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The Continental Slope off New England: A Long-Range Sidescan-Sonar Perspective

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Abstract

The first continuous overview of a large segment of the continental slope and rise off the northeastern United States has been obtained using the GLORIA II long-range sidescan-sonar system. Extensive dissection by canyon and gully systems and evidence of possible large-scale sediment sliding are seen on the slope. The style and degree of incision, as well as the numbers and locations of canyons, have been found to differ significantly from previously published maps. It is suggested that the slope is a significant source of the sediment that has been deposited on the rise, and that some abrupt changes in the courses of canyons may be the result of local structural control.

Introduction

A 500-km-long segment of the continental slope and upper continental rise southeast of New England (Fig. 1) was surveyed in 1979 by the U.S. Geological Survey (USGS) in cooperation with Great Britain's Institute of Oceanographic Sciences (IOS) by means of the GLORIA II long-range sidescan-sonar system. This IOS system [1,2] scans the sea floor for distances of 10–15 km on each side of the ship's track. Sonar images collected with this system constitute the first continuous overview of the ocean bottom in the New England slope and rise area, and provide new information about the regional morphology of that part of the continental margin.

The first small-scale bathymetric map of the continental slope off the northeastern part of the United States was published in 1939 by Veatch and Smith [3]. Their map covers only the upper slope from Lydonia Canyon to Hydrographer Canyon and is based on widely spaced echo-sounder profiles. They show a pinnate drainage pattern with steep divides between canyons. The more recent and widely used National Ocean Survey (NOS) bathymetric charts show a very different style of canyon and gully development. The pattern is most nearly dendritic, although in places it resembles a deranged drainage pattern. Large shelf-indenting canyons, which run onto the rise and are separated by rounded hills and promontories, dominate these charts. The GLORIA images discussed here reveal a pinnate drainage style similar to that mapped by Veatch & Smith [3] but deviate significantly from the NOS charts in the style and degree of incision as well as locations and trends of canyons.

The map in Figure 2 is an interpretation of geomorphic features from the GLORIA II long-range sidescan-sonar data. The interpretation was enhanced by using single-channel seismic-reflection data collected simultaneously with the sidescan data [4,5] and during two previous cruises [6,7]. This geomorphic map shows the locations and trends of morphologic features. Because the sidescan-sonar coverage is continuous, problems inherent in interpolating between conventional echo-sounder lines are eliminated, and the areal extents of surficial features can be more accurately mapped.

Discussion

The GLORIA II data from the continental slope off Georges Bank reveal a herringbone pattern of strong and weak reflections in water depths shallower than 1,500 m (Fig. 3). This pattern is interpreted as representing networks of gullies incised in the walls of submarine canyons and resembles the pinnate drainage patterns found subaerially in fine-grained sediments. Similar features have been seen in sonographs from the continental slope off western Europe [2,8–10] and from other parts of the eastern United States continental slope [11–

