A BIOLOGICAL AND GEOLOGICAL RECONNAISSANCE OF SELECTED TOPOGRAPHICAL FEATURES ON THE TEXAS CONTINENTAL SHELF

A Final Report
to the

U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
OUTER CONTINENTAL SHELF OFFICE
NEW ORLEANS, LOUISIANA

Contract No. 08550-CT5-4

From The
TEXAS A & M RESEARCH FOUNDATION
and
TEXAS A&M DEPARTMENT OF OCEANOGRAPHY

JANUARY 23, 1976

RESEARCH CONDUCTED BY THE

COLLEGE OF GEOSCIENCES

TEXAS A&M UNIVERSITY COLLEGE STATION, TEXAS

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TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

Page

Page

Page

*All dimensions refer to bottom depth.

Page

Page

Page

Page

Page

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION

AND

OBJECTIVES

INTRODUCTION

During U.S. Department of Interior, Bureau of Land Management (BLM) public hearings held in 1973, 1974 and 1975 prior to Texas Outer Continental Shelf (OCS) oil and gas lease sales, concern was expressed by the National Marine Fisheries Service, scientists from Texas A&M and the University of Texas and private citizens over the possible environmental impact of oil and gas drilling and production operations on coral reefs and fishing banks in or adjacent to lease blocks to be sold. As a result, certain restrictive regulations concerning drilling operations in the vicinity of the well documented coral reefs and biostromal communities at the East and West Flower Gardens were established by BLM, and Signal Oil Company was required to provide a biological and geological "baseline" study of the less well known Stetson Bank before a drilling permit could be issued.

Considering the almost total lack of knowledge of the geology and biotic communities associated with the South Texas OCS banks lying in or near lease blocks to be offered for sale in 1975, BLM contracted with Texas A&M University to provide the biological and geological "baseline" information required to facilitate judgments as to the extent and nature of restrictive regulations on drilling near these banks which might be required to insure their protection.

In pursuit of this, scientists from Texas A&M University were to direct their attention toward assessments of ground fish populations, reefal and epifaunal communities, meiofaunal and infaunal populations, unique biological and geological features, substratum type and distribution, and the biotic and geologic relationships between these banks and those farther north.

OBJECTIVES

As stated in our proposal to BLM, the general objectives of the project reported here were 1) to provide precise positioning, detailed bathymetric maps and side-scan sonar coverage of a number of specified sites (ultimately 15), 2) to provide enough descriptive information concerning selected banks (ultimately Baker, South Baker, North Hospital, Southern, Dream and Big Adam) to allow determinations as to their aesthetic and/or commercial value and 3) to document current "baseline" biological and geological conditions at the selected banks to serve as a basis of comparison for later environmental monitoring programs if they are warranted.

More specifically, the geological analyses were to consist of 1) size analyses, 2) carbonate analyses, 3) x-ray radiography, 4) core descriptions, 5) particle type identification, 6) x-ray diffraction (mineralogy) and 7) bed rock analyses. Biologic observations, sampling and analyses were designed to 1) characterize benthic communities within the study areas in terms of dominant or predominant macro-benthonic organisms, 2) insofar as possible, plot distribution of these communities on bathymetric charts of the areas, 3) provide gross impressions of the distribution and abundance of certain key species or groups of organisms, particularly groundfishes, other organisms of commercial importance and species of particular potential as "indicator" organisms for environmental monitoring purposes, 4) assess the condition or "health" of the communities, 5) document the observations photographically, 6) identify and quantify groups of meiofaunal organisms present in soft bottom sediment surrounding the banks.

When it was realized that there was no provision relating to assessment of environmental impact of drilling on the Algal-Sponge Zone (43-80 meters) in the U.S.G.S. Notice on the East Flower Garden monitoring program, we proposed to attempt to rectify the situation through a modification of our BLM contract.

Subsequently, BLM agreed to fund an extension of the original project requiring us to duplicate as far as possible submersible reconnaissance work done in 1974 on a southeast transect across the reef and Algal-Sponge Zone at the East Flower Garden Bank to a depth of 80 meters. The objective in this was to compare the observed 1974 conditions within the benthic communities with those found to exist in 1975, following nearby drilling, in an attempt to determine whether or not the drilling operation had any apparent environmental impact on the biota. Particularly, we were to be alert to any signs of mortality, stress or undue sedimentation on the coral reef and in the Algal-Sponge Zone.

It was understood that biological and geological samples representative of the sites, including videotapes and photographs, would be archived at Texas A&M University.

CHAPTER II

FIELD METHODS

FIELD METHODS

The project field efforts were split into two units. Phase I was devoted to mapping the banks and involved cruises aboard the M/V MISS FREEPORT in the winter of 1974 and a cruise aboard the R/V GYRE in the spring of 1975. Phase II was devoted to the photographic and visual reconnaissance of selected banks, biological sampling, geological sampling, sub-bottom profiling and supplemental mapping, and involved R/V GYRE cruises during the spring of 1975 to the South Texas Banks and the East Flower Garden.

Phase I--Mapping Cruises

INTRODUCTION

Under subcontract with Decca Survey Systems, Inc., Houston, Texas, a bathymetric and side scan sonar survey was accomplished over fourteen of the seventeen selected highs on the Texas continental shelf during the period of 15 October 1975--15 November 1975.

The survey was undertaken aboard the M/V MISS FREEPORT, chartered from Dearborn Marine, Inc., at Freeport, Texas. This utility boat, built in 1965 by Gulfport Shipbuilding Corp., Port Arthur, Texas (Hull No. 618), is 37.5 meters long and 8.2 meters wide. Its complement consisted of 6 crew members and 10 scientists.

Decca normally had two "Hi-Fix" navigators and two side scan sonar operators on board and, for part of the time, a hydrographer. The Bureau of Land Management Office, New Orleans, Louisiana, provided one representative for each cruise leg. One or more Menco, Galveston, Texas, persons were on board, being responsible for constructing and planting bench marks and buoys. The Oceanography Department provided the chief scientist and two or three graduate students per leg.

A portable van on board the vessel housed all electronic equipment and recorders necessary for the operation. Details of this equipment, location of certain parts, and other specifics are given in separate sections. Mobilization began on October 15, 1974, and the first cruise departed on the next day. Although priority had to be given to the highs off southern Texas, the first leg was undertaken to Twenty-nine Fathom Bank and Twenty-eight Fathom Bank, both south of Galveston. The reason for this was that Decca did not have their southern Hi-Fix chain in operation.

Although there are five selected banks around the West Flower Garden Bank, it was decided to give priority to the southern area as soon as the positioning equipment was operable. Consequently, the three banks--Little Sister, Thirty-two Fathom Bank, and Four Rocks--were left unsurveyed with the idea to do those at the end of the first phase of the program.

The survey phase did not run very smoothly. The fall of 1974 was rather rough with a large number of Northers and strong southerly winds in between. Except for a few days the sea states were 3-4 and greater. Such sea conditions are not bad when working on a larger vessel. The MISS FREEPORT, however, proved to be less stable and even at low sea states, she rolled. As a consequence, the depth records were sometimes difficult to read with any accuracy, as the transducer was mounted to the side of the vessel, and any rolling caused hyperbolic pictures of the bottom. When the bottom trace became too rough the surveys had to be terminated.

In addition, there were serious problems with the Decca equipment, primarily the Hi-Fix. The shore stations, especially the southern one, had many breakdowns resulting in considerable loss. Furthermore, the skywave effect very often prevented surveying. The southern Hi-Fix chain caused most of the problems. The station locations were not ideal. This gave serious delays when trying to survey the southernmost bank--East Banks--where skywaves limited the operational day from about 9 a.m. to 4 p.m.

Due to the low efficiency of the operation, we recommended that surveying of the three earlier-mentioned banks be postponed until the spring of 1975. B.L.M. agreed, insofar as costs would be less and results better during calmer spring weather.

Each of the five survey legs was rather short. Their termination was basically determined by weather. The chief scientists for the different legs were: Leg I, Dr. Arnold H. Bouma; Leg II, Dr. Richard Rezak; Leg III, Dr. William R. Bryant; Leg IV, Dr. Arnold H. Bouma; Leg V, Dr. Richard Rezak.

During the period 5 May 1975 to 12 May 1975 the remaining three banks were surveyed. Due to the difficulties with navigation encountered during the 1974 portion of Phase I, the Lorac Service Corporation, 8125 Westglen Drive, Houston, Texas 77042, was contracted to supply positioning and navigation. Hydrosurveys, Inc., 419 Mecca Drive, Lafayette, Louisiana 70501, was contracted to furnish the dual side scan equipment and two operators. Bathymetry was obtained by Texas A&M University using its own equipment.

The surveys were conducted aboard the R/V GYRE, operated by the Texas A&M University Department of Oceanography. The GYRE was built in 1973 by Halter Marine Services of New Orleans, Louisiana. It has an overall length of 53 meters and a beam of 11 meters. The ship's complement includes 10 crew members and 19 scientists.

In addition to completing the bank surveys, side scan sonar lines were run on Stetson Bank and the West Flower Garden Bank, where bottom sediments are known, in order to permit more accurate interpretation of the sonar records.

POSITIONING

During the winter cruises the Hi-Fix antenna was mounted approximately amidships at a distance of 23 meters from the ship's stern. Vessel positioning and navigation was accomplished by utilizing two of Decca's Hi-Fix service chains--Palacios and Galveston Bay. A third chain was set up especially for this survey to cover the area between Corpus Christi and Brownsville. This chain had towers in Brownsville and Kingsville.

All three chains were operated in the hyperbolic mode. Lanecounts were acquired at fixed production platforms and were tracked on an analog recorder. Closed lanecount traverses were made between the lanecount tie points (platforms) and the surveyed banks.

A pre-plot for each bank was prepared by Decca. A closely spaced, parallel set of survey lines was run in one direction over each area. and cross ties were made along a few lines at right angles to these. Table I presents the direction of the survey lines and the spacings for each bank.

While surveying, the navigators checked the location of the ship at intervals of 152 meters and adjusted the course in case a deviation from the preplots occurred. The Decca office replotted the fix location after the cruise before plotting the bathymetric data. These fix locations are on the finished bathymetric charts as small circles.

During the spring 1975 mapping cruise, navigation proved to be much superior to that of the winter cruises and permitted 24-hour operations. The positioning data was handled in the same way as during the winter cruises. The Lorac Service Corporation supplied pre-plots of each bank area. During the survey, the navigator noted the ship's position every 152 meters, and course corrections were applied when necessary. After completion of the cruise, post plots were prepared by Lorac, using the actual positions at each 152 meters fix.

The data on survey lines for the spring cruise are given in Table 1. The Lorac fixes during the surveys are plotted on each finished bathymetric chart as small circles. On these charts, each surveyed line is numbered, and every tenth fix on each line is numbered.

BATHYMETRY

During the winter mapping cruise the bathymetry was obtained by Decca using a compact Atlas-Deco 10 system manufactured in Germany. It operates on frequencies of 30 and 210 kHz, the latter being used most of the time. The echosounder transducers were located in a steel housing which was mounted along the port side of the vessel, 3.4 meters aft of the Hi-Fix antenna, at a depth of 1.7 meters below the water line.

Each navigation fix was noted on the depth record so that precise depths could be correlated with known geographic positions. The bathymetric charts of each bank surveyed during the winter cruise were prepared by

Decca Survey Systems, Inc. Because Decca did not utilize the side scan records in the preparation of the charts, some of the charts were later altered at Texas A&M University to accommodate the side scan information.

During the spring mapping cruise bathymetric and high-resolution sub-bottom profiles were obtained using a 12 kHz Raytheon PTR 105B with the signal fed into a Raytheon PFR 196 Recorder, and a 3.5 kHz Raytheon PTR 105B with the signal fed into a Raytheon PFR 193 Recorder. The transducers are hull-mounted, 3.6 meters aft of the bow at a depth of 3 meters. The recorders were operated at ¼-sec. scan speed (100 fathom scale). The depths on the records are in fathoms and were converted to meters for the preparation of the bathymetric charts. The Lorac antenna was located 14.6 meters aft of the hull-mounted transducers. Due to excessive noise on the 3.5 kHz record, a towed transducer mounted in a bat-fish was deployed from the starboard A-frame, a distance of 33.5 meters aft of the Lorac antenna. The fish was towed at a depth of 7.5 meters.

The cable to the 3.5 kHz fish was accidentally damaged on May 7 just before beginning the survey of Thirty-two Fathom Bank. Consequently, the survey of Thirty-two Fathom Bank was made with the 12 kHz depth recorder only. On May 10, while surveying Little Sister, we tried the hull-mounted 3.5 kHz transducer and found that it performed satisfactorily at those water depths. After completing the survey of Little Sister we returned to Thirty-two Fathom Bank and resurveyed lines 32FM26N and 32FM51E using side scan, 12 kHz and 3.5 kHz.

The final charts were constructed by the Department of Oceanography at Texas A&M University. The Lorac Service Corporation provided us with post plots of the survey tracks plotted on a scale of 1:12,000.

The depth contours are presented in 2-meter intervals. The bathymetry was read from the depth records, while the side scan records were used to locate the various tops of prominences. In addition to latitude and longitude and the UTM grid system, the BLM OCS lease block boundaries and benchmark locations are given.

SIDE SCAN SONAR

The side scan sonar fish was towed behind the vessel from the stern center. An electrically powered winch was mounted at the stern to stream and recover the towed sonar fish. A nominal value of 5.9 feet (1.8 meters) per drum revolution was used to calculate the amount of side scan cable payed out during a survey line.

The unit was an EG&G Mark B side scan sonar system, the recorder model was 259-3 and towed fish model 272. It operates at a frequency of 105 ± 10 kHz with a pulse duration of 0.1 milliseconds. The peak output is 118 db ref. 1 microbar at 1 meter. In the horizontal plane the beam width is 1° to left and right; in the vertical plane the beam width is 30° starting at 10° off the horizontal.

The recorder operates at 24-30 volts, 4-6 amperes, and makes two patterns from the center out corresponding to the left (port) and right (starboard) windows of the fish. The range is 76, 152 or 305 meters to each side. The paper is a wet paper, 27.9 cm wide with 200, 150, or 100 lines per inch depending on the range used.

The sonar recorder utilized a stylus rotation corresponding to 1,500 meter/second seawater sonic velocity. A low gain setting was applied to enhance the topographic relief, and at the same time to minimize the cross-talk.

A range of 200 meters per channel was used during this phase, in order to achieve the greatest overlap of coverage while taking the involved geometry into consideration. The useable range was limited principally by the depth of the water; in some cases, the fish was towed directly in the vessel's wake, resulting in "wake noise" on the record. The fish towing stability characteristics deteriorate somewhat when towed so close behind the vessel and near the surface. Occasionally this had to be done when the water depth was shallow to maintain a distance of about 40 meters off the bottom to ensure sufficient coverage.

Hydrosurveys, Inc., 419 Mecca Drive, Lafayette, Louisiana 70501, was contracted to furnish the dual side scan equipment and two operators for the spring mapping cruise. The equipment was identical to that used during the earlier Phase I cruises. However, the records obtained during the May 1975 cruise were far superior to those obtained earlier. This is probably due to the more experienced operators supplied by Hydrosurveys, Inc.

BENCHMARKS AND BUOYS

Benchmarks were made of 55-gallon oil drums filled with concrete. Normally they were planted after a survey to ensure a proper location. Attached to the benchmark was a polypropylene line with small floats at the free end, hanging 15 meters above the benchmark.

For positioning purposes, a buoy made from a 2.4 meter long, 15 cm diameter PVC tube, filled with foam plastic and taped and sealed on both ends was used. With the help of duct tape and hose clamps a 3 meter, 2.5 cm PVC tube was connected to one end to support a radar reflector and a light. A few sash weights attached to the bottom normally kept the buoy up straight in the water. However, the sea state often made it impossible to locate the buoy as it did not emerge sufficiently from the water. The buoy was tied to the benchmark in such a way that it could be retrieved easily.

Weather conditions prevented us from relocating some of the buoys, and it is possible that some sank or were torn loose. Some of the benchmarks may not be located where they were dropped as some banks are very actively fished for snappers. Since some buoys could not be located during a second visit to some areas, a second benchmark with buoy had to be dropped for navigation purposes.

Although the idea of benchmarks and buoys is very sound, the investigators feel that it has doubtful value on the smooth fishing banks, as fisherman induced movement may occur, and buoys may be stolen for their valuable polypropylene lines.

Table II presents the location of the benchmarks in degrees longitude and latitude, Hi-fix positions, and state coordinates (Texas Lambert Grid).

During the spring mapping cruise benchmarks were set on each bank, but due to their short life, none of the buoys were left after completion of the survey.

Phase II--Photographic and Visual Reconnaissance and Sampling Cruises

In accordance with Modification No. 2, dated 13 June 1975, to Contract No. 08550-CT5-4, the South Texas banks examined during these cruises (Table 4) were as follows: Baker, South Baker, Southern, Big Adam--Small Adam, and Dream.

In addition to these, a bathymetric and sparker survey was conducted on Hospital Bank. This survey was tied in to the Aransas--North Hospital survey, and it was found that the chart of Hospital Rock prepared by the Southwest Research Institute, although very accurate in detail, is in error as to the position of the bank. Our survey, using Lorac positioning, places the bank approximately 1006 meters to the east of its position on the Southwest Research Chart. No samples were taken from Hospital. A planned submersible transect on the Bank was scrubbed due to weather and sea state. However, approximately 1.0 hour of TV coverage of the bottom was taken from the surface using the Underwater Television while anchored on a peak in the center of the bank. Submersible transects were made at North Hospital Bank.

Visual assessment of the southeast and north part of the East Flower Garden Bank, from the crest of the reef out to the bank edge, was accomplished using the submarine (Fig. 1). Documentation was by videotape and color photography. A few samples were collected using the submarine's manipulator arm (Fig. 2). One SCUBA dive was performed at the crest of the reef.

EQUIPMENT USED

NAVIGATION

Navigation and positioning was supplied by the Lorac Corporation for the first four legs of the cruise. Two Lorac navigators were aboard permitting 24-hour operation. Lorac was not required for the last leg which was concerned with the East Flower Garden Bank.

