Wed Mar 23 10:11:51 EST 1994

GEOLOGIC FEATURES OF THE SEA BOTTOM AROUND A MUNICIPAL SLUDGE DUMPSITE NEAR 39ON, 73OW, OFFSHORE NEW JERSEY AND NEW YORK

U.S. Geological Survey Open-file Report 94-152

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URL: _http://bramble.er.usgs.gov/epubs/dwdrep1/index.html_

Initial Note for paper-format Open-file Report:

This Open-file Report in paper format is intended as a "voucher copy" of a presentation transmitted over the Internet computer network using the World Wide Web (WWW) protocol. It is intended to be viewed and read on a computer screen using WWW "browser" application programs such as ncsa-mosaic. It can also be downloaded and printed at remote sites. There is a slightly briefer article containing most of the information of this internet article that will be published with other papers presented at the NOAA-USGS 1993 Symposium on the U.S. Exclusive Economic Zone (EEZ), Reston VA, 2-4 November 1993.

This report, including illustrations, will be made available on the internet using an http (hypertext transfer protocol) server on a computer in the offices of the US Geological Survey, Branch of Atlantic Marine Geology, in Woods Hole, Massachusets. The server's WWW address, or URL (Universal Resource Locator), is http://bramble.er.usgs.gov. There are 14 text files (in html format) and 36 image files (in gif format). The reader must have a graphics-capable computer with a high-speed connection to the Internet, and a WWW browser program such as Mosaic. Mosaic is an application program which requests, receives, and displays computer-served information that includes graphic images. The report, or other WWW-served material on the Internet, can also be viewed, less conveniently, using the public-domain programs www or lynx.

The strength of internet communication is currency and quickness of access, combined with display of images. Other presentations will soon include scientific visualisations in multimedia displays of 3-dimensional images, animations, sounds, and so forth, some even controllable by the reader. While this report is unimaginative in content, it's an experiment in preparing presentations for the WWW and in using the Internet system.

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INTRODUCTORY COMMENT: (for computer viewers)
Intended particularly for newcomers to the World Wide Web

This is an experimental effort to produce a geologic paper over the Internet using the World-Wide-Web. It represents work in progress in the study of an offshore dump site, and is derived primarily from a poster display at a NOAA-USGS Symposium on the U. S. Exclusive Economic Zone (EEZ) in Reston, VA, 2-4 November 1993. A shorter, conventional paper version of this presentation will be published in the Symposium volume. For Open-file release, paper copies of this text and the figures are available through the USGS Open-file Services Section, in Reston, VA.

The presentation For the Internet has been prepared using NCSA's (National Center for Supercomputing Applications, at the University of Illinois -- Urbana-Champaign) xmosaic and John Bradley's xv programs, and is served by ncsa-httpd. It can also be viewed, less conveniently, using other public-domain programs such as www or lynx.

Using xmosaic or equivalent World-Wide-Web browsers, the reader can follow various hypertext paths for explanations and images. I haven't been very imaginative to create labrynthine threads of sidebars here, and I think it's straightforward. To look at text explanations click on the highlighted text. To return to where you were use the xmosaic "Back" button. Clicking on a highlighted reference will cause a jump to its position in the REFEFERENCES CITED file; again, use the "Back" button to return to the main text.

I have broken the text into its several files by section because short files transmit more conveniently. Transmission and display quickness is affected mostly by the image-files that have to be transported. In most places I use "thumbnail" images that you can click on to get the full-size image. It's a trade-off: the thumbnails come across the net much faster. In some cases I felt the in-text illustrations would be better bigger rather than tiny, thus to avoid need for immediate full-size retrieval, although the full-size illustrations remain accessible at the reader's choice.

Please keep in mind that in this medium there is no control of the readers' client capabilities. That is, what You see is created by Your machine. My files contain text and gif images; your machine supplies the fonts and the image viewer. There is no control by the author (or server) of fonts and font sizes or colors that the far-off viewer sees on his/her screen apart from some general classes provided by the web and html protocols. Similarly, the images will be better or worse for your viewing screen and viewing software. Quickness of the display process depends on the viewers' swap space and memory as well as on the "network bandwidth".

Incidentally, the html (hypertext markup language) that is this document's vehicle does not at this time have notation for degree symbols (or superscripts or subscripts)(or I haven't been able to unearth such a notation that works), so degree symbols in the titles and text do not display correctly. Do not let minor irritation deter your enthusiasm for the World-Wide-Web, however. Features of the developing system are being improved and expanded by many workers, worldwide, even as you read.

Please send your comments to my e-mail address, below. Now click on "BACK" to continue.

Jim Robb 24 Feb 1994
jrobb@nobska.er.usgs.gov [IMAGE: JR in Alvin]

INTRODUCTORY COMMENT: PLEASE CLICK HERE!

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code.

ABSTRACT

[IMAGE: 1] The sea-floor of a dumpsite area offshore New York and New Jersey (Deep-water dumpsite 106) was studied using detailed bathymetry, sidescan-sonar images, subbottom profiles, bottom photographs, and bottom-sediment samples. These data show that this continental rise area contains deposits of submarine landslides and pathways of sediment gravity flows. Images of the sea floor obtained with a deep-towed high-resolution sidescan sonar system show offshore-trending furrowed surfaces over parts of the area. If such furrows are old, one might expect them to have been obliterated by sediment resuspension and redeposition due to the mostly gentle contour-parallel bottom currents that are measured in the present day. While most of the sea-floor features were probably formed during Pleistocene or early Holocene (glacial or early post-glacial) times, our information suggests that vigorous present-day episodes of offshore-directed transport may continue to occur, at unknown intervals.

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INTRODUCTION

An area of the sea floor south of Hudson Canyon off New Jersey was mapped as part of a study to determine the effects of offshore dumping of municipal sewage sludge on the sea bottom. The dump site for municipal sludge lies within a large area of continental slope and continental rise that has been used for offshore dumping since the 1950's. The area is called Deep Water Dumpsite 106, because the original site lay approximately 106 miles offshore. [IMAGE: 1]

An Index Map showing the continental margin off the mid-Atlantic Coast of the U.S. Areas of the following GLORIA mosaic illustration and the site-mapping studies are outlined as rectangles; an area mapped using Sea Beam bathymetry is shown as an irregular polygon; and the most recent sludge dumpsite area is outlined as a smaller north-south rectangle.

Previous stratigraphic investigations of this offshore region using data from boreholes and seismic profiles show that sequences of continental rise sediments lap onto eroded, slightly seaward-dipping strata of the lower continental slope. [IMAGE: 2]

Airgun seismic-reflection profile across the central part of the study area. Nearly flat continental-rise sediments of Neogene age lap onto an unconformity on seaward-dipping Eocene strata of the continental slope.

Brecciated rocks and exotic sediments that are found in borehole samples, and faults and chaotic and distorted seismic facies that are revealed in profiles show that submarine landsliding has been the principal agent of deposition on the upper rise during the Cenozoic (Poag and Mountain, 1987).

Previous environmental geologic studies of the dumpsite area include those of Neiheisel (1979, 1983), who investigated geochemical and physical parameters of surface sediment samples. Hanselman and Ryan (1983), and Rawson and Ryan (1983) reported bottom observations from the deep sea research vessel (DSRV) Alvin. Ryan and Farre (1983) discussed geologic processes in the dumpsite area and inferred that both mass wasting and turbidity currents have been active and may presently be active within this area. Pratson and Laine (1989), mapped the surficial character of the sea bottom using 3.5-kHz echo-sounding profiles.

To study the geologic context and processes of this submarine dumpsite and to provide information for choosing appropriate sample sites where fine-grained material might be more likely to accumulate, the sea-floor of the dumpsite area was mapped using multibeam bathymetry, sidescan-sonar images, subbottom profiles, bottom photographs and video, and bottom-sediment samples.

ACKNOWLEDGEMENTS

Fred Grassle of Rutgers University organized the program to study the benthic environment of the deep-water dumpsite region near 39o N, 72o W, of which this investigation is one part. I thank the officers and crews of RV Atlantis II, Rv Oceanus, and RV Betty Chouest, the Alvin group and the Deep Submergence Laboratory of the Woods Hole Oceanographic Institution, and the Sea Beam processing group of the Graduate School of Oceanography, University of Rhode Island; Joyce Miller shepherded the collection and processing of the Sea Beam bathymetric data aboard Atlantis II. This research was funded by the National Undersea Research Program (NURP) of the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS).

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DATA AND METHODS

A bathymetric map made from data acquired aboard the RV Atlantis II in 1989 using a Sea Beam multibeam echos-sounding system was combined with a an image of part of the U.S. East Coast GLORIA mosaic (EEZ-SCAN 87 Scientific Staff, 1991).

[IMAGE: 3]
Bathymetric contours. Sea-Beam soundings gridded to 125-m interval and contoured at sea aboard RV Atlantis II, during September, 1989. Depressions are shaded.

In addition, visual observations, photographs, video recordings, and sediment samples were made during DSRV Alvin dives and a Jason transect (RV Atlantis II, 1989, RV Betty Chouest, 1991) (Jason is a deep-sea remotely operated vehicle). Higher resolution sidescan-sonar observations were made near the central part of the dumpsite area (RV Betty Chouest, 1991, and RV Oceanus 251, 1992), using a deep-towed 120 kHz system.