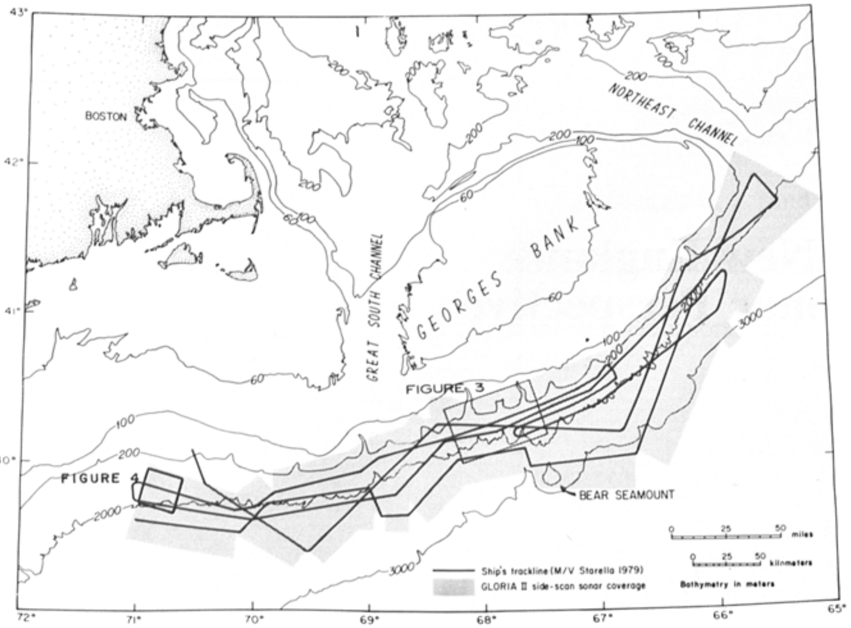

Figure 1. Location map showing extent of GLORIA II coverage. Heavy solid lines represent ship's trackline along which GLORIA II sonographs and airgun and 10 kHz echo-sounder profiles were collected. The area covered by the GLORIA II images is shaded.

13]. These canyon-and-gully systems resemble the terrain depicted by Veatch and Smith [3] in their 1939 map.

Closer inspection of the GLORIA images reveals variation in the density of gullies along the continental slope. An abrupt change takes place in the vicinity of Hydrographer Canyon. West of Hydrographer Canyon, the number of canyons and gullies decreases (see Fig. 2). West of Veatch Canyon, the GLORIA coverage is incomplete, but the sonographs suggest that the density of incision by canyons and gullies along the upper slope is less than it is to the east of Hydrographer Canyon. This decrease in canyon and gully occurrence is accompanied by a change in the profile of the slope. East of Hydrographer Canyon, where canyons and gullies are numerous, the slope exhibits a distinct shelf break and a concave profile. West of Hydrographer Canyon, the changes in slope angle are more gradual, and the slope is broader and less steep.

Gullies intersect the canyon axes at angles ranging from 45° to 90°. Small angles are dominant on the steep upper part of the slope, whereas large angles are more common on the lower part. Most gullies are 1–5 km long, and some large ones have tributaries. The gullies are more numerous than commonly thought [14,15]; two or three dozen have been observed on both sides of the upper 30 km of some of the large canyons, such as Lydonia, Oceanographer, and Powell Canyons. Individual gullies are generally less than 1 km apart and, on the deeply incised upper slope, the gullies are separated by steep-sided divides.

The canyons in much of the area are so closely spaced that the heads of the gullies associated with adjacent canyons meet at the crests of ridge-like intercanyon divides. An estimated 80% of the upper slope is dissected by canyon and gully systems. The lower slope and upper rise are much less extensively dissected. There, canyon axes can be as much as 30 km apart, as opposed to the typical 5 km spacing on the upper slope.

In general, the canyons in the study area run directly downslope. However, several exceptions were found. Some canyons (Oceanographer and Gilbert Canyons) turn as they reach the base of the slope and run obliquely across the upper rise. Other canyons (Lydonia, Gilbert, and Heezen Canyons) make sharp turns as they traverse the slope. Many canyons end before they reach the rise, and others merge with adjacent canyons. Some of the canyons seen on the rise do not appear to be connected to canyons on the slope. These sharp turns and midslope endings suggest local structural control.

Most scarps shown in Figure 2 are parallel to and face canyon axes. Exceptions were found on the slope and upper rise west of Alvin Canyon and on the slope and upper rise between Nygren and Munson Canyons. In the area west of Alvin Canyon, the presence of several downslope-facing scarps (Fig. 4) suggests that large amounts of slope material may have moved downslope. MacIlvaine and Ross [16] reported the existence in this area of numerous slump scars using seismic profiles, bottom photographs, and direct observations from a submersible. Arcuate scarps have also been seen in this area on midrange sidescan-sonar records (D. W. O'Leary, personal communication). Between Nygren and Munson Canyons, a broad, steep-sided trough extends downslope from downslope-facing scarps (Fig. 2). This feature, also noted on seismic profiles (D. W. O'Leary, personal communication), may represent a large slide scar.

