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Geomorphic Features of the Western North Atlantic Continental Slope between Northeast Channel and Alvin Canyon as interpreted from GLORIA II Long-Range Sidescan-Sonar Data

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INTRODUCTION

Complete sidescan-sonar coverage of a 500-km-long segment of the Continental Slope and upper rise southeast of New England (fig. 1) was obtained in 1979 with the GLORIA II long-range sidescan-sonar system. These sonar images constitute the first continuous overview of this part of the ocean bottom and have provided new information about the regional morphology of the slope and upper rise. Over 100 canyons and their associated gully systems are clearly discernable and many can be traced, uninterrupted, from the shelf edge, across the slope, and onto the rise. The northern flank of Bear Seamount is visible and scarps which may be related to large-scale sediment slumping and sliding have been identified in two locations.

The survey was carried out by scientists from the United States Geological Survey (USGS) and from the Institute of Oceanographic Sciences (IOS) in England using the IOS-developed (Somers and others, 1978) GLORIA II system. GLORIA II is a large (7.75 m long and 0.66 m in diameter), neutrally buoyant fish which is towed about 400 m behind the ship at a depth of 50 m. It can be towed at speeds of up to 18 km/hr and is capable of a slant-range of 30 km to each side giving a maximum of 1,080 km^2 of sonar coverage in one hour. However, because the range was limited by the water depth and the thermal structure of the water column in this area, a slant-range of 15 km to each side was used for much of the survey. Further information on the capabilities of GLORIA II can be found in Somers and others (1978) and Laughton (1981).

METHODS

Ship tracklines (fig. 1) for this survey were laid out to provide considerable overlap of images. Overlapping images, especially those that provide different insonification directions for the same area, are very helpful in the interpretation of the data. The sonographs were photographically stretched to compensate for variations in the ship's speed. The resulting images are approximately isometric, but are not corrected for slant-range distortions. A mosaic at a scale of 1:250,000 was made from these anamorphosed images.

Plate 1 shows a preliminary interpretation of the GLORIA sonographs. High-resolution seismic profiles collected along the GLORIA tracklines (fig. 1) and from other cruises (fig. 2) were used to help identify morphologic features. Since the sidescan images are not slant-range corrected, discrepancies sometimes exist between the apparent positions of a given feature on two overlapping images. In these cases a visual average between the positions in the images and the positions shown in any available seismic profiles was used to define the actual locations.

The heavy solid lines in plate 1 represent the axes of canyons, the axis of a canyon being the "line that follows the trend" (Bates and Jackson, 1980) of the canyon and about which related morphologic features are more or less symmetrically distributed. In general, this is also the thalweg of the canyon, although that is impossible to determine in areas where there is only sidescan coverage with no seismic profiles for control. The medium solid lines represent the axes of the secondary canyon features called "gullies" in this report. The hachured lines, termed "scarps" in plate 1, represent narrow elongate zones having a slope greater than that of the surrounding terrain. Other reflections of uncertain origin are represented in plate 1 by light solid lines.

DISCUSSION

One of the most striking features of the GLORIA II data from the Continental Slope off Georges Bank is the herringbone pattern of strong and weak reflections on the upper slope in water depths shallower than ~1,500 m (fig. 3). This pattern is interpreted to represent networks of gullies incised in the canyon walls. Similar features have been seen in sonographs of the Continental Slope off western Europe (Belderson and Stride, 1969; Belderson and Kenyon, 1976; Kenyon and others, 1978; and Laughton, 1981) and from other parts of the U.S. Atlantic Continental Slope (Teleki and others, 1981; McGregor and others, 1982; Twichell and Roberts, in press). These gullies intersect the canyon axes at angles between about 45° and 90°, the lower angles tending to predominate on the steep upper part of the slope while the near-right-angle intersections are more common on the lower part of the slope. Most of the gullies are between 1 and 5 km in length. Some of the larger ones show tributary gullies. The gullies are more numerous than commonly thought (see, for example, National Oceanic and Atmospheric Administration (NOAA) maps NOS NK 19-12 and NOS NK 19-11), two or three dozen gullies being found on both sides of the upper 30 km of some of the larger canyons (e.g., Lydonia, Oceanographer, and Powell Canyons). Individual gullies are generally less than a kilometer apart and on the deeply incised upper slope the gullies are separated by steep-sided divides.

