DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

U.S. Geological Survey Gulf of Mexico GLORIA Program

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Open-File Report 85-465

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1985

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INTRODUCTION

In 1983, the presidential proclamation of a U.S. Exclusive Economic Zone (EEZ) established Federal jurisdiction over the submerged lands extending 200 nautical miles seaward from the coast of the United States, the Commonwealths of the Northern Mariana Islands and Puerto Rico, the Virgin Islands and other U.S. territories and possessions (Fig. 1A). The EEZ adds over 3 million square nautical miles to our Federal lands, many of which contain potential energy and mineral resources. The vast size of the EEZ, which is approximately 30 percent larger than the subaerial land area of the United States, requires a coordinated national effort to evaluate and develop the potential resources of this area. In response to a basic need to map the EEZ as part of this national effort, the U.S. Geological Survey has begun a mapping program to characterize the sea-floor morphology of the entire EEZ.

As a first step in evaluating the EEZ, the USGS is completing a series of reconnaissance scale maps of the sea-floor morphology of the EEZ, using the GLORIA (Geological Long-range Inclined Asdic) system designed, developed, and operated by the Institute of Oceanographic Sciences (IOS), United Kingdom. GLORIA provides a map view of the sea floor in swaths 30, 45, or 60 km wide. The system is towed at a speed of 15-18 km/hr, allowing 27,700 square kilometers to be mapped per day (an area roughly the size of the State of New Jersey).

Mapping of the EEZ was initiated off the west coast of the United States during the spring and summer of 1984. The area mapped extended from the continental shelf edge to the seaward boundary of the EEZ between the Mexican and Canadian borders. In 1985 the USGS mapping effort will focus on the EEZ in the Gulf of Mexico. Approximately 365,000 square kilometers in the Gulf of Mexico will be mapped from the shelf edge seaward, starting in August and continuing until the middle of October (Fig. 1B). In 1982, a portion of the continental slope (approximately 40,000 square kilometers) seaward of Texas and Louisiana was surveyed using the GLORIA sidescan-sonar system. The data that will be collected in 1985 will be merged with this earlier survey.

A preliminary mosaic of the data will be constructed at a scale of 1:375,000. The sidescan sonar data, which are recorded digitally, will undergo post cruise processing to remove geometric distortions and to enhance the images (Chavez, 1984). Image-enhanced sonographs and geologic interpretations of these data will be published as a USGS Atlas Series: twenty-two 2-degree sheets at a scale of 1:500,000. Single-channel seismic reflection profile data collected during the survey will be included in the Atlas.

GULF OF MEXICO SURVEY

The GLORIA survey of the Gulf of Mexico will be divided into three parts, each focusing on a different region of the Gulf. The MV FARNELLA will depart Miami, Florida, in early August to begin the survey. Leg 1 will

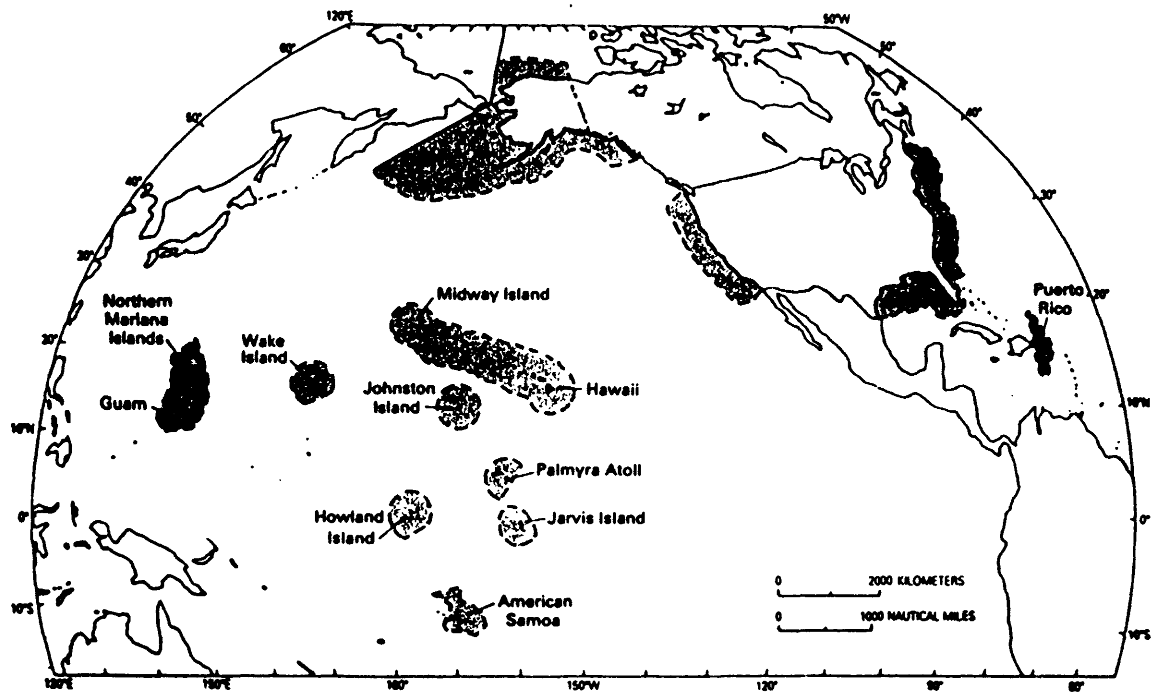

Fig. 1A Exclusive Economic Zone (EEZ) of the United States extending seaward 200 nautical miles from the U.S., the Commonwealths of the Northern Mariana Islands, Puerto Rico and the Virgin Islands, and its territories and possessions.

Proposed GLORIA sidescan sonar survey of the Gulf of Mexico

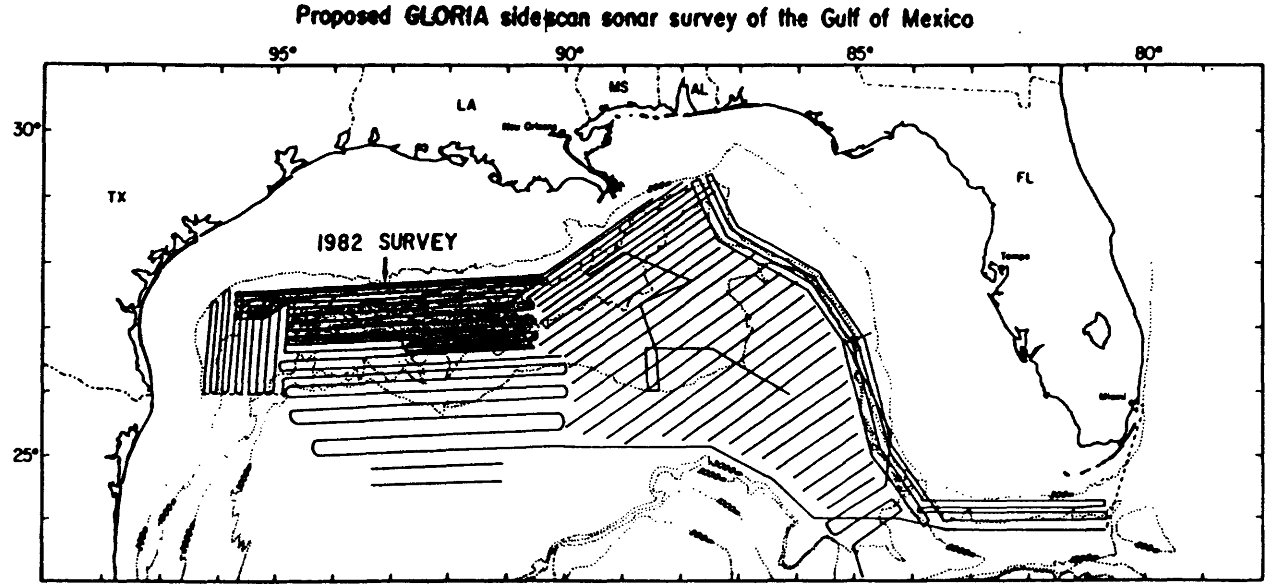

Fig. 1B Proposed tracklines for the 1985 GLORIA survey in the Gulf of Mexico. Shaded area on the slope seaward of Texas and Louisiana is the region surveyed in 1982.

survey in the western Gulf seaward of Texas and Louisiana, abutting the 1982 coverage (Fig. 1B). This initial leg will terminate in New Orleans in early September. Leg 2, immediately following, will focus on the continental slope in the central Gulf seaward of Mississippi and Louisiana, and the Mississippi Canyon and fan system, ending in Tampa, Florida. Leg 3, during early October, will survey the edge of the carbonate platform in the eastern Gulf, concentrating on the West Florida Escarpment and the straits of Florida. After a crew change, the ship will proceed to the Puerto Rico area to survey the Puerto Rico/Virgin Islands EEZ.