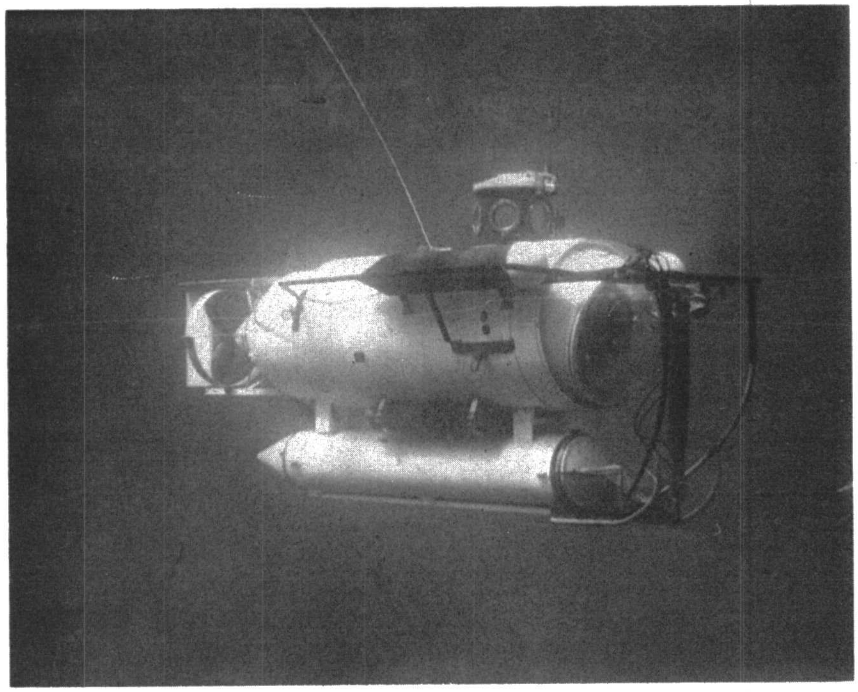

Figure 1. Texas A&M Oceanography Department research submersible DIAPHUS (1974).

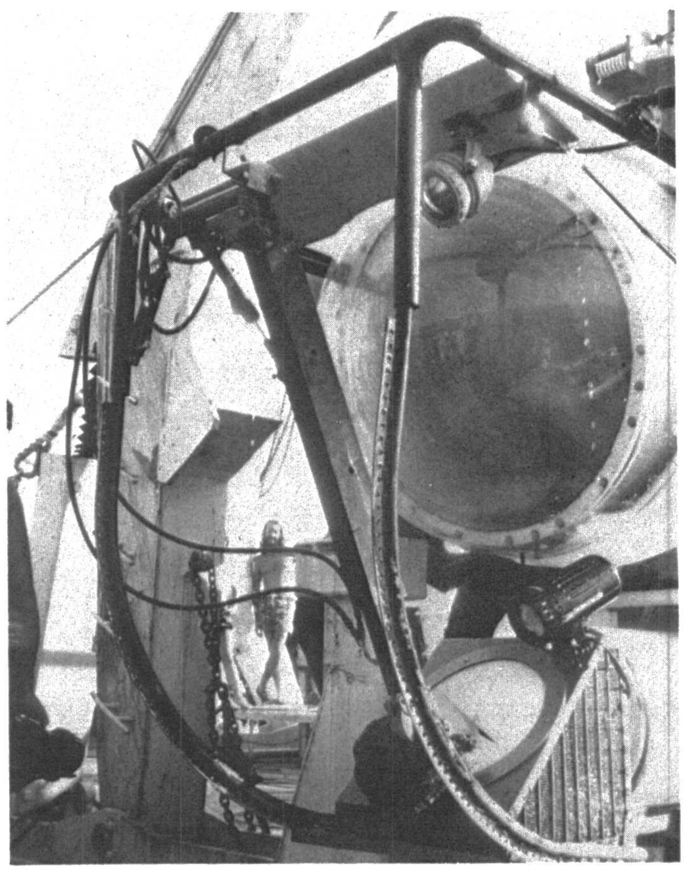

Figure 2. Main viewport, manipulator arm and sample basket (1975).

SAMPLING

Devices used for obtaining geological and biological samples are indicated below.

Sediments

Piston Corer (Fig. 3)

Mass: 909 kg

Length of Barrel: 6 meters

Diameter of Barrel: 7.62 cm ID, plastic liner

Break-away Piston

Gravity Corer

Mass: 136 kg

Length of Barrel: 2.4 meters

Diameter of Barrel: 7.62 cm ID Stainless Steel, plastic liner

Flapper valve at top of barrel

Box Corer (Fig. 4)

Mass: 113 kg

Box dimensions: 30 X 30 X 50 cm

Rocks

Rock Dredges

1. Pipe dredge--46 cm (Fig. 5)
2. Rectangular steel dredge

   Cutting Edge: 38 X 76 cm

   Chain Bag: 1 meter long

Biological

Box corer (as above)--for meiofauna

Submersible DRV DIAPHUS--for epifauna

Sport fishing gear--for fish

Rock Dredges (as above)--for epifauna

SUBMERSIBLE

The submersible used on this cruise was the DRV DIAPHUS owned and operated by the Department of Oceanography, Texas A&M University (Fig. 1 & 2). It was built by Perry Submarine Builders, Riviera Beach, Florida, in 1974.

Length: 6.05 meters

Mass: 4568 kg

Depth Capacity: 366 meters

Payload: 409 kg

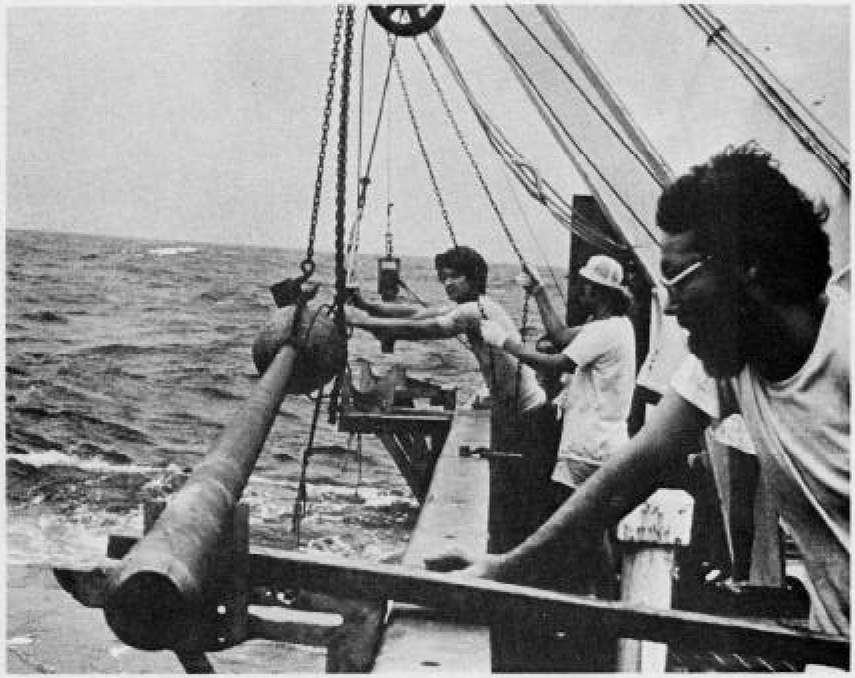

Figure 3. Piston corer.

Figure 4. Box corer.

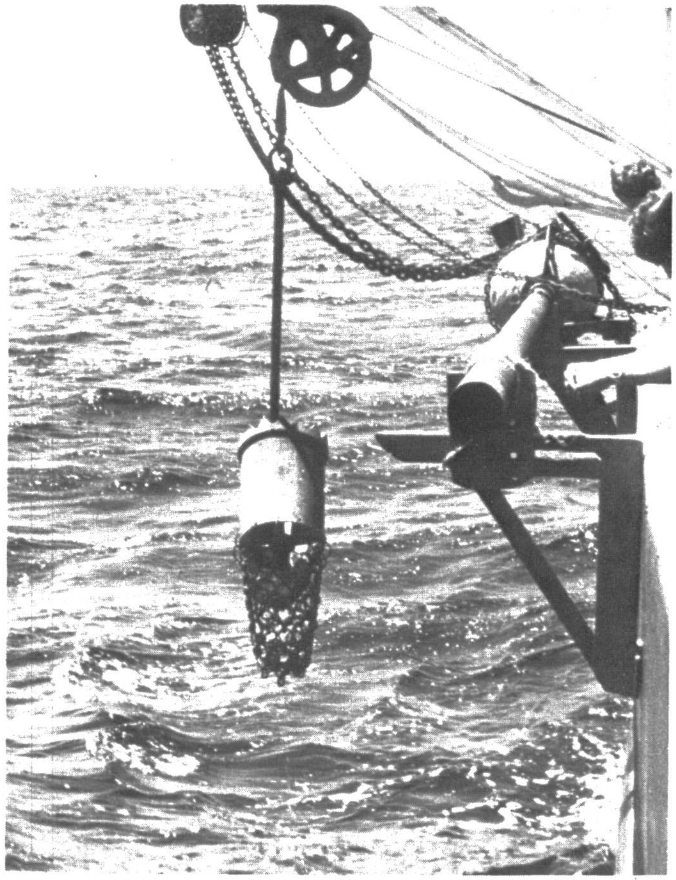

Figure 5. Pipe dredge.

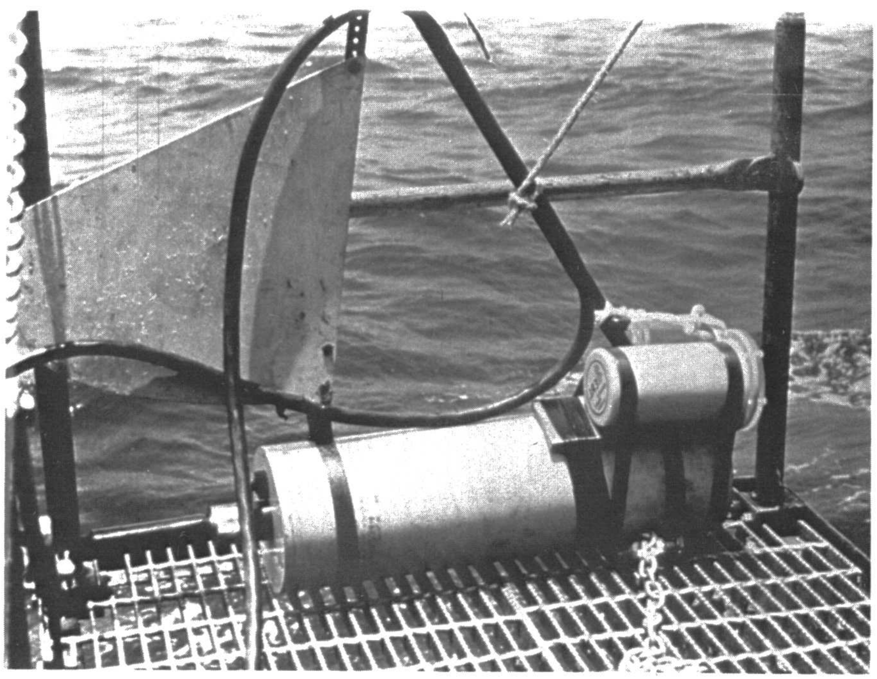

Figure 6. Towable underwater television.

Life Support Capability: 180 man hours

Speed: up to 4.6 km/hr.

Power: 36-volt D.C. system

110-volt A.C. for lights and TV recorder and camera

Passengers: one pilot and one observer

Viewports: Seven 20 cm viewports in conning tower and one 91 cm hemispherical viewport in nose

Photography: One externally mounted strobe light which will couple with standard camera systems inside sub

Scientific Sampling: Hydraulic manipulator arm with four functions: forward-aft, left-right, in-out, claw-open/claw close. Sample basket.

Table 5 lists submersible (submarine) dives made in conjunction with this project.

PHOTOGRAPHIC

A Nikon Model FTN camera was used for color transparency photographs of the bottom from the submersible. The camera was hand-held and coupled to an externally mounted strobe light (Sub-Sea Model 1000). Table 6 lists the number of slides taken during the submersible dives.

Film used was Kodak High Speed Ektachrome EH 135-36, film speed ASA 160. When ambient light conditions permitted, exposures were made without the strobe light using a film speed of ASA 400. This film required special processing.

A Nikonos underwater camera was used to a limited extent during SCUBA operations.

TELEVISION

A Sony TV system was used in the submersible to document the transects. This system consisted of an AVC 3400 TV camera, an AV 3400 TV recorder, and an 18 cm monitor. The TV system was supplied converted power (110 volts A.C.) from the main batteries of the submersible. The TV camera was mounted on a bracket and aimed through the forward viewing port but easily detached from the bracket for hand-held use. Mounting of the TV camera permitted TV coverage while the observer was taking 35 mm. still pictures, collecting samples or describing visual observations. TV coverage along transects was quite adequate but not 100 percent.

An identical TV system was modified as an Underwater Television for use from the deck of the ship (Fig. 6). Table 7 shows the extent of TV coverage of the banks visited.

SURVEYING

High-resolution sub-bottom profiling was conducted using a 3.5 kHz Raytheon PTR 105B with the signal fed into a Raytheon PFR 193 Recorder. The transducer was mounted in a Batfish (Fig. 7) and was deployed from the starboard "A" Frame at a distance of 33.5 meters aft of the Lorac Antenna. The fish was towed at a depth of 7.5 meters. During Leg IV a Del Norte minisparker was also used in conjunction with an EPC recorder. However, due to difficulties with the EPC recorder, very few records were obtained with this equipment.

TECHNIQUES EMPLOYED

The sequence of tasks on each bank varied considerably depending upon weather, sea state, and time of arrival on the bank. The specific tasks accomplished at each bank are as follows: submersible transects, 3.5 kHz high-resolution sub-bottom profiling, coring (piston and gravity) and/or dredging, box coring, hook-and-line fishing, and deploying buoys.

If the time of arrival at the bank was at night, the ship would anchor and samples of fish would be acquired by hook-and-line. In the morning a buoy would be deployed, and depending on the sea state, the submersible transects would be undertaken or postponed. If the sea state was too high for launch and retrieval of the submersible, then the 3.5 kHz sub-bottom profiles would be run and surface sampling of the bottom would be conducted.

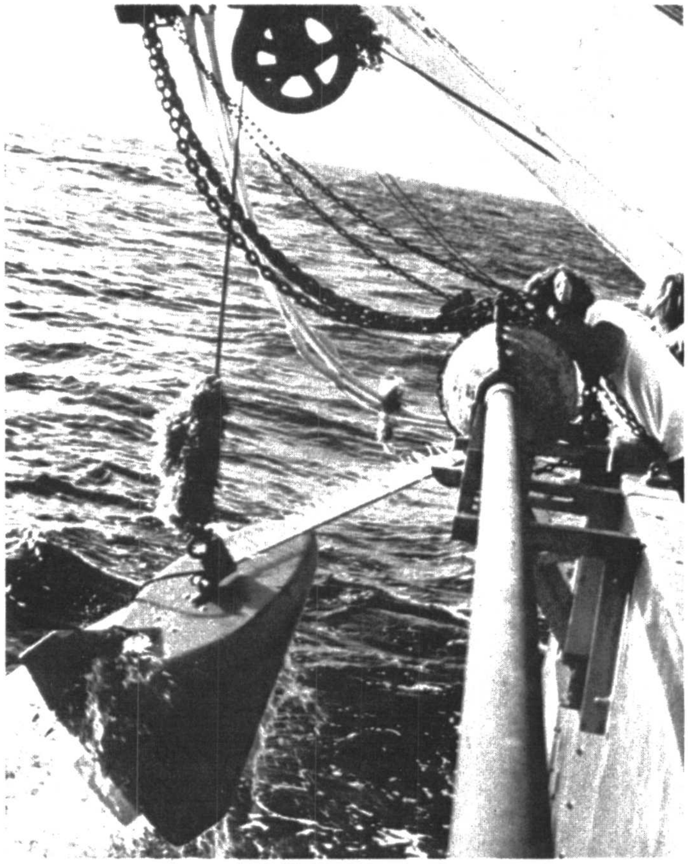

Figure 7. Batfish.

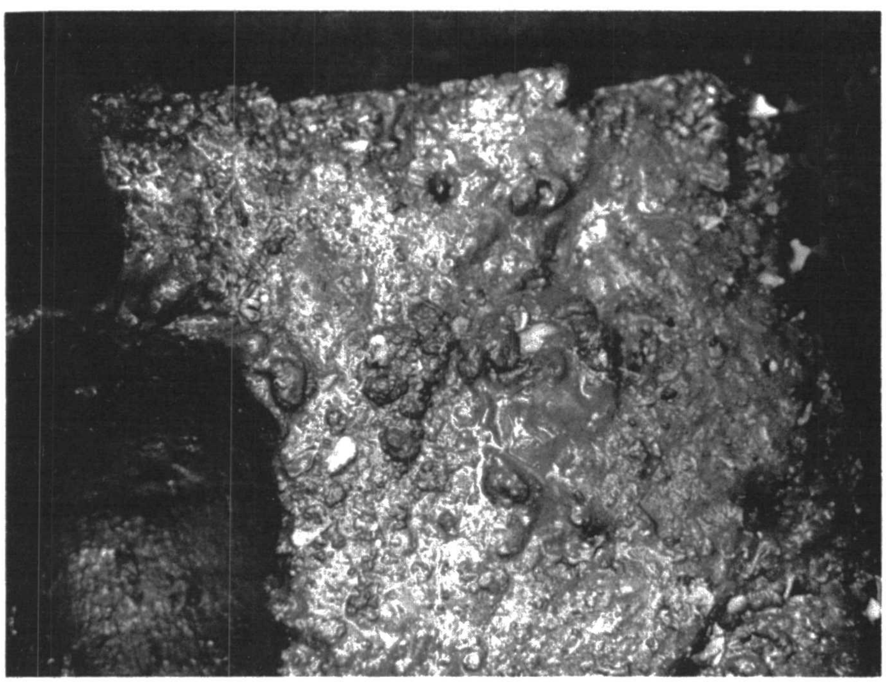

Figure 8. Undisturbed bottom sediment sample inside box corer (Figure 4) with a scoop taken out for chemical analysis and the meiofauna sampling tube inserted in upper left.

Tasks performed at master sampling stations were piston or gravity core and/or dredging, and box core. The first task at each station was usually the piston or gravity core. However, the time required for re-rigging the piston core varied from 30 to 45 minutes. If the ship arrived on station prior to the piston corer being ready, then a box core was taken first. Launch and retrieval of the box corer and the gravity corer is a fairly rapid procedure. The launch and retrieval of the piston core, however, is a very slow process. During the time the piston corer is in the water, the bridge was unable to use the main engines to hold position. Consequently, the piston core positions are generally some distance away from the box core positions, depending upon the wind velocity, sea state, and surface currents.

During Leg II the supply of plastic core liner aboard the ship was nearly depleted, and as the ship was in Corpus Christi at the end of that leg, we borrowed some core liner from the USGS, Marine Geology Branch. On Leg III after depleting the supply of our core liner, it was found that the USGS liner was slightly too large for our core barrel. Consequently, gravity cores were taken at the master stations during the remainder of that leg. At the end of Leg III a supply of proper diameter core liner was sent from our Galveston staging area to Corpus Christi. Approximately halfway through Leg IV the core weight on the piston corer became dangerously loose due to rusting of the supporting steel, and again the gravity corer was used in place of the piston corer for the remainder of that leg. Samples and subsamples taken from each bank are shown in Table 8.

STATION PROCEDURES

Navigation

All stations were selected on the sites on each bank which coincided with preplot positions supplied by Lorac. The navigator would maneuver the ship to the station site, and as soon as the ship was in position a signal was given to the afterdeck to lower the sampling device. Lorac positions were recorded for post plots at the time the device entered the water, the time the device reached the bottom, and the time the device was back at the surface. As wire angles were very small, the position taken when the device was on the bottom is the one plotted on the charts for the station.

