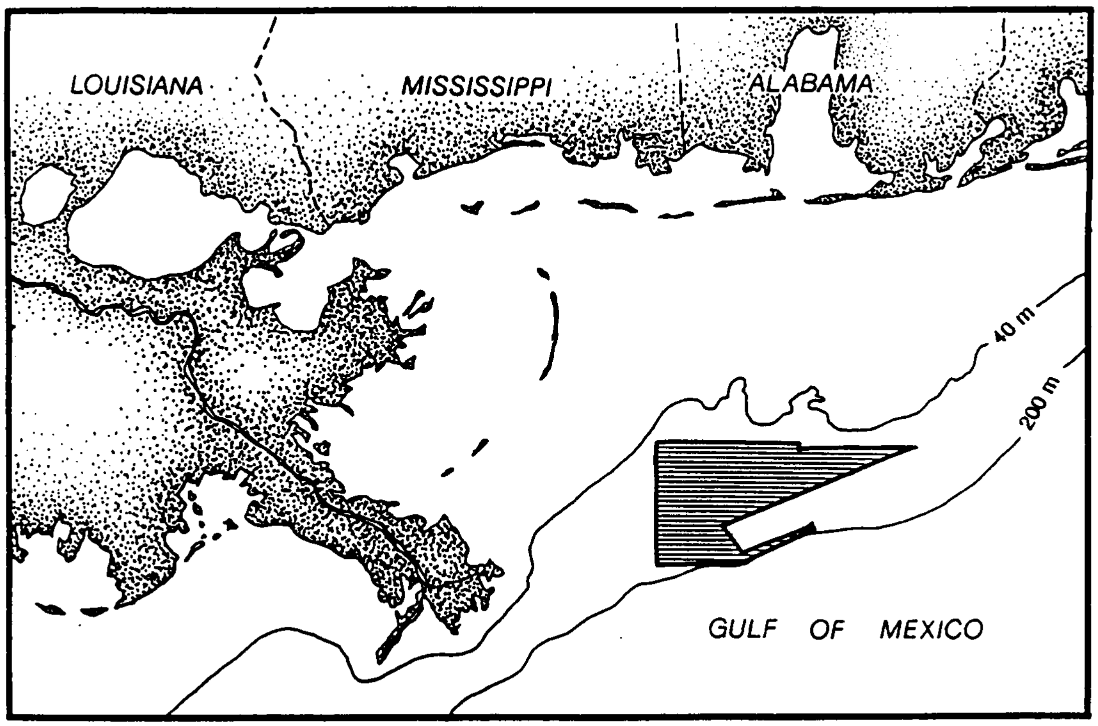
OCS Study
MMS 92-0026

Mississippi-Alabama Shelf Pinnacle Trend Habitat Mapping Study



MMS U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS Study
MMS 92-0026

Mississippi-Alabama Shelf Pinnacle Trend Habitat Mapping Study

Prepared by

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1.0 EXECUTIVE SUMMARY

As part of the Minerals Management Service's (MMS) continuing study of the Mississippi-Alabama shelf, areas in the outer shelf and slope were investigated for the presence of significant topographic features. Two surveys were conducted in the study area with the following objectives:

1) Geophysical identification and mapping of all significant topographic features located in the study area, and

2) Characterization of the biological communities associated with these features.

Survey 1, the geophysical characterization survey, was conducted between 11 September and 10 October 1990. A total of 92 line transects were surveyed consisting of 86 main lines in an east-west direction and 6 tie lines in a north-south direction. Side-scan and subbottom data were collected simultaneously. Side-scan swath width was designed to insure 100% bottom coverage. In deeper waters (> 91 m; 299 ft) at the southern end of the study area, a survey line spacing of 600 m (1,969 ft) and a side-scan sonar slant range of 400 m (1,312 ft) was employed to yield a swath width of 800 m (2,625 ft) with 25% sonographic record overlap. In shallower waters, survey line spacing had to be decreased to 500 m (1,641 ft). A side-scan sonar slant range of 300 m (984 ft) was employed to yield a swath width of 600 m (1,969 ft) with a 17% sonographic record overlap. A total of 4,077 km (2,200 nmi) of survey lines were run.

Geophysical data analysis consisted of:

1) Construction of a digitized "Target Table" plot showing exact locations of seafloor features based on both "real-time" and post-survey review of the side-scan records;

2) Construction of a "Sediment Reflectivity" map based on the independent reviews of two side-scan sonar and subbottom interpreters; and

3) The superimposition of these constructs of existing bathymetric data.

Two areas, physiographically differing in terms of slope angle and sediment cover were covered by this study: 1) the outer portion of the upper Mississippi/Alabama continental shelf (40 to 75 m; 131 to 246 ft); and 2) the upper portion (75 to 210 m; 246 to 689 ft) of the Mississippi/Alabama upper slope.

Small, relatively frequent outcrops of low-relief hard bottom are seen on the Alabama continental shelf. These patches appear to be different lithologically from those seen farther to the east in the Gulf of Mexico. They represent unique habitat features interspersed widely over otherwise featureless bottom and have a unique resident flora and fauna.

On the upper slope, below the 75-m (246-ft) contour, two types of hard-bottom shelf edge prominence areas were mapped:

1) An area of large pinnacle development between 80 and 90 m (262 to 295 ft) deep; and

2) An area of low relief hard bottom and small pinnacle or mound development in 110 to 130 m (361 to 427 ft) of water.

There is also an impressive scarp and extensive hard bottom associated with a large salt dome diapir feature seen in the southwest corner of the study area.

Area 1, the major pinnacle area, is located on a relatively level plateau between the 75 and 100 m (246 and 328 ft) bathymetric contours. Pinnacles in this area are large features occurring in clumps. The overall orientation of these features seems to be northwest to southeast.

Area 2 pinnacle features are generally smaller than those seen in Area 1. There are also reef-like mounds seen in Area 2, which, while they may show as much vertical relief as the pinnacle features, are broader across their base and have different sub-bottom signatures. Unlike the surrounding sediments of Area 1 which appear to be soft, the substrate seen in Area 2 appears to be continuous, low-relief hard bottom.

Biological characterization of the significant topographic features geophysically identified during Survey 1 of this study was conducted between 11 October and 7 November 1991. Initially, a prioritized list of features was compiled for investigations. Severe weather significantly reduced the amount of survey time available and, therefore, limited the number of features that were investigated. Sampling methods included video and still photograph data collection using a remotely operated vehicle (ROV), dredge sample collection, and hook-and-line fishing.

A majority of the ROV dives occurred in the Area 1 pinnacle trend, near the shelf edge. Features investigated occurred in water depths ranging from 90 to 95 m (295 to 312 ft) and had vertical relief ranging from 10 to 23 m (33 to 75 ft). Biological communities present on the features investigated during this study primarily consisted of tropical or subtropical suspension-feeding invertebrates. The epibenthos present on these features included antipatharians, ahermatypic hard corals, comatulid crinoids, sponges, alcyonarians, and hydroids. Coralline algae were present on the upper portions of the tallest feature (water depth < 72 m; 236 ft). Water depth appears to preclude the growth of coralline algae on all of the other features investigated. As coralline algae was the only observed species with reef building capabilities, it is surmised that these features are no longer growing, but are in some intermediate stage between active growth and fossilization.

The abundance of organisms occurring on the features is quite variable; however, in general, features with increased horizontal surfaces along their upper margins had increased abundances. A variety of organisms are associated with the epibiota, including crinoids, urchins, gorgonacephalids, and even an occasional fireworm. Both crinoids and gorgonocephalids are suspension feeders while the urchins are considered grazers and opportunists. The fireworm (*Hermodice carunculata*) is probably feeding on the ahermatypic corals present.

Fishes observed on the features studied encompassed several commercially important species including the red snapper (*Lutjanus campechanus*) and vermilion snapper (*Rhomboplites aurorubens*). Hook-and-line sampling conducted during the survey resulted in species similar to those identified in videotapes and still photographs. Species not landed were predominantly small plankton feeders (anthiids). Based on limited qualitative video observations, the abundance and diversity of fishes associated with these features appears very low.

Several potential features of possible low-relief hard bottom were investigated on the upper shelf in water depths of approximately 40 m (131 ft). The bottom was observed to be coarse sand and rubble and no hard-bottom areas were identified. Numerous potential low-relief hard-bottom areas on the upper shelf (as well as all of the Area 2 deepwater hard-bottom/pinnacle features) were not investigated during this study. Additional biological and geological data are needed concerning these features.

2.0 INTRODUCTION

2.1 Overview

The MMS is charged with the responsibility of leasing offshore tracts to industry for oil and gas exploration and development. This responsibility is accompanied by a mandate to minimize environmental impacts associated with these activities and to protect areas of significant environmental importance. Environmental characterization of offshore areas identified for potential leasing is paramount to the MMS. One important aspect requiring adequate environmental data is a determination of various stipulations needed for the leasing and development of particular areas. To this end, the MMS Environmental Studies Program undertakes a variety of projects designed to provide the environmental information necessary for informed decision-making concerning a specific lease area.

With increasing interest in oil and gas exploration in the area off the Mississippi-Alabama shelf, the need arose for site- or area-specific environmental information. With the intent of identifying the need for and then collecting environmental data concerning this area, the MMS funded a series of studies designed to provide this information. The first year study effort, called the Tuscaloosa Trend Regional Data Search and Synthesis Study (1984-1985), was a literature search and synthesis study conducted by Barry A. Vittor and Associates, Inc. All available information concerning the area was compiled and a report was prepared to describe the biological and geological environment present in the areas as well as some physical and chemical processes.

Following preparation of the Tuscaloosa Trend report, a series of studies designed to fill identified data gaps were undertaken by researchers from Texas A&M University (1987-1990). These efforts, termed the Mississippi-Alabama Marine Ecosystem Study, were designed to characterize the predominant chemical and physical processes occurring in the area, as well as providing information concerning the geologic and biological components of the area. Information concerning chemical and physical processes was collected on a shelf-wide basis over a three-year period. However, geophysical mapping and subsequent biological investigations were conducted in a very specific, well-defined area (Figure 2-1). During the study, significant topographic features were identified during transit in adjacent areas and to the west of areas geophysically mapped during Years 1 and 2. As a result of these findings, the MMS determined a need for further geophysical mapping followed by biological characterization of significant features.

The present study, entitled the Mississippi-Alabama Shelf Pinnacle Trend Habitat Mapping Program, was contracted to Continental Shelf

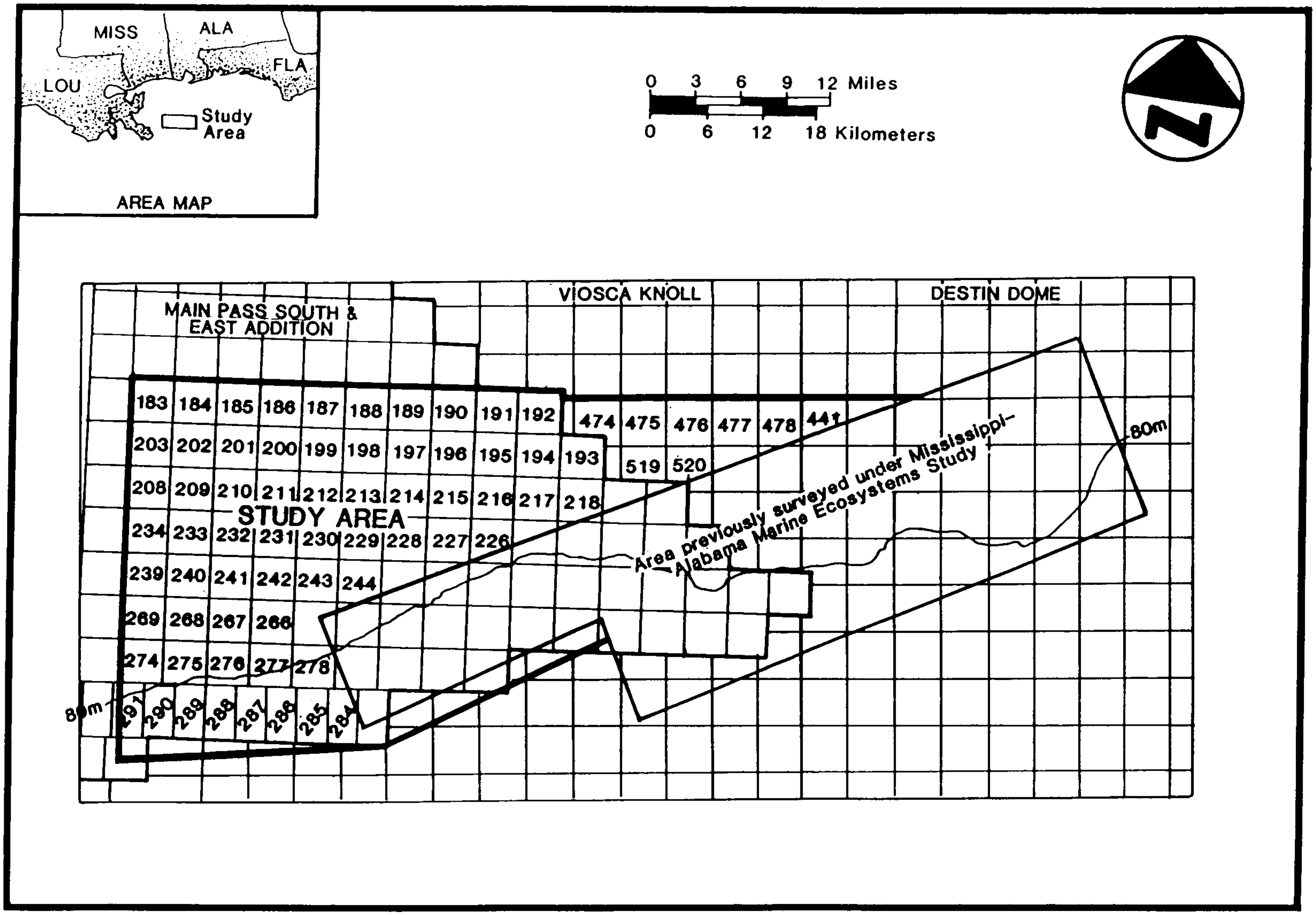

Figure 2-1. Location of the study area.

Associates Inc. to map and characterize topographic features present within the area immediately next to the previously investigated portions of the shelf (Figure 2-1).

2.2 Study Objectives

The general objectives of this study included:

1) **To geophysically survey and map significant topographic features located within the study area.** The distribution and size of significant features was investigated; bathymetric data were also collected throughout the entire study area; and

2) **To characterize the biological communities associated with these topographic features.** Biological zonation occurring on features was investigated on significant features occurring within the area. Biological zonation on the features was described as well as the apparent effects of abiotic parameters. The overall health of communities associated with investigated features was also evaluated.

3.0 FIELD SURVEY AND LOGISTICS

3.1 Overview

Data collection was divided into two separate field sampling efforts. The first field effort (Survey 1) was planned and conducted with the intent of collecting geophysical data (i.e., side-scan sonar and subbottom profiler data) throughout the study area, collecting 100% coverage of the seafloor using side-scan sonar to locate and characterize significant topographic features present within the area. Following geophysical identification of significant features, a second field effort (Survey 2) was planned to characterize the biological communities associated with previously identified features. A remotely operated vehicle (ROV) equipped with video and still photographic cameras was utilized to conduct the biological characterization.

3.2 Survey Vessel and Navigation

Both field surveys completed during this study utilized the R/V SEAHAWK, an 83-ft survey vessel. During Survey 1, a towfish was deployed from the vessel to acquire geophysical and bathymetric data, as discussed in Section 4.3. During Survey 2, an ROV was deployed to collect biological data, as discussed in Section 5.3. Navigation was performed using a Trimble 10X precision Loran C/GPS receiver integrated with Seatrac INS navigational software. This system provides real-time, color graphic displays of the vessel position, towfish or ROV position, track lines, and areas of interest. The towfish/ROV survey track was calculated from the integration of the vessel position, calculated using the Loran C receiver, and the towfish/ROV position, calculated using a FORE Trackpoint system. The FORE Trackpoint system is an ultrashort baseline navigational system that uses an active transponder attached to a towfish or ROV. The acoustic signal from the transponder is received by a hull-mounted hydrophone on the vessel and subsequently provided as input to the Trackpoint deck unit, allowing for computation of the range and bearing to the towfish or ROV. These data are relayed to the Seatrac INS software which computes and displays the position of the towfish or ROV relative to the vessel. All navigational data collected during this survey were recorded and archived by the Seatrac INS software in a DBASE III+ format on computer diskette.

3.3 Geophysical Characterization (Survey 1)

The geophysical characterization of the study area was conducted during the period from 11 September to 10 October 1990. A detailed summary of Survey 1 events is presented in Appendix A. A total of 92 survey lines, including 86 east-west lines and 6 north-south tie lines, were investigated using side-scan sonar and subbottom profiler (Figure 3-1). Prior to beginning the survey lines, the range of the side-scan sonar was tested at various swath widths within the study area to accurately assess the line spacing needed to provide 100% coverage. Adequate coverage was attained in deep water (i.e., greater than 91.4 m [300 ft], as occurs in the southern portion of the study area) using a line spacing of 600 m and a side-scan sonar range of 400 m (800 m swath width). In shallower water it was necessary to decrease the line spacing to attain adequate coverage. Under these conditions (i.e., less than 91.4 m [300 ft] water depth), a line spacing of 500 m with a side-scan sonar range of 300 m (600 m swath width) was used. Bathymetric data were collected simultaneous with geophysical data acquisition. A discussion of the geophysical and bathymetric data and its interpretation is presented in Section 4.0 (Geophysical Characterization and Mapping).

3.4 Biological Characterization (Survey 2)

The biological characterization survey was conducted during the period from 11 October to 7 November 1991. A detailed summary of the survey events is presented in Appendix B. Using data collected during the geophysical characterization survey, significant and representative topographic features and substrate types were selected and prioritized for investigation during Survey 2. A discussion of the features selected and their prioritization is presented in Section 5.0 (Biological Characterization and Community Description). Data collected concerning the biological communities present on the features that were surveyed are also presented in Section 5.0.

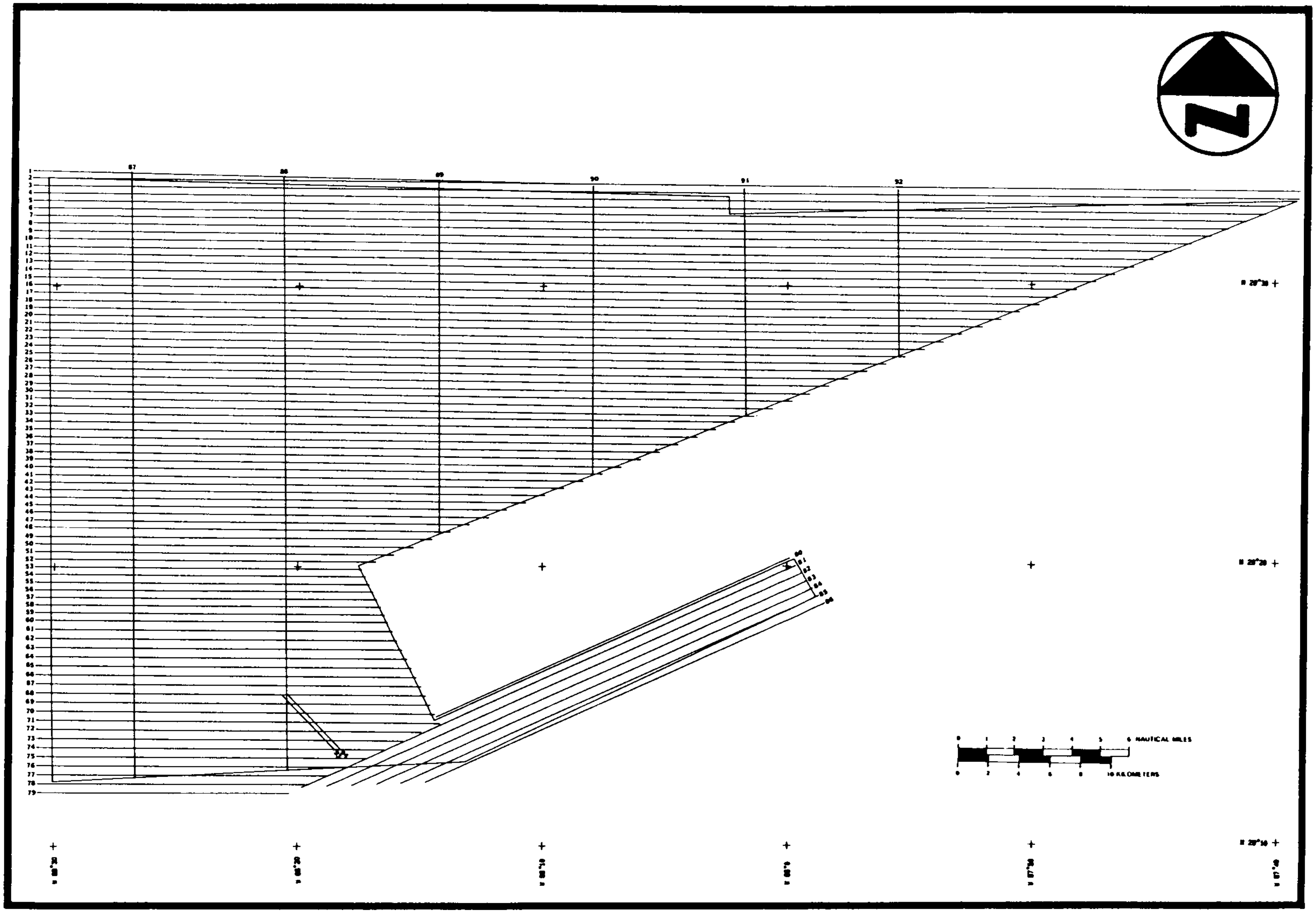

Figure 3-1. Geophysical survey lines.

