Mapping the Sea Floor Geology Offshore of The New York-New Jersey Metropolitan Area Using Sidescan-Sonar: Preliminary Report

by

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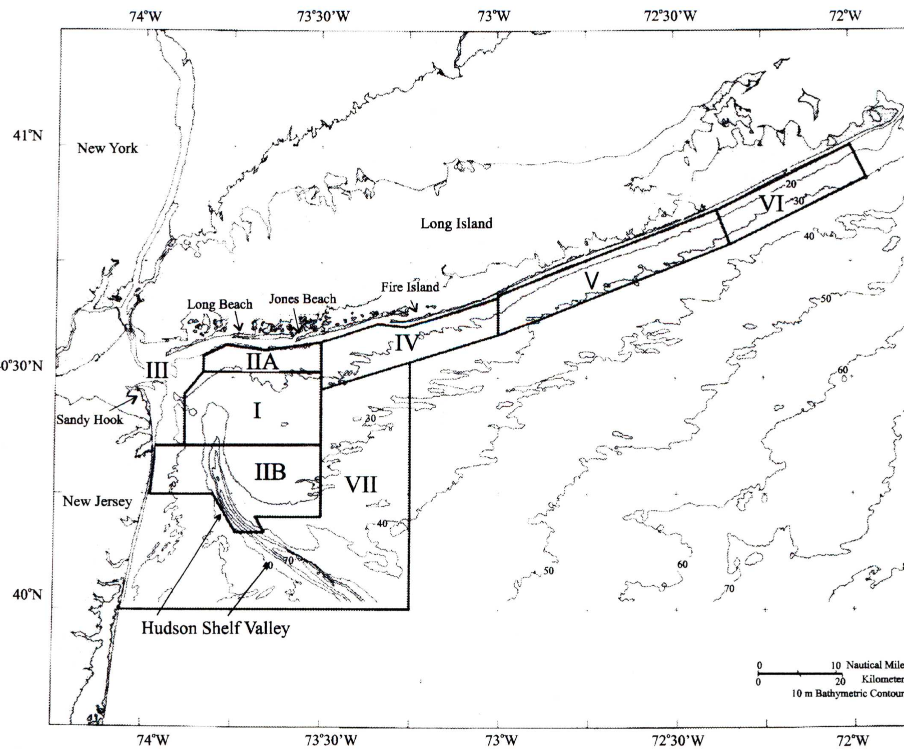

Figure 1. Map showing the location of the study areas. Roman numerals indicate areas to be surveyed as part of the USGS mapping effort in the New York-New Jersey metropolitan region. This report presents information from Areas I, IIA, and IIB.

INTRODUCTION

A focus for the U.S. Geological Survey (USGS) Coastal and Marine Geology Program is reconnaissance mapping of the shallow Exclusive Economic Zone (EEZ), with initial emphasis on the heavily utilized areas of the sea floor offshore of major metropolitan centers. The objective is to develop a detailed regional synthesis of the sea-floor geology that will provide information for a wide range of management decisions and form a basis for further process-oriented investigations. In 1995, the USGS, in cooperation with the U.S. Army Corps of Engineers (USACOE), New York District, began a program to generate reconnaissance maps of the sea floor offshore of the New York-New Jersey metropolitan area (Schwab and others, 1996a), one of the most populated coastal regions of the United States (Fig. 1, Sheet 1). The goal of this mapping program is to provide a regional synthesis of the sea-floor environment, including a description of sedimentary environments, sediment texture, sea-floor morphology, and geologic history to aid in understanding the impacts of anthropogenic activities such as ocean dumping. This mapping effort differs from previous studies of this area (e.g.,Williams, 1976; Freeland and Smith, 1978) by obtaining digital, sidescan-sonar images that cover 100 percent of the sea floor. These sidescan-sonar data will be digitally mosaicked to provide a base suitable for use in geographic information systems of the New York Bight region. In this report, we present a preliminary composite sidescan-sonar image of the sea floor along with preliminary interpretation based on surveys conducted in 1995 and 1996.

