, and 2 days in the Mid-Atlantic Bight region. Such values are low compared to residence times of 1 to 3 months for deep-sea nepheloid layers, and emphasize the relatively dynamic environment of the Continental Shelf area. Once material is deposited on the sea bottom, radioisotope studies (^{210}Pb) show that it may be mixed in to depths of 20 cm within a relatively short time (less than 20 years) by biological activity as well as by wave and current agitation.

On the inner Continental Shelf, a buried valley formerly occupied by the Hudson River was found to extend southward across the shelf from the New York area. Other buried valleys have been found running across the shelf from Delaware Bay and from the Toms River, but the existence of this ancient valley of the Hudson had been previously unknown. Its presence and the sediments transported through it may help to explain the sites and configurations of some submarine canyons along the Continental Slope, as well as the nature of a slightly shallower area along the southern bank of the present Hudson Channel on the Continental Shelf. The buried valley was found to be filled with interbedded sands and muds. Geotechnical tests of the overlying material show that it should not cause problems of stability for future engineering efforts.

Studies on the Continental Slope were primarily directed to determining its stability. Studies using seismic profiles, cores, and submersible dives showed that the slope has a very complex bathymetric surface which has probably remained largely unchanged since the ice age; there were few slump or landslide features found. However, small-scale (1-2 m) slides probably occurred from time to time on some of the steeper slopes, and geotechnical tests did show that some places may be marginally stable. The channelways and lower walls of submarine canyons should probably be viewed with caution as sites for semipermanent structures.

Seismic-reflection profiles along the upper Continental Slope commonly show "turbid zones" or "washouts" attributed to the presence of gas in the sediments. Studies to determine whether gas in the interstices of the sediment could have an effect on stability were largely inconclusive because of necessarily crude sampling techniques and our inability to determine *in-situ* pressures and quantities of gas. However, those analyses did show the presence of considerable amounts of hydrocarbon gases in some places, and that some of those gases may be thermogenic, related to deep-seated petroleum deposits in the area.

INDIVIDUAL INVESTIGATIONS

The different aspects of the marine geologic environment of the Mid-Atlantic Outer Continental Shelf area that were studied under this program are dealt with in separate chapters of the final report. Chapters 2 through 4 deal with ocean currents and the type of material being carried and distributed by them on the Continental Shelf of the Mid-Atlantic area. Chapter 5 discusses how deeply and how quickly material deposited on the sea bottom is mixed into underlying material of the Continental Shelf by marine animals or by waves and currents. Chapters 6 through 9 deal primarily with the question of bottom stability on the Continental Slope, the possibility of submarine landslides, and geological factors that would lead to such slope failures. Chapter 10 reports a study of the middle and inner shelf area and outlines a buried valley that has been found there. Each chapter is summarized in greater detail below.

Summary of Chapter 2
Semidiurnal bottom pressure and tidal currents on Georges Bank and in the Mid-Atlantic Bight

In chapter 2, Moody and Butman discuss a study of semidiurnal (M_2) tidal currents based on current-meter and bottom-pressure data acquired from 1975 to 1979 at stations in the Mid-Atlantic Bight and on Georges Bank (fig. 2). Because tidal currents dominate the average bottom stress, they play a major role in determining the fate of material introduced into the water. In both the Georges Bank and Mid-Atlantic areas, M_2 tidal currents are rotary: their velocity vectors sweep out an ellipse every tidal cycle (fig. 3). At most stations, the major axis of the tidal current ellipse is nearly perpendicular to local isobaths; that is, currents are strongest in offshore and onshore directions rather than longshore. Pressure records show that tidal height at the edge of the Continental Shelf is relatively uniform and has an amplitude of about 40 cm. In the Mid-Atlantic Bight, the onshore current reaches a maximum about 3 hours before high water. On Georges Bank the maximum onshore current occurs at about the same time as high water. The tidal currents are

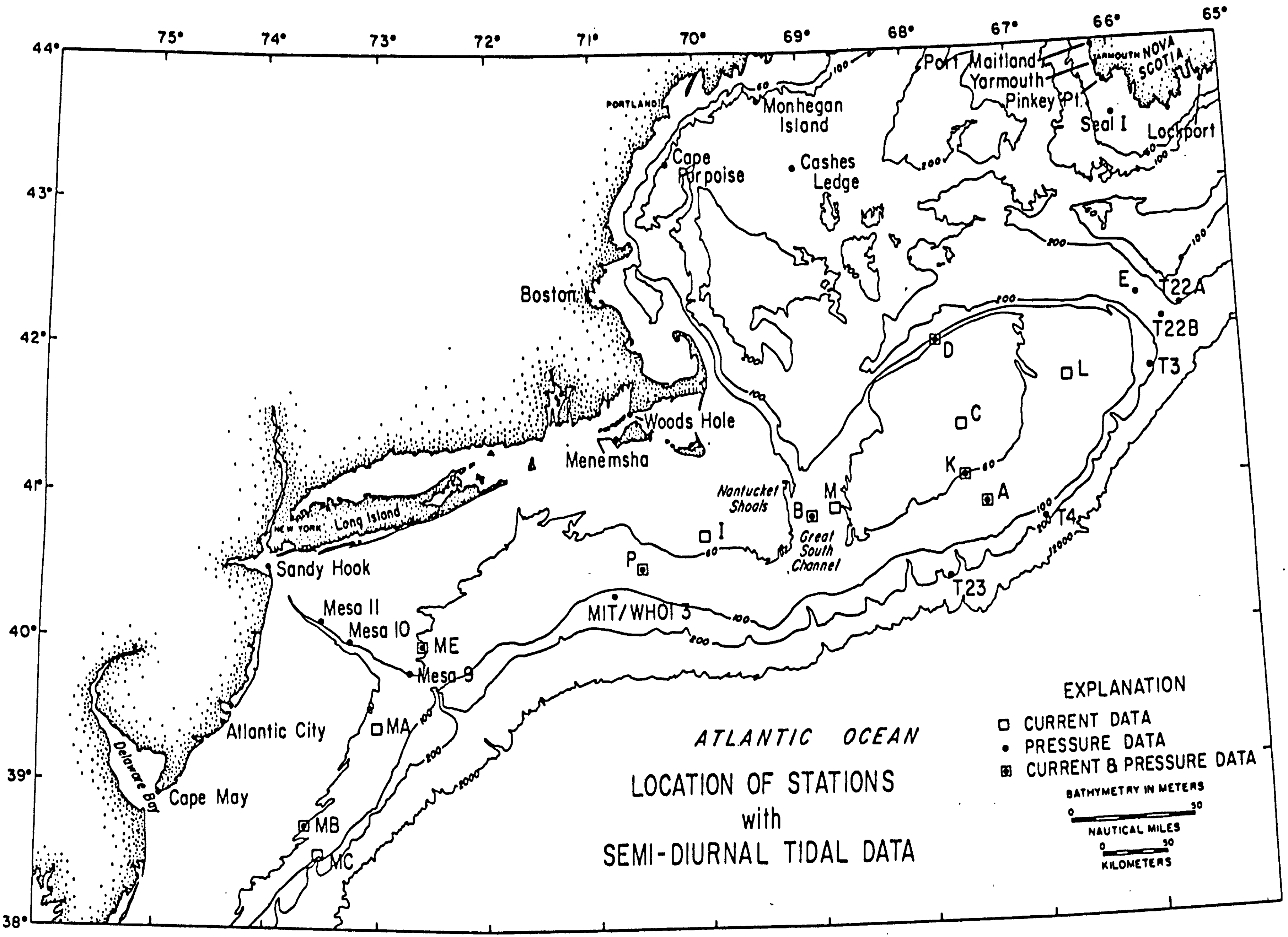


Figure 2. Locations of stations along part of the Atlantic coast of North America where semidiurnal tidal data were collected.

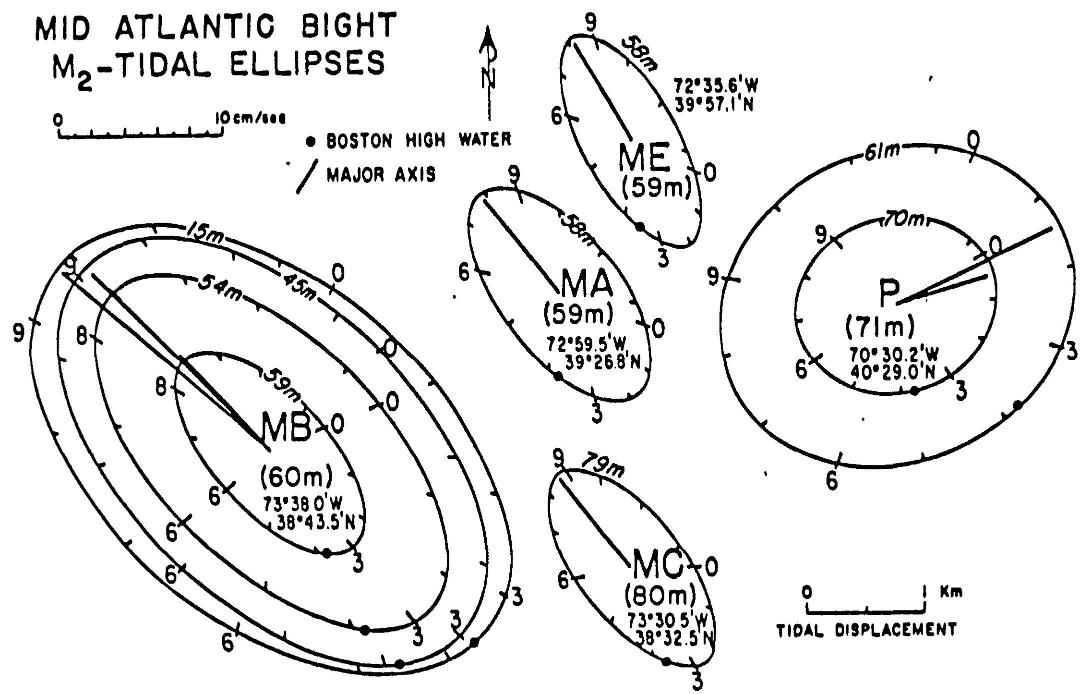


Figure 3. Example of Mid-Atlantic Bight M_2 tidal ellipses. The times indicated on the outside of the ellipse are Greenwich mean time. The depth of the tidal ellipse below the surface is shown on the ellipse circumference, and the water depth is shown in parentheses below the station identification letter in the center of the ellipse. The ellipses are arranged in approximate relative geographical positions. In order that these ellipses can be used with local tide tables, the approximate time of Boston high water is indicated by the solid circle on the ellipse. The solid circle corresponds to the phase of the M_2 surface tide at Boston.

stronger on Georges Bank (typically 74 cm/s near the surface) and are considerably weaker in the Mid-Atlantic Bight (typically 16 cm/s). Velocities of tidal current measured 1 m above the bottom varied between 22 cm/s and 32 cm/s on Georges Bank and were about 7 cm/s in the Mid-Atlantic Bight. Near-bottom tidal currents are weakest south of Cape Cod in a region of transition between the two areas corresponding in part to the "Mud Patch," an area of fine-grained bottom that was also studied by Bothner and others (chapter 4). The area has been identified as a potential present-day sink of fine-grained matter transported from Georges Bank.