4.0 GEOPHYSICAL CHARACTERIZATION AND MAPPING

4.1 Introduction

Ludwick and Walton (1957) conducted the first systematic study of the continental shelf edge prominences present within the northeastern Gulf of Mexico. Prominences located along the continental shelf edge of the Gulf of Mexico had been reported from various seafloor mapping efforts since the 1930s (Trowbridge 1930), but Ludwick and Walton (1957) specifically surveyed these features and first described them as "pinnacles." These investigators located areas, or trends, where these pinnacles were concentrated along the Mississippi-Alabama shelf, between the Mississippi River mouth and De Soto Canyon. Since that time, a number of site-specific marine geological studies have focused on small areas or portions of these outer continental shelf pinnacle trends (e.g., Shipp and Hopkins 1978; Woodward-Clyde Consultants, Inc. 1979; Continental Shelf Associates, Inc. 1985a; Schroeder et al. 1988a; and others). Other studies have focused on the upper shelf, and have omitted discussions of shelf edge prominences (Upshaw et al. 1966; Doyle and Sparks 1980; Kindinger 1988, 1989).

In 1989, the MMS funded the Mississippi-Alabama Marine Ecosystem Study to "describe the existing ecosystem and interrelate dominant natural processes..". Two of the major objectives of this study were 1) to describe the sediments and transition areas of the region, and 2) to determine the seafloor topography and its effects on sediment distribution (Brooks and Giammona 1990). This study tied together upper shelf and shelf break sedimentary processes and produced three types of maps: a bathymetric map; a side-scan sonar mosaic; and a sediment reflectivity map.

4.2 Goals and Objectives

In 1991, as a follow-up to the Mississippi-Alabama Marine Ecosystem Study, the MMS funded the present study termed the "Mississippi-Alabama Shelf Pinnacle Trend Habitat Mapping Program." The overall objectives of the program were to conduct geological and biological investigations of a pinnacle trend area first identified by Ludwick and Walton (1957) along the Mississippi-Alabama shelf break. This study effort complements the previous habitat mapping efforts of the Mississippi-Alabama Marine Ecosystem Study, and extends the area surveyed to the west (Figure 2-1). A detailed map was prepared locating pinnacles and hard-bottom areas within the study area. It also provides a map showing sediment trends and reflectivity in the same general format as the earlier effort of Brooks and Giammona (1990) and Laswell et al. (1990). No side-scan sonar mosaics are presented within this report. All map products are presented at a 1:120,000 scale (1 in. = 10,000 ft).

4.3 Methods

4.3.1 Side-scan Sonar

A Klein Model 590 Digital Side-Scan Sonar System was used during the survey. The Klein 595 System included the Klein Model 595 recorder, Model 422S-101HF 100 kHz dual frequency towfish, and 7,000 m of multi-conductor kevlar cable. The system produced side-scan sonar records that were fully image corrected for slant range and tow speed. All records were annotated with the event number, navigational position, and various operator notes including target information.

Raw data from the Klein 590 system were recorded digitally using a specially modified 8-mm digital cassette tape recorder.

4.3.2 Subbottom Profiler

A Klein model 532S-101 subbottom profiler, operating at 3.5 kHz, was integrated with the side-scan sonar towfish. Both records (side scan and subbottom) were displayed on the 595 recorder during data collection and digitally recorded on 8-mm tape.

4.3.3 Bathymetric Data

Bathymetric data were collected using an Odum Echotrac DF-3200 Precision Depth Recorder. The system has a reported accuracy of ± 0.01% of total depth. All bathymetric data were recorded on scrolls and annotated with event mark and other pertinent information by the operator during collection.

4.3.4 Data Analysis and Mapping

Following completion of the geophysical field survey in November 1990, a digitized post-plot file was constructed from the navigational data. Utilizing the real-time field logs and an initial review of the side-scan sonar, subbottom profiler, and bathymetric records, a "target table" was constructed (Appendix C). Features, targets, or target trends identified in this table included the following:

1) Possible hard-bottom areas and patch reefs;

2) Sediment shifts (i.e., reflectivity shifts);

3) Small hard targets (generally interpreted as man-made debris);

4) Sediment ridges (i.e., sand waves);

5) Pinnacles; and

6) The boundary of one large salt dome diapir located at the southwest edge of the study area.

Coordinates for these targets were entered electronically onto the digital post-plot database and a draft Target Plot map was subsequently generated. An oversized Target Plot map has been provided in Appendix D. A reduced version of the Target Plot has also been included as Figure 4-1.

Post-plot and target data were used in conjunction with the side-scan and subbottom data to generate a Sediment Reflectivity map. Sonographic records were independently reviewed by two experienced investigators. M. John Thompson of Continental Shelf Associates, Inc. reviewed the even-numbered lines and Dr. Gregg Brooks of the University of South Florida reviewed the odd-numbered lines. Each investigator created his own draft reflectivity map using the same interpretive techniques and classification patterns employed by Laswell et al. (1990). Once this independent review was completed, the two investigators reviewed their drafts together and the final Sediment Reflectivity map was developed. An oversized Reflectivity Map has been provided in Appendix E. A reduced version of the Reflectivity Map has also been included as Figure 4-2.

The techniques and classification patterns of Laswell et al. (1990) were applied to this analysis in order to maintain consistency between map products generated by this study and those of the Mississippi-Alabama Marine Ecosystems Study. Despite this approach, there are several essential differences evident in sediment reflectivity classification. Laswell et al. (1990) used a reflectivity (R) scale of 1 to 10 for the sonic backscatter patterns recorded in the Mississippi-Alabama Marine Ecosystems Study. In the present study, however, only six reflectivity signatures were defined from the areas surveyed. These reflectivity patterns were defined as follows:

R1 - Low reflectivity. Homogeneous light areas on the side-scan record, usually showing featureless seafloor and yielding a weak seafloor echo. Subbottom records in these areas generally revealed well-defined subsurface layers and, in some cases, infilled paleo-drainage channels;

R2 - Moderate reflectivity. Homogenous, often featureless seafloor yielding a moderate-density acoustic echo.

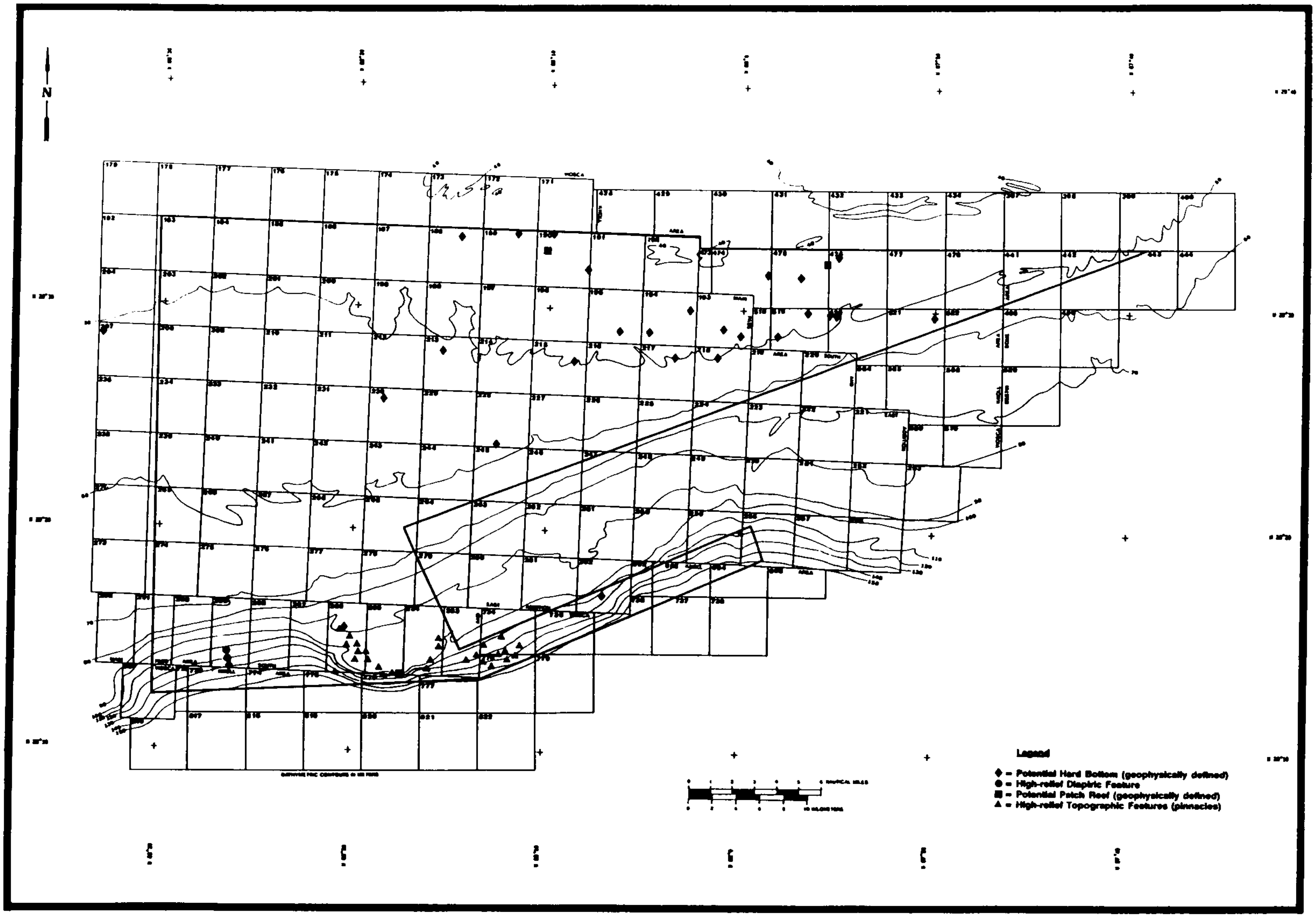

Figure 4-1. Topographic features identified in the study area.

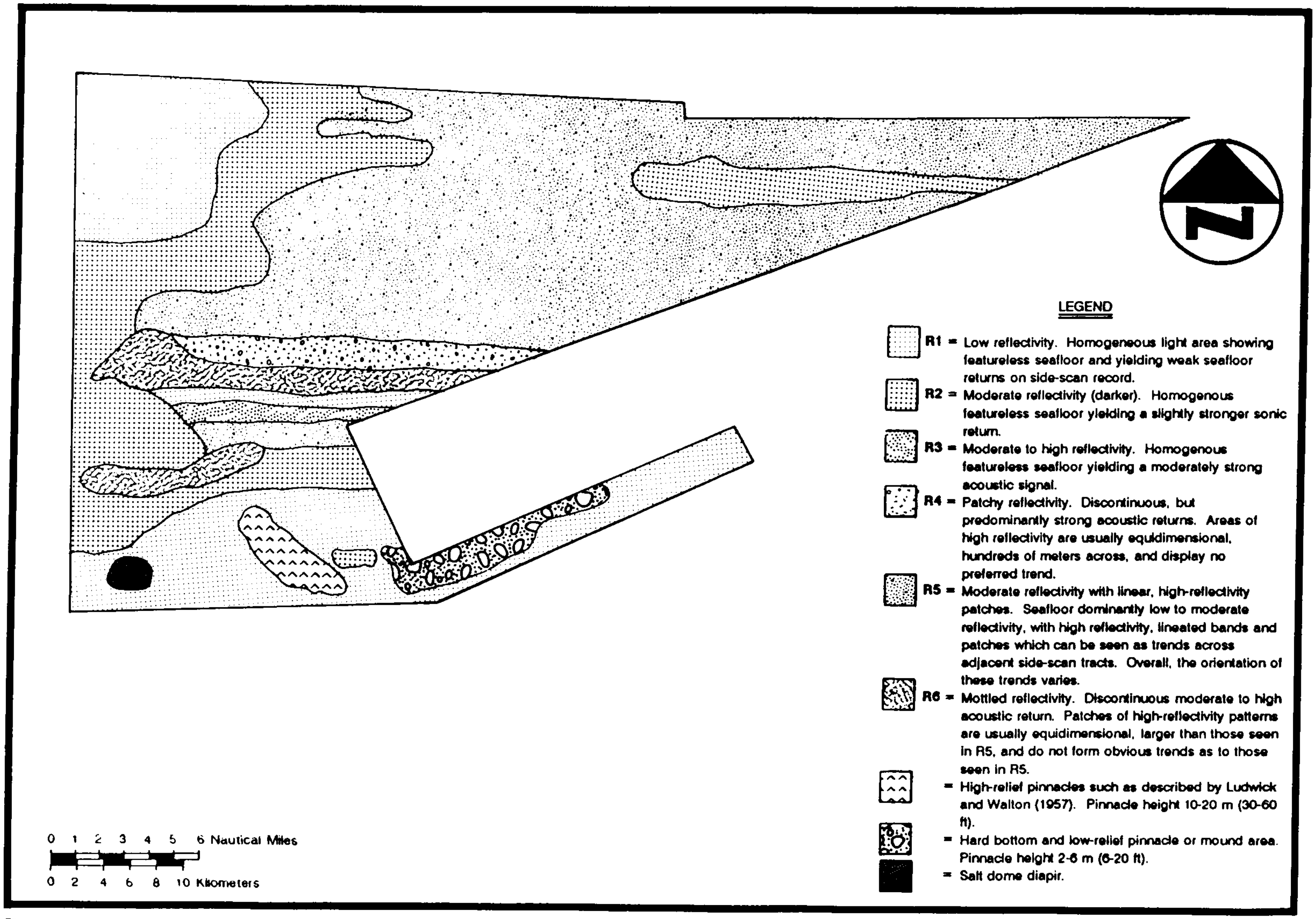

Figure 4-2. Sediment reflectivity map.

Well-defined subbottom layers were generally seen throughout this classification;

R3 - Moderate to high reflectivity. Homogenous, often featureless seafloor yielding moderately strong acoustic echoes. Subbottom penetration was intermittent;

R4 - Patchy reflectivity. Discontinuous, but predominantly strong acoustic echoes. Areas of high reflectivity were usually equidimensional, measured hundreds of meters across, and displayed no preferred orientation or trend. Subbottom data from these areas were restricted to the patches of weak acoustic return;

R5 - Moderate reflectivity with linear, high-reflectivity patches. In these areas, the seafloor generally returned low to moderately strong acoustic echoes, but high reflectivity features or trends (usually lineated) were frequently seen that could be traced between adjacent tracts. Subbottom delineation in R5 areas of this study was poor to non-existent; and

R6 - Mottled reflectivity. Discontinuous moderate to high reflectivity. High reflectivity patterns were usually equidimensional and showed no preferred trend. R6 patterns were smaller and more frequent than R4. Subbottom penetration was intermittent.

Two additional modifications to the Laswell et al. (1990) sediment reflectivity classification scheme are seen on the accompanying Sediment Reflectivity map. Site-specific data indicted the presence of a distinctive trend of high relief (10- to 20-m [30- to 60-ft] tall pinnacles) shallower than the 100-m (330-ft) isobath in approximately 80 to 90 m (260 to 295 ft) of water. Another small, hard-bottom pinnacle trend was evident deeper than the 100-m (330-ft) isobath in approximately 110 to 130 m (360 to 425 ft) of water. Because of their differing physiography, these areas have been delineated separately on the Sediment Reflectivity map (Figure 4-2).

Initially, the sonographic records lead both interpreters to classify the northeastern section of the study area as one which exhibited high relief ridges and numerous hard-bottom patches. Further review and discussion of the side-scan records, coupled with an evaluation of ground truthing data obtained in October 1991, lead to a revised classification for much of this area. It appears that this area is covered by a firmly packed, quartzose sand sheet (Mazzullo and Bates 1985) which greatly retards subbottom penetration. The area shows long-period, northeast- to southwest-oriented sand waves or sand ridges. The tops and leading edges of these ridges (relative to the side-scan sonar source) produced dark, mottled signatures leading to their misclassification as hard bottom. Eliminating these false or presumed false hard-bottom signatures greatly reduced the number of hard bottom signatures plotted. The number of suspected hard-bottom targets presently identified in Appendix C and graphically depicted on the Target Plot map (Appendix D and Figure 4-1) reflect those probable hard bottom signatures which cannot be explained as sand wave or sand ridge artifacts.

4.4 Results and Discussion

4.4.1 Upper Shelf

Two physiographically different areas have been covered in this study. A large portion of the area surveyed lies above the 75-m (245-ft) isobath, defined as the shelf break in this portion of the Gulf of Mexico. The Mississippi-Alabama shelf is broad and smooth with a seaward slope of less than 0.1 degree. Below the shelf break, this slope increases to approximately 1.0 degree. The shelf break itself has been formed by diapirs along the continental margin (Kindinger 1989).

Mazzullo and Bates (1985) divide the Mississippi-Alabama shelf into two distinct areas based on the grain-size morphology of surficial sediments. The eastern part of the Mississippi-Alabama shelf is covered by a thin, well-sorted layer of fine- to medium-grained quartzose sand transported to the shelf from eastern continental rivers during the Pleistocene and early Holocene. The western part of the upper shelf is covered by a layer of fine silts, sands, and clays associated with Mississippi River deposition.

The present study area straddles these sedimentary provinces (Figure 4-3). The eastern portion of the study area shows highly reflective sediments, long period sand waves, and very little subbottom penetration. The central portion of the study area represents a zone of interfacing sediments where silts and clays from the old St. Bernard Delta overlap the quartzose sand sheet. Surface layers in this central region are moderately reflective and a well-defined subbottom is evident. Farther to the west, the uniformly low sediment reflectivity is characteristic of silts and clays (Figures 4-2 and 4-3). In the northwest corner of the study area, a series of infilled paleo-drainage channels are evident on the subbottom records (Figure 4-4). It is suggested that these channels are associated with the easternmost extension of the St.

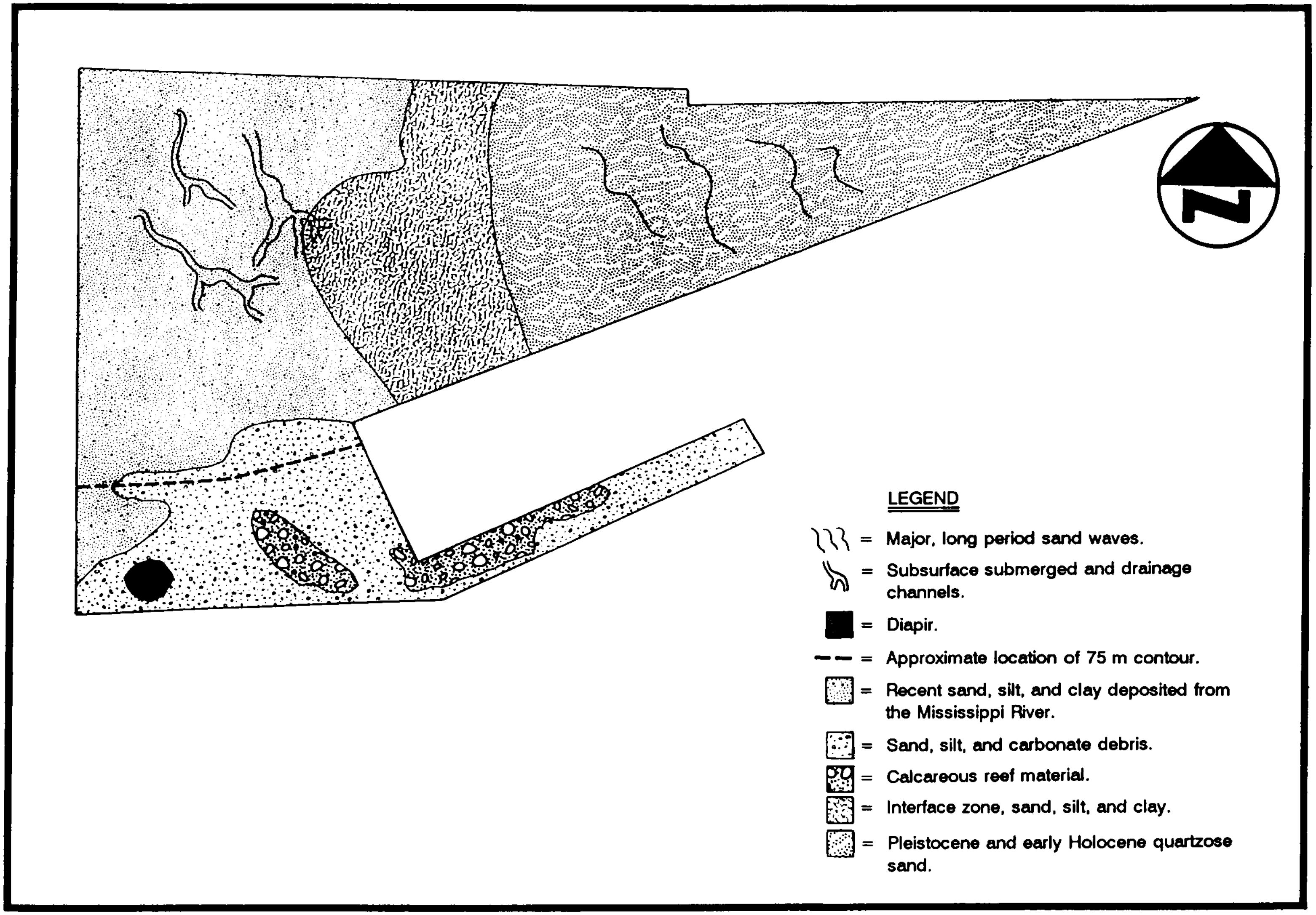

Figure 4-3. Surficial sediments within the study area (diagrammatic representation).