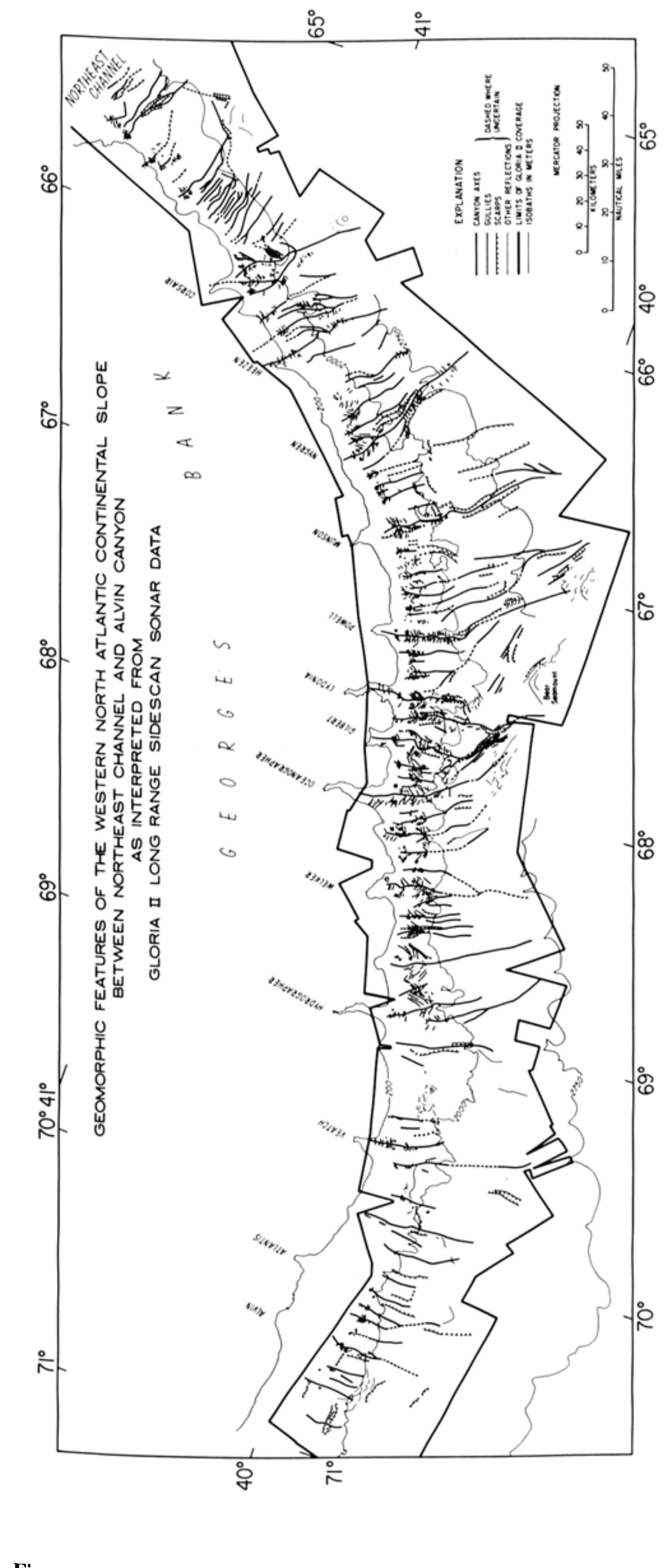

Figure 2. Morphologic features of the continental slope seaward of Georges Bank based on the interpretation of GLORIA II long-range sidescan sonographs and supported by high-resolution single-channel seismic profiles. See text for further explanation and discussion. After Scanlon [4]. Contours from bathymetric charts by Canadian Hydrographic Service and U.S. Department of Commerce, National Ocean Survey.