The canyons in the study 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 these canyon and gully systems; smooth, undissected intercanyon areas exist almost exclusively on the lower slope and upper rise.

The GLORIA II images show numerous small canyons and gullies which are not found on the most recent bathymetric charts (NOAA/NOS maps NK 19-9, NK 19-10, NK 19-11, NK 19-12, NJ 19-1, NJ 19-2) of the area. The most striking example is the canyon between Gilbert and Lydonia Canyons (fig. 3). This canyon was originally mapped and named (Jigger Canyon) by Veatch and Smith (1939), but it is not found on the current NOS charts.

The canyon axes on the upper slope are defined on the GLORIA sonographs by the convergence of gully networks, but it is impossible to resolve the details of the canyon floors on the upper slope at this scale. Near the base of the slope and on the upper rise, where the canyons are wider and less deeply incised, the broad flat floors appear to be bounded by relatively low (100-300 m) steep walls. One of these channels (immediately east of Oceanographer Canyon) splits into what are interpreted to be distributary channels as it reaches the upper rise (pl. 1).

In general, the canyons which indent the shelf are deeper than the others and can be traced further seaward. However, this is not true in every case. Some canyons, such as Jigger Canyon (between Lydonia and Gilbert, pl. 1), do not indent the shelf but are cut deeper into the slope and extend further onto the rise than the adjacent "large" canyons. On the other hand Veatch Canyon does indent the shelf, but cannot be traced onto the rise. In some places (e.g., below Powell Canyon and below Munson Canyon) discontinuous channels are seen on the lower slope and upper rise. Some extend for considerable distances onto the rise yet are not continuous with canyons on the upper slope.

These GLORIA II images also show that some canyons have very crooked courses. Oceanographer Canyon, for example, turns toward the east as it reaches the rise (pl. 1), and Gilbert Canyon makes some nearly right-angle turns as it traverses the slope.

Most of the scarps shown in plate 1 are parallel to and face canyon axes. There are two notable exceptions: on the slope and upper rise west of Alvin Canyon and on the slope and upper rise between Nygren and Munson Canyons. West of Alvin Canyon the Continental Slope is wider and more gently sloping than it is in any other part of the study area. Canyon and gully formation appear to be somewhat less pronounced here (see pl. 1), although it should be noted that the GLORIA II coverage does not extend to the shelf break here as it does in the rest of the study area. Here also, the presence of several downslope-facing scarps and an area of irregular, hummocky reflections (light solid lines in pl. 1) suggest that large amounts of slope material may have been removed by slumping or sliding. MacIlvaine and Ross (1979) report the existence in this area of numerous slump scars as detected by them on seismic profiles, in bottom photographs, and by direct observation from submersible. Several of the larger scarps west of Alvin Canyon as seen in GLORIA II images, are shown in plate 1.

Between Nygren and Munson Canyons a broad, scarp-bounded trough extends downslope from downslope-facing scarps (pl. 1). This feature, also noted on seismic profiles (D.W. O'Leary, pers. commun., 1982) may represent a large slide.

The northern part of Bear Seamount is visible in the sonographs of the Continental Rise south of Lydonia Canyon. The strong, arcuate reflection (pl. 1) of the steep hard flank of the seamount is shadowed by two similar but weaker reflections. These may be the result of a ringing effect (Belderson and others, 1972; Laughton, 1981) due to the high amplitude of the reflection.

CONCLUSIONS

The resolution of the GLORIA II system and the nature of sidescan data are such that a complete depiction of the Continental Slope cannot be produced from the data described here. However, several significant contributions to the picture have been made.

The upper part of the Continental Slope (shallower than 1,500 m) is closely dissected by canyon and gully systems. There are more canyons and much more extensive gullying than is commonly thought.

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 which has moved down the canyons.