A better understanding of the morphology, surficial geology, and sedimentary processes of the continental slope and rise in the Gulf of Mexico is important for evaluating and developing energy resources. Improvements in deep-water drilling technology have turned industry's interests towards exploration in this deep-water area. Results from the GLORIA survey will contribute to a better understanding of the depositional environments of these deep-water areas which will be useful in developing depositional models for exploration purposes and in identifying potentially hazardous areas.

The GLORIA data available from the 1982 survey illustrate some of the Gulf's geomorphic features and highlight the areas to be addressed by the complete survey (Fig. 2). The Gulf of Mexico, a small ocean basin, is geologically diverse. Geologically, the Gulf of Mexico EEZ can be divided into three major sedimentary provinces: a salt tectonic province in the western section, the Mississippi Canyon and Fan system in the central section, and a carbonate province in the eastern section that is separated from the terrigenous Mississippi Fan by the West Florida Escarpment. Each of the cruise legs will focus on a different area with different geologic problems, processes, and settings.

Western Gulf of Mexico

The continental shelf in the Gulf of Mexico prograded seaward during the Tertiary as depocenters migrated eastward with time from the Rio Grande area of Texas to the presently active Mississippi River area in the north central Gulf (Humphris, 1984). Loading by these Tertiary sediments onto an underlying salt layer of Jurassic age has resulted in extensive diapiric intrusion of the salt. The morphology of the continental slope is complex in response to this diapirism. Diapirs have created numerous isolated basins on the slope such as Orca Basin (Figs. 3 and 4), and have significantly influenced the paths of submarine canyons crossing this part of the slope. For example, Gyre Basin (Figs. 5 and 6) is interpreted to originally have been a submarine canyon that became an isolated basin when a salt diapir blocked its axis (Bouma, 1982). Oceanographic conditions in some of these basins, particularly Orca Basin, can be unique. This basin contains a dense brine layer, the surface of which is visible on seismic-reflection profiles (Fig. 6). A full understanding of these basins will be a major contribution to understanding the sedimentary and tectonic development of this margin.

The GLORIA sidescan data have been extremely valuable in defining the complex morphology in the western portion of the Gulf. Morphologic features, varying in size from piercement structures 1-2 km in diameter to basins as much as 30 km across, can be mapped with the sidescan system. Interpreting the

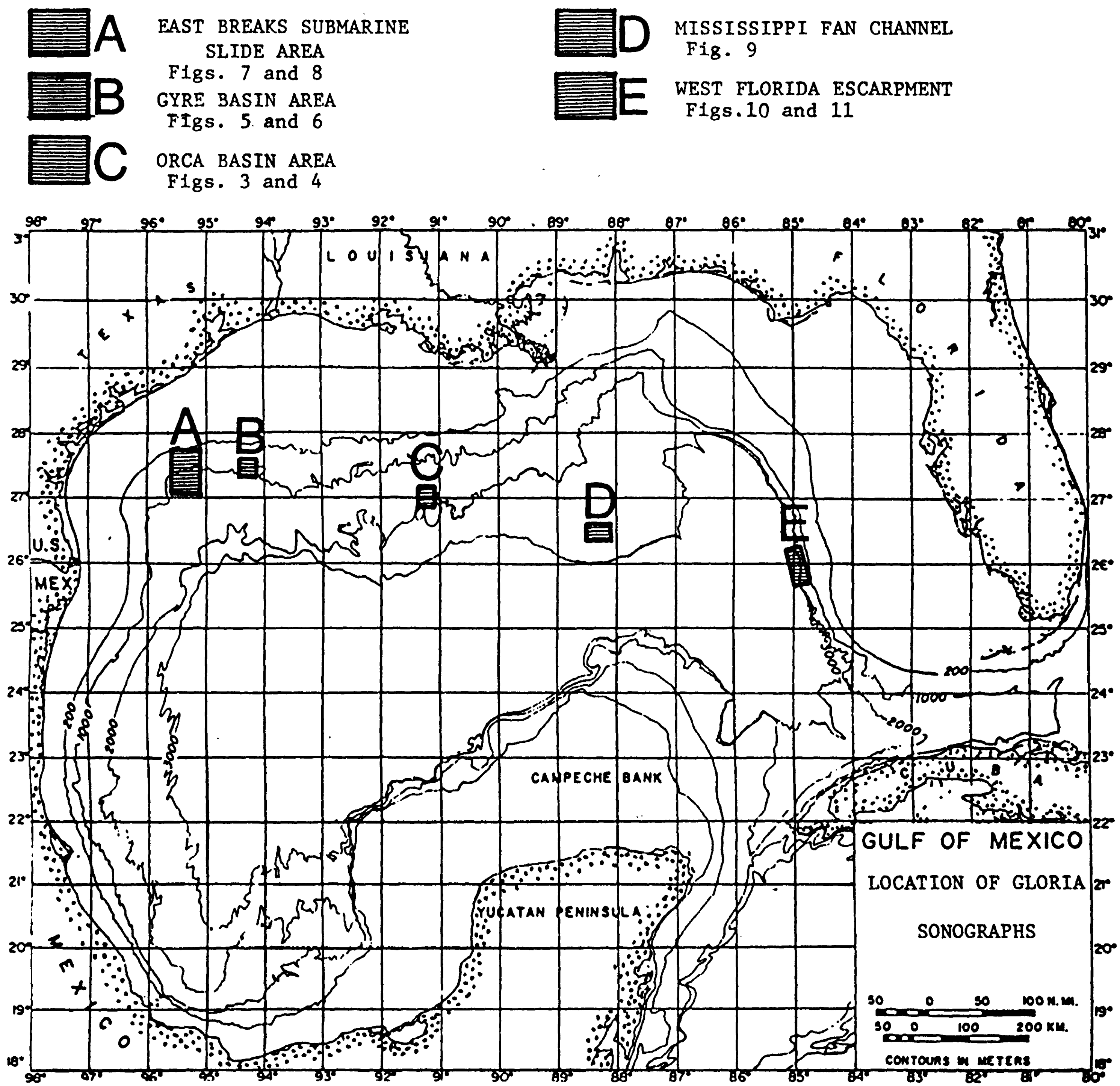

Fig. 2 Index map indicating the location of the GLORIA sonographs shown in figures 3, 5, 7, 9, and 10.