Summary of Chapter 3
Observations of near-bottom currents at the shelf break near Wilmington Canyon

Butman, Noble, and Moody, in chapter 3, discuss near-bottom currents at the shelf break near Wilmington Canyon on the basis of measurements made between August and December 1979 (fig. 4). The objectives of their work were to: (1) characterize the surface and near-bottom currents on the upper slope; (2) determine any relationship between the surface and near-bottom currents on the shelf and the currents on the upper slope; (3) document processes of near-bottom sediment resuspension and movement on the shelf and slope; and (4) test a near-bottom instrument package for use in the deeper waters of the Continental Slope. An example of their data is shown in figure 5.

They found that the currents at the edge of the shelf at their study site were strongly affected by Gulf Stream rings. Clockwise circulation around a ring can cause net flow to the northeast on the outer edge of the shelf for 15 to 20 days, opposite to the direction of the long-term mean flow. Maximum near-surface currents associated with the Gulf Stream rings reached 30 cm/s (0.6 kn). However, the Gulf Stream rings did not affect longshelf flow at 60 m on the Continental Shelf. An example of a water-mass map showing the Gulf Stream rings is shown in figure 6.

Along-slope (contour parallel) subtidal currents on the Continental Slope were essentially independent of the along-shelf flow observed on the shelf. However, the shelf-slope current systems are partially interrelated in their responses to the wind-driven circulation pattern. A longshelf wind toward the southwest will drive near-surface currents onshelf, consistent with Ekman dynamics, at a deep-water station. Because the coast imposes a barrier to cross-shelf flow, the onshelf current will be deflected longshelf. Thus, a southwestward wind will be associated with near-surface onshelf flow on the shelf. Net long-term current flows had offshelf components of 1-2 cm/s.

The observations of currents and bottom sediments suggest that at depths shallower than 234 m (upper slope) sediment finer than very fine sand (<62.5 μm in diameter) will occasionally be moved by bottom currents. However, sediments coarser than fine sand (>125 μm in diameter) will be moved very infrequently. The current observations suggest downslope movement of fine resuspended material, generally in the direction of the mean flow. Near-bottom currents at 234 m were strong enough to prevent deposition of silt and clay much of the time.

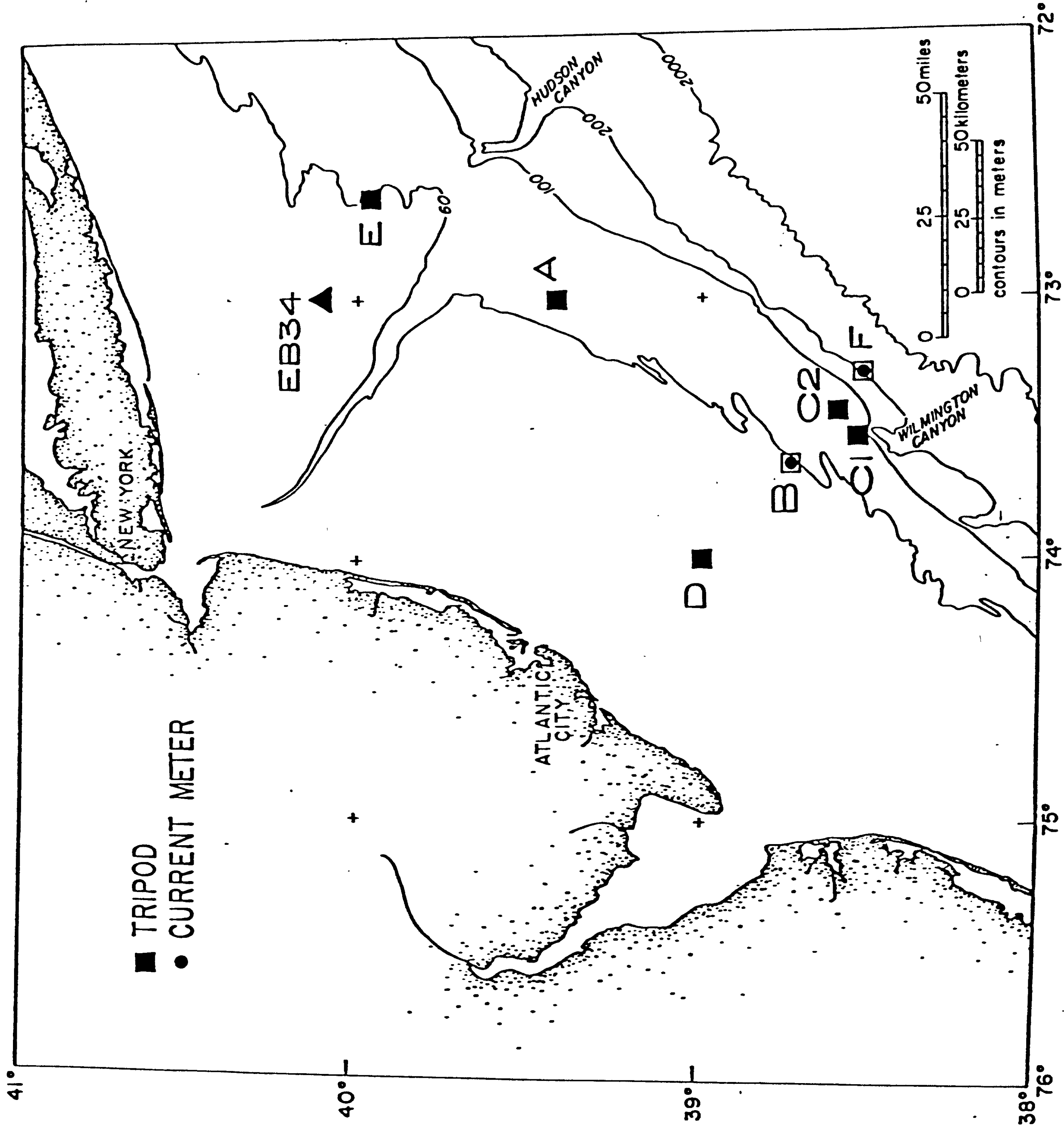


Figure 4. Locations of current and near-bottom observations made on the Middle Atlantic Continental Shelf as part of the study of currents and sediment movement. The measurements reported in this paper were made at stations B and F.

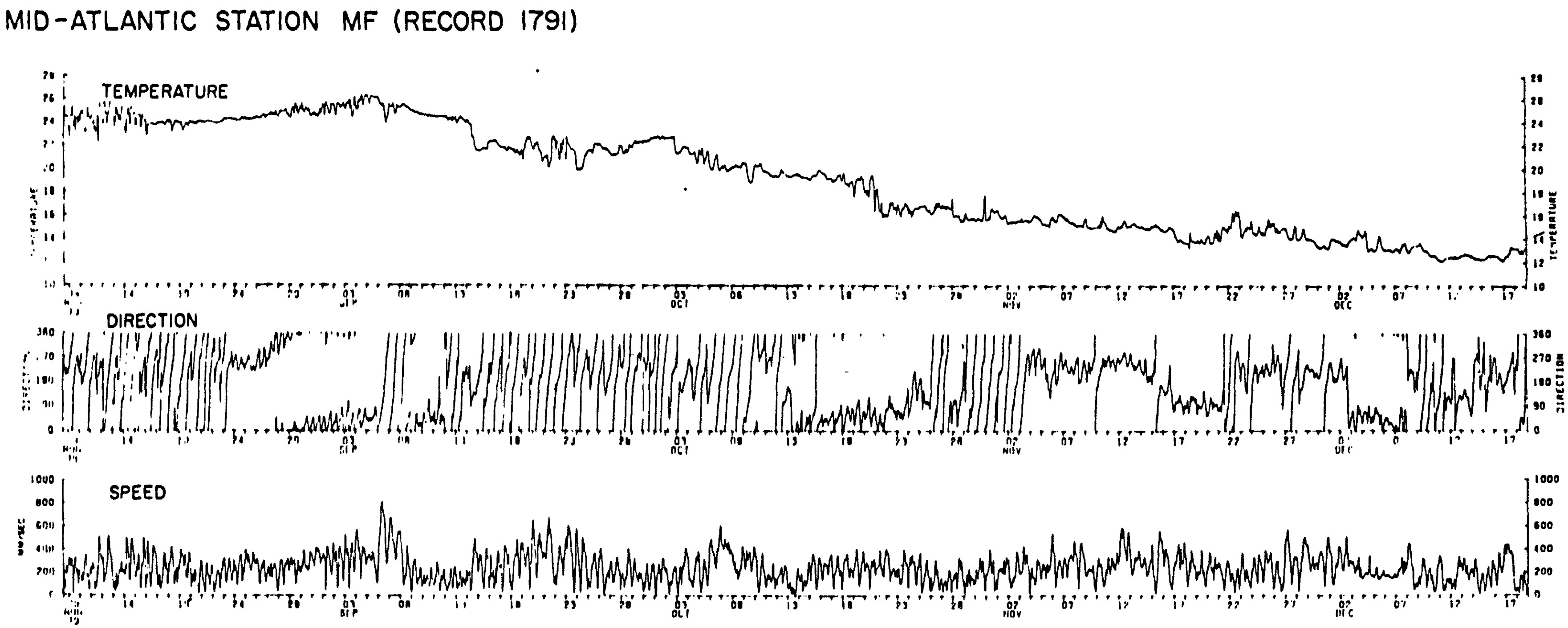
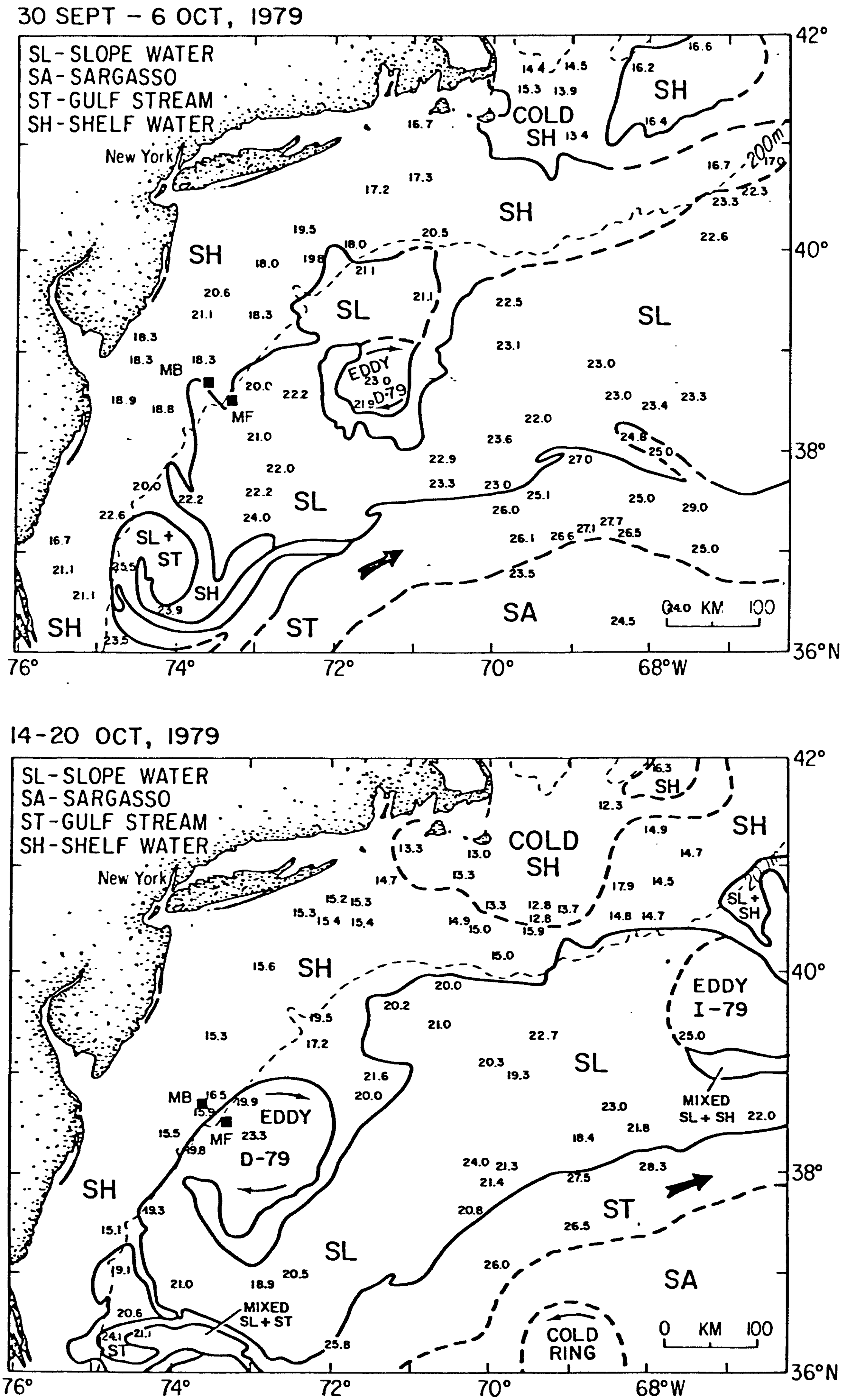