While some canyons can be traced for considerable distances across the rise, others end before reaching the base of the slope, and one appears to divide into distributary channels as it reaches the rise.

The channels observed on the upper rise are not all connected to canyons on the slope. This may indicate a distinct and different erosional regime on the rise.

Two areas of possible large-scale sediment sliding, one west of Alvin

Canyon and one between Nygren and Munson Canyons, have been pointed out for further study.

Finally, the GLORIA II long-range sidescan system has proved to be a valuable tool for large-scale reconnaissance mapping of the Continental Slope.

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REFERENCES CITED

Bates, R. L., and Jackson, J. A., eds., 1980, Glossary of geology (2nd edition): Falls Church, VA, American Geophysical Institute, 749 p.

Belderson, R. H., and Kenyon, N. H., 1976, Long-range sonar views of submarine canyons: Marine Geology, v. 22, p. M69-M74.

Belderson, R. H., Kenyon, N. H., Stride, A. H., and Stubbs, A. R., 1972, Sonographs of the sea floor: New York, Elsevier, 185 p.

Belderson, R. H., and Stride, A. H., 1969, The shape of submarine canyon heads revealed by ASDIC: Deep-Sea Research, v. 16, p. 103-104.

Kenyon, N. H., Belderson, R. H., and Stride, A. H., 1978, Channels, canyons, and slump folds on the continental slope between Southwest Ireland and Spain: Oceanologica Acta, v. 1, no. 3, p. 369-380.

Laughton, A. S., 1981, The first decade of GLORIA: Journal of Geophysical Research, v. 86, no. B12, p. 11,511-11,534.

MacIlvaine, J. C., and Ross, D. A., 1979, Sedimentary processes of the Continental Slope of New England: Journal of Sedimentary Petrology, v. 49, no. 2, p. 0563-0574.

McGregor, B., Stubblefield, W. L., Ryan, W. B. F., and Twichell, D. C., 1982, Wilmington submarine canyon: a marine fluvial-like system: Geology, v. 10, p. 27-30.

Somers, M. L., Carson, R. M., Revie, J. A., Edge, R. H., Barrow, B. J., and Andrews, A. G., 1978, GLORIA II - An improved long-range sidescan-sonar: in Oceanology International 78, London, 1978, BPS Exhibitions Ltd., p. 16-24.

Teleki, P. G., Roberts, D. G., Chavez, P. S., Somers, M. L., and Twichell, D. C., 1981, Sonar survey of the U.S. Atlantic Continental Slope; acoustic characteristics and image processing techniques: Offshore Technology Conference, 13th, Houston, TX, 1981, Proceedings, p. 91-95, 10 figs.

Twichell, D. C., and Roberts, D. G., Morphology, distribution, and development of submarine canyons on the United States Atlantic Continental Slope between Hudson and Baltimore Canyons: Geology, in press.

Veatch, A. C., and Smith, P. A., 1939, Atlantic submarine valleys of the United States and the Congo Submarine Valley: Geological Society of America Special Paper No. 7, 101 p.

FIGURE CAPTIONS

Figure 1. Location map showing extent of GLORIA II coverage discussed in this report. Heavy solids lines represent ship's trackline along which GLORIA II sonograms and airgun and 10 kHz echo-sounder profiles were collected. Shaded area represents the area covered by the GLORIA II images.

Figure 2. Map showing location of high-resolution single-channel seismic profiles used to aid in the interpretation of GLORIA II images.

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 shown above.
Bottom: Depth profile from seismic profile taken along ship's trackline.

Plate 1. Morphologic features of the Continetal 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.