Navigation for the data-acquisition cruises relied primarily on Loran-C supported by fixes from the satellite-based Global Positioning System (GPS). The fix-accuracy was closer than 100 m and allowed the data sets to be overlaid precisely on one another.

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DISCLAIMER

The use of trade, product, industry, or firm names in this report is for descriptive purposes only, and does not constitute endorsement by the U.S. Government.

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Bathymetric map

Bathymetry of the dumpsite region was mapped aboard RV Atlantis II during September, 1989, by using a Sea Beam multibeam echo-sounding system and computer software developed by the University of Rhode Island (Davis and others, 1986; Tyce, 1986). The map depicts 1750 km2 of the sea floor at a 10-m contour interval. The Sea Beam system uses 16 acoustic beams to measure water depths in a swath across the ship's track. Each beam is shaped by using two sets of hull-mounted transducers (one set mounted along the keel and another athwartship), and insonifies a 2.66 degree ellipse. The beams are corrected for pitch and roll so the swath of measured depths lies directly below the ship. The length of the acoustic pulse and the frequency of digitization limit the resolution of the range measurements to about 2.5 m. The maximum width of the swath mapped by the system corresponds to 73 percent of the water depth. Many individual echo soundings in swaths along the survey-ship's track are compiled and, in this case, were gridded into 125-m cells for contouring. [IMAGE: 3]

The trackline direction of this survey was primarily north-south. A textural effect of north-south banding and apparent low scarps can be seen in the computer-produced contour map at some places on the low slopes of the continental rise, due to small discrepancies from line to line in the gridded depths. Note that these artifacts are less apparent and show more clearly as locally noisy spots in the three-dimensional perspective illustration of the data. [IMAGE: 4]

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GLORIA: imagery and interpretation.

The Deep-Water-Dumpsite-106 region was part of the east-coast U. S. Exclusive Economic Zone that was surveyed in 1987 aboard Research Vessel (RV) Farnella, by the USGS in cooperation with the Institute of Oceanographic Science of the United Kingdom, to create a mosaic of GLORIA sidescan-sonar images (EEZ-SCAN 87 Scientific Staff, 1991).

The GLORIA is a long-range, wide-swath sidescan sonar system for use in deep oceanic waters greater than 200 m. GLORIA is an acronym derived from "Geologic LOng-Range Inclined Asdic". The GLORIA sensing instrument is towed about 50 meters (m) below the sea surface (Somers and others, 1978). Its 6.5-kiloHertz (kHz) signals are returned from bottom features that can be as far as 22 kilometers (km) to either side of the ship's track; in this part of the survey a 25-km track spacing was employed to ensure full coverage of high quality data. The data were digitally processed and compiled to produce the geometrically corrected and geographically mapped mosaic of the sea bottom (EEZ-SCAN 87 Scientific Staff, 1991). [IMAGE: 5]

While the acoustic images of the sea floor are correctly located on the mosaic maps, they are not aerial photographs, and they retain peculiarities common to sidescan-sonar data that interpreters must keep in mind. The northeast-trending gray stripes on this mosaic show the location of the ship's tracks; they are caused by the signals that return from a band too close below the ship to give a good side-looking view. Light areas on the GLORIA images are strong acoustic return signals, caused by bottom topography (reflections from places where the bottom surface slopes toward the receiver) and by various characteristics of the top several meters of sediment (backscatter) (Johnson and Helferty, 1990; Gardner and others, 1991). Some care must be taken because, in places, a change in image tone is an artifact of the assembly process, where data from adjacent tracks were juxtaposed in order to create the mosaic.

The appearance of topographic features depends on the look-direction of sidescan-sonar data. The bottom of a canyon can be obscured by acoustic shadow, or the top of a slope perceived by a change in image tone may not correspond to a topographic crest or break. Comparing the acoustic signature, or appearance, of the sea floor as it is seen in 3.5-kHz echo-sounding profiles or other seismic-reflection profiles to the GLORIA images helps to determine to what degree the images show topographic features or bottom sediment characteristics.

A small part of the USGS mosaic of the East Coast EEZ in the dumpsite area was magnified for comparison with the bathymetric data by increasing the pixel size, so there is no added detail in the larger scale image. All GLORIA images presented here have been processed into uniform square pixels 50 m on a side, and bottom features can be identified only if they are several times that size.

[IMAGE: 6] [IMAGE: 7] [IMAGE: 8]

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ASDIC is a British acronym for "Anti-Submarine Detection and Investigation Committee", an early WWII governmental body. A product of that committee's deliberations were techniques for acoustic ranging and direction finding to underwater objects. So those techniques and machinery became known cryptically as ASDIC. In the U. S. the word for these things became SONAR. SONAR, the U.S. word for asdic-related devices, stands for "SOund NAvigation Ranging".

DESCRIPTION OF THE SEA FLOOR

A regional view of the continental slope and rise off the northeastern U.S. depicted by the GLORIA survey (EEZ-SCAN 87 Scientific Staff, 1991) shows that, in comparison with neighboring areas to the northeast and southwest, the dumpsite area is not traversed by major submarine channels. To the northeast lies Hudson Canyon, the largest canyon of the U.S. east coast continental slope, and its well defined meandering channel on the continental rise. To the southwest the continental slope is intricately dissected by a number of canyons and valleys which feed into a complex system of channels and less well-defined, probably debris-choked, flow pathways on the rise.

[IMAGE: 5]

GLORIA sidescan-sonar mosaic of slope and rise off the mid-Atlantic coast of the U.S. shows the study area in relation to features of neighboring areas of the sea floor Bathymetric contours at 200, 1000, 2000, and 3000 meters. The areas of site study, Sea Beam bathymetry, and municipal sludge dumpsite are outlined.

Overlying the GLORIA images of the dumpsite area with the Sea Beam bathymetric contours shows a subdued but complex surface of the continental rise in the dumpsite area.

[IMAGE: 6] [IMAGE: 7] [IMAGE: 8]

Center: Composite illustration of GLORIA imagery and bathymetric contours of the dumpsite study area. The central part of this area was mapped using Sea Beam data, and is shown using a 10-m contour interval; contours of the peripheral area, at a 100-m interval, from Escowitz and others (1988); of the northeastern part, kindly provided by A. Shor). Note the congruence of the GLORIA backscatter pattern and the bathymetric contours. Central dark colored deposit separates lower areas, which finer scale imaging (below) shows to be furrowed.

Left image: GLORIA imagery of study area without overlay.

Right image: Contour lines and location of deep-towed 120-kHz sidescan-sonar imagery. Rectangle shows location of data illustrated below.

While the adjacent continental slope, to landward, has an average declivity of about 3.5o, the average declivity of the continental rise is about 0.45o, changing from about 1.9o in the uppermost part near the continental slope to about 0.29o in the seaward part of the study area. There is an intermittant trough at the base of the continental slope along a band of sedimentary mounds on the upper continental rise (see A on the perspective diagram below).

[IMAGE: 4]

Perspective image of Sea Beam bathymetric data set. View from southwest, looking northeast, across upper rise. Lower part of continental slope on upper left. Brightness of each grid cell in this image is varied with respect to a vertical sun angle and the viewer's position. Note the terrace or trough at the base of the continental slope (A), the slope-parallel wrinkles(?) (B), an area of probable slide deformation on the upper rise (C), and depressions (D). Slight north-south bands of noise show where data swaths abut. Image courtesy of Robert C. Tyce, University of Rhode Island.

There are hillocks and depressions having relief of 20-30 m on the rise surface, especially in the southern part of the mapped area. Continuous, well-defined channels are absent on the rise in the dumpsite area. Instead, broad flat low areas that are generally distinguished on the GLORIA images as high backscatter regions extend seaward from the debouchment of continental slope canyons or chute-like valleys.

Subbottom profiles show faulting and displacement of subsurface strata on the rise near the base of the slope as well as fracture and tilting of tabular blocks of surficial sediments; uneven sea-floor surfaces are observed at greater distances offshore, implying that blocky debris traveled long distances. [IMAGE: 9]

Above: Airgun seismic-reflection profile along upper continental rise near base of slope shows strata of uppermost rise, slump structures, and faults. Labeled scarp is shown in higher resolution profile below.

[IMAGE: 10]

Above: High-resolution 3.5-kHz subbottom profile shows faulting and tilting of surficial acoustically laminated strata on upper rise; graben created by slumping of upper rise sediments. Labeled scarp is crossed by airgun profile above.

In places acoustic profiles show subsurface reflecting surfaces that are truncated at the sea floor. In other places there are smooth and nearly acoustically transparent mud-flow(?) deposits or deposits of blocky debris.

[IMAGE: 11]

High-resolution 3.5-kHz subbottom profile across the seaward part of study area on upper continental rise. Arrow marks transition between area of smooth surface to the northeast, and rough, acoustically impenetrable surface, probably of blocky debris-flow deposits to the southwest.

Boulders derived from mass wasting of the continental slope are widely distributed on the surface of the continental rise. They were observed during a number of Alvin dives off the New York Bight (Hanselman and Ryan, 1983; Rawson and Ryan, 1983; Ryan and Farre, 1983). A boulder sampled during Alvin dive 2163 (1989) was identified to be of middle Eocene age (C. W. Poag, personal commun., 1990). Many boulders, commonly meters in diameter, which visually resemble the Eocene mudstone, were observed on the continental rise 12 to 45 km from the base of the slope.