Figure 5. Hour-averaged temperature, current direction, and speed at 15 m at station F (record 1791).

Figure 6. Experimental Ocean Frontal Analysis Charts (redrawn). The positions of stations B and F are labelled MB and MF, respectively. September 30 - October 6, 1979 and October 14 - 20, 1979.


30 SEPT - 6 OCT, 1979
SL-SLOPE WATER
SA-SARGASSO
ST-GULF STREAM
SH-SHELF WATER
New York
COLD SH
SH
SL
EDDY D-79
MB
MF
SL + ST
ST
SA
200m
KM 100
42°
40°
38°
36°N
76°
74°
72°
70°
68°W
14-20 OCT, 1979
SL-SLOPE WATER
SA-SARGASSO
ST-GULF STREAM
SH-SHELF WATER
New York
COLD SH
SH
SL + SH
EDDY I-79
SL
MIXED SL + SH
EDDY D-79
MB
MF
ST
SA
MIXED SL + ST
COLD RING
0 KM 100
42°
40°
38°
36°N
76°
74°
72°
70°
68°W

Summary of Chapter 4
Studies of suspended matter along the North and Middle Atlantic Outer Continental Shelf

Bothner and others report their studies of concentration and composition of suspended matter in samples acquired during August and September 1978 over the area from the Mid-Atlantic Bight to Georges Bank (fig. 7). They also discuss some tests they performed to check sampling techniques and the variability of suspended-matter concentration and composition at a single site over a 24-hour period. Further, they used sediment traps at three locations to investigate resuspended bottom sediments and to make rough estimates of the vertical flux of particulates. Example maps of their results are shown in figure 8.

The highest concentration of suspended sediment in bottom waters on the Continental Shelf occurs between Georges Bank and the Middle-Atlantic area over the fine-grained sediments known as the "Mud Patch," south of Martha's Vineyard. ^{14}C and ^{210}Pb profiles in sediment suggest that this area is an active depositional site. A well-defined nepheloid layer (concentration of fine-grained suspended matter) in bottom water was found on each of four cruises to this area. The long-term measurements show that this nepheloid layer persists under quiet conditions. Resuspension of bottom sediments by tidal currents appears to take place, particularly during short-term internal wave events and storms. A mean drift to the southwest of about 5 cm/s implies that some of the suspended material may be transported out of the Mud Patch, but its ultimate sink is unknown. The net accumulation of sediments based on ^{14}C suggests that more material is being transported in than is being transported out.

During August 1978, relatively high concentrations of Fe, Ti, and Zn were found in suspended-matter samples from the New York Bight, which reflect waste disposal.

Two 24-hour sampling programs indicate that variation of near-bottom suspended sediments over the tidal cycle is not large compared to the regional changes observed. Consequently, samples taken over the whole study area during the period of a single cruise can probably be viewed as synoptic with regard to tidal influence on suspended-matter concentrations.

Currents of greater than 10 cm/s velocity that occurred during the period of sediment-trap deployment may have reduced the usefulness of data from that experiment to determine vertical flux, because of difficulties in estimating trap efficiencies at current flows >10 cm/s. However, the data indicate that the most active area of resuspension occurred over the Mud Patch south of Martha's Vineyard compared to Georges Bank and the Mid-Atlantic Bight during the relatively quiet period of deployment. Further, calculations suggest that residence time of material in the nepheloid layer was approximately 5 hours on Georges Bank, 1.3 days in the Mud Patch, and 2 days on the Mid-Atlantic shelf. These values are low compared to estimates of particulate residence time of 1 to 3 months for the nepheloid layer in the deep sea, and emphasize the rapid exchange between particles on the sea floor and in suspension in the Continental Shelf environment, with the consequent enhanced opportunity for absorption and dispersion of pollutants.

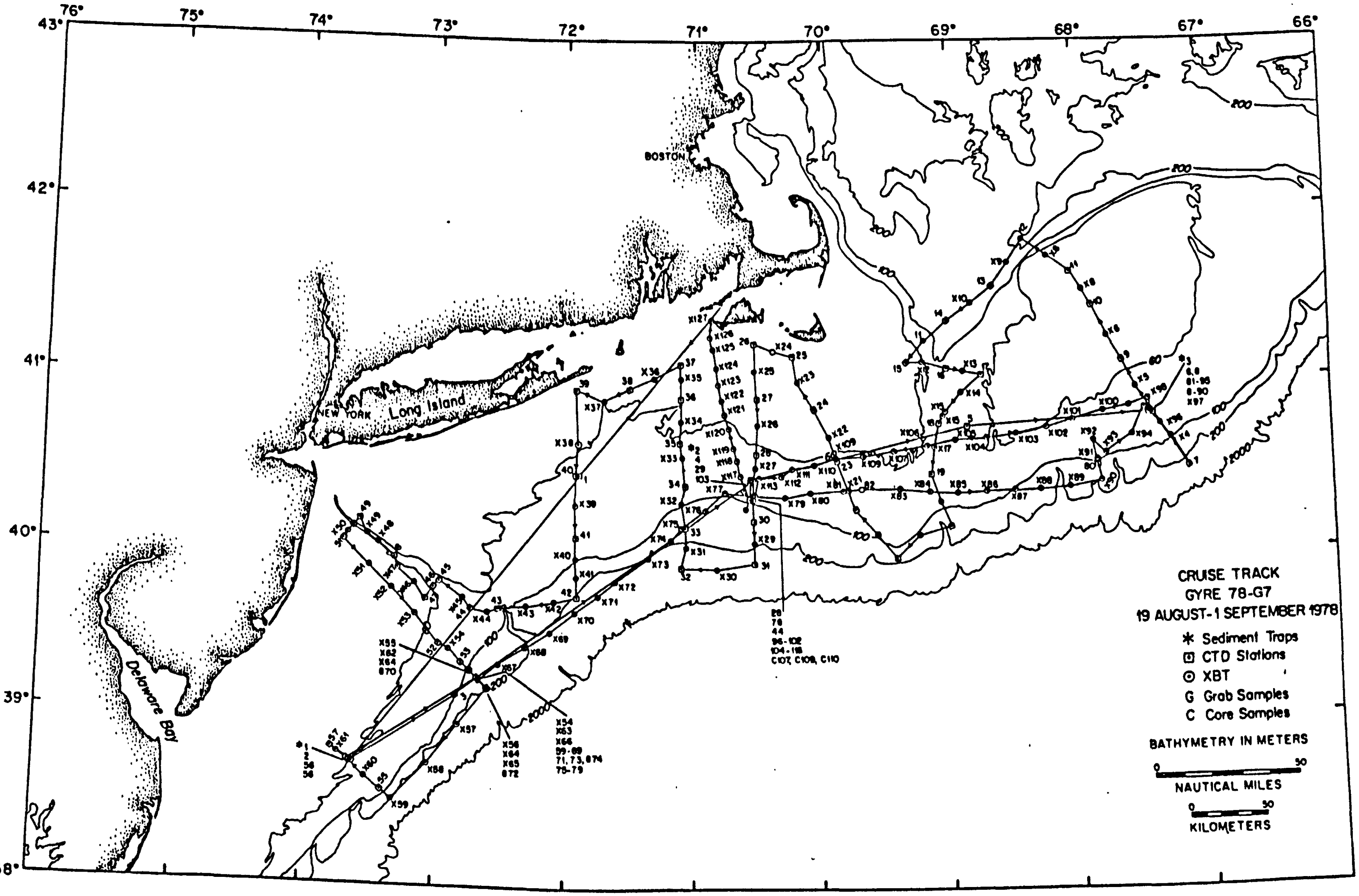


Figure 7. Underway XBT stations and stations occupied for suspended-matter and hydrographic (CTD) sampling during cruise aboard R/V GYRE August 19-Septmeber 1, 1978. Sediment-trap arrays were deployed at stations *1, *2, and *3. Twenty-four-hour stations with sample collections at approximately two-hour intervals were occupied at stations 54, 81, and 96.