BACKGROUND

The present investigation, conducted cooperatively with the USACOE, was motivated by the need to develop an environmentally acceptable solution for the disposal of dredged material from the New York - New Jersey Port, by the need to identify potential sources of sand for renourishment of the southern shore of Long Island, and by the opportunity to develop a better understanding of the transport and long-term fate of contaminants by investigations of the present distribution of materials discharged into the New York Bight over the last 100+ years.

Long-Term Fate of Contaminants - Approximately 125 x 10^6 m^3 of sewage sludge from the New York-New Jersey metropolitan region was disposed of at a site 20 km offshore (Fig. 2, Sheet 1) between 1923-1987 (O'Reilly and others, 1992). The Hudson Shelf Valley (Fig. 1, Sheet 1) cuts across the continental shelf, terminating near this disposal site, and provides a potential long-term sink for this material or a conduit for cross-shelf transport of this material. Recent studies have shown that some sewage sludge material has been transported south from the disposal site into the Hudson Shelf Valley where it is deposited in a series of bathymetric lows, reworked by biologic organisms, and occasionally resuspended during storm events (Buchholtz ten Brink and others, 1994, 1996). In addition, sewage sludge remaining in the original disposal site has been reworked and, in places, partially buried by fine-grained sand (Buchholtz ten Brink and others, 1996).

Disposal of Dredge Spoils - Approximately 5 X 10^6 m^3 of material needs to be disposed of each year to maintain the port of New York and New Jersey, a port that serves a regional market of about 15 million people (Fawsett and Marcus, 1991; Port Authority of New York and New Jersey, 1996). Currently 14-33 percent of dredged material is classified as contaminated and therefore not suitable for unrestricted ocean disposal (New Jersey Department of Commerce and Economic Development, 1995; Port Authority of New York and New Jersey, 1996; U.S. Army Corps of Engineers, New York District, 1995). The USACOE is developing a management plan for both uncontaminated and contaminated dredged materials; one option investigated is disposal offshore in new man-made islands or offshore pits (US Army Corps of Engineers, 1996).

Erosion of the South Shore of Long Island - Long-term erosion of the barrier islands along the south shore of Long Island, New York, has led the USACOE to begin long-term planning for potential renourishment of selected regions of the shoreline (U.S. Army Corps of Engineers, New York District, 1993). Such activities require an understanding of sources and the transport of sand in the inner shelf region. This is not the focus of this report though, as areas IV, V, and VI have not been surveyed yet.

These activities, as well as others, will benefit from a large-scale regional understanding of transport and accumulation of sediments and the near-surface structure in the New York Bight Apex. The sea-floor mapping program being overseen by the USGS will provide a detailed regional framework for developing this understanding.

FIELD WORK

The long-term objective of the USGS is to map the study area north of approximately latitude 40°N and west of longitude 73°15'W in water depths greater than about 8 m, and the shoreface/inner shelf (out to about 9 km offshore) along the entire south shore of Long Island. The study area has been divided into areas (Fig. 1, Sheet 1) that will each be surveyed by means of high-resolution sidescan-sonar and subbottom profiling. Surface sediment samples and bottom photography will be used to calibrate and interpret the sidescan imagery and shallow cores will help define the stratigraphy. Area I was surveyed in May 1995 using the RV SEAWARD EXPLORER and area II was surveyed in December, 1995 using the RV ARGO MAINE and in May, 1996 using the RV SEAWARD EXPLORER. The first phase of surveying Area IV was conducted in September, 1996 and will be the subject of a subsequent report. Areas I, II, IV, V, VI, and VII are being mapped by the USGS. Area III is being mapped by the USACOE, Waterways Experiment Station (WES) and will also be addressed in a subsequent report. Analyses of these data are being conducted cooperatively by investigators at the USGS, USACOE, Texas A&M University, and the State University of New York, Stoney Brook.