[IMAGE: 12] [IMAGE: 13]

Boulders observed during dives of RV Alvin in 1989. Boulders are about 2 m in diameter. A (left). Dive 2163, water depth about 2485 m; B (right). Dive 2165, water depth about 2405 m.

Smaller fragments (&gt10 cm in diameter) of semiconsolidated Eocene mudstone were recovered from benthic trawls on the upper continental rise as far as 11 km from the base of the slope. Fields of tens of boulders were observed with a short-range sonar system used by Alvin during dive 2165. Some boulders on the rise are associated with channels, where they may have been transported by turbidity currents or debris flows. Boulders observed during Alvin dives 2162, 2164, and 2165 near the sludge-dump area are not associated with channels. The 120-kHz sidescan-sonar surveys revealed offshore-trending ridges and furrows commonly associated with boulder-like targets, in the regions of high backscatter on the GLORIA mosaic, near the central part of the dumpsite area (Robb, 1991).

[IMAGE: 8] [IMAGE: 14] [IMAGE: 15]

Left: 120-kHz Sidescan-sonar tracklines (vehicle tracks) in relation to bathymetry. Rectangle locates next image.

Center: Mosaicked images over furrowed bottom area; 10-m contour interval. Closed-contours show depression (upper right quadrant: 2500-m contour identified) and the neighboring, downrise, elliptical high (near upper center of image). Rectangle locates the swath shown in the next image.

Right: A single swath of AMS-120 sidescan-sonar imagery, 900 m wide x 3300 m long. See location to left.

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DISCUSSION

In the dumpsite area, the irregularity of the sea bottom, characterized by surficial boulders, hills, hillocks, depressions, and faulted sedimentary strata, is similar to submarine landslide deposits off Hawaii (Lipman and others, 1988), parts of submarine debris flows (Prior and others, 1984), and to deposits created by subaerial debris avalanches (Siebert, 1984; Francis and Wells, 1988). This area shows a complex geologic history of localized events requiring closely-spaced profiles and images to outline the separate units.

The perspective view of the Sea Beam bathymetry data shows the trough along the base of the slope (A) and the lobate, mounded deposits to seaward of it on the uppermost rise (compare the seabeam bathymetric map).

[IMAGE: 4] [IMAGE: 3]

The origin of the slope-base trough is not well understood. Similar slope-base morphology is found along the northeast U.S. continental slope (Dennis O'Leary, personal commun., 1989). In places it appears to be formed by a reverse slope behind blocky landslide deposits which slid from the continental slope. In other places, surface strata of the rise appear to be truncated by the slope-base trough, and the trough may be an erosional feature, created by downslope-traveling flows at the change in slope (Ryan and Farre, 1981, Farre and Ryan, 1987). Its continuity along the slope base and across inter-canyon areas gives it a different character from subaerial avalanche impact pools, which are small circular pools not uncommonly found at the base of avalanche chutes along mountain fronts (Corner, 1980), and from depressions at the mouths of submarine canyons off Malta described by Biju-Duval and others, (1983). Many seismic profiles in this area and to the southwest show older (buried) trough and mound morphology at the slope base (Robb, 1986) that imply a repetetive or long-term process.

[IMAGE: 2]

This profile shows back-tilted blocks at the base of the slope on the rise and several truncated horizons in older, buried base-of-slope troughs or blocks within the onlapping rise strata.

The local highs on the rise may be displaced blocks of sediment that moved as a unit. The deepest depression in the study area, of greater than 50 m relief, associated with a high near 38o55'N, 72o08'W, may be a pull-apart gap at a displaced block. A line of shallow depressions, of less than 20 m relief, along the 2630-m contour (D on perspective illustration [4], and depression symbols on contour map [3]) may represent local non-deposition, refugia from sedimentation, where debris-flow deposition coalesced on a deeper part of the gently sloping rise surface, leaving the closed-contour lows.

The broad lows extending seaward from slope canyons or valleys that have high-backscatter sidescan-sonar characteristics (showing fine-scale roughness of the sea bottom; evidenced by 120-kHz sonar images) were interpreted from their 3.5-kHz signature (prolonged echo with absent or discontinuous subbottom reflections) to be underlain by turbidites by Pratson and Laine (1989). The offshore-trending furrows observed by the 120 kHz deep-towed system may have been formed by passage of sediment gravity flows that appear unchannelized to less resolved observation. Alternatively, those features may be longitudinal furrows such as are commonly observed on large landslide surfaces.

A "visual analog" [IMAGE: 16] [IMAGE: 17] .

Note the surface features of the Blackhawk landslide in California. Closer view to right. From Thornbury (1954).

In either case, the sidescan-sonar data and 3.5-kHz sub-bottom profiles show that the furrowed suface is covered in places by subsequent deposition. The low-backscatter tongue-like feature on the GLORIA images is shown by 3.5 kHz profiles to coincide with a surficial mud flow described above and by the 120 kHz sidescan sonar data to have a smooth surface. It is possible that both of these features were produced during a single slide episode.

If landslides or sediment gravity flows that are competent to transport boulder-sized rock clasts occur in the present-day, they would bury, or resuspend, remove, and redistribute waste dumps or structures of interest to man. The boulders on the rise have rounded forms and weathered surfaces which suggest they may be old in their present locations. On the other hand, drums of radioactive wastes that were dumped as recently as the 1950s appear to be half buried in the sediment surface like most of the boulders (Ryan and Farre, 1983), and some of the boulders appear to be on the surface. So the question of when the boulders arrived remains open to examination. Similarly not known are when (or how) the offshore-trending furrows and ridges observed by deep-towed sidescan sonar were created, or when the overlying, later debris flow deposit was emplaced.

The major morphology of this submarine landscape may be of Pleistocene origin, presumably linked to low sea levels, greater sediment input and generation of turbidity currents at a shoreline near the shelf edge, and consequent erosion and slumping on the continental slope. The GLORIA mosaic of the entire East Coast continental rise shows features predominantly caused by offshore-directed sediment transportation, either by mass-movement (landslide) or sediment gravity flow. There is little evidence in the sea-floor morphology of the mostly low-velocity boundary currents measured by bottom current meters in the present day (Fry and Butman, 1991).

An apparent discrepancy between geomorphologic evidence for offshore-directed transport and the measured present-day low-velocity contour-parallel currents is probably due to a short-term observational window of the current measurements. The present-day regime of dominantly contour-parallel currents has been present for less than 25,000 years. Although the meter-thick covering of recent sediments that those currents have moved about on the sea floor has not concealed the larger features that survive from a more active past environment, it might be expected to have filled and smoothed the microfeatures. Further investigation is required to distinguish and measure the frequency and geologic impact of events that occur episodically and that can be significant and dangerous to man's use of the sea floor.

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CONCLUSIONS

Mounded sediment deposits at the base of the continental slope, the faults and blocky strata observed in seismic reflection profiles, and the irregular surface morphology of the continental rise, with hills and hillocks, small mounds, boulders and depressions, all can be attributed to submarine landslides that originated on the continental slope. Many separate events or episodes of deposition have taken place, recorded by surface sediments and morphology. Material has been transported across the upper rise by sediment gravity flows through broad low regions. However, the frequency and intensity of the processes that emplaced the present surface deposits, and the causes and triggering mechanisms of mass movements remain to be determined. Whereas variable thickness and faulting in the subsurface strata at the base of the slope show that localized deposition by episodic mass movement and subsequent slumping has been an ongoing process of upper-rise formation, the more current question is how active the region has been historically, post Pleistocene, and what activity is likely to occur in the future.

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REFERENCES CITED

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Geologic Features of the Sea Bottom Around a Municipal Sludge Dumpsite near 39oN, 73oW, Offshore New Jersey and New York: U.S. Geological Survey Open-file Report 94-152

ILLUSTRATION AND CAPTIONS SUMMARY

[IMAGE: 1]

An Index Map showing the continental margin off the mid-Atlantic Coast of the U.S. Areas of the following GLORIA mosaic illustration and the site-mapping studies are outlined as rectangles; an area mapped using Sea Beam bathymetry is shown as an irregular polygon; and the most recent sludge dumpsite area is outlined as a smaller north-south rectangle.

[IMAGE: 2]

Airgun seismic-reflection profile across the central part of the study area. Nearly flat continental-rise sediments of Neogene age lap onto an unconformity on seaward-dipping Eocene strata of the continental slope. This profile shows back-tilted blocks at the base of the slope on the rise and several truncated horizons in older, buried base-of-slope troughs or blocks within the onlapping rise strata.

[IMAGE: 3]

Bathymetric contours. Sea-Beam soundings gridded to 125-m interval and contoured at sea aboard RV Atlantis II, during September, 1989. Depressions are shaded.

[IMAGE: 4]

Perspective image of Sea Beam bathymetric data set. View from southwest, looking northeast, across upper rise. Lower part of continental slope on upper left. Brightness of each grid cell in this image is varied with respect to a vertical sun angle and the viewer's position. Note the terrace or trough at the base of the continental slope (A), the slope-parallel wrinkles(?) (B), an area of probable slide deformation on the upper rise (C), and depressions (D). Slight north-south bands of noise show where data swaths abut. Image courtesy of Robert C. Tyce, University of Rhode Island.