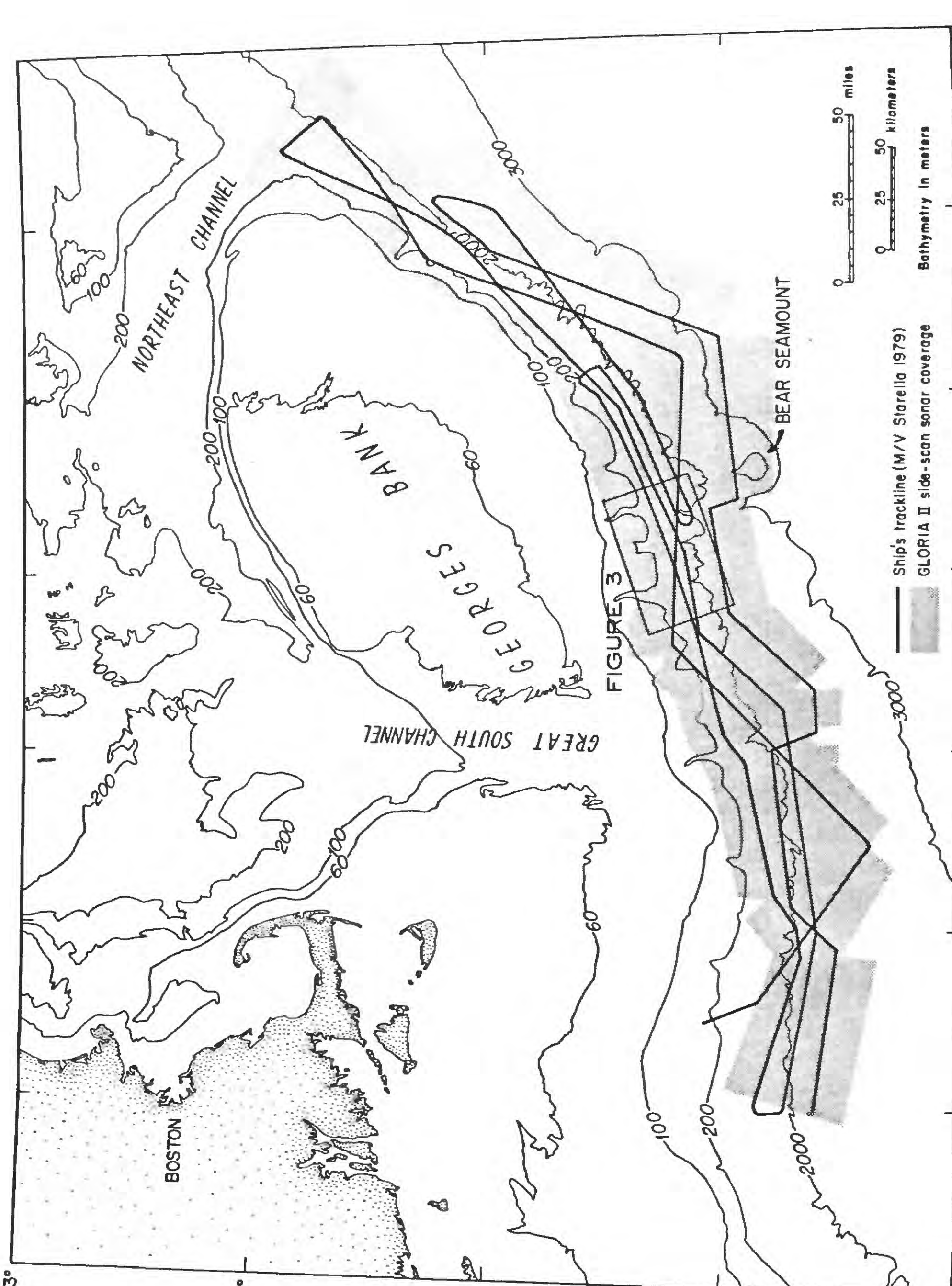