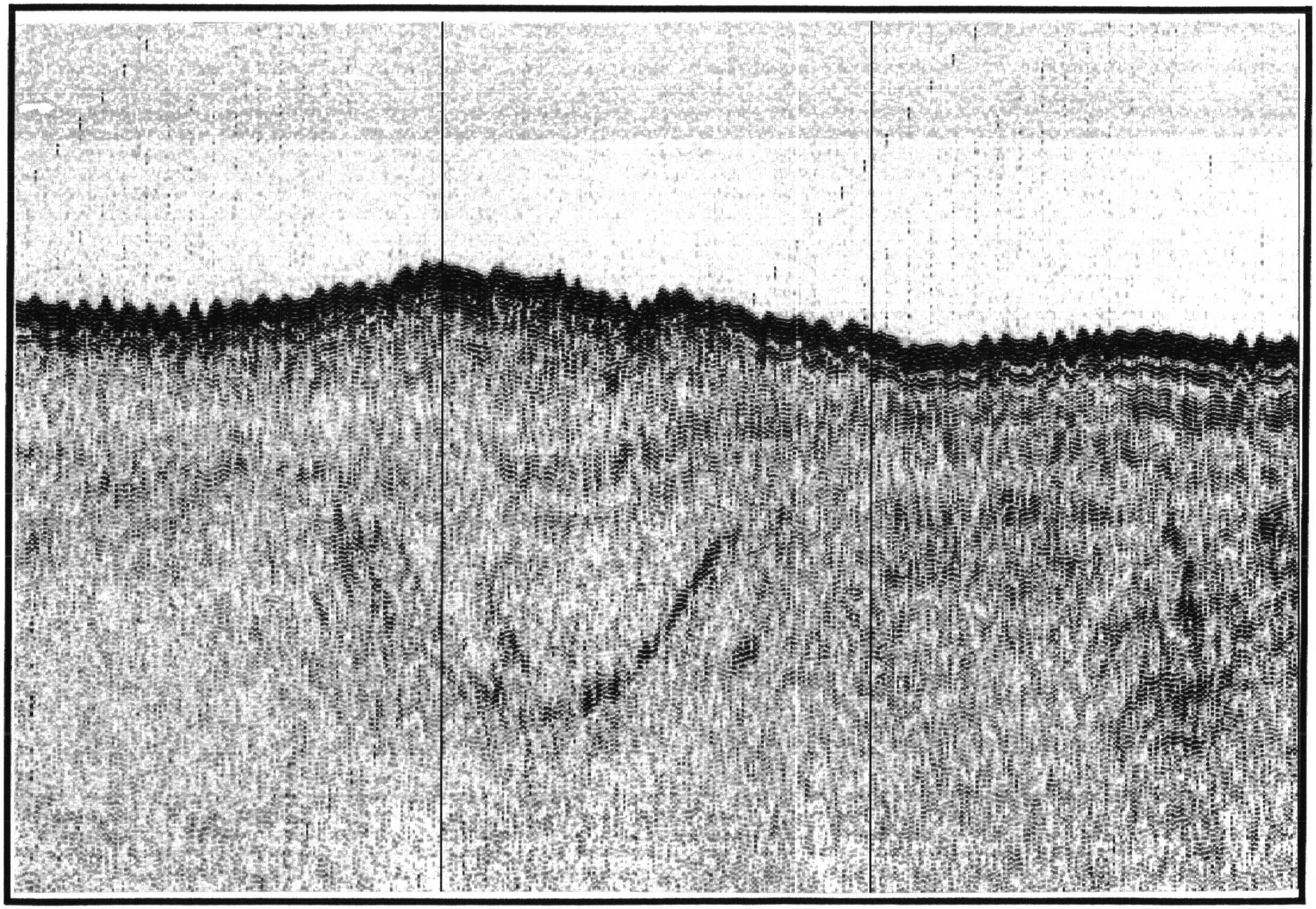

Figure 4-4. Infilled paleo-drainage channel.

Bernard Delta, created during the most recent sea level high (3,000 to 4,000 YBP). These channels have been overlain with sediments from the modern delta (G. Brooks, 1992, University of South Florida, personal communication).

A series of possible and probable low-relief hardbottom features, as determined from various geophysical signatures, are present on the shelf and along the shelf break (Figures 4-5, 4-6, and 4-7). These signatures occur in the eastern portion of the study area (i.e., along the Alabama shelf) and are similar to inner-shelf hard bottom types described by Schroeder et al. (1988b).

Schroeder et al. (1988b) defined four types of hard-bottom rock from the Alabama shelf in areas adjacent to those covered by this study. These were as follows:

1) Massive to nodular sideritic sandstones and mudstones;

2) Slabby, aragonite-cemented coquina and sandstone outcrops associated with storm-related ridges of shell hash and sand;

3) Dolomitic sandstones occurring in small, irregular outcrops; and

4) Calcite-cemented reef-like knobs.

Figure 4-5 is an example of a probable sideritic sandstone and mudstone hard-bottom area from the present study. Figure 4-6 is an example of a probable sandstone outcrop associated with a sand ridge. Figure 4-7 is an example of a probable small, irregular dolomitic sandstone outcrop. For reasons cited previously, these signatures are difficult to positively classify using side-scan and subbottom records alone. Artifacts or false positive readings may be produced as a result of sediment characteristics and the shape of the storm-related sand waves and ridges seen throughout this area. The hard-bottom areas plotted during this study (see Figure 4-1 and Appendix D) result from several reviews of the records and a careful reclassification of hard-bottom signatures following the ground truthing effort of October 1991. Signatures which represented examples of "calcite-cemented reef-like knobs" were not seen above the shelf break (75 m; 246 ft) during this study.

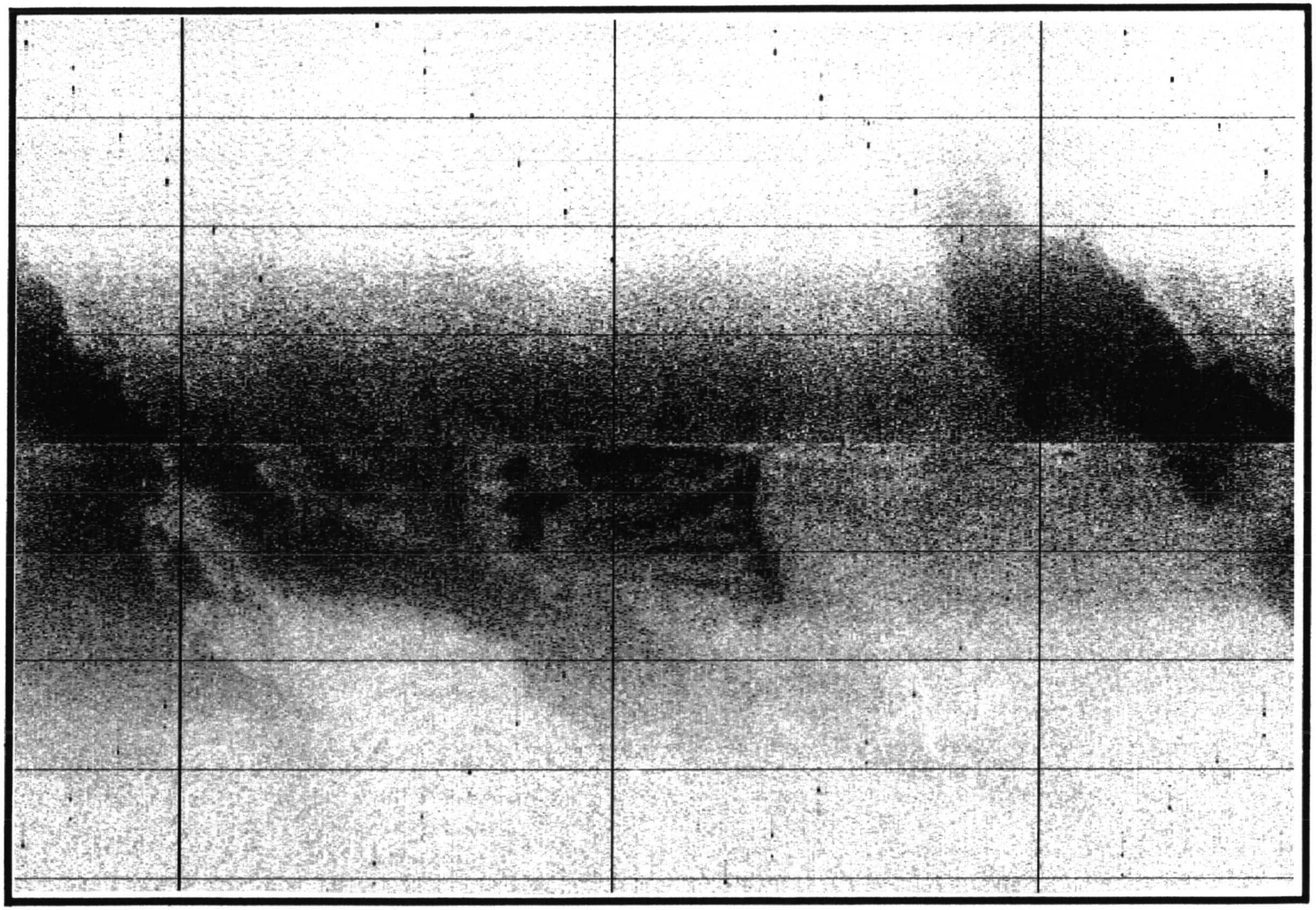

Figure 4-5. Probable nodular sideritic sandstone and mudstone hard bottom.

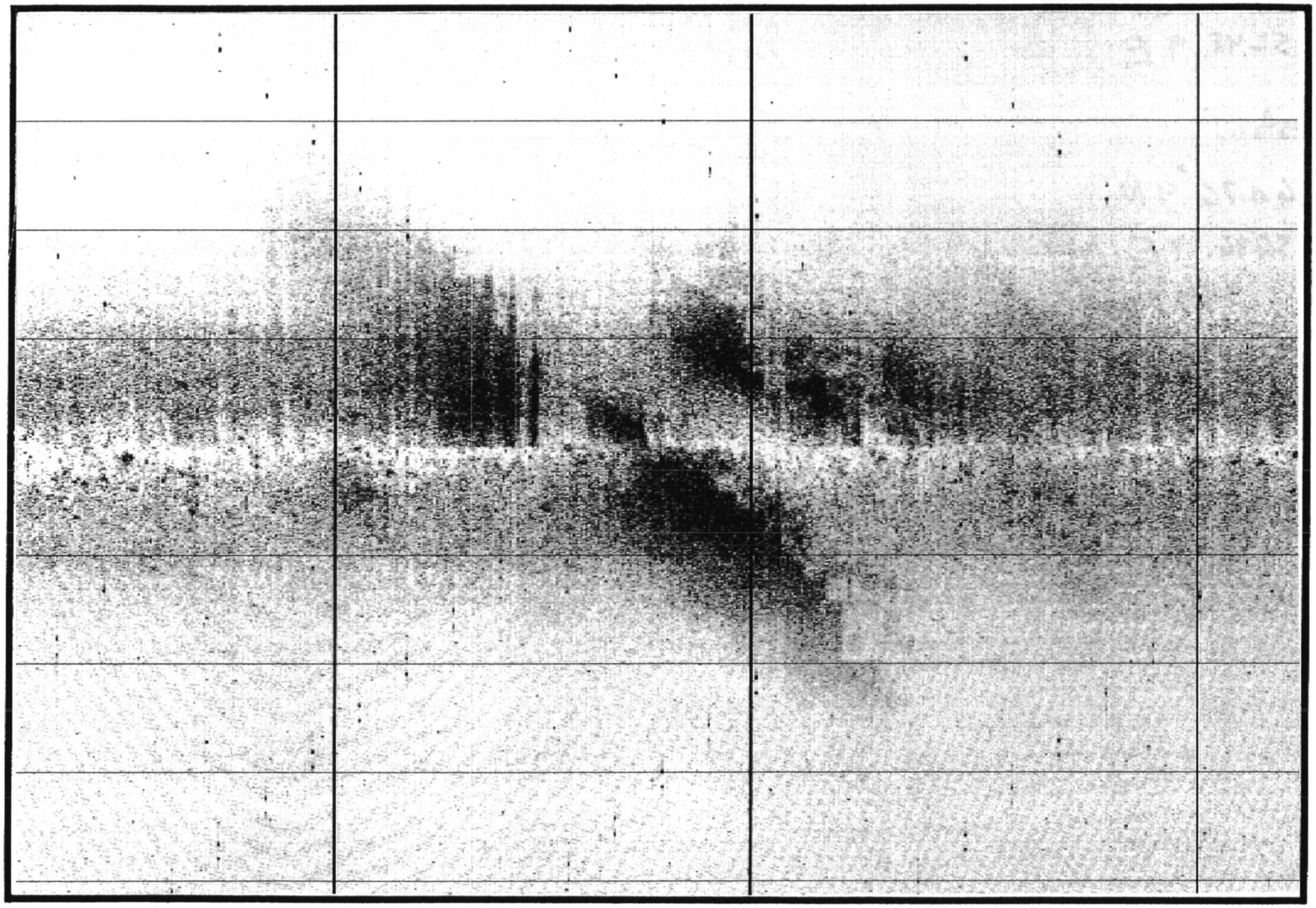

Figure 4-6. Probable aragonite-cemented coquina and sandstone hard bottom associated with storm-related ridges of sand and shell hash.

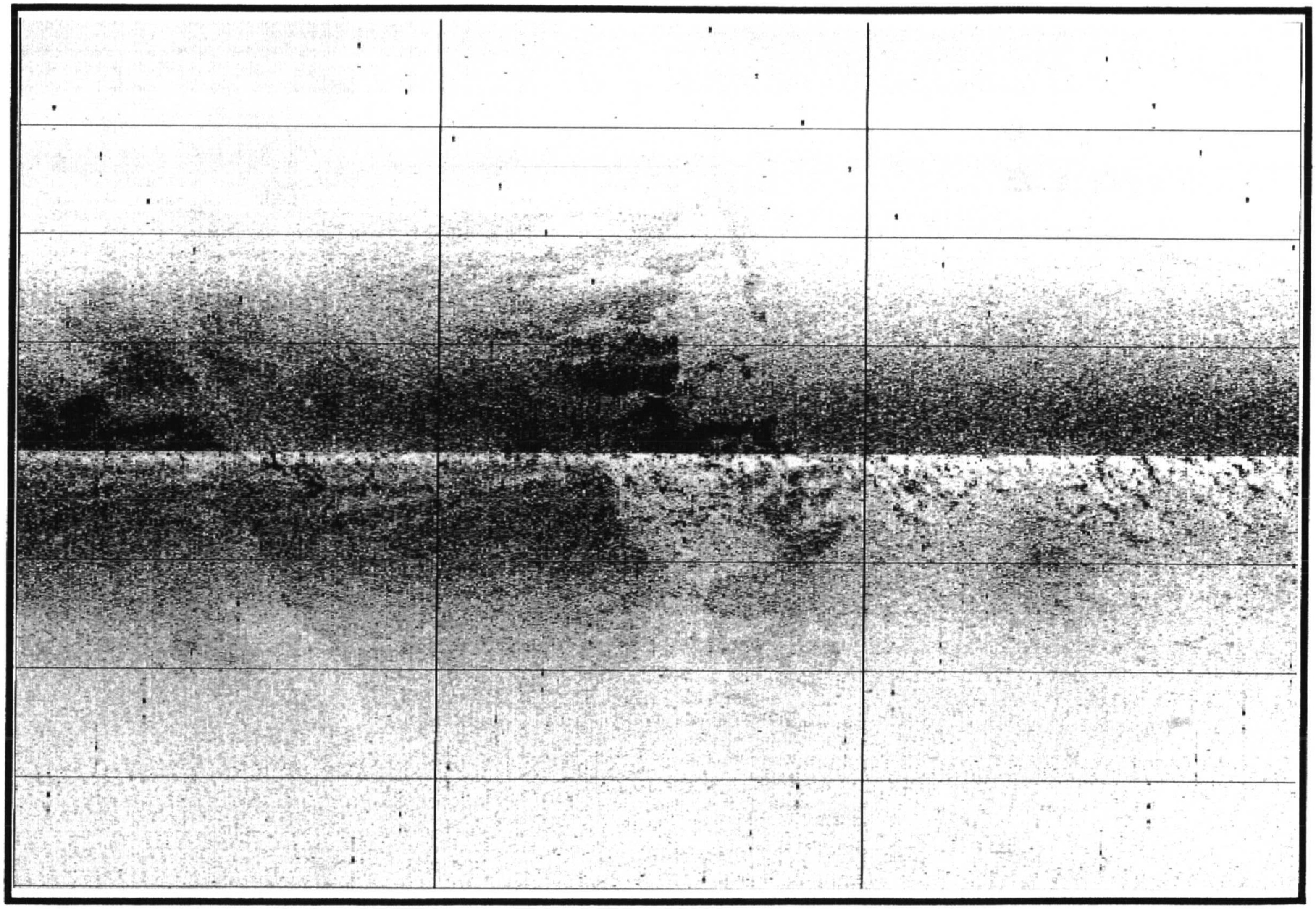

Figure 4-7. Probable small dolomitic sandstone hard bottom outcrop.

4.4.2 Shelf Break and Upper Slope

Beyond the shelf break, within the realm of the upper slope (75 to 400 m; 246 to 1,300 ft), deltaic mainland runoff sediments overlap with marine sediment sequences in a complicated pattern produced by marine deposition during sea level high stands and erosion during low stands (Kindinger 1989). Both organic and inorganic sediments exhibited such a high degree of sorting and commuted character that Ludwick and Walton (1957) concluded this seafloor area was still being influenced by waves and currents. Some of their samples contained considerable amounts of organic carbon while others showed large amounts of silt, clay, and quartzose sand. Within what they describe as the "Hinter" pinnacle zone or upper slope pinnacle zone, sediments sampled averaged 48.6% carbonate debris and 19.4% quartz. Within the pinnacle zone itself, carbonate sediments comprised 70.7% of the samples and quartz only 3.6%. In the deep Fore-Pinnacle Zone to seaward, carbonate material comprised 77.8% of the sediments while quartz made up 3.3%. This evidence lead Ludwick and Walton (1957) to conclude that the pinnacle zone is not presently an area of terrigenous deposition.

All investigations to date (e.g., Ludwick and Walton 1957; Shipp and Hopkins 1978; Schroeder et al. 1988a, 1988b; Sager et al. 1990) concur that, lithologically, the pinnacles of the Mississippi-Alabama continental shelf are hard, rigidly-cemented, irregularly-shaped aggregates of calcareous organic structures. Samples analyzed by Ludwick and Walton (1957) were composed of worm tubes, encrusting bryozoa, and calcareous algae. Calcareous red algae of the genus *Lithothamnion* made up 72% of the pinnacle rock analyzed by Ludwick and Walton (1957). To date, there have been no actual corings of specific pinnacles and the origins of the external carbonate rock covering these features today are not necessarily the same as their internal core.

Ludwick and Walton (1957) speculated that the pinnacles seen along the upper Mississippi-Alabama shelf slope originated as reefs during lower sea level stands. They suggested the pinnacle trends seen today represent eroded elements of reefs that developed during the early part of the Holocene rise in sea level. Today, these remnant structures are no longer growing but occupy an intermediate position between growth and fossilization (Ludwick and Walton 1957; Sager et al. 1990). These speculations are supported by Kindinger's (1988, 1989) work on stratigraphy and sedimentation on the Mississippi-Alabama shelf.

Seafloor mapping completed during the Mississippi-Alabama Marine Ecosystem Study (Brooks and Giammona 1990) indicated a far greater diversity and distribution of topographic features than envisioned by Ludwick and Walton (1957). Brooks and Giammona (1990) mapped pinnacle-type features ranging from less than 2 to greater than 20 m (<6 to >60 ft) in height. There were many small, isolated, reef-like structures showing low to moderate relief and of unknown geologic origin. Some of these reef-like features appeared to be hard substrates exposed by erosion during low sea level stands along Pleistocene shorelines. Others may have been small patch reefs or bank reefs that existed near these paleo-coastlines. As the largest features, pinnacles are generally believed to be remnants of offshore reefs which probably formed during the Holocene Transgression (Sager et al. 1990; Gittings et al. 1990).

Results of the present study indicate the presence of a variety of topographic features along the upper Mississippi-Alabama shelf slope. Two types of hard-bottom, shelf-edge prominence areas have been mapped (Figures 4-1 and 4-2) including:

- Area 1 - an area of large pinnacle development between the 80 and 90 m (260 to 295 ft) bathymetric contours; and

- Area 2 - an area of low relief hard-bottom and small pinnacle or mound development between the 110 and 130 m (360 to 426 ft) bathymetric contours.

There is also an impressive scarp and extensive hard-bottom development associated with the salt dome diapir feature present in the southwest corner of the study area, however, this feature has been extensively described elsewhere (Brooks and Giammona 1988).

Area 1, the major pinnacle zone, is located on a relatively level seafloor peninsula between the 75 and 100 m (246 and 330 ft) depth contours. This peninsula juts seaward into deeper waters, where depths drop sharply from 100 m (328 ft) on the peninsula to 110 m plus (330 ft plus) over a short distance. Pinnacles present in Area 1 fit the classic description of Ludwick and Walton (1957). They are large features which occur in clumps and are oriented in a northwest to southeast direction (Figures 4-1 and 4-8). If these features were once part of a Holocene barrier reef, that reef may have bordered the southeast side of a bay or intrusion into the paleo-coastline.

Features within Area 2 appear differently on the geophysical records (Figure 4-9). Pinnacle-like structures are evident, however they are generally considerably smaller than those of Area 1. There are also small mound features seen within Area 2 which, while they reach the same height above bottom as the pinnacle features, are broader and do not show the same subbottom characteristics (Figure 4-10). Unlike the surrounding sediments in Area 1 which appear soft, the substrate in Area 2 appears to be continuous, low-relief hard bottom.

