UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

POTENTIAL GEOLOGIC HAZARDS AND CONSTRAINTS FOR BLOCKS IN PROPOSED MID-ATLANTIC OCS OIL AND GAS LEASE SALE 59

By

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This report has not been edited for conformity
with Geological Survey editorial standards
or stratigraphic nomenclature.

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Metric equivalents:

1 meter = 3.2808 feet
1 kilometer = 0.6214 statute miles
1 nautical mile = 1.1508 statute miles = 1,852 meters

POTENTIAL GEOLOGIC HAZARDS AND CONSTRAINTS FOR BLOCKS IN PROPOSED MID-ATLANTIC OCS OIL AND GAS LEASE SALE 59

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ABSTRACT

Analysis of high-resolution geophysical data collected over 253 blocks tentatively selected for proposed OCS Oil and Gas Lease Sale 59 revealed potential geologic hazards to oil and gas exploration and development activities. These potential hazards are shallow recent faults and mass-movement areas on the continental slope. Relatively recent faulting and movement of shallow diapirs may have triggered some of the slumps and slides mapped. No potential hazards were observed on any blocks on the continental shelf.

Other geologic features, classified as constraints because they pose a relatively low degree of risk, can be dealt with using existing technology. Constraints found in the proposed Lease Sale 59 area are filled channels, erosion, sand waves, deep and shallow faulting, and gassy sediments.

Piston cores were collected for geotechnical analyses at selected locations on the continental slope in the proposed lease sale area. The core locations were selected to provide information on geotechnical properties of slumps, slides, and undisturbed sediments. The results indicate that localized areas of underconsolidated sediments exist primarily on valley walls and ridges of the upper slope.

INTRODUCTION

This document reports the results of the U.S. Geological Survey's high-resolution geophysical (HRG) study conducted to assess potential geologic hazards in blocks proposed for Mid-Atlantic OCS Lease Sale 59. The 253 blocks in the survey area, totaling 1,440,376 acres, are located in the Baltimore Canyon Trough in water depths of 85 m to 2,455 m (fig. 1).

Geologic features and conditions having a potential for risk to oil and gas exploration and development operations fall into two general classes depending on their degree of risk. The first and potentially more serious of these classes is termed hazards. Hazards have a relatively high inherent risk because existing drilling technology cannot routinely eliminate their potential for structural damage. Shallow recent faulting, with displacement of surficial sediments, and mass-movement (slumps, slides) of surface sediments are hazards which have been identified and located in the proposed Lease Sale 59 area.

The other risk-related class of geologic features or conditions is termed constraints. These offer lower risk because adverse effects can be eliminated or reduced to an acceptable level through conventional engineering practices. Constraints noted and mapped in the proposed sale area are filled channels, erosion, sand waves, deep and shallow faults, and gassy sediments. The rationale for these classifications and for the assessment of risk related to particular geologic features and conditions is discussed under the individual subject headings.

Location and identification of geologic features discussed in this report result from a multisensor, high-resolution geophysical survey, a geotechnical piston coring study, a comprehensive literature search, and personal contacts with scientists and engineers from other Federal agencies, academia, and the private sector. The impacts of natural hazards resulting from weather or ocean dynamics are not addressed by this report on geologic hazards. Hazards and constraints related to seismicity, although they may not be directly definable with high-resolution geophysical data, can often be inferred. In this case, our data merely detect (sometimes ambiguously) the geologic consequences of seismicity or of unstable soil conditions in the form of faults or structural complexes which appear to have resulted from mass-movement of sediments. Obviously, the timing and frequency of these events cannot be directly evaluated solely with geophysical and shallow geotechnical data. Seismicity or soil mechanics studies tailored to specific problems will be necessary to substantiate or clarify conclusions based on HRG surveys and shallow reconnaissance geotechnical coring studies.

This is the third open-file report dealing specifically with geologic hazards and constraints of the Baltimore Canyon Trough OCS region. Carpenter and Roberts (1979) provided a hazards assessment for blocks involved in OCS Lease Sale 40 and showed that the general area of the continental shelf in the Baltimore Canyon Trough, and Lease Sale 40 acreage in particular, is relatively free of hazards to petroleum exploration and development activities. Hall and Ensminger (1979) provided a hazards assessment for blocks involved in OCS Lease Sale 49 and reported that portions of the continental slope may be undergoing extensive mass movement; as a result, 27 lease blocks were withdrawn from that sale.

Acknowledgments: Data reduction and analyses for this report were a group effort by the Hazards Analysis Unit. Significant contributions to this document were made by G. B. Carpenter, D. K. Francois, L. K. Good, R. L. Lewis, N. T. Stiles, and T. M. Wilson. Figures 3 and 4 were provided by D. C. Twichell and figure 5 by J. E. Robb. J. S. Booth, D. L. Marks, B. A. McGregor, H. W. Olsen and T. L. Rice aided in the compilation of the geotechnical data.

PREVIOUS WORK

The continental slope between Hudson Canyon and Baltimore Canyon is bordered landward by a relatively wide continental shelf and seaward by a well developed continental rise. The continental slope is delimited approximately by the 200-m and 2,000-m isobaths. The most striking geomorphological features on the slope are the numerous submarine canyons with associated valleys and gullies which are incised into the slope from Hudson Canyon southward through the lease sale area. From north to south, the larger canyons are Hudson, Mey, Hendrickson, Toms, South Toms, Carteret, Lindenkohl, Spencer, Wilmington, and Baltimore (fig. 1 and 2). The major canyons were once linked to various Pleistocene drainage systems carrying glacial meltwater (Twichell and others, 1977). The Pleistocene lowering of sea level was probably instrumental in the formation and/or reexcavation of a large number of submarine canyons on the eastern U.S. continental margin.

The continental slope narrows and steepens from about 35 km in width near Hudson Canyon to approximately 22 km in width near Wilmington Canyon. The regional gradient increases southward reaching a maximum of 10^{o} in the vicinity of Wilmington Canyon. The slope from Wilmington Canyon to the southern perimeter of the area, just south of Baltimore Canyon, comprises a relatively steep (11^{o}) upper part between water depths of 120 to 1,200 m and a much more gentle (1^{o}) lower part extending to a depth of 2,200 m (Keller and others, 1979).

The dominant geologic structure in the Mid-Atlantic region is the Baltimore Canyon Trough, which extends more than 500 km subparallel to the shoreline between Long Island and Cape Hatteras. It is widest (200 km) off New Jersey (Schlee and others, 1977; Grow and others, 1978). The trough's southern margin is the Carolina platform and its northern border is the Long Island platform (Klitgord and Behrendt, 1979). A westward extension of the trough forms the Salisbury Embayment beneath the coastal plain of eastern Virginia, Maryland, Delaware, and most of New Jersey. On the seaward side of the Baltimore Canyon Trough, a massive reeflike

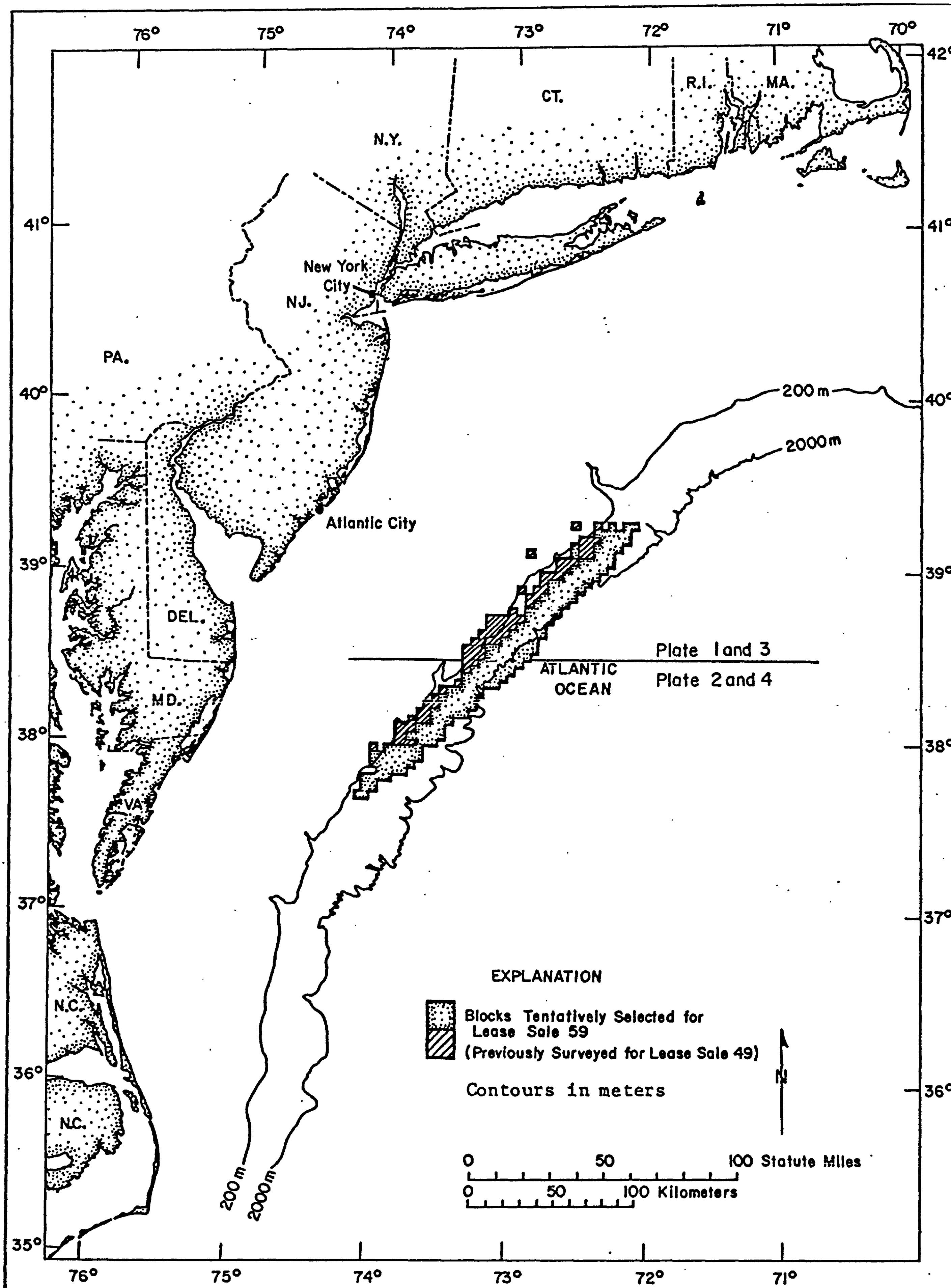


Fig. 1 Map showing the blocks tentatively selected for leasing and surveyed for geohazards in connection with proposed OCS Oil and Gas Lease Sale 59.

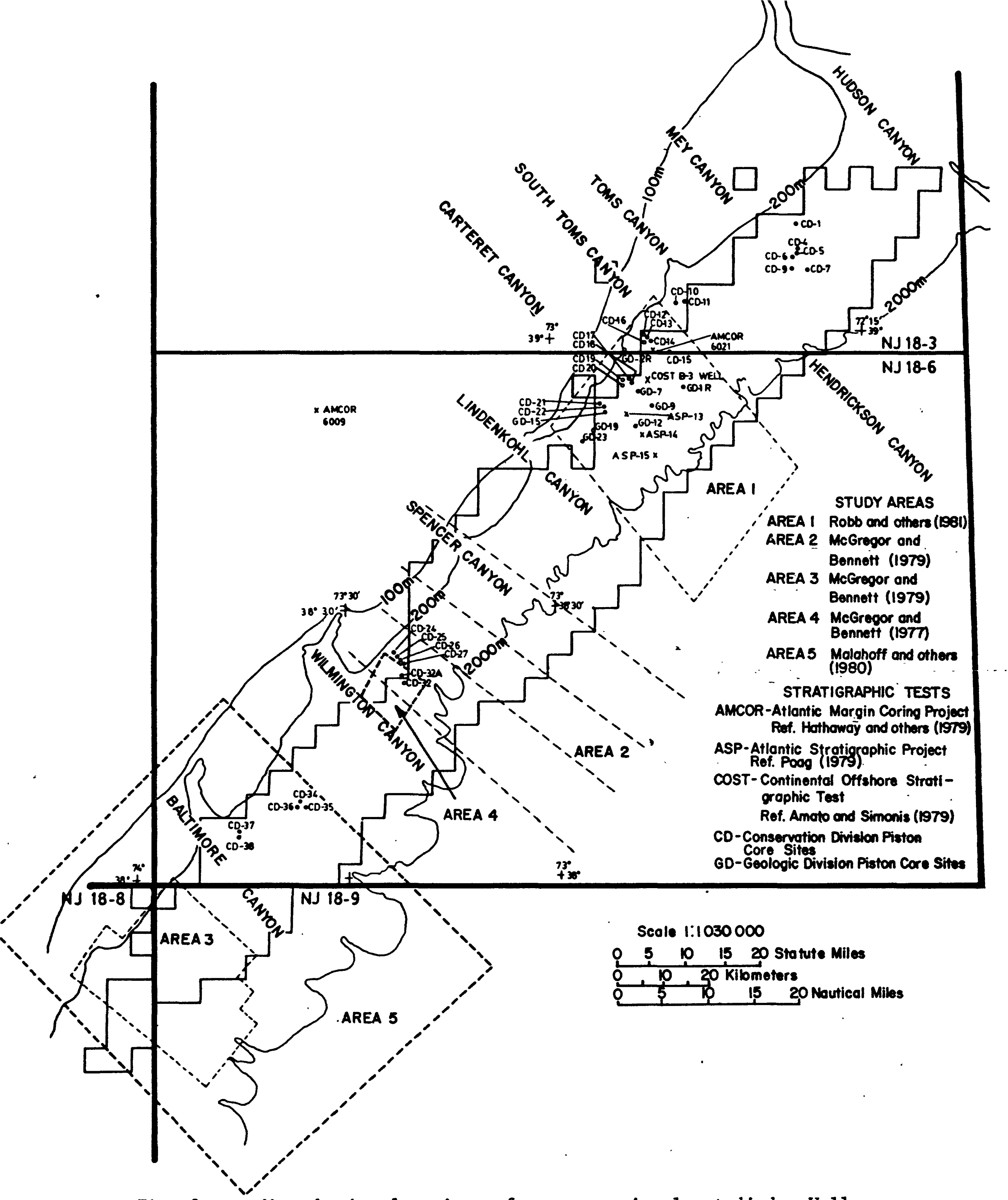


Fig. 2 Map showing locations of areas previously studied. Well locations and the locations of cores used in the geotechnical studies are also indicated (For more accurate locations of coring sites see plates 3 and 4 and table 1). Contours in meters.

structure (Jurassic shelf edge, Grow, 1980) appears to lie seaward of deeply buried fault zones.

The sedimentary framework of the continental slope consists of a variable Quaternary sedimentary sequence (0-450 m) and a thick Tertiary sedimentary sequence overlying Cretaceous strata (Keller and others, 1979). During Late Cretaceous time, calcareous shales, mudstones, glauconitic sandstones, and basal sandstones, some of which may outcrop on the continental slope, were deposited (Amato and Simonis, 1979).

The Tertiary sequence determined from the COST B-3 Well (see fig. 2 for well and core locations) is Eocene chalk and claystone overlain by Oligocene clay. This is followed by a sequence of Miocene clay, silty clay, and glauconitic sand (Amato and Simonis, 1979). Miocene age glauconitic sand and silty clay, inferred to have been deposited in an outer-shelf environment, was also found in Atlantic Stratigraphic Project (ASP) 14 Well (Poag, 1979). There is direct evidence from COST B-3 Well data that Pliocene sediments are found in the immediate area. However, thick sequences of Pleistocene sediments occur on the continental slope, and they range in thickness from 162 m in ASP 22 Well to more than 300 m in Atlantic Margin Coring Project (AMCOR) 6021 and ASP 23 Wells, where pre-Pleistocene sediments were not reached. The Pleistocene sequence is composed of silty and sandy clay (Poag, 1979). Holocene sediments on the continental slope are principally silty clay and clayey silt.

Mass-movement features described in the literature range from large slides, possibly capable of diverting major canyon systems, to small slumps and slides a few hundred meters or less across. McGregor and Bennett (1977 and 1979), Embley and Jacobi (1977), and Malahoff and others (1980), discussed slides tens of square kilometers in areal extent on the slope and rise in the Baltimore and Wilmington Canyon area (see fig. 2 for areas studied by McGregor and Bennett, 1977 and 1979, and Malahoff and others, 1980). A recent analysis of long-range side-scan sonar data indicates that large slide blocks may have diverted the Baltimore and Wilmington Canyon systems from a southeasterly trend on the slope to an easterly trend along the lower slope and rise (Twichell and others, 1980) figs. 3 and 4. Although these blocks have not been positively identified as slide

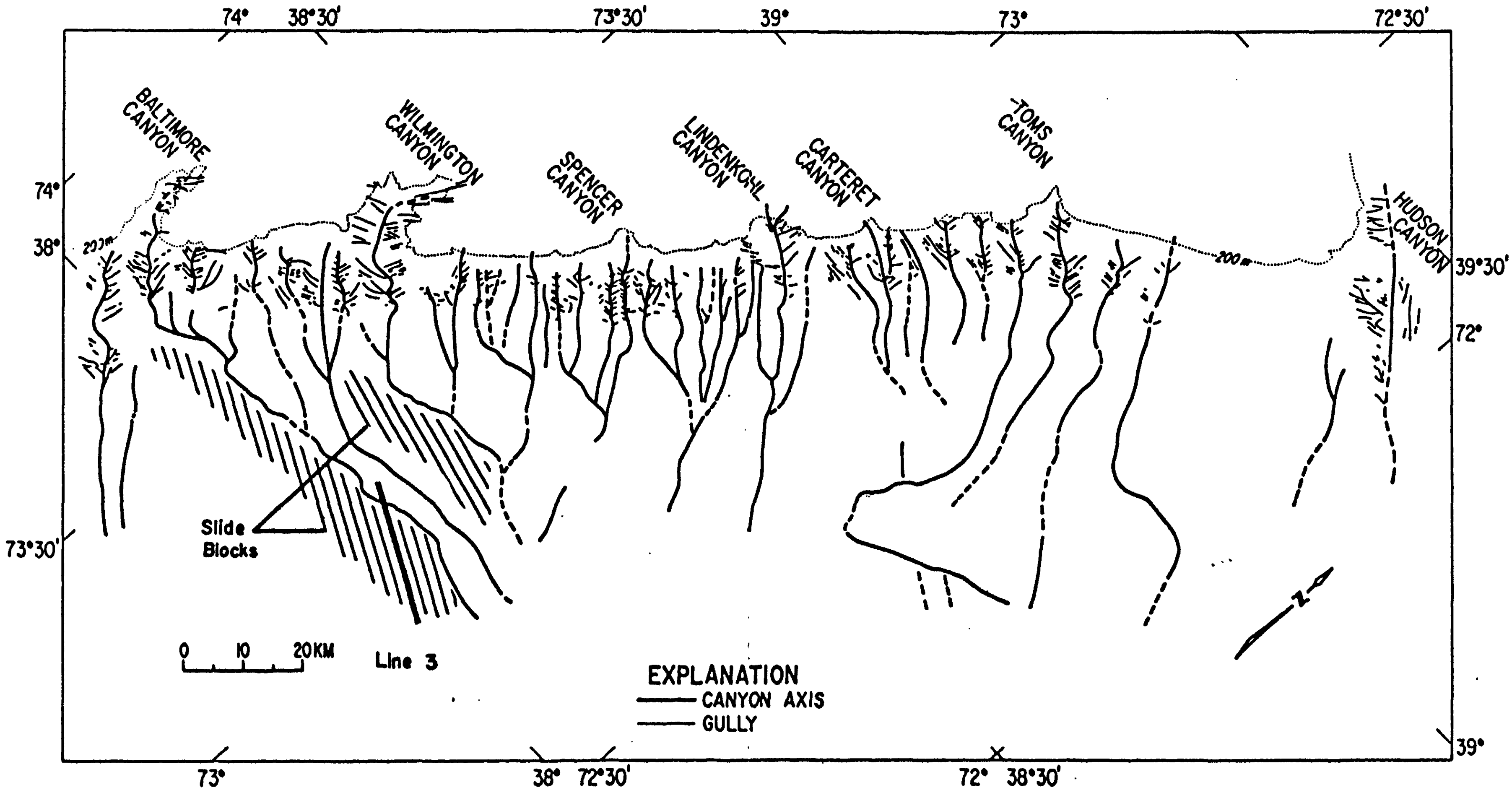


Fig. 3 Map showing major canyon and gully axes and the approximate locations of two large slide blocks south of Wilmington and Baltimore Canyons. Dotted line is approximate edge of continental shelf (200 m isobath). Thick solid line indicates the approximate location of the seismic profile shown as figure 4. Axes interpreted from long-range side-scan sonographs by Twichell and others (1980).