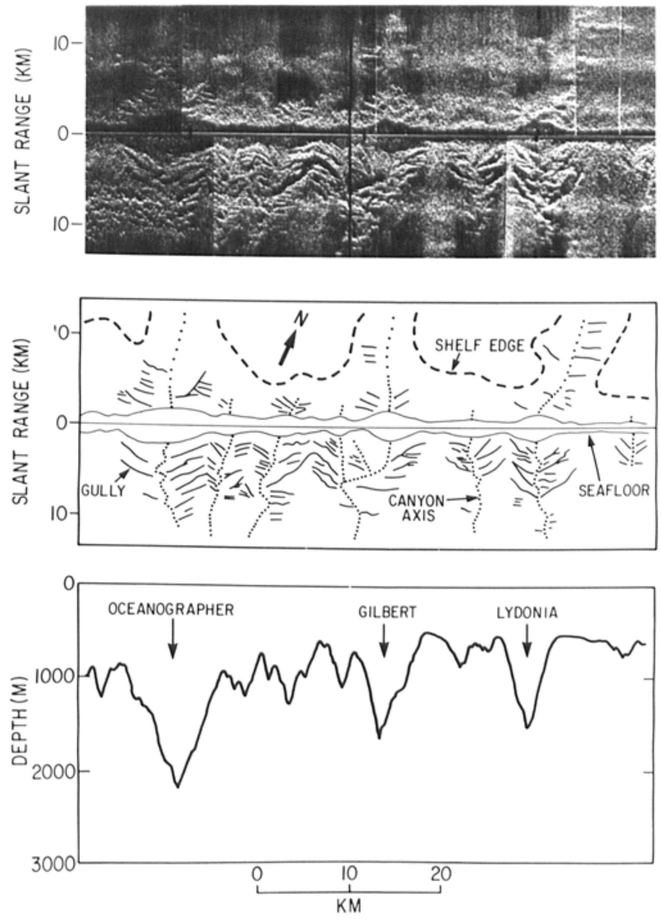

Figure 3. Top, GLORIA II sonograph (port and starboard) of the upper continental slope between Lydonia and Oceanographer Canyons, showing extensive canyon and gully development. Center, Interpretive line drawing of the sonograph. Bottom, Depth profile from seismic profile taken along ship's trackline. See Figure 1 for location.

Conclusions

The upper part of the continental slope (shallower than 1,500 m) is closely dissected by canyon and gully systems. The canyons are more numerous and the etching more extensive than previously indicated on bathymetric charts. The excavation of these gullies represents the removal of a large volume of sediment. This implies that the upper slope is the source of a significant percentage of the sediment that has moved down the canyons. In addition, two areas of possible large-scale sediment sliding are indicated: one west of Alvin Canyon and one between Nygren and Munson Canyons. Although some canyons can be traced for considerable distances across the rise, others end before reaching the base of the slope. Some channels observed on the upper rise are not connected to canyons on the slope, and several canyons change course abruptly. Local structural control is sug-

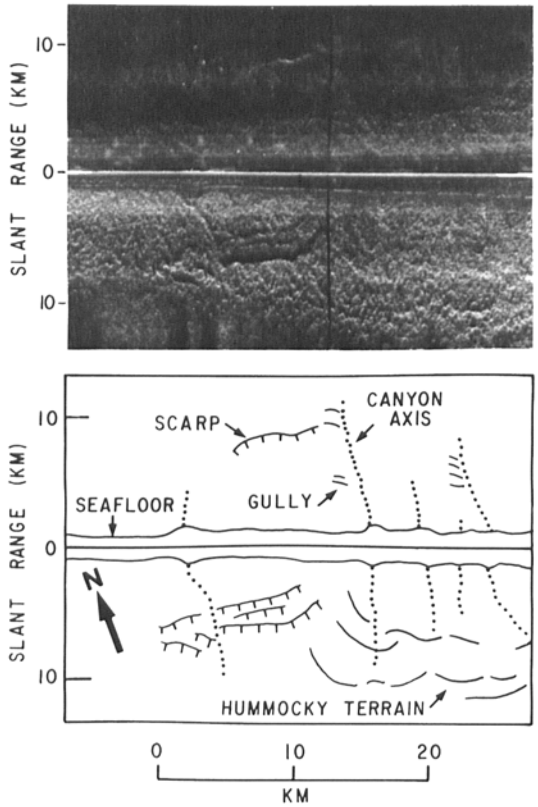

Figure 4. Top, GLORIA II sonograph (port and starboard) of part of the continental slope west of Alvin Canyon showing several downslope-facing scarps. Bottom, Interpretive line drawing of the sonograph. See Figure 1 for location.

gested. Finally, this study demonstrates the utility of the GLORIA II long-range sidescan system as a tool for large-scale reconnaissance mapping of the continental slope.

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