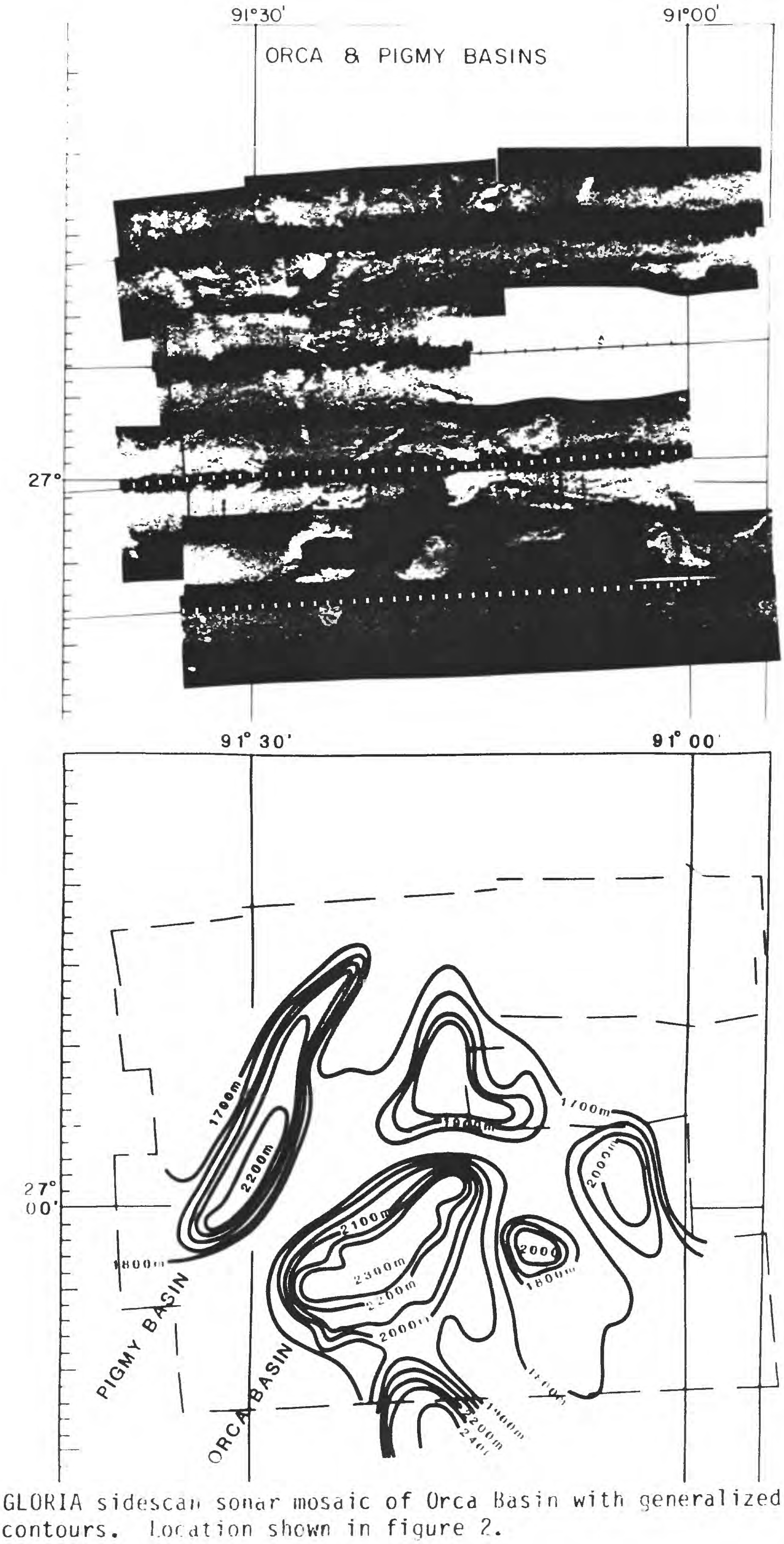

Fig. 3 GLORIA sidescan sonar mosaic of Orca Basin with generalized bathymetric contours. Location shown in figure 2.

ORCA BASIN

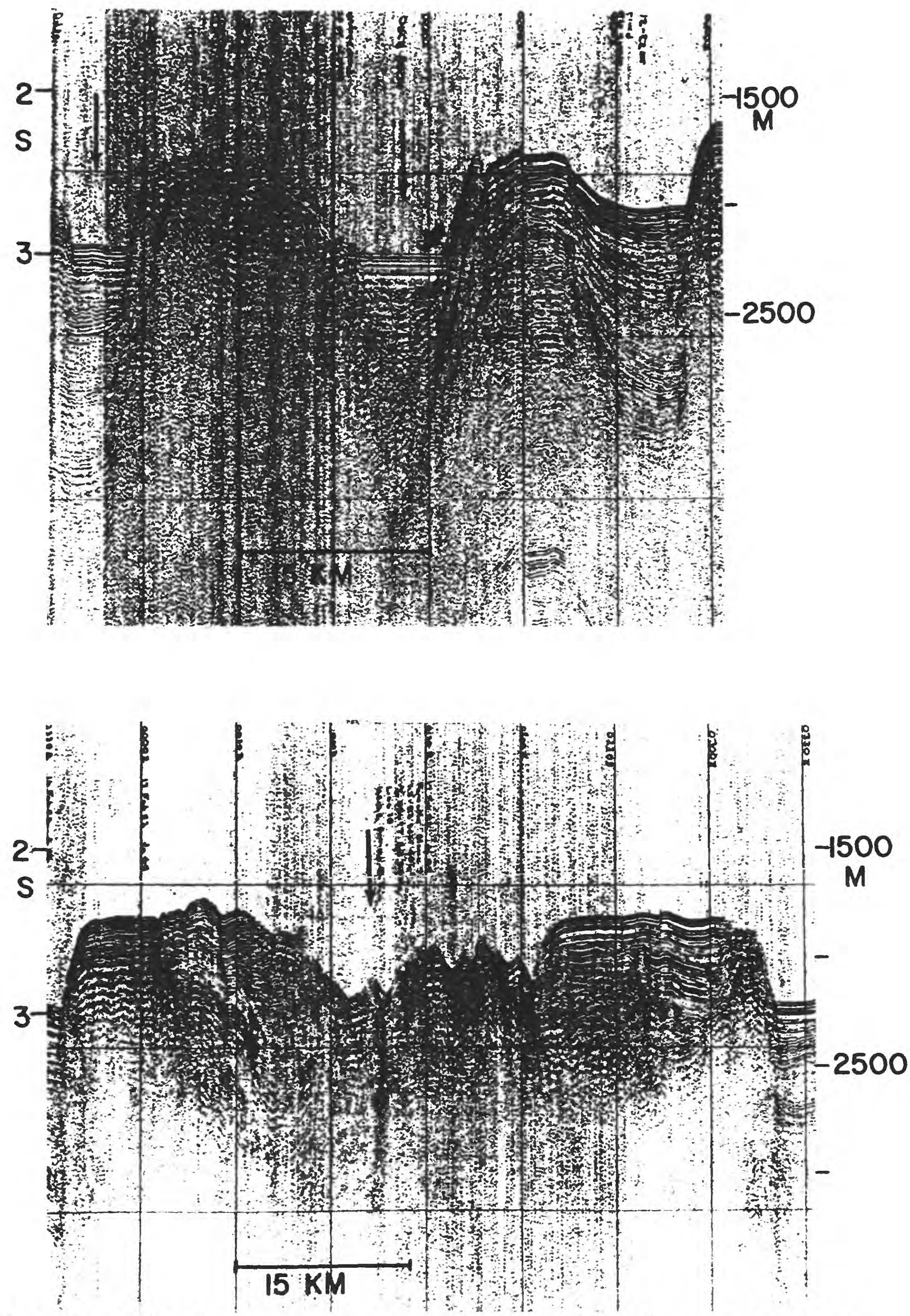

Fig. 4 Seismic reflection profiles across Orca Basin. Bold arrow points to surface of the brine layer. (See figure 3 dashed lines for profile locations.)