The geophysical data in areas I and II were acquired using a 100-105 kHz swept frequency sidescan-sonar system, a 2-7 kHz swept FM (CHIRP) subbottom profiler, a 500-2000 Hz Geopulse subbottom profiler, a two-channel 15 in^3 (~250 Hz) water-gun seismic-reflection system, a 3.5 kHz subbottom profiler, and a 200 kHz fathometer. The water-gun data were acquired digitally at a 5 s fire interval, 512 ms sweep, and 0.48 ms sample interval. The CHIRP subbottom data were acquired digitally at a 125 ms fire interval, 125 ms sweep, and 0.122 ms sample interval. In 1995, the Geopulse data were collected at a 0.5 s. fire and 500 ms sweep in analog form only. In 1996, the Geopulse data were acquired digitally at a 0.5 s. fire, 500 ms sweep, and a 0.062 ms sample interval. Ship tracklines were selected to provide continuous sidescan-sonar coverage of the sea floor. Sediment samples were collected using a Van Veen grab modified to include camera and video systems.

Ship navigation was conducted using a Differential Global Positioning System (DGPS). The sidescan towfish (which includes the CHIRP subbottom profiler) was navigated using an acoustic-ranging system to provide a distance from the ship to the instrument. The position of the towfish was calculated assuming that the towfish was directly behind the research vessel; i.e., that it followed the ship trackline. This assumption is relatively accurate when the research vessel was running in a straight line, and with a small amount of tow cable deployed. However, the fish position error increases in turns by 10's of meters. Using the ship navigation data, the position of bathymetric data, seismic-reflection data, and sample locations are accurate to within +/- 3 m. The ship navigation in conjunction with the ranging information provide accuracy of the sidescan imagery of approximately +/- 20 m.

DATA PROCESSING

The sidescan-sonar data were logged digitally at a sampling rate that resulted in a 0.18-m pixel size in the across-track direction and approximately 0.14-m in the along-track direction following the methodology outlined in Danforth and others (1991). A median filtering routine (Malinverno and others, 1970) was applied to the sidescan data to remove speckle noise, resulting in a 0.73-m pixel size. The data in area I were further processed and digitally mosaicked using procedures described in Danforth and others (1991) and Paskevich (1992) resulting in an enhanced, geographically correct, sidescan-sonar mosaic with 1-m/pixel resolution. The sidescan-sonar image shown in Figures 2 and 3 (Sheet 1) was created by merging the digital mosaic of area I surveyed in 1995 with preliminary digitized versions of analog mosaics produced onboard the ship in real-time (areas IIA and IIB); output resolution is 2m/pixel. This composite image was developed to allow rapid release of the preliminary survey results. The entire data set will eventually be mosaicked and published in digital form.

The CHIRP, Geopulse (1996 data only), and watergun subbottom data were logged digitally and processed using the PROMAX (Advance Geophysical Corporation) software package. The water-gun data collected in 1995 were processed using an Ormsby minimum phase band pass filter (100-580 Hz) and a time-varying gain was applied from 0-50 ms (> 50 ms constant gain). In addition, a minimum phase spiking deconvolution was applied to the water-gun data collected in 1996 to remove reverberation. The CHIRP subbottom data were processed by decimating the traces by 4 (keeping every fourth trace), combining and averaging 2 traces, and applying a time-varied gain from 0-100 ms. A static correction for tow-fish depth was added to the CHIRP data collected in 1996 (this information was not available for the data collected in 1995). The Geopulse data were processed by combining and averaging 4 traces and using a minimum phase spiking deconvolution (operator length = 10 ms) to remove reverberation, applying an Ormsby minimum phase band pass (325-3000 Hz), and applying a time-varying gain from 0-25 ms (>25 ms, constant gain).

Bathymetric data were collected digitally (Fig. 2, Sheet 1). These data were processed to remove water depth variations due to vessel heave, transducer draft, and tidal fluctuations. The vertical resolution of the bathymetric data is about 1 m. The data were gridded and contoured on a 50-m grid using the EarthVision software package (Dynamic Graphics, Inc).

