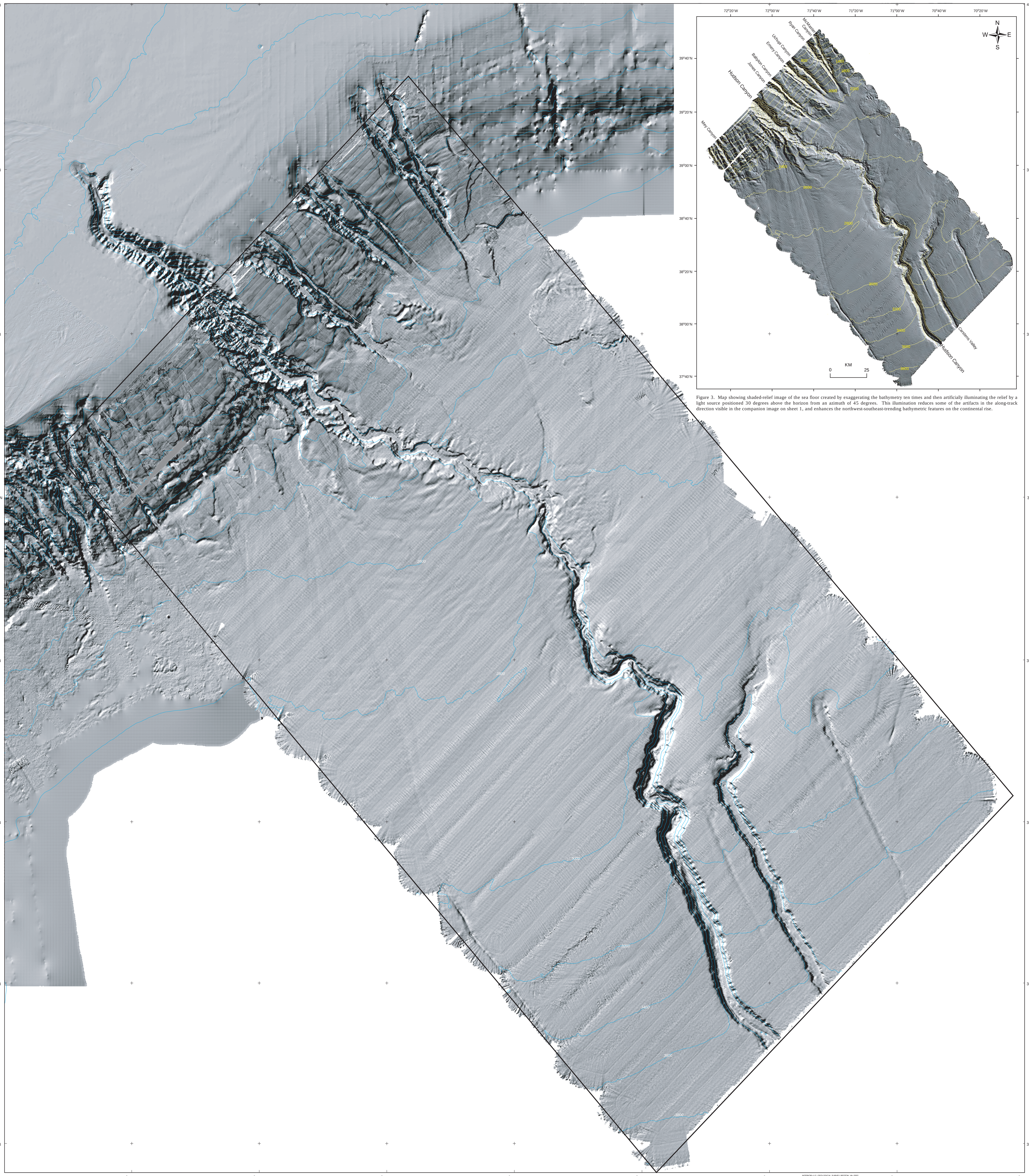

Mercator projection
World Geodetic System 1984
Longitude of central meridian 70° W; latitude of true scale 40° N.
False easting 0 m; false northing 0 m.
This map is not intended for navigational purposes.

SCALE 1:300,000
ONE CENTIMETER ON THE MAP REPRESENTS 3000 METERS ON THE SEA FLOOR
TOPOGRAPHIC CONTOURS IN METERS; INTERVAL VARIES
DATUM MEAN LOWER LOW WATER

Sheet 1.—Sea floor topography in shaded relief view, with sea floor depth as topographic contours.

Figure 3. Map showing shaded-relief image of the sea floor created by exaggerating the bathymetry ten times and then artificially illuminating the relief by a light source positioned 30 degrees above the horizon from an azimuth of 45 degrees. This illumination reduces some of the artifacts in the along-track direction visible in the companion image on sheet 1, and enhances the northwest-southeast-trending bathymetric features on the continental rise.