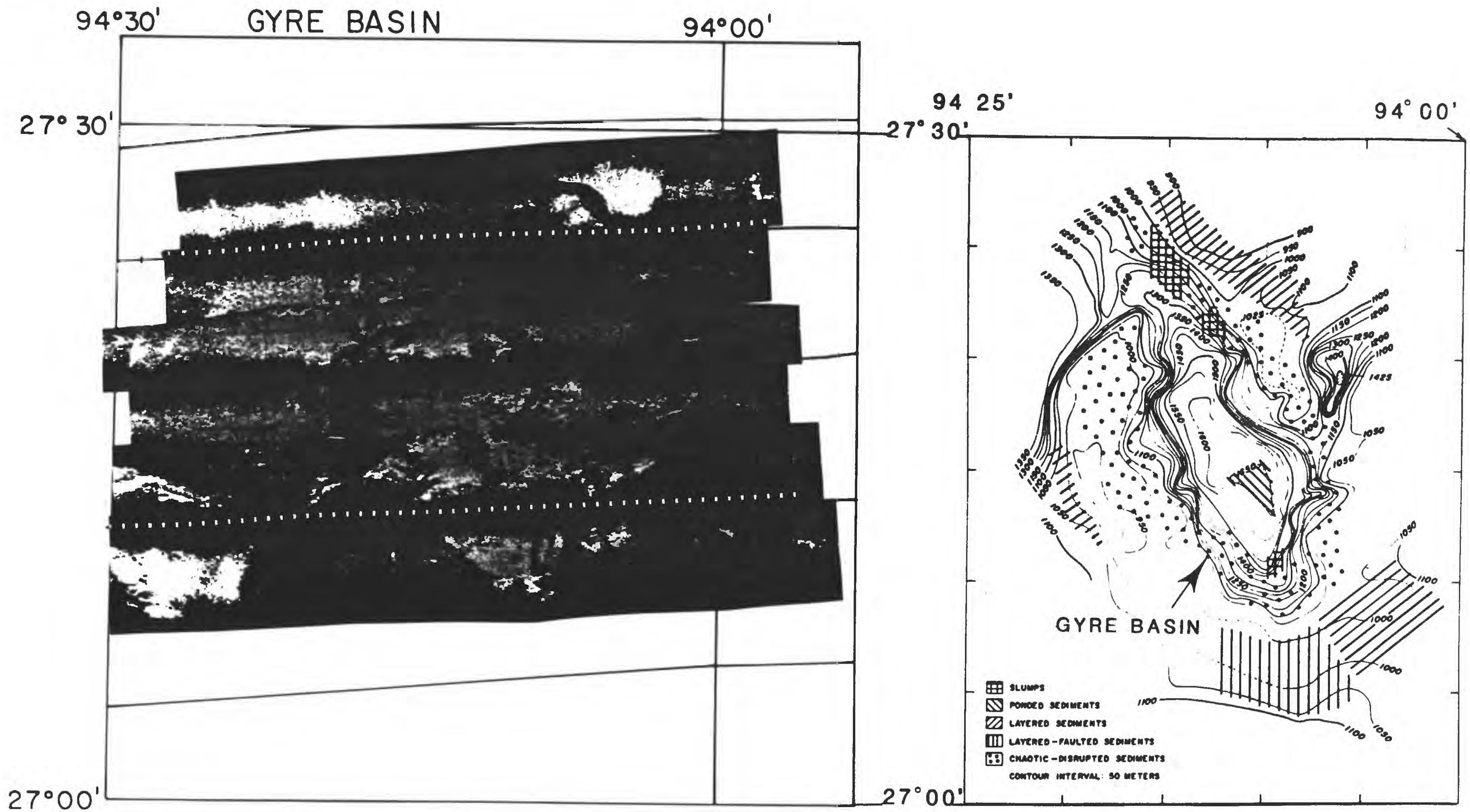

Fig. 5 GLORIA sidescan sonar mosaic of Gyre Basin. Line drawing shows the bathymetry for the basin and an interpretation of its geologic features by Bouma (1982) based on seismic reflection profiles. Location shown in figure 2.

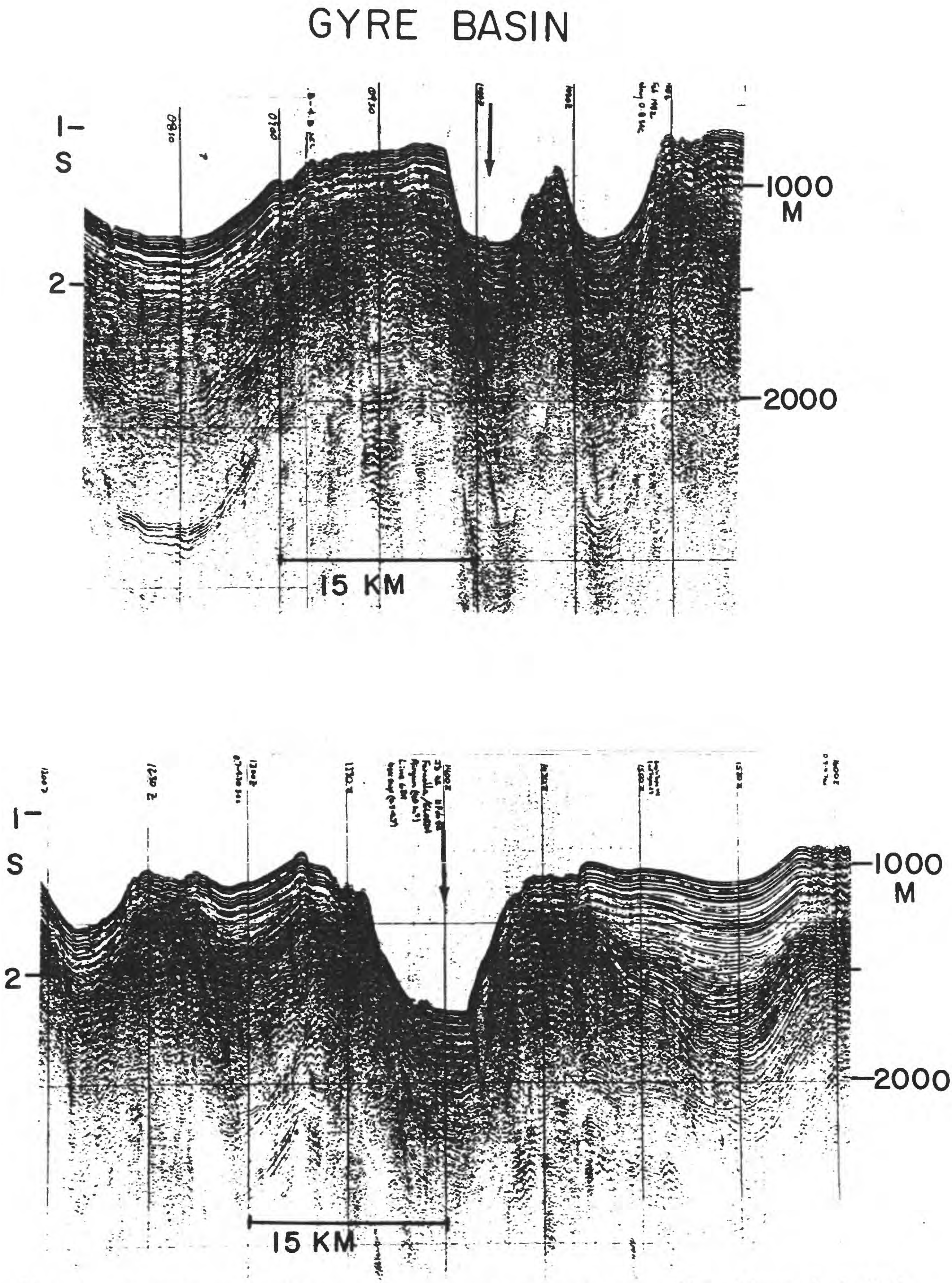

Fig. 6 Seismic reflection profiles across Gyre Basin. (See figure 5 dashed lines for profile locations.)

morphology is an important part of understanding the sediment distribution. The seaward edge of the salt deformation is marked by the Sigsbee Escarpment, approximately the 3000 m contour on figure 2. Seismic-reflection profiles across the escarpment suggest that a wedge of salt is over-riding sediments that were deposited in the deep water of the Gulf. The GLORIA data scheduled to be collected in August 1985 will be important in interpreting the geologic processes that occur along this salt front.