[IMAGE: 5]

GLORIA sidescan-sonar mosaic of slope and rise off the mid-Atlantic coast of the U.S. shows the study area in relation to features of neighboring areas of the sea floor Bathymetric contours at 200, 1000, 2000, and 3000 meters. The areas of site study, Sea Beam bathymetry, and municipal sludge dumpsite are outlined.

[IMAGE: 6] [IMAGE: 7] [IMAGE: 8]

Center: Composite illustration of GLORIA imagery and bathymetric contours of the dumpsite study area. The central part of this area was mapped using Sea Beam data, and is shown using a 10-m contour interval; contours of the peripheral area, at a 100-m interval, from Escowitz and others (1988); of the northeastern part, kindly provided by A. Shor). Note the congruence of the GLORIA backscatter pattern and the bathymetric contours. Central dark colored deposit separates lower areas, which finer scale imaging (below) shows to be furrowed. Left image: GLORIA imagery of study area without overlay. Right image: Contour lines and location of deep-towed 120-kHz sidescan-sonar imagery. Rectangle shows location of data illustrated below.

[IMAGE: 9]

Airgun seismic-reflection profile along upper continental rise near base of slope shows strata of uppermost rise, slump structures, and faults. Labeled scarp is shown in higher resolution profile below.

[IMAGE: 10]

High-resolution 3.5-kHz subbottom profile shows faulting and tilting of surficial acoustically laminated strata on upper rise; graben created by slumping of upper rise sediments. Labeled scarp is crossed by airgun profile above.

[IMAGE: 11]

High-resolution 3.5-kHz subbottom profile across the seaward part of study area on upper continental rise. Arrow marks transition between area of smooth surface to the northeast, and rough, acoustically impenetrable surface, probably of blocky debris-flow deposits to the southwest. This 3.5-kHz profile shows deposit overlying surface that is seen (elsewhere) to be furrowed.

[IMAGE: 12] [IMAGE: 13]

Boulders observed during dives of RV Alvin in 1989. Boulders are about 2 m in diameter. A (left). Dive 2163, water depth about 2485 m; B (right). Dive 2165, water depth about 2405 m.

[IMAGE: 8] [IMAGE: 14] [IMAGE: 15]

Left: 120-kHz Sidescan-sonar tracklines (vehicle tracks) in relation to bathymetry. Rectangle locates next image.

Center: Mosaicked images over furrowed bottom area; 10-m contour interval. Closed-contours show depression (upper right quadrant: 2500-m contour identified) and the neighboring, downrise, elliptical high (near upper center of image). Rectangle locates the swath shown in the next image.

Right: A single swath of AMS-120 sidescan-sonar imagery, 900 m wide x 3300 m long. See location to left.

A "visual analog" [IMAGE: 16] [IMAGE: 17]

Note the surface features of the Blackhawk landslide in California. Closer view on right. Photographs from Thornbury (1954).