DISCUSSION

Introduction

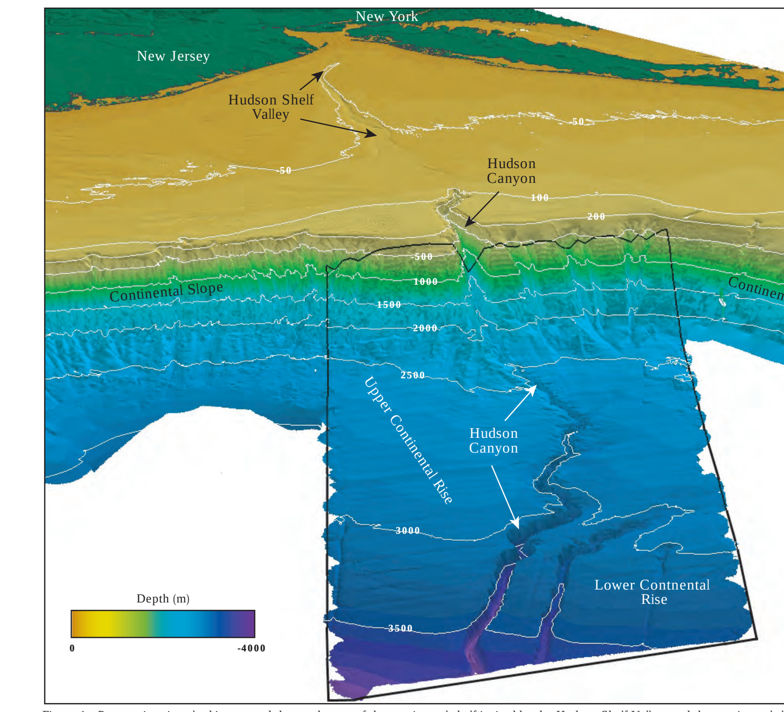

Figure 1. Perspective view, looking toward the northwest, of the continental shelf incised by the Hudson Shelf Valley, and the continental slope and rise incised by the Hudson Canyon. The black line outlines the limits of the survey carried out by the NOAA Ship *Ronald H. Brown* shown on sheets 1 and 2.

Hemipelagic Deposit

Hemipelagic sediment occurs in large patches on the upper rise on both sides of Hudson Canyon. This sedimentary facies has a smooth sea floor surface with low-backscatter intensity, and on subbottom profiles it shows a series of closely spaced reflections that parallel the sea floor (Figure 10 B). Such hemipelagic sediments consist primarily of terrigenous silt and clay in core samples from other areas (Damuth, 1980).

Sediment Waves

A field of sediment waves lies on the upper continental rise on the southwest side of Hudson Canyon, and is shown most clearly on the image of backscatter intensity (Figure 4). The waves begin about 25 km seaward

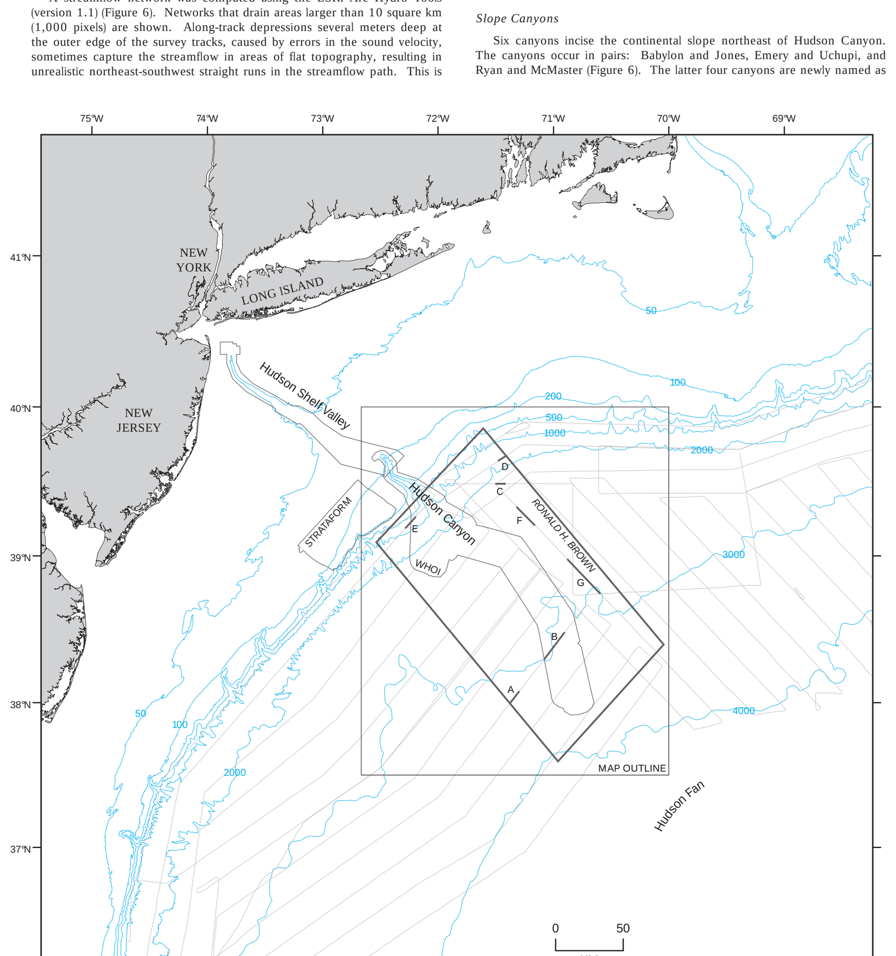

Figure 2. Map showing the location of the Hudson Canyon on the continental slope and rise offshore of the northeast United States. Data presented on sheets 1 and 2 are from the NOAA Ship *Ronald H. Brown* survey of the Hudson Canyon (outlined by the heavy black line), supplemented by multibeam surveys of the Hudson Shelf Valley (Butman and others, 2003), the Hudson Canyon (WHOI), and the outer shelf (STRATAFORM), and by the NOAA Coastal Relief Model. Light gray lines are the location of widely-spaced 3.5 kHz subbottom profiles. Lines labeled A-G are locations of profiles shown in Figure 10.

series of closely spaced reflections that parallel the sea floor (Figure 10 B). Such hemipelagic sediments in core samples from other areas consist primarily of terrigenous silt and clay (Damuth, 1980).