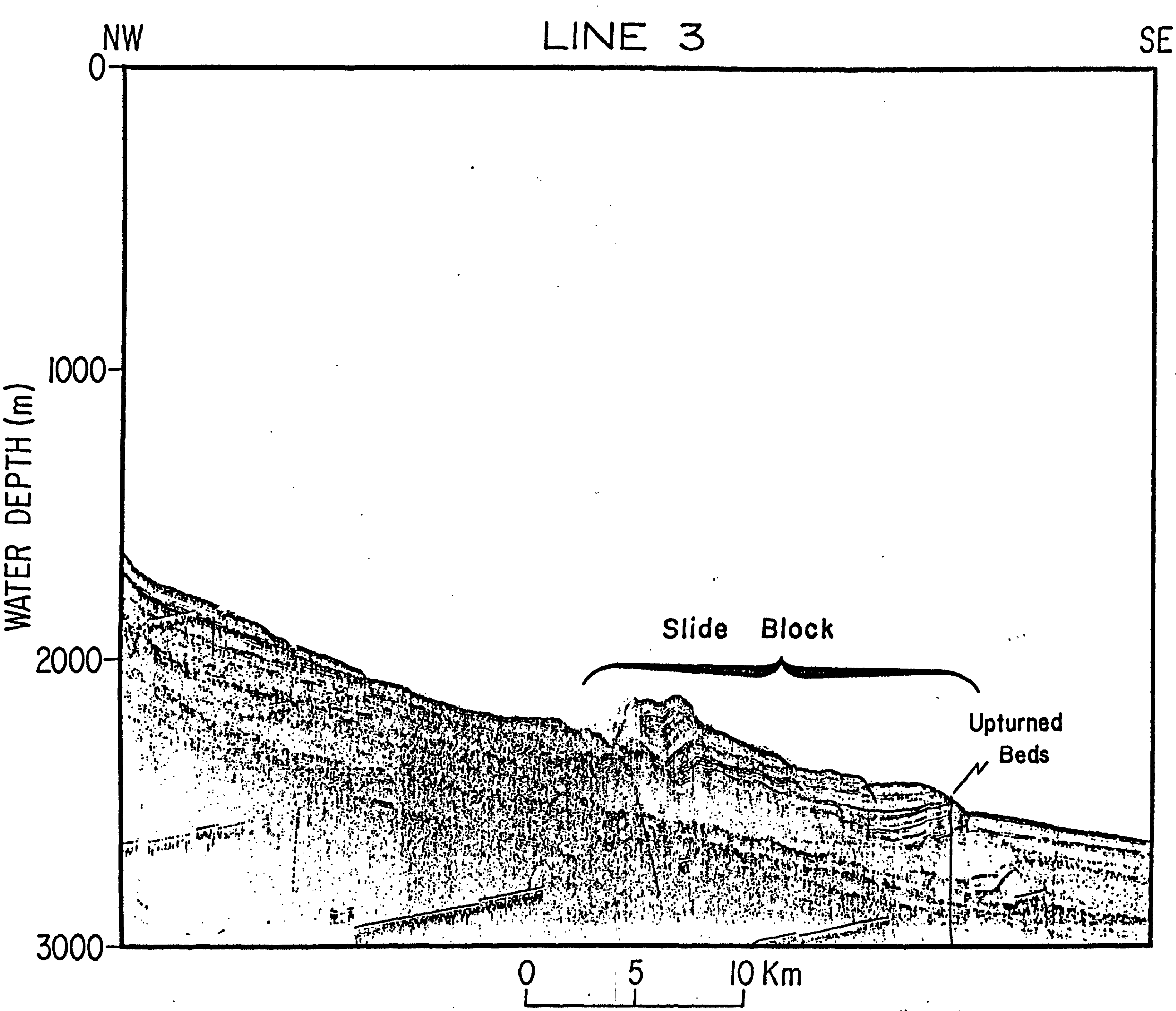


Fig. 4 Seismic profile (40-cu in. air gun analog record) crossing the lower portion of the slide block reported by Twichell and others (1980). The approximate location of this profile is plotted on fig. 3. Vertical exaggeration X13.7.

deposits, several features add credence to that possibility. During a 1980 Alvin dive on these features, W. L. Stubblefield observed gravel to cobble-size deposits which did not contain any visible shell hash and are therefore thought to be nonmarine (B. A. McGregor, U.S. Geological Survey, oral commun., 1981). Clay beds also were observed that dipped landward 70 to 90 degrees in exposures as much as 20 meters high (fig. 4) B. A. McGregor, U.S. Geological Survey, oral commun., 1981. These observed features are suggestive of displaced sediments. However, there is no well-defined scar or source area on the continental slope indicating the origin of the blocks, and it is believed that subsequent erosional and depositional processes have masked the source areas. In addition, onlapping appears to have occurred at the toes suggesting that considerable time has passed since emplacement (fig. 4). The slides are probably pre-Quaternary in age and present no hazard to drilling operations (B. A. McGregor and D. C. Twichell, U.S. Geological Survey, oral commun., 1981).

Mass-movements of a lesser magnitude have been reported to the south of Baltimore Canyon (McGregor and others, 1979; Malahoff and others, 1980) and mass-movement on a still smaller scale has been reported between Toms and Lindenkohl Canyons that involves between 1 and 2 percent of the total area studied (Robb and others, 1981) (fig. 2). Hall and Ensminger (1979) reported evidence of mass-movement in the Lease Sale 49 area and outlined zones of slumps or slides and potentially unstable slopes. Additional slumps and slides have been mapped for this report.

DATA COLLECTION AND INSTRUMENTATION

The majority of the geophysical data involved in this report were collected by Intersea Research Corporation of San Diego, California, under contract to the U.S. Geological Survey (Contract No. 14-08-0001-18929). The contractor supplied high-resolution geophysical data and related processing services. Data acquisition was monitored throughout the course of the fieldwork by U.S. Geological Survey observers.

The data were collected using an EDO Western Model 4077, 24-kHz narrow beam (10° cone) fathometer, a single channel (1/2-ms sampling rate) digital seismic profiler, and broad band analog acquisition system. The analog data were played back through a 450-Hz low-cut filter. A single Seismic Systems Incorporated 15-cubic-inch water gun was used as the sound source for the seismic system. Navigation was provided by Lorac using an integrated ARGO, LORAN C, and Satellite Navigation system. All analog subbottom reflection data were recorded on 19-inch, dry paper, flatbed recorders. Overall data quality ranged from good to excellent with good resolution and penetration on all systems.

A total of 7,564 km of multispectral, high-resolution acoustic data were collected from June to September, 1980, aboard RV Albert in an 800 x 2,400 m grid with shotpoints labeled at 305 m intervals. Proposed OCS Lease Sale 59 includes 70 blocks previously surveyed for geohazards in connection with OCS Lease Sales 40 and 49 (Contract Nos. 14-08-0007-15384 and 14-08-0001-16243). It was not considered cost effective or necessary to resurvey these blocks, but tie lines were run into these blocks at approximately 8,000-m intervals in order to facilitate merging the different data sets.

Despite the fact that different systems, which varied in terms of accuracy, resolution, and depth of subbottom penetration, were used for the three geohazards surveys, the match across the survey boundaries is good, particularly with respect to structural information. However, due to the differences in bathymetric survey systems (Sale 40 and 49 bathymetric data were not acquired with a narrow beam system) the depth calculations and resultant isobaths mismatched somewhat. Values generally agree within three percent at survey boundaries. However, the bathymetry was recontoured after reevaluating Sale 49 and 59 data for the best tie possible (See pls. 3 and 4).

Piston cores were taken by the RV Endeavor during September, 1979 by the U.S. Geological Survey. The scientific party included staff members of the U.S. Geological Survey, University of Rhode Island, and the Woods Hole Oceanographic Institution. Forty three piston cores were collected, subsampled, and stored aboard ship for future geotechnical analysis by Law Engineering Testing Company of McLean, Virginia, under contract to the U.S. Geological Survey (Contract No. 14-08-0001-18708), by Woodward and Clyde Associates of Plymouth Meeting, Pennsylvania under contract to the U.S. Geological Survey (Contract No. 14-08-0001-18707), and by the U.S. Geological Survey Marine Geotechnical Laboratory in Corpus Christi, Texas.

Copies of the final geotechnical data submitted by the contractors under Contract Nos. 14-08-0001-18707 and 14-08-0001-18708 are obtainable by the public as U. S. Geological Survey Open File Report, 81-366 by Olsen and others (1981). Copies of final geotechnical data submitted by the U.S. Geological Survey Marine Geotechnical Laboratory in Corpus Christi, Texas are obtainable by the public as U.S. Geological Survey Open File Report 81-733 by Booth and others (1981).

Copies of all contract deliverables under Contract Nos. 14-08-0007-15384 (Sale 40), 14-08-0001-16243 (Sale 49), and 14-08-0001-18929 (Proposed Lease Sale 59) have been archived with the National Geophysical and Solar-Terrestrial Data Center (NOAA/EDIS/NGSDC, Code D621, Boulder, Colorado 80303) and are available to the public (Refer to data sets AT 15384, AT 16243, and AT 18929). These data sets include microfilm copies of geophysical profiles and a series of navigation and interpretive maps, at a scale of 1:48,000, submitted by the contractors and copies of the contractors' final reports. The maps of surface and near-surface geology, near-surface geotechnical properties, and potential hazards and constraints (pls. 1 and 2) that are included in this report, supersede all previous compilations and should be considered the most up-to-date appraisal of hazards and constraints in the proposed Lease Sale 59 area.

All data and reports may also be reviewed at the U.S. Geological Survey Public Information Office located at 1725 K Street, N.W., Suite 213, Washington, D.C. 20006.

POTENTIAL GEOLOGIC HAZARDS

Problems with Data Interpretation

Age determination of geologic contacts is a critical aspect in the assessment of risk related to faulting and mass-movement structures. Because of the lack of stratigraphic well control, it is not possible to identify geologic contacts (geophysical horizons) in the lease area with certainty. A detailed seismic reflection survey by Robb and others (1981), was conducted in an area with relatively good well control (fig. 2). Utilizing a closely spaced seismic grid, they were able to map the distribution of Pleistocene and older sediments. From these data, they developed the generalized cross section in figure 5. This generalized section correlates with the observed data in the Hudson-Toms Canyons area and is the basis for identification of the various geologic contacts. However, because of intervening canyons and insufficient seismic penetration or resolution, it was not possible to carry stratigraphic correlations outside of their area of study. Therefore, a somewhat conservative view was taken during data analysis. For example, faults which reach the surface must be considered a potential hazard, since the age of sediments is not known with certainty.

Many of the mass-movement structures, particularly the larger ones, may be Pleistocene in age (McGregor, 1977) and related to conditions prevailing during low sea-level stands. Since these conditions are presently absent, contemporary large-scale failure of considerable masses of sediment (on the order of cubic kilometers) may not be a detrimental factor to oil and gas leasing on the East Coast. It may be that large-scale slope failures and mass-movement events are so rare that their time frame may be geologic as opposed to historic. We have been unable to assign a definite time of failure to any features we have indentified using the data available to us. However, sufficient evidence is found to warrant concern over the possibility that mass movement could be a present day

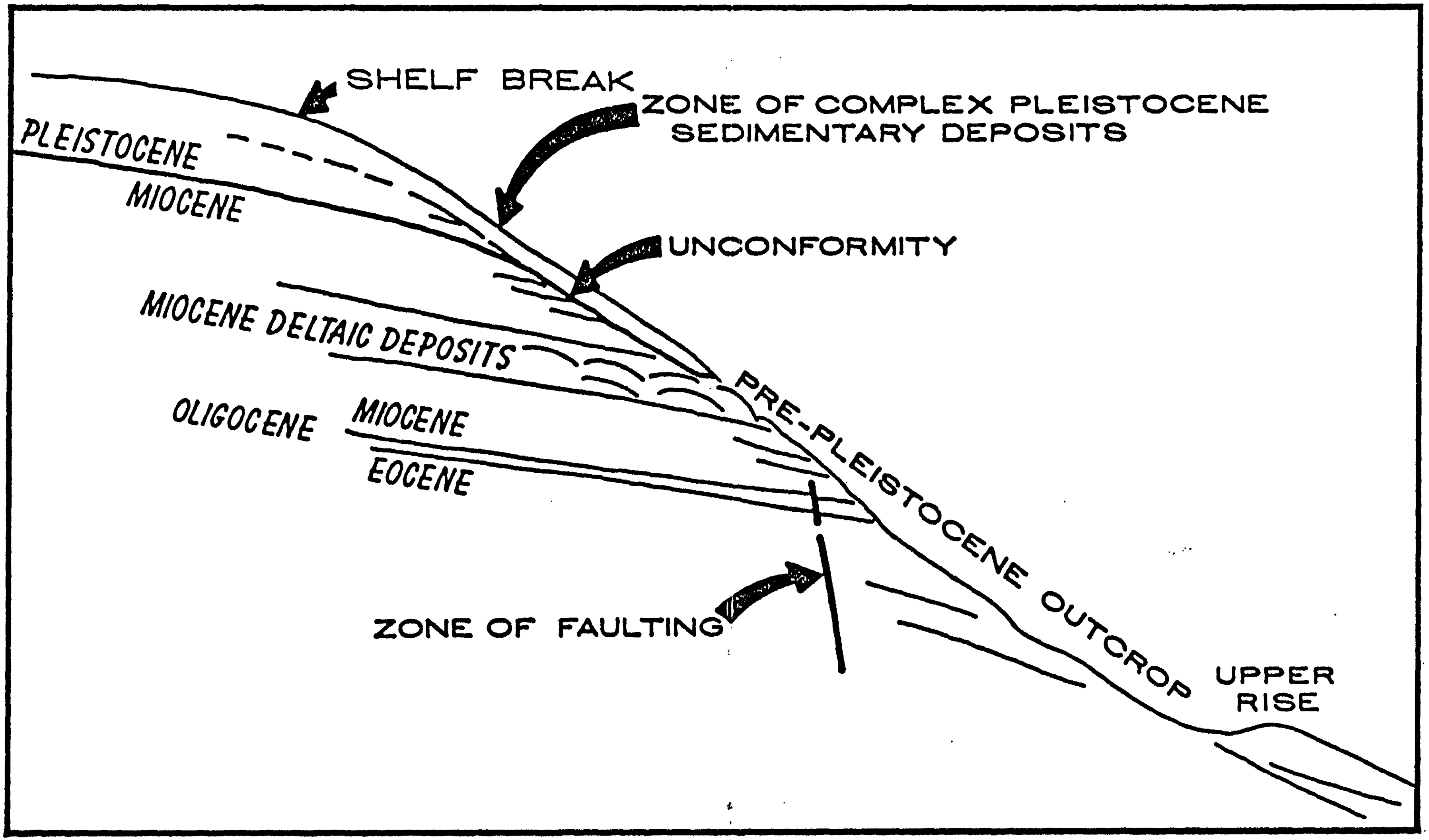


Fig. 5 Generalized cross section of the Mid-Atlantic Continental Slope. (From Robb and others, 1981).

problem. Further studies, including deep soil mechanics analyses may be needed to resolve these questions.

A complication in the assessment of risk in a submarine canyon province is that mass movements (especially gravity flows) originating at a locus of failure upslope of the lease blocks could sweep large volumes of debris through the blocks. The canyons and their tributary and distributary systems could serve as obvious conduits for such debris. However, even with a data base density much greater than ours, mass-movement structures or scars in canyons cannot be mapped with certainty utilizing conventional systems.

Faults

Unpredictable active fault displacement is perhaps the most obvious direct hazard which could result in significant structural damage to exploration and production platforms. Fault planes also may function as conduits for high-pressure gas from deep in the geologic section.

Three categories of faults are discussed in this report:

1. Deep faults--Faults observed on deep seismic records whose displacement apparently occurred in ancient times (classified as constraints in this report),

2. Shallow faults--Faults observed on high resolution, one second records but whose displacement planes do not reach the surface (classified as constraints in this report),

3. Shallow recent faults--Faults which show surface expression or have planes which lead to the surface (classified as potential geologic hazards in this report).

Our judgments concerning the age of the fault are limited by the capability of the reflection profiling system to define thin layers of sediment deposited since the last displacement as well as by knowledge of the age of those layers. Resolution of layers roughly 1 m thick is about the best that most systems provide. A reasonable sedimentation rate on the continental slope in this area is 10 cm/1,000 y (Ewing and others, 1973). Thus, the system resolution limit of 1 m represents a potential 10,000 y uncertainty in the age of the most recent displacement of the fault.

Most of the faults identified as shallow recent faults (category 3) in the proposed lease sale area are overlain by valleys or canyons where post-Pliocene sediment cover is thin and probably show surface expression or the appearance of a fault plane leading to the surface because of drape of a relatively thin veneer of sediments (See fig. 6). In areas where the sediment cover is thick and draping occurs over fault scarps, the axis of the flexures caused by draping trend at a shallow angle (compared to the fault plane) upslope and the magnitude of the flexures diminishes. However, where the sediment cover is thin, flexure axes extend in-line with the fault plane and intersect the surface. Therefore surface offsets resulting from drape cannot readily be distinquished from those resulting from post depositional fault displacement. Because recent displacement may have occurred in some of these faults, a conservative approach has been taken. Faults that appear to reach the surface, even if draping is suspected, have been classified as shallow recent faults. The relationship of sediment drape to faults and mass-movement processes is discussed in detail in the discussion section.

Mass Movement

Seismic profiles collected for proposed Lease Sale 59 show extensive evidence of failures of surface sediments on slopes, which indicates that hazards related to mass movement are likely to be the single most serious problem impacting exploration and development activities in the proposed Lease Sale 59 area. Twenty-seven blocks were deleted from Lease Sale 49 because of evidence of sediment mass movement. However, these mass-movement features in the Lease Sale 49 blocks were not mapped as discrete features, but as zones of slumps and slides and zones of potentially unstable slopes.

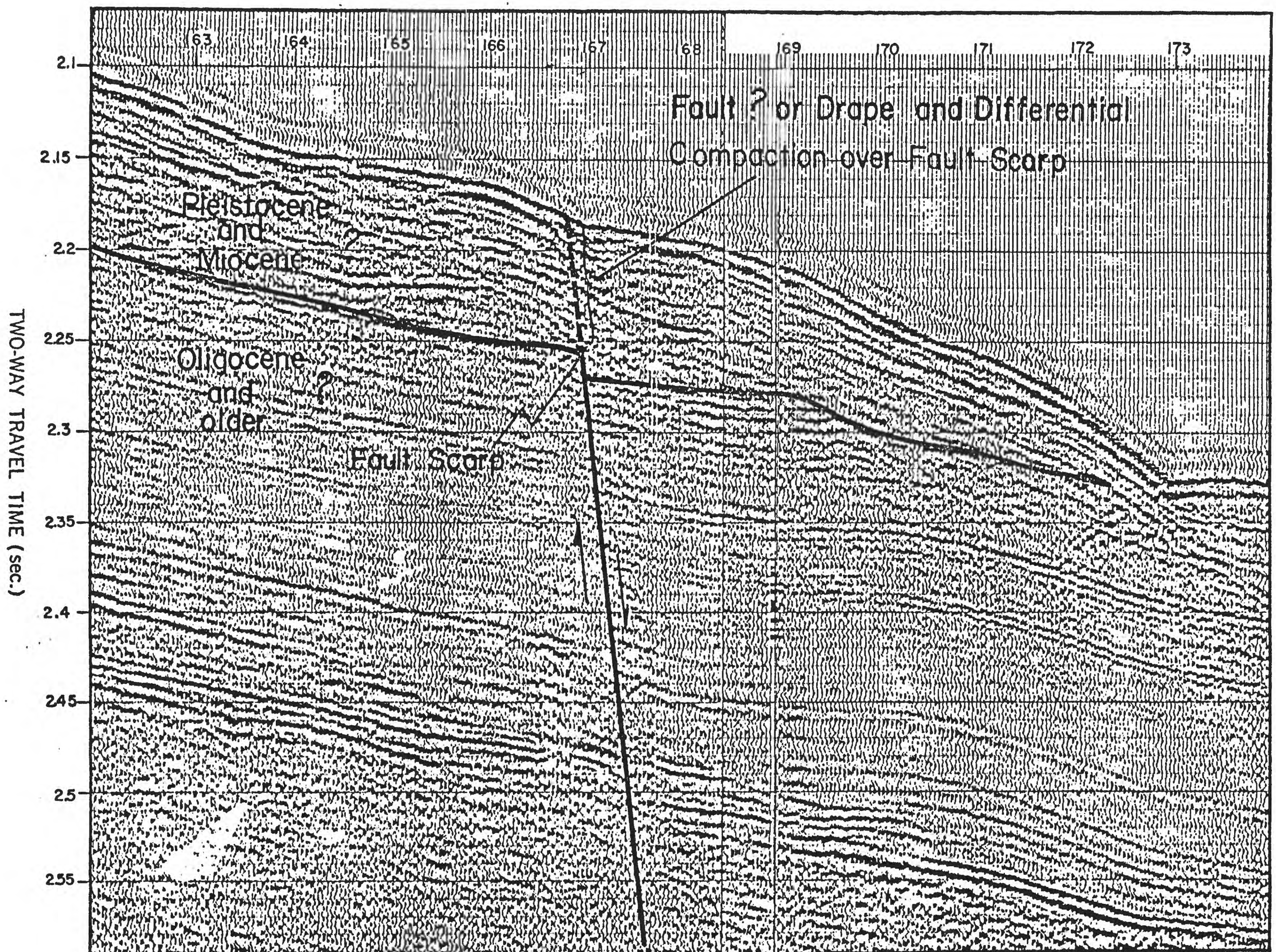


Fig. 6 Seismic profile (15 cu in. water gun digital record, line 3267 shotpoints 162-174) showing shallow fault which may reach the sea floor. Note well developed displacement of fault below 2.26 seconds and diffractions above 2.26 seconds which reach the sea floor. Vertical exaggeration X6.5.