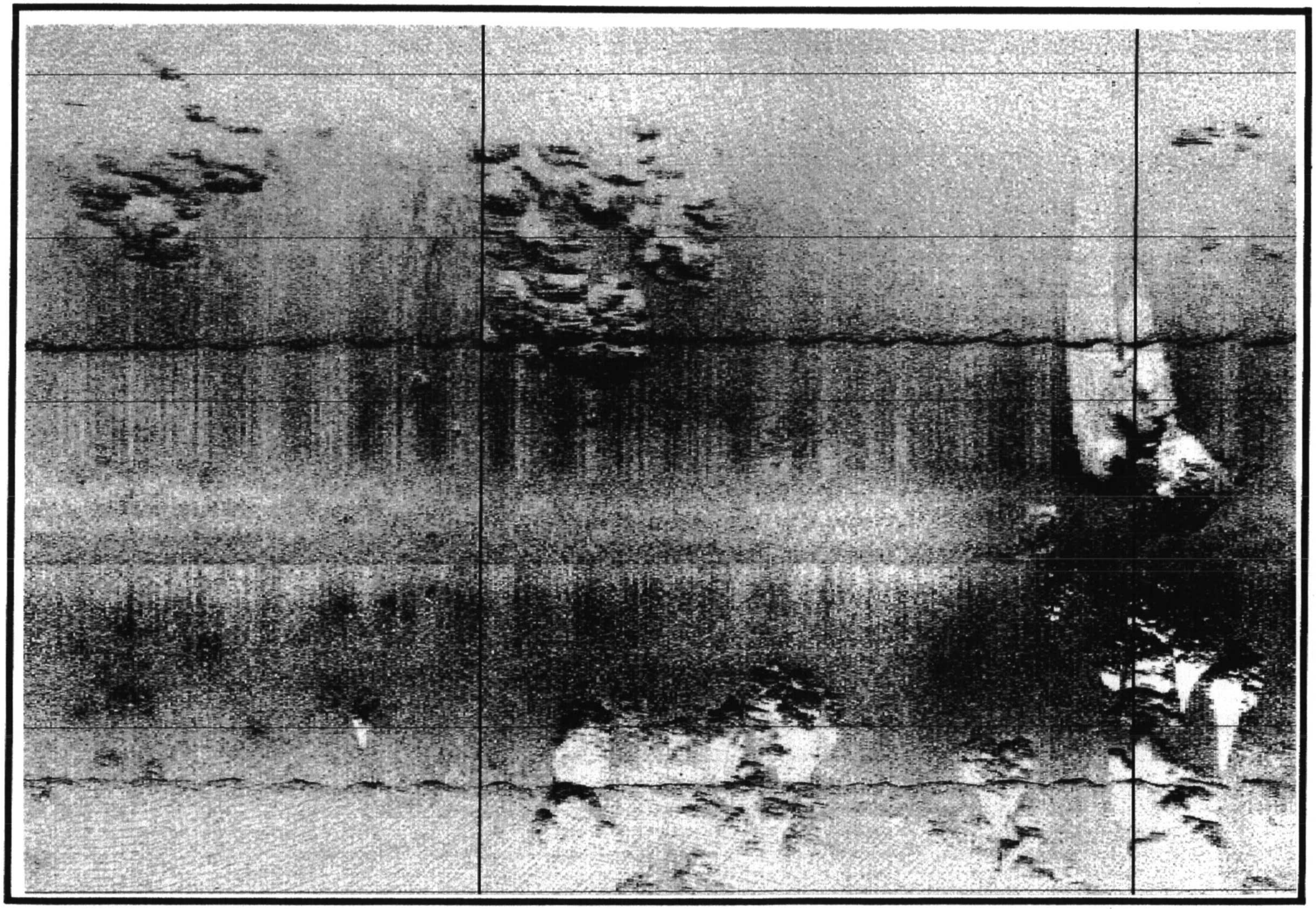

Figure 4-8. Large pinnacle clusters in <100 m (328 ft) of water (Area 1).

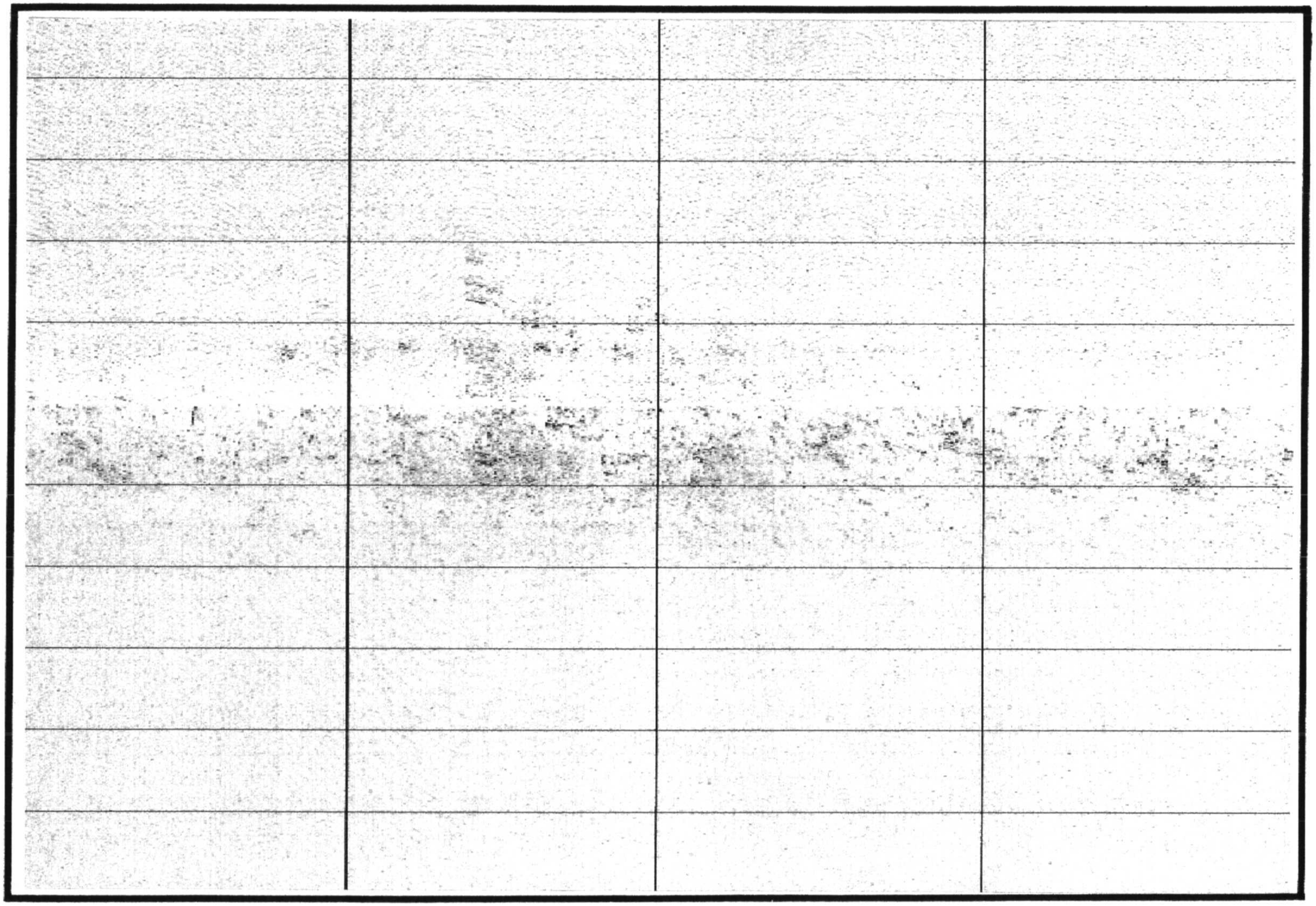

Figure 4-9. Small pinnacles and hard bottom in 120 m (394 ft) of water (Area 2).

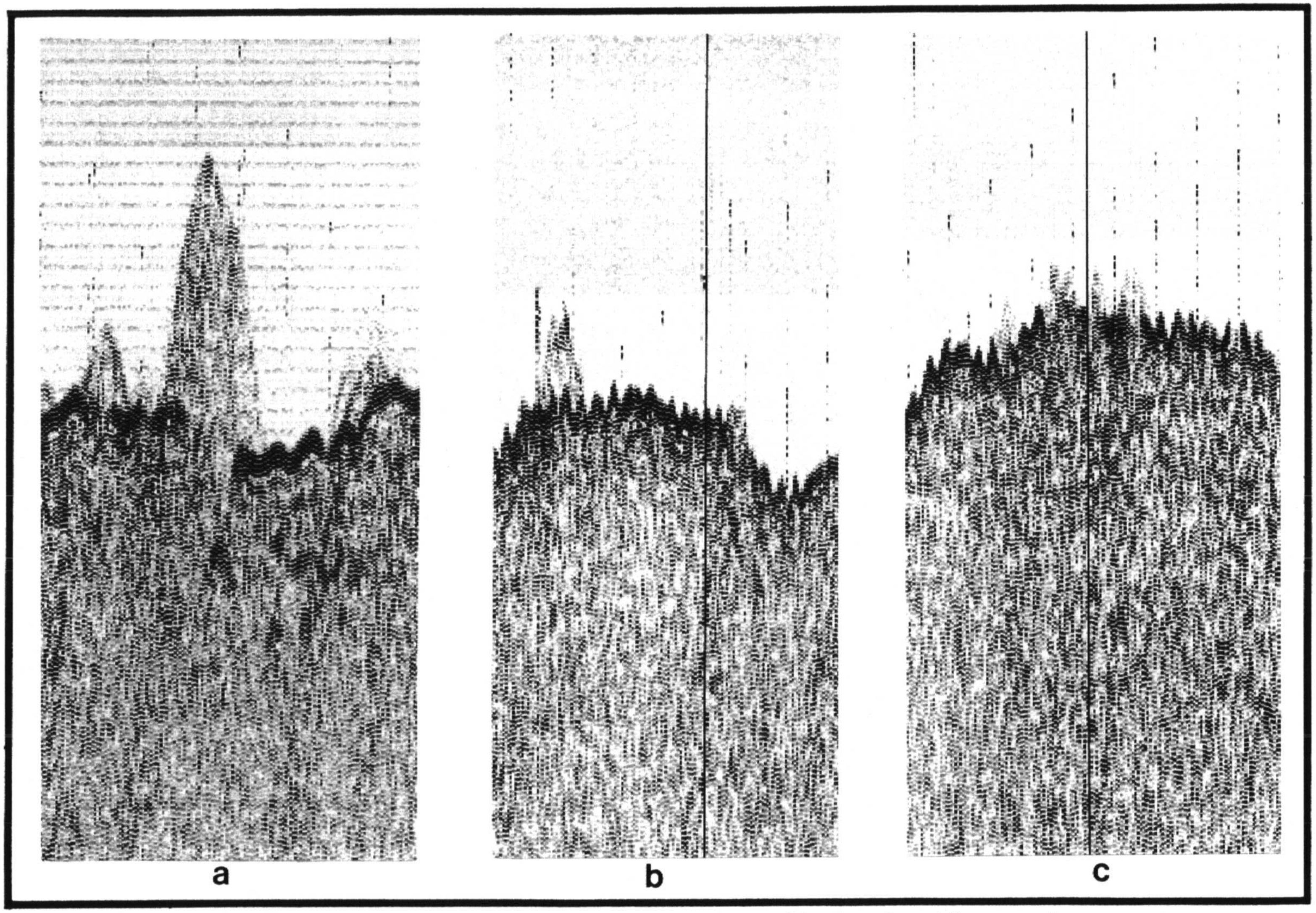

Figure 4-10. Subbottom signatures (a) Area 1 pinnacle, (b) Area 2 pinnacle, and (c) Area 2 reef-like mound.

Based on the descriptions in Sager et al. (1990) and Gittings et al. (1990), Area 2 would appear to be an older development of nearshore reefs and reef-like features. It is possible that the continuous hard-bottom evident in this area may be an even older, hard substrate which was exposed by erosion during the last low sea level stand (i.e., just before the beginning of the Holocene, approximately 12,000 to 15,000 YBP). Upon this hard substrate, the current pinnacles and mound-like reef structure may have developed as barrier and patch reefs, only to be inundated by the rapid rise of sea level in the early Holocene. The larger barrier reefs which formed the major structures present in Area 1 would have formed slightly later in the Holocene when sea level rise had slowed. They may have also formed the barrier reef counterpart for many of the inner bank or patch reef-like hard-bottom features surveyed and mapped during the Mississippi-Alabama Marine Ecosystem Study (Brooks and Giammona 1990).

5.0 BIOLOGICAL CHARACTERIZATION AND COMMUNITY DESCRIPTION

5.1 Introduction

The area investigated during this study lies on the Mississippi-Alabama continental shelf in water depths ranging from approximately 40 to 200 m. The Mississippi-Alabama shelf has been investigated by many researchers during various studies. During these undertakings, the occurrence of various types of hard bottom substrate and the various biological communities associated with them have been documented. Several of these previous studies investigated areas that actually occurred within the bounds of this study, while others have investigated adjacent and distant areas on the Mississippi-Alabama shelf.

Ludwick and Walton (1957) conducted a bathymetric and biological survey of topographic features present along the edge of the Mississippi-Alabama continental shelf. The location of the study area, as well as the location of the features mapped by these researchers, is shown in Figure 5-1. Some of the features mapped during this earlier investigation occurred within the area defined for this study. Ludwick and Walton (1957) documented calcareous shelf edge prominences present in a wide band (approximately 1.6 km) in water depths ranging from 68 to 84 m and 97 to 101 m. They identified pinnacle-like features with a typical vertical relief of 9 m; several features over 15 m in relief were also identified. Biota associated with these features included soft corals, ahermatypic hard corals, bryozoans, and sponges.

Woodward-Clyde Consultants, Inc. (1979) surveyed oil and gas lease blocks located to the east of the study area and recorded the presence of pinnacle features. Underwater television and still camera data were collected along six transects to describe the substrate and biological communities present. Biota associated with the pinnacle features included antipatharian sea whips and branching octocorals, muricid and paramuricid sea fans, and hard coral species described as "probably *Oculina*."

Live bottom surveys have investigated topographic features located in specific areas in conjunction with site-specific oil and gas exploration activities. Continental Shelf Associates, Inc. (1985b) investigated pinnacle features within Destin Dome Area Block 617, located to the east of the study area along the northwest edge of the De Soto Canyon. Based on underwater television/still camera data, pinnacles in water depths of 95 to 130 m (with up to 14 m of vertical relief) were described as extremely rugged and craggy with vertical faces, overhangs, and ledges. Extensive biotal coverage consisted of hydroids, antipatharians, octocorals, hard corals, crinoids, and bryozoans, along with

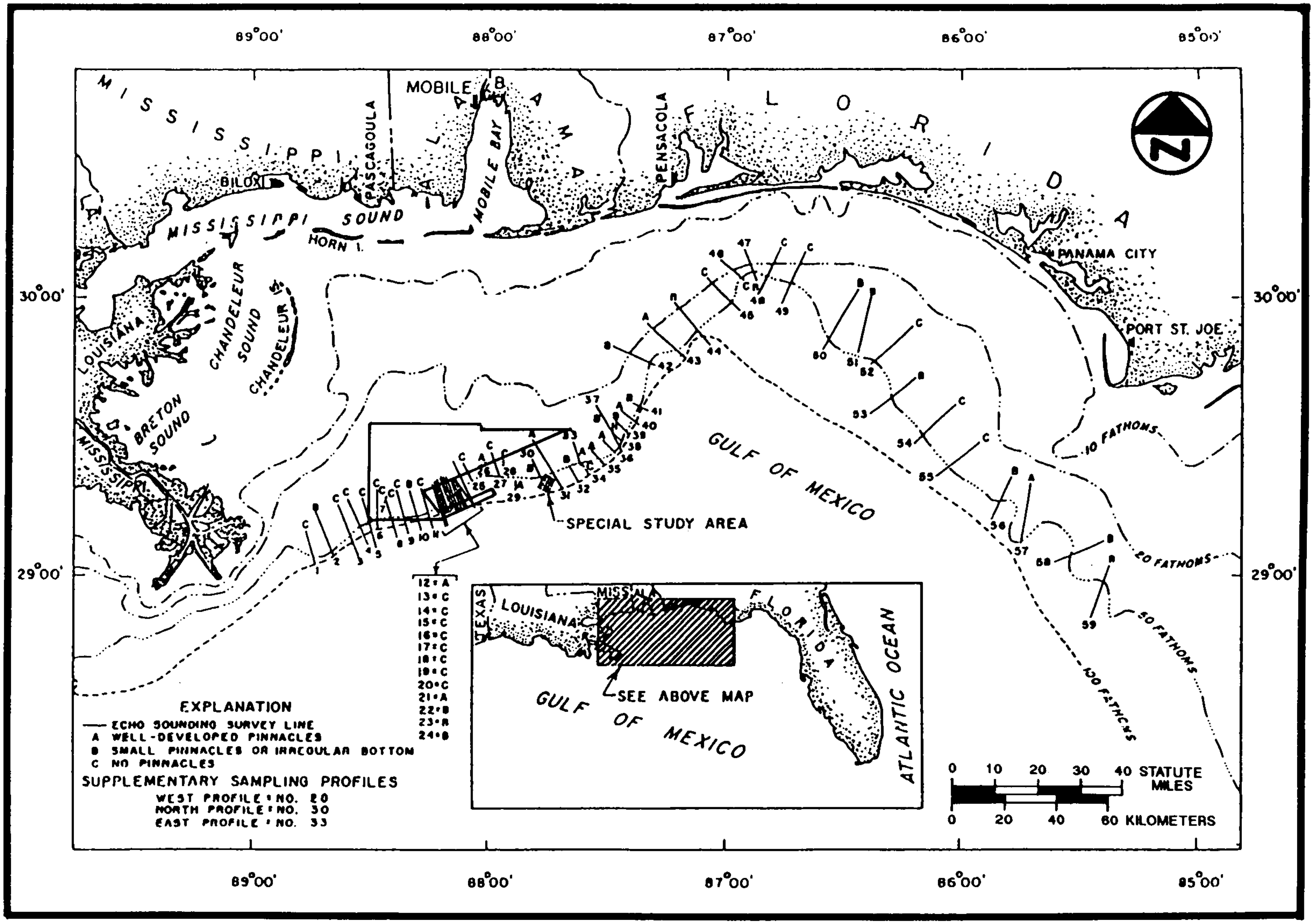

Figure 5-1. Transects surveyed by Ludwick and Walton (1957) in the northeastern Gulf of Mexico.

numerous species of fishes. Destin Dome Area Block 617 also occurs within an areas of pinnacle features surveyed by Ludwick and Walton (1957).

Recently, Brooks and Giammona (1988, 1990) conducted investigations of the Mississippi-Alabama continental shelf during the Mississippi-Alabama Marine Ecosystem Study. The study area evaluated by Texas A&M University (TAMU) scientists, located along the northwest margin of the De Soto Canyon in water depths ranging from 50 to 340 m, is immediately adjacent to the area evaluated during the present study (Figure 2-1). Three classes of topographic features were described by TAMU within the study area. These included 1) pinnacles, possibly formed by coral-algal assemblages; 2) linear ridges, possibly lithified dunes, and 3) features with enigmatic origin. Biological communities associated with these features were varied. However, these assemblages typically consisted of gorgonians, ahermatypic corals, antipatharians, sponges, comatulid crinoids, bryozoans, and oysters. Coralline algae were observed on relatively shallow features.

The present study effort investigated another portion of the Mississippi-Alabama continental shelf located west of the areas investigated during most of these prior studies. Significant topographic features geophysically mapped during Survey 1 were identified for further biological investigation. Three types of features were identified for biological characterization. In order of decreasing priority, the features identified for investigation were 1) pinnacle features present in approximately 80 to 90 m water depths in the south-central portion of the study area; 2) deepwater pinnacles and associated hard bottom located in approximately 110-130 m water depths located to the east of the first priority, major pinnacle trend; and 3) suspected low-relief hard-bottom features identified in the central and eastern portions of the upper shelf (water depths ranging from 45 to 55 m). The location of these features is presented in Figure 4-1. The following discussion describes the biological communities observed on those features investigated during Survey 2 of this study.

5.2 Goals and Objectives

The objectives of the biological characterization survey effort (Survey 2) were to investigate and characterize topographic features identified during geophysical investigations (Survey 1). The characterization was conducted using a remotely operated vehicle (ROV) to collect video and still photographic documentation of the biological communities associated with significant topographic features present within the study area. Since limited cruise time precluded the investigation of every feature present within the area, a prioritized listing of the targets slated for investigation was prepared in an attempt to select representative sites. In prioritizing the features, consideration was given to characteristics such as water depth, topographic relief of the features, previous data available concerning the features, and overall uniqueness of a feature. In addition to characterizing the features biologically, data interpretation allowed for determinations concerning the health of the communities and the effects of the nepheloid layer on the communities present. Further, a comparison to other communities present throughout the Gulf of Mexico was undertaken.

5.3 Methods

5.3.1 Remotely Operated Vehicle

A Phantom HD2 ROV was used to conduct biological investigations of selected features identified during the geophysical survey. The vehicle was outfitted with a Benthos 35-mm still photography mini-camera (Model 3782) and a color video camera (Sanyo Model LL-39). Photographic film used during Survey 2 consisted of Ektachrome 200 (slide film). Video data collected during the survey were recorded on VHS-format tapes. The vehicle was also equipped with dual underwater lights and a depth sensor. It was originally intended to use a manipulator arm to collect rock samples; however, limited cruise time did not allow for the use of this sampling device.

As a backup to the Phantom HD2 ROV, several additional vehicles were onboard and used during the survey. These vehicles included the Phantom 300 and 500, each of which was outfitted with still and video cameras similar to the Phantom HD2 vehicle.

5.3.2 Rock Dredge

A single rock dredge sample was collected during the biological characterization survey. Specimens collected in the dredge were sorted onboard into major taxonomic groups, then properly preserved with formalin and alcohol for further analysis.

5.3.3 Hook-and-Line Sampling

Hook-and-line sampling of fishes associated with pinnacles and other hard-bottom features within the study area was conducted during both day and night throughout the survey. Bait used for sampling included shrimp, squid, and cut fish. A variety of hook sizes and rig types were used to assure representative collection of fishes.

5.3.4 Data Analyses

All still photographic data were developed onboard. Upon return to the laboratory, still photographs were reviewed by experienced biologists who identified organisms to the lowest possible taxonomic level. Photographs were also sent to independent taxonomic experts for identification as needed.

Videotapes collected during each dive were reviewed by trained personnel using a Mitsubishi VCR (Model HS-U80) and a Mitsubishi color monitor (Model CS2054R). The VCR is equipped with a jog/shuttle feature which allows the reviewer to freeze individual frames and advance the picture one frame at a time, enabling the reviewer to attain the best possible view of organisms and substrate. All organisms were visually identified to the lowest possible taxonomic level. In addition, an estimate of the relative abundance of each species observed during the dive was estimated using criteria established by Stark (1968). These criteria have been used by researchers from TAMU during previous investigations in this vicinity (Brooks and Giammona 1988). These descriptors include the following:

- Rare - seldom observed, or a very small percentage of sightings at a location, observed only once or possibly twice at any particular station but possibly several times at stations with high overall abundances.

- Occasional - sporadically observed, typically at irregular intervals; usually several observations or more at stations with high overall abundances.

- Frequent - observed regularly; common; observed in a large portion of their habitat at a station.

- Abundant - a regularly encountered species observed in high numbers and comprising a high percentage of observations.

Information concerning substrate type was also recorded during videotape review. Species identified during each dive were categorized based on their location on the feature. Categories used for identifying locations on the feature included reef top, reef face, reef flat, and reef base. Three dives were made on the upper shelf in areas of suspected low relief hard bottom. During these three dives the only bottom type encountered was sand.