A suite of Van Veen grab samples was collected as a basis for groundtruthing the acoustic facies identified on the sidescan imagery (Fig. 2, Sheet 1). Grain-size analyses of the sediment samples (Table 1, Sheet 3) were conducted using a combination of wet sieve and Coulter Counter techniques following the methodology of Poppe and others (1985).

PRINCIPAL FEATURES OF THE SEA FLOOR

This is a progress report to present the composite sidescan-sonar image from areas I and II (Fig. 1, Sheet 1) and to illustrate the variability and range of detail in sedimentary environments revealed in the new observations. The sidescan-sonar imagery (Fig. 2, Sheet 1) identifies a range of features and sea floor environments in the study area, and provides new insight into the processes controlling the distribution of sediments and associated contaminants on the sea floor. One of the most striking characteristics of the sidescan imagery is the variability in acoustic backscatter over short spacial scales. The sea floor appears very inhomogeneous on scales of 100's of meters when mapped with 100 percent sidescan-sonar coverage, compared to descriptions based on seismic-reflection profiles or widely spaced sediment samples which suggested that the sea floor lithology was much more uniform (e.g., Williams, 1976; Williams and Meisburger, 1967; Freeland and Smith, 1978). From north to south, some principal features observed on the sidescan imagery include:

(1) In the nearshore area off Long Beach, there are sharply-defined, linear, shore-perpendicular to slightly shore-oblique, high-backscatter features that are interpreted to be rippled scour depressions. (Fig. 4, Sheet 2). Rippled scour depression (RSD) is a term used by Cacchione and others (1984) to describe similar features in other shelf environments. The RSDs extend from the nearshore limit of the area surveyed (~8 m water depth) to approximately 9 km from the coast (~19 m water depth). The RSDs identified on the sidescan-sonar mosaic are <1 m deep and are 40 to 250 m wide and can be continuously traced for as much as 6 km. The RSDs are floored with straight-crested, rippled, sandy gravel and gravelly sand; ripple crests are oriented roughly parallel to the shoreline (Fig. 5, Sheet 2). Between the RSDs, surface sediments are fine sand. The eastern boundaries of the RSDs are sharply defined while the western edges have a feathered appearance with individual "wisps" oriented roughly shore perpendicular (Fig. 4, Sheet 2). Exactly how these RSDs form is unknown, but they may be an erosional pattern indicative of cross-shelf sediment-transport processes from the shoreface (Cacchione and others 1984; Schwab and others, 1994; 1996b).

In this nearshore area, Upper Cretaceous- to early Tertiary-age Coastal Plain deposits (the upper surface of these deposits form a major regional unconformity) are buried by at least 10 meters (>15 ms of penetration on subbottom profiles) of Quaternary sediment (Fig. 6, Sheet 2). A complex series of fluvial channels were cut into the Coastal Plain strata off the south shore of Long Island and are filled with up to 50 m of Quaternary sediment (Fig. 6, Sheet 2). Detailed analysis of all subbottom data is being conducted to map this complex glacial drainage system.

(2) South of the RSDs off Long Beach, in the central part of the study area, seismic profiles (Fig. 7, Sheet 2) suggest that the Coastal Plain strata crops out on the sea floor and is covered in places with a thin veneer of sediment. The particularly complex pattern of high and low backscatter expressed on the sidescan imagery from this area (Fig. 8, Sheet 2) and the presence of gravel (in part, an erosional lag deposit from the outcropping Coastal Plain Strata), fine sand, and rock outcrops are consistent with this interpretation. The entire high-backscatter area is elevated by a few meters from the surrounding sea floor and is interpreted to be an area where erosional processes dominate.