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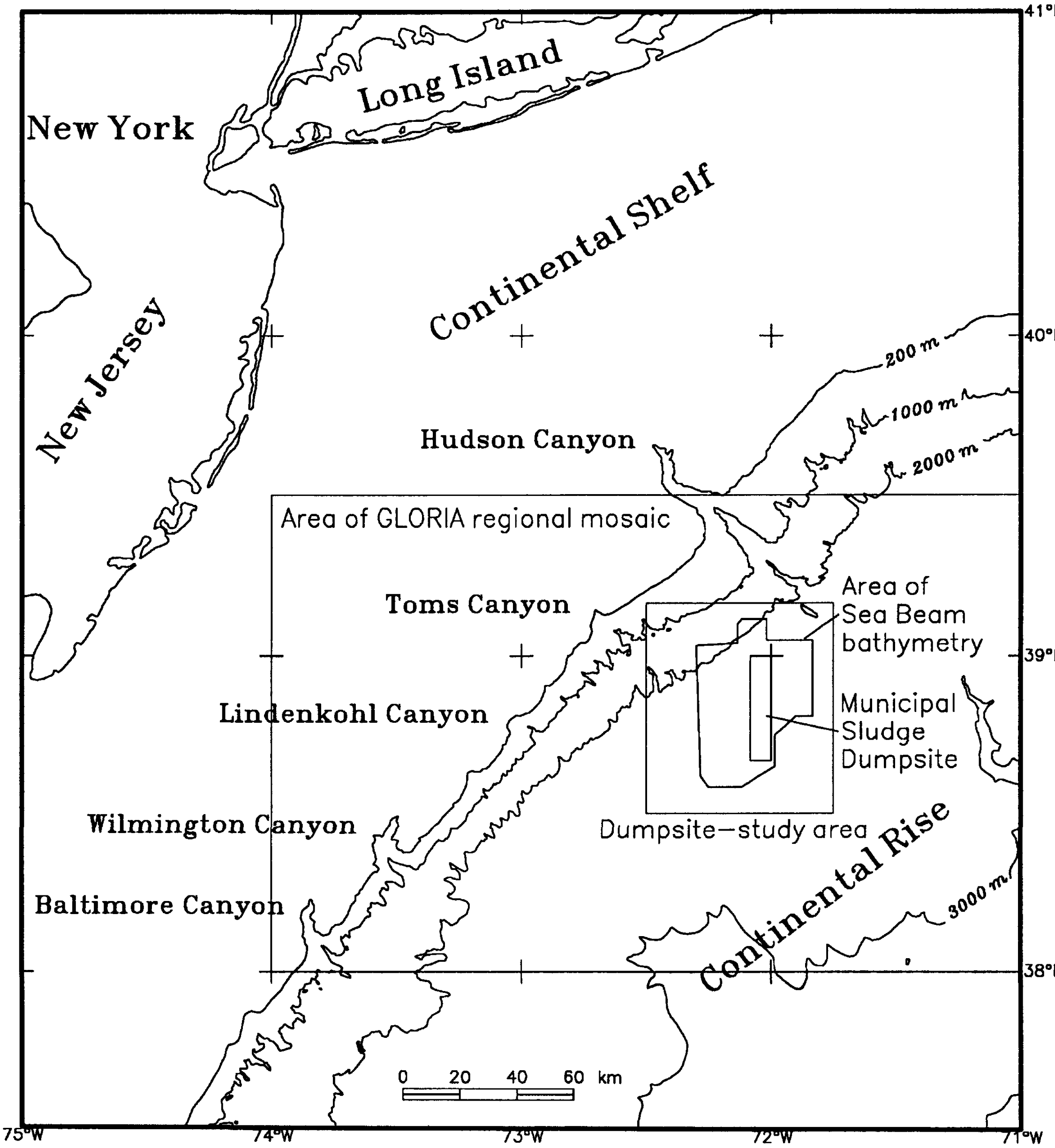
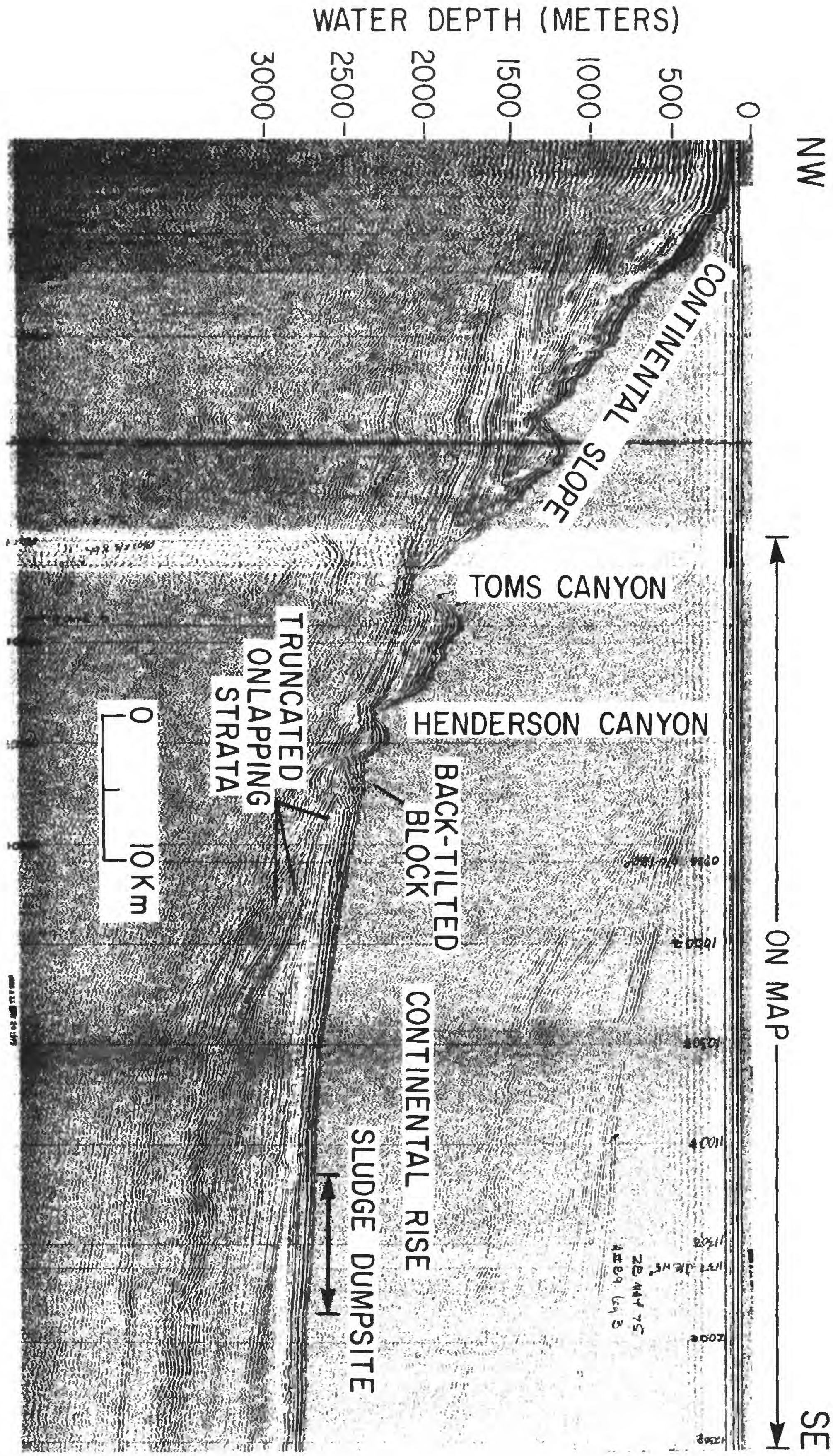
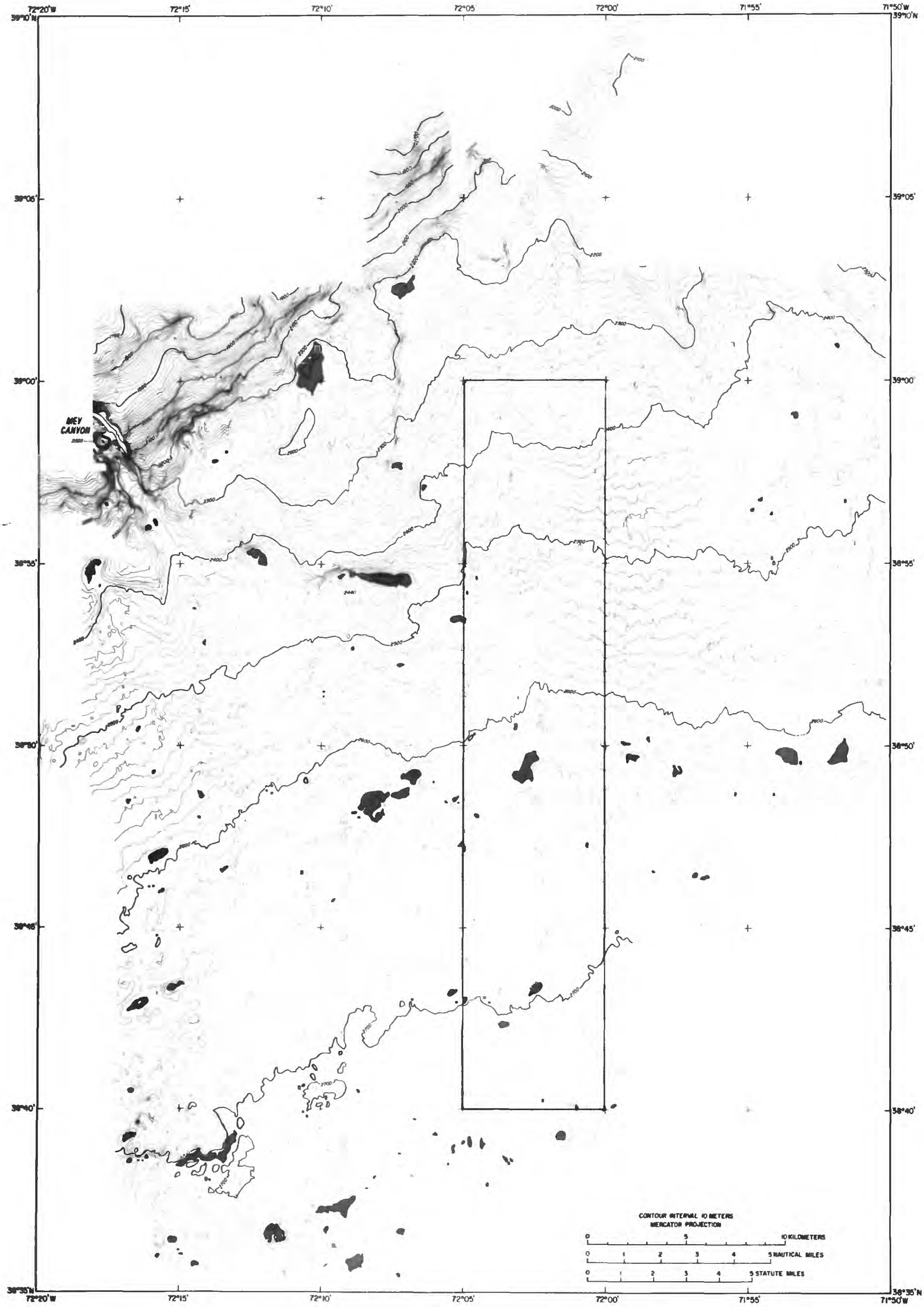
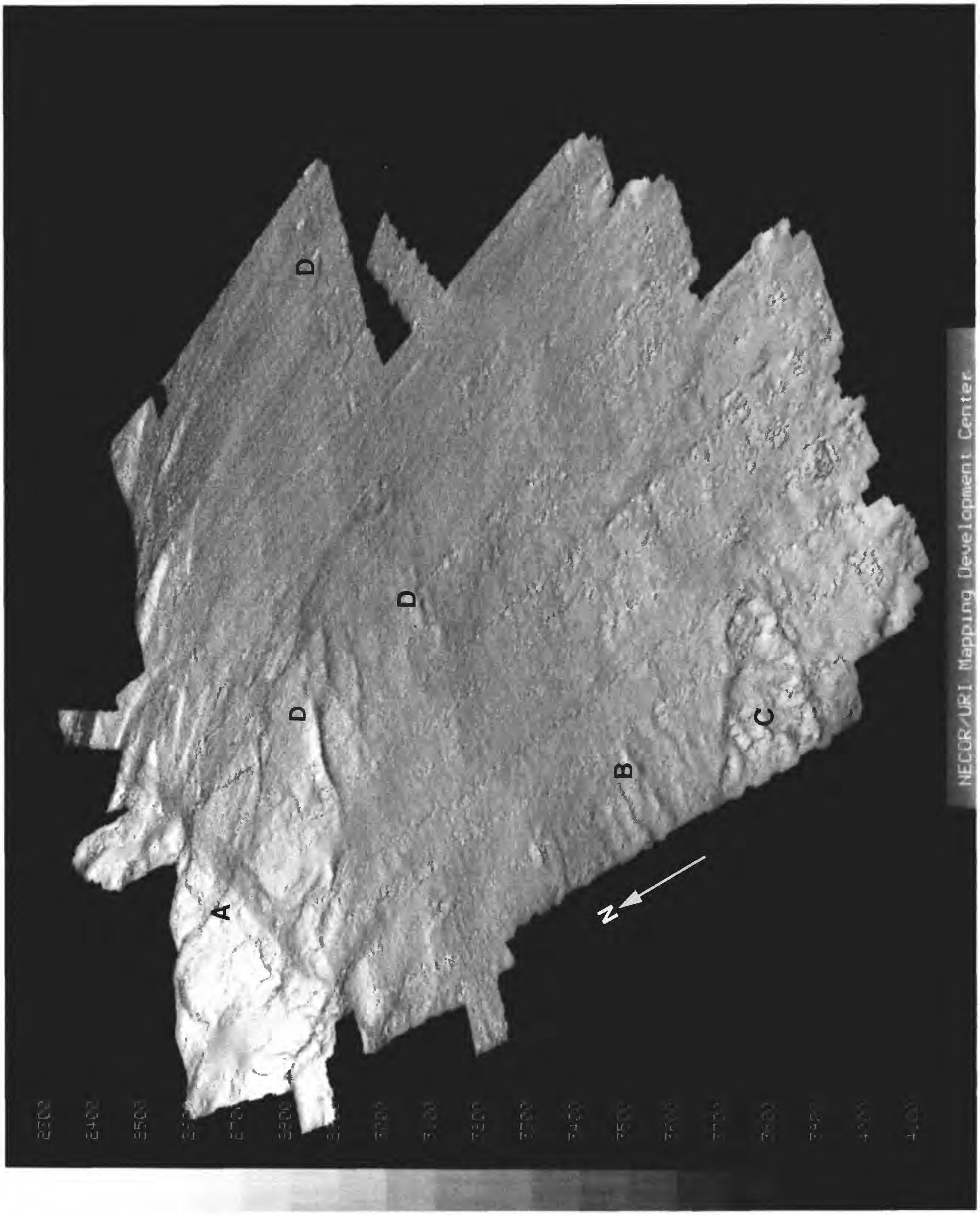

41°N
Long Island
New York
Continental Shelf
New Jersey
40°N
200 m
1000 m
2000 m
Hudson Canyon
Area of GLORIA regional mosaic
Toms Canyon
Area of Sea Beam bathymetry
39°N
Lindenkohl Canyon
Municipal Sludge Dumpsite
Wilmington Canyon
Dumpsite—study area
Continental Rise
Baltimore Canyon
3000 m
38°N
0 20 40 60 km
75°W
74°W
73°W
72°W
71°W