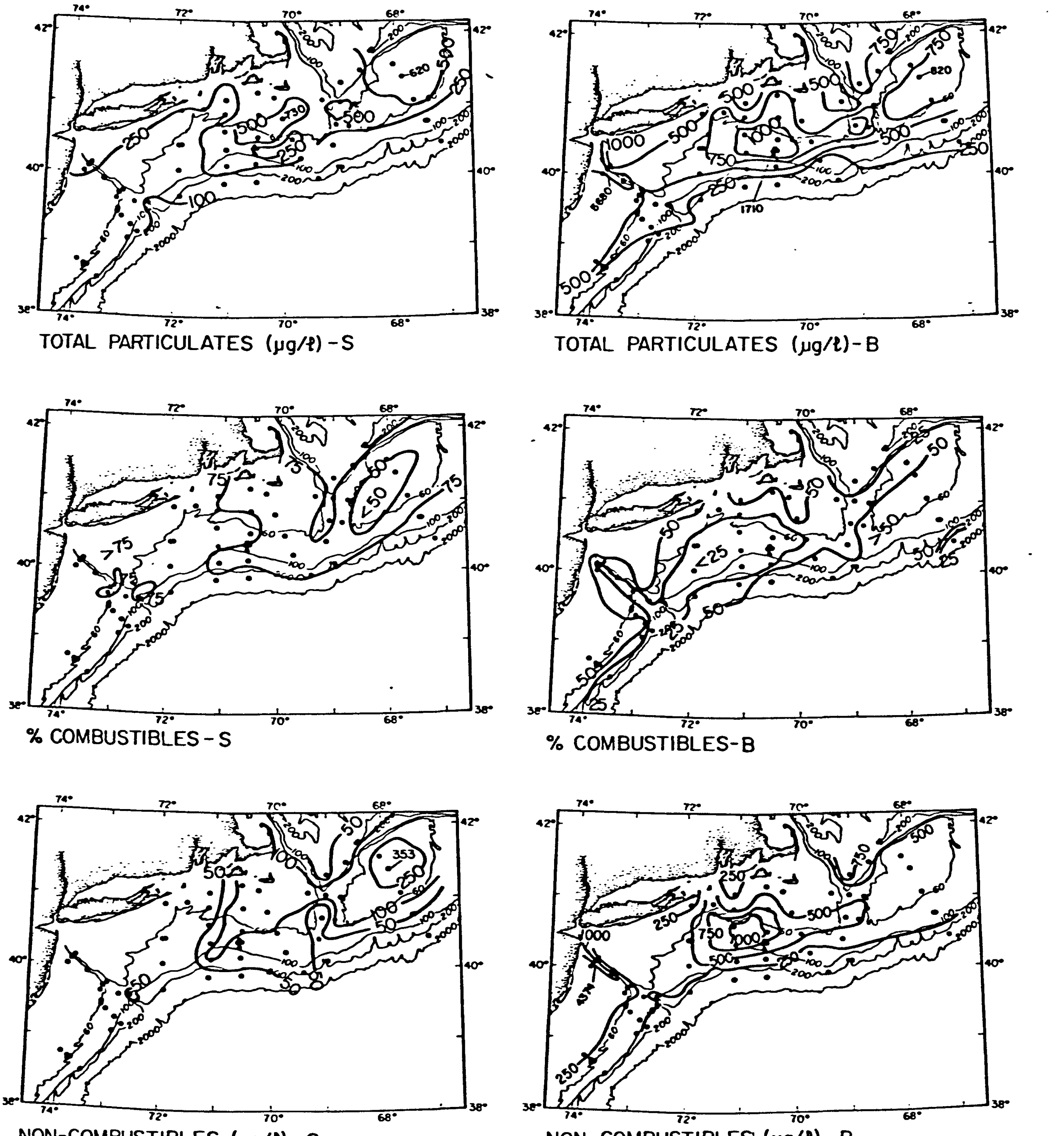


Figure 8. Areal distribution of suspended particulate matter in surface (S) and near-bottom (B) water during August 19-September 1, 1978. Top illustrations show total particulate distribution; middle plots show percent combustibles; bottom plots shown noncombustible concentrations. Depth contour in meters.

Summary of Chapter 5
^{210}Pb in sediment cores from the Atlantic Continental Shelf: estimates of rates of sediment mixing

Bothner and Johnson in chapter 5 discuss rates of mixing of surface sediments determined from measurements of ^{210}Pb. Geochemical pathways of ^{210}Pb leading to unsupported ^{210}Pb in marine sediments are diagrammed in figure 9. Measurements of the decrease in ^{210}Pb activity with depth in the sediment have been used to infer sedimentation rates (^{210}Pb half-life is 22.3 years). The technique can be effective in areas of high sedimentation rates. However, where low sedimentation rates and high activity of benthic infauna occur, the technique is probably more useful to estimate the depth of sediment mixing. Most places within the Georges Bank to Mid-Atlantic-Bight area are receiving little present-day sedimentation, and faunal mixing of relict sediments has occurred, including introduction of ^{210}Pb. The depth of active sediment mixing estimated from ^{210}Pb profiles typically extends to 20 cm and in some places to 28 cm. These estimates have application to predicting the rates and depth of mixing for pollutants having a chemical behavior similar to that of lead.

The ^{210}Pb profiles suggest sediment erosion on Georges Bank consistent with the high energy of tidal and storm currents of the area. High ^{210}Pb inventories in the fine-grained Mud Patch south of Martha's Vineyard support ^{14}C evidence that sediments are presently accumulating in the area, which appears to be the only site of present-day natural deposition on the Continental Shelf off the eastern United States except for the Gulf of Maine. It may receive its sediments and, potentially, contaminants from the Nantucket Shoals and Georges Bank regions.

Summary of Chapter 6
Geology and potential hazards of the Continental Slope between Lindenkohl and South Toms Canyons, offshore Mid-Atlantic United States

The Continental Slope extending from about 130 to 2,100-m water depths is a very different environment compared to the relatively shallow and flat ocean bottoms of the Continental Shelves. Considerable industry interest in possible hydrocarbon traps in the rocks below the middle part of the Continental Slope of the Mid-Atlantic Bight or Baltimore Canyon Trough area was shown during lease sale 59 in December 1981.

Because a number of reports were published recently regarding large slumps that could create possible hazards to drilling and production of hydrocarbons from the Continental Slope, Robb and others have studied a section of the slope in great detail in order to infer what geologic processes presently act or have acted on the slope in the past (fig. 10). The study was intended initially as an effort to map slump features, but the mapping has shown that few slump features exist that can be identified within the resolution of available tools. Robb and others used more than 2,250 km of echo-sounding and subbottom profiles, plus stratigraphic and lithologic information from 6 wells and 20 piston cores to characterize a 40 x 35 km area. They found that while many profiles might be interpreted individually to show slumps and slides in the superficial sediments of the slope, the mapping effort showed such interpretations to be in error. Use of many closely-spaced profiles to map features in three dimensions shows that a

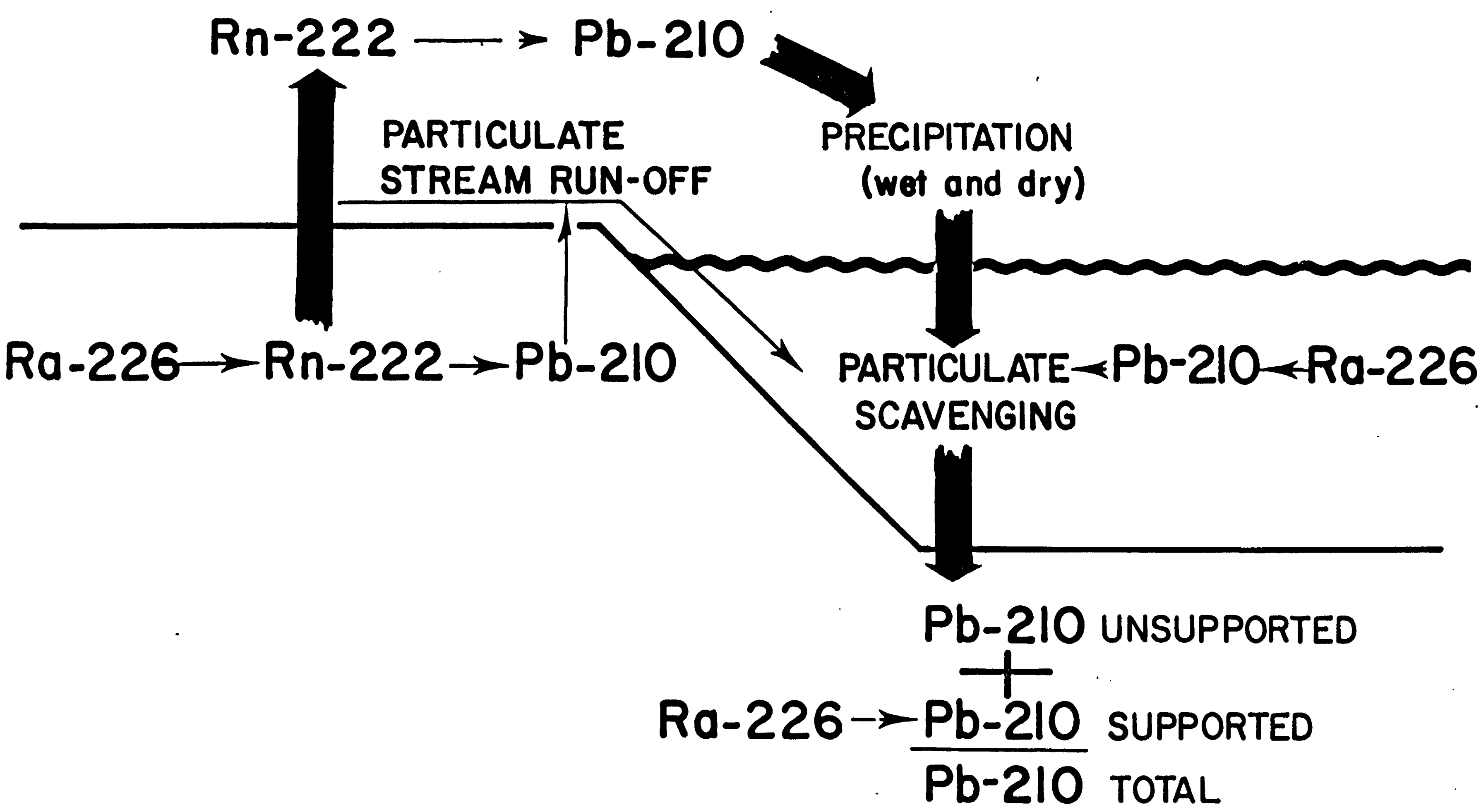


Figure 9. Geochemical pathways of ^{210}Pb leading to unsupported ^{210}Pb in coastal marine sediments.