The migrating depocenters in the Gulf have consisted of a series of deltas. On these deltas, as on the modern Mississippi Delta, sediment failure resulted in sediment slumps and slides, and was an important process in distributing sediments seaward. One such Pleistocene-age shelf-edge delta is located in the northwestern corner of the Gulf in the East Breaks area (Fig. 2, area A). Lerner (1969) described a major submarine slide which originated from the edge of this delta. This submarine slide can be mapped using the GLORIA sidescan data (Figs. 7 and 8). The body of the slide was included within the 1982 survey data, and the remainder of the slide, the toe, will be mapped in 1985.

It is important to understand the sediment distribution as influenced by the salt tectonics in order to evaluate the petroleum potential seaward of the shelf edge in the deep water of the Gulf. Significant petroleum discoveries have been made during the past year along the upper continental slope in what is called the Flexure trend. The salt has trapped Pliocene-Pleistocene sediments along this trend, which extends along the continental slope from the Mississippi River to the U.S.-Mexican border. Gas hydrates, oil seepage, and a chemosynthetic benthic community, similar to the group of organisms previously found at volcanic ocean-spreading centers, have been identified on the upper slope in the Green Canyon area (north of Orca Basin, Fig. 2) (Brooks and others, 1985). The flow of nutrient-rich fluids from the sediments is thought to support this benthic community. This benthic community poses questions on the geologic and geochemical conditions around salt diapirs.

Although some of the details of the sedimentary processes active on the continental slope of the western Gulf of Mexico have been recognized, many are not fully understood. A regional overview of the extent of these different environments and processes and their interrelationship will be provided by the GLORIA survey. This regional data will be central in identifying future topics and sites for detailed studies.

Central Gulf of Mexico

The Mississippi Delta, Canyon and Fan comprise a modern depositional system where sediments are actively accumulating. High deposition rates in this area result in unstable conditions causing sediment slumps. Slumps have been identified as far seaward as the Mississippi fan in 3,000 m of water (Walker and Massingill, 1970). As with the East Breaks submarine slide in the western Gulf, we plan to use the GLORIA system to map areas where sediment failure has occurred and to map the distribution of slump deposits in the deep water of the Gulf.

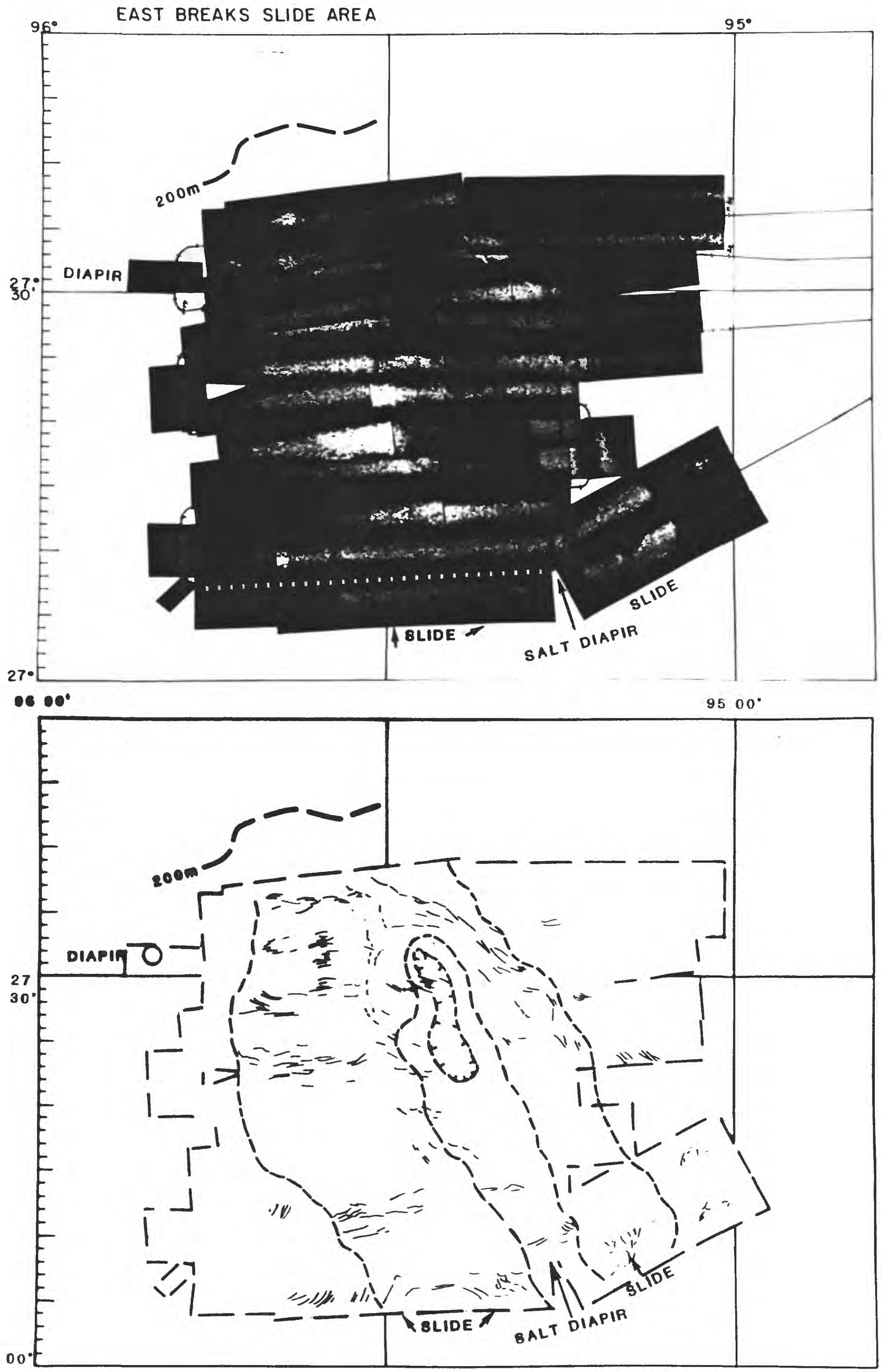

Fig. 7 GLORIA sidescan sonar mosaic of the East Breaks submarine slide. Location shown in figure 2.