The composition of the fish community was described based on the fishes collected by hook-and-line sampling as well as using the limited sighting that occurred in video and still photography data. Hook-and-line collections were conducted with the intent of gaining some other data to use in conjunction with the video and still photographic data. However, due to the limited nature of the video and still photography data, the fish communities were characterized primarily using the information obtained by hook-and-line sampling.

Specimens collected in the single dredge sample were sent to recognized taxonomic experts for identification. Ahermatypic corals were identified by Dr. Stephen Cairns at the Smithsonian Institution. Hydroids were identified by Dale Calder at the Royal Ontario Museum. Crinoids were identified by Dr. Charles Messing at NOVA Oceanographic Center.

Fishes collected by hook-and-line sampling were identified onboard. The fork length of each specimen was measured and recorded before release or suitable disposal of the fish.

5.4 Results and Discussion

5.4.1 ROV Investigations

A total of 12 separate ROV dives were conducted during Survey 2. Nine of the dives were conducted within the major pinnacle trend features (i.e., first priority features) identified in Figure 4-1. During marginal working conditions (i.e., due to weather), three dives were also attempted in shallow water in areas of suspected low-relief hard bottom features (i.e., third priority features).

The following is a discussion of the physical and biological observations made concerning respective topographic features visited during each dive, based on the analyses of videotape and still photographic data collected.

Dive 1. Dive 1 was conducted on a major topographic feature located at 29° 15' 13" N, 88° 20' 47" W (Figure 5-2). The feature, bathymetrically mapped using the ship's fathometer, ranged in depth from approximately 90 m at the base to 65 m at the top. This feature is a narrow ridge that extends in a north-south direction for approximately 1 km and is approximately 250 m wide. This feature was previously identified, mapped, and named 36-Fathom Ridge by researchers from Texas A&M University during a previous MMS-funded study. A single ROV dive was conducted on the crest of this feature. Due to its extensive size and the relatively limited amount of

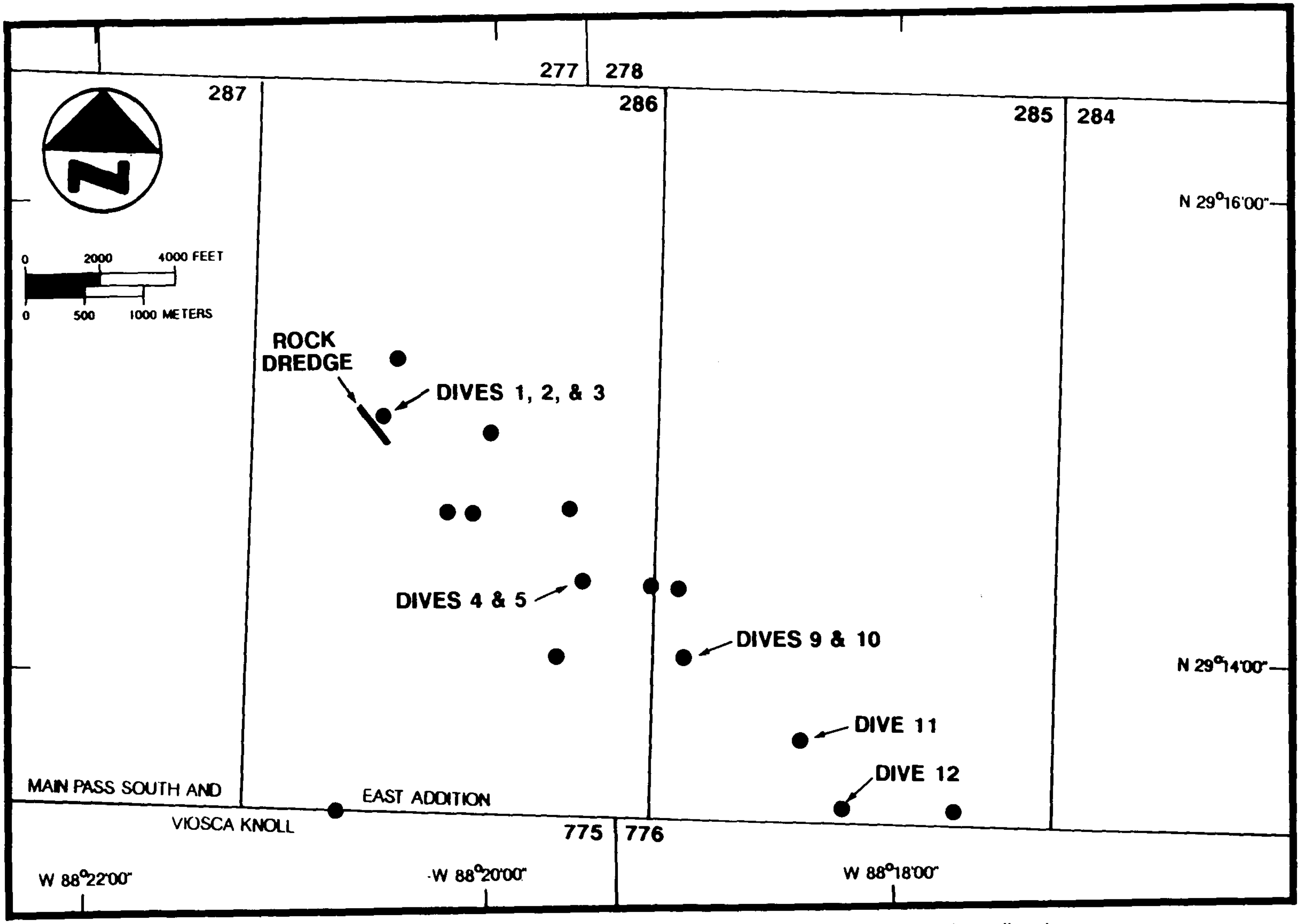

Figure 5-2. Locations of ROV Dives (1, 2, 3, 4, 5, 9, 10, 11, and 12) and rock dredge sample collection.

information available concerning the feature, additional biological characterization was conducted during Dive 2.

During Dive 1, observations were made at the base of the feature (i.e., at a depth of approximately 88 m) and vertically along several steep walls/faces up to a depth of 78 m, which jutted straight up from the feature's base. A list of the species observed on this feature during Dive 1 is presented in Table 5-1. At the base of the feature, biotal cover was relatively low. Water clarity was very good throughout the dive and no nepheloid layer was observed. The ahermatypic black coral, *Rhizopsammia manuelensis*, was the dominant organism observed. Several species of antipatharian (*Antipathes atlantica, A. furcata, Antipathes* spp.) were also occasionally observed. Several unidentifiable species of comatulid crinoids typically occurred throughout the area. Commonly, the rock faces were surrounded by aprons of relatively coarse sand and rubble that had accumulated around the base of the feature. In some locations, gradual sloping faces of the feature graded into the surrounding sediment and were often covered by very coarse rubble and rocks. These areas typically had very little attached biota, suggesting that the surface is eroding or breaking down. The resulting rubble precludes attachment by encrusting epifaunal organisms.

The walls of the feature are more densely populated with a variety of organisms. As observed at deeper locations around the base of the feature, *R. manuelensis* is probably the dominant species; however, this species density significantly increased as water depth decreased (i.e., as one ascended the rock walls). Several species of soft corals, *Antipathes* spp., were frequently present. Additionally, several ahermatypic corals were occasionally observed on vertical walls. These species included *Madracis myriaster* and a small cup coral (?*Balanophyllia floridana*). Comatulid crinoids were occasionally observed on the sheer rock walls as were several other soft corals (*Ellisella* sp., *Cirripathes* sp). A single fireworm, *Hermodice carunculata*, was observed at the base of the wall.

Only a limited number of fish species were observed during Dive 1 (Table 5-1). Roughtongue bass, *Holanthias martinicensis*, was the most common species observed. Other species occasionally observed included vermilion snapper, *Rhombolites aurorubens*; bank butterflyfish, *Chaetodon aya*; an unidentified squirrelfish, *Holocentrus* sp.; and an unidentified scorpionfish (Scorpaenidae).

Dive 2. Dive 2 was conducted on the same topographic feature as Dive 1 (Figure 5-2). The purpose of the dive was to investigate the biological communities associated with the vertical reef face/rock walls of the feature at depths shallower than those investigated during Dive 1. The dive location was

Table 5-1. Species identified from videotapes and still photographs during Dives 1, 2, and 3 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance			
	Reef Base[1]	Reef Face[1,2,3]	Reef Flat[2,3]	Reef Top[3]
Algae				
Corralinacea				
unidentified coralline algae	---	O[3]	---	O[3]
Porifera				
Calcarea				
Leucettida				
unidentified Leucettida	---	R[1], O[2]	O[2]	---
Demospongiae				
Verongida				
Aplysinellidae				
?*Aplysina* spp.	---	---	---	R[3]
Dictyoceratida				
Thorectidae				
Ircinia ?campana	R[1]	---	---	---
Hadromerida				
Clionidae				
?*Cliona* spp.	---	R[1]	---	---
Spirophorida				
Tetillidae				
Cinachyrella spp.	R[1]	---	O[2]	---
Astrophorida (= Choristida)				
Geodidae				
Geodia neptuni	---	---	R[2]	---
Geodia spp.	R[1]	---	---	R[3]

Table 5-1. Species identified from videotapes and still photographs during Dives 1, 2, and 3 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance			
	Reef Base[1]	Reef Face[1,2,3]	Reef Flat[2,3]	Reef Top[3]
Cnidaria				
Hydrozoa				
Hydroida				
Eudendriidae				
Eudendrium spp.	---	R[1]	---	---
unidentified hyroid	---	O[2]	O[2]	---
Anthozoa				
Alcyonaria				
Alcyonacea				
Nidaliidae				
Siphonogorgia agassizii	---	R[1]	R[2]	---
Plexauridae				
Bebryce spp.	---	---	---	O[3]
?*Scleracis* spp.	R[1]	---	---	R[3]
Thesea spp.	---	---	---	R[3]
Ellisellidae				
Ellisella spp.	O[1]	O[1,2], F[3]	F[2,3]	F[3]
?*Nicella* spp.	---	---	R[2]	O[3]
Zoantharia				
Scleractinia				
unidentified Scleractinia	---	R[1]	---	---
Pocilloporidae				
Madracis ?myriaster	---	O[1,2,3]	O[2,3]	O[3]
Oculinidae				
Oculina ?diffusa	---	O[3]	O[2,3]	O[3]
Caryophyllidae				
Rhizopsammia manuelensis	O[1]	F[1,2,3]	F[2,3]	F[3]
Guyniidae				

Table 5-1. Species identified from videotapes and still photographs during Dives 1, 2, and 3 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance			
	Reef Base[1]	Reef Face[1,2,3]	Reef Flat[2,3]	Reef Top[3]
Cnidaria (continued)				
?*Balanophyllia floridana*	---	O[1,2]	R[2,3]	R[3]
Antipatharia				
Antipathidae				
Antipathes spp.	O[1]	F[1,2,3]	F[2,3]	O[3]
Antipathes atlantica	O[1]	O[1,3], F[2]	F[2], O[3]	O[3]
Antipathes furcata	O[1]	O[1,3], F[2]	F[2], O[3]	O[3]
Cirripathes ?luetkeni	R[1]	O[1,2], F[3]	F[2,3]	F[3]
Mollusca				
Gastropoda				
unidentified Gastropoda	---	---	R[3]	---
Annelida				
Polychaeta				
Errantia				
Amphinomidae				
Hermodice carunculata	R[1]	---	---	---
Echinodermata				
Crinoidea				
Comatulida				
unidentified Comatulida (multiple species)	O[1]	F[1,3], O[2]	F[2,3]	F[3]
Asteroidea				
Valvatida				
Ophidiasteridae				
?*Linckia* spp.	R[1]	---	---	---

Table 5-1. Species identified from videotapes and still photographs during Dives 1, 2, and 3 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance			
	Reef Base[1]	Reef Face[1,2,3]	Reef Flat[2,3]	Reef Top[3]
Echinodermata (continued)				
Ophiuroidea				
Phrynophiurida				
Gorgonocephalidae				
unidentified Gorgonocephalidae	---	O[2,3]	O[2,3]	O[3]
Echinoidea				
Cidaroida				
Cidaridae				
Eucidaris tribuloides	---	O[1]	---	---
Stylocidaris affinis	---	R[2]	O[2], R[3]	R[3]
Diadematioda				
Diadematidae				
Diadema antillarum	---	R[3]	R[3]	---
Chordata				
Urochordata-Ascidiacea				
Enterogona				
Didemnum spp.	---	O[3]	---	O[3]
Vertebrata-Osteichthyes				
Teleostei				
Lophiformes				
Ogcocephalidae				
Ogcocephalus spp.	---	---	---	R[3]
Beryciformes				
Holocentridae				
Holocentrus sp.	---	O[1]	---	---

Table 5-1. Species identified from videotapes and still photographs during Dives 1, 2, and 3 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance			
	Reef Base[1]	Reef Face[1,2,3]	Reef Flat[2,3]	Reef Top[3]
Chordata (continued)				
Scorpaeniformes				
Scorpaenidae				
unidentified Scorpaenidae	R[1]	---	R[2]	---
Perciformes				
Serranidae				
unidentified Anthiid	O[1]	O[1,2]	O[2]	---
Holanthias martinicensis	---	O[3]	F[3]	F[3]
Liopropoma eukrines	---	---	---	R[3]
Serranus phoebe	---	O[1,2]	O[2], R[3]	O[3]
Priacanthidae				
Pristigenys alta	---	O[2]	O[2], R[3]	R[3]
Carangidae				
Seriola dumerili	---	O[2]	---	O[3]
Lutjanidae				
Lutjanus campechanus	---	O[2]	---	---
Rhomboplites aurorubens	O[1]	O[1,2]	O[2,3]	O[3]
Chaetodontidae				
Chaetodon aya	---	O[1,2]	O[2], R[3]	R[3]

1 Present during Dive 1.
2 Present during Dive 2.
3 Present during Dive 3.

conducted at 29° 15' 08" N, 88° 19' 52" W, along a steep wall located on the southwest side of the feature. During this dive, water depths ranged from 70 to 78 m. As was the case during Dive 1, water clarity was very good and no nepheloid layer was observed.

The reef face of the feature is composed primarily of vertical rock walls interrupted by small reef flats. These intermittent reef flats of the feature provide horizontal surfaces for epibiotal attachment. A list of the species observed during Dive 2 is presented in Table 5-1. The ahermatypic black coral, *R. manuelensis*, was the most common species associated with the vertical reef face. Several species of antipatharians (including *A. atlantica*, *A. furcata*, and *Antipathes* spp.) were frequently observed along the vertical walls. Other soft corals (*Ellisella* sp. and *Cirripathes ?luetkeni*) were also occasionally present. Several ahermatypic corals were occasionally present, including *Madracis ?myriaster* and *Oculina ?diffusa*). A small cup coral thought to be *Balanophyllia floridana* was also observed occasionally.

Investigations along the wall revealed the presence of relatively horizontal flat areas interspersed between sheer vertical walls. These reef flats occurred sporadically along the reef faces and had considerably increased biotal cover relative to adjacent vertical surfaces. This is probably due to the horizontal orientation which is more suitable for colonization and growth. The dominant species present were similar to those observed on the vertical rock substrate of the reef face. *R. manuelensis* was frequently observed as were several antipatharians (*Antipathes atlantica, A. furcata, Antipathes* spp.). Other frequent species included *Ellisella* sp., *Cirripathes ?luetkeni*, and several comatulid crinoid species. The ahermatypic corals *Madracis ?myriaster* and *Oculina ?diffusa* were also occasionally present as was the same cup coral (probably *Balanophyllia floridana*) observed on the vertical walls.

Several other species not observed on the reef face were present on the reef flats. These included several sponges (*Geodia neptuni*, *Cinachyrella* sp.), several unidentified orange sponges, an unidentified soft coral (possibly *Nicella* sp.), and the alcyonacean, *Siphonogorgia agassizii*.

Fishes observed during the dive included amberjack, *Seriola dumerili*; red snapper, *Lutjanus campechanus*; tattler, *Serranus phoebe*; vermilion snapper, *Rhomboplites aurorubens*; short bigeye, *Pristigenys alta*; and bank butterflyfish, *Chaetodon aya*. All species were observed occasionally during the dive.

Dive 3. Dive 3 was conducted on the same large topographic feature as Dives 1 and 2 (Figure 5-2). The intent of the dive was to investigate the top portions of the feature, including the upper reef faces and the reef crest. During investigations of the upper reef faces, several areas considered reef flat were also traversed. Information concerning species present in these reef flat areas has been included in this discussion. Water depths during the dive ranged from 72 to 65 m.

Reef faces and reef flats investigated during Dive 3 were very similar to those described previously for Dive 2. Biologically, the upper portions of the vertical rock faces present on the feature are not markedly different than the deeper areas. A list of the species observed during the dive is presented in Table 5-1. *R. manuelensis* continued to be the species most frequently observed, with the soft corals *Ellisella* sp., *Cirripathes* sp., *Antipathes* spp., and comatulid crinoids also being very common. The ahermatypic corals *Madracis ?myriaster* and *Oculina diffusa* were also occasionally present. While locally there were some areas of very dense biological growth, the overall density of organisms did not appear greater than in similar substrate types at slightly greater depths.

The crest of the feature (or reef top) was also investigated during Dive 3. The area can be characterized as a very irregular rock surface, with jutting and jagged areas interspersed with depressions typically about 1-2 m lower. Depressions often contained accumulations of coarse rubble and sand. Several species were observed frequently along the reef top. *R. manuelensis* was present on a majority of hard protruding and jutting surfaces. Several soft corals were present, including *Bebryce* sp., *Ellisella* sp., *Cirripathes* sp., and *Antipathes atlantica*. Comatulid crinoids were frequent throughout the reef crest. Unlike the deeper areas of this feature investigated in earlier dives, coralline algae were observed on hard substrates. Photographs presented in Figures 5-3 and 5-4 were taken on the reef crest during Dive 3.

Several other organisms were occasionally observed in the area. These included a bushy orange-red sea fan (possibly *Nicella* sp.), the ascidean *Didemnum* sp., and gorgonocephalids. Other invertebrates rarely observed included the urchin *Stylocidaris affinis*, a branching sponge (possibly *Aplysinia* sp.), the sponges *Geodia neptuni*, and several unidentified sponges. The long-spined urchin *Diadema antillarum* was also observed on the reef crest.

Fishes observed during the dive included roughtongue bass, *Holanthias martinicensis*; tattler, *Serranus phoebe*; short bigeye, *Pristigenys alta*; wrasse bass, *Liopropoma eukrines*; vermilion snapper, *Rhomboplites aurorubens*; amberjack, *Seriola dumerili*; batfish, *Ogcocephalus* sp.; and bank butterflyfish, *Chaetodon aya*.

Dive 4. Dive 4 was conducted on a topographic feature located at 29° 14' 35" N, 88° 19' 30" W, southeast of the first feature investigated during

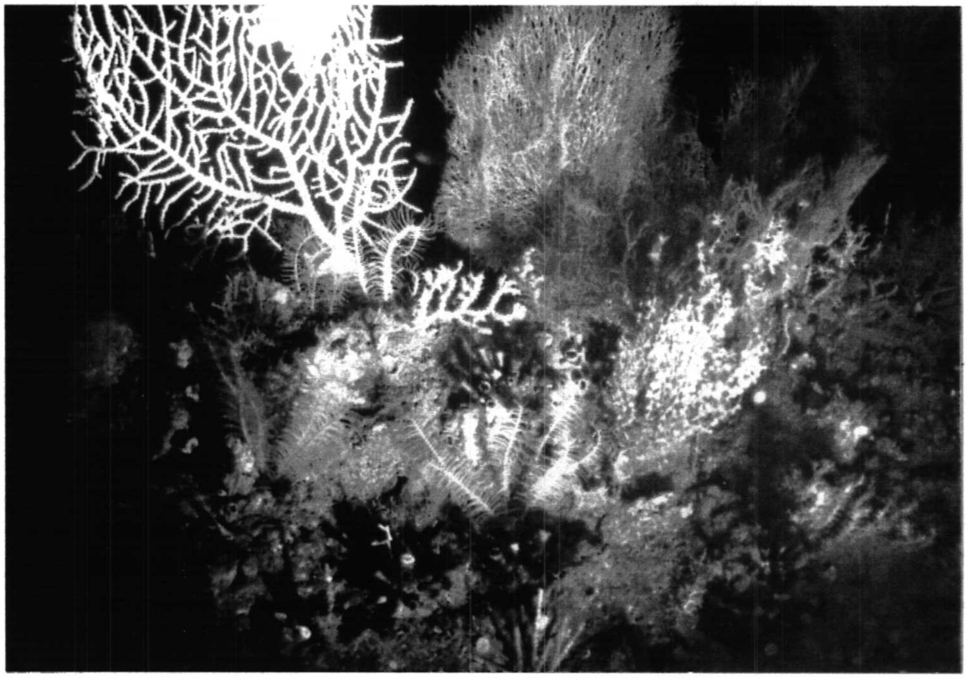

Figure 5-3. Heavy coverage of epibiota on reef top during Dive 3. *Antipathes* sp. (large sea fan) is present in the upper center of the photo.

Figure 5-4. Dense epibiotal coverage at the top of the reef during Dive 3. Numerous comatulid crinoids as well as the black coral *Rhizopsammia manuelensis* are present in the photo.

the survey. The location of the dive is shown in Figure 5-2. The feature was bathymetrically mapped using the ship's fathometer and found to range in depth from 89 m at the base to 74 m at the top. This topographic prominence is relatively small compared to the feature investigated during Dives 1 through 3. Bathymetric mapping revealed this feature to be approximately 350 m across (east-west) and 300 m long (north-south). During the dive, water depths ranged from 80 to 74 m. Water clarity throughout the dive was very good and no nepheloid layer was observed.

The reef top of this feature occurred at a water depth of approximately 74 m. The area investigated had many jagged protruding rocks resulting in significant vertical surfaces for biotal attachment. Several horizontal surfaces were also present, often with accumulations of coarse rubble and sand. A list of species observed during the dive is presented in Table 5-2. The most common organism was *R. manuelensis.* Other frequently observed species included the soft corals *Antipathes* spp., and *Ellisella* sp. and comatulid crinoids. Other ahermatypic corals occasionally present throughout the reef top included *Madracis ?myriaster* and a small cup coral (*?Balanophyllia floridana*).