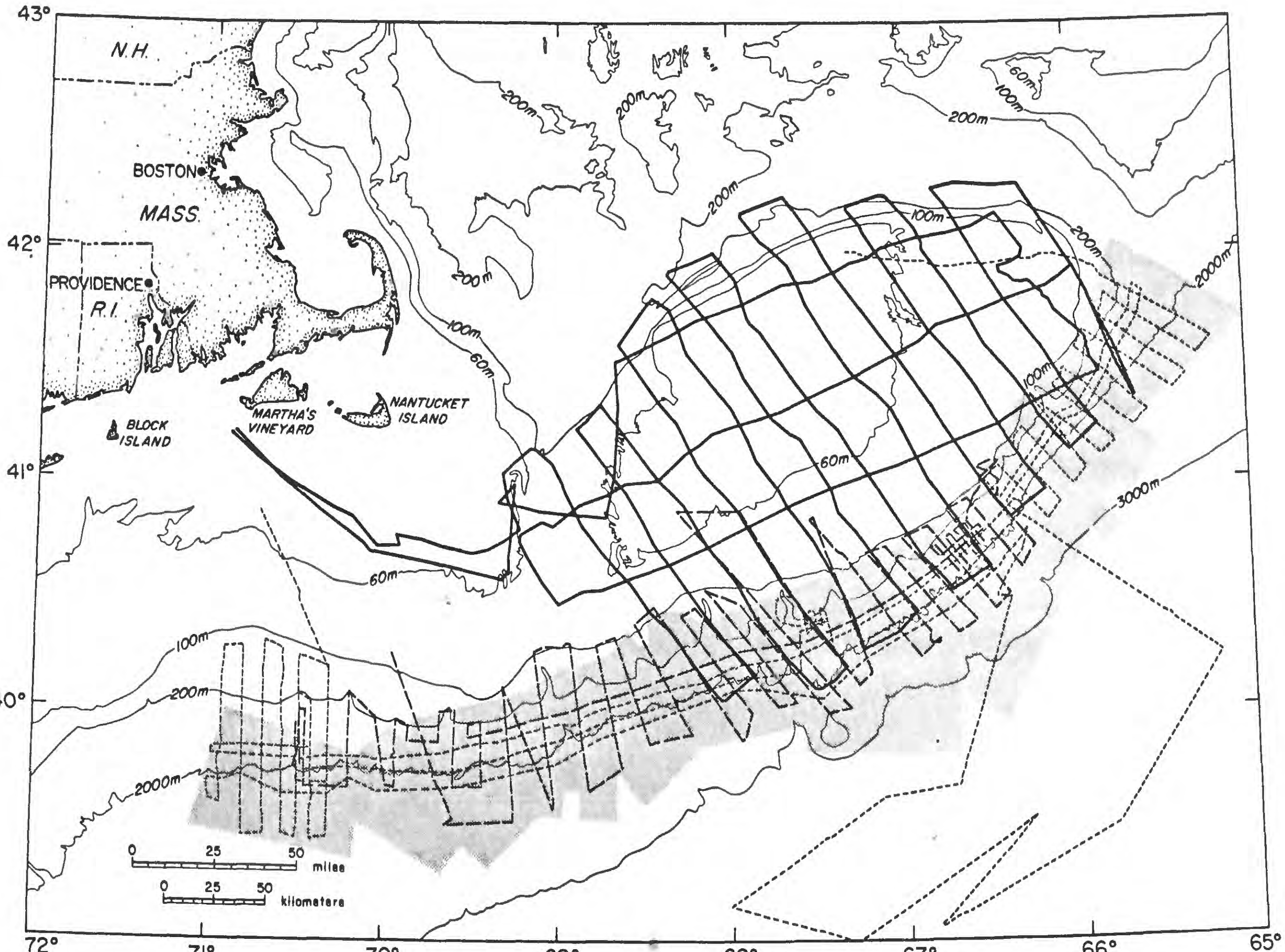