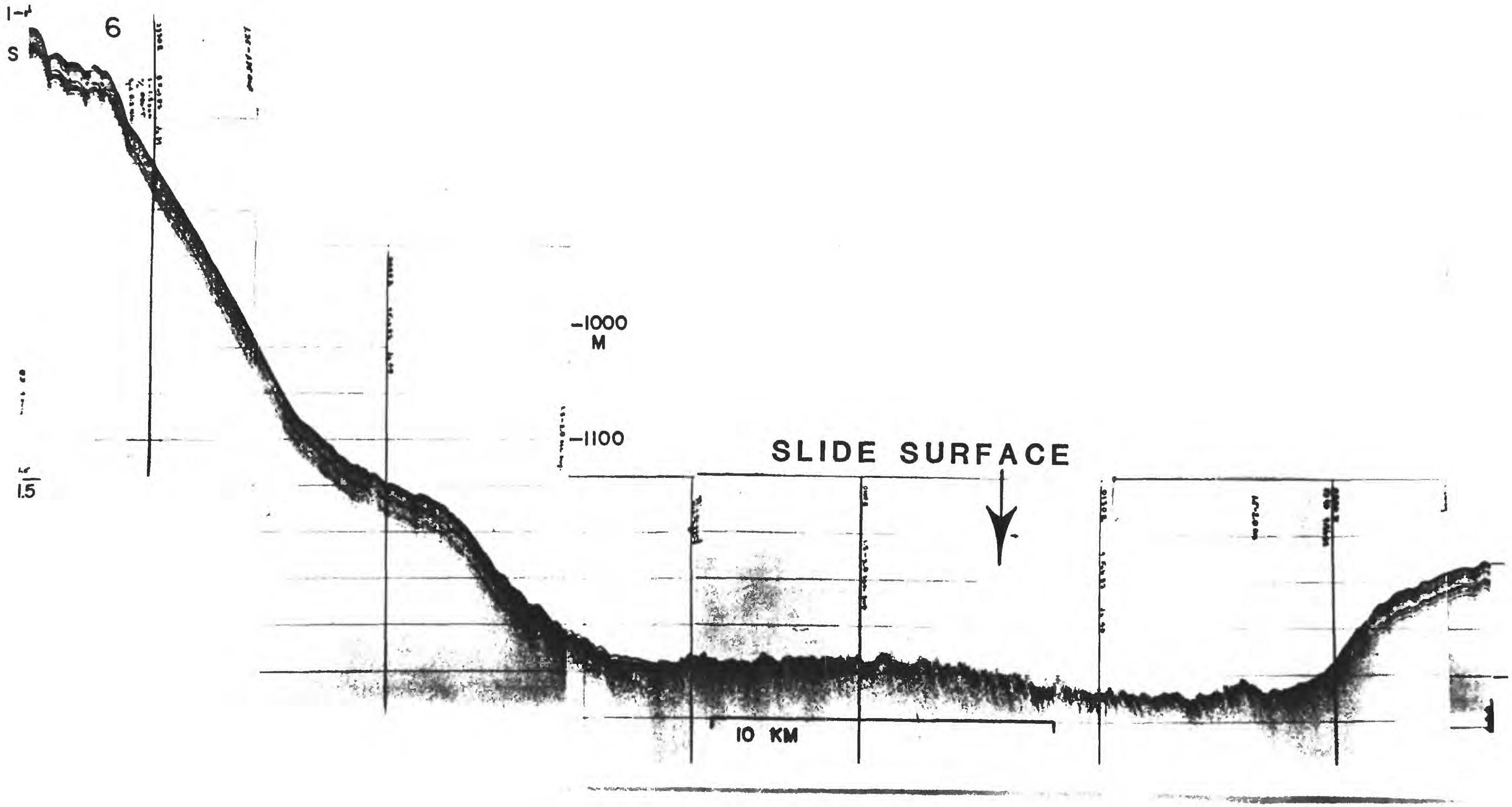

Fig. 8 A 10-kHz high-resolution profile across East Breaks submarine slide, which shows the irregular surface of the slide that contributes to the high reflectivity of the slide on the GLORIA mosaic. (See figure 7 dashed line for profile location.)

The Mississippi fan is a complex network of channel and levee deposits. A preliminary site survey in preparation for a series of drill holes on Deep Sea Drilling Project (DSDP) Leg 96, included GLORIA sidescan data to locate the fan channel. The meandering nature of this channel in the vicinity of the drill sites is shown in figure 9.

During the 1985 survey, the complete length of the Mississippi Canyon and fan channel will be mapped. The canyons off the U.S. West Coast, mapped with GLORIA in 1984 have a single channel feeding each fan. Whether this is the case for the Mississippi Canyon and fan will be investigated this September. Desoto Canyon in the northeastern corner of the Gulf, also has a channel in deep water located between the channel of the Mississippi and the West Florida Escarpment. The relationship of these two channels and their relative contribution of sediments to the deep Gulf will be addressed. The study of modern fans provides valuable insights into their sediment distribution, processes, and evolution; all are important to evaluate the petroleum potential and to develop oil fields of modern and ancient fans in an efficient manner.

Eastern Gulf of Mexico

The West Florida Escarpment is a steep slope (as much as 40°) that separates the shallow West Florida carbonate platform from the deep abyssal plain of the Gulf of Mexico (Fig. 2). Relief on the escarpment ranges from about 1,000 m at its northern end near De Soto Canyon to about 2,500 m west of the Florida Keys. The escarpment consists of Early Cretaceous to Miocene carbonates and is part of a reef trend that extends from Mexico through Texas, around Florida and the Bahamas (Bryant and others, 1969; Antoine and others, 1967), and northward under the eastern U.S. Atlantic continental margin into Canadian waters (Schlee and others, 1979; Jansa and Wade, 1975). This reef complex has significant oil finds associated with it.

Based on seismic-reflection profiles, the relief and morphology of the West Florida Escarpment were attributed to the vertical growth of a reef as the margin gradually subsided (Antoine and others, 1967; Corso and Buffler, 1984). The exposure of the reef along this escarpment was thought to be an ideal window to a better understanding of this extensive reef system, which is largely buried in the Gulf of Mexico and along the Atlantic margin. However, samples recently collected by dredging and during submersible dives have found only fine-grained back-reef lagoonal facies exposed on the escarpment face (Freeman-Lynde, 1983). The forereef and reef deposits themselves are missing. The mechanisms by which this erosion has taken place and how continuous it has been through time are not fully understood, yet these are important questions to answer in order to assess the potential reservoir facies of the buried parts of this reef trend.

Several processes contribute to the erosion of the escarpment, but their relative importance is unknown. At the southern end of the escarpment, large canyons incise the escarpment and are conduits through which shallow water carbonate sands and debris are transported to the base of the escarpment (Halley and others, 1984; Holmes, 1985). In the Straits of Florida, erosion by the strong Florida current may significantly contribute to the shape of this part of the escarpment. Further north, where the escarpment face is