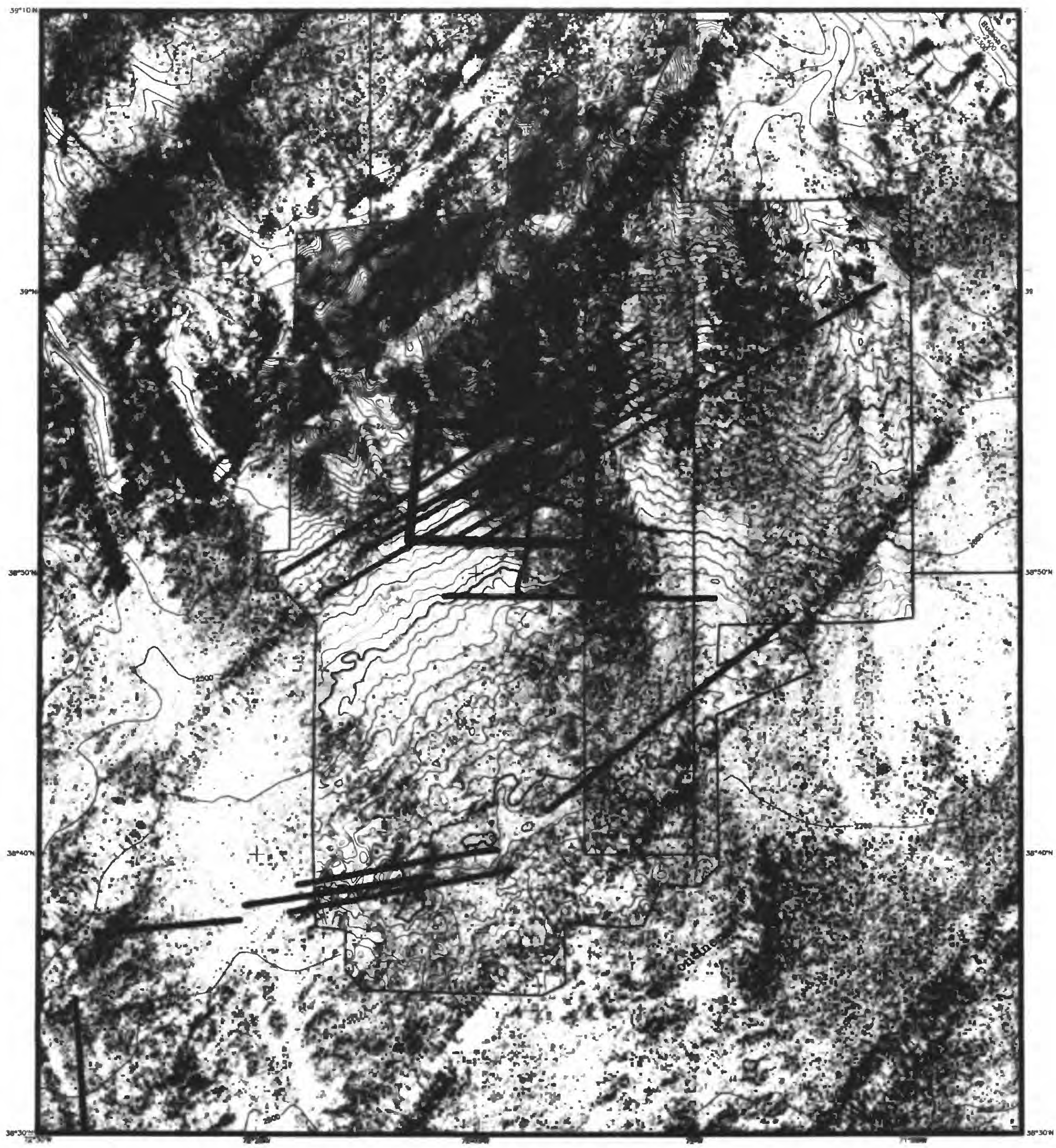

WATER DEPTH (METERS)
0
500
1000
1500
2000
2500
3000
NW
SE
CONTINENTAL SLOPE
TOMS CANYON
HENDERSON CANYON
BACK-TILTED BLOCK
TRUNCATED ONLAPPING STRATA
0
10 Km
ON MAP
CONTINENTAL RISE
SLUDGE DUMPSITE

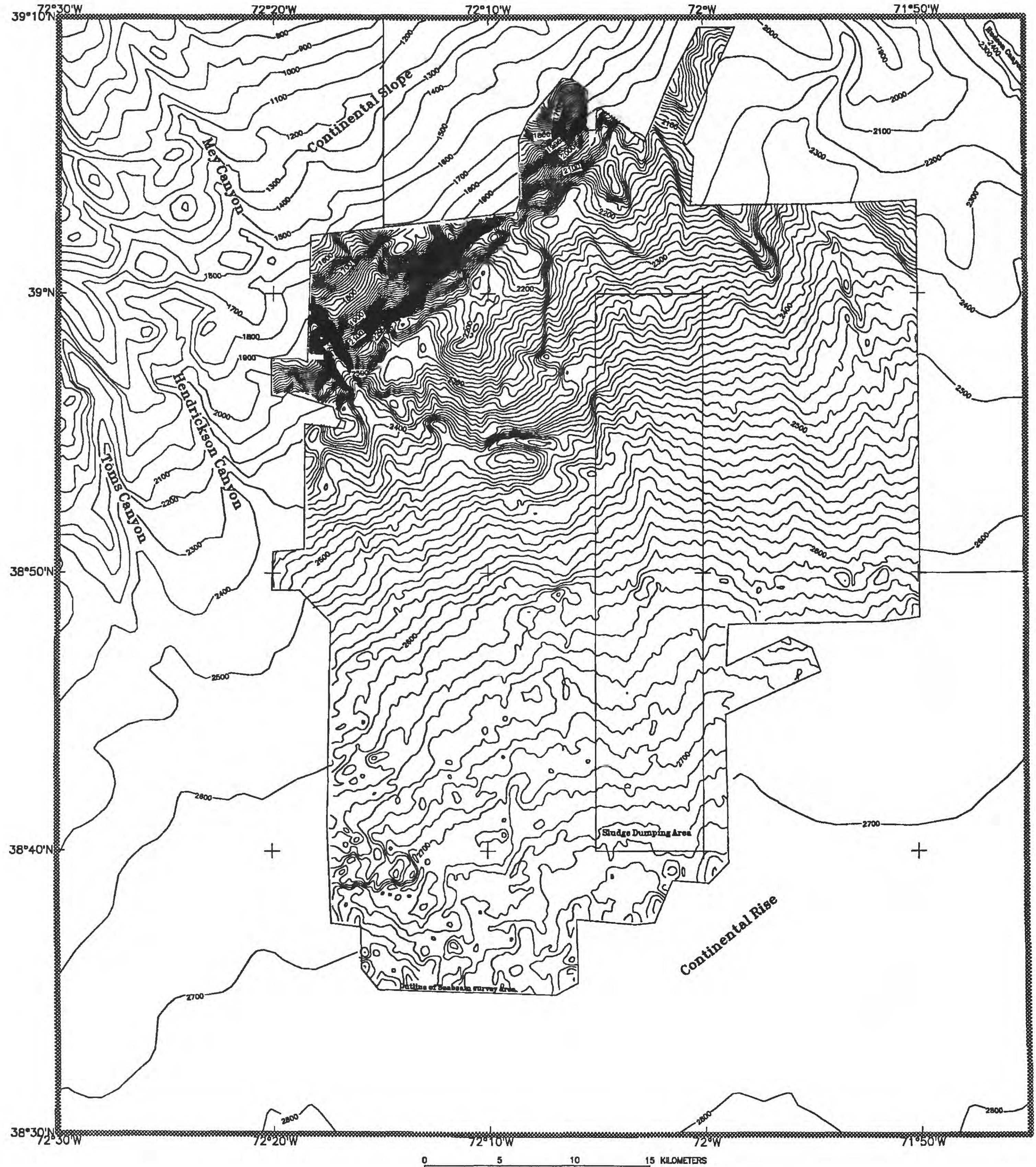

72°20'W
72°15'
72°10'
72°05'
72°00'
71°55'
71°50'W
39°10'N
39°05'
39°00'
38°55'
38°50'
38°45'
38°40'
38°35'N
HEY CANYON
CONTOUR INTERVAL 10 METERS
MERCATOR PROJECTION
0 5 10 KILOMETERS
0 1 2 3 4 5 NAUTICAL MILES
0 1 2 3 4 5 STATUTE MILES

