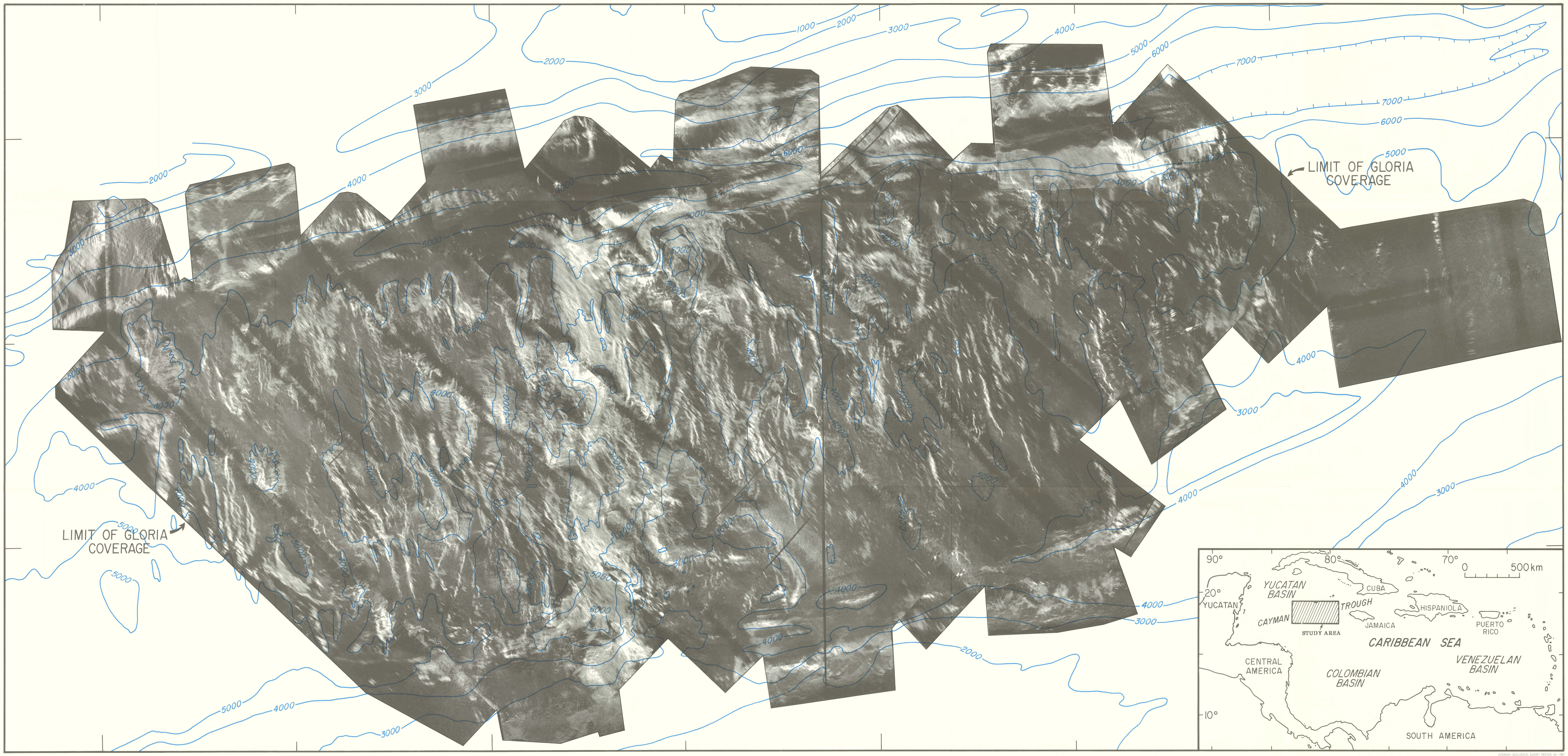

Bathymetry modified from Jacobs and others (1989)
Not to be used in navigation

MERCATOR PROJECTION
SCALE 1:402,000 AT LAT 18°30' N.