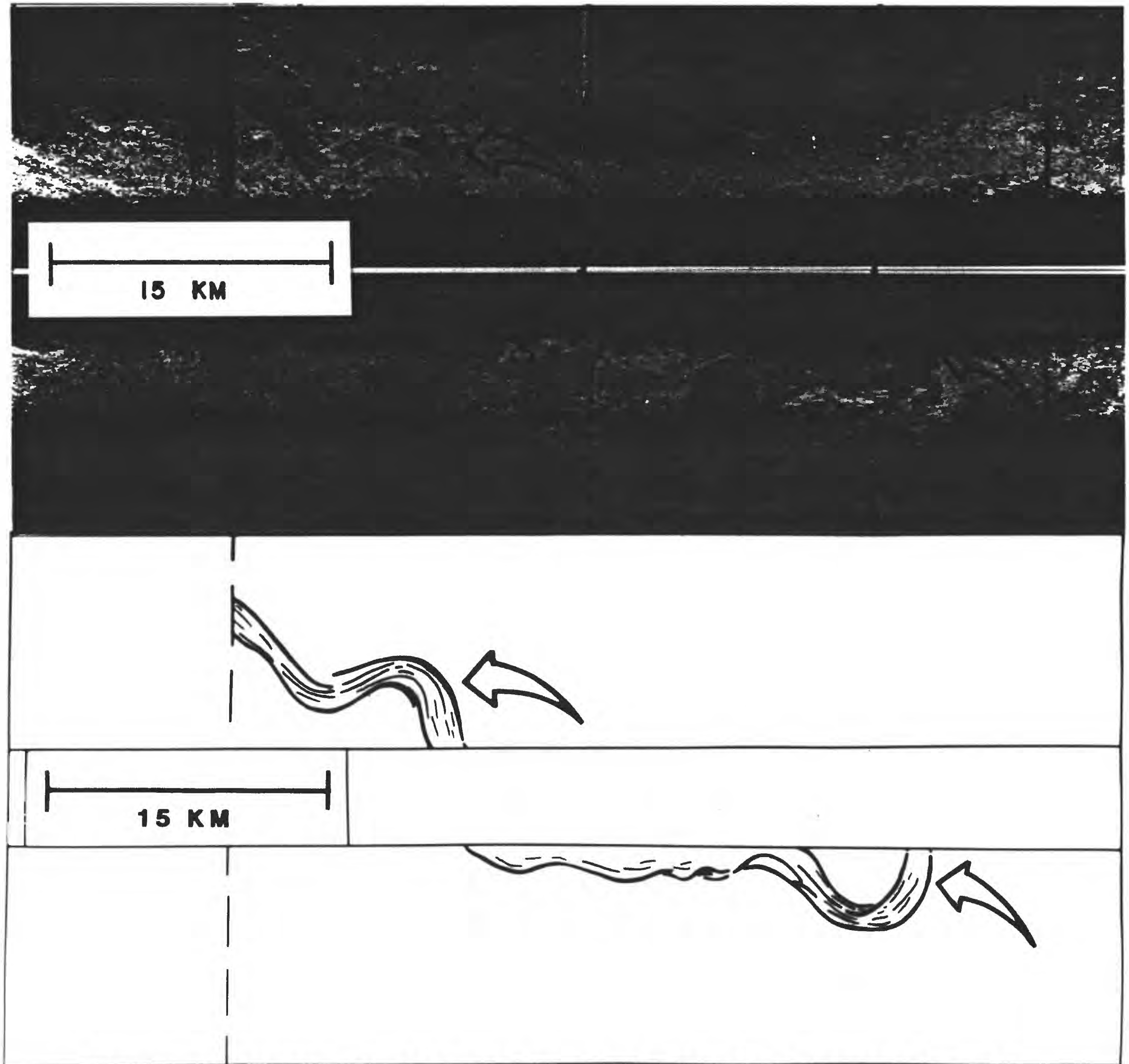

Fig. 9 GLORIA sidescan sonar image of the Mississippi fan channel (arrows). Location shown in figure 2.

straighter, slumps on the slope above the escarpment may contribute to its erosion (Doyle and Holmes, 1985). In this same area, seeping of saline water from the base of the escarpment may be corroding, undercutting, and steepening the escarpment near its base (Paull and others, 1984). This seeping saline water also has a chemosynthetic benthic community associated with it. The cause of the varied morphology of the escarpment will be addressed by the 1985 GLORIA survey.

In 1982, a GLORIA line was run along the southern third of the escarpment (Fig. 2). This line hints that the morphology of the escarpment is much more complex than shown on published maps and that modern sedimentary deposits associated with the erosion of the escarpment are varied and extend well seaward of its base (Figs. 10 and 11). The GLORIA and seismic-reflection profile data scheduled to be collected in October 1985, will be used to map the morphology of the escarpment as well as the slope above and abyssal plain below it, and to describe the types and extent of deposits in each area. The deposits below the escarpment may contain a partial record of the erosion of the escarpment. We will evaluate the interaction of processes in the carbonate province of the Florida platform with those of the clastic province to the north and west, the De Soto and Mississippi Canyon and fan systems, to determine the role of both provinces in contributing sediments to the deep Gulf.

FUTURE PROGRAM PLANS

On completion of reconnaissance mapping of the U.S. continental margin in the Gulf of Mexico with the GLORIA sidescan sonar system, areas of geologic interest will be identified for further study. Additional types of data will be collected with tools designed to address specific problems. Deep-towed sidescan systems and video-camera systems will provide information on details of the morphology, the processes responsible for the observed morphology, and inferred textural differences. In order to further define the processes associated with a particular geologic phenomenon or setting, an additional suite of data to be collected may include: 1) observations, samples, and measurements using submersibles or deep-towed remote controlled systems (ANGUS, ARGO-JASON); 2) measurements of currents and bottom-sediment transport by tripods; 3) piston cores and dredged samples; 4) measurements of sediment properties using available drillcores; 5) measurement of geotechnical properties of the sediments using *in situ* probes; and 6) additional seismic reflection profiles. This variety of data is needed to unravel the processes of sedimentation and to aid in the resource evaluation and development seaward of the shelf edge in the deep water of the Gulf of Mexico.

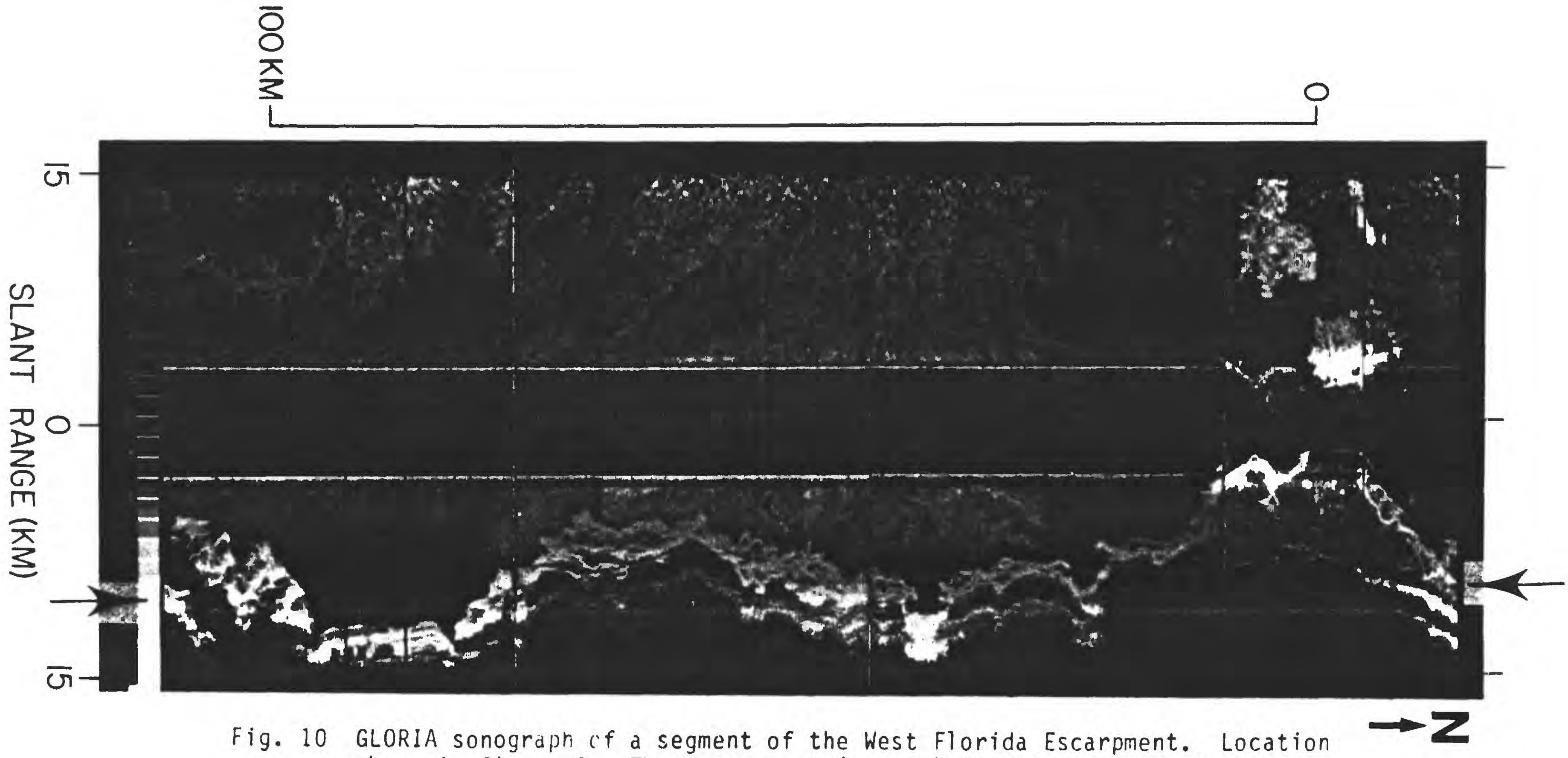

Fig. 10 GLORIA sonograph of a segment of the West Florida Escarpment. Location shown in figure 2. The escarpment (arrows) itself shows as the sinuous area of high acoustic reflectivity. Linear changes in acoustic reflectivity parallel to the escarpment probably indicate terraces. Reentrants in the escarpment with areas of weak reflectivity at their bases which may be small fans created by off-shelf spillover of fine-grained sediments. The area of high reflectivity seaward of the escarpment is of uncertain origin. Because it is removed from the base of the escarpment by several kilometers it may be the result of mass-wasting; the inner part of the deposit has been covered.