Twenty-three of those 27 are included in proposed Lease Sale 59 as well as 46 other blocks previously offered in Lease Sale 49.

A high confidence level in the data set acquired for proposed Lease Sale 59 has allowed for delineation of discrete mass-movement features. Part of this data set consisted of comparison lines (tie lines) acquired over existing Lease Sale 49 data in areas that are included in proposed Lease Sale 59. These comparison lines raised the confidence level in the Lease Sale 49 data set and made it possible to delineate discrete mass-movement features which could not previously be resolved with confidence. The ability to delineate discrete mass-movement features, coupled with evidence which indicates that significant mass-movement features thus far mapped are old (Pleistocene in age), indicates that stable areas outside of the sediment mass-movement feature boundaries exist.

The possibility of slope failure in a specific area cannot be determined solely by the analysis of seismic data. In order to make slope-failure predictions, comprehensive geophysical, geological, and geotechnical studies must be performed. In this study, shallow piston cores were taken in an effort to gain knowledge of the competency of surficial slope sediments. These data are discussed in the Slope Stability Analysis section and are tabulated in the Appendix. Because of the limited coverage and penetration of the cores, only general assumptions can be made with the data. We must therefore rely on postfailure evidence (features found on seismic data) and the sedimentary history of the area as guides in the determination of hazard potential.

Present-day sedimentation rates are low (10 cm/1000 yrs--Ewing and others, 1973), and the mass-movement features mapped in this report probably reflect conditions during the Pleistocene when sedimentation rates were higher. Mass-movement features have been mapped, and areas having large concentrations of such features may pose a significantly higher risk to petroleum activities than areas where mass-movement-related structures are rare or absent.

The topography of the slope of the Mid-Atlantic region is extensively dissected by submarine canyons and their tributary systems. This morphology necessitates great care in the interpretation of seismic profiles, because some of the features seen on seismic reflection data (glide plane, slump block, scar, hummocky topography) that collectively define mass-movement could be side echoes from nearby canyon walls or other out-of-plane reflections superimposed on the normal-incidence data. Additionally, many small features may have been missed by our mapping because they are obscured by diffractions and/or they lie between the lines of our data grid. Any interpretation of mass-movement must consider the three-dimensional aspects of reflection data, particularly in regions of extremely complex topography such as are found in the Wilmington to Toms Canyon areas. Moore (1977) cautions that some of the seismic characteristics of slides are shared with channel-distributary-levee systems, and thus a number of deposits which appear to be slides may actually be submarine fans or levees. In highly dissected areas, definitively identifying and separating those complexes that result from mass movement from those caused by erosion or depositional processes can be difficult. If detailed bathymetric data are available, mental integration of the seismic and bathymetric data sets facilitates interpretation, and computer modeling techniques can further aid in separating real events from out of plane reflections.

CONSTRAINTS

Aspects of the Atlantic OCS near-surface geology whose adverse effects can be minimized through the use of existing design and engineering technology are classified as constraints to development. These second-order features and conditions include sand waves, erosion, filled channels, deep and shallow faults, gassy sediments (acoustically turbid zones), and bottom objects.

Constraints are presented by sand waves because they are assumed to be mobile (sand ridges are static). High-velocity bottom currents, particularly those due to storms, can remobilize sand-size particles and result in significant horizontal crest and trough displacements (McKinney and others, 1974). Lateral migration of the crest can leave platform supports or wellhead plumbing unsupported by removing surrounding support materials. Erosion or scour would have essentially the same effect, but on a somewhat smaller scale.

Filled channels may pose problems in terms of foundation support for large structures. The mechanical properties of channel fill can differ markedly from bordering sediments, resulting in differential settling of structures that straddle the boundary between the two sediment types. Since grain size in channel-fill deposits can range from clays to boulders, problems with mud circulation and emplacement of surface casing also can occur.

Deep and shallow faults below unconsolidated foundation zone sediments are considered to be constraints to operations rather than hazards because they do not displace the sea floor and in this area are probably Tertiary in age (Robb and others, 1981a). The risk of reactivation of these older faults is probably minimal because of the low level of earthquake activity prevailing in the area (Coffman and von Hake, 1973). Despite low seismicity and long quiescence, these faults are planes of weakness and should be considered to have a limited potential for failure. Fault planes also are potential conduits for hydrocarbons, originating at depth and migrating upward, which may pose some risk related to blowouts or cratering of surficial sediments.

Gassy sediments are not thought to pose significant risk to petroleum exploration and development but are presented as constraints because of the possibility of spontaneous, gas-induced slope failure. In the context of this report, gassy sediments are taken to mean near-surface sediments which contain enough gas, either in the bubble phase or dissolved, to be detectable as acoustically turbid zones or blankouts on high-resolution seismic reflection data.

Acoustically turbid zones are rather prevalent in the near-surface sedimentary section in shelf-edge areas ranging from 85 to 200 m in water depth. While gas in foundation zone sediments poses no risk in itself, under certain conditions it can affect load bearing capacity and the stability of those sediments. Given the correct parameters as to surface slope, gas concentration, and sediment compaction and porosity, gassy sediments can spontaneously liquefy when subjected to cyclic loading. The potential for gas-related sediment liquefaction in the proposed Sale 59 area is not known, but the problem is common in the Mississippi Delta region and has been the subject of a number of studies (Whelan and others, 1978). It is difficult, however, to draw any inferences from these studies as to the likelihood of gas-induced stability problems on the Atlantic OCS because the regions are geologically dissimilar.

High methane concentrations have been encountered in cores of upper Pleistocene age on the outer shelf (Atlantic Continental Margin Coring Project - Sites 6007 and 6021; (fig. 2) Hathaway and others (1976)) and on the slope (personal observations). Accordingly, where turbid units occur at the margins of steep slopes (for example canyon margins), the risk of foundation failure may be significantly higher than in other areas unless proper engineering design is incorporated.

A condition related to shallow gas is that of hydrated gas. A gas hydrate is an ice-like, crystalline lattice of water molecules in which gas molecules (in this case, hydrocarbons) are physically trapped (Tucholke and others, 1977). We can find nothing definitive in the literature reporting the existence of gas hydrates in any of the proposed Lease Sale 59 blocks, nor do our geophysical data suggest their existence.

Problems presented by bottom objects (debris, ordnance, and so forth) are relatively straightforward. Repositioning of the structure is the simplest method of mitigating this problem, but no bottom objects were identified in our data within the proposed lease sale area.

DISCUSSION

Distribution of Hazards

Two generalities can be made about the distribution of shallow faults and mass-movement features in the proposed sale area (pl. 1 and 2): (1) shallow faulting is absent in the south half of the area, and (2) the occurrences of mass-movement features are fewer to the south of Toms Canyon than to the north. These observations can be attributed to both real differences in geology and to artifacts of data acquisition.

Shallow Faults

Two factors control the mapped distribution of shallow faults: frequency of deep faulting and irregularity of the sea floor. Shallow faulting is often closely related to or is generally an extension of deep faulting. Deep faulting, although not mapped in great detail, appears to be more common in the north half of the area (fig. 7). Consequently, shallow faulting is also encountered there more often. The sea floor is smoother north of Toms Canyon than in the rest of the area, and the ability to resolve and detect faulting is improved.

Mass Movement

The distribution of mass-movement-related features appears to be controlled by Pleistocene sedimentation rates. Mass-movement features are more common near the major canyon systems (between Toms and Hudson Canyons and in the Wilmington and Baltimore Canyon areas) where sedimentation rates were probably highest during the Pleistocene. The Pleistocene sequences in these areas would have been formed by spill-over type or sheet-flow sedimentation and deltaic sedimentation processes, whereas the sedimentation processes in the areas between Wilmington and South Toms

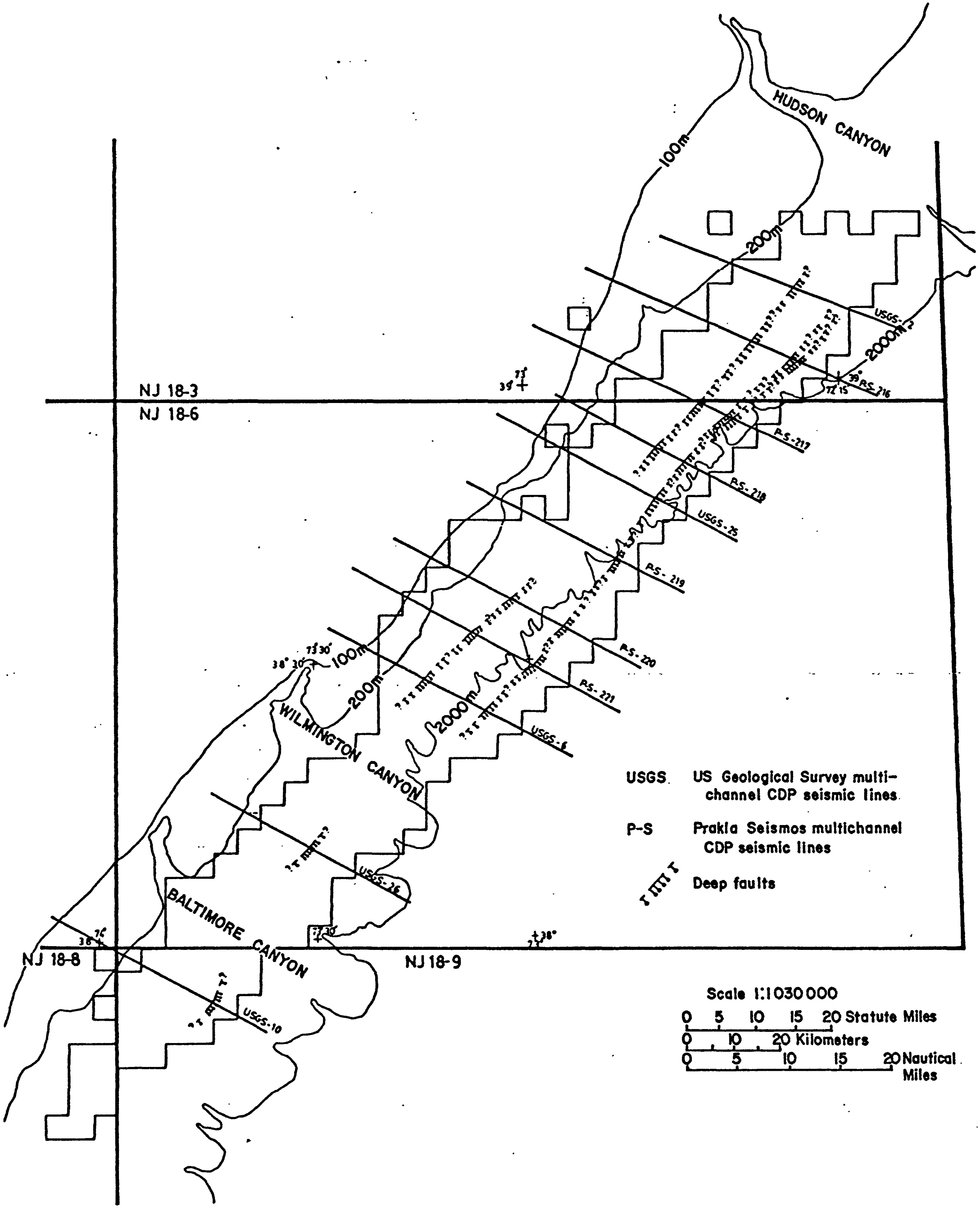


Fig. 7 Map showing the approximate locations of deep faults and the locations of publicly available deep seismic data over the area. Contours in meters.

Canyons might be better typified as levee and over-bank depositional regimes with delta front processes operating high on the slope.

Many of the mass-movement features that have been observed in our data are subtle, and it is likely that more mass-movement structures than we were able to map exist around Wilmington Canyon and south but are obscured by the rugged topography. A detailed study by Robb and others (1981a) indicates that slumping between Lindenkohl and South Toms Canyon is less frequent than might be expected for an area with relatively steep gradients, and relatively high sedimentation rates. Their findings are probably applicable to the area between Spencer and Lindenkohl Canyons as well. The sedimentary regime of the area southwest of Spencer Canyon, however, is probably similar to that of the area between Hudson and Toms Canyons and the Wilmington-Baltimore Canyon area.

Discussion of Selected Features

Sediment failures that can be recognized on seismic records in the area between Toms and Hudson Canyons occur as differential compaction, slump, and slide features (differential compaction features as discussed in this report are defined as sedimentary structures believed to have developed as a result of sedimentation and differential compaction over topographic irregularities). Compaction features can be difficult to distinguish from slumps particularly if differential compaction features and slumps are intermixed and seismic resolution is poor. Slumps generally have a well-developed scarp and a well-defined slip or failure plane. Differential compaction features have no well-developed scarp and no distinct failure plane. Instead, reflectors are down-turned or warped, but no breaks in the reflectors are apparent.

The warping of reflectors is initiated by sediment drape over topographic irregularities; as sedimentation progesses, warping is preserved up-section. The dynamic processes (localized flow, creep and small scale sliding) which operated within these flexure zones during deposition would have been different from those that occurred upslope or downslope. As sedimentation progressed and compaction of the sediments occurred, differential compaction over the topographic irregularities would have enhanced the warping. Consequently, these flexure zones could be zones of weakness with the potential of developing into slump or glide planes. An example of this evolutionary process is shown in figure 8. The reflectors at point A in figure 8 would show reverse dip if the section is corrected for the sloping water bottom. This suggests that depression of the reflectors has occurred as a result of increased overburden pressure. At this depth (A) in the differential compaction feature, the flexure axis appears to have developed into a slip plane. Near the surface, however, the geometry of the flexure appears as a normal drape structure.

Implicit in this compaction process is a long time period. This is in contrast to slumping which occurs, relative to the geologic time scale, as a catastrophic event. It is likely that differential compaction features in this area developed during the Pleistocene and are inactive today. However, because distinguishing between differential compaction features and slumps is difficult and depends on the resolution of the instrumentation, and because the potential for development into slumps may exist, differential compaction features have been grouped together with slumps and slides.

The small slump in figure 8 downslope from the differential compaction feature probably was caused by some combination of these three events: (1) oversteepening at the base of the differential compaction feature (progressive slope failure), (2) differential compaction over the irregular Oligocene topography below and, (3) relief of confining pressure as sediment failure down slope occurred (retrogressive slope failure) (see pl. 1 for location of downslope sediment failure).

Lines 3291 and 3279 (pl. 5, fig. 9A-E, and 10) show the probable relationship of differential compaction and slump features with topographic irregularities and shallow faults.

Figures 9A-E schematically show the probable depositional sequence of events shown on pl. 5.

Fig. 9A. Faulting of geologic units A' and A. Unit A' is probably Oligocene and unit A, Eocene and older (J. Hampson, U.S. Geological Survey, oral commun., 1981).

Fig. 9B. Unit B, probably Miocene, is deposited.

Fig. 9C. Unit B is eroded leaving scarps (s). This could have happened in several stages and may have occurred in the middle or upper Miocene.

Alternatively, unit B may have been deposited in several stages during the Miocene and the scarps (s) could be delta fronts or seaward limits of sedimentation (J. Hampson, U.S. Geological Survey, oral commun., 1981).

Fig. 9D. Unit C is deposited and draping occurs over the scarps produced in unit B. At shotpoints 121.5-122.5 and 128-130, fig. 9D and pl. 5, thickening of the unit has occurred at the expense of sediment thinning immediately upslope.

Fig. 9E. As unit D is deposited the process of filling the depressions or lows at the expense of sediment immediately upslope continues and produces upslope-trending flexures. As a result of differential compaction over these scarps as the sediment load increases over time, the flexures are enhanced.

The family of faults labeled 1 in plate 5 and figures 9A-E has no cause-and-effect relationship to the overlying flexures. In the same figures, the seawardmost fault, 2, shows communication to the sea floor via the flexure that appears to be a low angle extension of the fault or possibly the slip plane of a slump. This flexure may have been caused by movement along the fault but probably was caused by differential compaction of sediments deposited over an inactive fault scarp and not postdepositional displacement of the fault. The fault in line 3279,

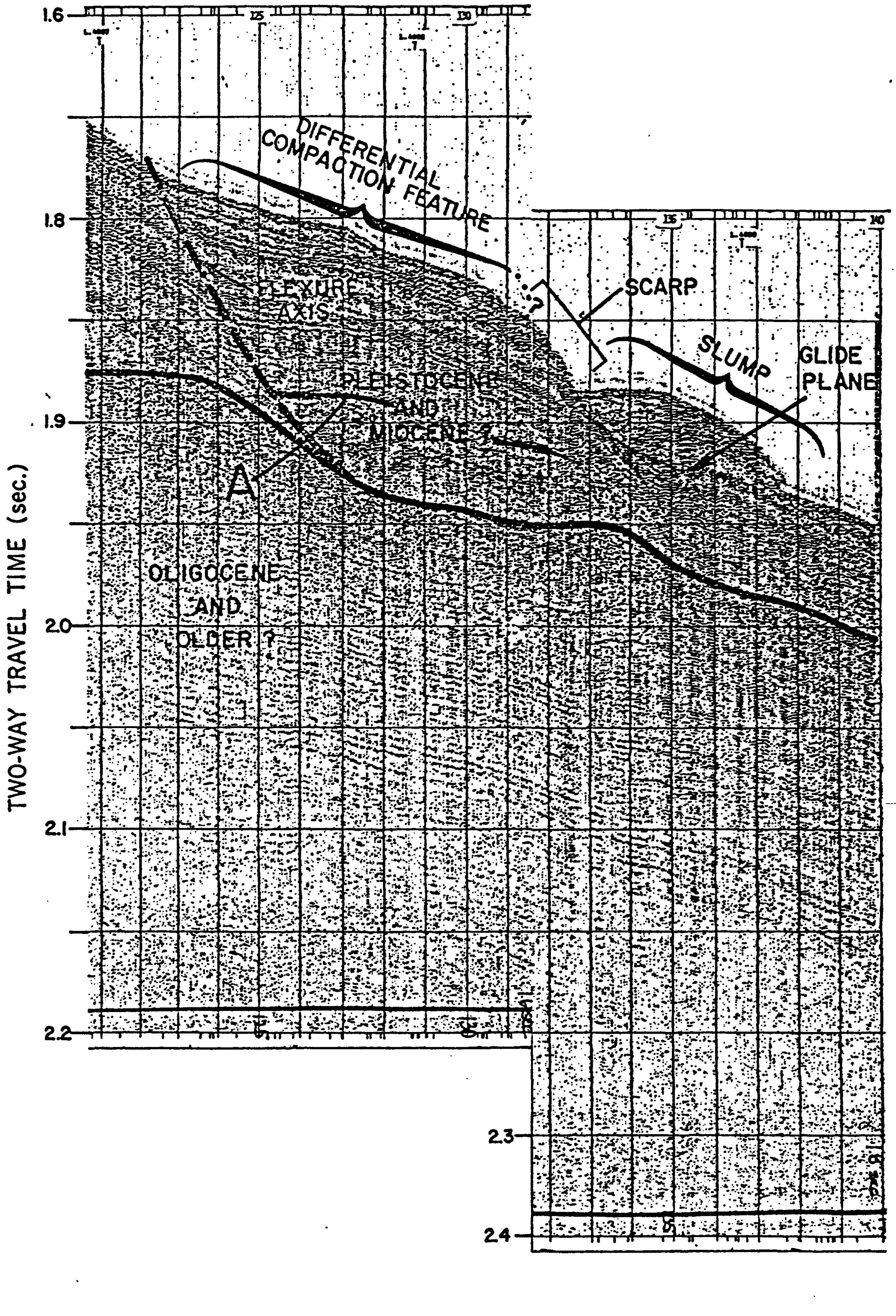


Fig. 8 Seismic profile (15-cu in. water gun analog record, line 3281 shotpoints 121-140) crossing a differential compaction feature and slump. Vertical exaggeration X15.