0 10 20 30 40 50 60 70 80 90 100 KILOMETERS

0 10 20 30 40 50 NAUTICAL MILES

BATHYMETRIC CONTOURS IN METERS
CLOSED, HACHURED CONTOURS INDICATE DEPRESSIONS

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GLORIA SIDESCAN-SONAR IMAGERY AND GENERALIZED BATHYMETRY

INTRODUCTION

In 1985, the U.S. Geological Survey (USGS), in cooperation with the Institute of Oceanographic Sciences (IOS) of the United Kingdom, conducted a four-day seismic, magnetic, and GLORIA (*Geological LOng Range Inclined Asdic*) sidescan-sonar survey of the central Cayman Trough in the Caribbean Sea. A seismic and gravity survey was conducted in the same area by the USGS in 1987. The results of these and earlier surveys (sheet 3, tracklines) are published as a series that includes three maps (GLORIA mosaic, interpretation, and ships' tracklines); a magnetic anomaly map (MF-2083-B [Dillon and others, in press a]); and a free-air gravity map (MF-2083-C [Dillon and others, in press b]). Bathymetry used in the series is from Jacobs and others (1989).

GEOLOGIC SETTING

The Cayman Trough is an east-oriented strike-slip transform-spreading system (Holcombe and others, 1973) that has formed the northwestern Caribbean plate boundary since Eocene time (Molnar and Sykes, 1969; Malfait and Dinkelman, 1972). Approximately midway between the eastern and western ends of the trough, at long 81°40' W., is a north-trending rift valley. The Oriente transform fault lies along the northern wall of the trough east of the rift valley, forming the boundary between the continental rocks of the Cayman Ridge and the oceanic rocks of the trough (Ewing and others, 1960; Eggler and others, 1973; Perfit, 1977). West of the rift valley the Swan Island transform fault forms the southern margin of the trough and generally follows the contact between the continental rocks of the Nicaraguan Rise and the oceanic rocks of the trough. The rift valley is located on the crest of the Mid-Cayman Rise (Holcombe and others, 1973), a broad, elevated central region of the Cayman Trough that is about 400 km wide (sheet 2, profile 1). The area mapped for this series covers most of the Mid-Cayman Rise.

DATA COLLECTION

The GLORIA II digital sidescan-sonar system, described by Somers and others (1978), was used to survey the central region of the Cayman Trough approximately between long 79°30' and 83°00' W. On each side of the GLORIA instrument are two rows of transducers, each containing 30 elements that operate between 6.2 kilohertz (kHz) on the starboard side and 6.8 kHz on the port side. The tracklines are oriented about 135° or about 45° to the two principal sea-floor topographic trends--the north-trending ridges and the basins that dominate the floor of the Cayman Trough, and the east-trending north and south walls of the trough. Experience has shown that a track angle of 45° to a topographic trend provides the clearest image. The maximum width of the sidescan swath on the sea floor at water depths greater than 3,000 m is about 40 km (20 km on each side of the towed instrument). During this survey, an average of about 50 percent swath overlap (on one side) was maintained in order to eliminate data gaps and to facilitate image enhancement. Consequently, the trackline spacing is about 30 km. Data collected on the right side of the track do not have the clear resolution realized on the left swath.

A two-channel 80-in^3 airgun seismic system provided along-track subsurface control, and 10-kHz and 3.5-kHz echo sounders were used for detailed bathymetric control. Total magnetic field was measured by a towed proton-precession magnetometer system.

Navigation was provided by Global Positioning System (which functioned approximately 12 hours per day), by transit satellites, and by Loran C. Loran C was of marginal value in this area.

DATA PROCESSING

Techniques to correct for geometric and radiometric distortions and to enhance the sidescan-sonar images (Chavez, 1986) were applied to the Cayman Trough data, which then were digitally compiled into a map-coordinated system to create the sidescan-sonar mosaic. Geometric corrections are applied to distortions created by water-depth offsets and slant range. Because the GLORIA system starts recording data immediately after the acoustic signal is transmitted, the original images show a dark band on each side of the ship's track (a number of pixels that are not part of the sea-floor image) whose width is proportional to the water depth beneath the ship. The water-depth offset program calculates the location on each side of the ship's track where the nonimaged pixels were mapped. The slant-range correction removes distortions created by differences in the near- and far-range depression angles by mapping target reflections at their true distance from the ship's track, assuming planar sea bottom.