Box Coring

The box corer was lowered on the hydrowinch wire from a boom just aft of the deck house. Ordinarily, the time en route to the bottom was approximately one minute. The return trip to the surface varied from one to two minutes. After the box corer was brought to rest on the bucket it was sampled in the following sequence:

Master Station	Secondary Station
1. Hydrocarbon Sample	1. Geological Sample
2. Meiofauna Sample	
3. Geological Sample	
4. Trace Metal Sample	

The box corer was returned to the bottom at each station until sufficient sediment was obtained for all samples. However, due to the large size of the box corer, it was normally possible to take all subsamples from a single lowering.

Meiofauna

Samples were obtained with the box corer (Fig. 4) which sampled a bottom area of 0.09 m^2. If a large volume of water was overlaying the sediment, it was removed by gentle siphoning, and a meiofaunal sample was taken if the sediment surface appeared to be relatively undisturbed. This was accomplished by slowly pushing a 30 cm length of plastic core liner (I.D. 3.5 cm; 9.62 cm^2 area) approximately 15 cm into the sediment held by the sampler (Fig. 8). Sample cores were then extruded from the core tubes, sectioned into 5 cm increments, preserved in 5 percent buffered formalin, and returned to the laboratory for extraction.

Hydrocarbon Samples

Cleaned, wide-mouth pint jars were inserted directly into the sediment in the box corer until they were nearly filled (Fig. 8). The sample was then removed, covered with a double layer of Saran Wrap and the screw lid fastened as tightly as possible. Sample numbers were written on tape fastened to the outside of the covers. Samples were then frozen and later conveyed to the USGS in Corpus Christi for analysis.

Epifauna and Groundfishes

Epifauna and groundfishes inhabiting the banks were assessed visually from the submarine or underwater television and documented on videotape and 35 mm. color photographs. Sampling of epifauna was accomplished primarily through the use of rock dredges, grab samplers and the submarine's manipulator arm. Specimens were either frozen or preserved in 10 percent buffered formalin or 95 percent ethyl alcohol. Archived specimens are indicated in the Tables in Chapter VI.

Fish for Chemical Analyses

Snappers of the species *Lutjanus campechanus* and *Rhomboplites aurorubens* and groupers of the genus *Mycteroperca* were collected by hook-and-line at the banks. An average of three specimens for each of the two snapper species were taken at each bank. Only three groupers were caught during the trip. All specimens were labeled, double bagged in polyethylene bags, frozen, and coveyed to Dr. Arthur Horowitz of the Texas A&M University Oceanography Department for analysis (Table 9).

Submarine Transects

Submarine transects were selected at each bank on the basis of topography and geological sampling. After launch of the submarine it proceeded on the surface to the desired dive site and submerged. Upon reaching the bottom it followed a predetermined course using the gyrocompass. Tracking of the submarine from the ship, which is anchored during submarine operations, was accomplished by taking visual bearings and radar ranges on a two foot diameter tether buoy attached to the submarine by a light polypropylene line. In sea conditions not favorable to radar, a 4.3 meter rubber ZODIAC boat was sent to the position of the tether buoy to provide a larger "target" for the radar. Course corrections were conveyed to the submarine from the ship through the underwater telephone (UQC). A maneuvering board plot of the submarine's position relative to the stationary ship was kept during each dive.

The procedure followed by observers in the submarine is illustrated by the following reproduction of written instructions given to each in preparation for their dive:

Correlation of Observations made from a Submarine

The critical elements to be correlated in order to derive a "picture" of the study area are: 1) the observation (verbal, television, photographic, sample collected); 2) the depth; and, 3) the position at which the observation was made. Numbers 1 and 2 can be linked directly by the observer while in the process of taking and recording observations inside the submarine. Item 3, however, can only be correlated with the other two on the basis of time synchronization. Many hours of analysis and a great deal of uncertainty concerning position and depth of observations can be avoided if the observer and pilot follow the procedure outlined below in recording observations and data on audio and video tape.

1. Label tape with date, area of operation, cruise No., dive No., time, pilot's name, observer's name.
2. Report time leaving surface.
3. Report times and depths of observations made during descent.
4. Report time reaching bottom, depth, bottom type and other observations.
5. Every 5 minutes or so report time, depth and pertinent observations.
6. Report time and depth for each U.Q.C. communication.
7. Report time and depth for each stop.
8. Report time, depth when getting underway each time.
9. For each series of observations report time and depth.
10. Report time, depth, and label designation for each frame or sequence of frames of still photographs taken and for each scene of movie film taken.
11. Report time and depth for each scene of T.V. tape taken.

It has been found that audio taped, video taped and still and motion picture photographed observations are complementary and all very useful. The audio tapes, however, prove to be most significant in later correlation of all types of observations. Use the audio tape as continually as possible, even if you leave it running the entire time. Do not, however, turn it on and forget it because it will run out in 30 minutes or an hour depending on the tapes used. When an audio tape runs out (and this can only be detected by visually inspecting the tape recorder periodically) change it.

Records of observations taken as described above can be readily correlated with timed position fixes taken for the sub by the support vessel. These fixes will be acquired every 5 or 10 minutes depending on the requirements of the observer for scientific purposes.

Some very useful standard observations should be entered on the audio tape along with the time-depth reports. These are: water temperature, visibility, current direction and approximate magnitude, bottom type and color.

Table 1. Data on Direction and Distance of Survey Lines

Bank	Direction and Distance Apart of Regular Survey Lines		Direction and Number of Tie Lines		Number of Survey Miles (Statute Miles)
29 Fathom Bank	NW- SE	450-500'	NE- SW	5	33
28 Fathom Bank	N- S	750-800'	E- W	4	63
Baker	N- S	600'	E- W	2	26
South Baker	N- S	800'	E- W	2	7
Aransas	NE- SW	800'	NW- SE	1	22
North Hospital	NE- SW	800'	NW- SE	1	
Southern	N- S	800'	E- W	2	12
Dream	E- W	800'	N- S	2	23
Big Adam Rock	NE- SW	800'	NW- SE	2	67
Small Adam Rock	NE- SW	800'	NW- SE	4	
Blackfish Ridge	E- W	800'	N- S	4	18
Little Adam Rock	E- W	800'	N- S	3	38
Mysterious	WNW-ESE	600'	NNE-SSW	4	62
East Bank	E- W	1,500'	N- S	2	72
Four Rocks	N- S	800'	0		23
32 Fathom Bank	N- S	800'	E- W	4	160
Little Sister	N- S	800'	E- W	3	139

Table 2. Bench Mark Locations

Bank	Lat./Long.	Hi-Fix Chain Name	Hi-Fix X, Y
29 Fathom	28° 08' 31" 93° 29' 21"	920.56 541.74 Galveston	3775 600 X 154 070 Y
28 Fathom	27° 54' 53" 93° 26' 50"	906.78 596.32 Galveston	3792 940 X 72 150 Y
Baker	27° 44' 49" 96° 13' 56"	293.42 777.96 Palacios	2733 466 X 762 779 Y
South Baker	27° 40' 33" 96° 16' 20"	286.80 831.14 Palacios	2721 006 X 736 610 Y
Aransas	27° 35' 24" 96° 27' 05"	983.82 465.27 Brownsville	2663 516 X 704 459 Y
North Hospital	27° 34' 10" 96° 28' 49"	970.24 466.34 Brownsville	2654 366 X 659 846 Y
Southern	27° 26' 21" 96° 31' 28"	892.00 510.74 Brownsville	2640 738 X 649 275 Y
Dream	27° 02' 32" 96° 42' 11"	632.42 690.06 Brownsville	2584 860 X 504 130 Y
Big Adam Rock	26° 57' 06" 96° 48' 59"	549.30 732.30 Brownsville	2548 400 X 470 750 Y
Small Adam Rock	None	None	None
Blackfish	26° 52' 34" 96° 46' 36"	536.26 794.62 Brownsville	2561 739 X 443 405 Y
Little Adam Rock	26° 47' 34" 96° 49' 04"	491.60 853.10 Brownsville	2548 743 X 413 009 Y
Mysterious	26° 45' 54" 96° 42' 16"	525.28 882.16 Brownsville	2585 854 X 403 376 Y
East Bank	26° 02' 47" 96° 54' 36"	319.01 1344.66 Brownsville	2522 116 X 141 309 Y

Spring Mapping Cruise

Bank	Lat./Long.	Lorac Coordinates	X, Y
Four Rocks	28° 27' 33" 94° 00' 32"	G. 623.35 R. 830.30	3603 342 X 261 837 Y
32 Fathom	28° 01' 47" 94° 31' 29"	G. 482.28 R. 1139.17	3443 640 X 99 035 Y
Little Sister	28° 51' 41" 94° 15' 16"	G. 575.07 R. 1065.45	3533 308 X 41 353 Y

Table 3. Summary of Mapping Cruises

Leg I:	Depart Galveston:	15 October 1974
	Arrive Galveston:	22 October 1974
	Banks Surveyed:	29 Fathom Bank 28 Fathom Bank
Leg II:	Depart Galveston:	24 October 1974
	Arrive Aransas Pass:	29 October 1974
	Banks Surveyed:	Baker South Baker
Leg III:	Depart Aransas Pass:	2 November 1974
	Arrive Port Mansfield:	8 November 1974
	Banks Surveyed:	Dream Big Adam Small Adam East Banks (Part)
Leg IV:	Depart Port Mansfield:	9 November 1974
	Arrive Port Aransas:	15 November 1974
	Banks Surveyed:	North Hospital Aransas East Banks (Part)
Leg V:	Depart Aransas Pass:	16 November 1974
	Arrive Galveston:	24 November 1974
	Banks Surveyed:	Mysterious Little Adam Rock Blackfish
Spring Cruise:	Depart Galveston:	5 May 1975
	Arrive Galveston:	12 May 1975
	Banks Surveyed:	Four Rocks 32 Fathom Bank Little Sister

Table 4. Summary of Reconnaissance and Sampling Cruises

Leg I:	Depart Galveston:	21 May 1975
	Arrive Galveston:	28 May 1975
	Banks Studied:	Baker
		South Baker
Leg II:	Depart Galveston:	29 May 1975
	Arrive Galveston:	2 June 1975
	Banks Studied:	Southern
		South Baker
Leg III:	Depart Galveston:	6 June 1975
	Arrive Galveston:	10 June 1975
	Banks Studied:	Dream
		Big Adam
		Small Adam
Leg IV:	Depart Galveston:	11 June 1975
	Arrive Galveston:	15 June 1975
	Banks Studied:	Big Adam
		Dream
		North Hospital
		Hospital
Leg V:	Depart Galveston:	21 June 1975
	Arrive Galveston:	24 June 1975
	Banks Studied:	East Flower Garden

Table 5. DIAPHUS Submarine Dives, Spring 1975

Dive No.	Date	Locality	Observer	Bottom Time Hrs.	Bottom Time Min.
75- 1	May 25	South Baker	Bright	1	17
75- 2	May 27	Baker	Rezak	4	04
75- 3	May 27	Baker	Bright	1	37
75- 4	June 1	Southern	Bright	4	07
75- 5	June 1	Southern	Bouma	3	00
75- 6	June 2	South Baker	Bouma	1	21
75- 7	June 2	South Baker	Berryhill	1	40
75- 8	June 2	South Baker	Abbott	1	45
75- 9	June 2	South Baker	Green	0	39
75-10	June 12	North Hospital	Teerling	1	16
75-11	June 12	North Hospital	Rezak	1	13
75-12	June 13	Dream	Sidner	1	00
75-13	June 13	Dream	Bright	3	00
75-14	June 13	Big Adam	Cunningham	1	22
75-15	June 22	East Flower Garden	Bright	8	10
75-16	June 23	East Flower Garden	Duprel	3	00
75-17	June 23	East Flower Garden	Giammona	1	36
75-18	June 23	East Flower Garden	Cunningham	0	30
75-19	June 23	East Flower Garden	Trabant	0	50

Table 6. 35mm Color Slides Made During Submersible Dives, Spring 1975

Sub Dive	Number of Slides *	
75- 1	16	South Texas Fishing Banks
75- 2	25	
75- 3	16	
75- 4	105	
75- 5	144	
75- 6	36	
75- 7	36	
75- 8	22	
75-10	26	
75-11	14	
75-12	27	
75-13	65	
75-14	6	
75-15	314	East Flower Garden
75-16	124	
75-17	74	
75-18/19	36	
TOTAL	1086	

* variations in numbers of slide photographs taken per dive were due to differences in objectives of the dives and instructions concerning additional photographic requirements given to observers by the principal investigators.

The greatest numbers of photographs were taken by the principal investigators during initial dives in the two regions studied. All slides are marked individually by dive number, depth, and sequence, and are archived in loose-leaf notebooks in Dr. Bright's office.

Table 7. Recorded Television Coverage of Banks Visited

* DIAPHUS TV Tapes	Hrs.	Min.	Percent of Bottom Time Covered by T.V.
South Baker	3	30	52
North Hospital	1		40
Dream	2	30	63
Big Adam	1		73
Southern	5		70
Baker	4	30	79
East Flower Garden	7		50
*** Underwater TV**			
Big Adam	1		100
Dream		30	100
Hospital Rock	1	30	100
TOTAL	27	30	300

* All video tapes are labeled as to dive, locality and time and are archived in Dr. Bright's laboratory.

Table 8

Samples and Subsamples Taken From Each Bank

	No. of Piston Cores	No. of Rock Dredges	No. of Box Cores	No. of Van Veens	No. of Gravity Cores	Subsamples			
						Meio-fauna	Trace Metals	Geo-logical	Hydro-carbon
Baker	6	0	10	13	0	4	4	18	4
South Baker	4	1	10	2	0	4	4	10	4
Southern	2	6	11	0	8	4	4	16	4
Dream	2	3	11	6	2	4	4	19	4
Big & Little Adam	0	2	15	2	5	5	5	18	5

Table 9. Fish Collected for Chemical Analysis

Species	Location	Date	Bottom Depth
Rhomboplites aurorubens	Baker Bank	May 23	56 meters
	"	"	"
	"	"	"
	"	"	"
	South Baker Bank	May 25	60 meters
	"	May 27	62 meters
	"	?	64 meters
	Southern Bank	May 29	56 meters
	"	"	"
	"	"	"
	"	May 30	60 meters
	"	"	"
	"	June 1	72 meters
	Dream Bank	June 7	68 meters
	"	June 8	"
	"	"	"
	Big Adam Bank	June 9	60 meters
	"	"	"
	"	"	"
	North Hospital	June 12	55-58 meters
	"	"	"
	"	"	"
Lutjanus campechanus	Baker Bank	May 22	58 meters
	"	"	"
	South Baker Bank	May 25	64 meters
	"	"	"
	"	"	"
	Southern Bank	May 30	60 meters
	"	"	"
	"	"	"
	Dream Bank	June 8	68 meters
	Big Adam Bank	June 9	60 meters
	"	"	"
	"	"	"
	"	"	"
	Hospital Rock	June 14	58 meters
Mycteroperca sp.	Southern Bank	May 30	60 meters
Grouper	Hospital Rock	June 14	58 meters

CHAPTER III

INTRODUCTORY

OVERVIEW

An Introductory Overview of the Biology and Geology of Topographical Highs on the Texas Outer Continental Shelf

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and Willis E. Pequegnat

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College Station, Texas

INTRODUCTION

In 1974-1975 the U. S. Department of Interior, Bureau of Land Management, Outer Continental Shelf Office, because of planned oil and gas lease sales, contracted with our group to provide them with a reconnaissance of selected topographical highs (banks) on the Texas Outer Continental Shelf from Baker Bank south. The substantial results of that study appear in the following sections of this report. In addition to the B.L.M. sponsored project we have had opportunities and funding from various sources to study, between 1970 and 1974, the biology and geology of banks farther north (Fig. 1).

Bright and Pequegnat, 1974, described the biota of the West Flower Garden Bank which, with the East Flower Garden, represents the most complete and complexly developed reef and hard-bank assemblage on the Texas-Louisiana Outer Continental Shelf. The reader is referred to that publication for a bibliography of papers dealing with Western Gulf banks. It is the purpose of this summary to relate in a comparative sense the results of the present study to those of the past in an attempt to understand the overall nature of hard-bank communities of the Texas Outer Continental Shelf.

METHODS

Our studies have been ecologically-oriented biological and geological surveys. Sampling techniques have, therefore, employed corers, grabs, dredges, hook-and-line fishing, spearfishing, rotenone poisoning, gathering, observation and photography by SCUBA divers, underwater television, and most effectively, observation and sampling by research submersible

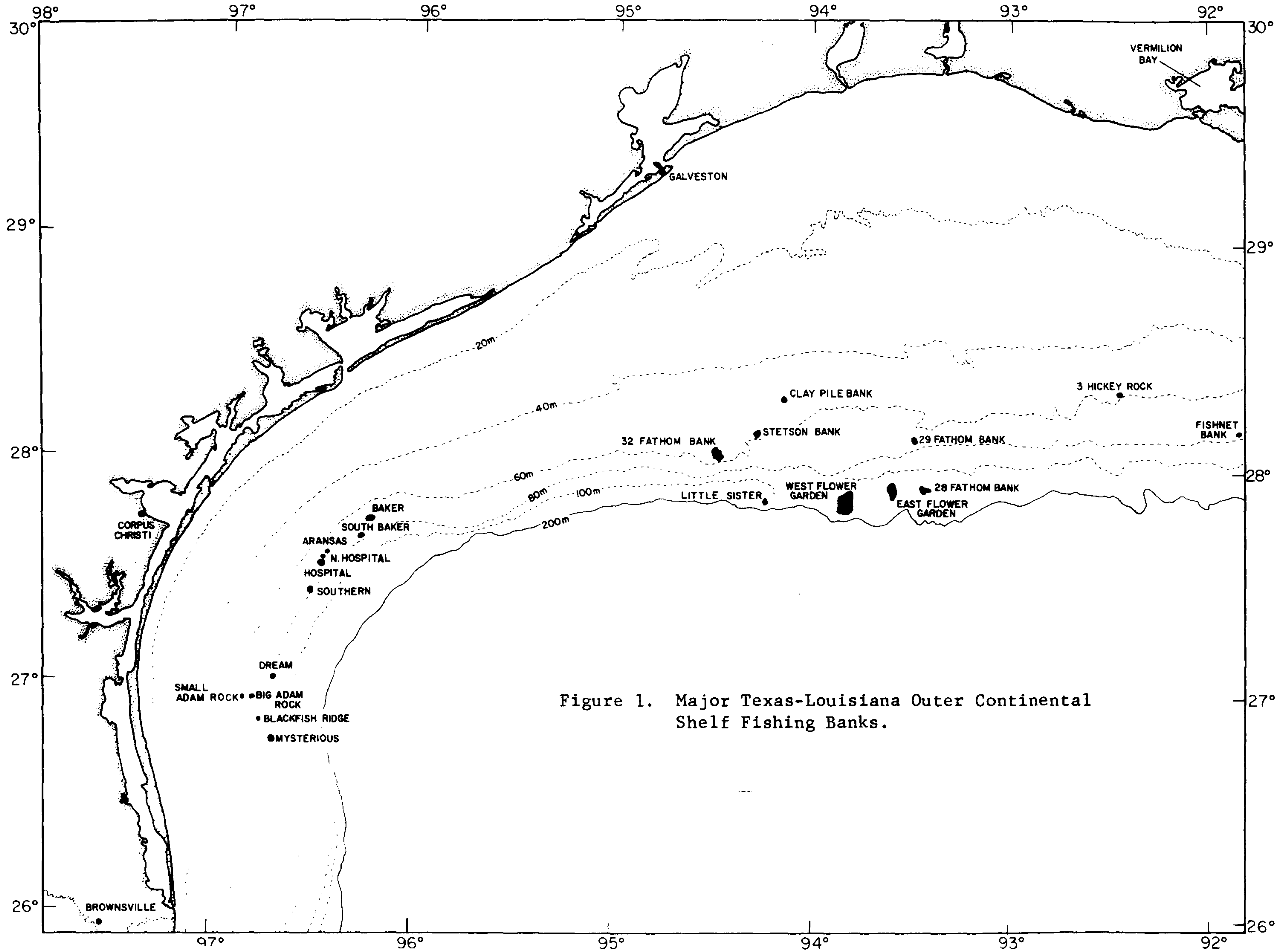


Figure 1. Major Texas-Louisiana Outer Continental Shelf Fishing Banks.