Rise Valleys

The shaded-relief maps (sheet 1, Figure 3) and the drainage network map (Figure 6) show linear valleys that originate on the lower rise in water depths between 3,000 and 3,200 m (the four largest of these valleys are shown in Figure 7). The origin of these valleys on the lower continental rise makes them distinctly different from Hudson Canyon and the other canyon-associated valleys. The rise valleys are shallow, straight features with bowl-like heads that are 6-69 m deeper than the surrounding sea floor (Figures 3 and 7). Farther downslope, where they exit the survey area, they have less than 10 m relief. High-resolution seismic profiles show that hemipelagic sedimentary layers are truncated around the heads of these valleys, indicating an erosional origin. Thinning of the layers within the valleys suggests that the valleys are maintained by preferentially reduced deposition (Figure 10 A). Farther downslope the shallower of these valleys have subdued levees to either side, but the deeper valleys continue to have eroded walls. The rise valley at the southwestern edge of the survey area lacks a bowl-like head, and it may have been filled by mass-transport deposits (see Mass-Transport Deposits in the Upper Continental Rise section above).

The origin of the rise valleys is unknown, but the fact that they are well removed from the continental slope suggests that they are not formed by turbidity currents, which would have originated on the outer continental shelf or continental slope. Additionally, they do not appear to be the result of erosion by bottom currents, because bottom currents flow roughly perpendicular to the trend of the valleys (Heezen and others, 1966; Pratson and Laine, 1989). Pore-water discharge may be a mechanism for forming these rise valleys (Johnson, 1939; Robb, 1984). Notably, the heads of the valleys originate above the seaward edge of a major gas-hydrate province mapped beneath the continental rise (Tucholke and others, 1977; Dillon and others, 1995). Sedimentary bedding there dips landward (Tucholke and others, 1977), so the attitude of the beds could focus fluid flow (gas and water) and stimulate sapping in this zone.

Chronology

A relative chronology can be defined from the stratigraphic stacking of the different seismic facies that are recorded on high-resolution seismic profiles. The oldest strata are those exposed by erosion along the canyon walls (Figure 10 B, C). In the section of the canyon that cuts the continental slope, these strata are of Cretaceous, Paleogene, and Neogene age (Weed and others, 1975; Gibson and others, 1968). Neogene sediments are exposed within the canyon where it crosses the continental rise (Ericson and others, 1952; Mountain and Tucholke, 1985).

The high-resolution seismic profiles have a maximum penetration of about 50 m subbottom. Although no cores from the survey area are known to be directly dated so as to provide sedimentation rates, we can infer the age of the upper 50 m of sediment from related data. Dated cores from uneroded areas of the continental slope and rise to the south of our survey indicate sedimentation rates between about 5 and 15 cm/k.y. (Embley, 1980; Klasik and Pilkey, 1975). Within the survey area, mapping and interpretation of seismic stratigraphy shows that up to about 400 m of upper Pliocene and Quaternary sediments are present (Mountain and Tucholke, 1985), yielding a similar average sedimentation rate of ~11.5 cm/k.y. Thus the shallow seismic facies documented in the high-resolution profiles probably represent between 0.3 and 1.0 m.y. of sediment accumulation (i.e., middle to upper Pleistocene and younger).

Scarps are cut into hemipelagic sediment on the continental slope, and they presumably reflect source areas for the mass-transport deposits that overlie hemipelagic sediment in several places on the rise (Figure 10 G). These features indicate that the mass-transport deposits generally postdate the hemipelagic sediments (Figure 10 C, D). Most recently, the surfaces of some mass-transport deposits have been reworked into sediment waves, reflecting the action of overbank flow of turbidity currents and/or bottom currents, probably in the Holocene.

The shallow stratigraphy and sea-floor features show dramatic changes in the style of sedimentation during the middle to late Pleistocene and Holocene. Initially, deposits on the continental rise were a mix of turbidites and hemipelagic sediments. Turbidity currents generated on the outer shelf or upper slope were transported across the upper rise through a network of submarine canyons to the Hudson Fan seaward of the study area (Figure 2). Hudson Canyon and several canyons to the east, extending perhaps to Block Canyon, coalesced on the upper rise to form the 'gather area' that supplied sediment from a large part of the continental slope to the Hudson Fan (Schlee and Robb, 1991). Within the survey area during this time, fine-grained turbidites were deposited on the levees to either side of the canyons, and hemipelagic sediment including contourites deposited from bottom currents accumulated on the slope and on areas of the rise away from the canyons.

A period dominated by mass wasting followed the period of turbidite and hemipelagic deposition. At this time large sections of the southern New England continental slope as well as the slope to either side of Hudson Canyon failed, and the displaced sediments spread as broad sheets and fingers over large parts of the upper rise. These mass-transport deposits nearly filled all the canyons north of Hudson Canyon (Pratson and Laine, 1989; EEZ-Scan Scientific Staff, 1991; O'Leary, 1993). Turbidity currents may have been active at this time, but they were inefficient in eroding and reopening the choked portions of valleys on the rise northeast of Hudson Canyon. The age of these mass-wasting deposits is unknown, but the absence of significant sediment covering them suggests they are latest Pleistocene or early Holocene in age. It is possible that they correlate with the last lowstand of sea level, ca. 15,000 B.P., when the outermost shelf and slope were loaded with rapidly deposited, glacially and fluvially derived sediments (Emery and Uchupi, 1984; O'Leary, 1993).