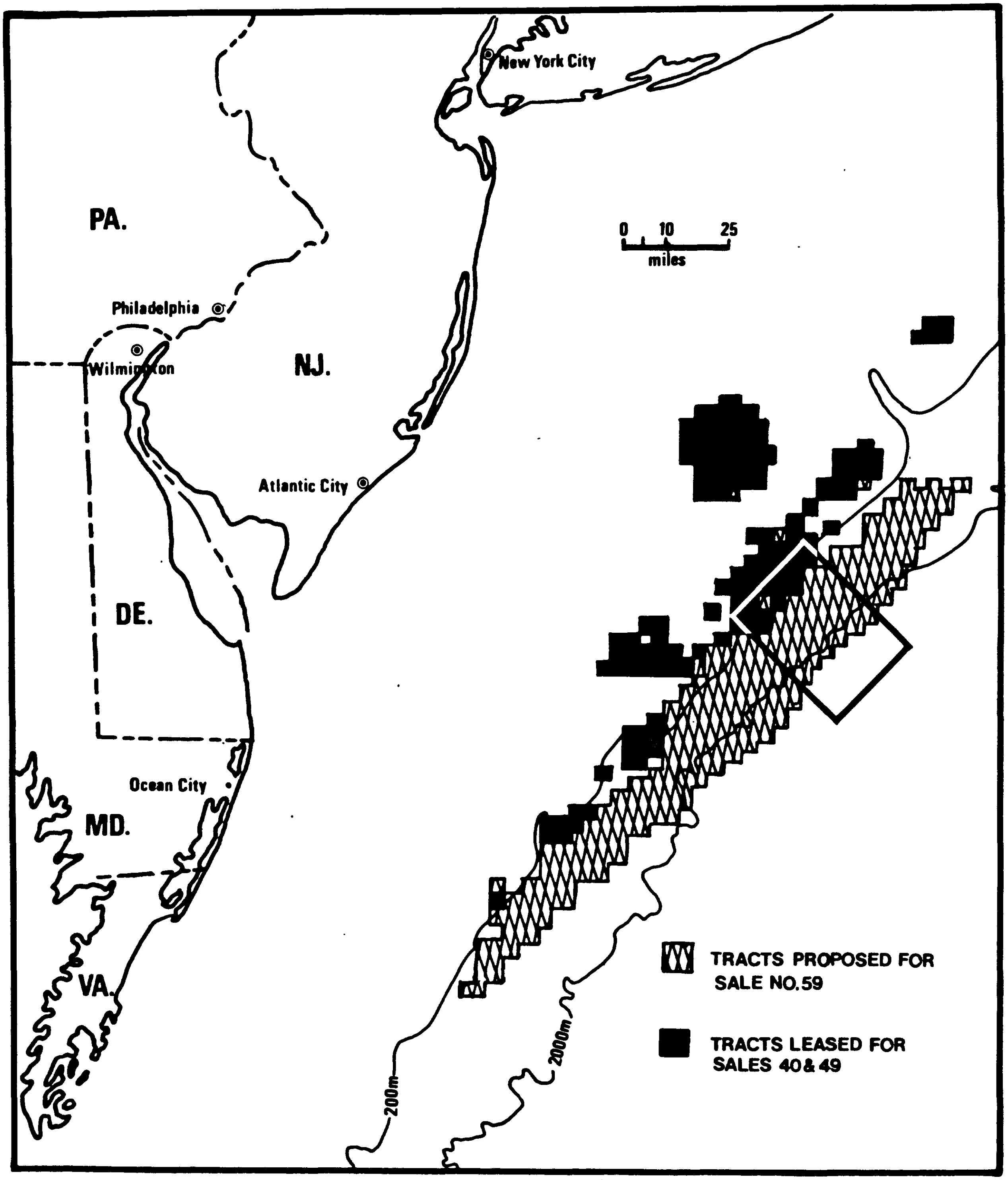


Figure 10. Map showing location of study area in relation to tracts leased or proposed for lease.

deceptive appearance of such features on many two-dimensional seismic profiles can result from a rough topographic surface having underlying depositional reflectors and erosional unconformities.

It was found that in the area between Lindenkohl and South Toms Canyons off New Jersey, Pleistocene sediment is about 450 m thick at the top of the slope and thins to nearly zero or is absent on much of the mid and lower slope, where Eocene to Miocene-aged sediments are exposed in many places (fig. 11). Intercanyon depositional lobes of Neogene and Quaternary sediments overlie a low-relief late-Oligocene erosional surface on the mid slope. The slope is generally mantled by a thin cover (less than 2 m) of Holocene sediments, and its surface appears to be mainly relict from late Pleistocene time.

Five slump or slide features were identified in Pleistocene sediments and occupy about 1.3 percent of the slope surface mapped (fig. 12). Sidescan-sonar data indicate that canyon thalwegs should be viewed with caution as potential structure sites because canyon-wall erosion (rock falls and small slides) and downcanyon transport may create occasionally hazardous conditions.

Robb and others included a bathymetric map and geologic map of their study area as well as a map of potential hazards.

Summary of Chapter 7
Geotechnical properties and slope stability analysis of surficial sediments on the Baltimore Canyon Continental Slope

Studies directed to the engineering aspects of the Continental Slope are reported by Booth and others in chapter 7. They briefly review sample data available within the Mid-Atlantic Continental Shelf area, and discuss the results of geotechnical tests on samples from 34 piston cores recovered during 1979 and 1980 (fig. 13). Most cores penetrated less than 10 m. Laboratory vane shear and triaxial tests showed erratic profiles of shear strength vs. depth and a variability of index properties (bulk density, water content, liquid and plastic limits, and grain-specific gravity) which imply that the Continental Slope of the Baltimore Canyon Trough area is a complex environment (figs. 14, 15). The sediments (only Quaternary sediments were tested) are essentially inorganic sands, silts, and clays and range from low to high plasticity. No exotic minerals or abnormal textures were indicated by the geotechnical data. Based on slope stability analyses using an infinite-slope model, without pore-pressure data, the surficial sediments represented by the cores are stable. However, index-property data and assessments of consolidation state suggest that excess pore pressures may exist in some areas, and thus that these areas may be only marginally stable. All possible consolidation states are represented by the cores, as judged from the index properties and plasticity data.

Booth and others present the results of their individual tests in tables and graphs included in Appendix II (see table 1).

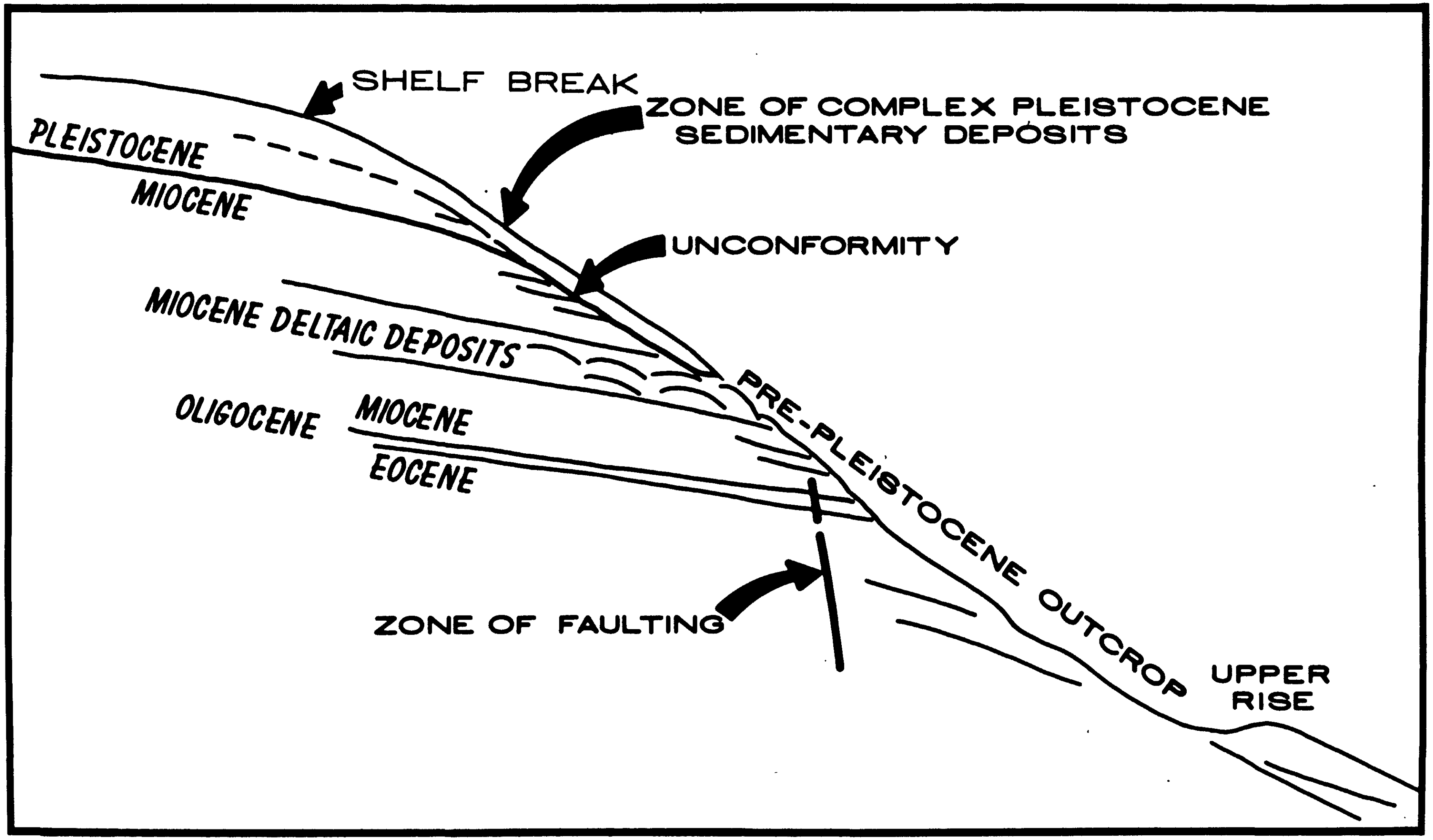


Figure 11. Generalized cross section of Continental Slope between Lindenkohl and South Toms Canyons.