Where not exposed on the sea floor, contact between these Coastal Plain strata and overlying Quaternary deposits are expressed as a major regional unconformity in subbottom profiles (Figs. 6 and 7, Sheet 2). These Coastal Plain strata are offset at the New York Bight Fault (Hutchinson and Grow, 1985) with uplift to the east (Fig. 3, Sheet 1, and Fig. 7, Sheet 2), but there is no evidence for disruption or internal deformation within the overlying Quaternary deposits, nor is there a surface expression of this fault on the sea floor where the Coastal Plain strata crops out.

(3) Diamond Hill mound (Fig. 3, Sheet 1), the location of Ambrose Light, was formed by dumping sometime between 1845 and 1888 (Williams, 1976). This dumpsite is expressed on as a bathymetric high approximately 8 m higher than the surrounding sea floor (Fig. 2, Sheet 1) and on the sidescan imagery as an area of numerous, overlapping high backscatter "dots" which are interpreted to represent individual dumps.

(4) The Mud Dumpsite (Fig. 2, Sheet 1, and Fig. 9, Sheet 2), presently used for disposal of dredge spoils from the New York Harbor estuary, is roughly defined by the 16 m isobath, about 10 m shallower than the adjacent sea floor. Subbottom profiles, however, suggest that this is an area where the Coastal Plain strata is close to the sea-floor surface (Fig. 10, Sheet 2). Thus disposal of dredge spoils is probably not the entire cause of the bathymetric high. The site is marked by numerous small high-backscatter "dots" on the sidescan imagery (Fig. 9, Sheet 2). These dots are interpreted as individual dumps of dredged and other material disposed in this region since the late 1800's (Freeland and Smith, 1978; US Army Corps of Engineers, 1996). The imagery reveals that historical dumping was not contained within any designated disposal site. Note that the surficial sediment characteristics in this region might vary considerably depending on the sample location with respect to these individual dumps.

(5) The relatively featureless low-backscatter area in the center of the study area (Fig. 11, Sheet 2) coincides with an area where subbottom profiles indicate that there is about 25 m (<35 ms of subbottom penetration) of Quaternary sediment deposited over the Coastal Plain Unconformity (Fig. 10, Sheet 2). Surface sediment samples suggest that this is mostly a medium- to fine-grained sand deposit. The sidescan imagery suggests that there is active sediment transport in this area, as suggested by the clearly defined bands of high and low backscatter sub-parallel to the axis of the Hudson Shelf Valley (Fig. 11, Sheet 2), interpreted to be sand waves, and the burial and reworking of sewage sludge material seen in cores collected in the sewage disposal area (Buchholtz ten Brink and others, 1994, 1996).

(6) The Hudson Shelf Valley (HSV) cuts northward into the study area (Fig. 3, Sheet 1), with the floor about 25 m deeper than the surrounding shelf near the valley head. The sediments on the shelf adjacent to the Hudson Shelf Valley are moderate- to low-backscatter fine sand to the east and high-backscatter coarse sand, gravel, and boulders to the west (along with outcropping Coastal Plain Strata; see below) (Fig. 2, Sheet 1). The HSV is floored by low-backscatter fine-grained sediment which presumably has been winnowed from the surrounding shelf (Fig. 12, Sheet 2). The sidescan imagery collected over the east flank of HSV reveals a series of low-backscatter, circular areas with no resolvable bathymetric expression (Fig. 12, Sheet 2). These features are thought to indicate a minor textural variation of the surface sediment. Subbottom profiles suggest that the trend of the circular patterns correlates to a possible offset of the Coastal Plain strata (Fig. 13, Sheet 3) suggesting that the circular features are structurally controlled, possibly an artesian ground-water phenomenon. The fact that roughly north-northwest trend of the pockmarks area (and HSV) coincides with no known subbottom stratigraphic trend (the underlying Coastal Plain strata strike to the northeast and dip to the southeast), further suggests a deeper structural cause for this geomorphic feature; possibly a fault or fracture. Further processing and analysis of the watergun seismic-reflection profiles may provide a firmer interpretation on the origin and trend of the circular patterns on the sidescan imagery and the relation of this trend to the origin of the HSV.