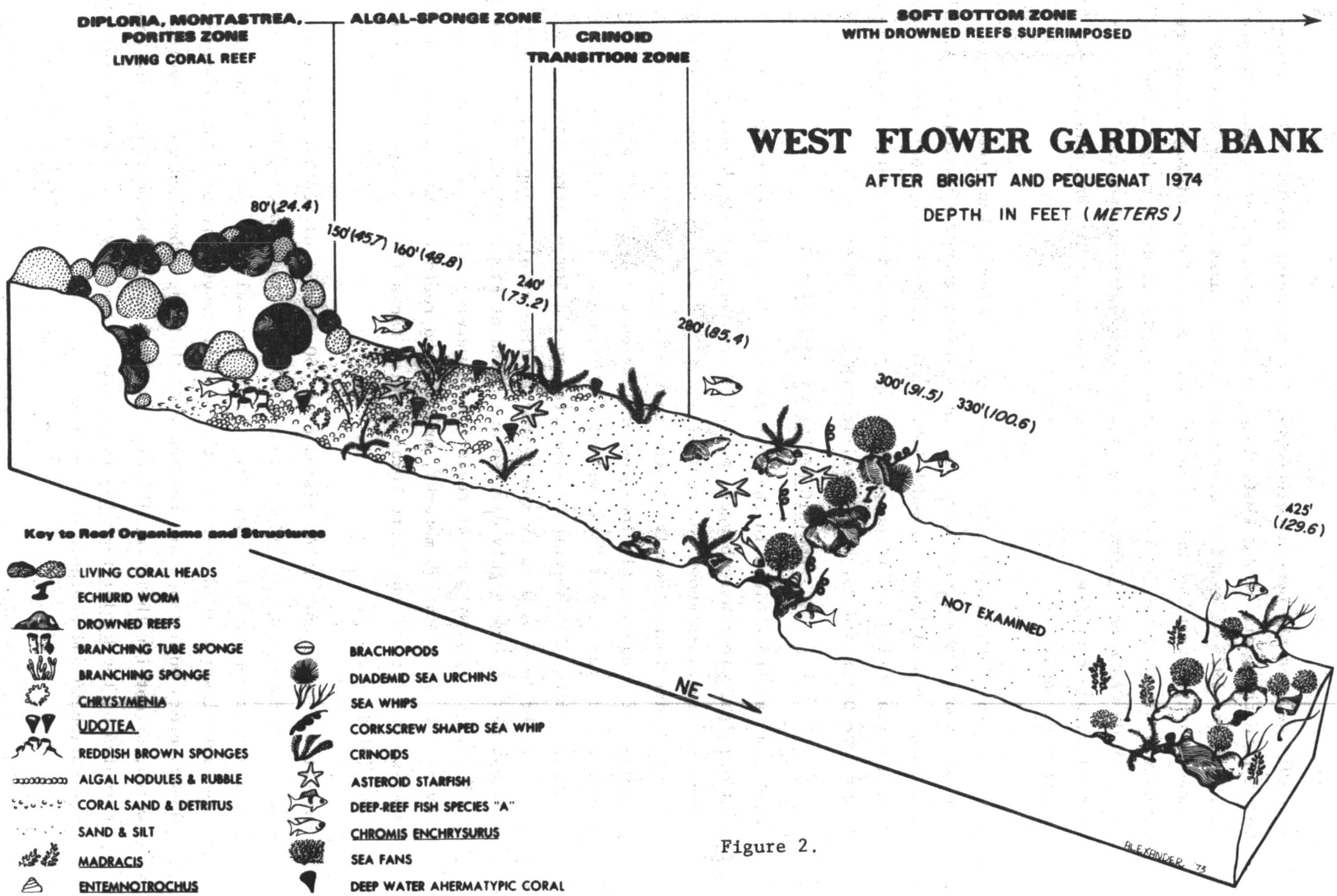
In 1972 we used the General Oceanographics submarine NEKTON GAMMA to investigate that part of the West Flower Garden lying below 45 meters depth. In 1974 and 1975 we examined eleven additional banks with the Texas A&M Oceanography Department submarine DIAPHUS. Most of the biological and geological observations described here are results of dives made in the DIAPHUS. The NEKTON GAMMA and DIAPHUS are both equipped with manipulator arms, external sample containers, portable television recorders and cameras, all of which were used.

Three of the bathymetric charts presented here were taken from previous publications. The others were generated during the U. S. Bureau of Land Management funded study of South Texas Outer Continental Shelf fishing banks using Decca Hi-Fix and Lorac positioning, Decca and Hydrosurveys side-scan sonar and Decca and Raytheon precision depth recorders.

BENTHIC MACROBIOTA AND FISHES

Reef and hard-bank biota in the Western Gulf are easily distinguishable into at least four assemblages, all of which are faunally linked and composed of organisms known to occur at the diversely populated East and West Flower Garden Banks, namely: 1) the sparse Claypile Bank biota (35-55 meters); of predominantly low-growing filamentous and leafy algae and sponges with occasional "meadows" of high-standing leafy algae occupied by numerous fish; 2) the more diverse Stetson and Three Hickey Rock biota 28-56 meters); dominated by the hydrozoan fire coral Millepora alcicornis and sponges; 3) the highly diverse and abundant Flower Gardens/Twenty-eight Fathom Bank biota with coral reefs (22-49 meters), algal nodule and sand-covered platforms (45-76 meters), and drowned reefs (76-100+ meters); 4) the deep-water biota of the South Texas Fishing Banks (53-78 meters) and Fishnet Bank (61-82 meters).

Bright and Pequegnat, 1974, listed over 250 species of benthic invertebrates and more than 100 fishes from the West Flower Garden, the distinctive biotic zonation of which (Fig. 2) is basically the same as that of the East Flower Garden (Fig. 3), though differences are apparent. Above 45-49 meters both banks are covered with thriving submerged coral reefs which, except for their total lack of shallow-water alcyonarians, are good examples of the Diploria-Montastrea-Porites community so common on reefs in the Caribbean and Southern Gulf of Mexico.



DIPLORIA, MONTASTREA, PORITES ZONE
LIVING CORAL REEF
ALGAL-SPONGE ZONE
CRINOID TRANSITION ZONE
SOFT BOTTOM ZONE
WITH DROWNED REEFS SUPERIMPOSED
WEST FLOWER GARDEN BANK
AFTER BRIGHT AND PEQUEGNAT 1974
DEPTH IN FEET (METERS)
80'(24.4)
150'(45.7) 160'(48.8)
240' (73.2)
280'(85.4)
300'(91.5) 330'(100.6)
425' (129.6)
NOT EXAMINED
NE
ALEXANDER '73
Key to Reef Organisms and Structures
LIVING CORAL HEADS
ECHIURID WORM
DROWNED REEFS
BRANCHING TUBE SPONGE
BRANCHING SPONGE
CHRYSYMENIA
UDOTEA
REDDISH BROWN SPONGES
ALGAL NODULES & RUBBLE
CORAL SAND & DETRITUS
SAND & SILT
MADRACIS
ENTEMNOTROCHUS
BRACHIOPODS
DIADEMID SEA URCHINS
SEA WHIPS
CORKSCREW SHAPED SEA WHIP
CRINOIDS
ASTEROID STARFISH
DEEP-REEF FISH SPECIES "A"
CHROMIS ENCHRYSURUS
SEA FANS
DEEP WATER AHERMATYPIC CORAL

Figure 2.

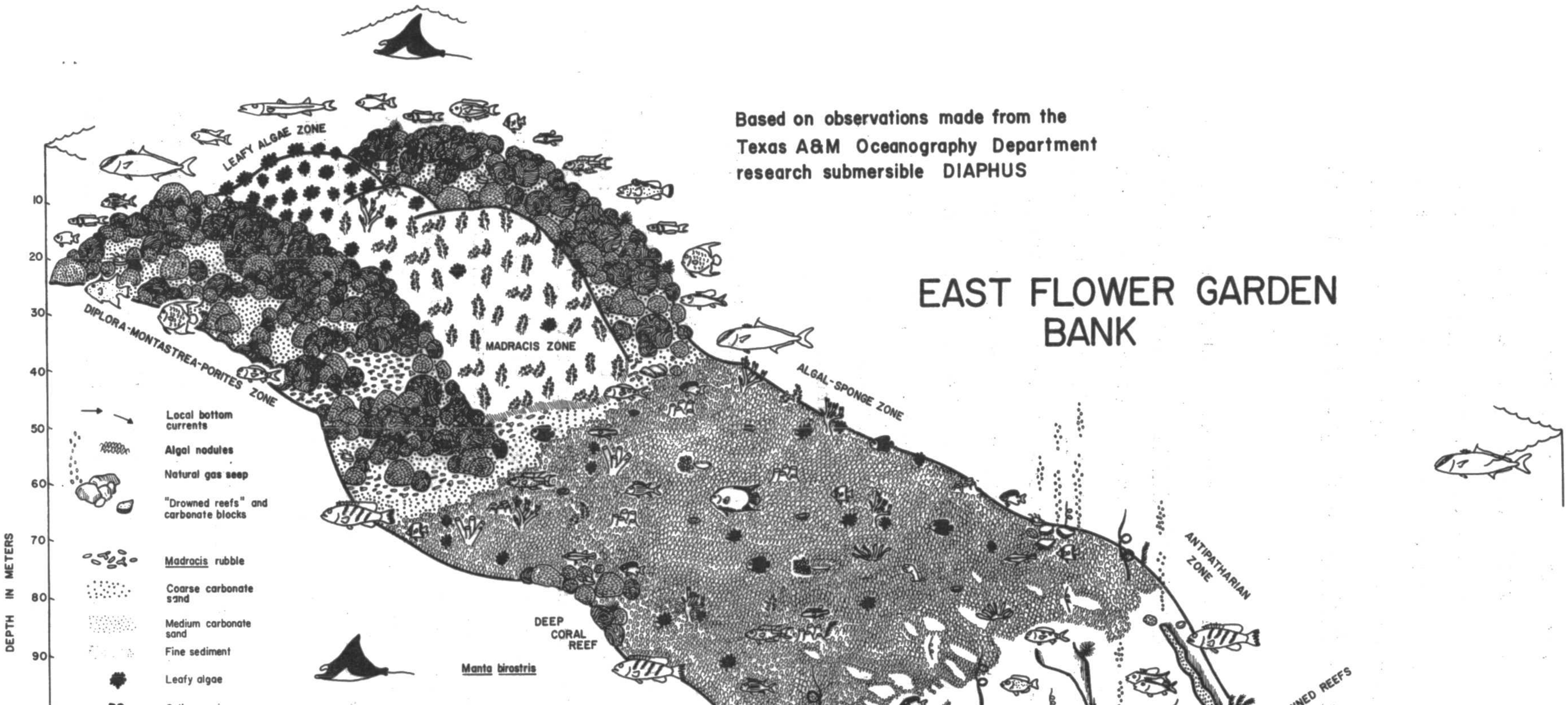

Based on observations made from the
Texas A&M Oceanography Department
research submersible DIAPHUS
EAST FLOWER GARDEN
BANK
LEAFY ALGAE ZONE
DIPLORA-MONTASTREA-PORITES ZONE
MADRACIS ZONE
ALGAL-SPONGE ZONE
ANTIPATHARIAN ZONE
DEEP CORAL REEF
DEPTH IN METERS
10
20
30
40
50
60
70
80
90
Local bottom currents
Algal nodules
Natural gas seep
"Drowned reefs" and carbonate blocks
Madracis rubble
Coarse carbonate sand
Medium carbonate sand
Fine sediment
Leafy algae
Manta birostris

Figure 3.

The East Flower Garden harbors, in addition, sizeable knolls occupied almost entirely by populations of the small branching coral Madracis mirabilis (Madracis Zone). Finger-sized remains of dead Madracis are extremely important components of the sediment on and adjacent to the reef. In some cases the coarse carbonate sand which typically occurs between coral heads in the Diploria-Montastrea-Porites Zone is entirely supplanted by Madracis rubble.

Other knolls at the East Flower Garden are covered completely by lush growths of leafy algae including Caulerpa, Chrysymenia, Halymenia, Goiophloea, Lobophora, Microdictyon, and others. The presence at the East Flower Garden of this Leafy Algae Zone, the Madracis Zone and knolls of intermediate biotic composition which bear various types of sponges, Madracis clumps, patches of leafy algae, and extensive encrustations of coralline algae is indicative of a greater degree of lateral biotic variability on the 28 or so hectare crest of this bank than is found at the West Flower Garden where the Diploria-Montastrea-Porites Zone predominates everywhere above 45-49 meters (approximately 40 hectares).

Table 1 indicates that the coral reefs at the East and West Flower Gardens (22-49 meters) house more species of epifauna and fishes than do zones deeper on the same banks or on other banks, particularly where stony corals and fishes are concerned. It is interesting, however, that we have rarely encountered snappers on the Flower Garden reefs, though the Red snapper, Lutjanus campechanus, is abundant on the lower reaches of the banks around rocks and drowned reefs. Mycteroperca spp. are present more uniformly at all depths but appear more conspicuous around topographical irregularities on the banks below the reefs due to the general reduction in fish abundance and numbers of species there. On the other hand, the smaller Epinephelus spp., though common on the coral reef, are not often seen at greater depths.

In comparison to the biotic populations of the Flower Gardens above 49 meters, those of the banks occupying similar depth ranges elsewhere on the shelf (Stetson, Three Hickey Rock, Claypile) are less diverse and numerically smaller. Stetson (Fig. 4) supports an epifaunal community dominated

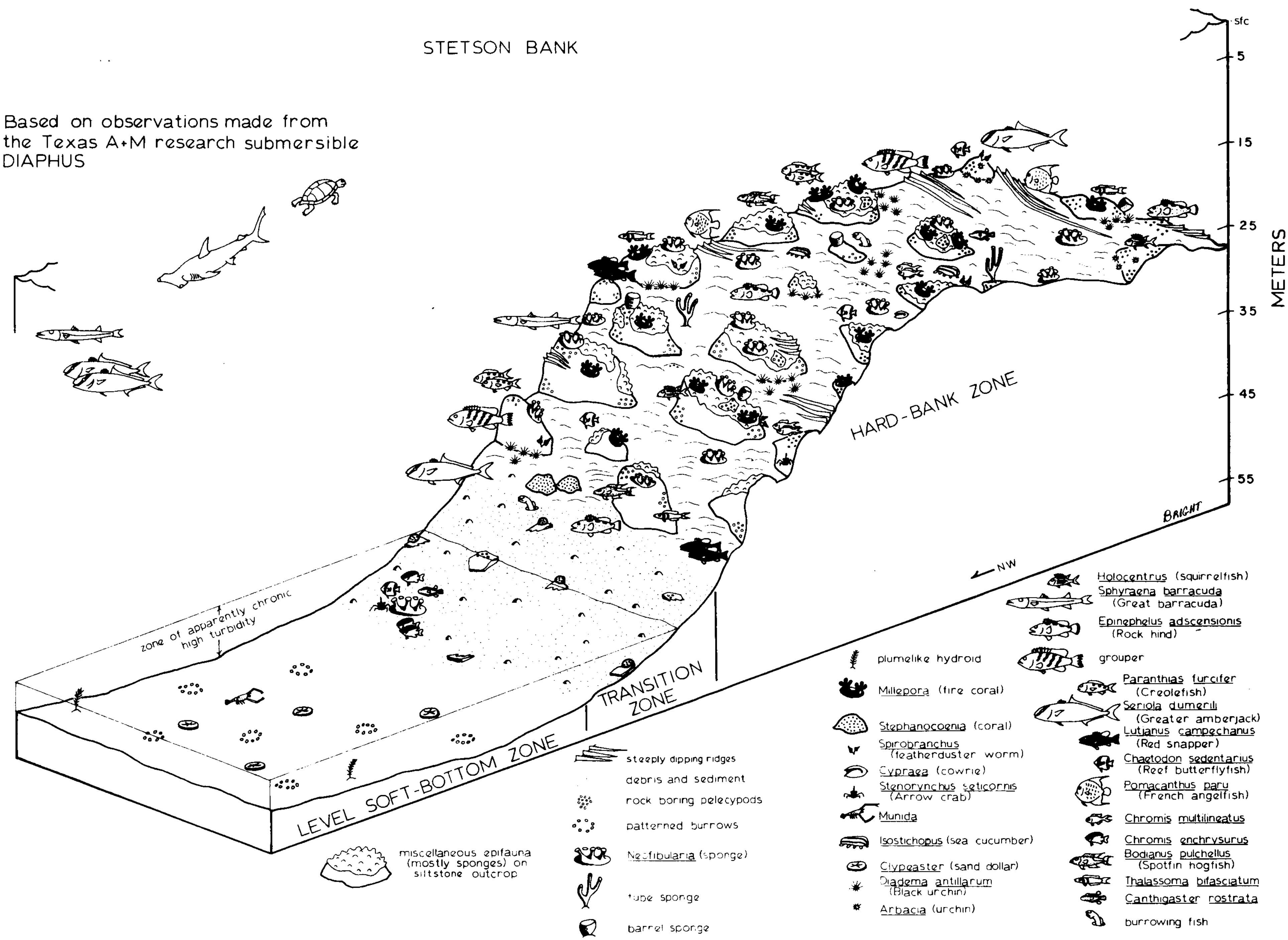

STETSON BANK
Based on observations made from the Texas A+M research submersible DIAPHUS
sfc
5
15
25
35
45
55
METERS
HARD-BANK ZONE
TRANSITION ZONE
LEVEL SOFT-BOTTOM ZONE
zone of apparently chronic high turbidity
NW
BRIGHT
miscellaneous epifauna (mostly sponges) on siltstone outcrop
steeply dipping ridges
debris and sediment
rock boring pelecypods
patterned burrows
Neofibularia (sponge)
tube sponge
barrel sponge
plumelike hydroid
Millepora (fire coral)
Stephanocoenia (coral)
Spirobranchus (featherduster worm)
Cypraea (cowrie)
Stenorynchus seticornis (Arrow crab)
Munida
Isostichopus (sea cucumber)
Clypeaster (sand dollar)
Diadema antillarum (Black urchin)
Arbacia (urchin)
Holocentrus (squirrelfish)
Sphyraena barracuda (Great barracuda)
Epinephelus adscensionis (Rock hind)
grouper
Paranthias furcifer (Creolefish)
Seriola dumerili (Greater amberjack)
Lutjanus campechanus (Red snapper)
Chaetodon sedentarius (Reef butterflyfish)
Pomacanthus paru (French angelfish)
Chromis multilineatus
Chromis enchrysurus
Bodianus pulchellus (Spotfin hogfish)
Thalassoma bifasciatum
Canthigaster rostrata
burrowing fish

Figure 4.

by the hydrozoan stony coral, Millepora alcicornis, sponges, and the rock-boring pelecypod, Jouannetia quillingi (Bright et al., 1974). The substratum at Stetson is siltstone and claystone in various stages of induration, most of the outcrops being soft siltstone and easily perforated by rock borers, which abound. A majority of the surface area of the rock is bare, and where epifauna occurs it is generally restricted to the upper halves of the outcrops, where anything up to 100 percent cover has been observed. We have never visited Three Hickey Rock but have viewed photographs which indicate obvious similarities to Stetson in the nature of the biota, Millepora and sponges appear to predominate. In general, we feel that Stetson and probably Three Hickey are manifestations of a hard-bank assemblage composed primarily of a limited number of the species occurring on the coral reefs at the East and West Flower Gardens with notable deficiences in the populations of anthozoan corals and fishes. Where the important commercial and sport fishes are concerned, however, Stetson seemingly compares well (Table 2).