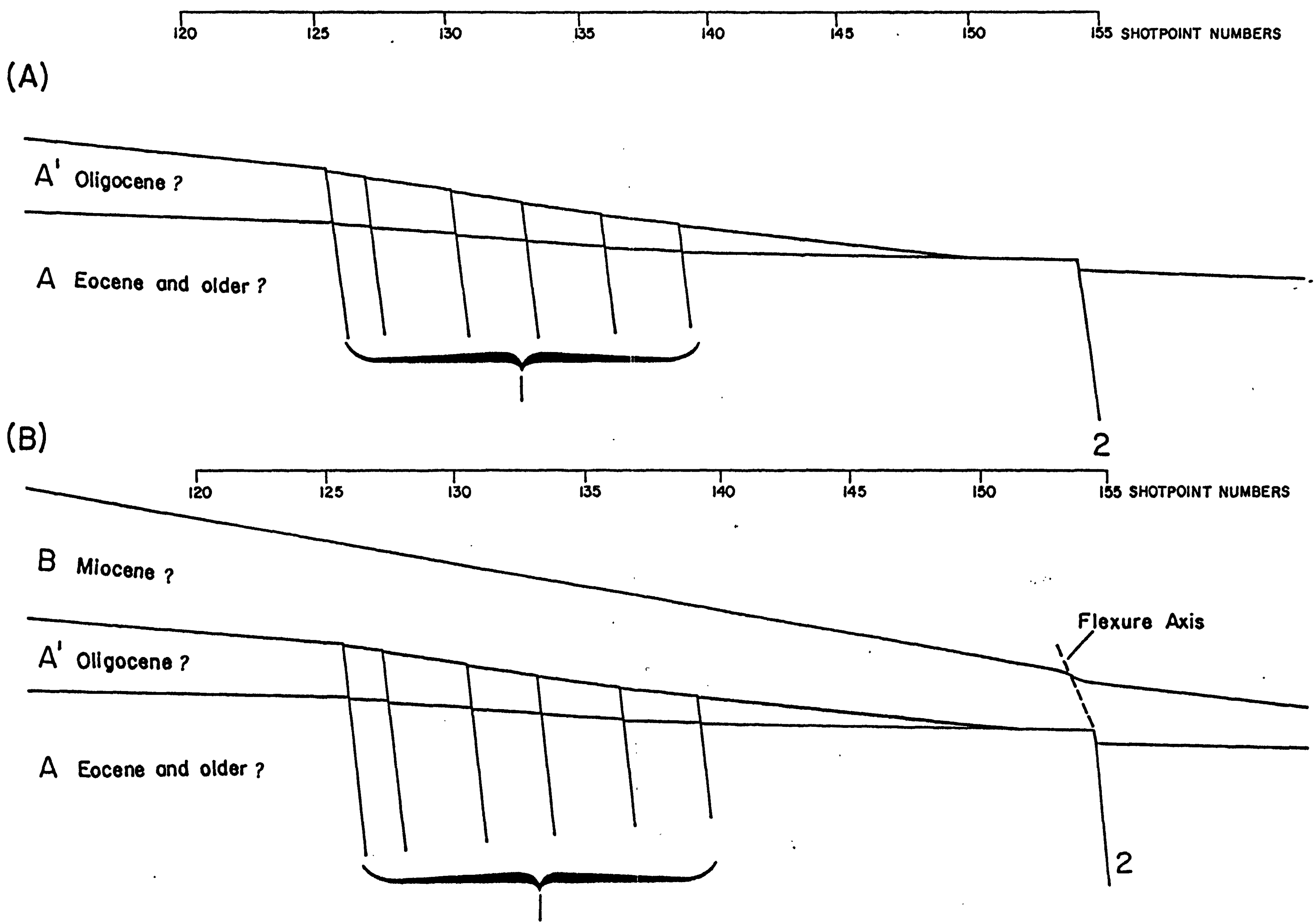
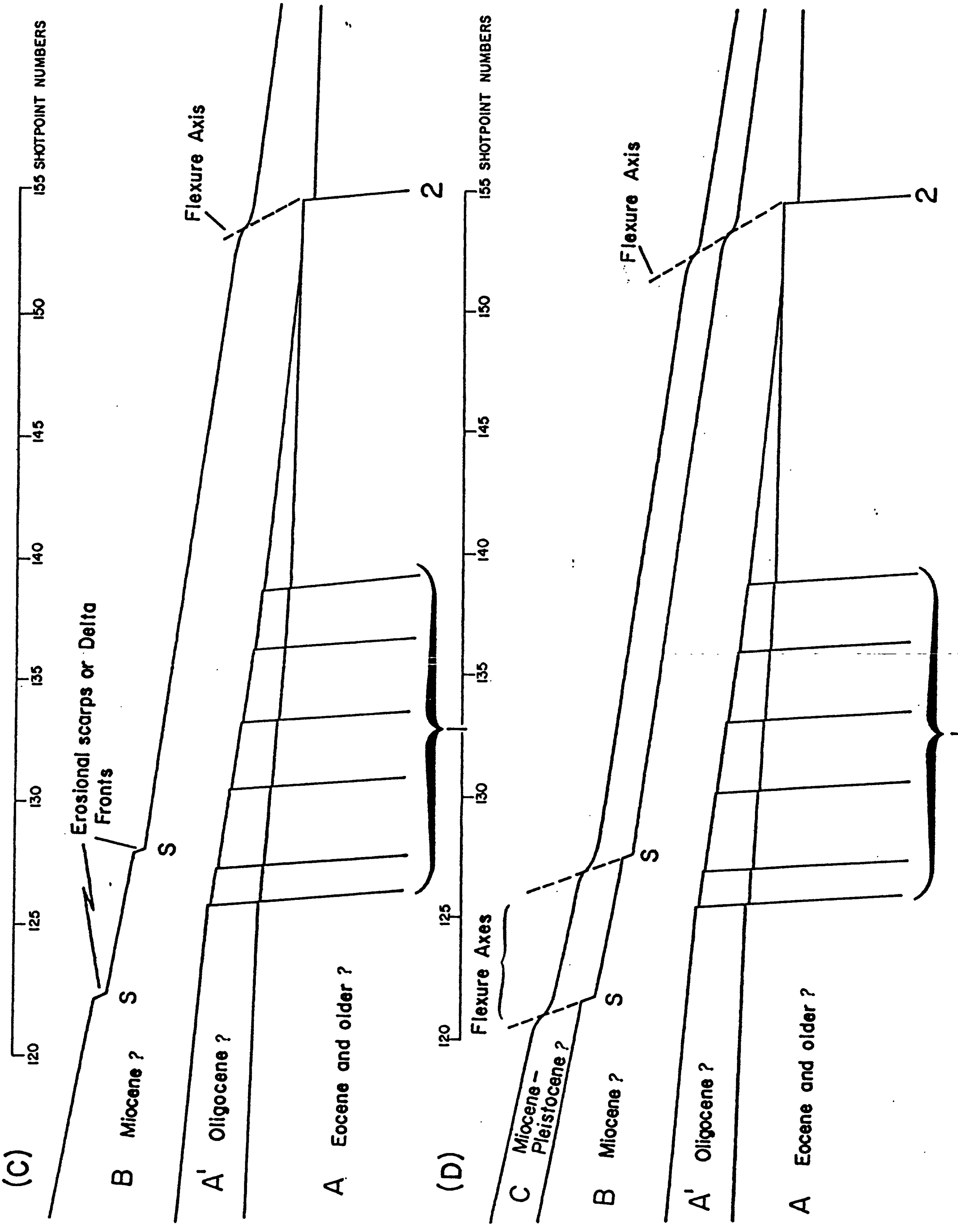
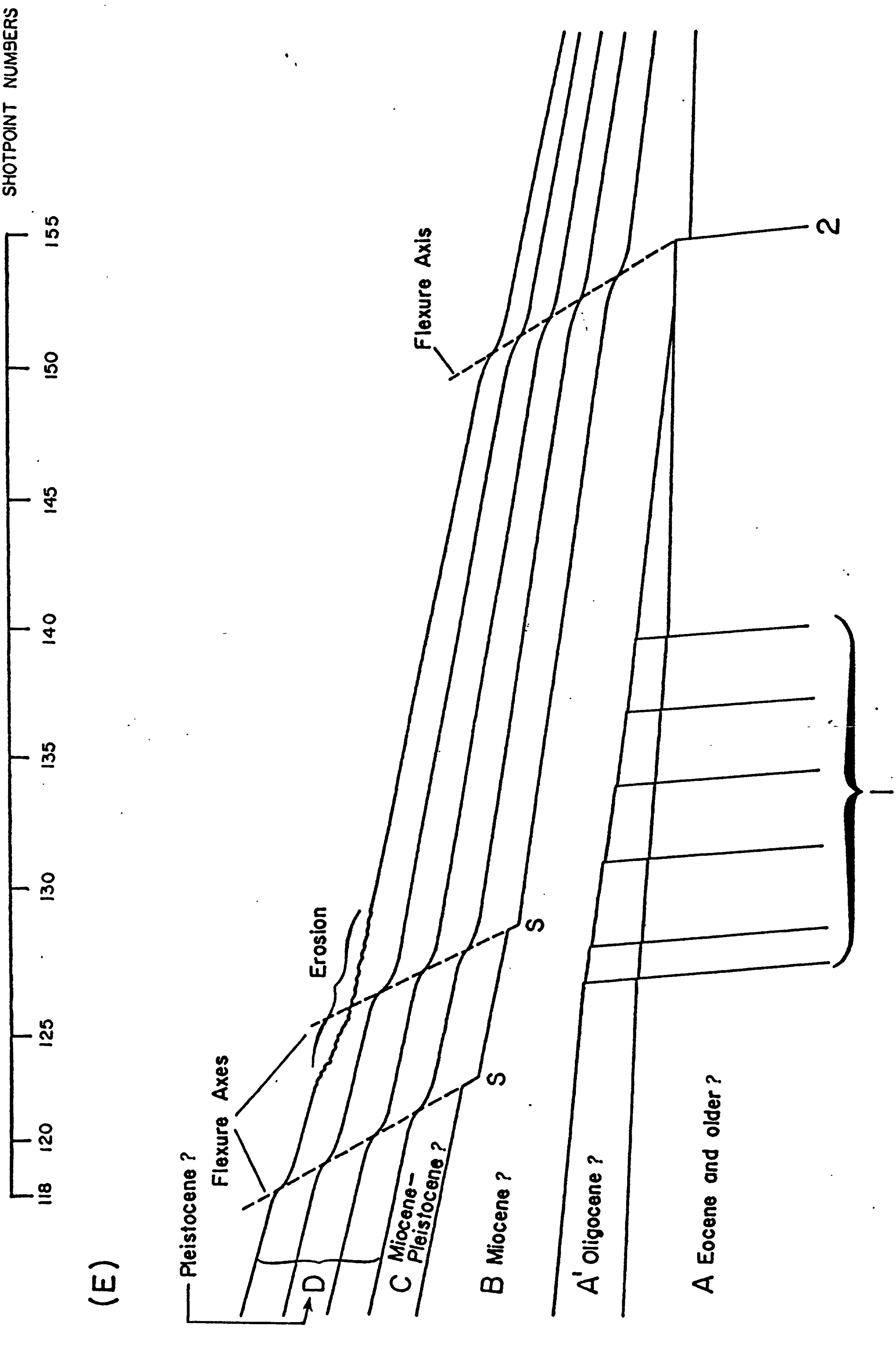


Fig. 9A-E Diagrammatic cross-sections of line 3291 (pl. 5), showing the probable post-Eocene sedimentation history southwest of Hudson Canyon (figures 9C-9E on following pages).


(C)
120
125
130
135
140
145
150
155 SHOTPOINT NUMBERS
Erosional scarps or Delta Fronts
S
S
Flexure Axis
2
1
B
Miocene ?
A'
Oligocene ?
A
Eocene and older ?
(D)
120
125
130
135
140
145
150
155 SHOTPOINT NUMBERS
Flexure Axes
Flexure Axis
S
S
2
1
C
Miocene–Pleistocene ?
B
Miocene ?
A'
Oligocene ?
A
Eocene and older ?

(fig. 9C and 9D)


SHOTPOINT NUMBERS
118
120
125
130
135
140
145
150
155
(E)
Pleistocene ?
Flexure Axes
Erosion
Flexure Axis
D
C Miocene–Pleistocene ?
B Miocene ?
A' Oligocene ?
A Eocene and older ?
S
S
1
2

(fig. 9E)

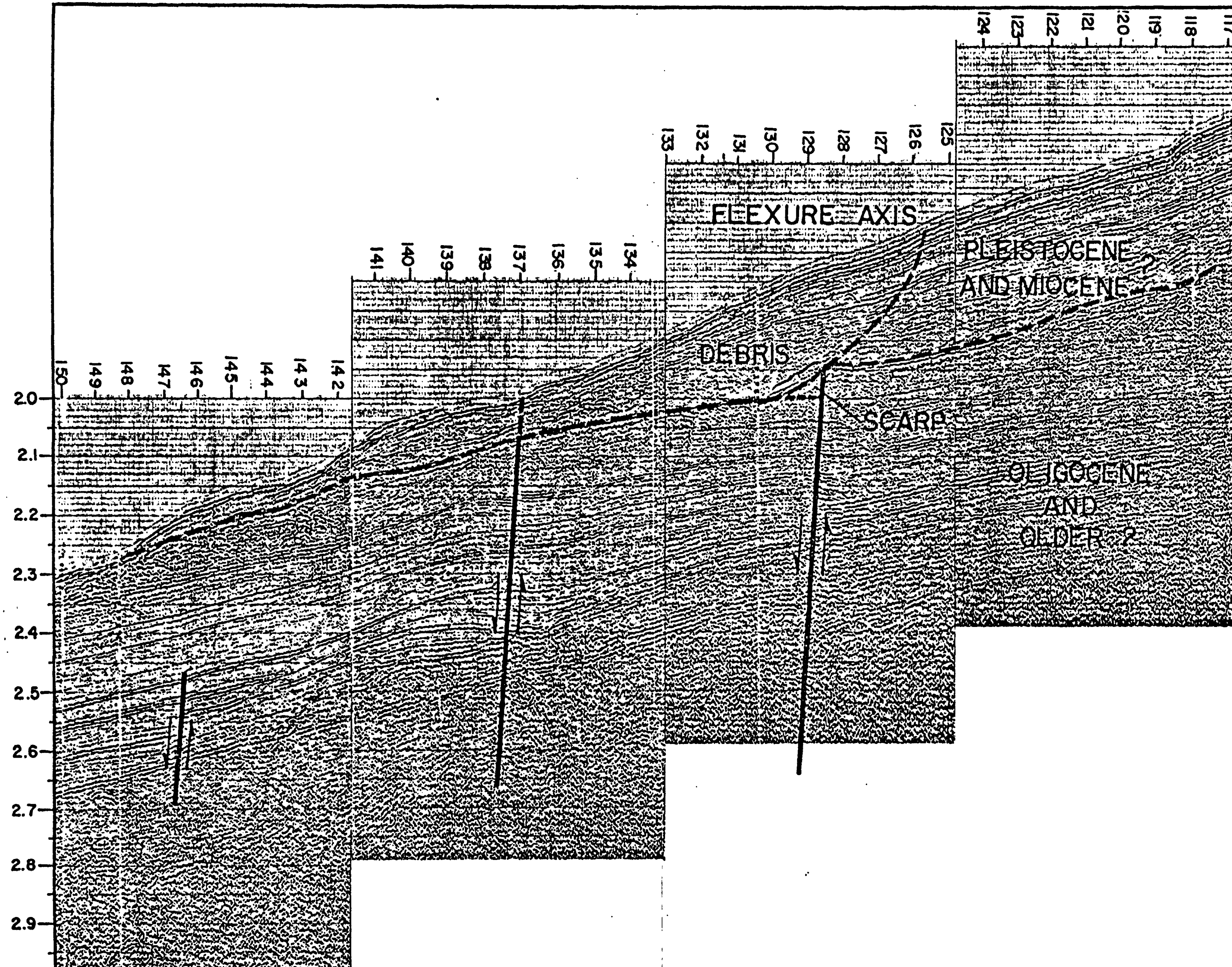


Fig. 10 Seismic profile (15-cu in. air gun analog record, line 3279 shotpoints 117-150) showing two persistent faults south of Hudson Canyon. The fault at sp. 137 shows possible surface offset. Vertical exaggeration X6.7.

shotpoint 128 (fig. 10), shows an even more direct relationship with flexures in that the fault line leads directly to the flexure axis. The common denominator in the interpretation of structures on lines 3279 and 3291 (figs. 9A-E and 10) is believed to be the existence of scarps and not postdepositional fault movement.

We feel that this relationship is an essential one for hazard assessments in the Mid-Atlantic slope area. Sedimentation over old fault scarps with subsequent differential compaction produces features which can easily be interpreted as recent slumps and/or as extensions of fault planes, particularly if data resolution is poor. This in turn would suggest recent movement along the fault. The combination of historically recent faulting and slump-prone sediments is probably the most severe potential geologic hazard to platform integrity. However, any possible hazard related to flexures and draping, differential compaction features, and minor slumping produced over geologically old fault scarps can be mitigated using modern engineering technology and practices. We cannot state with certainty that these differential compaction or slump features are totally unrelated to relatively recent fault movement nor can we conclusively state that these faults only occur in Miocene and Pliocene or older sediments because stratigraphic test well control is not available. Nevertheless, our evidence indicates that these features are controlled by underlying topography and not by historically recent fault activity.

Rotational slumps with well-developed scarps and glide planes are observed in blocks NJ 18-3-911, -824 and -781. The slumps in blocks NJ 18-3-824 and -781 are on sides of valleys and the one in block NJ 18-3-911 is on a ridge or intervalley area. Figures 11, 12, and 13 show seismic lines and bathymetric profiles respectively across block NJ 18-3-911. Figure 14-A is a map view of the slump as interpreted solely from Sale 59 data. Figure 15 shows a seismic line across the slump in block NJ 18-3-824.

The large slump in block NJ 18-3-911 has occurred on a 3.5-degree slope in the southeastern quarter of the block (pl. 1 and fig. 14). Since this feature lies on the border of the proposed sale area, the full extent of the slump is not known. Its approximate extent can be mapped, however, from existing National Ocean Survey bathymetric data (NOS NJ 18-3) (See

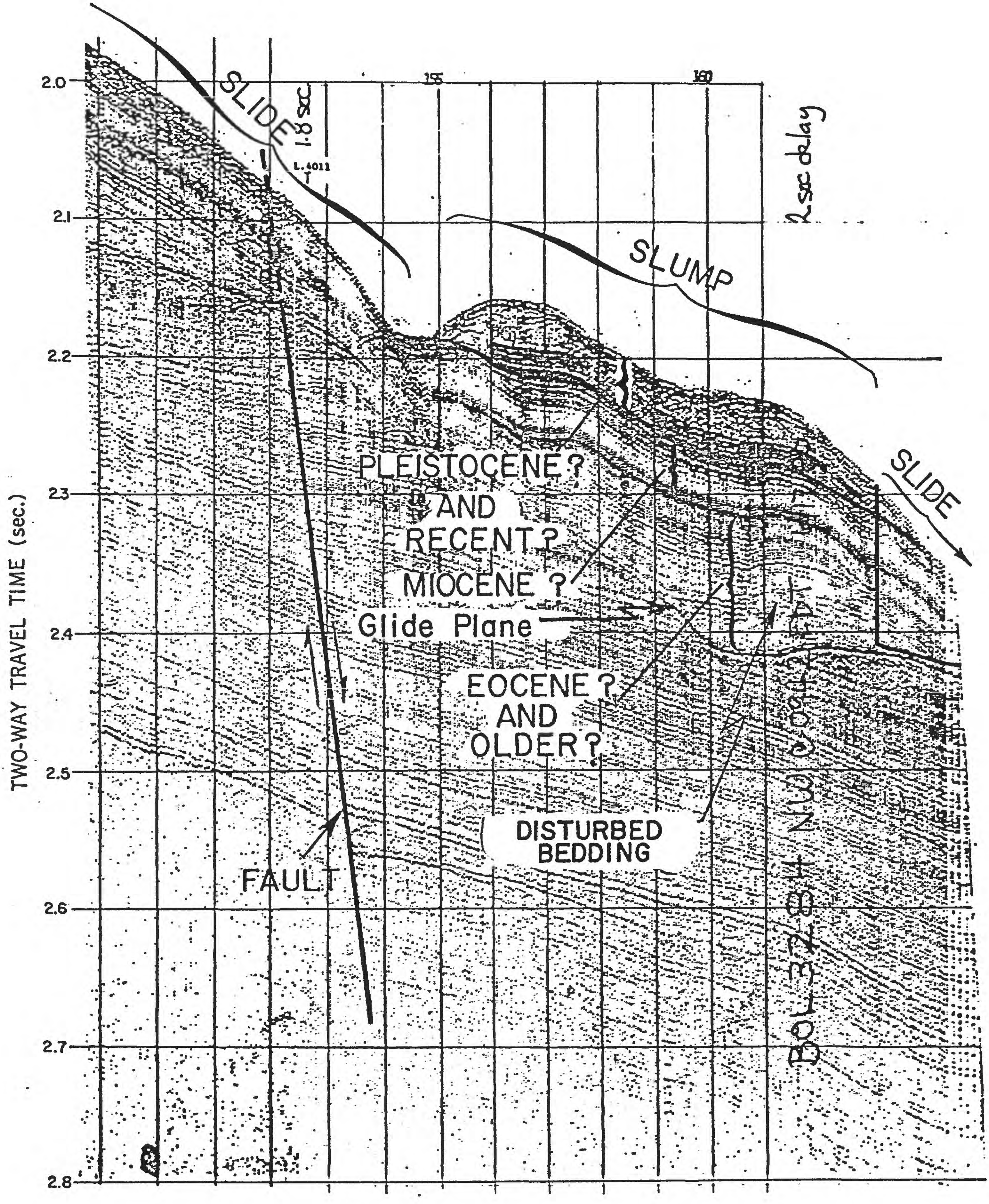


Fig. 11 Seismic profile (15-cu in. water gun analog record, line 3284 shotpoints 139-161) crossing the large slump in block NJ 18-3-911. Although the fault trace does not appear to reach the surface, retrogressive sliding may have obscured the trace. Vertical exaggeration X15.