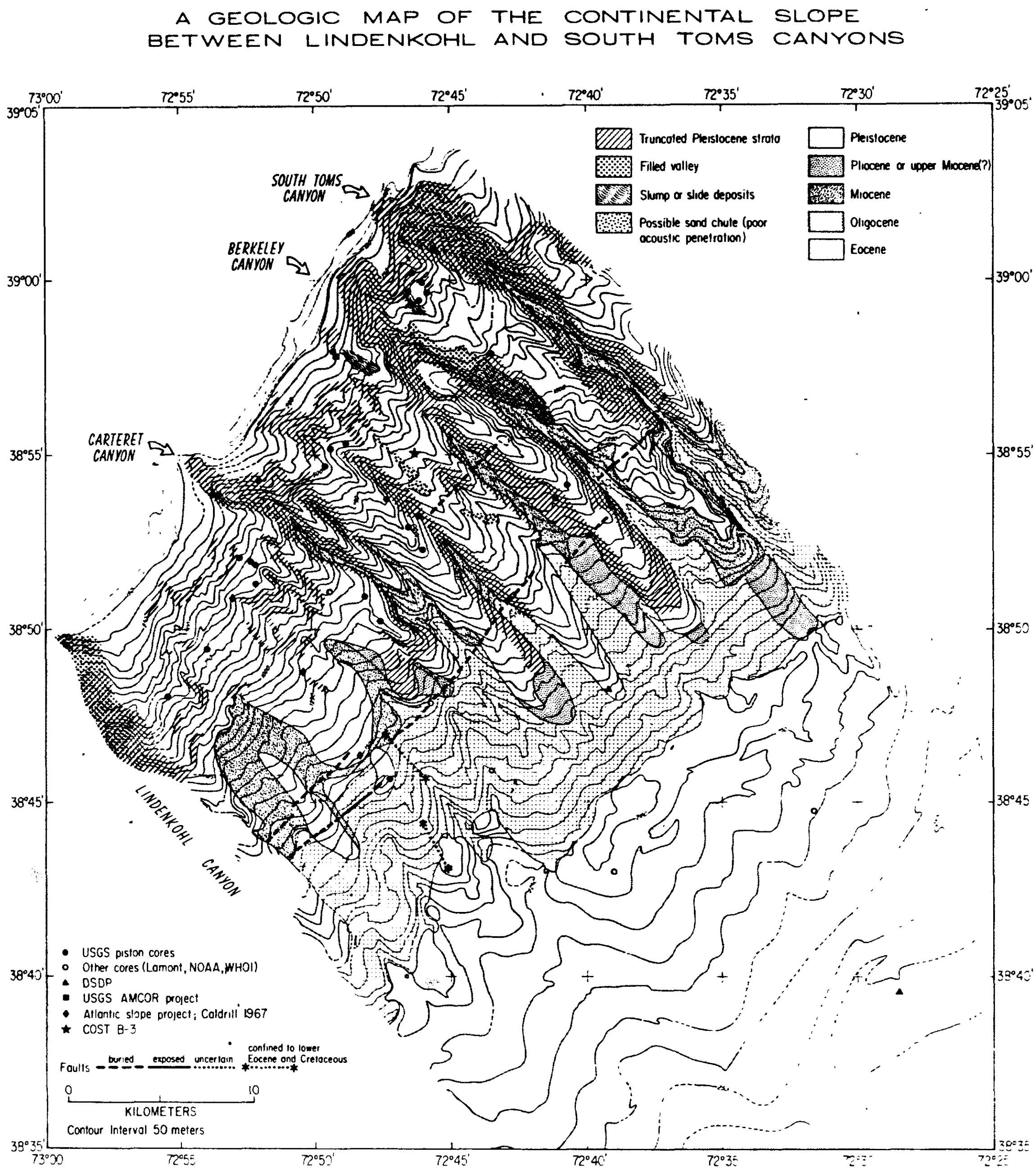


Figure 12. Geologic map of the Continental Slope.

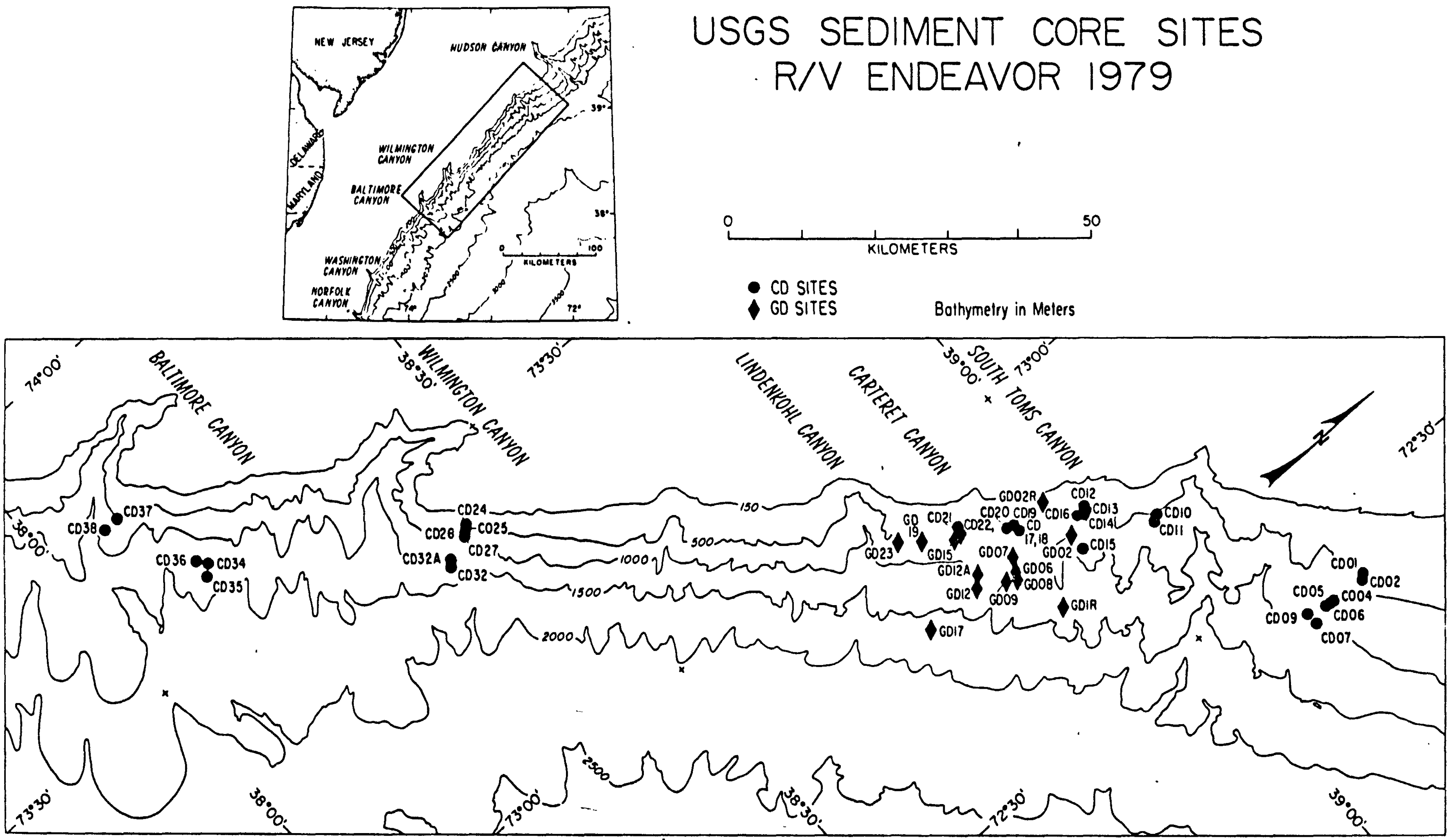


Figure 13. Map of piston-core sites, R/V ENDEAVOR cruise, 1979, Mid-Atlantic.

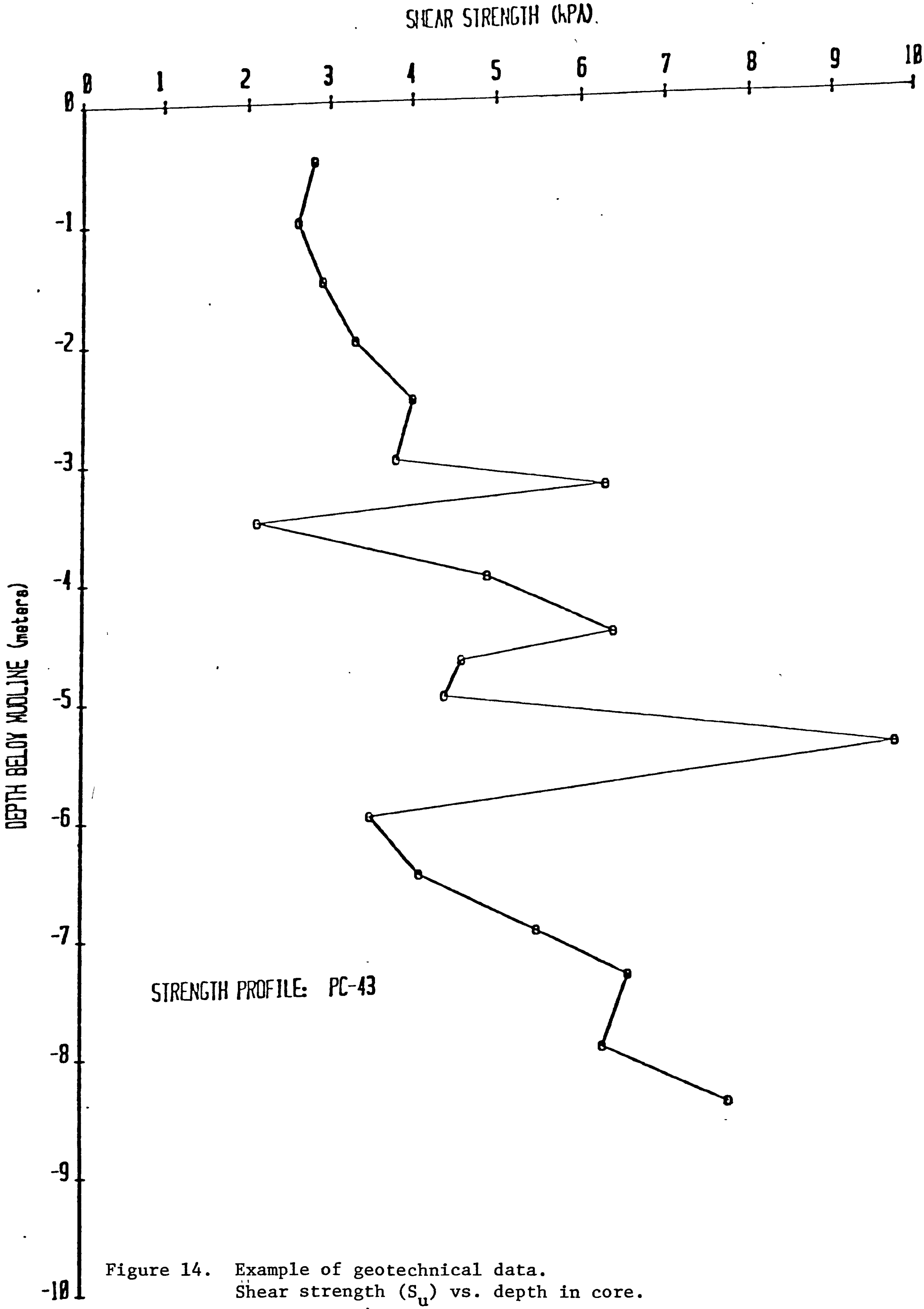


Figure 14. Example of geotechnical data.
Shear strength (S_u) vs. depth in core.