Possibly because the crest of Claypile Bank is somewhat deeper, approximately 35 meters, the Millepora-Sponge assemblage occupying Stetson has not developed there. Although the substratum is comparable to that at Stetson the fact that the outcrops are much lower in relief may be significant. The benthic community which has developed at Claypile is a rather limited one composed primarily of several species of leafy algae and a sparse population of sponges. The presence of numerous rock borers possibly pelecypods, reflects the similarity of the outcropping rocks to those of Stetson. In places on Claypile sizeable meadows of leafy algae resembling Sargassum were recorded on videotape, but none was collected and the identification is speculative. The greatest concentrations of fishes were, however, seen in and over these meadows. Our information of Claypile is scanty, but it is obviously occupied by a benthic assemblage which must be categorized separately from those occupying the other banks studied. Corals of any kind are insignificant, although Siderastrea siderea occurs rarely in small knobs several inches in diameter. The fishes seen there all occur on the Flower Garden Banks, but the most conspicuous species, one which we have not yet identified and therefore called burrowing fish "C," has been seen by us at the Flower Gardens only below the coral reefs. There are verbal reports from sport divers of a large mollusk population at Claypile.

Twenty-eight Fathom Bank, unlike Stetson, Three Hickey, and Claypile is comparable to those parts of the East and West Flower Garden Banks designated Algal-Sponge Zone in Figures 2 and 3. A comparison of Table 3 with the two columns in Table 1 covering the 49-92 meter depth range at the Flower Gardens shows that the diverse populations on all three banks are extremely similar within that depth range. Twenty-eight Fathom Bank, however, lacks the coral reef and other communities which cap the Flower Garden Banks. The bottoms in the Algal-Sponge Zones of all three banks are covered primarily with nodules (up to fist size and larger) composed of encrustations of coralline algae, mostly Lithothamnium with some Lithophyllum, and lesser amounts of the encrusting foraminifer Gypsina plana (Hogg, 1975; Abbott, 1975). The coralline algae are important and abundant on the coral reef as well as in the Algal-Sponge Zone and they extend significantly onto the Drowned Reefs to depths exceeding 90 meters. In the lower reaches of the Algal-Sponge Zone the nodules give way to coralline algal crusts adhering to the hard carbonate substratum. The coralline algae decrease downward in percent cover but are still moderately abundant in depths of 80 meters or more. Among and attached to the nodules is a sizeable population of leafy algae, generally the same organisms which occur in the Leafy Algae Zone at the East Flower Garden. Sponges are very conspicuous, particularly the encrusting Neofibularia nolitangere oxeata, the tube sponge Callyspongia vaginalis, and the branching Verongia sp. Other particularly conspicuous invertebrates of this zone are small saucer-shaped growths of agariciid stony corals and a large anemone, Condylactis sp. The expected fishes are seemingly as abundant at Twenty-eight Fathom Bank as in similar depths at the Flower Gardens, the commercial species being well represented.

Natural gas seeps issued abundantly from Twenty-eight Fathom Bank and the East

Flower Garden below the coral reef. These seeps are intermittent in nature and characteristically emit repeated short bursts of several to hundreds of bubbles, each less than one inch in diameter. There is no evidence that such seeps have had any effect on the benthic populations. We have observed very small amounts of white mucus-like material at the points from which gas escapes the rock. No such "deposits" have been detected where gas escapes through sand, although the bottom of a large surge channel at 70-80 meters at the East Flower Garden was found to be totally covered with a similar-appearing substance. Speculation that fishes are attracted to gas seeps have not been confirmed by our observations. The fish are nearly always inclined to position themselves over or beside rocks, outcrops, or bottom irregularities. Where they occur, the gas seeps happen also to be associated with these features. However, fishes congregating nearby seem to be oblivious of the gas, showing no behavior which would indicate an affinity for it. In addition to the East Flower Garden and Twenty-eight Fathom Banks, gas seeps have been seen by us at Fishnet, Claypile, and Baker.

The deepest hard-bank assemblage examined by us (Antipatharian Zone, Fig. 5) occupies all of the South Texas Fishing Banks visited (Baker, South Baker, North Hospital, Hospital Rock, Southern, Dream, and Big Adam). We presume it also occurs at Aransas Bank, but we have no observations there. Fishnet Bank bears the Antipatharian Zone biota as do the Drowned Reefs and portions of the Flower Garden Banks adjacent to them.

The Antipatharian Zone represents a transition downward from the shallow-water benthic biota to a truly deep-water assemblage (Table 1). Interestingly, whereas the assemblage is developed at the crests of the South Texas Banks (53 meters or so), truly comparable deep-water populations at the Flower Gardens usually start at depths greater than 70 meters. The generally clearer water at the Flower Gardens may be a factor here, particularly in influencing the lower limit of lush coralline and soft algal growth. Missing from the zone proper are any stony corals except sparse populations of the saucer-shaped agariciid, a small species of *Madracis*,

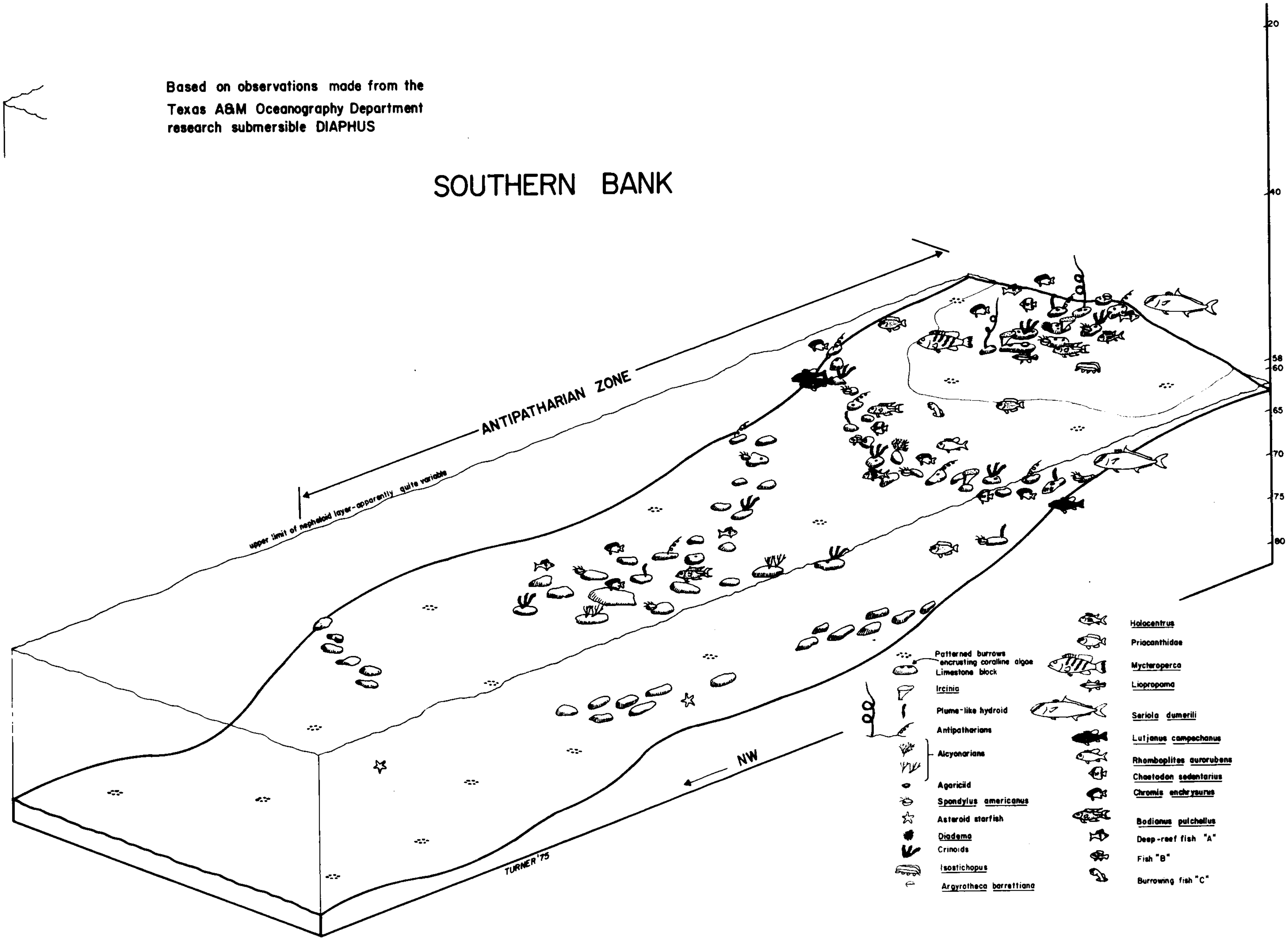


Figure 5. Southern Bank, representative of the South Texas Fishing Banks.

and solitary ahermatypic varieties. Lithophyllum is present in reduced quantities, and leafy algae are sparse. Present are abundant populations of comatulid crinoids, deep-water alcyonarian fans, deep-reef fish "A" and fish "B," all of which are either absent from or rare above 76 meters. The most conspicuous organisms in this zone are the bedspring-shaped white antipatharian "sea whips." Whereas their depth range extends almost to the coral reef, they are very rarely seen shallower than 55 meters at the Flower Gardens (Fig. 2 and 3). On the South Texas Fishing Banks and Fishnet they are abundant from the crests down, thinning out with depth. The South Texas Banks apparently differ from the others in their possession of conspicuous populations of the large white sponge Ircinia campana.

The deep-reef fish "A" is a particularly reliable indicator of this assemblage. It has not been seen shallower than 80 meters at the Flower Gardens but occurs from the crests downward at Fishnet and the South Texas Banks. The Yellowtail reeffish, Chromis enchrysurus, is undoubtedly the most abundant species of its size, 5-10 cm, on the Texas-Louisiana banks below 50 meters and within the Antipatharian Zone particularly. It frequents all of the banks in schools of up to several hundred, though it occurs in smaller groups and singly. At least in the spring, Chromis enchrysurus occupies territories and engages in agonistic behavior toward other fishes in which it changes temporarily from its typically dark-above/light-below coloration to a dusky gray. Although we have no evidence to indicate it, the species would seem to be an ideal forage fish for snappers and groupers.

The South Texas banks are particularly subject to nearly total inundation by the thick nepheloid layers (turbid water layers) which overlie the predominantly soft bottom of the Texas-Louisiana Outer Continental Shelf (Fig. 5). Off South Texas the difference between relief of the hard-banks and thickness of the nepheloid layers is so little that it is probable that most of the time only the top 10 or so meters of the banks are in relatively clear water. We strongly suspect that during storms or prolonged heavy weather the banks are entirely covered by turbid water. Even the rocks at the tops of these carbonate banks are covered with a thin veneer of fine sediment wherever the sparse epifauna and coralline algae do not occur. It is our impression that the epifauna and coralline encrustations are best developed at the crests of these banks and tend to decrease in abundance downward into the nepheloid layer. The nepheloid layer we observed at Stetson Bank was well down toward its base (Fig. 4), those at the Flower Gardens were well off the hard-banks altogether (Fig. 2 and 3), and that at Fishnet started at 80 meters (Fishnet crests at about 61 meters). The Flower Gardens are, therefore, because of their position at the edge of the continental shelf, bathed perpetually by clear oceanic water. Stetson is probably subject to occasional heavy doses of turbid neritic water, while the South Texas banks must frequently be covered by the nepheloid layer. We speculate, therefore, that the assemblages of the South Texas banks are rather adapted to turbid water conditions, whereas those of Stetson and the Flower Gardens are possibly less tolerant.

Even so, there seem to be indications that biota of the Antipatharian Zone thrive better in clear water. Certainly they are more numerous on the Drowned Reefs at the Flower Gardens than on the South Texas banks, and appear to be better developed at the tops of the South Texas banks than on their flanks. Big Adam Rock which has relatively little relief above the surrounding soft bottom was entirely covered by the nepheloid layer when we examined it. We found that it has a much sparser benthic population than those of its neighbors a few miles north. Fishnet Bank, on the other hand, with a nepheloid layer somewhat farther down on its sides, appeared to us to harbor a more diverse and abundant Antipatharian Zone population than any of the South Texas banks. However, speculations concerning the significance of the nepheloid layer as a controlling environmental factor are as yet unconfirmed.

Though Lutjanus campechanus and Rhomboplites aurorubens were about as abundant on the South Texas Fishing banks as on the northern banks, we were surprised at the few sightings and hook-and-line captures of Mycteroperca in the south. Moreover, though we expected to encounter them, there were no sightings or captures of species of Epinephelus on the South Texas banks, Fishnet Bank, on the other hand, harbored at least a moderate population of Mycteroperca, as do the lower reaches of the Flower Gardens, and Epinephelus was present. If indeed the groupers and hinds are less abundant on the South Texas banks, the reasons are not apparent. We raise the question only because there is a possibility that there should be some concern over the status of the serranid populations off South Texas.

On the other hand we point out that on the banks from Stetson north we have observed large schools of good-sized Creole fish, Parathias furcifer, and the species is sometimes caught on hook-and-line. We wonder if this species as well as the Cottonwick, Haemulon melanurum, which is abundant and easily caught on all the banks, may deserve some consideration as future commercial fishery potentials.

Whereas the macrobenthos and fishes of the hard bottom are perhaps the most conspicuous elements of the fishing bank assemblages, and the ones about which environmental concern is most frequently expressed, certain inconspicuous members of the soft bottom biota may, because of their short life cycles, be more suitable for use as "early warning" biological indicators of environmental stress due to contaminants introduced by man. The following section deals with pragmatically important aspects of the populations of some of these potentially useful meiofaunal forms.

MEIOFAUNA

MEIOFAUNAL-SEDIMENT CORRELATIONS

The accompanying tabular data (Table 4) shows the results of the multiple linear regression work. This Table shows that the coarse and medium silt size sediment has the highest correlation in all cases to the number of meiofaunal individuals found in a sample. The fine and very fine clay has the second highest correlation but it is negative, whereas the coarse and medium silt is positively correlated. The coarse and medium silt seems to have a definite influence on the meiofaunal variations between stations. The multiple correlations are significant for the nematodes, polychaetes and total meiofauna, but only at the 0.05 level. As can be seen from the Table, the polychaetes are most highly correlated to the sediment, the nematodes second, and the total meiofauna is also correlated to a significant degree. We note that the harpacticoid copepods have the lowest multiple correlation coefficient and the foraminiferans are also not very highly correlated to the sediment.

From the above findings, we are able to designate an intergroup ratio that can be most useful as a baseline parameter and as a sensitive indicator of chemical change of the environment. This takes the form of the ratio described in the next section.

THE NEMATODE/HARPACTICOID COPEPOD RATIO

A valuable conclusion results from the above correlations to the effect that if the harpacticoid copepod populations are not highly correlated with sediment fractions whereas the nematode populations are, then any activity that changes sediment characteristics at a known point may have a substantial effect on the nematode/harpacticoid copepod ratio. On the other hand, if sediment structure is held constant and this ratio is observed to change in a previously studied area (i.e., where a baseline study had been done), then one can deduce that another kind of environmental impact may be taking place.

THE MACROINFAUNAL/MEIOFAUNAL RATIO

Our findings from previous studies show that the relationship between numbers of macroinfaunal organisms and the permanent meiofauna is quite definitive for a given type of sediment cover. In a way it specific enough as to reflect the geological and other physical characteristics of the area with considerable precision. We anticipate that each bank on the continental shelf will have its own signature Macro/Meio ratio. It will change in response to environmental modifications, as does the nematode/harpacticoid copepod ratio, but in a different manner. When the two ratios are calculated, one may deduce whether or not a given region has suffered previous environmental impacts and, if so, the general nature of the impacts, and, if not, one can predict how the ratios will shift in response to specific kinds of impacts that may result from a proposed action.

GEOLOGY OF THE BANKS

The banks of the Texas Outer Continental Shelf may be divided into two main groups. Those banks north of 27° 46' N. Lat. are associated with salt domes in the subsurface and their distribution is generally the same as the distribution of shallow salt domes. The banks south of 27° 46' N. Lat. are not associated with any shallow subsurface structures and their distribution is most probably controlled by an ancient shoreline at approximately 60 meters during the Late Pleistocene.

The relief on the banks is quite variable with those banks in the northern area generally having greater relief. Twenty-eight Fathom Bank has the greatest amount of relief with a maximum of 118 meters in a distance of 670 meters. The least amount of relief is on Thirty-two Fathom Bank with a total of 6 meters in a distance of 3,201 meters.

Banks such as those described here occur on the outer shelf eastward to the head of the Mississippi Canyon. The crests of these banks increase in depth towards the east, the deepest one is in the Mississippi Canyon at a depth of 179 meters. This increase in depth of crests is due to downwarping of the shelf caused by the weight of the Mississippi Delta.

All of the banks are covered by a heavy growth of coral and coralline algae except for Stetson and Claypile Banks. These two banks are the only ones known to have outcrops of Tertiary bedrock exposed at the surface of the bank. Some of the banks such as the West and East Flower Gardens are living coral reefs. Most of the banks are covered by dead reefs (drowned reefs) that were living from 6,000 to 18,000 years ago at times when sea level was considerably lower than it is at present.