A final stage of sedimentation and erosion from turbidity currents and bottom currents followed the period of mass wasting. During this period, turbidity currents appear to have been restricted largely to Hudson Canyon. Mass-transport deposits in the other canyons were relatively undisturbed, suggesting that they experienced little turbidity current activity. Along Hudson Canyon, much of the sediment in the turbid flows appears to have bypassed the upper rise and was deposited on the deeper Hudson Fan and the Hatteras Abyssal Plain. The only recognizable record of this period of sedimentation is the sediment waves southwest of Hudson Canyon, which indicates that some flows were large enough to overtop the canyon rims. The waves probably reflect reworking and deposition by a combination of the turbid flows and bottom currents. In most places, high-resolution seismic profiles do not resolve sediment covering the mass-transport deposits. However, this is not surprising if these deposits were emplaced as recently as 15,000 yr. B.P., because only about 2 m of sediment would have accumulated at the likely sedimentation rates of <15 cm/k.y. Cores will be needed to define the timing of this and earlier stages of sedimentation more completely.

Region	Depth (m)	Along-axis slope (°)	Width (Rim to rim) (km)	Wall slope (°)	Floor width (km)	Depth below adjacent sea floor (m)
Continental slope	100 – 2,200	1.5	0.8-12	10-15	0.2-0.9	440-1,120
Upper rise	2,200-3,000	0.6	2.5-11	1-8	0.2-2.1	20-521
Lower rise	>3,000	0.5	4.5-5.5	10-20	.5-2.2	187-547

Table 1. Physiographic characteristics of Hudson Canyon

Facies	Location	Area (km²)	Area (%)
Failed slope	*Continental slope*	1,450	6
Mass-transport deposits	*Upper rise*	4,993	20
Buried mass-transport deposits	*Upper rise*	332	1
Hemipelagic deposits	*Continental slope, Upper rise, Lower rise*	11,469	46
Sediment waves	*Upper rise*	3,416	14
Outcrop of old strata	*Continental slope, Upper rise, Lower rise*	3,071	13

Table 2. Sediment facies

Acknowledgments

This work was supported by the NOAA Ocean Exploration program and by the U.S. Geological Survey (USGS) Coastal and Marine Geology Program. We thank the officers and crew of the NOAA Ship *Ronald H. Brown* for their assistance at sea. Peter Rona was chief scientist on the cruise. Tom Bolmer and Dave Dubois (Woods Hole Oceanographic Institution) and William Danforth (U.S. Geological Survey) assisted in data collection and processing. B. Tucholke provided multibeam from the R/V *Atlantis* survey for the portion of Hudson Canyon between the Hudson Shelf Valley survey and the NOAA Ship *Ronald H. Brown* survey, and Larry Mayer (University of New Hampshire) provided multibeam data from the outer shelf collected during the STRATAFORM project. B. Tucholke was supported by Office of Naval Research Grant N000140110965 and by NOAA Grant NA06RU0139, Subaward 1508 for processing and interpretation of multibeam data.

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SEA FLOOR TOPOGRAPHY AND BACKSCATTER INTENSITY OF THE HUDSON CANYON REGION OFFSHORE OF NEW YORK AND NEW JERSEY

by
Bradford Butman[1], David C. Twichell[1], Peter A. Rona[2], Brian E. Tucholke[3], Tammie J. Middleton[4], and James M. Robb[1]
2006
[1]U.S. Geological Survey, [2]Rutgers University, [3]Woods Hole Oceanographic Institution, [4]ETI Professionals Inc.