Anamorphic corrections are applied so that along- and across-track image scales are the same. The across-track pixel resolution for a 30-s repetition rate is about 50 m, but along track, it is about 125 m. Corrections were made to remove this distortion as well as for variations in the ship's speed.

Radiometric corrections are used to change the DN (digital number) value rather than the spatial location or pixel distortion discussed above. These corrections minimize effects on DN value such as spherical spreading of sound waves and variations in transducer response with reception angle.

Data processing requires reconciliation of the ship's track relative to a series of control points, usually four, along an approximately straight segment of the ship's track, so the track on the processed mosaic may not correspond precisely with the ship's true location at all points. Differences in map location of up to 2 km (about 0.5 cm on the mosaic) were noted between features on this mosaic and the same features as mapped using a U.S. Navy swath-bathymetry system (CAYTROUGH, 1979). In addition, ridge crests mapped from strong arrivals on sidescan-sonar images may not correspond to ridge crests located on the bathymetric map because the sidescan-sonar returns may be reflecting from rock outcrops on the side of ridges rather than on the crests. The orientation of outcropping rock surfaces (strong reflection lineament) may not necessarily parallel that of the ridge crests.

COMMENTS ON THE GLORIA MOSAIC

The white areas on the mosaic represent strongly reflected acoustic returns and dark areas represent weakly reflected returns. The strength of the acoustic return is a function of (1) the acoustic impedance contrast at the sea floor or within the upper few tens of centimeters of sediment, (2) the angle of incidence, (3) sea-floor roughness (minimum of 4 cm of relief for GLORIA), and (4) water depth (acoustic attenuation and background noise).

The mosaic interpretation presented herein (sheets 2 and 3) is a product of the sidescan-sonar survey, seismic profiles, bathymetric mapping, and samples of bottom materials. Tracklines of seismic profiles used for the interpretation are printed on the same sheet with the interpretation (sheet 3). The seismic and bathymetric data provide the control for mapping the abyssal plains and sediment ponds where the sidescan-sonar imagery is not definitive and for interpretations that lie outside the area of sidescan-sonar coverage. These sidescan images do not clearly differentiate between surfaces covered with draped pelagic sediments or ponded turbidites, or abyssal plains. The seismic and bathymetric data also provide depth information useful in determining whether abyssal plains noted on several tracklines are connected or isolated. On the other hand, the sediment shelf on the north wall of the trough (Cayman Ridge) can be mapped on the mosaic in detail and with confidence unattainable with only seismic and bathymetric data. The Oriente transform fault is another feature that can be traced and mapped with more accuracy using the sidescan-sonar mosaic.

The two circular features located in the northeastern part of the sidescan-sonar image (at about long 80°40' W., lat 18°58' N., and 80°30' W., 18°58' N.), just south of the Oriente transform fault, appear to overlie the north slope of an escarpment that is capped by high-relief pinnacles. These pinnacles, about 7 km south of the circular features, apparently are unrelated to them. It is probable that the circular features are artifacts of the processing system because they are not apparent on the unprocessed data.

GEOLOGIC INTERPRETATION

Two dominant lineaments are evident in the mosaic: a northerly trend representing morphology resulting from the sea-floor spreading process in the rift valley, and an east-northeasterly trend of the northern and southern boundary walls. The bright, northerly oriented band at long 81°40' W. is caused by strong reflections from the bare-rock surface of the rift valley. The lineaments east and west of the rift valley trend parallel or subparallel to the rift valley, suggesting that there has been little change in the orientation of the spreading system within the survey area. The number and size of the sediment ponds trapped in the valleys between the ridges increases with increasing distance (increasing age) from the rift valley. Excluding the Oriente and Swan Island transform faults, indications of strike-slip faulting in the Cayman Trough are few, and, where evident, displacement does not appear to exceed 10 km.