(7) Subbottom profiles over the area west of the HSV indicate that this is an area of relatively thin sediment cover (< 4 m) and outcropping Coastal Plain strata (Fig. 13, Sheet 3). The complex patterns of high and low backscatter expressed on the sidescan imagery from this area, the presence of gravel, fine sand, and rock outcrops are consistent with this interpretation (Fig. 14, Sheet 3).

A general northeast-southwest trending "fabric" on the sidescan imagery is thought to be an expression of differential erosion of the Coastal Plain strata (bedding planes that strike northeast-southwest) which is covered, in places, by a thin veneer of fine-grained sediment (Fig. 15, Sheet 3). Thus, the high backscatter areas on the imagery are interpreted to be either outcropping Coastal Plain strata or gravelly lag deposits resulting from the erosion of these strata. The low backscatter areas between these outcrops is primarily a medium- to fine-grained sand. The presence of sand waves (Fig. 14, Sheet 3) suggest that these sediments are reworked by modern processes.

(8) Fishing activity, as indicated by bottom trawl or dredge marks on the sea floor, is observed in the sandy areas to the east and west of the Hudson Shelf Valley (Fig. 16, Sheet 3). Resurveying of this area following a major storm could qualitatively reveal the extent of reworking of the sea-floor sediments by storms.

SUMMARY

This report presents a preliminary synthesis of results of systematic high-resolution mapping of the sea floor of the New York Bight Apex, principally by means of 100%-coverage sidescan sonar and seismic-reflection methods. The survey provides a new and detailed view of the sea floor, and a new framework for understanding the regional sediment transport system of the New York Bight. Preliminary interpretation of the imagery: (1) provides a framework for assessment of anthropogenic impact of historic and ongoing waste disposal operations; (2) shows changes in sediment properties over short spatial scales that are controlled by both modern processes and the subsurface stratigraphic and structural framework; (3) suggests a variety of active sediment transport processes. The sidescan-sonar data will be mosaicked digitally and will be available for incorporation into geographic information systems of the New York Bight.

ACKNOWLEDGMENTS

We thank the captains and crews of the Research Vessels SEAWARD EXPLORER, ARGO MAINE, and ATLANTIC SURVEYOR for their skill and cooperation at sea. David Twichell, William Dillon, Page Valentine, and Robert Oldale provided helpful reviews of the manuscript. This project was jointly funded by the U.S. Geological Survey and the U.S. Army Corps of Engineers. Any use of trade names or company names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey, the U.S. Army Corps of Engineers, nor Texas A&M University.