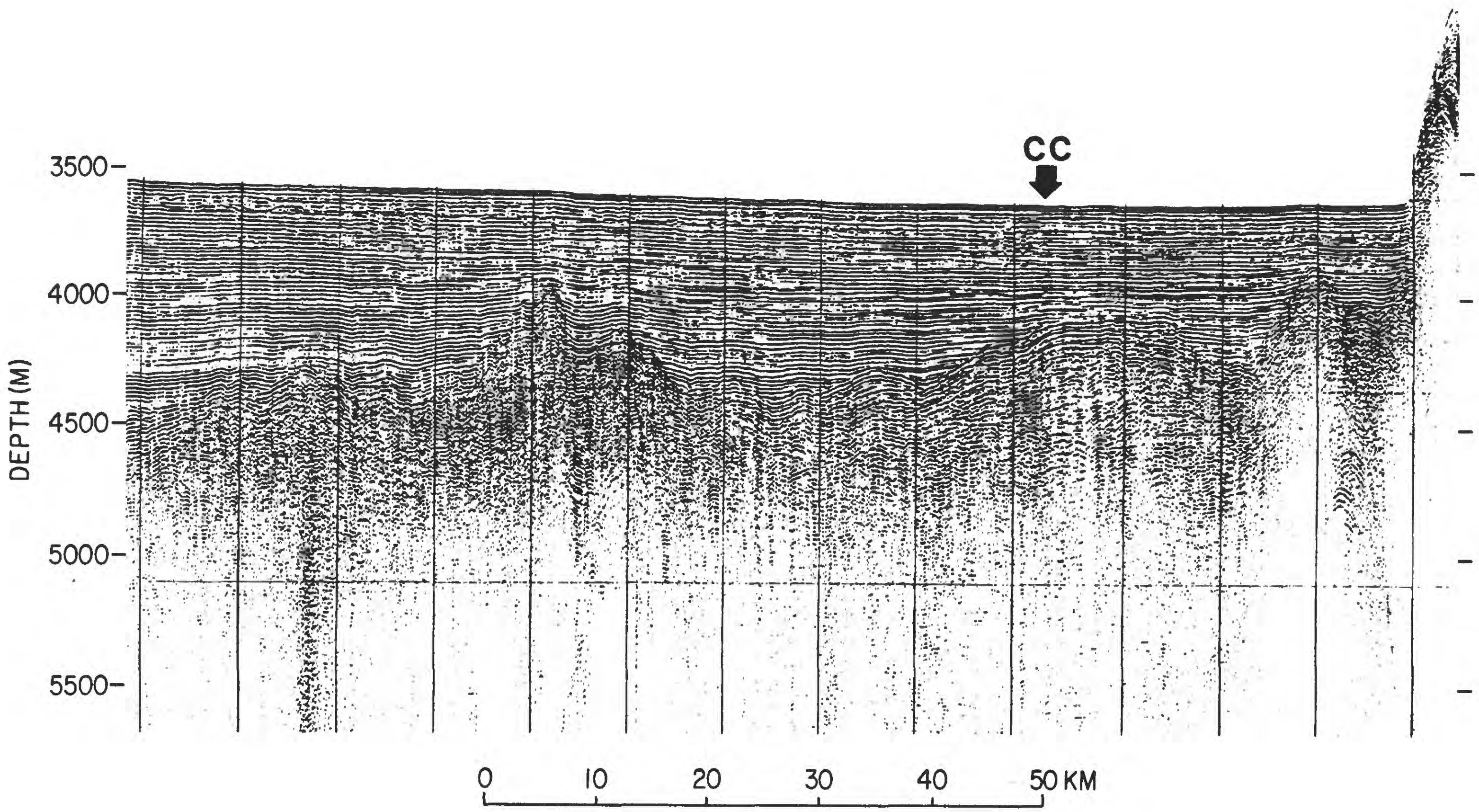

Fig. 11 Single-channel reflection profile immediately seaward of the base of the escarpment.

REFERENCES

Antoine, J., Bryant, W., Jones, B., 1967, Structural features of continental shelf, slope and scarp, northeastern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 51, p. 257-262.

Bouma, A.H., 1982, Intraslope basins in northwest Gulf of Mexico: a key to ancient submarine canyons and fans, in Watkins, J.S., and Drake, C.L., eds., Studies in the Continental Margin Geology: American Association of Petroleum Geologists Memoir 34, p. 567-581.

Brooks, J.M., Kennicutt, M.C. II., Bidigare, R.R., and Fay, R.A., 1985, Hydrates, oil seepage, and chemosynthetic ecosystems on the Gulf of Mexico slope: EOS, Transactions of American Geophysical Union, v. 66, p. 106.

Bryant, W., Meyerhoff, A.A., Brown, N., Farrer, M., Pyle, T., and Antoine, J., 1969, Escarpments, reef trends and diapiric structures, eastern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 53, p. 2506-2542.

Chavez, P.S., Jr., 1984, U.S. Geological Survey Mini Image Processing System (MIPS): U.S. Geological Survey Open-File Report 84-353, 12 p.

Corso, W., and Buffler, R.T., 1984, Seismic stratigraphy of Lower Cretaceous platforms and margins, eastern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 69, p. 246.

Doyle, L.J., and Holmes, C.W., 1985, Shallow structure, stratigraphy and carbonate sedimentary processes of the West Florida Upper Continental Slope: American Association of Petroleum Geologists Bulletin (in press).

Freeman-Lynde, R.P., 1983, Cretaceous and Tertiary samples dredged from the Florida escarpment, eastern Gulf of Mexico: Transactions of Gulf Coast Association Geological Society, v. 33, p. 91-99.

Halley, R.B., Pierson, B.J., Schlager, W., 1984, Alternative diagenetic models for Cretaceous talus deposits, Deep Sea Drilling Project Site 536, Gulf of Mexico: Initial reports of the Deep Sea Drilling Project, v. 77, p. 397-408.

Holmes, C.W., 1985, Accretion of south Florida platform, late Quaternary development: American Association of Petroleum Geologists, v. 69, p. 149-160.

Humphris, C.C., Jr., 1984, Interrelations of Tertiary deposition, growth faulting, and salt movement, northern Gulf of Mexico, in Characteristics of Gulf Basin Deep-Water Sediments and Their Exploration Potential: Fifth Annual Research Conference Gulf Coast Section of Society of Economic Paleontologists and Mineralogists, p. 50-51.

Jansa, L.F., and Wade, S.A., 1975, Geology of the continental margin off Nova Scotia and Newfoundland, in Offshore Geology of Eastern Canada, Canada Geological Survey Paper 74-30, 2, 51-105.

Lerner, P., 1969, Salt tectonics and Pleistocene stratigraphy on continental slope of northern Gulf of Mexico: American Association of Petroleum Geologists Bulletin 53, p. 2431-2479.

Paull, C.K. Hecker, B., Commeau, R., Freeman-Lynde, R.P., Newman, C., Corso, W.P., Golubic, S., Hook, J.E., Sikes, E., and Curray, J., 1984, Biological communities at the Florida Escarpment resemble hydrothermal vent taxa: Science, v. 226, p. 965-967.

Schlee, J.S., Dillon, W.P., and Grow, J.A., 1979, Structure of the continental slope off the eastern United States: Society of Exploration Paleontologists and Mineralogists, Special Publication No. 27, p. 95-117.

Walker, J.R., and Massingill, J.V., 1970, Slump features on the Mississippi Fan, northeastern Gulf of Mexico, Geological Society of America Bulletin, v. 81, p. 3101-3108.