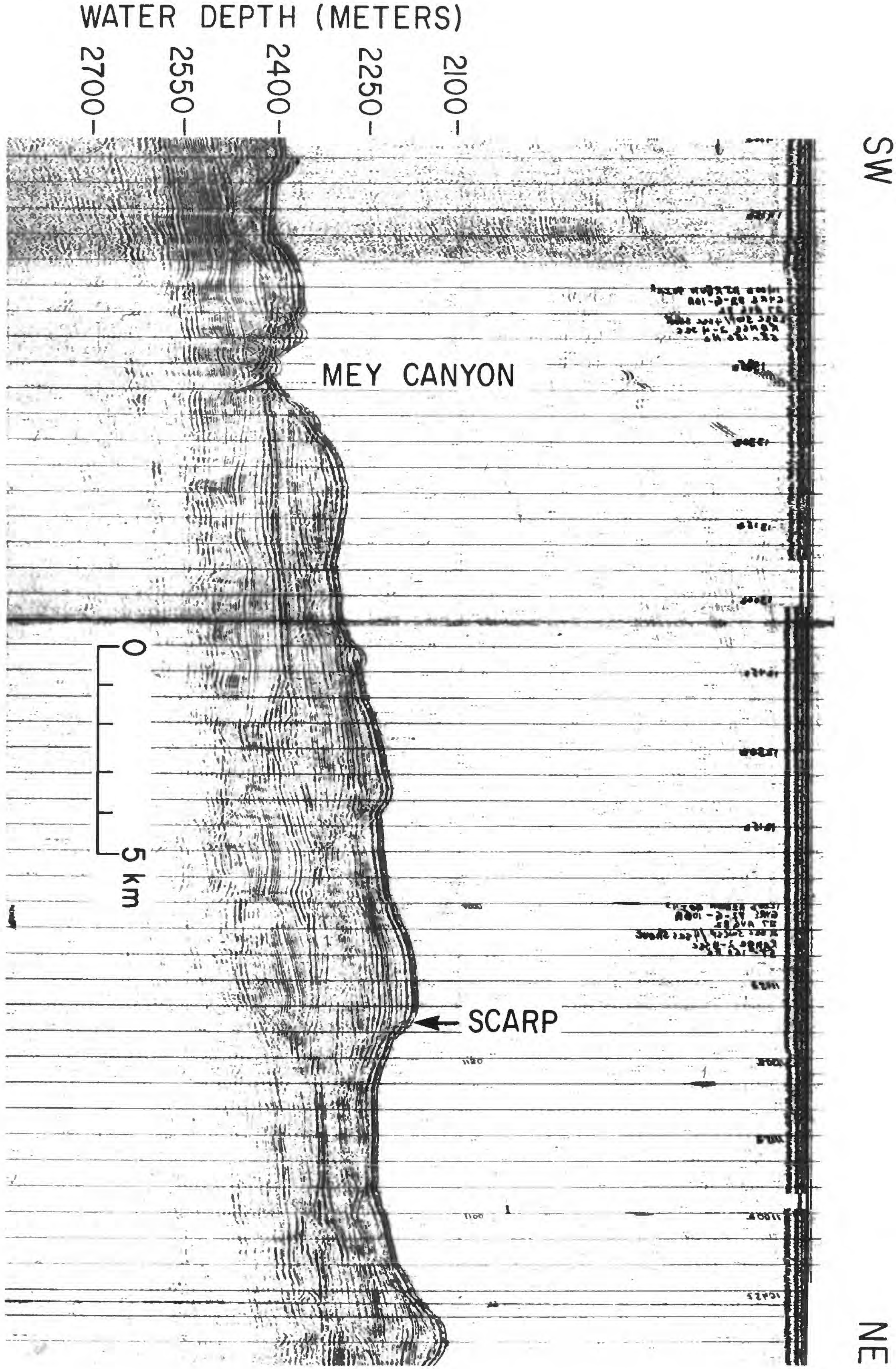


NECOR/URI Mapping Development Center
A
B
C
D
D
D
N

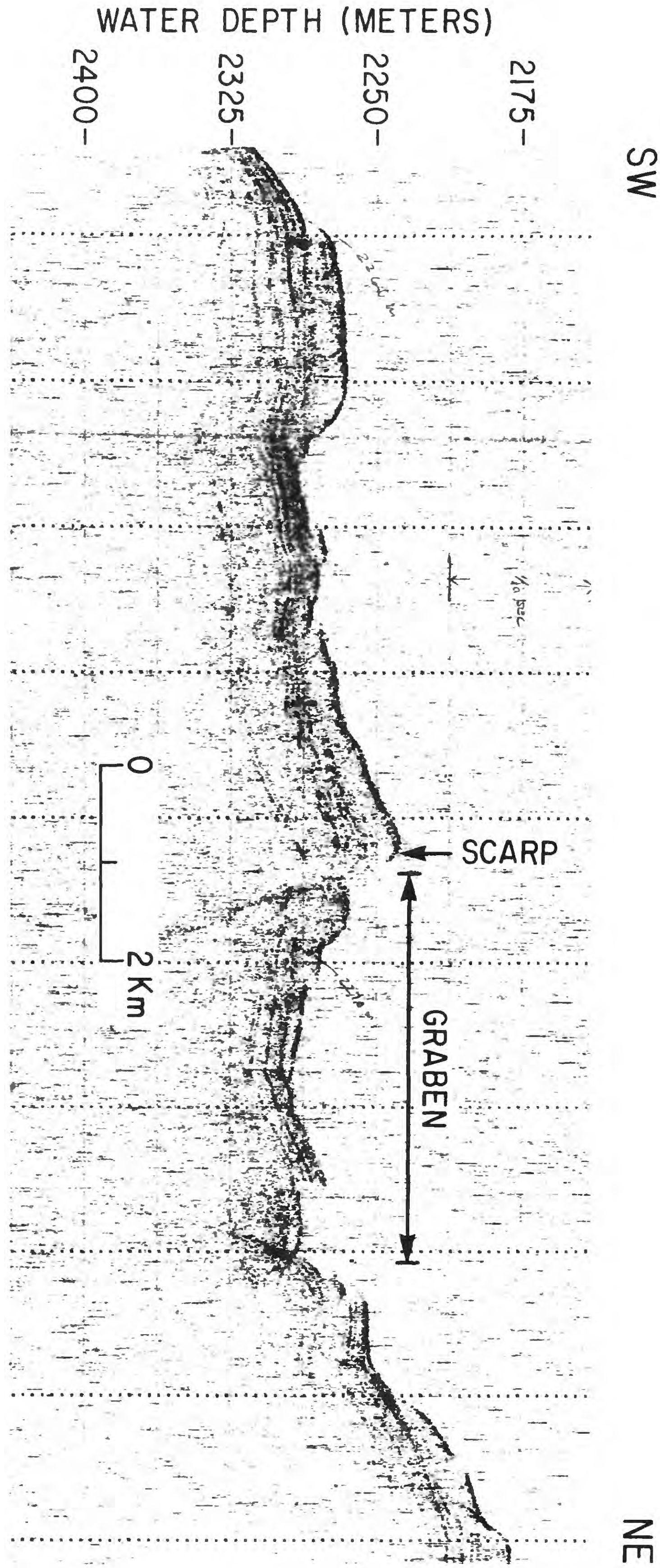

Baltimore Canyon
Wilmington Canyon
Continental Shelf
(no GLORIA images)
Continental Slope
Toms Canyon
Hudson Canyon
Wilmington Valley
Continental Rise
200m
1000m
2000m
3000m
74°
73°
72°
71°W
38°
39°N

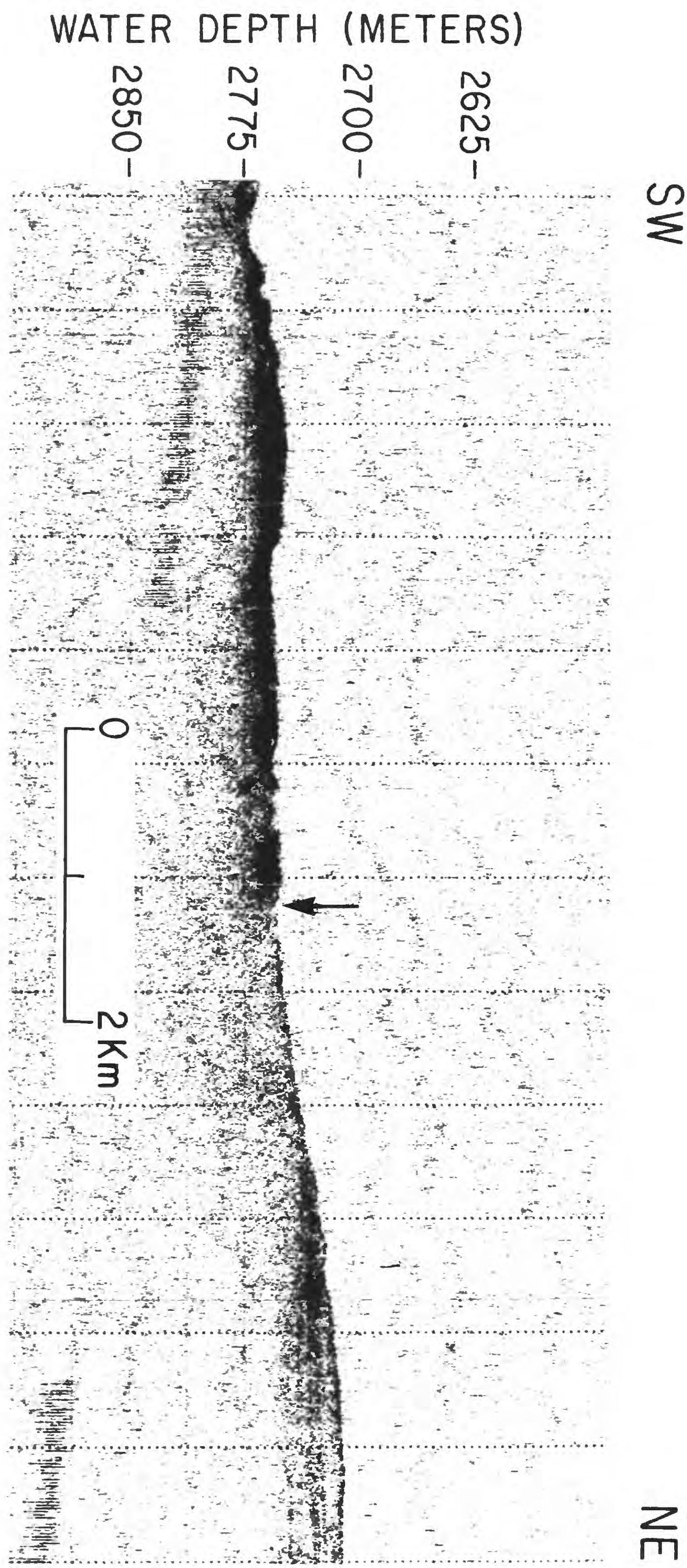



72°30'W
72°20'W
72°10'W
72°W
71°50'W
39°10'N
39°N
38°50'N
38°40'N
38°30'N
Continental Slope
Mey Canyon
Hendrickson Canyon
Toms Canyon
Sludge Dumping Area
Outline of Seabeam survey area.
Continental Rise
0
5
10
15 KILOMETERS