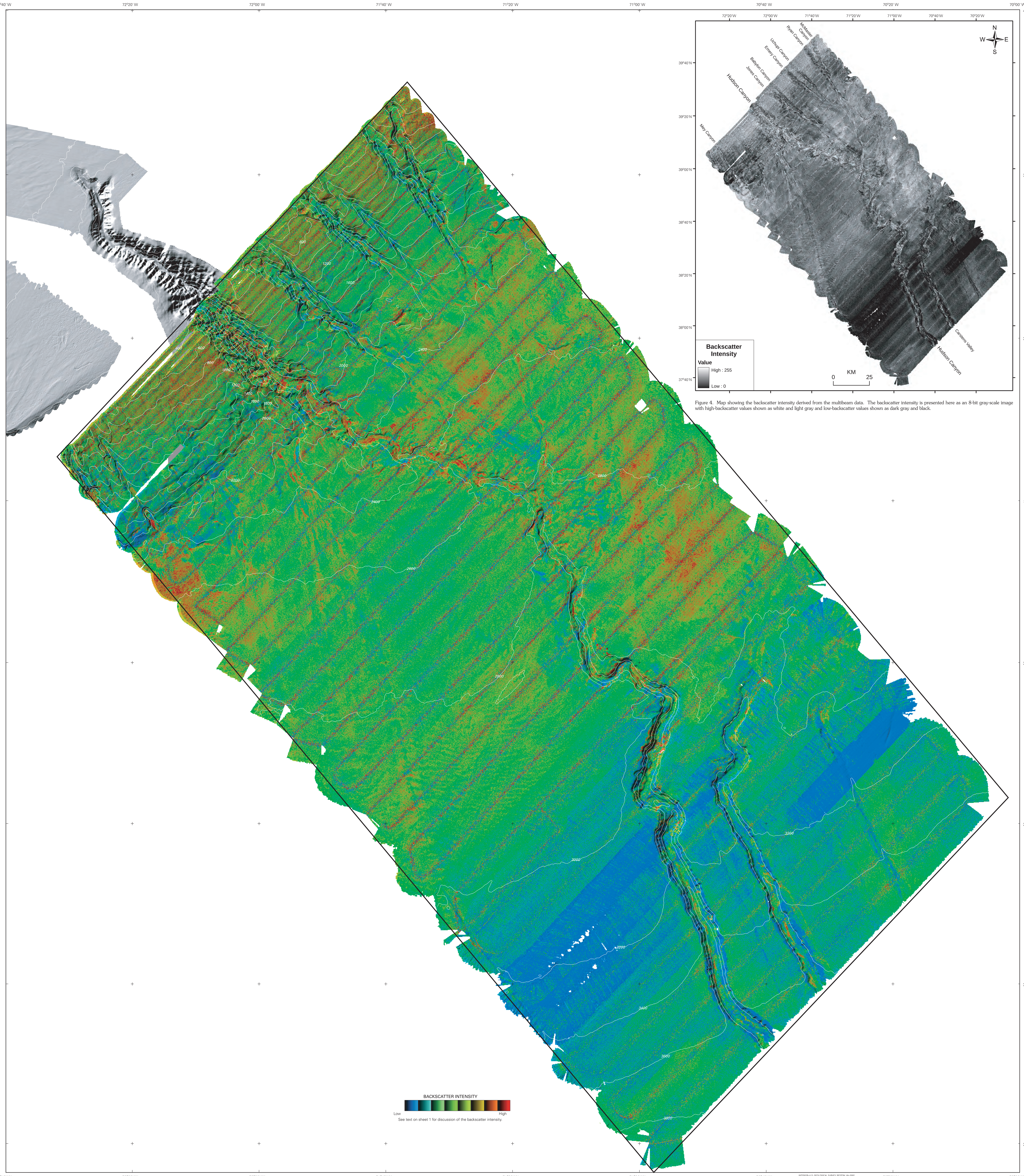

Figure 4. Map showing the backscatter intensity derived from the multibeam data. The backscatter intensity is presented here as an 8-bit gray-scale image with high-backscatter values shown as white and light gray and low-backscatter values shown as dark gray and black.

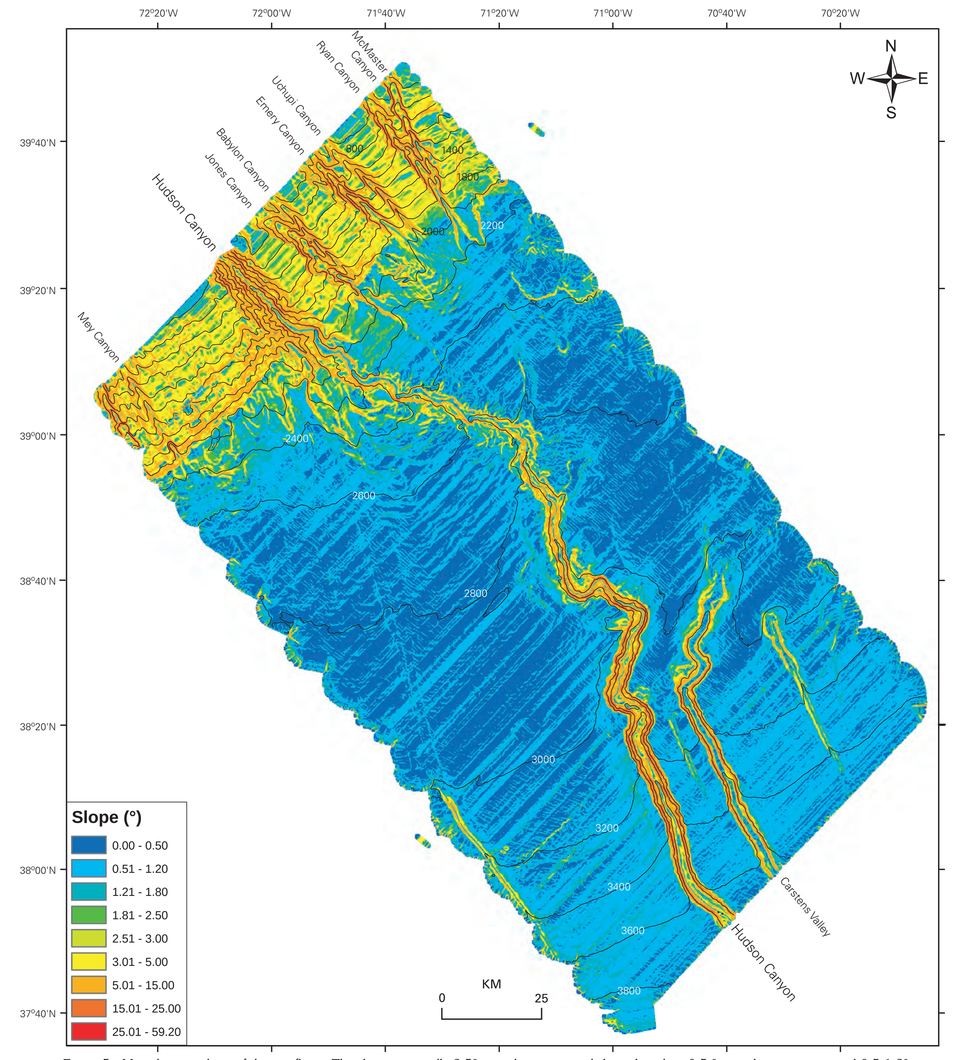

Figure 5. Map showing slope of the sea floor. The slope is typically 3-5° over the continental slope, less than 0.5 ° over the upper rise, and 0.5-1.2° over the lower rise. The slope of the canyon walls range from 5-25°.