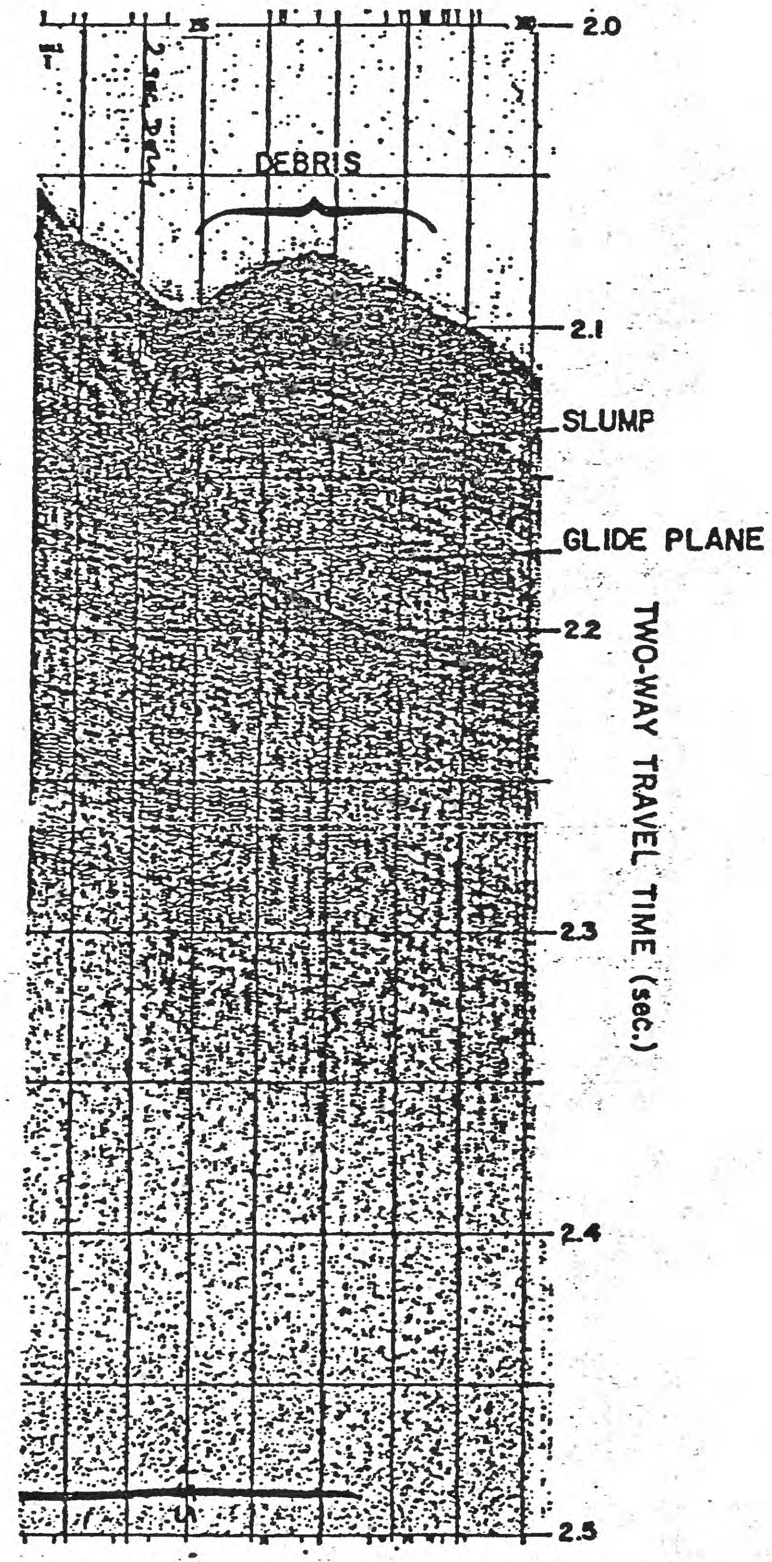


Fig. 12 Seismic profile (15-cu in. water gun analog record, line 3281 shotpoints 153-160) crossing the large slump in block NJ 18-3-911. Irregular mound is thought to be debris from failure upslope. Vertical exaggeration X15.

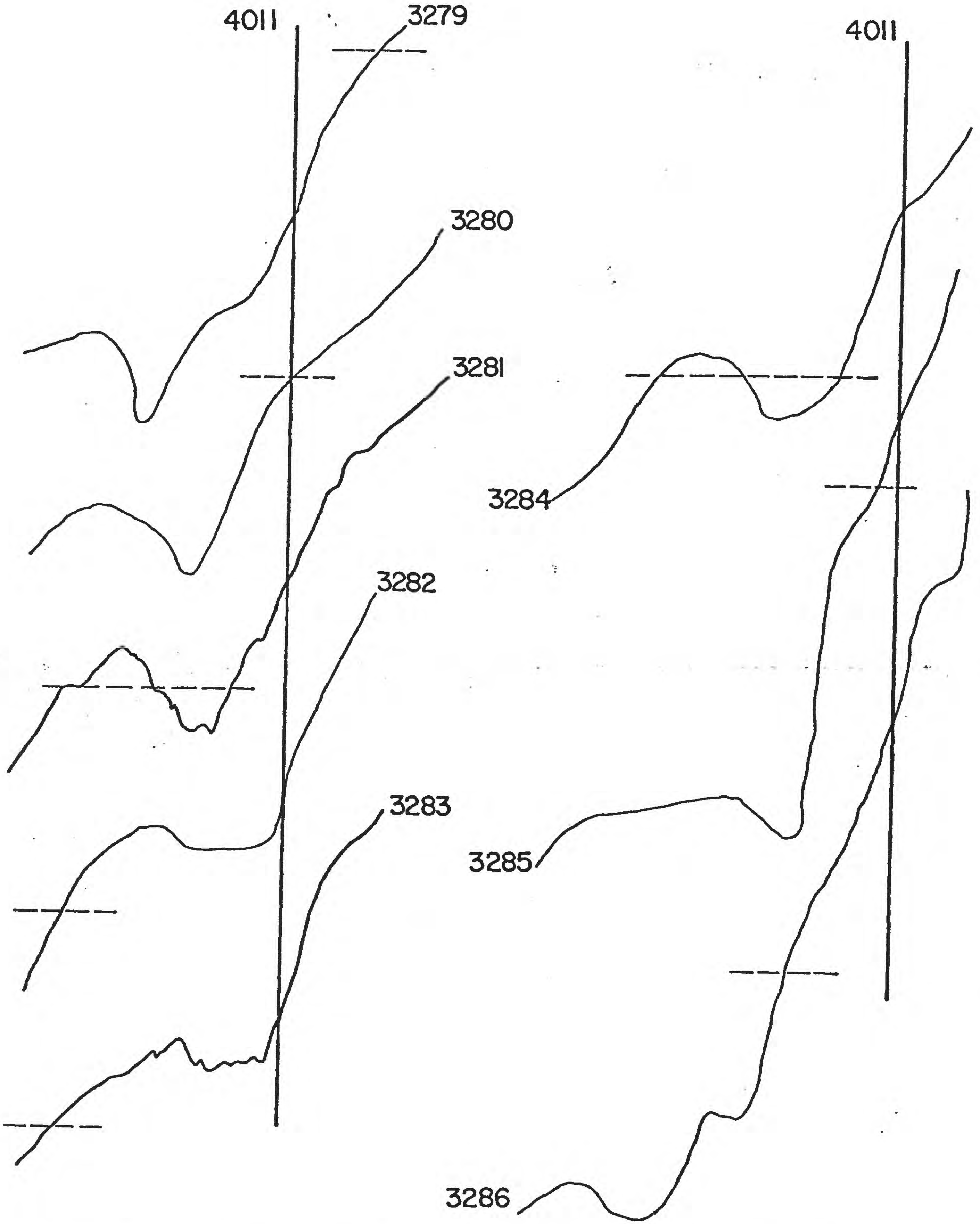


Fig. 13 Bathymetric profiles (24 khz, 10° beam) over the large slump in NJ 18-3-911. Note the irregular surfaces of profiles 3281 and 3283, thought to be debris from upslope. Dashed line is 1572 m isobath. Vertical exaggeration X23.

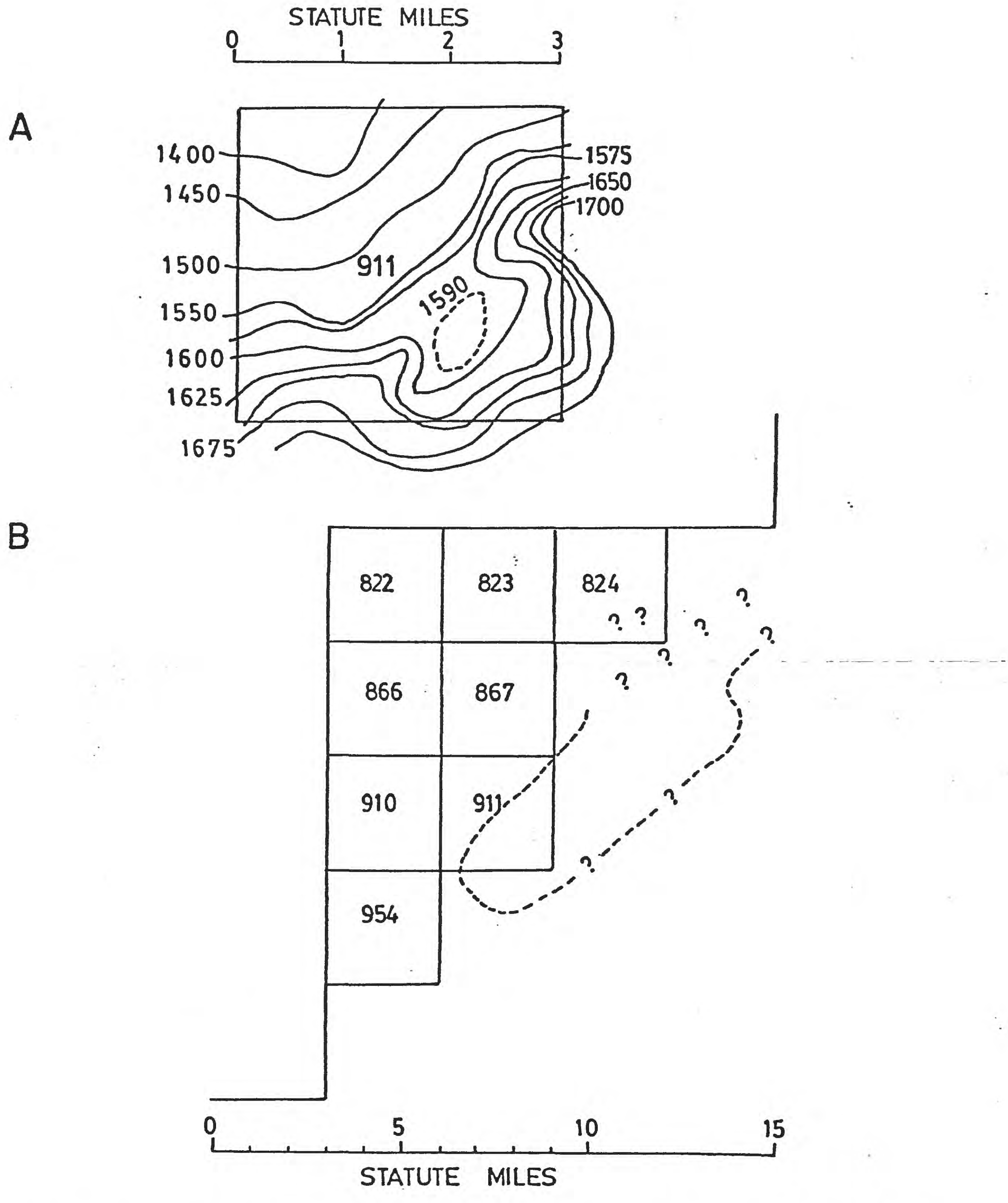


Fig. 14 A, Bathymetric detail of the southwest section of the slump, and B, approximate extent of the slump in block NJ 18-3-911. Contours in meters.

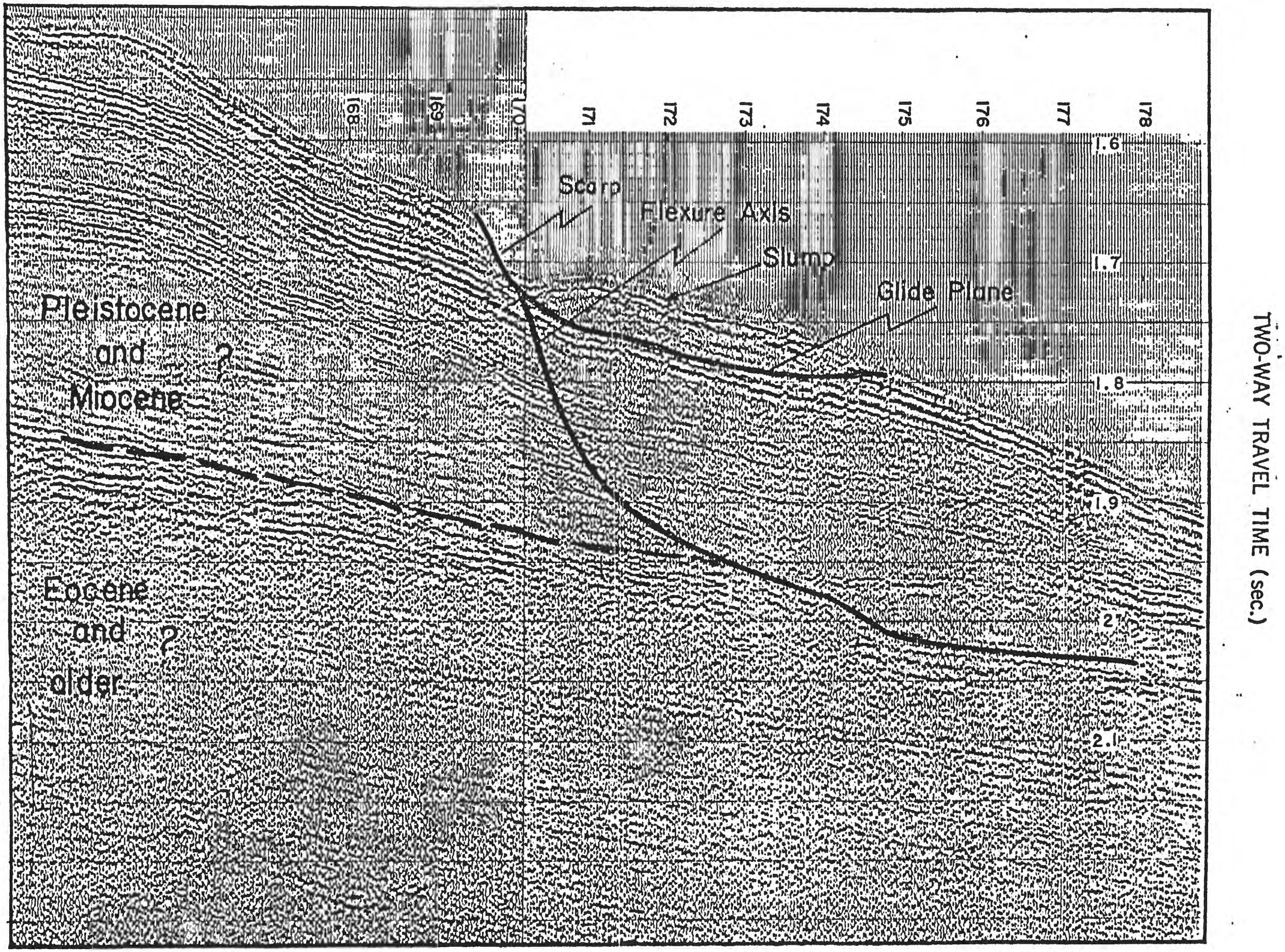


Fig. 15 Seismic profile (15-cu in. water gun analog record, line 3293 shotpoints 168-178) crossing slump in block NJ 18-11-824. Note small slump superimposed on compaction feature produced as a result of irregular topography on Eocene erosional surface. Vertical exaggeration X6.5.

fig. 14-A and B). The slump appears to be 15 km long by 5 km wide for a total areal extent of 75 sq km. If an average thickness of 200 m is assumed (calculated from the proposed Sale 59 seismic data assuming 1,676 m/s sediment velocity--U.S. Geological Survey, 1976, unpublished data) the volume of slumped material is approximately 15 cu km. This feature is a remarkably clear example of submarine slump failure with rotation through an angle of about 1-1/2 degrees from the initial (2 degrees) to the present (1/2 degree) bed attitude near the head of the slump. Because of the lack of data coverage, the amount of debris bulldozed downslope by this slump cannot be determined, but it would be reasonable to assume that a considerable quantity of debris was included (see fig. 11). Upslope, the slump is bounded by a deep-seated, NE trending normal fault (fig. 11 and pl. 1). Near the surface, fault throw is 4 to 8 m, and at a depth of about 420 m subbottom, fault throw is 8 to 12 m. Because of the proximity of the fault to the slump and because of the near-surface expression of the fault, it is possible that movement along the fault triggered the slump. Late Pleistocene or recent movement may be indicated, inasmuch as the slump block along this fault contains what appear to be conformable Pleistocene sediments over Miocene and Pliocene or older sediments.

Approximately two-thirds of the slump block (fig. 11) is composed of Eocene, and Miocene, and Pliocene sediments. The upper third, presumed to be primarily Pleistocene sediments overlain by a relatively thin layer of Holocene sediments, may have overloaded the otherwise stable Eocene-Pliocene sequence. In this overloaded state, only a minor shift in the fault might have been sufficient to trigger the slump. Upslope is a series of slump, slide, and compaction features. A debris deposit on the large slump in block NJ 18-3-911 suggests that at least some of the upslope failures occurred after the failure of the large block (figs. 8 and 12). An alternative interpretation is that the slump in block NJ 18-3-911 was caused by sediment overloading by debris from mass-movement upslope. The large slump and smaller mass-movement features upslope could have been caused by any combination of progressive or retrogressive slope failure, possibly triggered initially by fault,displacement or seismic activity.

A large slump and two large slides have been mapped south of Baltimore Canyon. The slump in blocks NJ 18-9-133 and -134 (pl. 2) was first reported by McGregor and others (1979). The two slides in blocks NJ 18-8-304, -305 and -348 and in blocks NJ 18-9-6 and -50 may have been caused by movement in mud diapirs (fig. 16). Penetration of the seismic system was insufficient to determine with certainty the level of strata from which the diapirs originate, but it apparently was on the order of 400 m subbottom. Strata at this level are likely to be Miocene, Pliocene or older. Although the source of the plastic material forming the diapirs or even identification of the features as diapirs cannot be certain, the sedimentary history of this area is conducive to their formation. Rapid sedimentation rates during Pleistocene low stands in sea level could have resulted in excess sedimentary loading, creating high pore pressures and underconsolidation conditions in Miocene and Pliocene strata. This could have facilitated flow of the more plastic sedimentary layers within newly overburdened strata. While there is some debate as to which phenomenon--slumping or diapir formation--would occur first, the general consensus is that they are nearly simultaneous. Mud flowing into a diapir would trigger slumping due to the resulting change in gradient. With the removal of overburden by the slump, diapir growth would be facilitated (J. M. Coleman, Louisiana State University, oral commun., 1981). If these diapirs had formed as a result of rapid Pleistocene sedimentation rates, their formation may have been a Pleistocene or early post-Pleistocene phenomenon, and so present conditions could well be in equilibrium. However, the age of formation and the present state of activity cannot be determined with seismic data, and the features must be considered as having the potential for activity.

Although not considered drilling hazards, the diapirs may provide hydrocarbon traps at depths as shallow as 100 m subbottom. Therefore, gas could be encountered during open-hole drilling. Conceivably these features are not diapirs but are biological or erosional in origin. In this case, slumping could have been caused by differential compaction over the irregular surface, rather than movement at depth. In either case, hydrocarbon traps could have developed, and encountering shallow gas during drilling operations should be anticipated.