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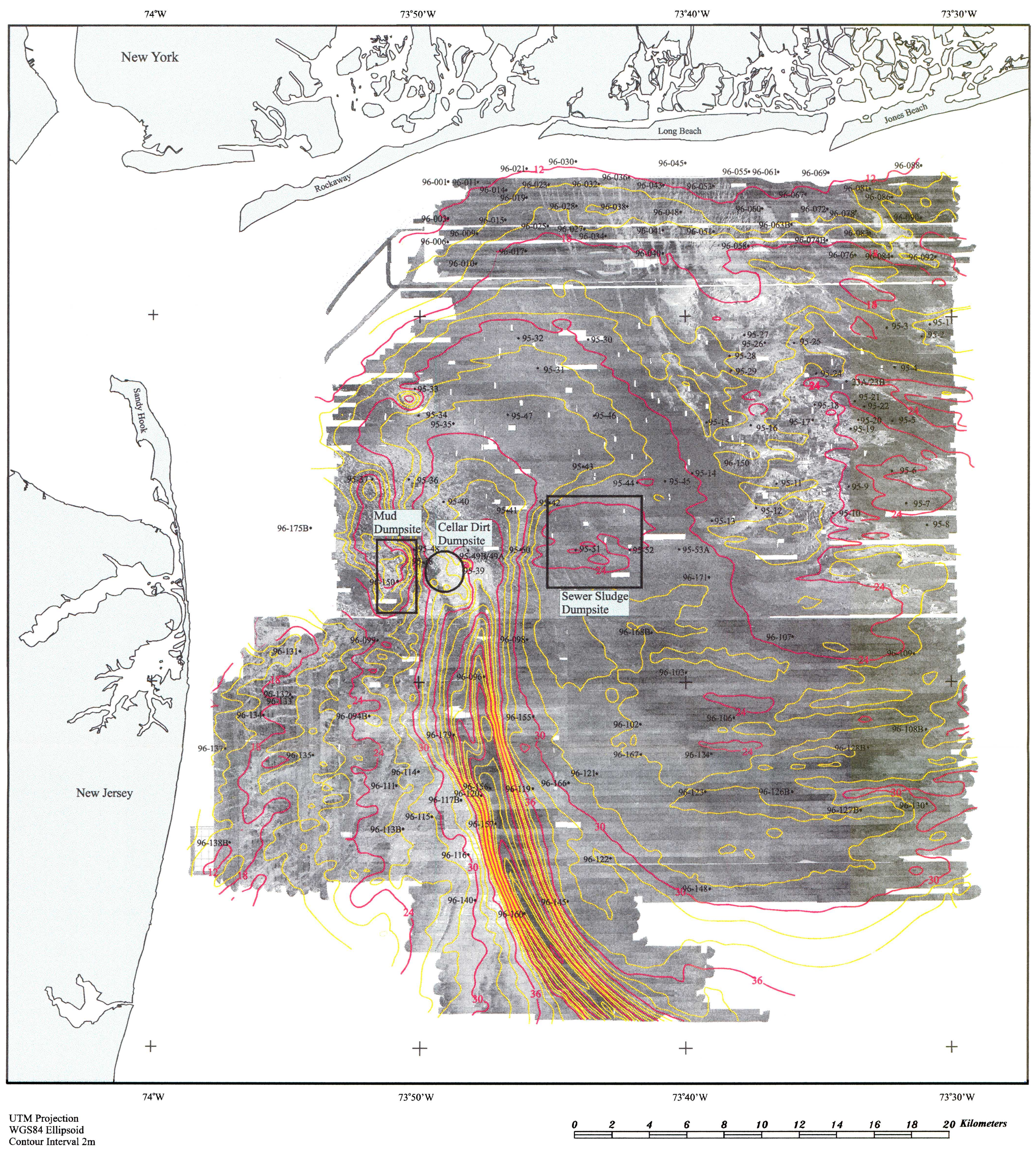

Figure 2. Sidescan-sonar mosaic of the New York Bight (Areas I and II). Bathymetry (based on data collected on these surveys), locations of the present Mud Dumpsite, and other historical disposal areas, and locations of sediment samples collected in 1995 (95-sample number) and 1996 (96-sample number) are shown on the image. The area of high backscatter to the east of the Mud Dumpsite is the historical Cellar Dirt Dumpsite (used for disposal of construction materials). High backscatter (light tones) are areas of coarse-grained sediments and outcropping rock, low backscatter (dark tones) are areas of finer-grained sediments. In general, the areas of the sea floor displaying the highest backscatter are blanketed by sandy gravel and gravelly sand, areas of moderate backscatter are blanketed by medium to fine sand (dominant sediment type), and the darkest areas are muddy. The image is a composite of the digitally mosaicked data from the 1995 survey in the northern portion of the region (area I on Figure 1), and the analog mosaics produced in the field during the 1996 survey (areas IIA and IIB on Figure 1). Further digital processing of the analog images will reduce the changes in tone between images and other artifacts which reflect the individual survey tracklines.