NORTHERN BANKS

Direct geological observations using submersibles have been made at West Flower Garden, East Flower Garden, Twenty-eight Fathom, Stetson, and Claypile Banks. Typical of the larger banks on the northern shelf is the occurrence of gently sloping terraces covered with sediment bounded by steep rocky cliffs. These terraces and associated cliffs are especially obvious on the West Flower Garden and Twenty-eight Fathom Banks. The rocky cliffs represent drowned reefs that are now dead but were flourishing during a lower stand of sea level. Scattered over the terraces are isolated patch reefs that developed as sea level rose. These features are well illustrated on the chart of the West Flower Garden Bank. The rocky cliffs, patch reefs, as well as the irregular parts of the hard substrate of the Algal-Sponge Zone are places where large schools of snapper, grouper, Creole fish, barracuda and jacks seem to congregate. There are three drowned reef levels at the West Flower Garden Bank. They occur at 56, 91, and 128 meters. At the East Flower Garden Bank there is one large drowned reef that occurs from about 63 meters to a depth of 85 meters. At Twenty-eight Fathom Bank drowned reefs occur at 52, 56, 80, and 90 meters on the north side and a single reef from 100 to 170 meters on the south side.

The sediments that surround the actively growing reefs are coarse sands and gravels grading into finer sediments with increasing depth of water. The distribution of sediment types on the West Flower Garden is typical of the actively growing reefs. At the crest of the reef, between the large coral heads, a coarse coral-molluscan sand covers the bottom. This sand is moved by severe storms into chutes that carry it to the base of the reef where it is spread by currents into a narrow band immediately adjacent to the base of the reef at depths of from 45 meters to 49 meters. Close to the base of the reef are large blocks of reefrock that have been torn loose by storms and tumbled down the steep slopes. Beginning at a depth of about 49 meters and extending to a depth of about 73 meters the bottom is covered by a coarse gravel composed of nodules of coralline algae. This sediment is the substrate of the Algal-Sponge Zone illustrated in Figure 2. From 85 meters to a depth of 106 meters the sediment consists of a foraminiferal-coral-coralline algae sand. Below 106 meters the sand gives way to the sandy, silty clays that are the normal deposits of the outer continental shelf.

Thirty-two Fathom Bank has a very low relief but the nature of the record on the precision depth recorder indicates a hard bottom. No direct observations nor sampling have been conducted at Thirty-two Fathom Bank. However, our experience with other banks at comparable depths indicates that the bottom there should be covered with the hard, coralline algae nodules typical of the Algal-Sponge Zone, but this has not been verified.

SOUTHERN BANKS

Direct geological observations have been made on Baker, South Baker, North Hospital, Hospital Rock, Southern, Dream, and Big Adam. The greatest relief on the southern group of banks is found on Southern with a maximum of 22 meters, the average relief on the other banks being about 10 to 12 meters. As mentioned earlier, these banks differ from the northern banks in that they are not associated with salt domes. The banks are all drowned reefs that were thriving coral-algae reefs during lower stands of sea level.

Southern Bank is typical of this group and the diagram in Figure 5 illustrates the nature of the bottom topography. Three levels of reef development are shown at 72, 68, and 63 meters. These are identical to the massive rocky, drowned reefs of the northern banks but have very little relief. The substrate between these reef levels is a pavement of dead coralline algae covered by a thin film of fine clay and silt size sediment deposited from the nepheloid layer which more or less continuously covers all but the crests of these banks.

As these reefs are no longer actively growing, the coarse, gravelly and sandy sediments that are found surrounding actively growing reefs to the north are not present at the surface. Sediment cores taken adjacent to the drowned reefs show the sandy and gravelly sediment to be covered by about a foot of sandy and silty clay.

SUMMARY

Biotic assemblages of reefs and hard-banks of the Texas-Louisiana Outer Continental Shelf can be distinctly grouped according to their natures into four general categories: 1) the sparse Claypile Bank biota (35-55 meters) of predominantly low-growing filamentous and leafy algae and sponges with occasional "meadows" of high-standing leafy algae occupied by numerous fish; 2) the more diverse Stetson and Three Hickey Rock biota (28-56 meters) dominated by the hydrozoan fire coral *Millepora alcicornis* and sponges; 3) the highly diverse and abundant Flower Gardens/Twenty-eight Fathom Bank biota with coral reefs (22-49 meters), algal nodule and sand-covered platforms (45-76 meters), and drowned reefs (76-100+ meters, bearing an assemblage of organisms directly comparable to the deep-water biota of category 4 described below); 4) the deep-water biota of the South Texas Fishing Banks (53-78 meters) and Fishnet Bank (61-82 meters) characterized by the presence of antipatharian whips, deep-water alcyonarian fans, comatulid crinoids, certain species of deep-dwelling fishes, and sparse populations of encrusting coralline algae.

Commercial snappers and groupers frequent all of the banks, though there is a possibility that serranid populations may be smaller on the South Texas Banks than on the others. The most abundant conspicuous fish on the banks, excluding the coral reefs at the Flower Gardens, is the small Yellowtail reeffish, *Chromis enchrysurus*.

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Table 1. Organisms encountered by us at various fishing banks, with indications of relative abundances.
**** very abundant, *** abundant, ** moderate population, * known to be present, p - presumed present.

	Claypile	Stetson	East Flower Garden and West Flower Garden				South Texas Fishing Banks	Fishnet
Depths in meters	35-55	28-56	22-49	49-76	76-92	92-107	53-78	61-82
CORALLINE ALGAE								
encrusting		*	****	***	**	*	*	*
nodules				****	*			
Lithothamnium spp.			****	****	**			
Lithophyllum spp.		*	**	**	*		*	*
CALCAREOUS GREEN ALGAE			*	**				*
LEAFY ALGAE	**		****	***	*		*	*
FORAMINIFERS (encrusting)								
Gypsina plana		*	*	***	*			
SPONGES	**	***	**	***	**	*	**	**
Agelas sp.		*	**	*	*	*	*	
Callyspongia spp.	**	*	**	**				
Ircinia campana							**	
Neofibularia nolitangere	*	**	*	***	**		*	
Verongia spp.	*		**	***				
PLUME-LIKE HYDROIDS		*		**	**	**	**	
ALCYONARIAN WHIPS								
Ellisella sp.					*	*		
ALCYONARIAN FANS					**	**	**	
Hypnogorgia sp.	*						*	*
Scleracis sp.				*	*		**	
Thesea sp. "B"					*			
Thesea sp. "A"							*	
ANTIPATHARIANS			*	***	***	**	***	***
ANEMONES								
Condylactis sp.			*	***	**			
HYDROZOAN CORALS								
Millepora alcicornis		***	***	*				
ANTHOZOAN STONY CORALS								
Stephanocoenia intersepta		*	*					
Madracis decactis		*	**					
Madracis mirabilis			****					
Madracis asperula				*				
Madracis brueggemanni				*			*	
Agaricia agaricites agaricites			**					
Saucer-shaped agariciid			*	**	*		*	
Helioceris cucullata			*	*				
Siderastrea sidera	*		*					
Porites astreoides			****					
Diploria strigosa			****					
Diploria spp.			****	**				
Colpophyllia natans			***					
Colpophyllia spp.			***					
Montastrea annularis			****					
Montastrea cavernosa			****	**				
Scolymia sp.			*					
Mussa angulosa			*					
ahermatypic solitary sp. "A"							*	
ahermatypic solitary sp. "B"						*		
ahermatypic solitary		*						

Depths in meters	Claypile 35-55	Stetson 28-56	East Flower Garden and West Flower Garden 22-49	49-76	76-92	92-107	South Texas Fishing Banks 53-78	Fishnet 61-82
GASTROPODS								
Busycon spp.							*	*
Cypraea spp.		*	**				*	
PELECYPODS								
rock borers	***	****						
Jouannetia quillingi		****						
Lithophaga bisculcata		*						
Lima sp.			***					
Spondylus americanus			***	***			***	
BRACHIOPODS								
Argyrotheca barrettiana					***	***	**	
POLYCHAETE WORMS								
Hermodice sp.			**	**			***	****
Spirobranchus giganteus		**	****	**				
CRABS								
Carpilius corallinus			*					
Stenorynchus seticornis		**	**	**	**	*	*	
LOBSTERS								
Panulirus sp.			*					
Scyllarides sp.			*				*	
MANTIS SHRIMPS								
Gonodactylus spp.		*	*	***				
STARFISH								
Narcissia trigonaria				*	*			
BASKET STARS								
Gorgonocephalidae					**		**	**
SEA URCHINS								
Clypeaster sp.		**				**		
Diadema antillarum		****	****		*		*	**
SEA CUCUMBERS								
Isostichopus sp.	*	**	*				**	
CRINOIDS				*	****	****	****	****
PATTERNED BURROWS	****	****		**	****	****	****	****
FISHES								
Ginglymostoma cirratum Nurse shark			*					
Manta birostris Manta ray			**					
Gymnothorax moringa Spotted moray			*	*				
Gymnothorax spp. moray eels		*	*	*				
Aulostomus maculatus Trumpetfish			**					
Holocentrus ascensionis Longjaw squirrelfish			**					
Holocentrus spp. (large species)	*	**	***	**	**		**	
Holocentridae (small species)		**	**	*			**	*
Myripristis jacobus Blackbar soldierfish		*	*					
Sphyraena barracuda Great barracuda		***	***	*			***	

Depths in meters	Claypile 35-55	Stetson 28-56	East Flower Garden and West Flower Garden 22-49	49-76	76-92	92-107	South Texas Fishing Banks 53-78	Fishnet 61-82
Epinephelus adscensionis Rock hind	**	***	***	**				
Epinephelus cruentatus Graysby			**	*				
Epinephelus spp. hinds	**		***	**				*
Dermatolepis inermis Marbled grouper			*	*	*			
Mycteroperca spp. groupers		**	**	**	**		*	**
Paranthias furcifer Creolefish		***	***	**			*	
Serranus annularis Orangeback bass				**				
Liopropoma sp. basslet		**	*	**			**	**
Priacanthidae bigeyes	**		*	**	*		**	**
Priacanthus arenatus Bigeye		*	*					
Apogon spp. cardinalfishes		*	***				**	
Malacanthus plumieri Sand tilefish			*	**	**			
Sand tilefish burrows			*	**				
Amblycirrhitus pinos Redspotted hawkfish			**	*				
Rachycentron canadum Cobia							*	
Caranx spp. jacks		**	**	*			**	
Caranx ruber Barjack			**					
Seriola dumerili Greater amberjack	**	**	**	**	*		**	**
Selene vomer Lookdown							*	
Scomberomorus spp. mackerels		*	*				*	
Lutjanus campechanus Red snapper	p	***	*	***	***	***	***	***
Lutjanus spp. snappers (not Red)		*	*				*	
Rhomboplites aurorubens Vermilion snapper	p	***	*				***	***
Haemulon melanurum Cottonwick		**	*	**	**		**	
Calamus spp. porgys		**	**	**			*	
Equetus spp. drums	*	*	*	*	*	*	*	
Equetus acuminatus High hat		*		*			*	
Equetus lanceolatus Jackknife-fish			*	*	*	*	*	
Mulloidichthys martinicus Yellow goatfish		*	**	*				
Pseudupeneus maculatus Spotted goatfish	**	**	**	*				
Chaetodon aculeatus Longsnout butterflyfish			*	*				
Chaetodon ocellatus Spotfin butterflyfish		**	***					
Chaetodon sedentarius Reef butterflyfish	*	***	***	***	*	*	***	***
Pomacanthus spp. angelfishes		***	***	*			*	
Pomacanthus paru French angelfish	**	***	***	*				
Pomacanthus arcuatus Gray angelfish		*	*					

Depths in meters	Claypile 35-55	Stetson 28-56	East Flower Garden and West Flower Garden 22-49	49-76	76-92	92-107	South Texas Fishing Banks 53-78	Fishnet 61-82
Holacanthus ciliaris Queen angelfish		**	**	**			*	
Holacanthus bermudensis Blue angelfish	*	**	*	**	*	*	**	**
Holacanthus tricolor Rock beauty			**	**	*	*		*
Centropyge argi Cherubfish			*	***				
Eupomacentrus spp. damselfishes		***	***	*			**	
Eupomacentrus partitus Bicolor damselfish			***	*				
Chromis cyaneus Blue chromis		*	***					
Chromis multilineatus Yellow-edge chromis		**	***					
Chromis enchrysurus Yellowtail reeffish	*	****	***	****	***	***	****	****
Bodianus rufus Spanish hogfish		**	***					
Bodianus pulchellus Spotfin hogfish		**	**	***	*	*	***	***
Halichoeres garnoti Yellowhead wrasse			*					
Thalassoma bifasciatum Bluehead		****	****	*				
Clepticus parrai Creole wrasse			****					
Scarus spp. parrotfishes			**	*				
Sparisoma viride Stoplight parrotfish			**	*				
Gobiosoma sp. sharknose goby		***	****	***			*	
Acanthurus spp. surgeonfishes		**	**	*				
Acanthurus coeruleus Blue tang		*	*					
Balistes capriscus Gray triggerfish		*	*					
Balistes vetula Queen triggerfish		**	**	*			*	
Canthidermis sufflamen Ocean triggerfish			***					
Melichthys niger Black durgon			***					
Lactophrys triqueter Smooth trunkfish			**					
Canthigaster rostrata Sharpnose puffer		***	***	***			*	
Ogcocephalus vespetilia Batfish				*				
Deep-reef fish "A"					***	***	***	*
Fish "B"							**	
Burrowing fish "C"	****	**		**			*	

Table 2. Summary of results of hook-and-line fishing from our research vessels, 1972-1975. *** most frequently caught,** often caught, * sometimes caught.

	EFG + WFG	Stetson	South Texas Fishing Banks
Carcharhinid sharks	*		**
Gymnothorax spp. morays	*		*
Enchelycore nigricans Viper moray	*		
Holocentrus spp. squirrelfishes	***	**	**
Sphyraena barracuda Great barracuda	**	**	***
Epinephelus guttatus Red hind	*		
Epinephelus adscensionis Rock hind	**	**	
Epinephelus cruentatus Graysby	***		
Mycteroperca spp. groupers	**	*	*
Dermatolepis inermis Marbled grouper	*		
Paranthias furcifer Creole fish	*	*	*
Priacanthidae bigeyes	**	**	
Malacanthus plumieri Sand tilefish	**		*
Rachycentron canadum Cobia			**
Seriola dumerili Greater amberjack	***	***	***
Caranx spp. jacks	**	**	*
Selene vomer Lookdown			*
Coryphaena hippurus Dolphin	*		* juveniles
Scomberomorus spp. mackerels	*	*	*
Lutjanus campechanus Red snapper	***	***	***
Lutjanus spp. snappers	*	*	*
Rhomboplites aurorubens Vermilion snapper	***	***	***
Haemulon melanurum Cottonwick	***	***	***
Calamus spp. porgies	**	*	*
Pomacanthus spp. angelfishes	*	*	
Acanthurus spp. surgeonfishes	*	*	
Balistes vetula Queen triggerfish	**	*	
Balistes capriscus Gray triggerfish		*	
Canthidermis sufflamen Ocean triggerfish	*		
Melichthys niger Black durgon	*		

Table 3. Conspicuous benthic organisms and groundfishes seen at Twenty-eight Fathom Bank. Depths given indicate our observations only and do not preclude presence of the species at other depths.

	Depths of observation (meters)	Comments
Algae		
Coralline algae	52-91	Probably Lithothamnium and Lithophyllum. Forming nodules. Encrusting outcrops and rubble.
Soft algae	52-67	Probably extend somewhat deeper.
Sponges		
Neofibularia	52-61	
Agelas	61	
Anemones		
Condylactis	61	
Antipatharians	52-85	
Echinoderms		
Sea cucumber	55	Probably Isostichopus.
Comatulid crinoids	67-88	
Fishes		
Holocentrus spp.	67	
Mycteroperca spp.	52-67	
Paranthias furcifer	67	Dense schools.
Epinephelus spp.	52-67	
Malacanthus plumieri	52-61	
Seriola dumerili	55-67	
Lutjanus campechanus	61	
Equetus spp.	52	
Chaetodon sedentarius	67	
Holacanthus sp.	67	Either H. bermudensis or H. ciliaris.
Pomacanthus paru	52-67	
Centropyge argi	61	
Chromis enchrysurus	52-88	Very abundant.
Bodianus pulchellus	67-88	
Balistes capriscus	67	
Balistes vetula	52-67	
Xanthichthys ringens	67	Sargassum triggerfish.

Table 4. Partial and Multiple Correlation Coefficients Between Meiofaunal Groups and Grain Size Classes

TAXA	VERTICAL SECTION (cm)	PARTIAL CORRELATION COEFFICIENTS			MULTIPLE CORRELATION COEFFICIENTS	TEST OF SIGNIFICANCE (F)			
		SAND	SILT	CLAY	TOTAL SAND, SILT, CLAY	SAND	SILT	CLAY	TOTAL SAND, SILT, CLAY
[1]Nematoda	0-5	.197	.348	-.430	.4745	1.4084	15.3358**	.3358	5.7182**
[2]Nematoda	0-5	.238	.417	-.453	.3954	1.7772	5.9655*	4.6819*	4.1415**

[1]Only numbers of individuals transformed $(\ln x + 1)$

[2]Both numbers of individuals transformed and grain sizes $(\arcsin \sqrt{x})$

*Significant $P \leq 0.05$ but not at $P \leq 0.01$

**Highly significant $P \leq 0.01$

Table 4 continued.

TAXA	VERTICAL SECTION (cm)	PARTIAL CORRELATION COEFFICIENTS						
		SAND	SILT			CLAY		
		Granule to Very Fine	Coarse & Medium	Fine	Very Fine	Coarse	Medium	Very Fine
[1]Nematoda	0-5	.024	.492	.160	-.086	-.136	-.066	-.210
[1]Nematoda	0-5	.197	.564	.079	-.266	-.157	-.348	-.419
[2]Nematoda	0-5	.238	.488	.178	-.124	-.164	-.302	-.398
[1]Nematoda	total	.226	.645	.025	-.229	-.159	-.299	-.405
[1]Foraminiferida	0-5	.341	.505	-.047	-.281	-.241	-.328	-.450
[1]Foraminiferida	total	.330	.505	-.020	-.236	-.203	-.305	-.444
[1]Harpacticoid Copepoda	0-5	.082	.543	.077	-.097	-.112	-.221	-.243
[1]Harpacticoid Copepoda	total	.103	.561	.078	-.093	-.095	-.219	-.262
[1]Polychaeta	0-5	.077	.681	.162	-.040	-.043	-.037	-.291
[1]Polychaeta	total	.241	.654	.078	-.220	-.160	-.228	-.405
[1]Total Meiofauna	0-5	.240	.630	.029	-.239	-.177	-.311	-.402
[1]Total Meiofauna	total	.223	.647	.046	-.218	-.153	-.298	-.397

[1]Only numbers of individuals transformed ($\ln x + 1$)

[2]Both numbers of individuals transformed and grain sizes ($\arcsin \sqrt{x}$)

Table 4 continued.