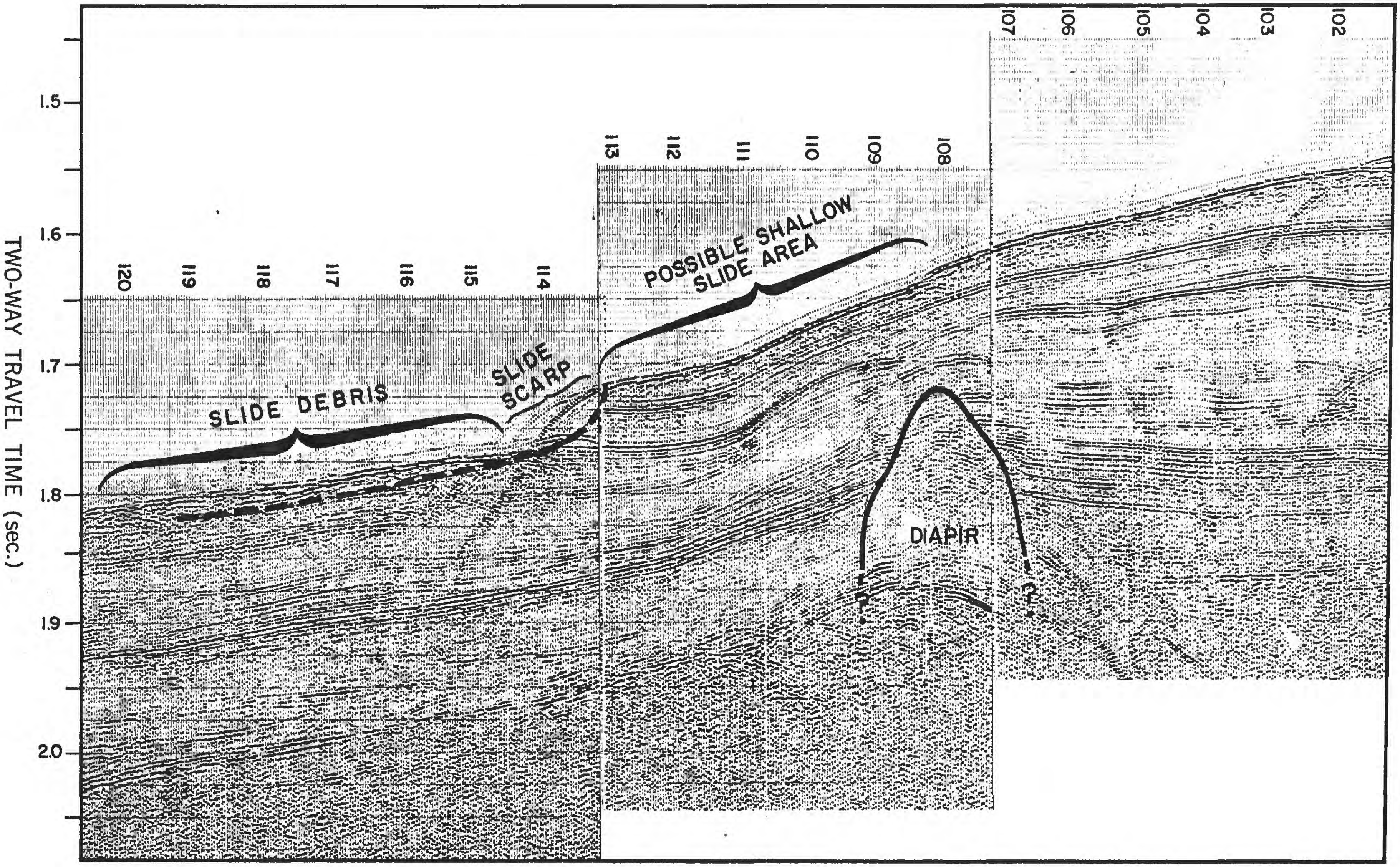


Fig. 16 Seismic profile (15-cu in. water gun digital record, line 3067 shotpoints 102-120) showing possible mud or shale diapir and slide material. The source area for this diapir is believed to be at 2.0 seconds or lower. Vertical exaggeration X3.9.

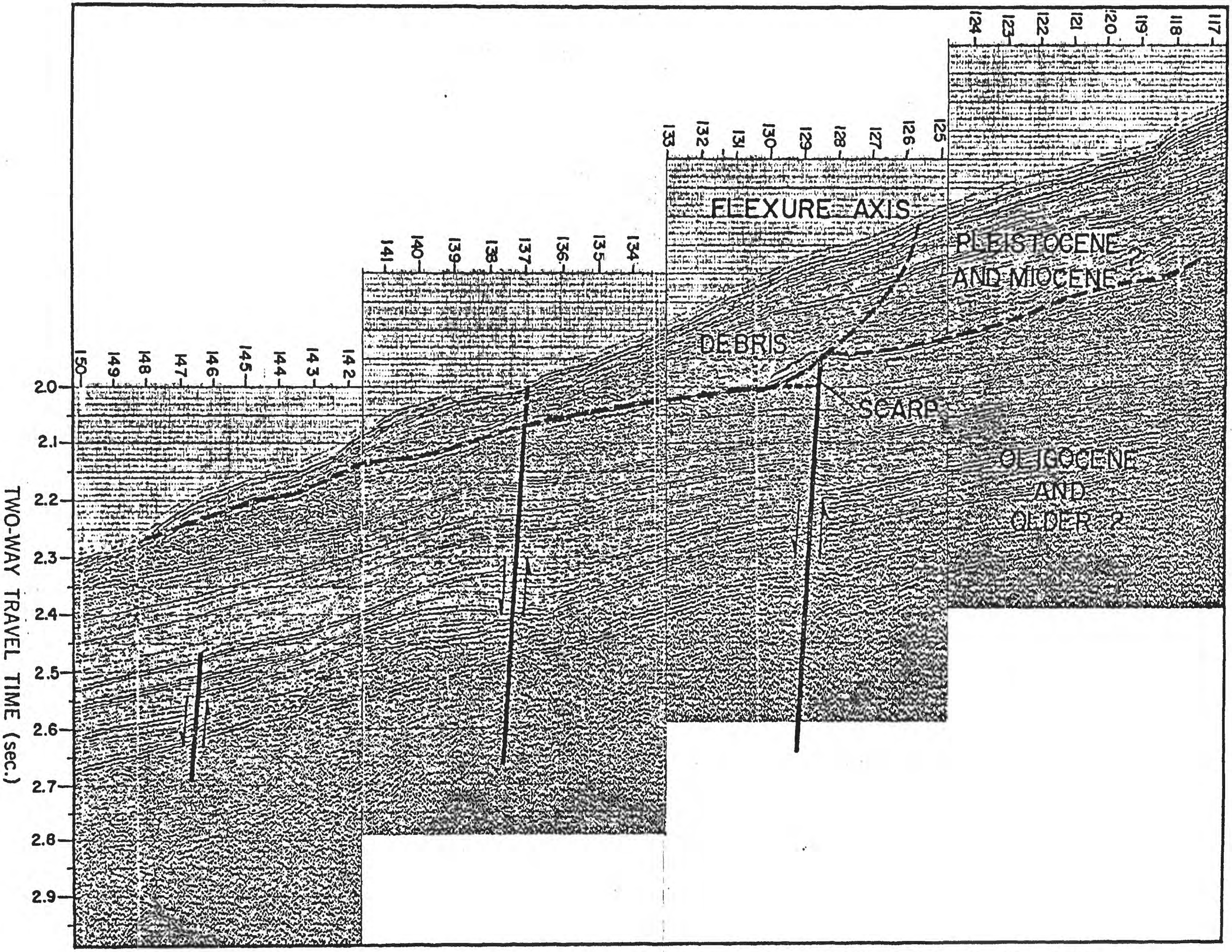


Fig. 10 Seismic profile (15-cu in. air gun analog record, line 3279 shotpoints 117-150) showing two persistent faults south of Hudson Canyon. The fault at sp. 137 shows possible surface offset. Vertical exaggeration X6.7.

SLOPE STABILITY ANALYSIS

As previously mentioned, piston cores were collected from a variety of locations on the continental slope in the proposed Baltimore Canyon lease sale area by the U.S. Geological Survey from the RV Endeavor during September 1979. A variety of different slope environments were sampled including slumps, slides, and slide scarps, and areas of apparently undisturbed sediments. Subsections of these cores were selected for geotechnical analysis by the U.S. Geological Survey on the basis of X-radiography and visual examination, which served as a means for evaluating sample quality. Geotechnical tests were then run on the samples by Law Engineering Testing Company in McLean, Virginia, Woodward and Clyde Consultants in Plymouth Meeting, Pennsylania, and the U.S. Geological Survey Marine Geotechnical Laboratory in Corpus Christi, Texas. The piston cores were tested for gas content aboard the RV Endeavor by the U.S. Geological Survey Marine Organic Geochemistry Laboratory of Reston, Virginia.

The geotechnical test program included: (1) consolidation tests to determine the consolidation state and compressibility characteristics of the sediments; (2) consolidated-undrained triaxial tests with pore pressure measurements to determine both drained and undrained strength parameters; and (3) index property measurements on the consolidation and triaxial test specimens and at additional locations in several cores. These measurements included Atterberg limits, particle-size distribution, specific gravity, and water content.

These geotechnical data were used, together with existing geophysical data, to evaluate the stability of the bottom sediments at each coring site. The first step in this evaluation involved comparison of the shear strength of the material, determined from laboratory measurements, with the gravity-induced shear stresses in situ, calculated from the infinite-slope model for stability analysis. The available shear strength on a failure plane may be considered in terms of its drained or undrained behavior, depending on the sediment characteristics and loading mechanisms. The results of this comparison are expressed in terms of the factor of safety (FS) which is the ratio of the available shear strength of the sediment to the applied shear stress (that is, acting in situ). The results include FS for both drained and undrained conditions at each piston coring site, based on the minimum strength parameters measured on samples of the core at that site. These FS values are used to indicate where slope failure is most likely to occur. However, FS values of either $FS \leq 1$ or $FS > 1$ alone do not represent absolute conditions of slope stability but must be considered with additional factors such as in situ gas, slide mechanics, the presence of cements, assumptions attendant to the infinte slope model, and so forth.

Calculations of infinite slope failure analysis were made for both undrained and drained conditions. (See figure 17 in the Appendix). Definitions of symbols and units used in figure 17 and derivations of the FS formulas listed below are in the Appendix.

1. Undrained Analysis

$$FS = \frac{s_u/\bar{\sigma}_v}{\sin\alpha \cos\alpha}$$

2. Drained Analysis

$$FS = \frac{\tan\bar{\phi}}{\tan\alpha}$$

For each core sample, minimum strengths obtained were used for FS calculations. That is:

1. For drained FS, minimum measured $\bar{\phi}$ angles were used.
2. For undrained FS, we used ($s_u/\bar{\sigma}_v$) values consistent with the lowest overconsolidation ratio (OCR) value measured from consolidation tests in the core.

The safety factors were calculated in all cases for the estimated maximum and average slopes in the region where each core was collected. Safety factors less than or equal to 1.0 were obtained for maximum estimated slopes in the following:

1. CD-9 PC-7
2. CD-15 PC-18
3. CD-22 PC-24
4. CD-22 PC-25
5. CD-26 PC-30
6. CD-32A PC-33

In only one instance was a safety factor less than 1.0 obtained for the estimated average slope (CD-32A, PC-33).

In all cases where low safety factors were obtained, the low FS values were associated with low OCR values in the range of about 0.5 to 1.0. Each OCR value, determined from a consolidation test, is a ratio of maximum previous effective overburden stress ($\bar{\sigma}_m$) to the calculated effective overburden stress ($\bar{\sigma}_v$). If $\bar{\sigma}_m$ equals $\bar{\sigma}_v$ (OCR = 1), the sediment is considered to be normally consolidated. Those materials with an OCR less than 1.0 are considered underconsolidated. It is noteworthy, and appears to be of practical importance, that underconsolidated materials occur in the near-surface sediments and that these materials occur both as discrete layers within cores and also scattered vertically throughout some cores. These underconsolidated materials were seen to occur primarily at sites located on canyon walls.

Some cores in the proposed Lease Sale 59 area contained surface layers (up to 10 m thick) with low OCR values (that is, 0.4 to 0.8 range) and may be substantially underconsolidated. These cores were obtained on both valley walls and intervalley ridges on the upper slope. The measured residual gas levels were above background in a few of these cores. In no instance was the measured gas content close to saturation levels (about 300,000 ppm by volume) for in situ conditions of temperature and pressure.

The question arises whether the underconsolidated zones are localized in their lateral and vertical extent, or whether they persist as underconsolidated layers over large areas. The latter possibility is of concern because these underconsolidated zones might be potential slide planes for major mass movements.

We are inclined to believe that the underconsolidated zones are localized laterally because:

1. The available evidence (core data, seismic records) does not point to free gas as a potential source of excess in situ pore pressure, which is one possible explanation for soft layers in the geologic section.

2. The association of underconsolidated materials with canyon walls suggests a variety of depositional processes that could account for their occurrence (for example, shelf spillover deposits, or small-scale mass-wasting events). This explanation suggests that underconsolidated materials result from localized sedimentary processes rather than from widespread rapid sedimentation.

3. From a regional point of view, the average present-day sedimentation rates are not believed to be of sufficient magnitude (about 10 cm/1,000 yrs, Ewing and others, 1973) to account for widespread layers of underconsolidated materials.

4. At certain times (for example, low stands of sea level), or at certain locations, rates of accumulation could have been high (that is, consistent with the occurrence of underconsolidated deposits in localized areas). This is supported by HRG data which show highly variable thicknesses of Pleistocene and Recent sediments.

5. After reviewing available data (HRG data, cores, previous studies), we believe these localized zones to be much smaller than a lease block.

A major practical issue is the question of whether soft layers occur at depths greater than those penetrated by the piston cores (5-10 m at best) and, if so, where and under what conditions. Analysis of proposed lease sale geophysical data has revealed two possible near-surface diapiric structures, both located near and southwest of the Baltimore Canyon. These diapiric structures may consist of overpressured and underconsolidated muds of Miocene age. These diapiric structures are reviewed in the discussion section (see page 41). No near-surface (0-200 m or more) gassy zones (bright spots) have been detected by high-resolution seismic data in the proposed

Sale 59 area. There are no geotechnical data available which identify deeper buried zones of underconsolidated sediments. Deeper geotechnical studies might have to be performed at proposed drilling sites to help resolve this issue.

Other points to bear in mind when evaluating the FS values are:

1. All cores have been disturbed to some unknown degree, and therefore the results presented here are to be considered only approximations.

2. No in situ geotechnical information (for example, in situ pore pressures) is available to corroborate any of the strengths obtained from laboratory tests. The state of the art in obtaining reliable in situ geotechnical and geochemical data at water depths of 246 to 1,342 m where these cores were collected is still in an early stage.

3. Although residual gas content measurements revealed only background levels in many cores (1 to 25 ppm by volume), these data do not represent in situ conditions (Miller and others, 1981). There is currently no instrumentation capable of measuring gas content, volume, temperature, and pore pressure in situ in deep-water sediments.

4. The cores represent limited regional coverage. The U.S. Geological Survey would not advise extrapolation of these data to adjacent areas for oil and gas exploration or development.

5. The FS values are for static slope conditions. They do not take into account any possible influence of dynamic processes, such as cyclic loading induced by earthquakes, on shear-strength values and ultimately on factor of safety values. Existing data are inadequate to evaluate possible in situ dynamic loading effects on slope stability.

6. Finally, the strength values used for FS calculations were intentionally selected from the lower end of their range to reflect the most conservative estimated conditions.

SUMMARY

1. Shallow recent faults and mass-movement features are present in the proposed Lease Sale 59 area.

   A. Faults intersecting the sea floor occur in the proposed sale area most commonly in valleys or canyons. Their intersection with the bottom surface is most likely the result of sediment draping or removal of sediment cover and not of recent displacement. Stratigraphic identifications and age determinations are uncertain, however, and these faults must be considered as having potential for present-day movement.

   B. Numerous sediment-mass-movement features are mapped which are probably Pleistocene in age. Many mass-movement features appear to have been progressively formed over long periods of time and are associated with topographic irregularities. The general distribution of mass-movement features probably reflects the high sedimentation rates during the Pleistocene. Near Hudson Canyon, a large mass-movement complex may have been triggered by fault movement, and south of Baltimore Canyon two slides may have been caused by movement in mud diapirs.

2. The geotechnical test results and analyses indicate the majority of the cored sediments are normally consolidated to slightly overconsolidated, and hence have no apparent instability problems. The geotechnical data have limited regional coverage and apply only to shallow depths (10 m maximum--6-7 m average). Test results indicate the presence of some localized zones of underconsolidated sediments, primarily on valley walls and ridges on the upper slope. These zones may represent discrete areas where either mass movement has occurred or the potential for mass movement may exist. Two core sites have been identified as being on possible slump scars or slump features (CD-7, CD-34). The sediments

within these and other identified mass-movement features may be disturbed and/or remolded sediments, probably with smaller shear strength values than nearby undisturbed sediments. Consequently, these areas may represent a higher risk to platform integrity than undisturbed areas.

3. High resolution geophysical profiling techniques can only detect what has already happened, not predict what will happen such as the potential for sediment mass movement. The combination of possible recent faulting and the existence of sediment-mass-movement features dictates that the dynamic sedimentary regime be understood prior to oil and gas activities. A block-specific survey alone will not properly establish the geologic hazard potential for a specific block. Therefore, a site-specific survey may have to include data collection outside the lease-block boundaries.

4. The following blocks in proposed Lease Sale 59 show evidence of possible geologic hazards.

   A. Mass-movement-related structures

      NJ 18-3 -733, -734, -735, -777, -778, -779, -780, -781, -821, -822, -823, -824, -865, -866, -867, -908, -909, -910, -911, -953, -954, -990, -993, and 994

      NJ 18-6 -22, -23, -26, -28, -63, -108, -113, -114, -157, -453, -454, -496, -497, -546, -627, -800, -843, -844, -888, -889, and -975

      NJ 18-8 -304, -305, and -348

      NJ 18-9 -6, -49, -50, -90, -93, -133, and -134

   B. Recent shallow faulting

      NJ 18-3 -864, -865, -909, -910, -911, -952, -953, -954, and -995

      NJ 18-6 -197, -330, -373, and -846

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APPENDIX

Factor of Safety (FS) Derivations
for Infinite Slope Stability Model

$\bar{\phi}$ = friction angle with respect to effective stress in degrees
α = slope angle in degrees
$\bar{c}$ = cohesion intercept in terms of effective stress in kN/m^2
z = depth to failure plane from sediment surface in meters
b = width of soil element in meters
γ_b = bouyant unit weight of soil element in kN
W_b = bouyant weight of soil element in kN
$\bar{\sigma}_v$ = effective vertical stress in kN/m^2
T = shearing resistance on failure plane in kN
τ = shear stress on failure plane in kN/m^2
N = effective force normal to failure plane in kN
$\bar{\sigma}_n$ = effective stress normal to failure plane in kN/m^2
s = available shear strength in kN/m^2
s_u = available undrained shear strength in kN/m^2
s_d = available drained shear strength in kN/m^2

A. Undrained Analysis:

$$FS = \frac{\text{available undrained shear strength}}{\text{shear stress required for equilibrium}}$$

$$FS = (s_u/\tau)$$

$$FS = \frac{s_u/\bar{\sigma}_v}{\cos\alpha \sin\alpha}$$

where $\bar{\sigma}_v = \gamma_b z$
$= (\gamma_b z) \cos\alpha \sin\alpha$

Undrained analysis is appropriate in examining sediment stability under short term failure conditions. In this case, the sediment is sheared to failure before any excess pore pressure generated during shearing has time to dissipate.

B. Drained Analysis:

$$FS = \frac{\text{available drained shear strength}}{\text{shear stress required for equilibrium}}$$

$$= s_d/\tau \text{ with } s_d = \bar{c} + \bar{\sigma}_n \tan \bar{\phi}$$

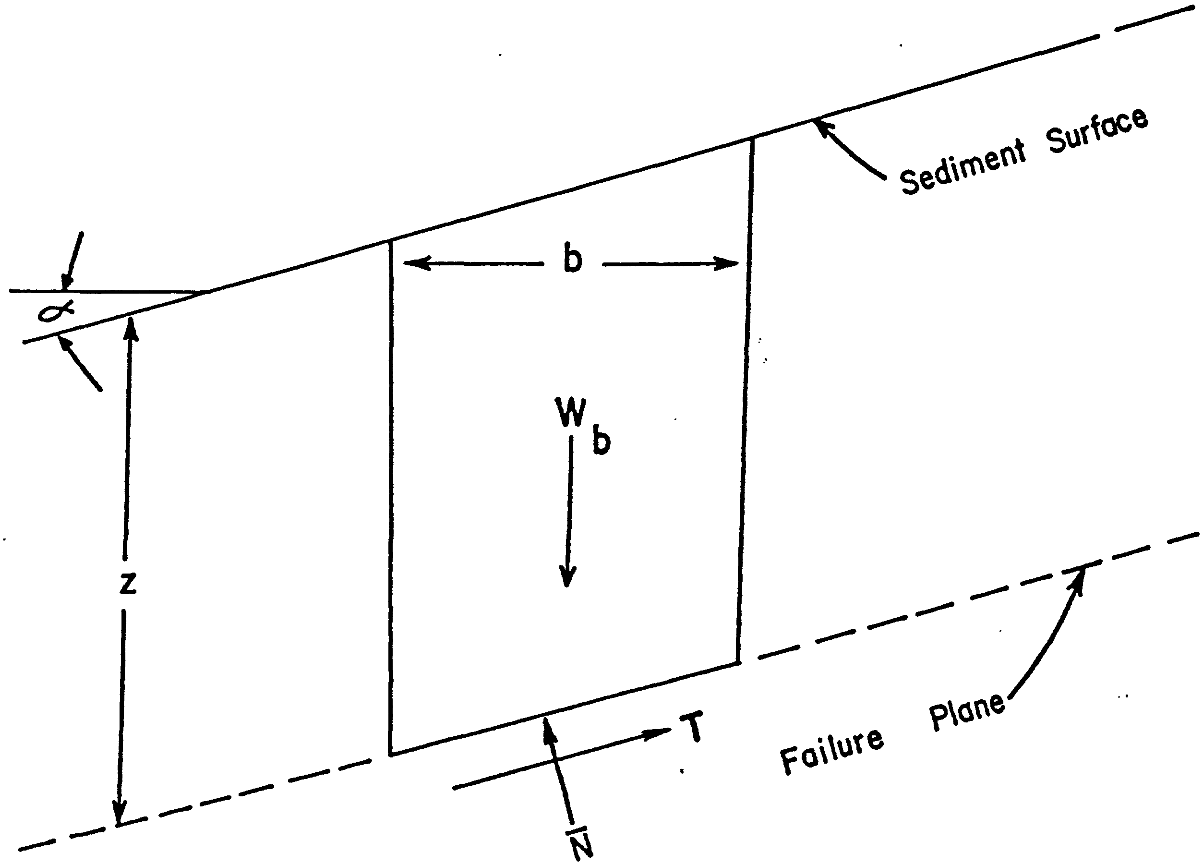
Assume $\bar{c} = 0$

since $\bar{\sigma}_n = (\gamma_b z) \cos^2 \alpha$

$$FS = \frac{(\gamma_b z \cos^2 \alpha) \tan \bar{\phi}}{\gamma_b z \cos \alpha \sin \alpha}$$

$$FS = \frac{\tan \bar{\phi}}{\tan \alpha}$$

Drained analysis is appropriate for use with long term stability analysis. Drained analysis will typically yield higher FS values than undrained analysis for normally consolidated and underconsolidated clays.