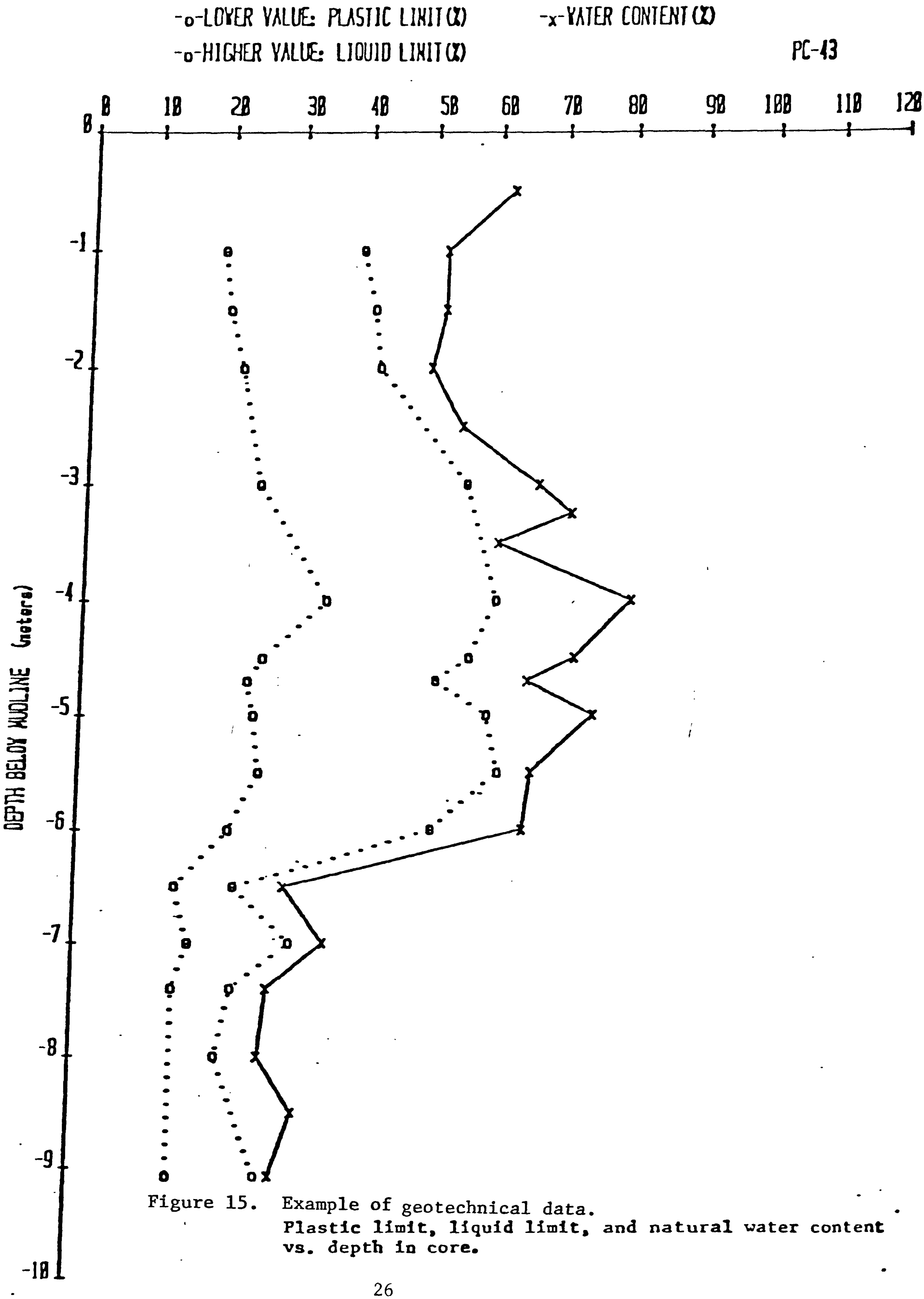


Figure 15. Example of geotechnical data.
Plastic limit, liquid limit, and natural water content vs. depth in core.

Summary of Chapter 8

Summary report of the residual light hydrocarbon analyses of interstitial gases in piston core samples from the North and Mid-Atlantic Continental Slope environments

Gas-charged sediments were recovered during earlier USGS core drilling on the Continental Shelf, and zones of probable gas-charged sediments were reported along the Mid-Atlantic Continental Shelf break in USGS hazards studies (using seismic profiling) prior to lease sale 49. Interstitial gas pressures in sediments may lead to drastic reduction in sediment strengths.

Miller and others (chapter 8) report on the results of a study of interstitial gases found in 61 piston cores and gravity cores from the Mid and North Atlantic Continental Slope (fig. 13).

Gas-charged sediments are defined as containing sufficient gas in the dissolved and bubble phase so that they are represented on high-resolution seismic-profiles by "acoustically turbid zones" or "wash outs," where reflectors that would normally appear are not visible. There is very little, if any, reliable published data on _in situ_ molecular gas composition, distribution, volume, pressure, and temperature in marine surface-sediments upon which estimates of critical solubility, temperature, and pore volume-pressure relationships that affect stability may be based. Similarly in this study, those _in situ_ data are not known, and the measurements were, of necessity, made from gas recovered as soon as possible following recovery of piston cores. Consequently, these data represent residual concentrations and compositions obtained after outgassing at ambient temperature and pressure during retrieval of the piston corer. The results may be viewed as the minimum possible concentrations of residual hydrocarbon gases in the sediments.

Results of the study show that residual interstitial light-hydrocarbon concentrations (methane and higher homologues) range from less than 10 ppm to more than 16,000 ppm (volume gas/volume sediment). Values greater than 100 ppm are one or more orders of magnitude greater than the light-hydrocarbon background levels for the Mid-Atlantic OCS. Holocene-Pleistocene sediments at AMCOR site 6021-C, a 300-m deep stratigraphic test well at the top of the Continental Slope near South Toms Canyon, contain methane in sufficient concentration to be present in the free-gas phase; such concentrations may have originated from pre-existing natural methane hydrates. Although the concentrations recovered from the short piston cores of the sediment surface are small, residual gas concentrations in several cores were found to increase with depth of burial indicating that higher gas concentrations may be present at depth. These data suggest that if cyclic loading were to occur and to result in bubble coalescence and excess pore pressures at greater burial depths, then significant changes in consolidation characteristics could occur that might affect stability.

Summary of Chapter 9

Submersible observations of potential geologic hazards along the Mid-Atlantic Outer Continental Shelf and uppermost slope

Chapter 9, by Slater and others, reports observations from 15 submersible dives along the uppermost Continental Slope to depths of 365 m (fig. 16).

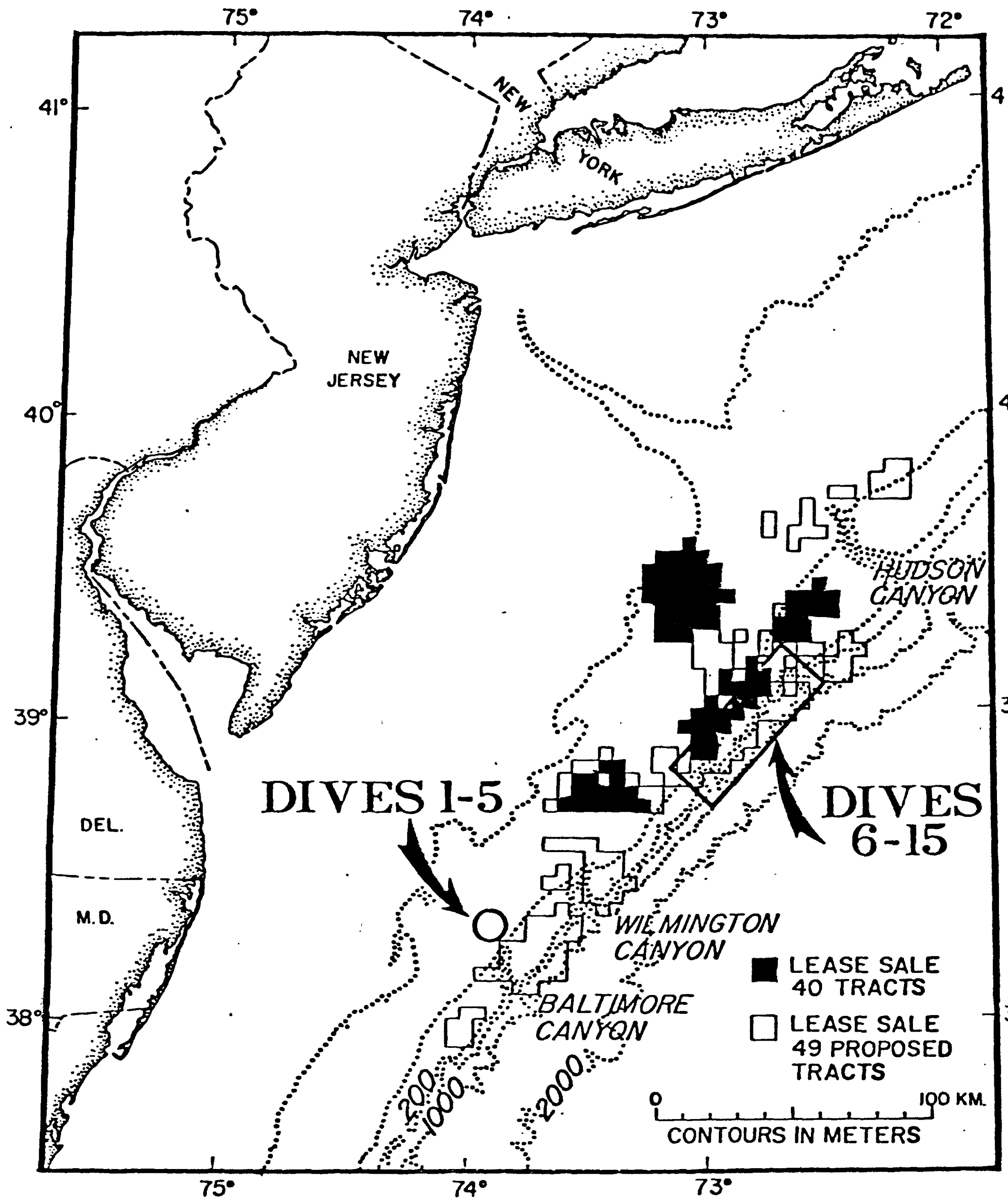


Figure 16. Locations of dive areas on the Continental Shelf and on the uppermost Continental Slope in the Mid-Atlantic area.