The outline of the rift valley is well displayed, but details are obscured by the strength of the reflections from the young, bare-rock surface. However, a north-trending line of volcanic structures is evident in the rift valley east of Mt. Dent; they probably formed along the spreading axis. It is not clear whether they are active. The basalt-gabbro contacts located on the east and west walls of the rift valley were mapped using the results of numerous traverses by the deep-sea research submersible *Alvin* (CAYTROUGH, 1979). Particularly bright patches, which correspond to depressions on the multibeam bathymetry, at the northern and southern ends of the rift valley are nodal basins that are characteristic of rift-transform intersections (see Fox and Gallo, 1986, for a summary of the subject). Nodal basins are typically shaped like a right triangle with the hypotenuse facing the direction of the transform motion. This is evident on the sidescan-sonar imagery and the multibeam bathymetry in the Cayman Trough; the hypotenuse of the northern nodal basin faces east-southeast and that of the southern nodal basin faces northwest. East-trending escarpments of oceanic rocks have been mapped and dredged (Perfit, 1977) along the northern and southern margins of the trough at about long 80°25' W. The northern escarpment is capped by north-trending pinnacles, whereas the southern one appears to be a ridge. Although a direct correlation cannot be made, it is possible that the southern escarpment correlates with the east-oriented structures that parallel the southern margin to the west (at about long 81° W).

The northern margin of the Cayman Trough is a steep escarpment of the south flank of the Cayman Ridge. The escarpment is interrupted by a step fault covered with sediment (sheet 2, profile 2). The sediment-covered surface of the fault block (sediment shelf) can be readily and accurately mapped using the sidescan-sonar imagery. The flat surface of the sediment shelf indicates that it was a perched abyssal plain or sediment pond, but subsequently the surface has been tilted southward. A limestone-basalt contact, south of Grand Cayman Island, was mapped using the results from the research submersible *Alvin* (Emery and Milliman, 1980). Farther west, the imagery shows channels of sediment flow from the wall and sediment shelf down to abyssal plains that lie at the base of the wall. The trend and the nature of the surface expression of the Oriente transform fault also can be viewed with unprecedented precision using the sidescan-sonar mosaic. Between long 81° W. and 82°30' W., the boundary between the Cayman Ridge and the Cayman Trough is complicated by the presence of the Oriente Ridge (profile 2), which appears to be an extrusion of serpentinite based on its location, smooth surface, symmetry, and one dredge sample (serpentinite). The sidescan-sonar image recorded only weak returns from the ridge, perhaps because the ridge has both a smooth surface covered with a thin layer of pelagic sediment, and a gentle gradient. The veneer of pelagic sediment was not shown on the map because it is so thin and to include it would have only detracted from the portrayal of the underlying serpentinite ridge.

The southern margin of the Cayman Trough is formed by the northern escarpment of the Nicaraguan Rise, on which there are only small, discontinuous step faults. Numerous sediment-free channels are evident on the wall at about long 80°30' W. The tilted abyssal plain and other sediment accumulations indicate that there has been some recent movement along this margin. Escarpments possibly formed by strike-slip motion can be identified on the sidescan-sonar imagery in the abyssal plain south of the escarpment of oceanic crustal rocks (about long 80°30' W.). The large abyssal plain south of the limits of the mosaic at about long 80° W. was mapped using seismic data (see sheet 3, tracklines). West of the rift valley, there is no recognizable surface expression of the Swan Island transform fault.

In summary, the combination of seismic, bathymetric, and sidescan-sonar data provides the bases for mapping the surface features of the central Cayman Trough with unprecedented accuracy.

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GLORIA SIDESCAN-SONAR IMAGERY AND GEOLOGIC INTERPRETATION OF THE CENTRAL CAYMAN TROUGH, NORTHWESTERN CARIBBEAN SEA

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