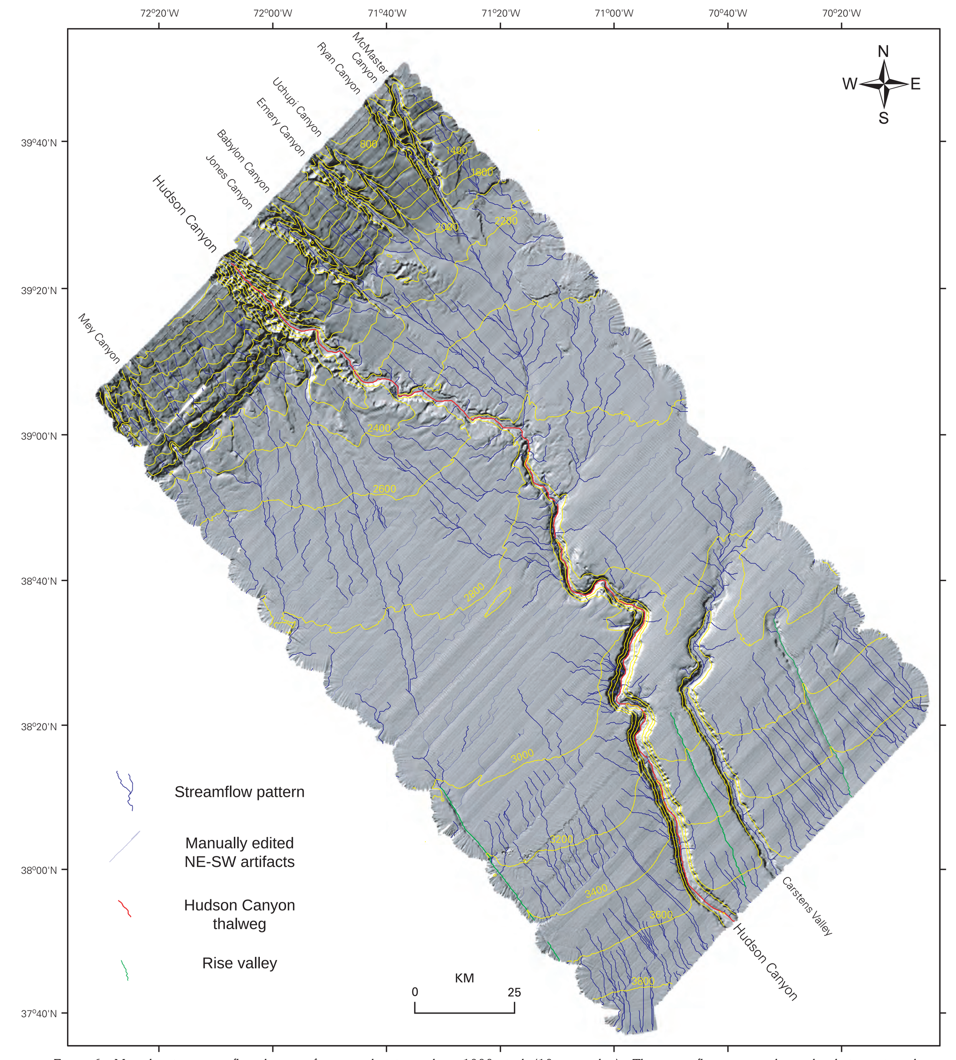

Figure 6. Map showing streamflow drainage for areas draining at least 1000 pixels (10 square km). The streamflow pattern shows the drainage into the Hudson Canyon from the northeast, the down-slope drainage along the mass-transport pathways to the southwest of Hudson Canyon, and downslope drainage characterized by numerous individual pathways on the lower rise. The unnaturally straight northeast-southwest trending streamflows that run parallel to the ship track, especially noticeable in the southwest corner of the map, result from errors in the multibeam data at the outer edges of the swaths.