In addition, several other species were frequently observed on the reef top, primarily along horizontal or near-horizontal surfaces. These included the soft coral *Bebryce* sp. and *Antipathes* spp. An orange soft coral (possibly *Nicella*) and a white fan-like soft coral (possibly *Scleracis* sp.) were also observed occasionally. The sponge *Geodia* sp. and the urchin *Stylocidaris affininis* were also present.

Species present on the vertical reef face were very similar to those occurring on the vertical surfaces on the reef top. *R. manuelensis* was the most common species present, with the soft corals *Antipathes* spp., *Ellisella* spp. and *Cirripathes ?leutkeni* also observed occasionally. Comatulid crinoids were observed occasionally as well as the urchin *Stylocidaris affinis* and several gorgonocephalids seen attached to antipatharians. The photograph presented in Figure 5-5 was taken during Dive 4.

Fishes observed during the dive included roughtongue bass, *Holanthias martinicensis*; amberjack, *Seriola dumerili*; short bigeye, *Pristigenys alta*; blue angelfish, *Holacanthus bermudensis*; and bank butterflyfish, *Chaetodon aya*.

Dive 5. Dive 5 was conducted on the same feature investigated during Dive 4. Water depths during the dive ranged from 82 to 74 m. As was the case during Dive 4, the reef top and reef face of the feature were investigated. The location of the dive is shown in Figure 5-2. Water clarity throughout the dive was very good and no nepheloid layer was observed.

Table 5-2. Species identified from videotapes and still photographs during Dives 4 and 5 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance Reef Face[4,5]	Relative Abundance Reef Top[4,5]
Porifera		
Demospongiae		
Keratosa-Verongida		
Aplysinellidae		
?*Aplysina* spp.	---	O^{5}
Astrophorida (= Choristida)		
Geodidae		
Geodia spp.	---	R^{4}, O^{5}
Cnidaria		
Hydrozoa		
Hydroida		
Eudendriidae		
unidentified hydroids	R^{4}	R^{4}
unidentified hydroids	R^{5}	R^{5}
Eudendrium spp.	---	O^{5}
Anthozoa		
Alcyonaria		
Alcyonacea		
Plexauridae		
Bebryce spp.	---	F^{4}, O^{5}
?*Scleracis* spp.	---	O^{4}, R^{5}
Ellisellidae		
Ellisella spp.	$O^{4,5}$	$F^{4,5}$
?*Nicella* spp.	---	$O^{4,5}$
Zoantharia		
Scleractinia		
Pocilloporidae		
Madracis ?myriaster	$O^{4,5}$	$O^{4,5}$
Caryophyllidae		
Rhizopsammia manuelensis	$F^{4,5}$	$F^{4,5}$
Guyniidae		
?*Balanophyllia floridana*	$R^{4,5}$	$O^{4,5}$
Antipatharia		
Antipathidae		
Antipathes spp.	$F^{4,5}$	$F^{4,5}$
Antipathes atlantica	$O^{4,5}$	$F^{4,5}$
Antipathes furcata	$O^{4,5}$	$O^{4,5}$
Cirripathes ?luetkeni	$O^{4,5}$	O^{4}, F^{5}

Table 5-2. Species identified from videotapes and still photographs during Dives 4 and 5 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance	
	Reef Face[4,5]	Reef Top[4,5]
Echinodermata		
Crinoidea		
Comatulida		
unidentified Comatulida (multiple species)	O[4,5]	F[4,5]
Ophiuroidea		
Phrynophiurida		
Gorgonocephalidae		
unidentified Gorgonocephalidae	O[4,5]	O[4,5]
Echinoidea		
Cidaroida		
Cidaridae		
Eucidaris tribuloides	---	R[4], O[5]
Stylocidaris affinis	---	O[4,5]
Diadematioda		
Diadematidae		
Diadema antillarum	---	R[4,5]
Chordata		
Urochordata-Ascidiacea		
Enterogona		
Didemnum spp.	R[5]	O[5]
Vertebrata-Osteichthyes		
Teleostei		
Perciformes		
Serranidae		
Anthias nicolsi	---	R[4]
Holanthias martinicensis	O[4,5]	F[4,5]
unidentified Anthiid	O[4,5]	O[4,5]
Liopropoma eukrines	---	R[5]
Paranthias furcifer	---	R[5]
Priacanthidae		
Pristigenys alta	R[4,5]	R[4,5]
Carangidae		
Seriola dumerili	O[4,5]	O[4,5]
Chaetodontidae		
Chaetodon aya	R[4,5]	R[4,5]
Pomacanthidae		
Holacanthus bermudensis	---	R[4,5]

[4] Present during Dive 4.
[5] Present during Dive 5.

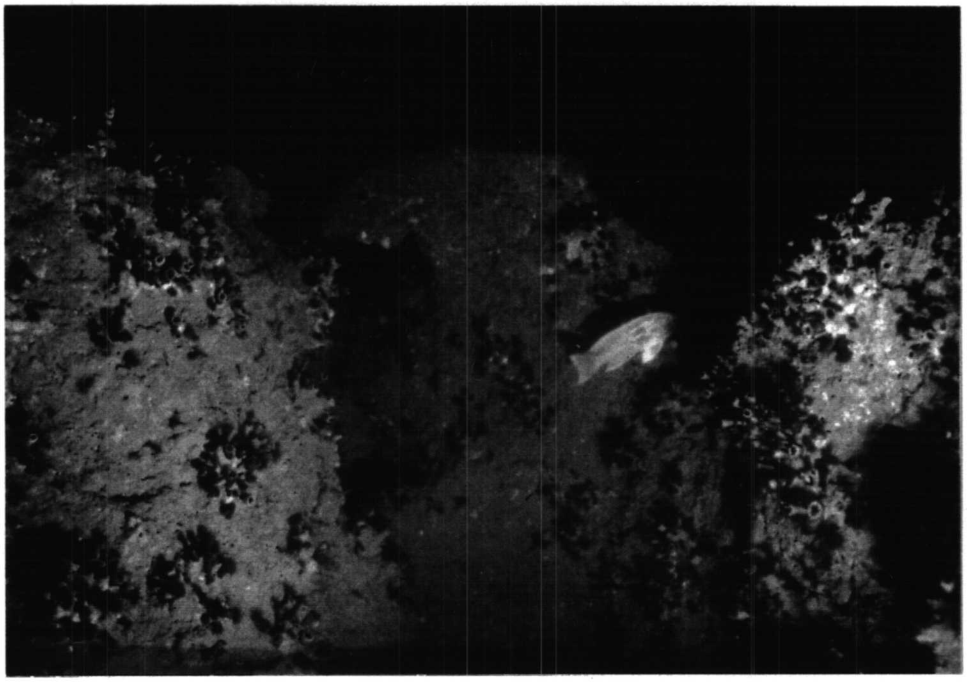

Figure 5-5. Jagged top of the feature investigated during Dive 4. An anthiid (*Anthias nicholsi*) swims among the outcrops populated with *Rhizopsammia manuelensis*.

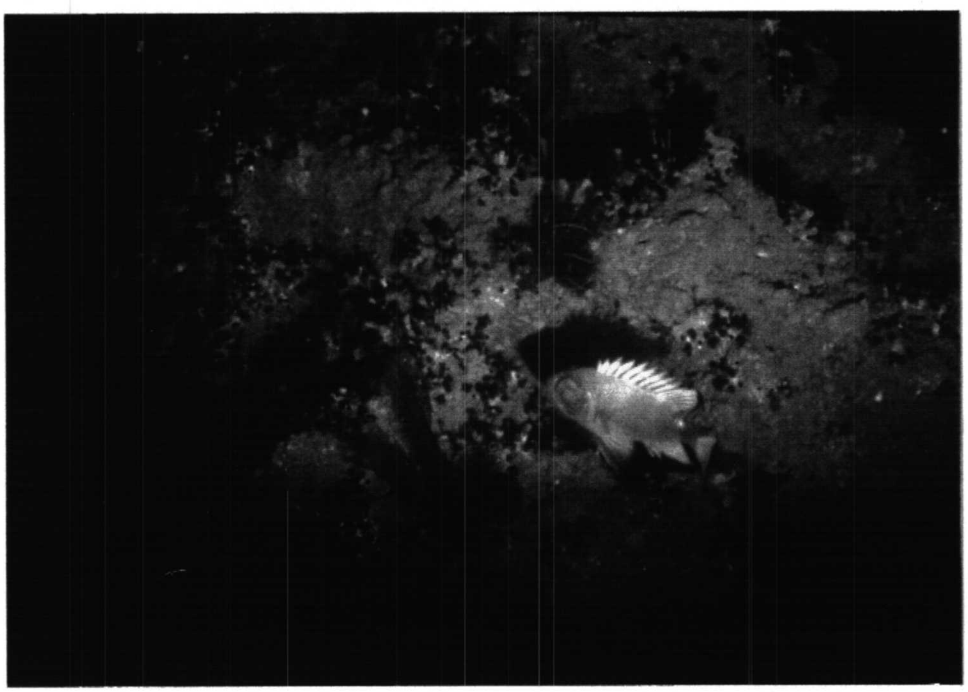

Figure 5-6. A short bigeye (*Pristigenys alta*) along the reef face observed during Dive 5. Also present on the rock are comatulid crinoids and *Rhizopsammia manuelensis*.

As observed during Dive 4, the reef top surveyed during Dive 5 was a jagged surface with significant vertical surfaces. A list of species identified during the dive is presented in Table 5-2. Similar species as those described for Dive 4 were observed on the reef crest and reef face. *R. manuelensis* was the most commonly observed species with several soft corals, including *Antipathes* spp., *Ellisella* sp. and *Cirripathes* sp. being frequently observed. Several species observed occasionally during Dive 5 that were not observed during Dive 4 included the urchin *Eucidaris tribuloides*, the hydroid *Eudendrium* sp., the soft coral *Bebryce* sp., and several sponges thought to be *Aplysinia* sp. The photograph presented in Figure 5-6 was taken during Dive 5.

Fishes observed during the dive include all of those observed during Dive 4 as well as wrasse bass, *Liopropoma eukrines* and several creolefish, *Paranthias furcifer*.

Dive 6. Dive 6 was conducted on a suspected low-relief hard-bottom area located at 29° 31' 47" N, 88° 07' 19" W. The location of this dive is shown in Figure 5-7. The feature was identified from a review of the geophysical data collected during Survey 1. The site was revisited during Survey 2 and an attempt was made to identify any hard bottom areas using the ship's fathometer. An area of slightly elevated bottom topography was identified and investigated during the dive. Water depths during the dive ranged from 38 to 42 m.

A majority of the bottom was at a depth of approximately 42 m, however, an elevated ridge rising up to approximately 38 m was suspected to be an area of low-relief live bottom. Both the elevated area and the deeper surrounding environs were investigated. Coarse sand and sediment was observed on the bottom and no hard bottom was evident. Several small depressions with accumulations of old shell were observed as well as numerous sea stars, *Luidia clathrata*. Water clarity during the dive was much better than expected with visibility estimated at approximately 6 to 10 m. No nepheloid layer was present.

Dive 7. Dive 7 was conducted on a suspected low-relief hard-bottom area located at 29° 28' 59" N, 88° 05' 03" W. The location of this dive is shown in Figure 5-7. The feature was identified from a review of the geophysical data collected during Survey 1. The site was revisited during Survey 2 and an attempt was made to identify any hard bottom areas using the ship's fathometer. An area of slightly elevated bottom topography was identified and investigated during the dive. Water depths during the dive ranged from 39 to 42 m.

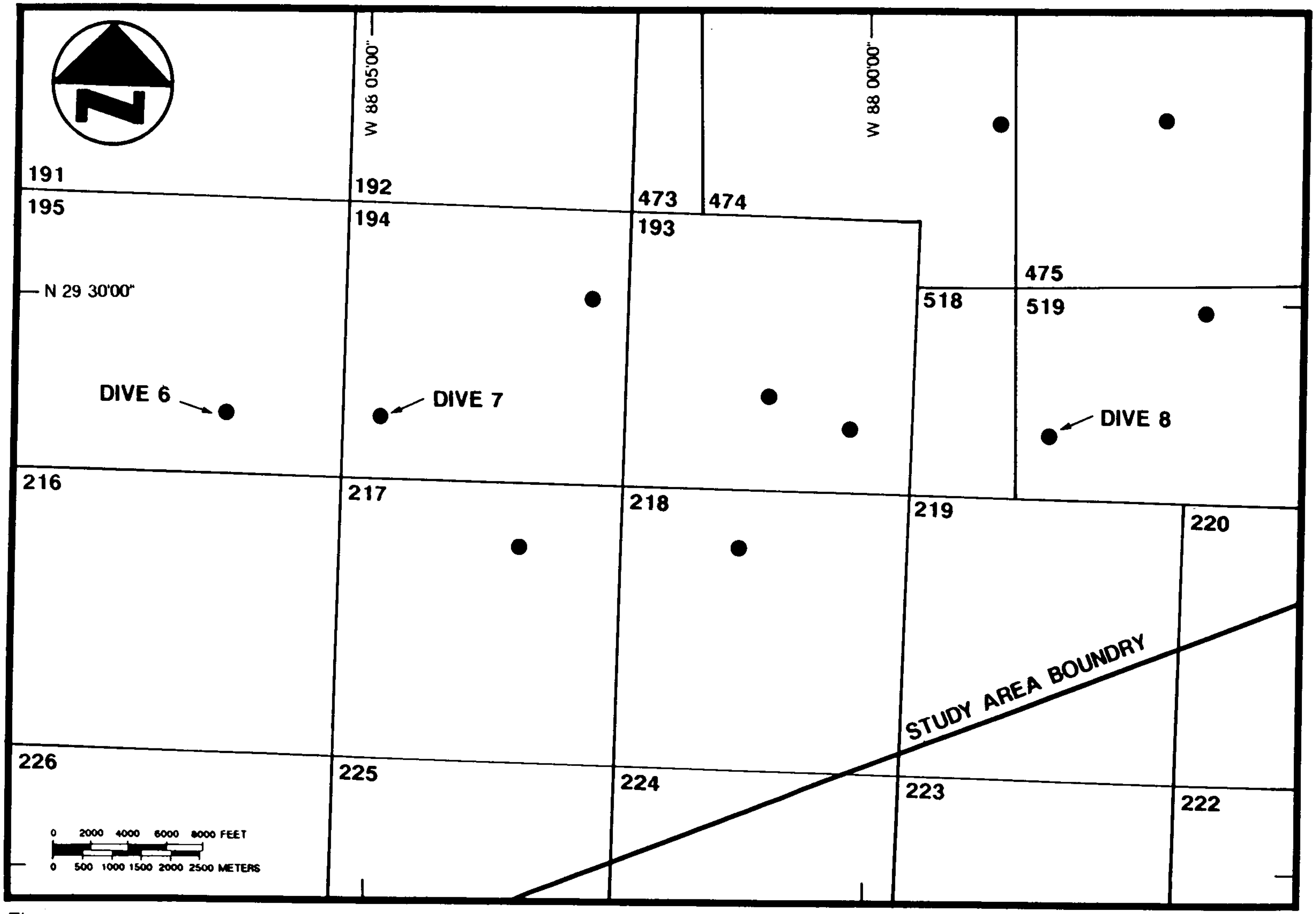

Figure 5-7. Locations of Dives 6, 7, and 8

As noted during Dive 6, the suspected low-relief hard-bottom area was a slightly elevated region located in a water depth of approximately 39 m and surrounded by an area of slightly deeper water. Both the elevated and the surrounding deeper areas were investigated during the dive. No hard bottom was observed during this dive. The bottom was predominantly coarse sand with considerable bioturbation. The coelenterate jellyfish *Cassiopeia xamachana* was frequently observed throughout the dive area while the coralline algae *Peysonellia inomea* was also common. Water clarity during the dive was very good, ranging from 6 to 10 m. No nepheloid layer was present.

Dive 8. Dive 8 was conducted on a suspected low-relief hard-bottom area located at 29° 31' 38" N, 87° 59' 27" W. The location of this dive is shown in Figure 5-7. The feature was identified from a review of the geophysical data collected during Survey 1. The site was revisited during Survey 2 and an attempt was made to identify any hard bottom areas using the ship's fathometer. An area of slightly elevated bottom topography was identified and investigated during the dive. Water depths during the dive ranged from 36 to 40 m.

Similar to previous dives (Dives 6 and 7) conducted on low relief targets in the central portion of the study area, the suspected target occurred in a slightly elevated area at a water depth of approximately 36 m and was surrounded by water depths of approximately 40 m. Once again no hard bottom was identified during the dive. The bottom was coarse sand with considerable bioturbation. Water clarity was very good, ranging from 6 to 10 m, and no nepheloid layer was observed.

Dive 9. Dive 9 was conducted on a topographic feature located at 29°. 14' 05" N, 88° 19" 17" W. The location of this dive is shown in Figure 5-2. The feature was bathymetrically mapped using the ship's fathometer and found to range in depth from 92 m at the base to 78 m at the top. This feature is similar in size to the one investigated during Dives 4 and 5 having a width of approximately 375 m (east-west) and a length of approximately 400 m (north-south). During this dive, water depths ranged from 80 to 85 m. Water clarity was very good and no nepheloid layer was observed.

The reef top and reef face were investigated during Dive 9. A list of the species observed during the dive is presented in Table 5-3. As observed during Dives 1 through 5, the reef face of this feature had steep vertical rock walls rising to the reef top. One difference between this feature and the feature surveyed during Dives 4 and 5 concerns the reef top. The reef top of this feature was relatively flat, having very few jagged vertical surfaces. As a result, the density of organisms on the reef top of this feature is greater than that observed on the feature investigated during Dives 4 and 5.

Table 5-3. Species identified from videotapes and still photographs during Dives 9 and 10 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance	
	Reef Face[9,10]	Reef Top[9,10]
Porifera		
Calcarea		
Leucettida		
unidentified Leucettida	---	R[9,10]
Astrophorida (= Choristida)		
Geodidae		
Geodia spp.	---	R[10]
Cnidaria		
Hydrozoa		
Hydroida		
Eudendriidae		
unidentified hydroid	R[9,10]	R[9,10]
Eudendrium spp.	---	O[9], R[10]
Anthozoa		
Alcyonaria		
Alcyonacea		
Plexauridae		
Bebryce spp.	---	F[9,10]
Ellisellidae		
Ellisella spp.	F[9,10]	F[9,10]
?*Nicella* spp.	---	O[9,10]
Zoantharia		
Scleractinia		
Pocilloporidae		
Madracis ?myriaster	O[9,10]	O[9,10]
Oculinidae		
Oculina ?diffusa	O[9,10]	O[9,10]
Caryophyllidae		
Rhizopsammia manuelensis	F[9,10]	F[9,10]
Guyniidae		
?*Balanophyllia floridana*	O[9,10]	O[9,10]
Antipatharia		
Antipathidae		
Antipathes spp.	F[9,10]	F[9,10]
Antipathes atlantica	O[9,10]	O[9,10]
Antipathes furcata	O[9,10]	O[9,10]
Cirripathes ?luetkeni	F[9,10]	O[9,10]

Table 5-3. Species identified from videotapes and still photographs during Dives 9 and 10 (A = Abundant; F = Frequent; O = Occasional; R = Rare).

Species	Relative Abundance	
	Reef Face[9,10]	Reef Top[9,10]
Echinodermata		
Crinoidea		
Comatulida		
unidentified Comatulida (multiple species)	F[9,10]	F[9,10]
Ophiuroidea		
Phrynophiurida		
Gorgonocephalidae		
unidentified Gorgonocephalidae	O[9,10]	O[9,10]
Echinoidea		
Cidaroida		
Cidaridae		
Stylocidaris affinis	---	R[10]
Diadematioda		
Diadematidae		
Diadema antillarum	---	O[9,10]
Chordata		
Urochordata-Ascidiacea		
Enterogona		
Didemnum spp.	R[9,10]	O[9,10]
Vertebrata-Osteichthyes		
Teleostei		
Perciformes		
Serranidae		
unidentified Anthiid	O[9,10]	O[9,10]
Holanthias martinicensis	O[9,10]	F[9,10]
Liopropoma eukrines	---	R[9,10]
Serranus phoebe	R[9,10]	R[9,10]
Priacanthidae		
Pristigenys alta	---	O[9,10]
Carangidae		
Seriola dumerili	O[9,10]	O[9,10]
Lutjanidae		
Lutjanus ?campechanus	---	R[10]
Rhomboplites aurorubens	O[9,10]	O[9,10]
Chaetodontidae		
Chaetodon aya	---	R[10]

[9] Present during Dive 9.
[10] Present during Dive 10.

The reef face appeared very similar to those described previously. *R. manuelensis* was the most common species observed. Other frequently observed species included soft corals *Antipathes* spp., *Cirripathes* sp., and *Ellisella* sp. Several ahermatypic hard corals were occasionally observed, including *Oculina* sp., *Madracis ?myriaster* and a solitary cup coral (*?Balanophyllia floridana*). Comatulid crinoids were also frequently observed on the reef face.

The reef top of this feature had denser epibiotal cover than that observed on previously surveyed features in the area. The soft coral *Bebryce* sp. was abundant on the reef top. Other frequently observed species included *Ellisella* sp., comatulid crinoids, and antipatharians (*Antipathes* spp.). Occasionally observed species included the ascidean *Didemnum* sp., the long-spined urchin *Diadema antillarum,* and several unidentified gorgonians and sponges. Gorgonocephalids were also occasionally observed associated with antipatharians (*Antipathes* spp.). Several unidentified hydroids were also observed as was *Eudendrium* sp. The photograph presented in Figure 5-8 was taken during Dive 9.

Fishes observed on this feature were similar to those previously observed in earlier dives on the other topographic features. They included roughtongue bass, *Holanthias martinicensis*; vermilion snapper, *Rhomboplites aurorubens*; amberjack, *Seriola dumerili*; short bigeye, *Pristigenys alta*; tattler, *Serranus phoebe*; and wrasse bass, *Liopropoma eukrines*. The abundance of fishes at this feature appeared low, similar to the previous feature investigated during Dives 4 and 5.

Anthropogenic debris was observed at this feature, including the sighting of several fishing lines tangled along the walls of the reef face.

Dive 10. Dive 10 was conducted on the same topographic feature as Dive 9. The location of this dive is shown in Figure 5-2. Water depths during the dive ranged from 83 to 78 m. As was noted during the previous dive, water clarity was very good and no nepheloid layer was observed.