TAXA	VERTICAL SECTION (cm)	MULTIPLE CORRELATION COEFFICIENTS	TEST OF SIGNIFICANCE (F)		
		TOTAL SAND, SILT, CLAY	Coarse & Medium Silt	Fine & Very Fine Clay	Total Sand, Silt, Clay
Nematoda	0-5	.3233	5.7964*	0.1934	1.0239
[1]Nematoda	0-5	.5743	13.8298**	3.4892	2.8904*
[2]Nematoda	0-5	.4233	7.7625*	0.5075	1.5727
[1]Nematoda	total	.6312	17.8510**	4.5127	3.6673*
[1]Foraminiferida	0-5	.4765	8.0830*	2.0641	1.9508
[1]Foraminiferida	total	.4945	8.3494*	2.4280	2.0961
[1]Harpacticoid Copepoda	0-5	.4224	7.8760*	1.9904	1.5669
[1]Harpacticoid Copepoda	total	.4255	8.4690*	1.7591	1.5870
[1]Polychaeta	0-5	.6102	18.2032**	3.8340	3.5390*
[1]Polychaeta	total	.6472	19.2765**	4.8161*	3.9316*
[1]Total Meiofauna	0-5	.6047	15.9799**	3.9462	3.2783*
[1]Total Meiofauna	total	.6280	17.8357**	4.5788*	3.6170*

*Significant $P \leq 0.05$ but not at $P \leq 0.01$

**Highly significant $P \leq 0.01$

[1]Only numbers of individuals transformed ($\ln x + 1$)

[2]Both numbers of individuals transformed and grain sizes ($\arcsin \sqrt{x}$)

MAPS

(Stetson Bank contours in feet)

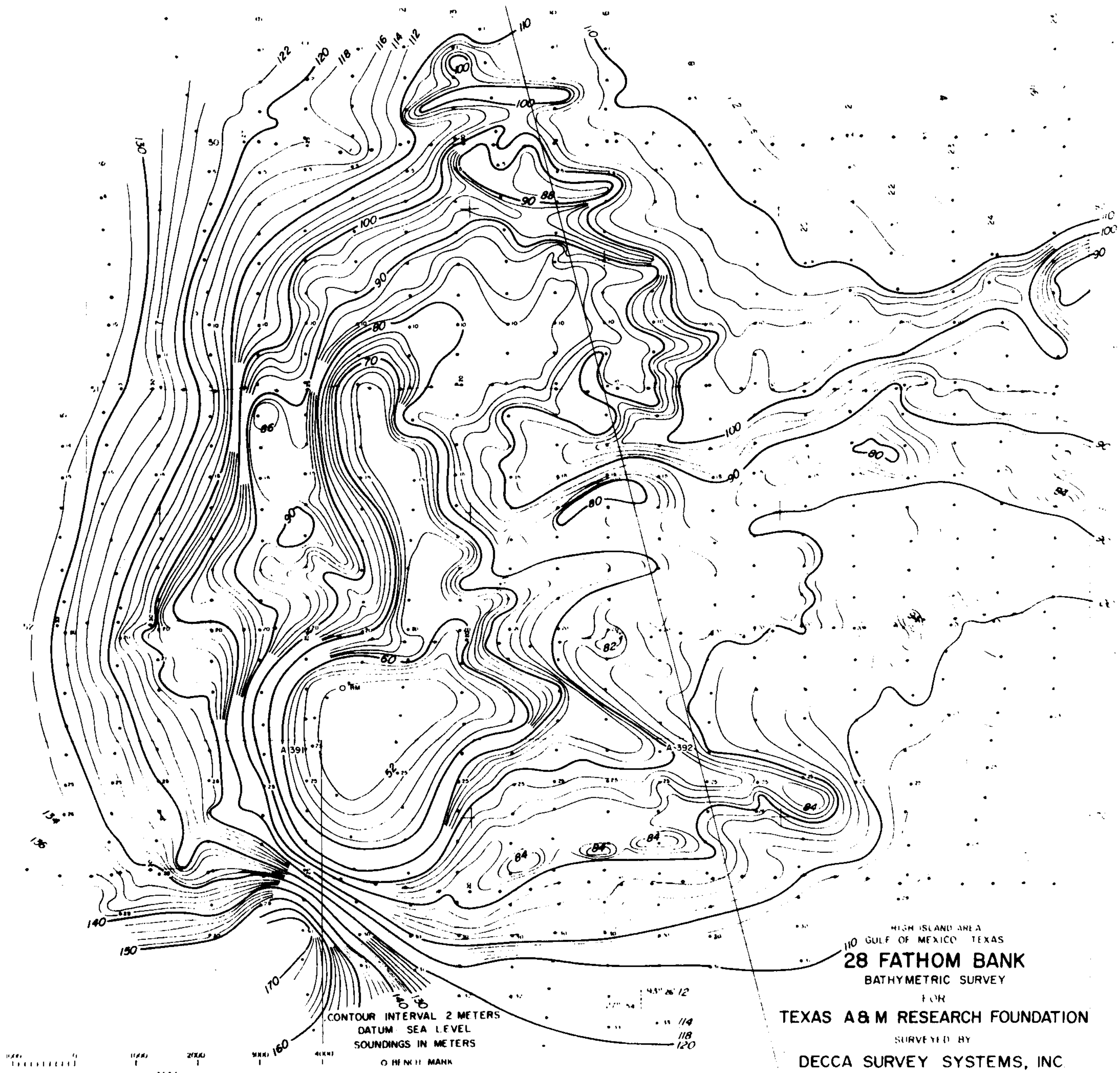
CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK

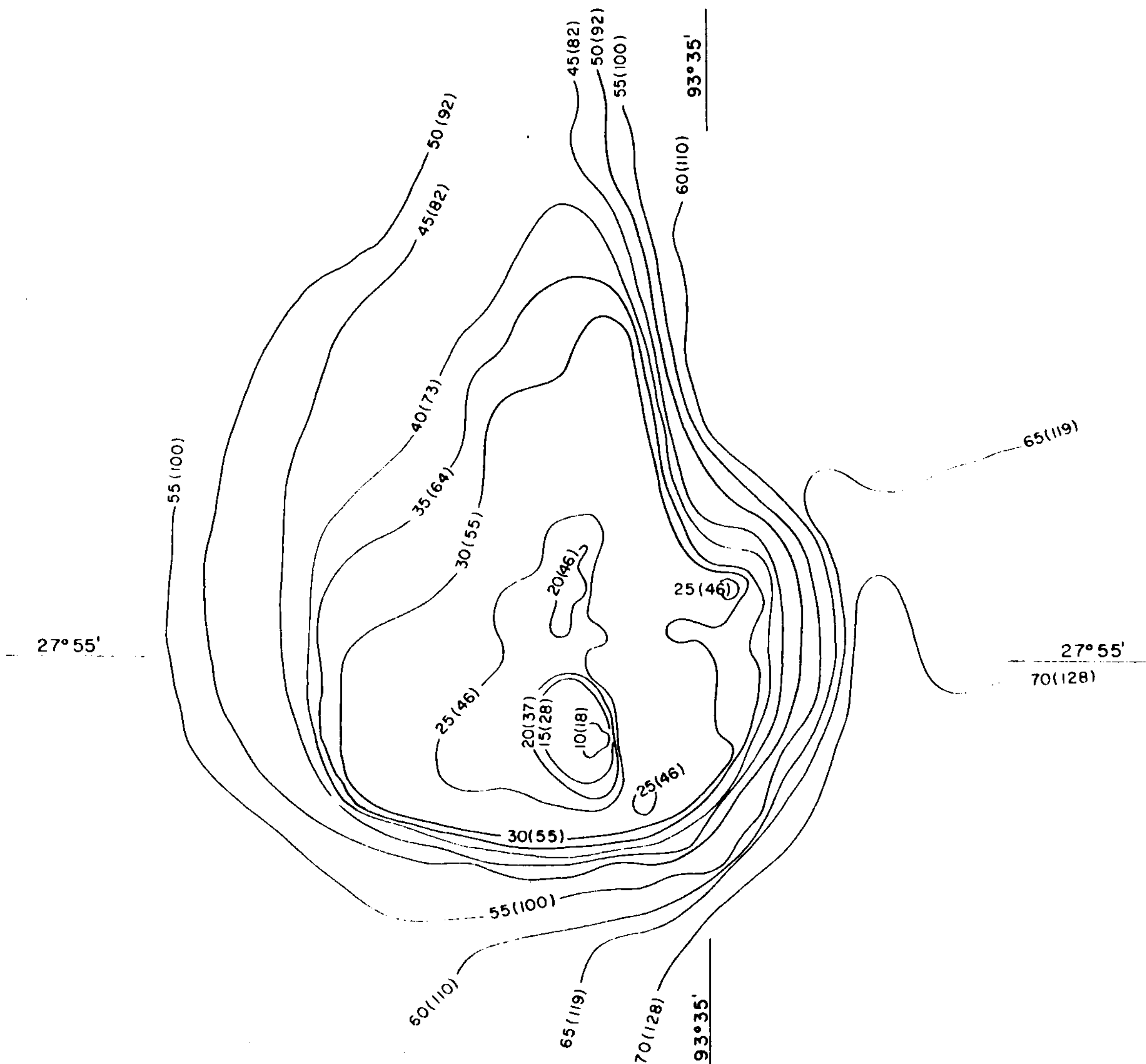
1000 0 1000 2000 3000 4000
FEET

HIGH ISLAND AREA
GULF OF MEXICO - TEXAS

29 FATHOM BANK

BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
SURVEYED BY
DECCA SURVEY SYSTEMS, INC.

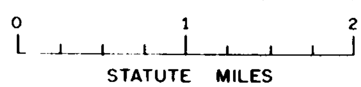

HIGH ISLAND AREA
GULF OF MEXICO TEXAS
28 FATHOM BANK
BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
SURVEYED BY
DECCA SURVEY SYSTEMS, INC
CONTOUR INTERVAL 2 METERS
DATUM SEA LEVEL
SOUNDINGS IN METERS
O BENCH MARK
A-391
A-392

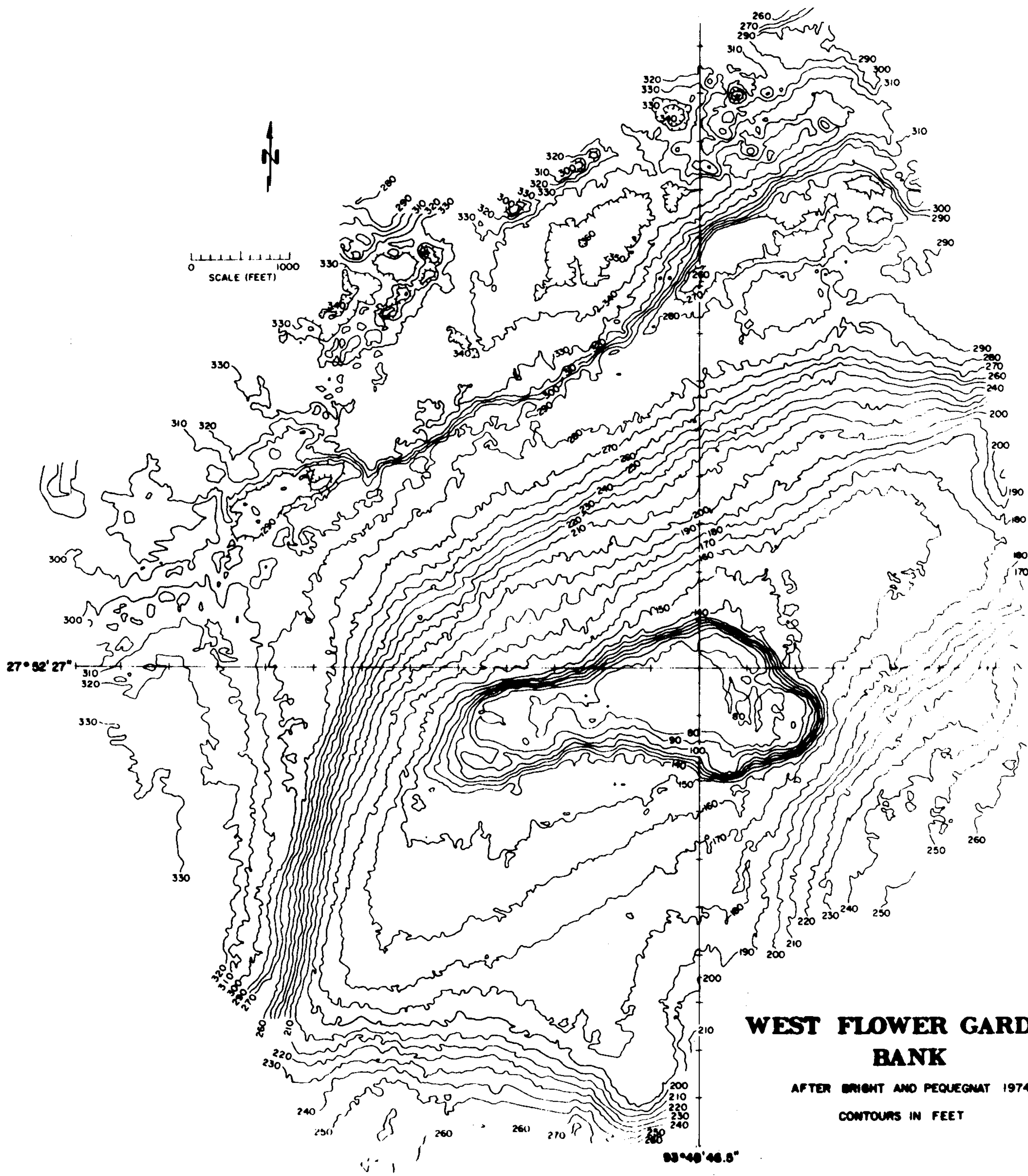


EAST FLOWER GARDEN BANK

AFTER PARKER AND CURRAY 1956

CONTOURS IN FATHOMS (METERS)