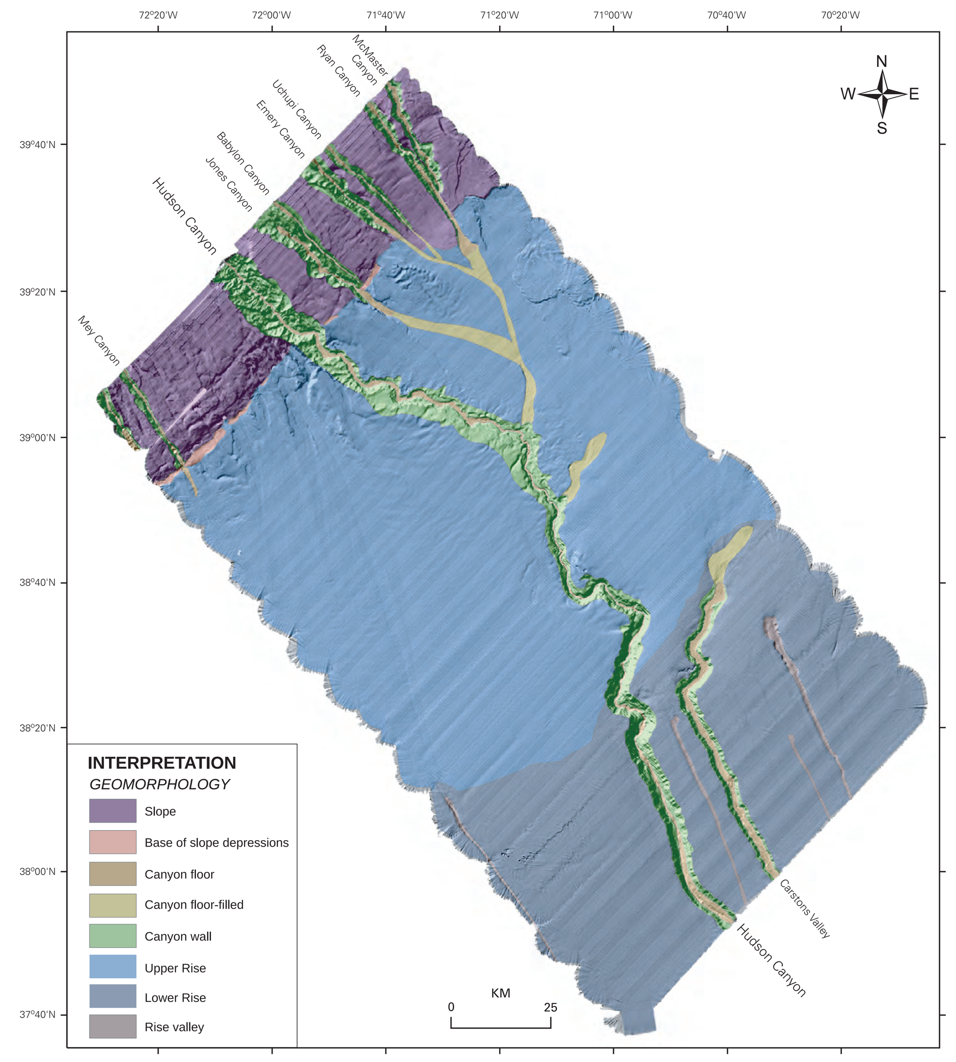

Figure 7. Geomorphic provinces identified in the study area.

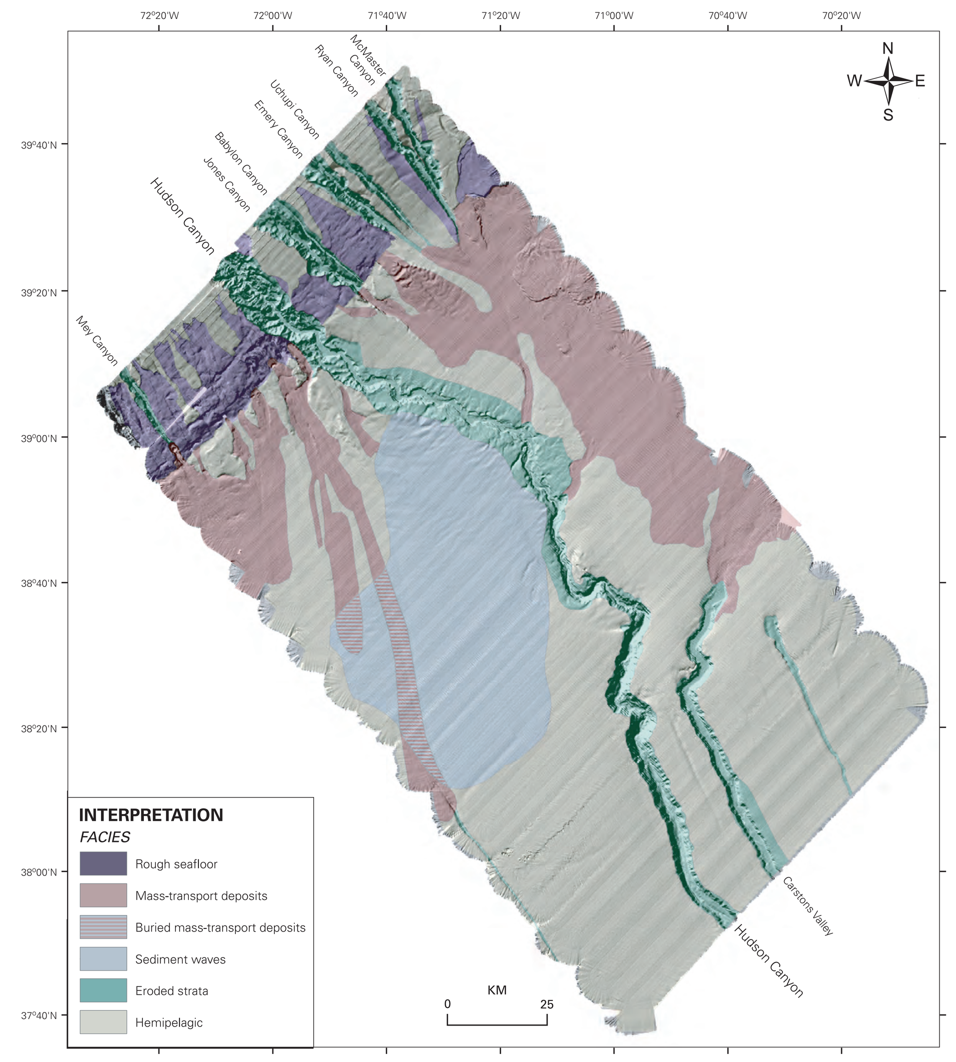

Figure 8. Map of sea-floor environments based on backscatter intensity and subbottom characteristics revealed in widely spaced 3.5-kHz subbottom profiles.