This dive was conducted to gather additional data concerning the reef top and reef faces. In addition, data collection along the bottom of the feature was planned in order to investigate the reef base. Unfortunately, a problem with the ROV forced the dive to be terminated prematurely; Dive 10 encompassed only the reef top and face. As a result, no information could be collected concerning the biota present at the base of this feature.

Epibiota present on the reef top and face were similar to that observed during the previous dive (Dive 9). A list of the species observed

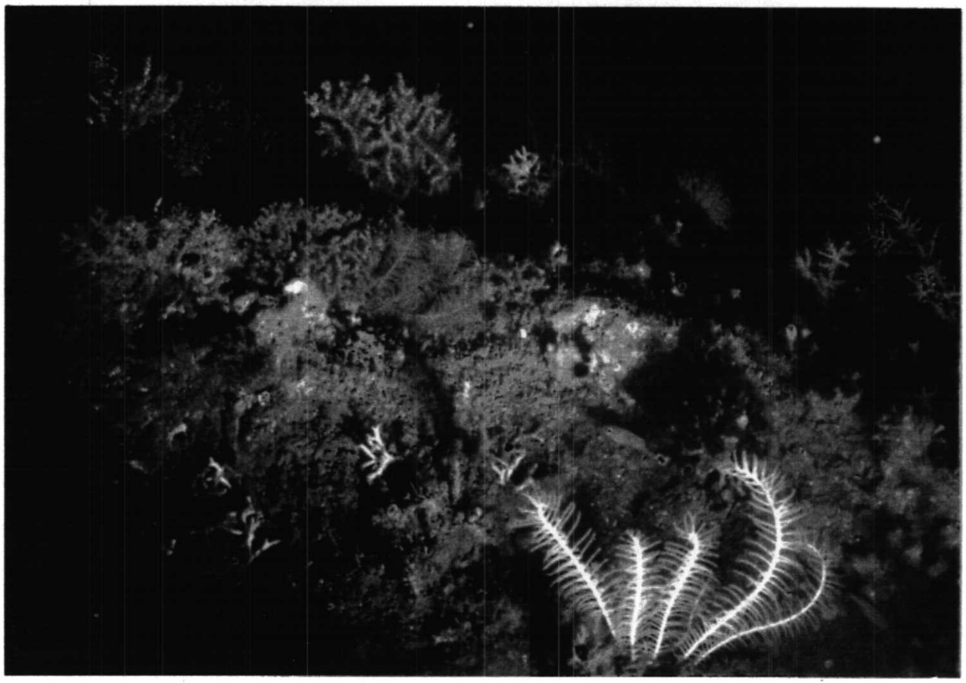

Figure 5-8. Epibiota observed on the reef top during Dive 9. A comatulid crinoid is present in the foreground as well as the hard coral *Madracis* sp.

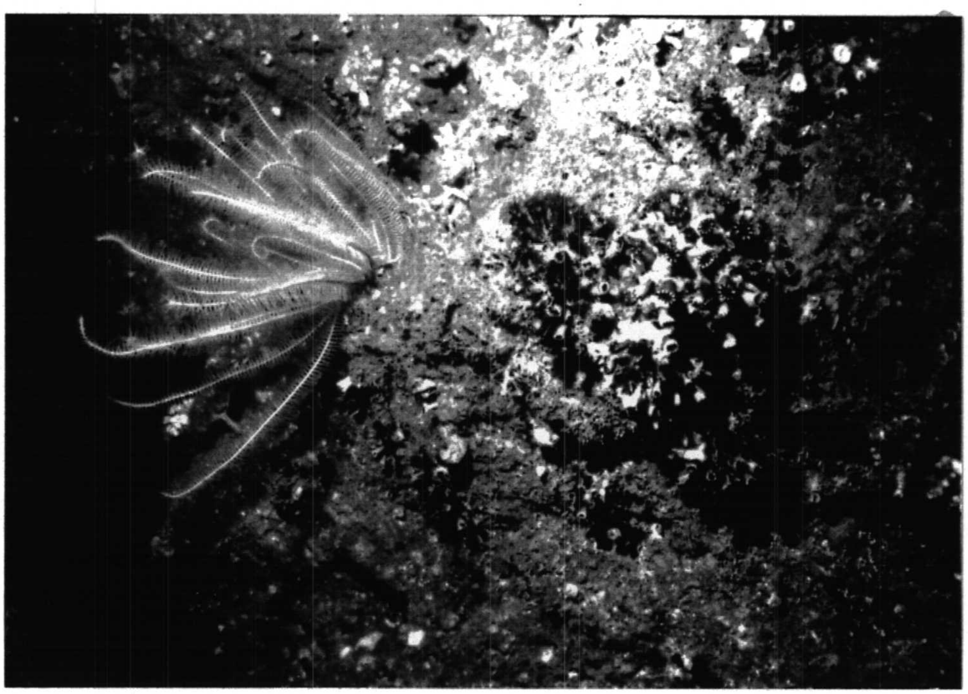

Figure 5-9. Comatulid crinoid on the reef face observed during Dive 10. Also present is the black coral *Rhizopsammia manuelensis*.

during the dive is presented in Table 5-3. Several species not observed during Dive 9 were rarely observed including the sponge, *Geodia neptuni*, the urchin *Stylocidaris* sp., an unidentified echinoid, and several unidentifiable orange sponges. The log-spined urchin *Diadema antillarum* was not observed during the dive. The photograph presented in Figure 5-9 was taken during Dive 10.

Fish species noted during Dive 10 were also similar to those observed previously during Dive 9. Two additional species, including bank butterflyfish, *Chaetodon aya*, and an unidentified lutjanid (possibly red snapper, *Lutjanus campechanus*), were also observed during the dive.

Dive 11. Dive 11 was conducted on another topographic feature located at 29° 13' 49", 88° 18' 35" W. The location of this dive is shown in Figure 5-2. The feature was bathymetrically mapped using the ship's fathometer and found to range in depth from 94 m at the base to 83 m at the top. This feature was smaller than previously investigated features approximately 200 m in width (east-west) and 250 m in length (north-south). During the dive, water depths ranged from 83 to 93 m. At the very deepest portion of the survey, increased turbidity was evident. Visibility ranged from approximately 3 to 5 m in this area. Water clarity became significantly improved with only a slight decrease in depth (i.e., at approximately 90 m water depth). It is not clear if this turbid water was a nepheloid layer or a localized turbidity plume.

This feature was somewhat different than the previous topographic features investigated during the survey. No vertical sheer rock reef face was present. A limited amount of vertical substrate was present due to large jutting rocks; however, a majority of the feature had a more sloping horizontal terrain which formed a mound-like prominence. As a result of this gradual sloping and the absence of sheer rock walls, only two general reef areas were surveyed for biological characterization: the reef top and the reef base. A list of species identified during the dive is presented in Table 5-4.

The base of the feature was an area overlain with coarse sand and rubble. Small emergent rocks, colonized by several epifaunal species, protruded from areas of coarse sand. At the base of the emergent portion of the feature, small rock ledges (typically 1 to 2 m in height) were noted bordered by coarse sand and rubble. In these lower regions, relatively few species were present. *R. manuelensis* was the most common species present, occurring primarily on vertical surfaces. The soft corals *Ellisella* sp. and *Cirripathes* sp., comatulid crinoids, and several antipatharians (?*Antipathes* spp.) were also observed occasionally.

Table 5-4. Species identified from videotapes and still photographs during Dives 11 and 12 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance	
	Reef Base[11,12]	Reef Top[11,12]
Porifera		
Calcarea		
Leucettida		
unidentified Leucettida	R[12]	O[11,12]
Astrophorida (= Choristida)		
Geodidae		
Geodia spp.	---	R[11]
Cnidaria		
Hydrozoa		
Hydroida		
Eudendriidae		
unidentified hydroid	O[11]	O[11]
Eudendrium spp.	O[11]	O[11]
Anthozoa		
Alcyonaria		
Alcyonacea		
Nidaliidae		
Siphonogorgia agassizii	---	R[12]
Plexauridae		
?*Scleracis* spp.	---	O[11,12]
Thesea spp.	---	O[12]
Ellisellidae		
Ellisella spp.	O[11,12]	F[11,12]
?*Nicella* spp.	---	O[11,12]
Zoantharia		
Scleractinia		
Pocilloporidae		
Madracis ?myriaster	R[11]	F[11]
Oculinidae		
Madrepora carolina	R[11]	O[11]
Oculina ?diffusa	---	F[11]
Caryophylliidae		
Rhizopsammia manuelensis	O[11], R[12]	F[11], O[12]
Guyniidae		
?*Balanophyllia floridana*	---	O[11,12]
Antipatharia		
Antipathidae		
Antipathes spp.	O[11]	F[11]
Antipathes atlantica	O[11]	O[11], R[12]
Cirripathes ?luetkeni	O[11,12]	O[11,12]

Table 5-4. Species identified from videotapes and still photographs during Dives 11 and 12 (A=Abundant; F=Frequent; O=Occasional; R=Rare).

Species	Relative Abundance: Reef Base[11,12]	Relative Abundance: Reef Top[11,12]
Mollusca		
Gastropoda		
unidentified Gastropoda	---	R[12]
Echinodermata		
Crinoidea		
Comatulida		
unidentified Comatulida (multiple species)	O[11], R[12]	O[11], R[12]
Ophiuroidea		
Phrynophiurida		
Gorgonocephalidae		
unidentified Gorgonocephalidae	---	O[11,12]
Echinoidea		
Cidaroida		
Cidaridae		
Stylocidaris affinis	---	O[11], R[12]
Diadematioda		
Diadematidae		
Diadema antillarum	---	R[11]
Chordata		
Urochordata-Ascidiacea		
Enterogona		
Didemnum spp.	---	O[11]
Vertebrata-Osteichthyes		
Teleostei		
Lophiformes		
Ogcocephalidae		
Ogcocephalus sp.	R[11]	R[12]
Perciformes		
Serranidae		
unidentified Anthiid	O[11,12]	O[11,12]
Holanthias martinicensis	R[12]	O[12]
Paranthias furcifer	---	R[11]
Lutjanidae		
Rhomboplites aurorubens	O[11]	O[11]
Chaetodontidae		
Chaetodon aya	---	R[11,12]

[11] Present during Dive 11.
[12] Present during Dive 12.

Significant differences in epibiota were immediately apparent higher on the feature. *R. manuelensis* was present in increased density, as well as several other ahermatypic corals including *Madrepora carolina*, *Madracis ?myriaster*, and *Oculina* sp. All three species were considered to be frequently present. Other species present included antipatharians (*Antipathes* spp.), comatulid crinoids, several soft corals (probably *Nicella* sp. and *Scleracis* sp.), a solitary cup coral (probably *Balanophyllia floridana*), gorgonocephalids, and several unidentified sponges.

Fishes observed associated with the feature include vermilion snapper, *Rhomboplites aurorubens*; creolefish, *Paranthias furcifer*; bank butterflyfish, *Chaetodon aya*; and batfish, *Ogcocephelus* sp.

A large section of anchor cable was observed on the seafloor, at the base of the feature. The cable was heavily encrusted with biota and had probably been there for a long time. No damage to the feature was observed during the dive.

Dive 12. Dive 12 was conducted on a topographic feature located at 29° 13' 33" N, 88° 18' 13" W. The location of this dive is shown in Figure 5-2. This feature was bathymetrically mapped with the ship's fathometer. The feature was similar in size to the feature investigated during Dive 11; however, the height of the present feature was smaller. The feature had a width of approximately 250 m (east-west) and a length of approximately 300 m (north-south). The base of the feature was located in approximately 95 m of water, reaching maximum height of approximately 10 m in a depth of 85 m. During this dive, water depths ranged from 88 to 95 m. Water clarity during the dive was very good and no nepheloid layer was observed.

As described previously for Dive 11, only two areas, the reef top and reef base, were identified. Species identified during this dive are listed in Table 5-4. The base of the feature exhibited a significant overburden of coarse sand and rubble. Several small emergent rocks with sparse epibiotal growth were present near the base. Several organisms were occasionally present including *Ellisella* sp. and *Cirripathes* sp.

The number of species present on the feature was relatively high; however, the density of organisms was still relatively low. The most abundant species included comatulid crinoids, *Ellisella* sp., and *Cirripathes* sp. Other species occasionally present included the ahermatypic coral *R. manuelensis*, a cup coral (probably *Balanophyllia floridana*), and the soft corals *Nicella* sp., *?Scleracis* sp., and *Thesea* sp. The alcyonacean *Siphonogorgia agassazii* was present as well as several gorgonocephalids. A gastropod, possibly *Polystira* sp., was also observed several times during the dive.

Several fishes including bank butterflyfish, *Chaetodon aya*; roughtongue bass, *Holanthias martinicensis*; vermilion snapper, *Rhomboplites aurorubens*; and batfish, *Ogcocephalus* sp. were observed during the dive.

5.4.2 Rock Dredge

A single rock dredge sample was collected during Survey 2. The location of the rock dredge is shown in Figure 5-2. The dredge was collected along the edge of the feature investigated during Dive 1. Specimens collected in the dredge are listed in Table 5-5. Due to the jagged and irregular nature of the features investigated, it was very difficult to successfully complete dredge sampling. As a result, relatively few organisms were collected. The identification of dredge specimens allowed for verification of identifications made from videotape and still photographic data.

5.4.3 Hook-and-Line Sampling

Fishes captured by hook-and-line sampling during Survey 2 are listed in Table 5-6. Relative abundance rankings and the size range of each species landed have also been included. Fish collected were typical species landed in the Gulf of Mexico, including several commercially important species (e.g., vermilion snapper, *Rhomboplites aurorubens*; red snapper, *Lutjanus campechanus*; red porgy, *Pagrus pagrus*; and gag, *Mycteroperca microlepis*. One unusual, very colorful species not thought to be common throughout the northern Gulf of Mexico, the spanish flag (*Gonioplectrus hispanus*), was landed on two different occasions.

5.5 Biological Community Composition

Biological communities present on the features investigated during this study primarily consisted of tropical or subtropical suspension-feeding invertebrates. With the exception of the upper-shelf sand areas investigated during Dive 6 through 8, all of the dives were conducted on features considered to be high relief (greater than 5 m). The epibenthos present on these features included antipatharians, ahermatypic hard corals, comatulid crinoids, sponges, alcyonarians, and hydroids. Coralline algae were also present on the upper portions of the tallest feature (water depth <72 m). Water depth appears to preclude the growth of coralline algae on all of the other features investigated.

The abundance of organisms encountered during this study was quite variable; however, in general, those prominences with increased horizontal surfaces within the upper portions of the feature exhibited increased abundances. A variety of epifaunal organisms were also found in association with attached epibiota, including crinoids, urchins, gorgonacephalids, and even

Table 5-5. Samples collected by rock dredge during Survey 2.

Cnidaria
- Hydrozoa
  - Hydroida
    - Eudendriidae
      - *Eudendrium fruticosum*
      - *Modeeria rotunda*
- Anthozoa
  - Scleractinia
    - Pocilloporidae
      - *Madracis myriaster*
    - Oculinidae
      - *Madrepora carolina*
    - Caryophylliidae
      - *Rhizopsammia manuelensis*
      - *?Paracyathus (junvenile)* sp.

Echinodermata
- Crinoidea
    - Comatulida
      - *Comactinia meridionalis*

Table 5-6. Fishes landed by hook-and-line sampling.

Species	Relative Abundance	Size Range (in.)
Rhomboplites aurorubens (vermilion snapper)	1	9.5-17.5
Pagrus pagrus (red porgy)	2	10.0-13.5
Seriola dumerili (amberjack)	3	17.0-24.5
Serranus phoebe (tattler)	4	6.75-8.5
Lutjanus campechanus (red snapper)	5	12.3-15.5
Coryphaena hippurus (dolphin)	6	16.5-22.0
Mycteroperca microlepis (gag)	7	19.0-23.0
Pristigenys alta (short bigeye)	8	9.5-11.0
Gonioplectrus hispanus (Spanish flag)	9	9.5-10.0

an occasional fireworm. Both crinoids and gorgonocephalids are suspension feeders, while the urchins are considered grazers and opportunists. The fireworm (*Hermodice carunculata*) is probably feeding on the ahermatypic corals present.

Generally the biological assemblages associated with the features investigated during this study were similar to those identified on the features described by TAMU researchers. The feature they described, a 36-Fathom Ridge, was also investigated during this study and with similar findings. The other pinnacle-like features described during this study were in the immediate vicinity of 36-Fathom Bank and also had similar species. The feature exhibits similar species as those encountered on the other high-relief features investigated during the TAMU study. These researchers previously noted that the abundance of fish seemed quite low. Our investigations of these features revealed a similar unusually low fish abundance. Although no quantitative data were collected during this investigation, the consistency of other observations made concerning 36-Fathom Bank may indicate that similar abundances could also be expected on the other features investigated in the vicinity of 36-Fathom Bank.

Fishes observed on the features surveyed included several commercially important species, including the red snapper (*Lutjanus campechanus*) and vermilion snapper (*Rhomboplites aurorubens*). Hook-and-line sampling conducted during the survey resulted in a species list similar to that compiled from videotapes and still photographs. Species not landed were predominantly small plankton feeders (anthiids). Overall, the abundance and diversity of fishes associated with the features was very low based on limited qualitative video and photographic data.

5.6 Biotic Zonation and Abiotic Parameters

A variety of abiotic parameters may play a major role in determining the structure of biological communities that occur at a particular location. Every species has certain preferences and tolerances with respect to various abiotic parameters such as substrate type, water depth, water clarity, temperature, salinity, and dissolved oxygen. Some or all of these factors may determine whether a species can live in a given environment. No data concerning typical water quality parameters (e.g., temperature, salinity, and dissolved oxygen) were collected during this study. Based on previous investigations throughout the Mississippi-Alabama OCS, it is unlikely that these parameters have a significant effect on the biological zonation observed on topographic features investigated during this study. Generally, the environment of the study area is a well-mixed open ocean/coastal shelf environment exhibiting limited vertical stratification. Based on the limited number of observations pertaining to biological communities present on features investigated, other abiotic parameters including substrate type, substrate orientation, and suspended sediment load probably play the greatest role in community zonation.

A majority of the species observed on the features investigated during the study were similar. Based on qualitative observations and data, density variations were observed between different locations and substrates; however, the individual species present remained the same. Generally, the density and relative number of species present near the base of each feature was low. At the base of each feature where rock faces were surrounded by aprons of coarse sediment, the lower 1 to 2 m of rock substrate exhibited very little, if any, biotal cover. This may be due to increased suspended sediment in the water (e.g., as a result of resuspension). Species that were present were typically taller forms (i.e., gorgonians *Ellisella* spp. and *Cirripathes* sp.) which were not smothered by high loadings of suspended sediment. Relatively few small ahermatypic corals were present; those species that did exist in this zone occurred on vertical faces, thereby reducing the effect of sedimentation. Researchers from TAMU (Brooks and Giammona 1990) noticed a similar phenomena on other features investigated on the Mississippi-Alabama shelf.

At higher elevations (i.e., away from the base of the reef) it appears likely that sedimentation plays a lesser role in community development than does suitable substrate for attachment. On vertical reef faces, the relative density of organisms was considerably less than on horizontal reef flats and reef tops. This trend, as observed during other investigations of topographic features, appears to be an indication of the relative ability of these organisms to colonize a vertical surface as opposed to a horizontal surface. Species observed among these habitats on each of the features investigated were similar. However, on more horizontal surfaces there was a decrease in certain species of soft corals (e.g., *Bebryce* sp. and *Nicella* sp.) and a relative decrease in the densities of ahermatypic corals. This may also be related to the amount of sedimentation that occurs on these features.

Based on data collected during this study, it is not possible to determine longitudinal variations in biological community structure for those features occurring in the study area. TAMU researchers suggested, however, that longitudinal variation does occur in the biological communities within their broader study area. This broader study area does encompass the area evaluated during the present study. TAMU scientists related this variation to sedimentation associated with increasing distance from the outflow of the Mississippi River. While data have not been collected over sufficient longitudinal variation to examine this possibility, the biological communities and their relative densities are similar to those identified previously by TAMU researchers.

During the present investigations, a nepheloid layer was not observed impinging on any features. As a result, it is not possible to examine the role the nepheloid layer may play in biological community composition within the study area.

5.7 Community Health

Assessing the health of biological communities present on those topographic features investigated during this study is a relatively subjective process. Biologists and ecologists knowledgeable of the species present in the area have reviewed the video and still photographic data collected during this study with the intent of determining community health. In addition to objectively assessing the species present, their densities and abundances, and general appearance, several other very subjective indicators of community health were considered. These include bleaching and/or presence of recently dead corals, damage resulting from anchoring, and the evidence of general anthropogenic debris in the area.

Benthic epibiota on the features investigated appeared to be in good health. No signs of mass mortality were observed in any species present. No recent scars on the features resulting from anchoring were observed during the investigations. Even the amount of anthropogenic debris typically present around topographic features (e.g., drink cans) was very low and limited to several discarded fishing lines and one large and very old cable. This relatively low amount of debris is quite surprising based on other investigations of hard bottom features conducted throughout the Gulf of Mexico.

The health of fish assemblages present on the features is very difficult to assess based on relatively few observations. One fishing boat was sighted operating in the area during one survey. Generally, the number of fishes present on each feature was surprisingly low considering the significant amount of vertical relief present. The reasons for this are not known; however, the presence of primarily small individuals of most species may be indicative of the fishing pressure being exerted on these features.

6.0 SUMMARY AND CONCLUSIONS

6.1 Geology

The investigations of Schroeder et al. (1987, 1988b) and the side-scan and subbottom data acquired during the present study show small, relatively frequent, low-relief hard-bottom patches along the Alabama shelf. Hard-bottom patches in this area differ lithologically from those seen farther to the east in the Gulf of Mexico; in addition, they have correspondingly different side-scan signatures. Biologically, these habitats have not been thoroughly surveyed. Because they represent unique habitat features present within wide areas of otherwise featureless seafloor, they may be presumed to have a resident fauna of their own; however, the faunal composition has not been extensively described.