NORTHEAST CHANNEL
GEORGES BANK
GREAT SOUTH CHANNEL
FIGURE 3
BEAR SEAMOUNT
BOSTON
Ship's trackline (M/V Starella 1979)
GLORIA II side-scan sonar coverage
0 25 50 miles
0 25 50 kilometers
Bathymetry in meters
43°
42°
41°
40°
72°
71°
70°
69°
68°
67°
66°
65°
60
100
200
2000
3000

Figure 1



TRACKLINE LOCATIONS

R/V FAY 1975
R/V ISELIN 1978
R/V GILLISS 1979
M/V STARELLA 1979 extent of GLORIA coverage

Figure 2

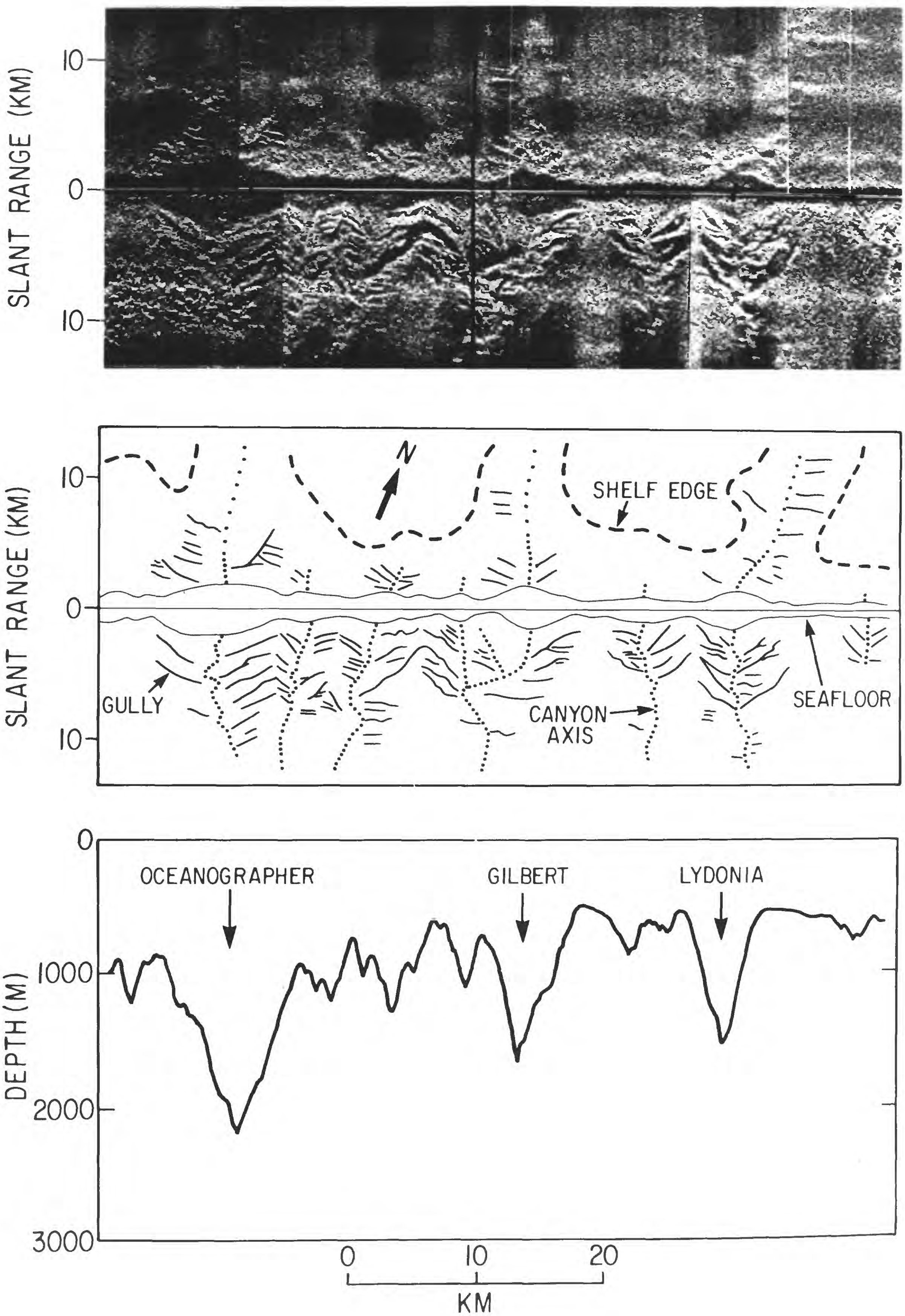

SLANT RANGE (KM)
10
0
10
N
SHELF EDGE
GULLY
CANYON AXIS
SEAFLOOR
OCEANOGRAPHER
GILBERT
LYDONIA
DEPTH (M)
0
1000
2000
3000
0
10
20
KM

Figure 3