WATER DEPTH (METERS)
2700
2550
2400
2250
2100
SW
NE
MEY CANYON
SCARP
0
5 km


WATER DEPTH (METERS)
2400-
2325-
2250-
2175-
SW
NE
SCARP
GRABEN
0
2 Km


WATER DEPTH (METERS)
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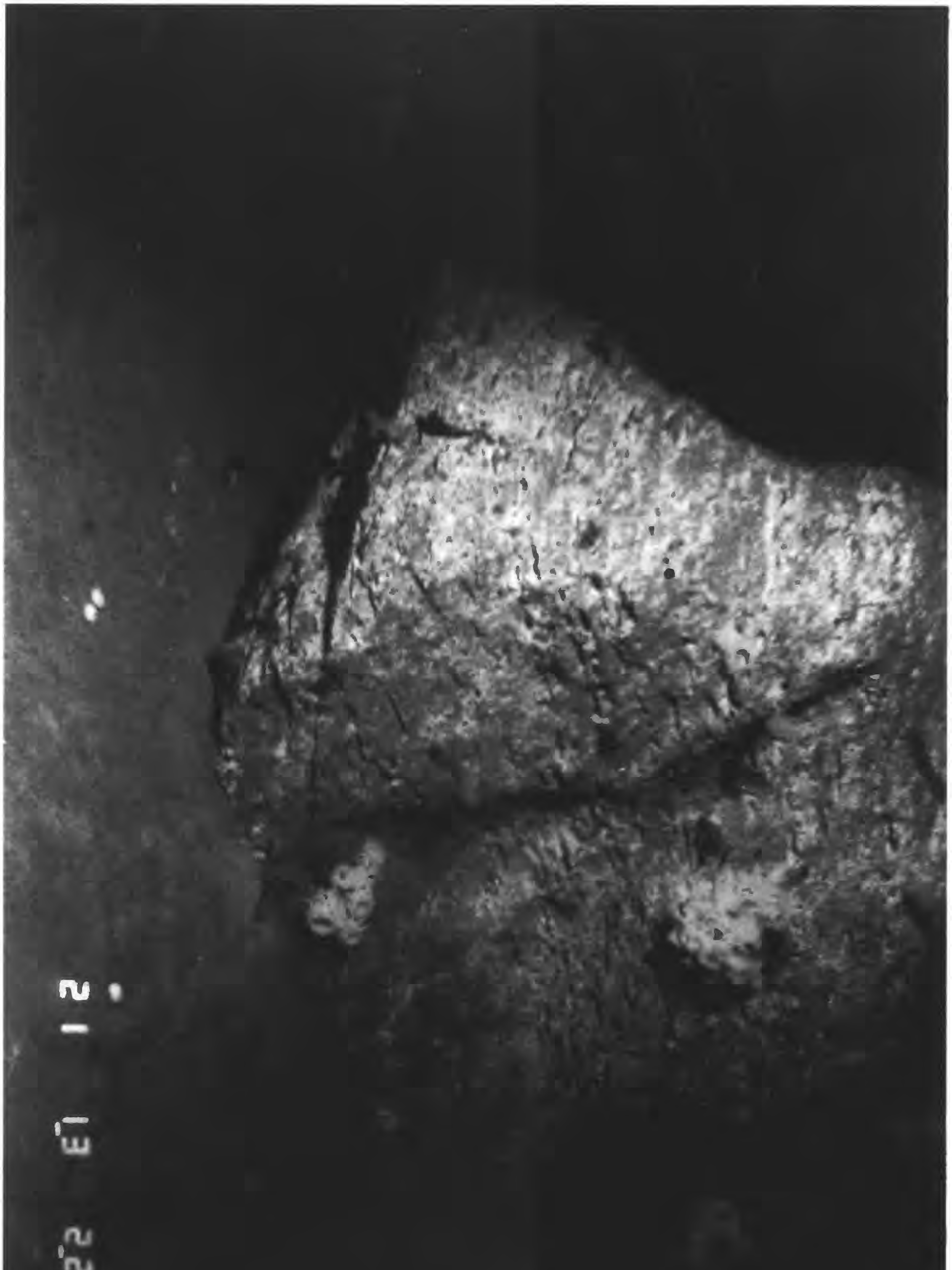
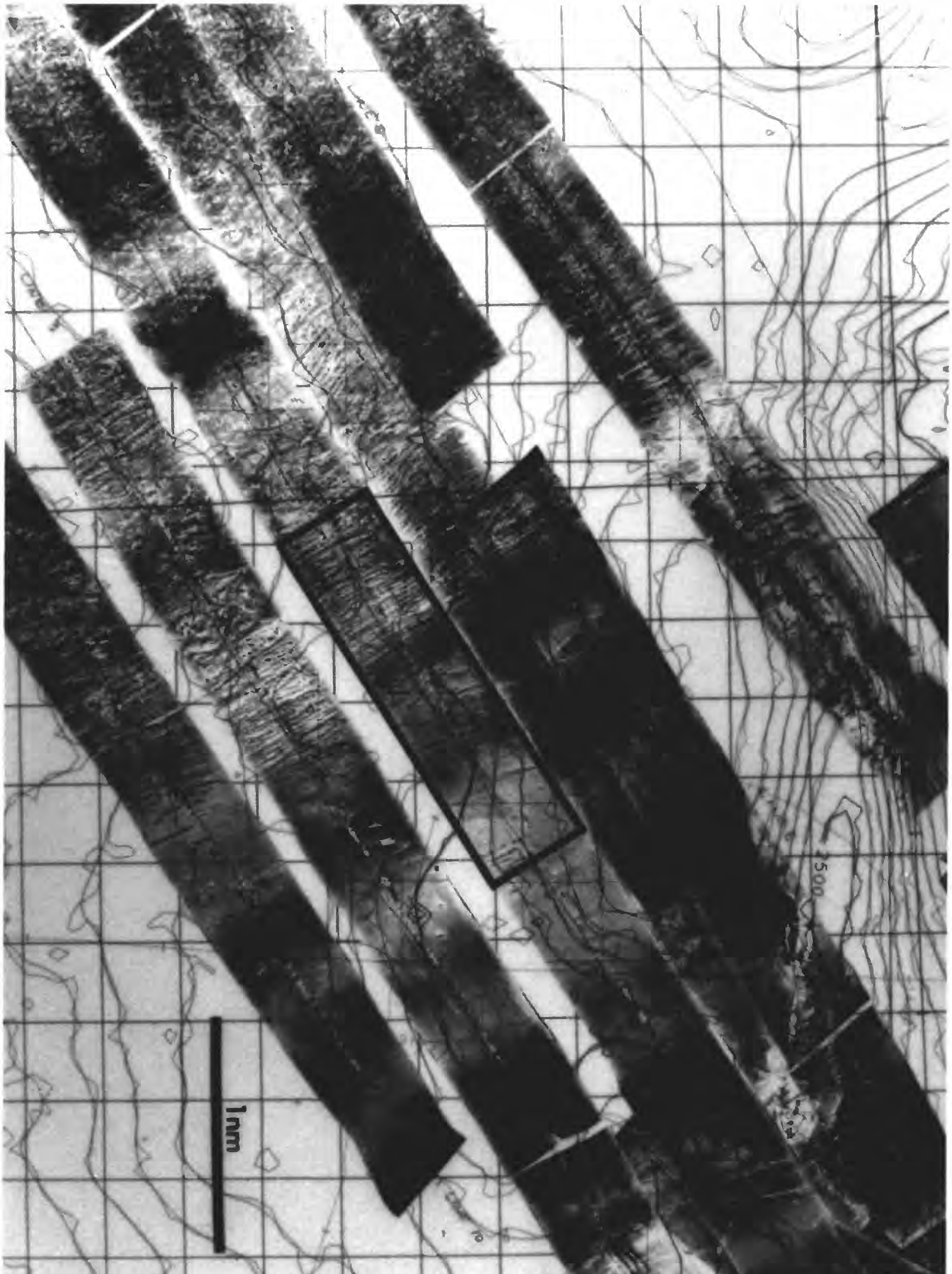
2775-
2700-
2625-
SW
NE
0
2 Km




1mm
2500


900 m