The pinnacle and hard-bottom complexes located along the shelf slope in the Gulf of Mexico have been more thoroughly mapped since the time of Ludwick and Walton (1957), but very little new information is available concerning their lithologic composition or geologic origin. Suggested periods of reef development presented in this report, as well as those offered by Brooks and Giammona (1990), are supported by sea level stand data and upper shelf depositional history outlined in Kindinger (1988, 1989); it must be emphasized, however, that these interpretations are unsubstantiated. No investigations into the core structure of these shelf edge prominences and pinnacles have been conducted, and no isotope dating of their carbonate structure has been attempted. One interesting question is how the Mississippi-Alabama shelf pinnacles relate geologically to the southwest Florida shelf pinnacles reported in the Southwest Florida Shelf Regional Biological Communities Survey (Environmental Science and Engineering, Inc. et al. 1987) as well as to other shelf edge prominences seen around the Gulf and Atlantic seaboard (Uchupi 1966).

6.2 Biology

Although limited biological investigations were made, several significant topographic features were studied. Biological communities occurring on the features were dominated by tropical and subtropical suspension-feeding invertebrates. Communities were similar on all of the features investigated with subtle differences related to feature orientation and size. Generally, horizontal surfaces in the upper regions of the features investigated had the most diverse and abundant biological communities. At deeper locations near each feature's base, communities were reduced in density and diversity. This variation is thought to be due to the effects of sediment resuspension in these areas. Overall, the communities observed on high-relief features during these investigations were consistent with those observed on similar features during previous investigations (Continental Shelf Associates, Inc. 1985b; Brooks and Giammona 1988, 1990).

Observations were made on a few upper shelf features suspected to be low-relief hard bottom. No hard bottom was observed at any of these sites; however, the presence of low-relief features that are periodically covered by shifting sand and sediments cannot be excluded. If these features were present and periodically buried with sediment, it is very likely that epibiota and fishes associated with the substrate would be minimal. Further investigation is needed of the other numerous possible low-relief features identified during this study. Investigations of the deep-water features identified geophysically during this study effort are needed to acquire geological and biological information. The depth of these features is greater than others investigated previously along the Mississippi-Alabama shelf, thereby making a comparison or speculation concerning their biological component very difficult. The features appear similar to the 36-Fathom Bank feature investigated during the TAMU study. The 36-Fathom Bank was ranked quite high during the previous study in terms of the epibiotal community development.

6.3 Data Gaps

Based on the results of this study and a review of existing available information, recommended future research topics concerning topographic features and the environment of the Mississippi-Alabama shelf include:

1) Additional biological and geological investigation of pinnacle features, especially those located and identified geophysically in deepwater;

2) Investigations to determine the origin, current state, and probable future of these structures, both biologically and geologically. Such studies should include the collection of additional rock samples and cores to determine the geological/biological origin of these structures;

3) Investigations concerning the geographic and temporal distribution of turbidity/nepheloid layers that may occur throughout the Mississippi-Alabama shelf; and

4) Investigations of the tolerance of species occurring within the study area to various abiotic parameters during all stages of their life history, particularly those parameters influenced by man (e.g., turbidity).

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APPENDICES

APPENDIX A

SURVEY 1 (GEOPHYSICAL CHARACTERIZATION) SCHEDULE

APPENDIX A

Table A-1. Survey 1 (geophysical characterization) schedule.

Date	Survey Operation
11 September 1990	Travel to Tampa; mobilize R/V SEAHAWK.
12 September 1990	Cruise Day #1 - Complete mobilization; depart St. Petersburg.
13 September 1990	Cruise Day #2 - Transit to study site.
14 September 1990	Cruise Day #3 - Arrive at site; begin surveying deepwater line to test side-scan coverage; adjust line spacing to 500 m; continue surveying.
15 September 1990	Cruise Day #4 - Continue surveying until 1600 h; side-scan problem; must terminate; will take approximately 30 hr.
16 September 1990	Cruise Day #5 - Continue surveying at 1500 h; surveying in northern end of study area.
17 September 1990	Cruise Day #6 - Continue surveying.
18 September 1990	Cruise Day #7 - Continue surveying.
19 September 1990	Cruise Day #8 - Continue surveying.
20 September 1990	Cruise Day #9 - Continue surveying.
21 September 1990	Cruise Day #10 - Continue surveying.
22 September 1990	Cruise Day #11 - Continue surveying; completed 667 of 2200 m needed to survey the study area.
23 September 1990	Cruise Day #12 - Continue surveying; bad weather; terminate operations at 0630; weather too rough; forecast is bad; head to Pascagoula to resupply vessel.
24 September 1990	Cruise Day #13 - In Pascagoula; bad weather continued; resupply vessel; arrange for fathometer repair; weather improving tomorrow; depart Pascagoula at 2300 h.

Table A-1. Survey 1 (geophysical characterization) schedule.

Date	Survey Operation
25 September 1990	Cruise Day #14 - On site; weather marginal but workable; resume surveying.
26 September 1990	Cruise Day #15 - Continue surveying.
27 September 1990	Cruise Day #16 - Continue surveying.
28 September 1990	Cruise Day #17 - Continue surveying; completed 1050 of 2100 m.
29 September 1990	Cruise Day #18 - Continue surveying; weather marginal.
30 September 1990	Cruise Day #19 - Fish damaged at 0030 h; crashed into uncharted large feature; must terminate and repair fish; continue bathymetric mapping of the area.
1 October 1990	Cruise Day #20 - Resume surveying at 0045 h; 1235 of 2200 m completed.
2 October 1990	Cruise Day #21 - Continue surveying.
3 October 1990	Cruise Day #22 - Continue surveying; 1470 of 2200 m completed.
4 October 1990	Cruise Day #23 - Continue surveying.
5 October 1990	Cruise Day #24 - Continue surveying.
6 October 1990	Cruise Day #25 - Continue surveying.
7 October 1990	Cruise Day #26 - Continue surveying.
8 October 1990	Cruise Day #27 - Continue surveying; complete surveying at 1800 h; underway to St. Petersburg.
9 October 1990	Cruise Day #28 - Transit to St. Petersburg.
10 October 1990	Cruise Day #29 - Arrive St. Petersburg; demobilize vessel; CSA crew returns to Jupiter.

APPENDIX B

SURVEY 2 (BIOLOGICAL RECONNAISSANCE) SCHEDULE

APPENDIX B

Table B-1. Survey 2 (biological reconnaissance) schedule.

Date	Survey Operation
11 October 1991	CSA personnel (2) depart Jupiter; travel to Tampa to meet R/V SEAHAWK.
12 October 1991	Cruise Day #1 - R/V SEAHAWK finalizing mobilization of vessel; depart dock. Begin transit to study site at approximately 1200 h.
13 October 1991	Cruise Day #2 - Transiting to study site; arrive at site in late evening hours (approximately 2300 h).
14 October 1991	Cruise Day #3 - Locating pinnacle features in main pinnacle ridge (first priority features) for investigation using fathometer and navigation system; conduct ROV Dive #1. Collected Dredge #1 in main pinnacle zone. Weather becoming unworkable in late afternoon (seas 3-5'; forecast calling for 20-25 kt winds and 6-8'seas tonight and tomorrow).
15 October 1991	Cruise Day #4 - Early morning transit to nearshore area off Pascagoula; seas 3-5'; winds 20-25 kt. Conditions unworkable. Dock vessel at Pascagoula.
16 October 1991	Cruise Day #5 - Conditions unworkable; seas 4-6', winds 15-20 kt. Forecast is improving, plan nighttime departure to be on-site in the early morning. Depart dock at 2300 h.
17 October 1991	Cruise Day #6 - On-site. Conditions workable (seas 2-4'; winds 10 kt). Pick up MMS observer on platform (R. Bennett). Relocate pinnacle features (first priority targets). Conduct two dives on pinnacle features.

Table B-1. Survey 2 (biological reconnaissance) schedule.

Date	Survey Operation
18 October 1991	Cruise Day #7 - Conduct two morning dives on pinnacle features. Transit to rig to drop off R. Bennett. Return to study site. Conduct one more dive on pinnacle features.
19 October 1991	Cruise Day #8 - Conduct two dives on pinnacle features.
20 October 1991	Cruise Day #9 - Problem with ROV; must repair; transit to upper shelf area to investigate shallow water targets (third priority targets) using smaller ROV. Dive at three upper shelf targets (all sand - no hard bottom). Other vehicle repaired, ready to dive in deeper water. Return to pinnacle site.
21 October 1991	Cruise Day #10 - Conduct three dives on pinnacle features. Weather forecast not good. Seas are building (2-4'). Remain on-site to evaluate conditions in the morning.
22 October 1991	Cruise Day #11 - Conditions marginal (seas 2-4'). Conduct one dive before seas preclude ROV use. Decide to attempt a rock dredge. Dredge hangs; davit breaks; all equipment recovered however no dredge sample is collected and major repairs are needed before dredging can continue. Seas building (4-6'). Too rough to work. Ship loses primary anchor. Must go to shore to repair. Transit to nearshore area off Horn Island to evaluate condition in the morning. Weather forecast is not good.
23 October 1991	Cruise Day #12 - Conditions unworkable (seas 4-6'; winds 15-20 kt). Transit to dock at Pascagoula.

Table B-1. Survey 2 (biological reconnaissance) schedule.

Date	Survey Operation
24 October 1991	Cruise Day #13 - Conditions questionable, depart Pascagoula to investigate. Eleven miles off Horn Island conditions unworkable; return to dock.
25 October 1991	Cruise Day #14 - Repeat steps taken yesterday. Conditions still unworkable. Return to dock.
26 October 1991	Cruise Day #15 - Weather forecast states conditions are unchanged. Remain at dock.
27 October 1991	Cruise Day #16 - Depart dock; transit to within 40 miles of study site; conditions unworkable (seas 3-5', winds 15-20 kt). Return to anchorage behind Petit Bois Island to await workable conditions.
28 October 1991	Cruise Day #17 - Conditions still unworkable. Return to dock in Pascagoula.
29 October 1991	Cruise Day #18 - Conditions unworkable. Remain at dock in Pascagoula.
30 October 1991	Cruise Day #19 - Conditions unworkable. Remain at dock in Pascagoula.
1 November 1991	Cruise Day #20 - Conditions unworkable. Remain at dock in Pascagoula.
2 November 1991	Cruise Day #21 - Conditions unworkable. Remain at dock in Pascagoula.
3 November 1991	Cruise Day #22 - Conditions unworkable. Remain at dock in Pascagoula.
4 November 1991	Cruise Day #23 - Conditions unworkable. Remain at dock in Pascagoula.

Table B-1. Survey 2 (biological reconnaissance) schedule.

Date	Survey Operation
5 November 1991	Cruise Day #24 - Conditions unworkable. R/V SEAHAWK must depart. Begin transit back to Tampa.
6 November 1991	Cruise Day #25 - In transit to Tampa.
7 November 1991	Cruise Day #26 - Arrive in Tampa. Demobilize vessel. CSA personnel return to Jupiter.

APPENDIX C

TARGET TABLE

APPENDIX C

Table C-1. Target table.

Line	Latitude	Longitude	Description
3	29°33'23"N	88°09'57"W	Hard Bottom
	29°33'23"N	88°11'41"W	Hard Bottom
4	29°33'10"N	88°14'38"W	Hard Bottom
5	29°32'30"N	87°45'11"W	Sediment Shift
	29°32'33"N	87°47'35"W	Sediment Shift
	29°32'39"N	87°54'06"W	Small Target
	29°32'54"N	88°16'30"W	Small Target
6	29°32'34"N	88°10'12"W	Hard Bottom
	32°47'14"N	87°54'13"W	Sediment Ridge
	29°32'15"N	87°46'52"W	Small Target
7	29°32'04"N	87°51'57"W	Sediment Ridge
	29°32'04"N	87°52'19"W	Sediment Ridge
	29°32'08"N	87°55'39"W	Patch Reef
	29°32'19"N	88°10'54"W	Sediment Shift
8	29°31'49"N	87°52'12"W	Small Target
	29°31'48"N	87°50'52"W	Sediment Shift
9	29°31'29"N	87°48'15"W	Sediment Shift
	29°31'29"N	87°48'39"W	Sediment Shift
	29°31'31"N	87°50'44"W	Sediment Shift
	29°31'32"N	87°51'26"W	Sediment Shift
	29°31'35"N	87°57'03"W	Hard Bottom
	29°31'37"N	87°58'41"W	Hard Bottom
	29°31'46"N	88°08'06"W	Hard Bottom
11	29°30'55"N	87°51'41"W	Small Target
	29°31'11"N	88°09'41"W	Sediment Shift

Table C-1. Target table.

Line	Latitude	Longitude	Description
	29°31'12"N	88°10'06"W	Sediment Shift
	29°31'24"N	88°29'14"W	Small Target
	29°31'24"N	88°29'28"W	Small Target
	29°31'24"N	88°30'14"W	Small Target
12	29°31'08"N	88°29'57"W	Small Target
	29°30'57"N	88°10'55"W	Sediment Ridge
13	29°30'29"N	87°55'30"W	Small Target
	29°30'29"N	87°55'49"W	Sediment Shift
	29°30'52"N	88°29'35"W	Small Target
	29°30'54"N	88°30'36"W	Small Target
14	29°30'24"N	88°10'39"W	Small Target
	29°30'06"N	87°48'17"W	Sediment Shift
	29°30'05"N	87°47'55"W	Sediment Shift
15	29°29'50"N	87°48'37"W	Sediment Shift
	29°29'50"N	87°49'37"W	Sediment Shift
	29°29'50"N	87°50'02"W	Hard-bottom
	29°29'51"N	87°50'28"W	Sediment Shift
	29°29'52"N	87°50'57"W	Sediment Shift
	29°29'55"N	87°53'43"W	Sediment Ridge
	29°29'56"N	87°55'04"W	Hard Bottom
	29°29'54"N	87°55'28"W	Hard Bottom
	29°29'55"N	87°56'38"W	Hard Bottom
16	29°29'56"N	88°18'33"W	Small Target
	29°29'55"N	88°16'22"W	Sediment Shift
	29°29'42"N	88°01'16"W	Small Target
17	29°29'18"N	87°52'17"W	Sediment Shift
	29°29'25"N	87°58'07"W	Sediment Ridge
	29°29'27"N	88°00'46"W	Sediment Ridge

Table C-1. Target table.

Line	Latitude	Longitude	Description
	29°29'28"N	88°01'09"W	Sediment Ridge
	29°29'11"N	88°33'11"W	Sediment Ridge
	29°29'29"N	88°02'46"W	Sediment Ridge
	29°29'28"N	88°03'01"W	Sediment Ridge
	29°29'30"N	88°03'44"W	Sediment Shift
	29°29'30"N	88°03'59"W	Sediment Ridge
	29°29'30"N	88°04'24"W	Sediment Ridge
	29°29'30"N	88°04'31"W	Sediment Ridge
	29°29'44"N	88°24'37"W	Small Target
	29°29'44"N	88°26'07"W	Small Target
18	29°29'23"N	88°21'04"W	Sediment Shift
	29°29'21"N	88°16'39"W	Sediment Shift
	29°29'22"N	88°15'19"W	Sediment Shift
	29°29'17"N	88°09'23"W	Sediment Ridge
	29°29'15"N	88°07'07"W	Sediment Ridge
	29°29'14"N	88°05'47"W	Sediment Ridge
	29°29'12"N	88°04'33"W	Sediment Ridge
	29°29'12"N	88°02'44"W	Sediment Ridge
19	29°28'56"N	88°03'11"W	Small Target
	29°28'57"N	88°04'53"W	Hard Bottom
	29°28'40"N	88°33'13"W	Hard Bottom
	29°28'59"N	88°06'26"W	Hard Bottom
	29°28'59"N	88°06'55"W	Hard Bottom
	29°29'12"N	88°26'12"W	Small Target
20	29°28'59"N	88°30'46"W	Small Target
	29°28'59"N	88°29'27"W	Small Target
	29°28'57"N	88°28'06"W	Small Target
	29°28'41"N	88°03'11"W	Small Target

Table C-1. Target table.

Line	Latitude	Longitude	Description
	29°28'39"N	88°02'57"W	Small Target
21	29°28'16"N	87°54'30"W	Small Target
	29°28'25"N	88°03'30"W	Sediment Ridge
	29°28'24"N	88°05'59"W	Sediment Ridge
	29°28'26"N	88°06'01"W	Sediment Ridge
	29°28'34"N	88°16'03"W	Small Target
	29°28'33"N	88°16'10"W	Small Target
	29°28'34"N	88°16'24"W	Small Target
	29°28'41"N	88°25'33"W	Small Target
22	29°28'16"N	88°16'04"W	Small Target
	29°28'02"N	87°57'30"W	Small Target
23	29°27'50"N	88°01'18"W	Hard Bottom
	29°27'50"N	88°03'30"W	Hard Bottom
	29°28'00"N	88°15'36"W	Hard Bottom
24	29°27'44"N	88°15'46"W	Small Target
	29°27'38"N	88°08'43"W	Hard Bottom
	29°27'38"N	88°07'58"W	Small Target
25	29°27'37"N	88°29'57"W	Small Target
26	29°27'12"N	88°16'23"W	Small Target
31	29°25'49"N	88°14'14"W	Small Target
	29°25'53"N	88°18'36"W	Hard Bottom
32	29°25'43"N	88°30'40"W	Small Target
	29°25'38"N	88°03'26"W	Small Target
	29°25'31"N	88°14'00"W	Small Target
34	29°25'07"N	88°22'29"W	Sediment Shift
	29°24'58"N	88°07'39"W	Sediment Shift
36	29°24'34"N	88°23'18"W	Small Target
	29°24'32"N	88°19'25"W	Small Target

Table C-1. Target table.

Line	Latitude	Longitude	Description
	29°24'27"N	88°12'43"W	Small Target
	29°24'23"N	88°07'40"W	Small Target
37	29°24'14"N	88°17'22"W	Small Target
38	29°23'55"N	88°12'41"W	Hard Bottom
47	29°21'35"N	88°22'45"W	Small Target
53	29°19'59"N	88°24'43"W	Small Target
54	29°19'40"N	88°20'51"W	Small Target
56	29°19'09"N	88°25'29"W	Small Target
57	29°18'50"N	88°17'52"W	Small Target
	29°18'53"N	88°27'17"W	Small Target
	29°18'53"N	88°27'51"W	Small Target
67	29°15'47"N	88°20'10"W	Hard Bottom
	29°15'45"N	88°21'12"W	Hard Bottom
68	29°15'26"N	88°20'29"W	Pinnacle
69	29°15'03"N	88°15'27"W	Pinnacle
	29°15'06"N	88°20'00"W	Pinnacle
70	29°14'46"N	88°20'13"W	Pinnacle
	29°14'46"N	88°20'05"W	Pinnacle
	29°14'47"N	88°19'37"W	Pinnacle
	29°14'44"N	88°15'23"W	Pinnacle
	29°14'44"N	88°15'02"W	Hard Bottom
71	29°14'26"N	88°19'05"W	Pinnacle
	29°14'26"N	88°19'12"W	Pinnacle
	29°14'28"N	88°19'32"W	Pinnacle
72	29°14'11"N	88°26'28"W	Dome
	29°14'08"N	88°19'40"W	Pinnacle
	29°14'08"N	88°19'03"W	Pinnacle
	29°14'05"N	88°15'49"W	Pinnacle

Table C-1. Target table.

Line	Latitude	Longitude	Description
73	29°13'47"N	88°15'58"W	Pinnacle
	29°13'47"N	88°18'28"W	Pinnacle
	29°13'51"N	88°25'45"W	Pinnacle
	29°13'52"N	88°26'24"W	Dome
74	29°13'31"N	88°27'01"W	Dome
	29°13'32"N	88°26'45"W	Pinnacle
	29°13'29"N	88°20'45"W	Pinnacle
	29°13'29"N	88°18'15"W	Pinnacle
	29°13'28"N	88°17'42"W	Pinnacle
	29°13'28"N	88°17'26"W	Patch Reef
75	29°13'10"N	88°17'51"W	Sediment Shift
81	29°17'07"N	88°07'04"W	Hard Bottom
	29°16'17"N	88°09'10"W	Hard Bottom
	29°16'09"N	88°09'32"W	Hard Bottom
	29°15'54"N	88°10'11"W	Sediment Shift
	29°15'14"N	88°12'08"W	Pinnacle
	29°14'48"N	88°13'01"W	Pinnacle
	29°14'03"N	88°14'57"W	Hard Bottom
	29°13'37"N	88°16'00"W	Pinnacle
82	29°13'53"N	88°14'27"W	Hard Bottom
	29°14'05"N	88°13'57"W	Pinnacle
	29°14'20"N	88°13'20"W	Pinnacle
	29°14'48"N	88°12'08"W	Hard Bottom
83	29°14'47"N	88°11'10"W	Pinnacle
	29°14'31"N	88°11'53"W	Pinnacle
	29°14'21"N	88°12'20"W	Pinnacle
	29°14'05"N	88°12'59"W	Pinnacle
84	29°13'55"N	88°12'35"W	Hard Bottom

Table C-1. Target table.

Line	Latitude	Longitude	Description
	29°14'10"N	88°11'51"W	Hard Bottom
	29°13'54"N	88°12'36"W	Pinnacle
	29°14'12"N	88°11'46"W	Pinnacle
	29°14'20"N	88°11'25"W	Pinnacle
	29°15'14"N	88°09'08"W	Hard Bottom
91	29°13'45"N	88°26'16"W	Hard Bottom
	29°22'24"N	88°29'50"W	Small Target
92	29°27'00"N	88°20'34"W	Small Target
	29°26'06"N	88°20'35"W	Hard Bottom
	29°25'46"N	88°20'34"W	Hard Bottom
	29°24'53"N	88°20'33"W	Hard Bottom
	29°23'44"N	88°20'32"W	Small Target
	29°15'29"N	88°20'25"W	Hard Bottom
	29°15'00"N	88°20'25"W	Hard Bottom
93	29°30'22"N	88°14'19"W	Hard Bottom
	29°29'00"N	88°14'18"W	Hard Bottom
	29°23'53"N	88°14'15"W	Hard Bottom
95	29°29'36"N	88°01'42"W	Hard Bottom
	29°30'45"N	88°01'42"W	Hard Bottom
96	29°32'14"N	87°55'26"W	Hard Bottom
	29°31'53"N	87°55'28"W	Hard Bottom
	29°30'35"N	87°55'26"W	Hard Bottom
	29°29'46"N	87°55'26"W	Hard Bottom

APPENDIX D

TOPOGRAPHIC FEATURES PLOT

APPENDIX E

SEDIMENT REFLECTIVITY PLOT

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.