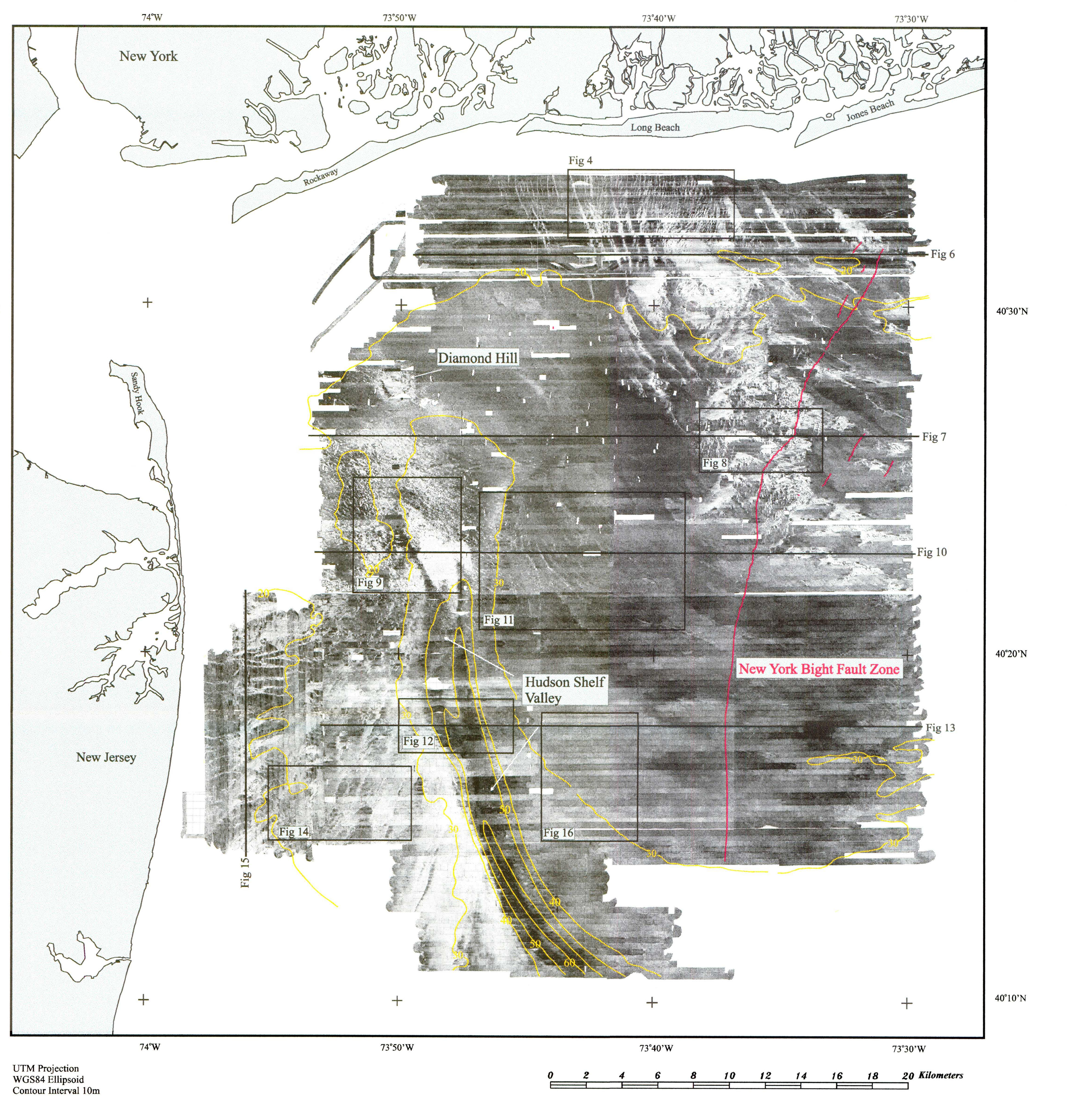

Figure 3. Sidescan-sonar mosaic of the sea floor shown in Figure 2 showing locations of figures used in this report, location of the New York Bight Fault Zone (Hutchinson and Grow, 1984), the Hudson Shelf Valley, and Diamond Hill.

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