Where:

$$W_b = (\gamma_b z)b = \bar{\sigma}_v b$$

$$T = W_b \sin\alpha = (\gamma_b z)b \sin\alpha$$

$$\bar{N} = W_b \cos\alpha = (\gamma_b z)b \cos\alpha$$

$$\tau = (\gamma_b z) \cos\alpha \sin\alpha$$

$$\bar{\sigma}_n = (\gamma_b z) \cos^2\alpha$$

$$\bar{\sigma}_v = \gamma_b z$$

$$s_d = \bar{c} + \bar{\sigma}_n \tan\bar{\phi}$$

Fig. 17 Infinite-slope stability analysis diagram with formulas for calculations of bouyant weight of soil (W_b), shear force on failure plane (T), shearing stress on failure plane (τ), and effective force normal to failure plane ($\bar{N}$).

Slope Stability Analysis Tables

The geotechnical core test results have been compiled in the following tables with help from H. W. Olsen and T. L. Rice of the U.S. Geological Survey in Denver, Colorado, and J. S. Booth, B. A. McGregor, and D. L. Marks of the U.S. Geological Survey in Woods Hole, Massachusetts (written commun., 1981). When appropriate, factor of safety values were computed for both average and maximum slope angles near core-site locations. Only surface and near-surface faults located near core site locations are mentioned under Geologic Factors. Evidence of gas within each piston core is mentioned under Geologic Factors. Local in situ evidence of gas (for example, acoustically turbid zones) is discussed under the Additional Comments section. Refer to table 1 for a summary of core site locations.

Table 1

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-1 Core No: PC-5 Block No: NJ 18-3-776

Latitude: 39°12.23' Longitude: 72°24.30'

Water Depth: 412 m Core Recovery: 6.66 m

Slope Angle, α: 11° average and 15° maximum locally

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	27.5°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.35
Overconsolidation Ratio, OCR:	1.0-3.0

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.9*	1.4**
Factor of Safety (drained):	2.7*	1.9**

Geologic Factors:

Feature Sampled: Intervalley ridge on upper slope.

Faults: No shallow faults detected in block.

Gas: Approximately 19,000 ppm by volume detected in core at 618 cm. This value is below saturation at STP.

Additional Comments:

Deep normal fault (old fault) that has no shallow expression in block. No acoustically turbid zones evidencing gas. Sediment is normally consolidated to slightly overconsolidated.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-4 Core No: PC-3 Block No: NJ 18-3-820

Latitude: 39°09.12' Longitude: 72°24.30'

Water Depth: 708 m Core Recovery: 6.94 m

Slope Angle, α: 9° average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	21°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.22
Overconsolidation Ratio, OCR:	0.7-1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.4*
Factor of Safety (drained):	2.4*

Geologic Factors:

Feature Sampled: Wall of intervalley ridge midslope.

Faults: No shallow faults detected in block.

Gas: Approximately 3,000 ppm by volume detected in core. This value is below saturation at STP.

Additional Comments:

Consolidation state of sediment is normal

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-5 Core No: PC-4 Block No: NJ 18-3-820

Latitude: 39°08.90' Longitude: 72°24.09'

Water Depth: 740 m Core Recovery: 6.37 m

Slope Angle, α: 4° average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	23.5°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.26
Overconsolidation Ratio, OCR:	1.0-1.4

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.7*
Factor of Safety (drained):	6.2*

Geologic Factors:

Feature Sampled: Intervalley ridge midslope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Consolidation state of sediment is normal

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-6 Core No: PC-9 Block No: NJ 18-3-820

Latitude: $39^{o}08.53'$ Longitude: $72^{o}24.32'$

Water Depth: 784 m Core Recovery: 8.03 m

Slope Angle, α: 5^{o} average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	27^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.26
Overconsolidation Ratio, OCR:	0.75-1.00

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.0*
Factor of Safety (drained):	5.8*

Geologic Factors:

Feature Sampled: Intervalley ridge midslope.

Faults: No shallow faults detected in block.

Gas: Approximately 3,600 ppm by volume detected in core. This value is below saturation levels at STP.

Additional Comments:

Sediment is slightly underconsolidated

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-7 Core No: PC-10 Block No: NJ 18-3-865

Latitude: 39°07.27' Longitude: 72°23.25'

Water Depth: 979 m Core Recovery: 7.82 m

Slope Angle, α: 5° average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	24.5°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.26
Overconsolidation Ratio, OCR:	0.8-1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.0*
Factor of Safety (drained):	5.2*

Geologic Factors:

Feature Sampled: Intervalley ridge midslope on possible slump scar; may be debris flow material.

Faults: No shallow faults detected in block area.

Gas: No appreciable amounts of gas above background level detected in core.

Additional Comments:

Consolidation state of sediment is normal. Slumps are present downslope from core site in block.

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-9 Core No: PC-7 Block No: NJ 18-3-864

Latitude: 39°07.23' Longitude: 72°24.94'

Water Depth: 1148 m Core Recovery: 4.47 m

Slope Angle, α: 3° average and 7° maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	24°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.08
Overconsolidation Ratio, OCR:	0.5-6.0

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.5*	0.66**
Factor of Safety (drained):	8.5*	3.63**

Geologic Factors:

Feature Sampled: Canyon axis midslope.

Faults: Shallow fault detected downslope and southeast of core site.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

There appears to be loose fill over an erosional surface within block. Stiffness boundary in core at approximately 3 m depth accounts for high OCR value.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-10 Core No: PC-11 Block No: NJ 18-3-903

Latitude: $39^{o}03.69'$ Longitude: $72^{o}41.32'$

Water Depth: 435 m Core Recovery: 8.24 m

Slope Angle, α: 7^{o} average and maximum

Geotechnical Data:

Texture: Clayey silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	27.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.23
Overconsolidation Ratio, OCR:	0.4-1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.9*
Factor of Safety (drained):	4.2*

Geologic Factors:

Feature Sampled: Intervalley ridge upper slope.

Faults: No shallow faults detected in block.

Gas: Approximately 2,935 ppm by volume detected in core. This value is below saturation at STP.

Additional Comments:

Sediment is slightly underconsolidated to normally consolidated. Possible excess pore pressure associated with low OCR, or low OCR may be due to sample disturbance.

Presumed age of sediments is Pliestocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-11 Core No: PC-12 Block No: NJ 18-3-903

Latitude: $39^{o}03.30'$ Longitude: $72^{o}40.58'$

Water Depth: 566 m Core Recovery: 7.72 m

Slope Angle, α: 3^{o} average and 5^{o} maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	28.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.43
Overconsolidation Ratio, OCR:	1.6-2.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	8.2*	5.0**
Factor of Safety (drained):	10.4*	6.2**

Geologic Factors:

Feature Sampled: Intervalley ridge upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is slightly overconsolidated.

Presumed age of sediment at core base is Pleistocene (C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979)

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

<u>Site Data</u>:

Site No: CD-12 Core No: PC-14 Block No: NJ 18-3-990

Latitude: $39^{o}00.16'$ Longitude: $72^{o}46.43'$

Water Depth: 403 m Core Recovery: 5.1 m

Slope Angle, α: 7^{o} average and 11^{o} maximum

<u>Geotechnical Data</u>:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	27.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.37
Overconsolidation Ratio, OCR:	1.0-3.0

<u>Stability Analysis</u> (Infinite Slope Model):

Factor of Safety (undrained):	3.1*	2.0**
Factor of Safety (drained):	4.2*	2.7**

<u>Geologic Factors</u>:

Feature Sampled: Axis of Valley on headwall upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

<u>Additional Comments</u>:

Sediment is normally consolidated to slightly overconsolidated. Core is located north and upslope of slump.

Age of sediment is Pleistocene (sparse occurrence of fauna (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-13 Core No: PC-15 Block No: NJ 18-3-990

Latitude: $38^{o}59.98'$ Longitude: $72^{o}46.07'$

Water Depth: 471 m Core Recovery: 8.19 m

Slope Angle, α: 5^{o} average and 6^{o} maximum

Geotechnical Data:

Texture: Clayey silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:		19.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:		0.21
Overconsolidation Ratio, OCR:		0.9-1.6

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	2.4*	2.0**
Factor of Safety (drained):	4.0*	3.4**

Geologic Factors:

Feature Sampled: Headwall of valley-upper slope.

Faults: No shallow faults detected in block area.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is normally consolidated to slightly overconsolidated. Core is located NE of slump in block. Age of sediments is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commum., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-14 Core No: PC-16 Block No: NJ 18-3-990

Latitude: $38^{o}59.66'$ Longitude: $72^{o}45.80'$

Water Depth: 543 m Core Recovery: 5.37 m

Slope Angle, α: 7^{o} average and 9^{o} maximum

Geotechnical Data:

Texture: Clayey Sandy Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:		31.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:		0.47
Overconsolidation Ratio, OCR:		1.3-3.5

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.9*	3.0**
Factor of Safety (drained):	5.0*	3.9**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block area.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Core is located east of slump

Sediment is slightly to moderately overconsolidated.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-15 Core No: PC-18 Block No: NJ 18-3-991

Latitude: 38^{o} 57.98' Longitude: 72^{o} 43.52'

Water Depth: 810 m Core Recovery: 8.08 m

Slope Angle, α: 6^{o} average and 14^{o} maximum

Geotechnical Data:

Texture: Silty Clay over Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	24^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.16
Overconsolidation Ratio, OCR:	0.5-1.0

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.5*	0.7**
Factor of Safety (drained):	4.2*	1.8**

Geologic Factors:

Feature Sampled: Intervalley ridge on midslope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Possible trapped excess pore pressure in the section of the core associated with the low OCR value.
Age of the sediment is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-16 Core No: PC-17 Block No: NJ 18-3-990

Latitude: 38°59.40' Longitude: 72°46.16'

Water Depth: 475 m Core Recovery: 8.33 m

Slope Angle, α: 3° average and 6° maximum

Geotechnical Data:

Texture: Mostly Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	24°	
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.20	
Overconsolidation Ratio, OCR:	0.8-1.4	

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.8*	1.9**
Factor of Safety (drained):	8.5*	4.2**

Geologic Factors:

Feature Sampled: Intervalley ridge on upper slope.

Faults: No shallow faults detected in block.

Gas: Approximately 6,266 ppm by volume detected in core at 770-778 cms. This value is below saturation at STP.

Additional Comments:

Sediment is normally consolidated. Age of sediment is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979)

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-17 Core No: PC-19 Block No: NJ 18-6-65

Latitude: 38°55.36' Longitude: 72°48.90'

Water Depth: 592 m Core Recovery: 6.76 m

Slope Angle, α: 7° average and 10° maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	25°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.35
Overconsolidation Ratio, OCR:	(upper) 5.0-0.6 (lower)

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	2.9*	2.0**
Factor of Safety (drained):	3.8*	2.6**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Stiff sediment cap over soft clay. Possible trapped pore pressure associated with OCR. Presumed age of sediment is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979)

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-18 Core No: PC-20 Block No: NJ 19-6-65

Latitude: $38^{o}55.32'$ Longitude: $72^{o}48.80'$

Water Depth: 598 m Core Recovery: 3.72 m

Slope Angle, α: 7^{o} average and 10^{o} maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	27.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.60
Overconsolidation Ratio, OCR:	2.5-4.7

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	5.0*	3.5**
Factor of Safety (drained):	4.2*	3.0**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is overconsolidated with higher OCR values at 1.5-1.7 m and lower OCR values at 3.1-3.25 m of the core.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-19   Core No: PC-21   Block No: NJ 19-8-65

Latitude: 38°55.23'   Longitude: 72°49.49'

Water Depth: 595 m   Core Recovery: 5.05 m

Slope Angle, α: 3° average and 8° maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	26°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.27
Overconsolidation Ratio, OCR:	0.6-1.1

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	5.2*	2.0**
Factor of Safety (drained):	9.3*	3.5**

Geologic Factors:

Feature Sampled: Valley headwall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is slightly underconsolidated to normally consolidated.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-20 Core No: PC-22 Block No: NJ 18-6-65

Latitude: 38° 54.71' Longitude: 72° 49.59'

Water Depth: 525 m Core Recovery: 6.89 m

Slope Angle, α: 4° average and 9° maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	31°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.27
Overconsolidation Ratio, OCR:	0.7-2.1

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.9*	1.8**
Factor of Safety (drained):	8.6*	3.8**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is slightly underconsolidated to slightly overconsolidated. Age of sediments is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-21 Core No: PC-23 Block No: NJ 18-6-108

Latitude: 38° 52.15' Longitude: 72° 52.74'

Water Depth: 505 m Core Recovery: 7.4 m

Slope Angle, α: 4° average and 8° maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	25.5°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.59
Overconsolidation Ratio, OCR:	2.9-6.7

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	8.5*	4.3**
Factor of Safety (drained):	6.8*	3.4**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults found in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is overconsolidated. Small slump is located upslope from core site. Age of sediments is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-22 Core No: PC-24 Block No: NJ-18-6

Latitude: 38^{o} 51.87' Longitude: 72^{o} 52.27'

Water Depth: 637 m Core Recovery: 6.26 m

Slope Angle, α: 8^{o} average and 15^{o} maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	19^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.24
Overconsolidation Ratio, OCR:	1.0-1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.7*	1.0**
Factor of Safety (drained):	2.4*	1.3**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is normally consolidated. A small slump is located upslope from core site. Age of sediments is Pleistocene (dated by C. W. Poag, Woods Hole, written commun., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-22 Core No: PC-25 Block No: NJ 18-6-108

Latitude: 38° 51.86' Longitude: 72° 52.30'

Water Depth: 607 m Core Recovery: 6.21 m

Slope Angle, α: 8° average and 15° maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	28°	
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.25	
Overconsolidation Ratio, OCR:	0.75-1.3	

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.8*	1.0**
Factor of Safety (drained):	3.8*	2.0**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No evidence of shallow faults in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is normally consolidated. A small slump is located upslope from core location. Age of sediment is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-24 Core No: PC-28 Block No: NJ 18-6-539

Latitude: 38° 24.91' Longitude: 73° 23.54'

Water Depth: 328 m Core Recovery: 3.23 m

Slope Angle, α: 7° average and 10° maximum

Geotechnical Data:

Texture: Clayey Silty Sand

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	32°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0 .56
Overconsolidation Ratio, OCR:	0.7-1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	4.6*	3.3**
Factor of Safety (drained):	5.1*	3.5**

Geologic Factors:

Feature Sampled: Intervalley ridge on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is slightly underconsolidated to normally consolidated.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-25   Core No: PC-29   Block No: NJ 18-6-583

Latitude: 38^{o} 24.74'   Longitude: 73^{o} 23.24'

Water Depth: 392 m   Core Recovery: 2.75 m

Slope Angle, α: 4^{o} average and 6^{o} maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	27^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.82
Overconsolidation Ratio, OCR:	3.4-8.7

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	11.8*	7.9**
Factor of Safety (drained):	7.3*	4.8**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background level detected in core.

Additional Comments:

Sediment is overconsolidated. The core is located NNE of a slump.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-26 Core No: PC-30 Block No: NJ 18-6-583

Latitude: 38^{o} 24.51 Longitude: 73^{o} 22.92'

Water Depth: 520 m Core Recovery: 5.51 m

Slope Angle, α: 10^{o} average and 19^{o} maximum

Geotechnical Data:

Texture: Clayey Silt and Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	24.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.23
Overconsolidation Ratio, OCR:	0.9-2.1

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.3*	0.75**
Factor of Safety (drained):	2.6*	1.30**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sedimemt is normally consolidated to slightly overconsolidated. The core is located NE of a slump.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-27 Core No: PC-31 Block No: NJ 18-3-583

Latitude: 38^{o} 24.38' Longitude: 73^{o} 22.80'

Water Depth: 553 m Core Recovery: 5.58 m

Slope Angle, α: 2^{o} average and 8^{o} maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	29^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.83
Overconsolidation Ratio, OCR:	3.5-7.1

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	23.8*	6.0**
Factor of Safety (drained):	15.9*	3.9**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is overconsolidated. The core is located NE of a slump.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-32 Core No: PC-32 Block No: NJ 18-6-627

Latitude: 38^{o} 22.05' Longitude: 73^{o} 21.05'

Water Depth: 1098 m Core Recovery: 8.02 m

Slope Angle, α: 2^{o} average and 8^{o} maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	29^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.15
Overconsolidation Ratio, OCR:	0.5-1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	4.3*	1.1**
Factor of Safety (drained):	15.9*	3.9**

Geologic Factors:

Feature Sampled: Intervalley ridge mid slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is slightly underconsolidated to normally consolidated. The core is located downslope from a slump.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-32A Core No: PC-33 Block No: NJ 18-6-583

Latitude: 38° 22.49' Longitude: 73° 21.98'

Water Depth: 1040 m Core Recovery: 8.17 m

Slope Angle, α: 9° average and 16° maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	23°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.12
Overconsolidation Ratio, OCR:	0.4-1.1 (lower zone is soft)

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	0.8*	0.5**
Factor of Safety (drained):	2.7**	1.5**

Geologic Factors:

Feature Sampled: Valley wall on midslope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Trapped gas may be associated with lower OCR.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-34 Core No: PC-34 Block No: NJ 18-6-843

Latitude: 38^{o} 08.72' Longitude: 73^{o} 36.42'

Water Depth: 1221 m Core Recovery: 5.8 m

Slope Angle, α: 7^{o} average and maximum

Geotechnical Data:

Texture: Silty Clay/Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	22^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.33
Overconsolidation Ratio, OCR:	1.5-2.9

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	2.7*
Factor of Safety (drained):	3.3*

Geologic Factors:

Feature Sampled: Intervalley ridge on mid-slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

The core is located within an area of a slump. There may be a softer zone at about 3 m depth in the core for which there is no consolidation or triaxial test data.

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-35 Core No: PC-35 Block No: NJ 18-6-843

Latitude: 38° 08.01' Longitude: 73° 35.57'

Water Depth: 1342 m Core Recovery: 7.21 m

Slope Angle, α: 3° average and 5° maximum

Geotechnical Data:

Texture: Clayey Silt and Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	24.5°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.30
Overconsolidation Ratio, OCR:	1.2-1.8

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	5.7*	3.5**
Factor of Safety (drained):	8.7*	5.2**

Geologic Factors:

Feature Sampled: Intervalley ridge on midslope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is normally consolidated. The core is located downslope and south of a slump.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-36 Core No: PC-36 Block No: NJ 18-6-843

Latitude: 38^{o} 08.12' Longitude: 73^{o} 37.25'

Water Depth: 1300 m Core Recovery: 7.33 m

Slope Angle, α: 8^{o} average and maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	26.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.20
Overconsolidation Ratio, OCR:	0.5-2.4

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.4*
Factor of Safety (drained):	3.6*

Geologic Factors:

Feature Sampled: Valley headwall on midslope.

Faults: No shallow faults detected in block.

Gas: No gas measurements taken on core.

Additional Comments:

Initial core disturbed. The site was resampled but no gas measurements were taken on second core. Sediment is slightly underconsolidated to overconsolidated. There appears to be a weak layer 3-4 m deep in core, possibly a zone of excess pore pressure.

* Average Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-37 Core No: PC-37 Block No: NJ 18-6-884

Latitude: 38^{o} 05.71' Longitude: 73^{o} 45.02'

Water Depth: 573 m Core Recovery: 3.84 m

Slope Angle, α: 9^{o} average and 22^{o} maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	29.5^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.61
Overconsolidation Ratio, OCR:	2.2-4.9

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	4.0*	1.8**
Factor of Safety (drained):	3.6*	1.4**

Geologic Factors:

Feature Sampled: Valley wall on upper slope.

Faults: No shallow faults detected in block.

Gas: No gas measurements taken on core..

Additional Comments:

Sediment is overconsolidated.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: CD-38 Core No: PC-38 Block No: NJ 18-6-884

Latitude: 38^{o} 04.54' Longitude: 73^{o} 45.04'

Water Depth: 877 m Core Recovery: 2.9 m

Slope Angle, α: 9^{o} average and 10^{o} maximum

Geotechnical Data:

Texture: Clayey Silt

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	29^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.55
Overconsolidation Ratio, OCR:	1.1-2.3

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.6*	3.2**
Factor of Safety (drained):	3.1*	3.5**

Geologic Factors:

Feature Sampled: Valley wall on midslope.