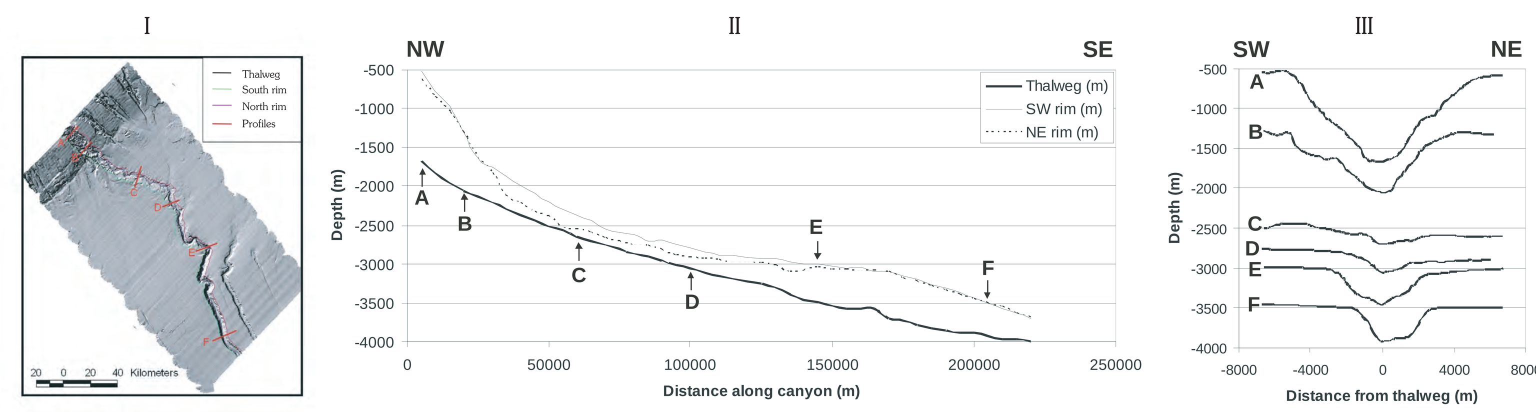

Figure 9. Profiles showing the morphology of Hudson Canyon. Map (I) shows the location of the profiles shown in panels II and III. Panel II shows profiles along the thalweg of Hudson Canyon as well as along the northeastern and southwestern rims of the canyon. The profiles are based on measurements every 5-km along the thalweg and coinciding measurements on the two canyon rims from lines perpendicular to the thalweg. The canyon has the most relief on the upper continental slope, the least relief on the upper rise along the stretch of the canyon adjacent to the sediment-wave field, and increased relief on the lower rise. Cross-canyon profiles nearly perpendicular to the canyon thalweg (III) also illustrate the change in canyon relief across the survey area. Locations of profiles in Panel III are shown on the map (I) as well as by the lettered arrows on Panel II.

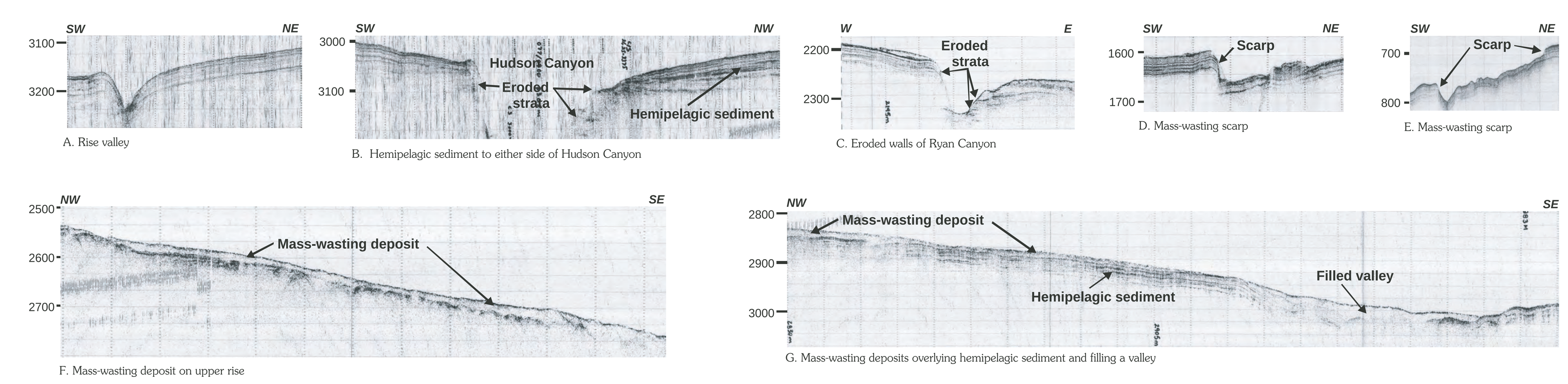

Figure 10. High-resolution seismic profiles showing (A) a lower continental rise valley that is cut into hemipelagic sediment and maintained by preferentially reduced sedimentation within the valley, (B) outcrop of older strata on the walls of Hudson Canyon and hemipelagic deposits to either side of the canyon, (C) outcrop of older strata on the walls of Ryan Canyon where it crosses the lower continental slope, (D) mass-wasting scarp on the lower continental slope northeast of Hudson Canyon, (E) mass-wasting scarp on the middle continental slope southwest of Hudson Canyon, (F) mass-transport deposit on the continental rise northeast of Hudson Canyon showing the deposit's seismically transparent nature and rough surface, and (G) mass-transport deposit overlying hemipelagic sediment and partially filling a valley on the upper continental rise. Profile locations shown in Figure 2.

Mercator projection

World Geodetic System 1984
Longitude of central meridian 75° W; latitude of true scale 40° N.
False easting 0 m; false northing 0 m.

This map is not intended for navigational purposes.

SCALE 1:300,000
ONE CENTIMETER ON THE MAP REPRESENTS 3000 METERS ON THE SEA FLOOR

TOPOGRAHIC CONTOURS IN METERS; INTERVAL VARIES
DATUM MEAN LOWER LOW WATER

Sheet 2.—Backscatter intensity draped over sea floor topography in shaded relief view, with topographic contours.

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