Five dives were made near the head of Baltimore Canyon, 5 dives were made in the head of South Toms Canyon, 3 dives to the head of Carteret Canyon, and 2 dives to the upper slope between Carteret and South Toms Canyons. During the dives near Baltimore Canyon, a bioturbated silt-covered sea floor was observed, having slopes greater than 15^{o} in some places. The intercanyon areas showed little biological or current activity compared to canyon heads, where greater faunal density and diversity and evidence of weak currents were seen. Considerable man-made trash and trawl marks were reported. Biological activity, bioturbation, burrowing trails, and near-subsurface feeding probably mix and change the appearance of surface sediments rapidly, so that current ripples or other surface-sediment phenomena may not survive long. Sand sediments and some areas of iron-stained sands were observed at the shallower parts of the dives on the Continental Shelf. Over the shelf break, sandy silts and silts predominate. A number of observations suggest that a cover of silty sediment several centimeters thick overlies a more consolidated greenish clay in the Carteret Canyon to South Toms Canyon area.

Scarps less than 1-m high and 1 to 2 m long were observed in the heads of both Carteret and South Toms Canyon. They exposed the greenish clay mentioned above and probably represent small slump structures in the heads of the canyons (fig. 17). However, the evidence of weak currents and small slump structures observed during these dives does not nesessarily imply that hazardous conditions exist at these sites.

Transcripts and photographs from these dives are filed at the Woods Hole, Massachusetts office of the U.S. Geological Survey.

Summary of Chapter 10
Shallow subbottom strata, middle and inner Continental Shelf south of Hudson Shelf Valley, offshore eastern United States

Investigation of subbottom conditions in the nearshore area of the New York Bight are reported in chapter 10 by Knebel. Using Uniboom and minisparker, high-resolution subbottom profilers, and vibracore samples, he found that a previously undetected buried valley extends across the shelf under the Hudson Divide southwest of the present-day Hudson Channel on the Continental Shelf (fig. 18). This valley was probably occupied by the Hudson River during one of the Pleistocene lowstands of sea level. The significance of such valleys to engineering studies lies in the possible difference in composition and bearing capacity between the valley fill and surrounding material. The valley fill in this case consists of heterogeneous fluvial deposits. It is capped by 10 to 30 m of sediment, the upper part of which is interbedded layers of marine sand and mud. Geotechnical tests of samples from vibracores show that the muddy layers are overconsolidated, probably because the region underwent subaerial dessication during one or more periods of lowered sea level. However, local variations may exist and the stability of the sea floor should be evaluated on a site-specific basis for future engineering work. The profiles of this study revealed no shallow faulting.

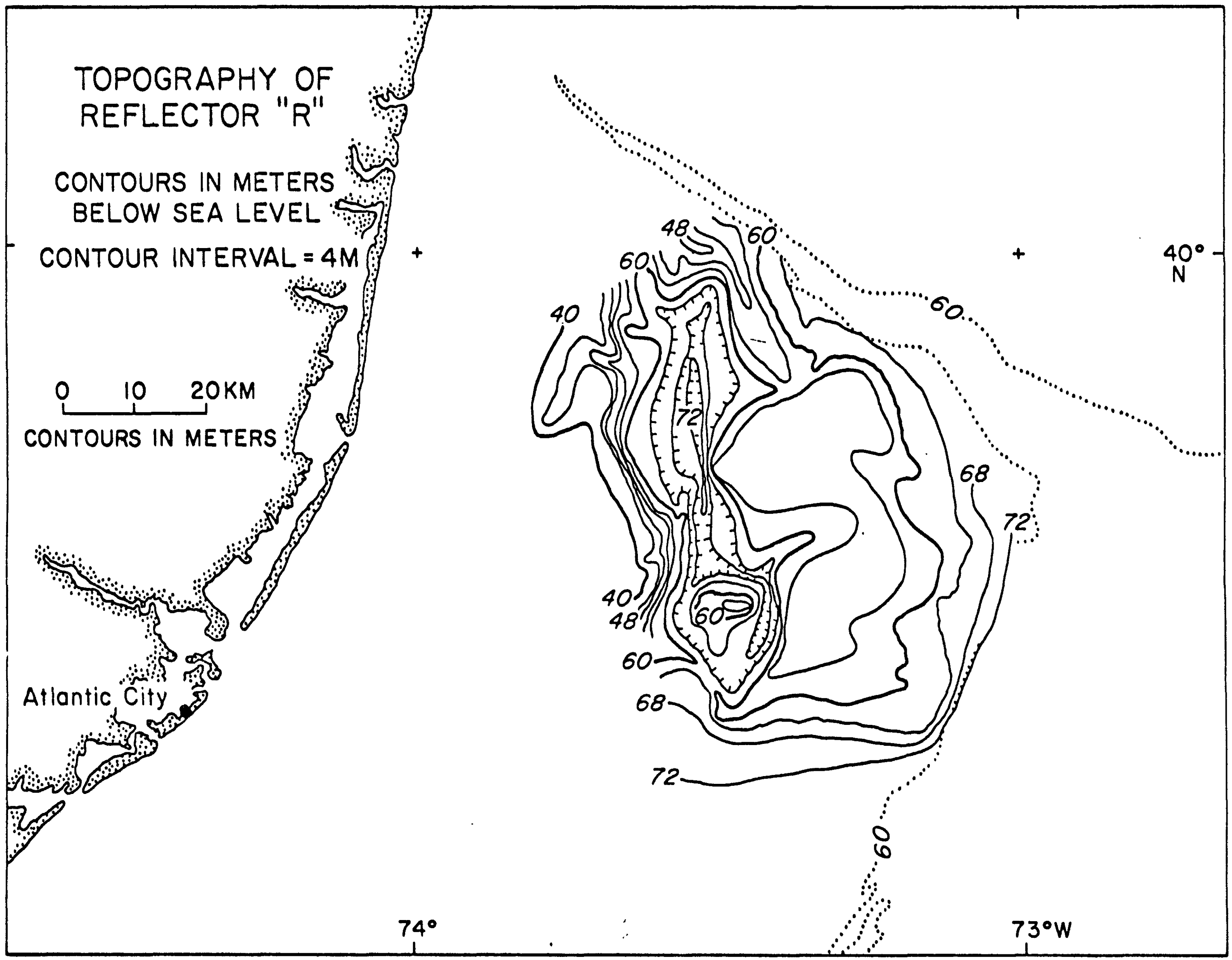


Figure 18. Topography of reflector R, showing location and trend of large subbotom valley beneath Hudson Divide. Topography determined from seismic-reflection profiles. Sound velocity in sediments is assumed to be 1,463 m/s. Dotted line is present 60-m isobath on the Continental Shelf and shows relative location of topographic Hudson Shelf Valley.

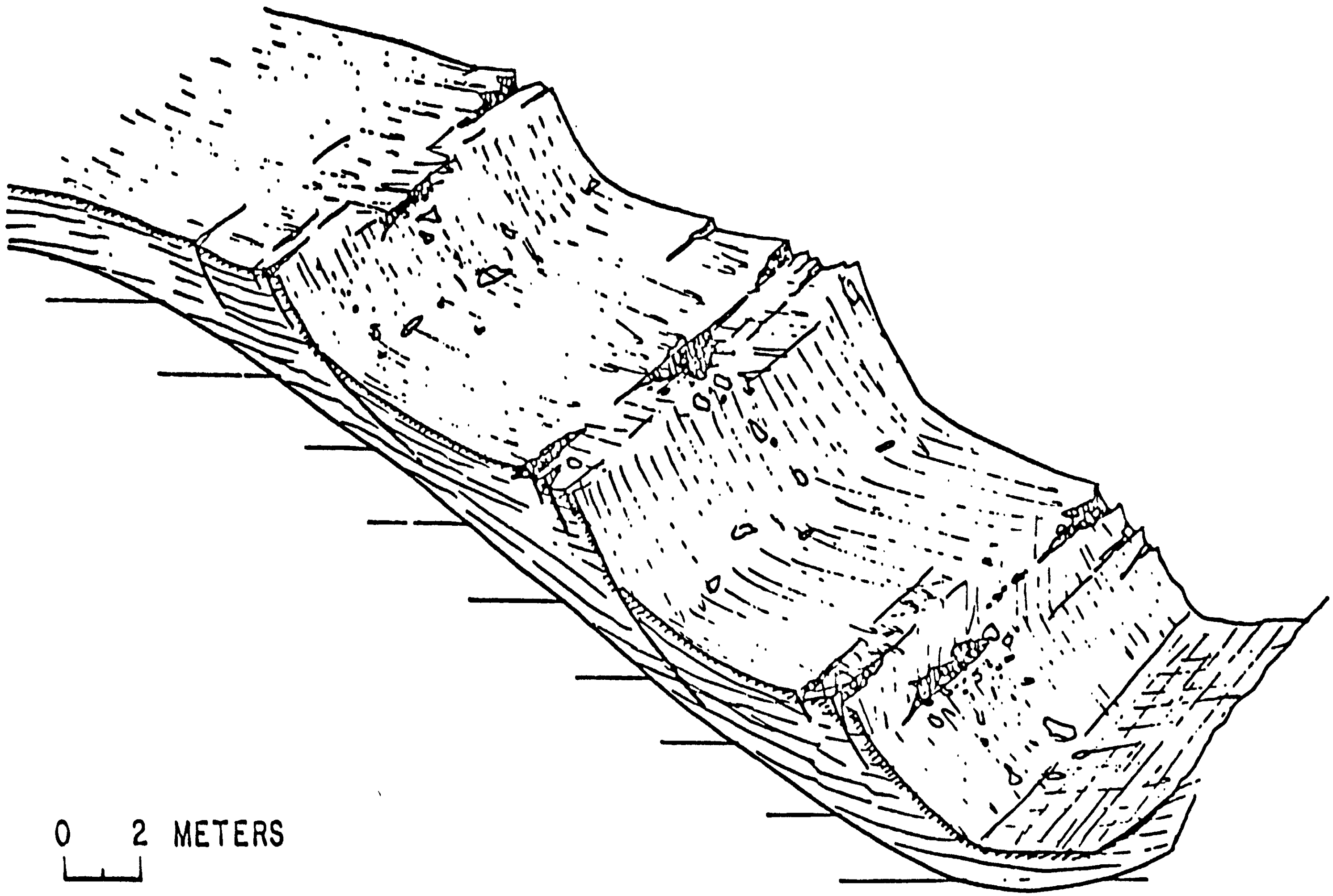


Figure 17. Diagrammatic section of Carteret Canyon wall showing inferred structural control of observed morphology.

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