Faults: No shallow faults detected in block.

Gas: No gas measurements taken on core.

Additional Comments:

Sediment is slightly overconsolidated.

* Average Slope Angle
** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-1R   Core No: PC-54   Block No: NJ 18-6-67

Latitude: 38^{o} 54.13'   Longitude: 72^{o} 40.75'

Water Depth: 1145 m   Core Recovery: 8.58 m

Slope Angle, α: 7^{o} average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	22^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.25
Overconsolidation Ratio, OCR:	2.5

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	2.1
Factor of Safety (drained):	3.3

Geologic Factors:

Feature Sampled: Valley wall (near crest) midslope

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is slightly overconsolidated.

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-2R Core No: PC-39 Block No: NJ 18-3-989

Latitude: 38^{o} 57.94' Longitude: 72^{o} 49.40'

Water Depth: 246 m Core Recovery: 5.72 m

Slope Angle, α: 8^{o} average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	25^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.28
Overconsolidation Ratio, OCR:	3.1

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	2.0
Factor of Safety (drained):	3.3

Geologic Factors:

Feature Sampled: Valley headwall on upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is overconsolidated.
Possible gas-turbid zone in high-resolution geophysical data.

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-07 Core No: PC-52 Block No: NJ 18-6-65

Latitude: 38° 53.02' Longitude: 72° 47.37'

Water Depth: 813 m Core Recovery: 6.13 m

Slope Angle, α: 13° average and maximum

Geotechnical Data:

Texture: Silty Clay	
Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	28°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.30
Overconsolidation Ratio, OCR:	No Data Available

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.4
Factor of Safety (drained):	2.3

Geologic Factors:

Feature Sampled: Valley wall on midslope.

Faults: No shallow faults in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Age of sediments is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-09 Core No: PC-53 Block No: NJ 18-6-110

Latitude: 38° 52.32' Longitude: 72° 46.06'

Water Depth: 1035 m Core Recovery: 10.06 m

Slope Angle, α: 5° minimum, 10° maximum ?

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	22°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.25
Overconsolidation Ratio, OCR:	1.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.5**
Factor of Safety (drained):	2.3**

Geologic Factors:

Feature Sampled: Valley wall (near crest) midslope.

Faults: No shallow faults detected in block.

Gas: Approximately 3,965 ppm by volume detected in core. This value is below saturation at STP.

Additional Comments:

Sediment is normally consolidated.

** Maximum Slope Angle

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-12 Core No: PC-40 Block No: NJ 18-6-153

Latitude: 38° 50.26' Longitude: 72° 47.53'

Water Depth: 1113 m Core Recovery: 7.08 m

Slope Angle, α: 11° average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	26°
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.25
Overconsolidation Ratio, OCR:	2.2

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.3
Factor of Safety (drained):	2.5

Geologic Factors:

Feature Sampled: Valley wall on midslope.

Faults: No shallow faults detected in block.

Gas: No appreciable amount of gas above background levels detected in core.

Additional Comments:

Sediment is slightly overconsolidated.

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-15 Core No: PC-43 Block No: NJ 18-6-108

Latitude: 38^{o} 51.37' Longitude: 72^{o} 52.18'

Water Depth: 620 m Core Recovery: 9.42 m

Slope Angle, α: 5^{o} average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	30^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.32
Overconsolidation Ratio, OCR:	No Data Available

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.7
Factor of Safety (drained):	6.6

Geologic Factors:

Feature Sampled: Featureless (smooth) upper slope.

Faults: No shallow faults detected in block.

Gas: Approximately 14,204 ppm by volume detected in core at 881-890 cms. This value is below saturation at STP.

Additional Comments:

Age of sediment is Pleistocene and Holocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-19 Core No: PC-45 Block No: NJ 18-6-151

Latitude: 38^{o} 49.52 Longitude: 72^{o} 54.03'

Water Depth: 688 m Core Recovery: 6.97m

Slope Angle, α: 6^{o} average and maximum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	28^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.32
Overconsolidation Ratio, OCR:	3.1

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	3.1
Factor of Safety (drained):	5.3

Geologic Factors:

Feature Sampled: Featureless (smooth) upper slope.

Faults: No shallow faults detected in core.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Sediment is overconsolidated.
Age of sediment is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

Table 1 Continued

Baltimore Canyon Sample Sites: Slope Stability Analysis

Site Data:

Site No: GD-23 Core No: PC-44 Block No: NJ 18-6-151

Latitude: 38^{o} 48.11' Longitude: 72^{o} 55.42'

Water Depth: 575 m Core Recovery: 4.5 m

Slope Angle, α: 9^{o} average and minimum

Geotechnical Data:

Texture: Silty Clay

Angle of Shearing Resistance with Respect to Effective Stress, $\bar{\phi}$:	28^{o}
Undrained Shear Strength, Effective Vertical Stress Ratio, $S_u/\bar{\sigma}_v$:	0.30
Overconsolidation Ratio, OCR:	No Data Available

Stability Analysis (Infinite Slope Model):

Factor of Safety (undrained):	1.9
Factor of Safety (drained):	3.4

Geologic Factors:

Feature Sampled: Featureless (smooth) upper slope.

Faults: No shallow faults detected in block.

Gas: No appreciable amounts of gas above background levels detected in core.

Additional Comments:

Age of sediment is Pleistocene (dated by C. W. Poag, U.S. Geological Survey Woods Hole, written commun., 1979).

Table 2.--Geotechnical Core Locations

Site No.	Core No.	Block	Sale Area	Latitude	Longitude	Water-depth (meters)
CD-1	PC 5	776	59	39° 12.23'	72° 24.30'	412
CD-4	PC 3	820	49	39° 09.12'	72° 24.30'	708
CD-5	PC 4	820	49	39° 08.90'	72° 24.09'	740
CD-6	PC 9	820	49	39° 08.53'	72° 24.32'	784
CD-7	PC 10	865	59	39° 07.27'	72° 23.25'	979
CD-9	PC 7	864	59	39° 07.23'	72° 24.94'	1148
CD-10	PC 11	903	49	39° 03.69'	72° 41.32'	435
CD-11	PC 12	903	49	39° 03.30'	72° 40.58'	566
CD-12	PC 14	990	49	39° 00.16'	72° 46.43'	403
CD-13	PC 15	990	59	38° 59.98'	72° 46.07'	471
CD-14	PC 16	990	59	38° 59.66'	72° 45.80'	543
CD-15	PC 18	990	59	38° 57.98'	72° 43.52'	810
CD-16	PC 17	990	59	38° 59.40'	72° 46.16'	475
CD-17	PC 19	65	59	38° 55.36'	72° 48.90'	592
CD-18	PC 20	65	59	38° 55.32'	72° 48.80'	598
CD-19	PC 21	65	59	38° 55.23'	72° 49.49'	595
CD-20	PC 22	65	59	38° 54.71'	72° 49.59'	525
CD-21	PC 23	108	59	38° 52.15'	72° 52.74'	505
CD-22	PC 24	108	59	38° 51.87'	72° 52.27'	637
CD-23	PC 25	108	59	38° 51.86'	72° 52.30'	607
CD-24	PC 28	539	49	38° 24.91'	73° 23.54'	328
CD-25	PC 29	583	49	38° 24.74'	73° 23.24'	392
CD-26	PC 30	583	49	38° 24.51'	73° 22.92'	520
CD-27	PC 31	583	49	38° 24.38'	73° 22.80'	553
CD-32	PC 32	627	59	38° 22.05'	73° 21.50'	1098
CD-32A	PC 33	583	49	38° 22.49'	73° 21.98'	1040
CD-34	PC 34	843	59	38° 08.72'	73° 36.42'	843
CD-35	PC 35	843	59	38° 08.01'	73° 35.57'	1342
CD-36	PC 36	843	59	38° 08.12'	73° 37.25'	1300
CD-37	PC 37	884	59	38° 05.71'	73° 45.02'	573
CD-38	PC 38	884	59	38° 04.54'	73° 45.04'	877
GD-1R	PC 54	67	59	38° 54.13'	72° 40.75'	1145
GD-2R	PC 39	989	49	38° 57.94'	72° 49.40'	246
GD-07	PC 52	65	59	38° 53.02'	72° 47.37'	813
GD-09	PC 53	110	59	38° 52.32'	72° 46.06'	1035
GD-12	PC 40	153	59	38° 50.26'	72° 47.53'	1113
GD-15	PC 43	108	59	38° 51.37'	72° 52.18'	620
GD-19	PC 45	151	49	38° 49.52'	72° 54.03'	688
GD-23	PC 44	151	49	38° 48.11'	72° 55.42'	575

Table 3.--Individual Block Slope Gradient Characteristics in Proposed Lease Sale 59

Block No.	Water Depth (meters)		Slope	
	Min	Max	Maximum Slope Angle Range	Average Slope Direction
NJ 18-3				
686	139	146	5.7° or less	SE
689	175	332	5.7° or less	SE
691	314	644	5.7° or less	SE
693	631	1025	5.7°-19.3°	SE
694	775	1390	5.7°-19.3°	SE
733	135	511	5.7° or less	SE
734	345	735	5.7° or less	SE
735	490	875	5.7° or less	SE
736	630	985	5.7°-19.3°	SE
737	760	1110	5.7° or less	SE
775	217	644	5.7°-19.3°	SE
776	310	679	5.7°-19.3°	SE
777	386	766	5.7° or less	SE
778	515	905	5.7° or less	SE
779	740	1127	5.7°-19.3°	SE
780	895	1190	5.7° or less	SE
781	965	1407	5.7°-19.3°	SE
818	248	826	5.7°-19.3°	SE
819	324	781	5.7°-19.3°	SE
820	612	986	5.7°-19.3°	Variable
821	622	1059	5.7°-19.3°	SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope Maximum Slope Angle Range	Average Slope Direction
822	785	1171	5.7°-19.3°	SE
823	910	1239	5.7° or less	SE
824	1112	1580	5.7° or less	SE
856	88	104	5.7°-19.3°	SE
862	510	1110	5.7°-19.3°	Variable
863	614	1158	26.6° or more	SE
864	740	1174	5.7° or less	SE
865	870	1341	5.7°-19.3°	SE
866	1075	1352	5.7°-19.3°	SE
867	1178	1486	5.7° or less	SE
904	583	1066	5.7°-19.3°	NE
905	631	1304	5.7°-19.3°	Variable
906	689	1264	19.3°-26.6°	Variable
907	882	1359	26.6° or more	Variable
908	1028	1369	5.7°-19.3°	Variable
909	1163	1604	19.3°-26.6°	Variable
910	1242	1630	5.7° or less	SE
911	1335	1705	5.7°-19.3°	SE
948	608	1138	19.3°-26.6°	Variable
949	637	1347	19.3°-26.6°	Variable
950	1023	1713	26.6° or more	Variable
951	1082	1689	26.6° or more	Variable

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
952	1239	1820	26.6° or more	Variable
953	1303	1700	5.7°-19.3°	SE
954	1493	1825	5.7°-19.3°	S
990	295	832	5.7°-19.3°	SE
991	609	1111	19.3°-26.6°	Variable
992	707	1248	19.3°-26.6°	SE
993	1040	1465	19.3°-26.6°	Variable
994	1070	1912	26.6° or more	E
995	1326	2030	26.6° or more	Variable
996	1440	2105	26.6° or more	Variable
997	1616	2112	26.6° or more	S
NJ 18-6				
22	567	1126	19.3°-26.6°	SE
23	797	1415	26.6° or more	Variable
24	958	1302	26.6° or more	Variable
25	1112	1823	26.6° or more	Variable
26	1294	1953	26.6° or more	Variable
27	1548	2207	26.6° or more	Variable
28	1640	2147	26.6° or more	Variable
63	107	307	5.7° or less	SE
65	435	996	19.3°-26.6°	SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

	Water Depth (meters)		Slope	
Block No.	Min	Max	Maximum Slope Angle Range	Average Slope Direction
66	747	1182	19.3°-26.6°	SE
67	945	1420	19.3°-26.6°	Variable
68	1170	1690	19.3°-26.6°	Variable
69	1400	1955	26.6° or more	Variable
70	1601	2233	26.6° or more	Variable
71	1680	2345	26.6° or more	Variable
108	279	930	5.7°-19.3°	SE
109	739	1304	19.3°-26.6°	SE
110	925	1520	26.6° or more	Variable
111	1145	1606	5.7°-19.3°	SE
112	1390	1820	19.3°-26.6°	SE
113	1610	2085	19.3°-26.6°	SE
114	1799	2310	26.6° or more	Variable
152	611	1224	5.7°-19.3°	SE
153	980	1561	5.7°-19.3°	SE
154	1180	1820	26.6° or more	Variable
155	1393	1850	5.7°-19.3°	SE
156	1570	2065	5.7°-19.3°	SE
157	1840	2185	5.7°-19.3°	SE
194	431	1062	19.3°-26.6°	SE
196	857	1420	5.7°-19.3°	SE
197	1245	1710	5.7°-19.3°	SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
198	1540	1980	5.7°-19.3°	Variable
199	1749	2085	5.7°-19.3°	Variable
200	1890	2193	5.7°-19.3°	SE
235	98	139	5.7° or less	SE
236	121	200	5.7° or less	SE
237	153	613	5.7°-19.3°	SE
238	414	1088	5.7°-19.3°	SE
239	773	1332	19.3°-26.6°	SE
240	1155	1893	26.6° or more	SE
241	1437	1975	5.7°-19.3°	SE
242	1734	2173	19.3°-26.6°	Variable
243	1945	2268	19.3°-26.6°	Variable
279	123	171	5.7° or less	SE
280	143	441	5.7°-19.3°	SE
281	214	1006	5.7°-19.3°	SE
282	692	1350	19.3°-26.6°	SE
283	1114	1640	26.6° or more	Variable
284	1380	2028	26.6° or more	Variable
285	1670	2212	26.6° or more	Variable
286	1900	2227	5.7°-19.3°	Variable
322	113	318	5.7°-19.3°	SE
323	133	496	5.7°-19.3°	SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
324	180	941	5.7°-19.3°	SE
325	491	1344	5.7°-19.3°	SE
326	1066	1700	19.3°-26.6°	SE
327	1326	1990	26.6° or more	SE
328	1580	2150	19.3°-26.6°	Variable
329	1835	2346	26.6° or more	Variable
330	2120	2350	5.7°-19.3°	S
365	104	146	5.7° or less	SE
366	131	510	5.7°-19.3°	E
367	240	979	26.6° or more	Variable
368	534	1326	26.6° or more	SE
369	950	1675	5.7°-19.3°	SE
370	1415	1969	19.3°-26.6°	SE
371	1625	2170	26.6° or more	Variable
372	1880	2273	26.6° or more	Variable
373	1999	2335	5.7°-19.3°	SE
408	95	199	5.7° or less	SE
409	120	259	5.7°-19.3°	SE
410	161	391	5.7°-19.3°	SE
411	365	1414	26.6° or more	SE
412	851	1708	26.6° or more	Variable
413	1300	2000	26.6° or more	Variable

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
414	1645	2194	26.6° or more	Variable
415	1920	1950	5.7°-19.3°	Variable
416	2090	2320	5.7°-19.3°	Variable
417	2215	2348	5.7°-19.3°	S
452	110	298	5.7°-19.3°	SE
453	128	677	5.7°-19.3°	SE
454	354	1277	26.6° or more	SE
455	849	1751	19.3°-26.6°	Variable
456	1375	2019	26.6° or more	Variable
457	1604	2157	26.6° or more	Variable
458	1816	2228	26.6° or more	Variable
459	2099	2308	5.7°-19.3°	SE
460	2210	2382	5.7°-19.3°	SE
496	118	809	5.7°-19.3°	SE
497	354	1190	26.6° or more	SE
498	695	1630	5.7°-19.3°	SE
499	1320	1899	26.6° or more	SE
500	1670	2156	5.7°-19.3°	Variable
501	1945	2306	5.7°-19.3°	Variable
502	1955	2330	5.7°-19.3°	Variable
503	2059	2414	5.7°-19.3°	Variable
540	319	1238	26.6° or more	SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
541	821	1781	26.6° or more	SE
542	1319	1902	5.7°-19.3°	SE
543	1676	2054	5.7°-19.3°	SE
544	1817	2218	26.6° or more	SE
545	2066	2280	5.7°-19.3°	SE
546	2220	2455	5.7°-19.3°	SE
584	717	1641	26.6° or more	SE
585	1355	1964	26.6° or more	High - left side Low - center
586	1676	2084	26.6° or more	NE - left of center SE - right of center
587	1868	2169	5.7°-19.3°	NE
588	2082	2275	5.7°-19.3°	SSW
589	2188	2332	5.7°-19.3°	SE
627	702	1425	5.7°-19.3°	SE
628	1141	1781	26.6° or more	ENE
629	1524	2068	26.6° or more	SSW - bottom half NE - upper right
630	1788	2167	26.6° or more	SE
631	2003	2181	5.7°-19.3°	Low - right side SE
632	2152	2308	5.7°-19.3°	SE
669	587	1378	19.3°-26.6°	Variable
670	1078	1653	26.6° or more	High - upper right ENE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
671	1219	1745	19.3°-26.6°	SE
672	1449	1922	19.3°-26.6°	SE
673	1748	2129	26.6° or more	SE
674	1888	2218	5.7°-19.3°	SE
712	634	1368	26.6° or more	SE
713	883	1548	26.6° or more	SE
714	1047	1561	26.6° or more	SE
715	1338	1862	26.6° or more	NE High - left side
716	1664	1976	5.7°-19.3°	SE
717	1906	2074	5.7°-19.3°	SE
755	490	1278	26.6° or more	SE
756	694	1377	19.3°-26.6°	SE
757	1271	1638	26.6° or more	SE
758	1362	1736	26.6° or more	SE High - lower left
759	1516	1857	5.7°-19.3°	SE
760	1633	2019	5.7°-19.3°	SE
761	1732	2102	26.6° or more	High - center NE
798	308	972	26.6° or more	SE
799	745	1440	5.7°-19.3°	SE
800	1050	1514	26.6° or more	High - upper left SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
801	1213	1685	26.6° or more	ESE
802	1557	1860	26.6° or more	SE
803	1581	1864	19.3°-26.6°	ESE
804	1799	2048	5.7°-19.3°	SE
841	181	974	26.6° or more	SE
842	667	1284	5.7°-19.3°	SE
843	1048	1440	19.3°-26.6°	SE
844	1318	1651	5.7°-19.3°	SE
845	1399	1782	5.7°-19.3°	SE
846	1612	1872	5.7°-19.3°	SE
884	269	1124	26.6° or more	S
885	473	1227	26.6° or more	SE
886	998	1424	26.6° or more	NE
887	1288	1576	5.7°-19.3°	E
888	1279	1687	26.6° or more	SE
889	1562	1777	5.7°-19.3°	SE
927	224	762	5.7°-19.3°	SE
928	586	1268	26.6° or more	NE
929	908	1351	26.6° or more	SE
930	1130	1541	26.6° or more	Variable
931	1185	1667	19.3°-26.6°	NE
932	1452	1792	19.3°-26.6°	E - SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
933	1509	1904	19.3°-26.6°	E - SE
971	395	1216	19.3°-26.6°	SE
972	590	1249	19.3°-26.6°	SE
973	860	1210	5.7°-19.3°	SE
974	1019	1363	26.6° or more	E - SE
975	1217	1594	5.7°-19.3°	High - left half SE
976	1325	1819	5.7°-19.3°	High - right half SE
<u>NJ 18-8</u>				
41	130	208	5.7° or less	SE
129	195	551	5.7°-19.3°	SE
216	534	1220	26.6° or more	SE
217	644	1274	19.3°-26.6°	SSW
260	723	1302	26.6° or more	SE
261	1089	1464	19.3°-26.6°	SE
304	836	1296	19.3°-26.6°	SE
305	939	1500	19.3°-26.6°	NE High - left side
347	966	1281	19.3°-26.6°	SE
348	1089	1452	19.3°-26.6°	SE
<u>NJ 18-9</u>				
2	323	1132	26.6° or more	SE

Table 3.--Individual Block Slope Gradient Characteristics--Continued

Block No.	Water Depth (meters) Min	Max	Slope: Maximum Slope Angle Range	Average Slope Direction
3	724	1353	26.6° or more	SE
4	1010	1572	26.6° or more	E - SE
5	1027	1650	5.7°-19.3°	SSW
6	1050	1468	5.7°-19.3°	SE
45	239	987	5.7°-19.3°	SE
46	685	1349	26.6° or more	SE
47	1071	1514	19.3°-26.6°	E - SE
48	1090	1554	26.6° or more	SE
49	1510	1759	19.3°-26.6°	SE
50	1379	1791	5.7°-19.3°	SW
89	405	1104	26.6° or more	E - SE NE - upper right corner
90	840	1459	26.6° or more	NE
91	1159	1599	26.6° or more	SE
92	1433	1742	5.7°-19.3°	SE
93	1452	1772	5.7°-19.3°	SE
133	750	1374	26.6° or more	SSE
134	953	1519	19.3°-26.6°	SSE
135	1101	1570	19.3°-26.6°	NE - upper right corner E - SE
136	1347	1782	19.3°-26.6°	ENE
177	819	1575	19.3°-26.6°	NE
178	1100	1733	19.3°-26.6°	SE