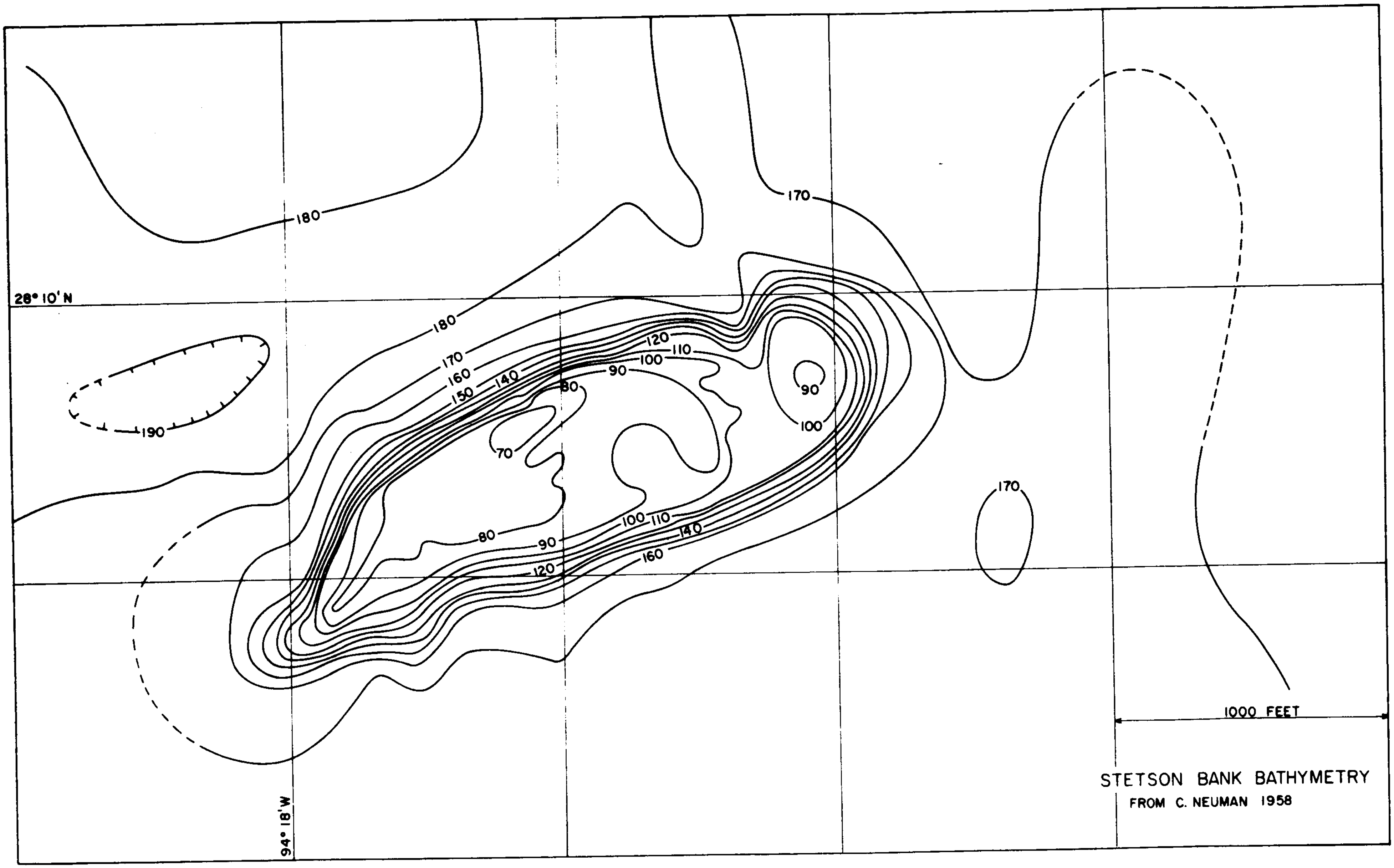




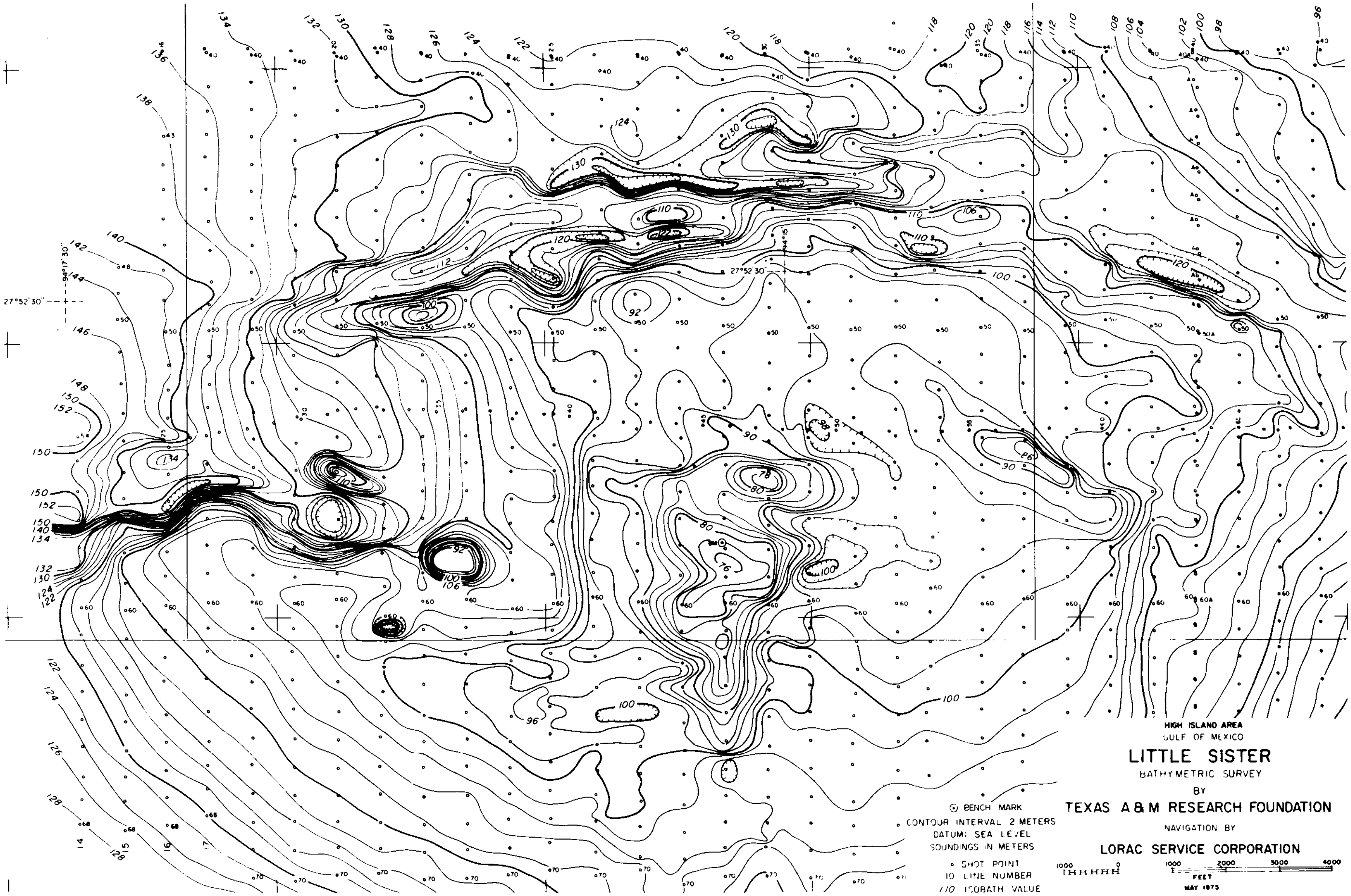
WEST FLOWER GARDEN BANK

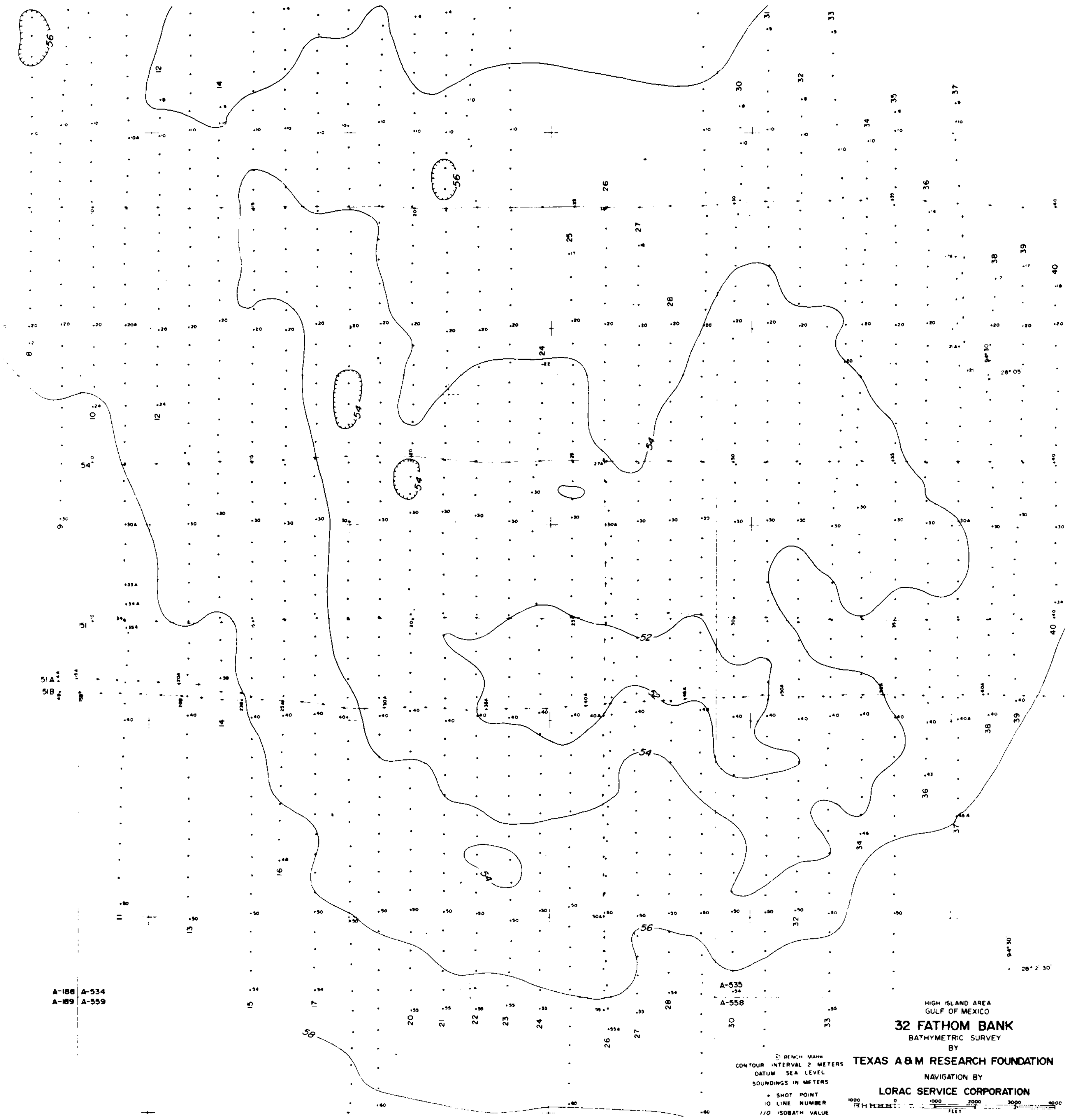
AFTER BRIGHT AND PEQUEGNAT 1974

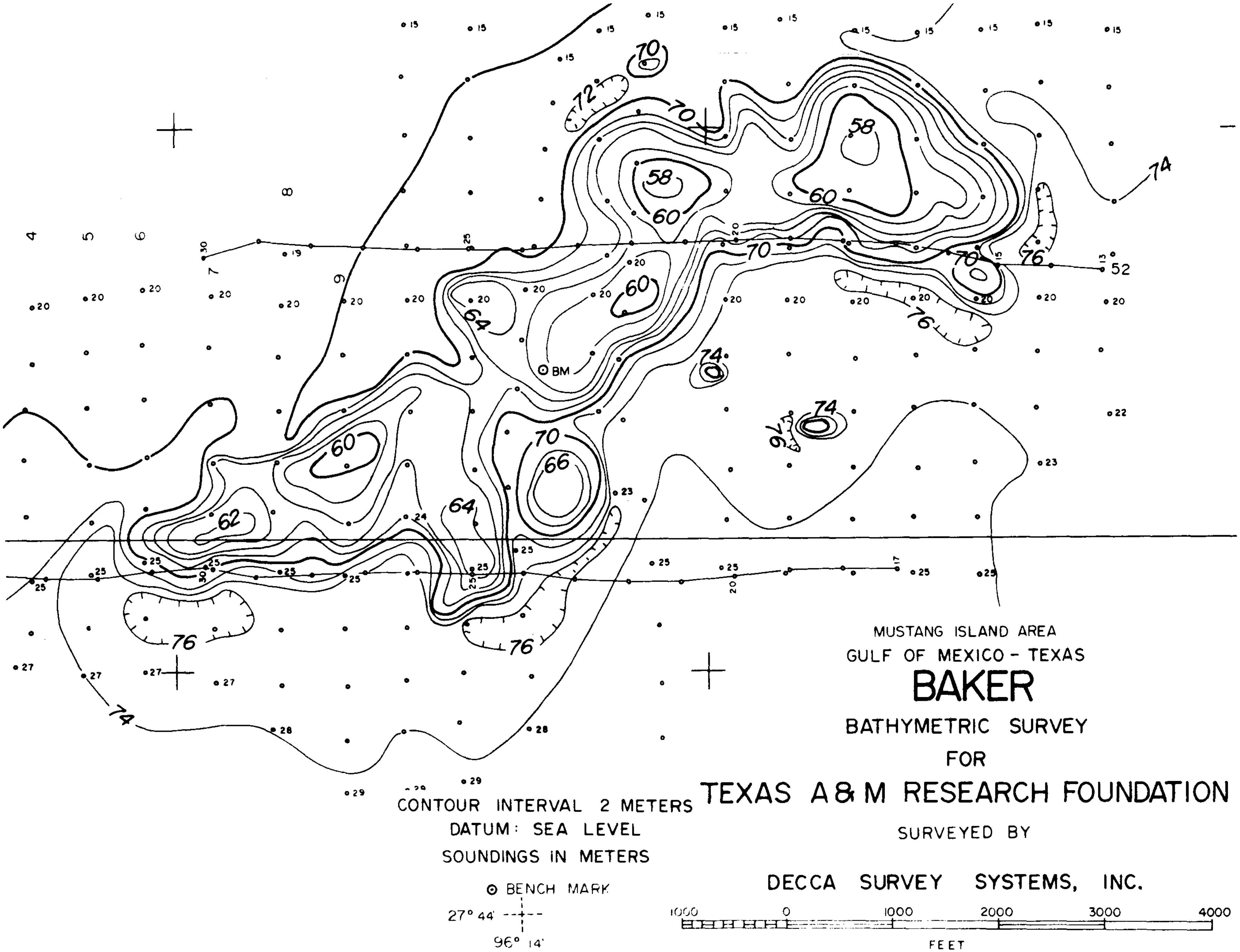
CONTOURS IN FEET

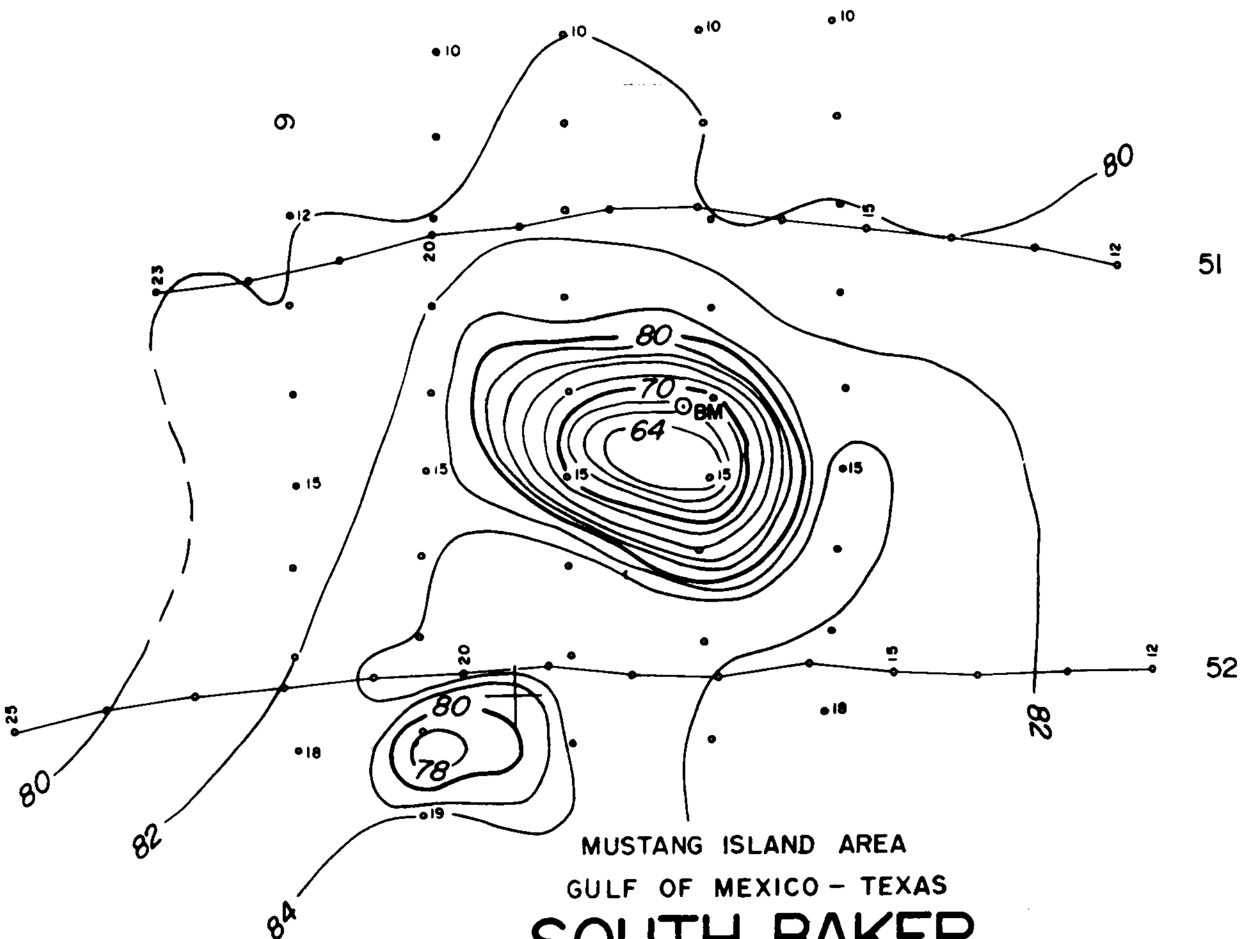


180
170
180
170
160
150
140
120
110
100
90
80
70
190
90
100
170
100
110
140
160
90
80
120
28° 10' N
94° 18' W
1000 FEET
STETSON BANK BATHYMETRY
FROM C. NEUMAN 1958


HIGH ISLAND AREA
GULF OF MEXICO
LITTLE SISTER
BATHYMETRIC SURVEY
BY
TEXAS A & M RESEARCH FOUNDATION
NAVIGATION BY
LORAC SERVICE CORPORATION
BENCH MARK
CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
SHOT POINT
10 LINE NUMBER
110 ISOBATH VALUE
1000 0 1000 2000 3000 4000
FEET
MAY 1975
27°52'30"


HIGH ISLAND AREA
GULF OF MEXICO
32 FATHOM BANK
BATHYMETRIC SURVEY
BY
TEXAS A&M RESEARCH FOUNDATION
NAVIGATION BY
LORAC SERVICE CORPORATION
BENCH MARK
CONTOUR INTERVAL 2 METERS
DATUM SEA LEVEL
SOUNDINGS IN METERS
SHOT POINT
10 LINE NUMBER
110 ISOBATH VALUE
FEET
A-188 A-534
A-189 A-559
A-535
A-558


MUSTANG ISLAND AREA
GULF OF MEXICO - TEXAS
BAKER
BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
SURVEYED BY
DECCA SURVEY SYSTEMS, INC.
CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK
27° 44'
96° 14'
1000 0 1000 2000 3000 4000
FEET
BM



MUSTANG ISLAND AREA

GULF OF MEXICO – TEXAS

SOUTH BAKER

BATHYMETRIC SURVEY

27° 40'
96° 16'

FOR

TEXAS A& M RESEARCH FOUNDATION

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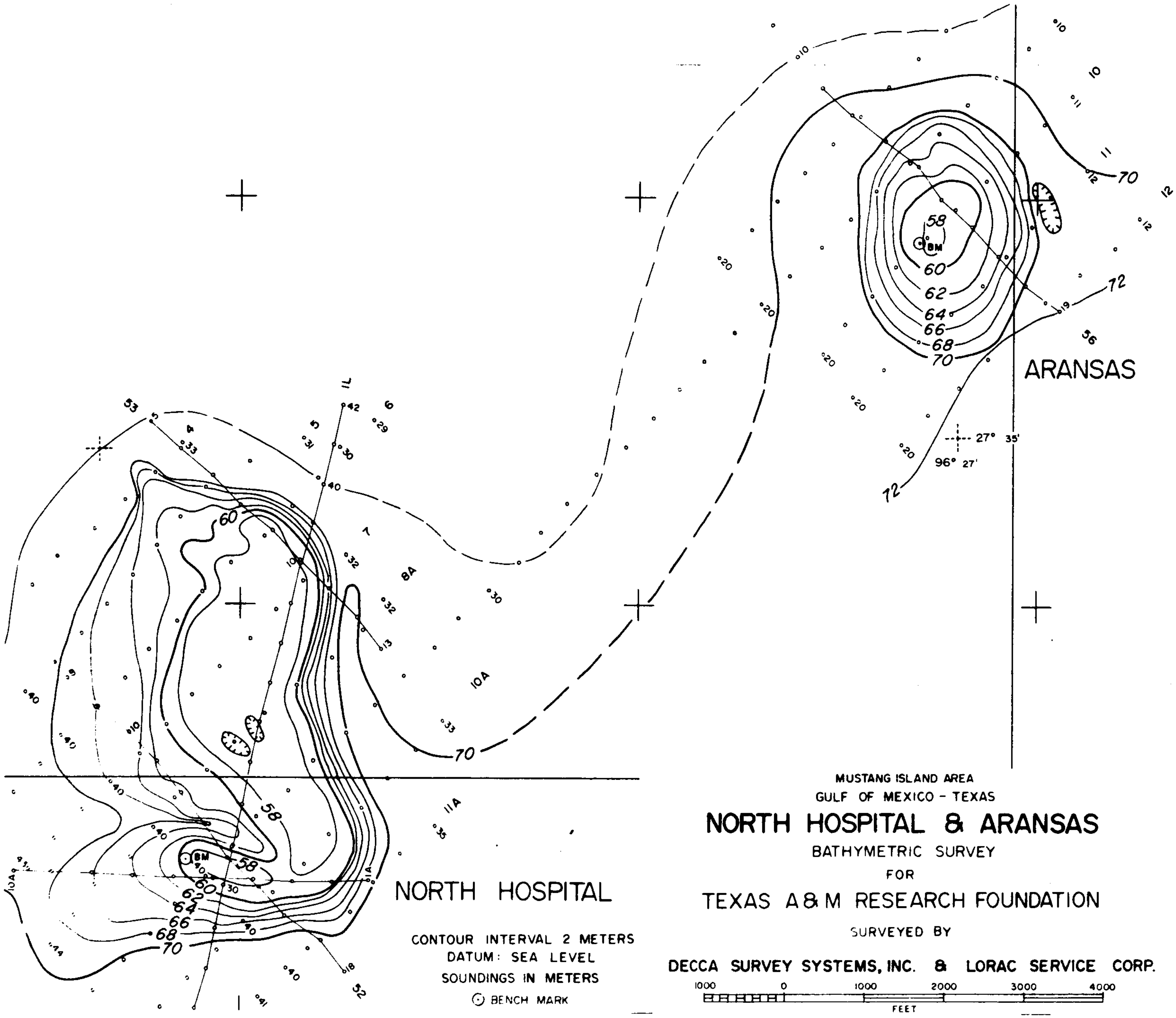
DECCA SURVEY SYSTEMS, INC.

CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK

1000 0 1000 2000 3000 4000
FEET



MUSTANG ISLAND AREA
GULF OF MEXICO - TEXAS

NORTH HOSPITAL & ARANSAS

BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
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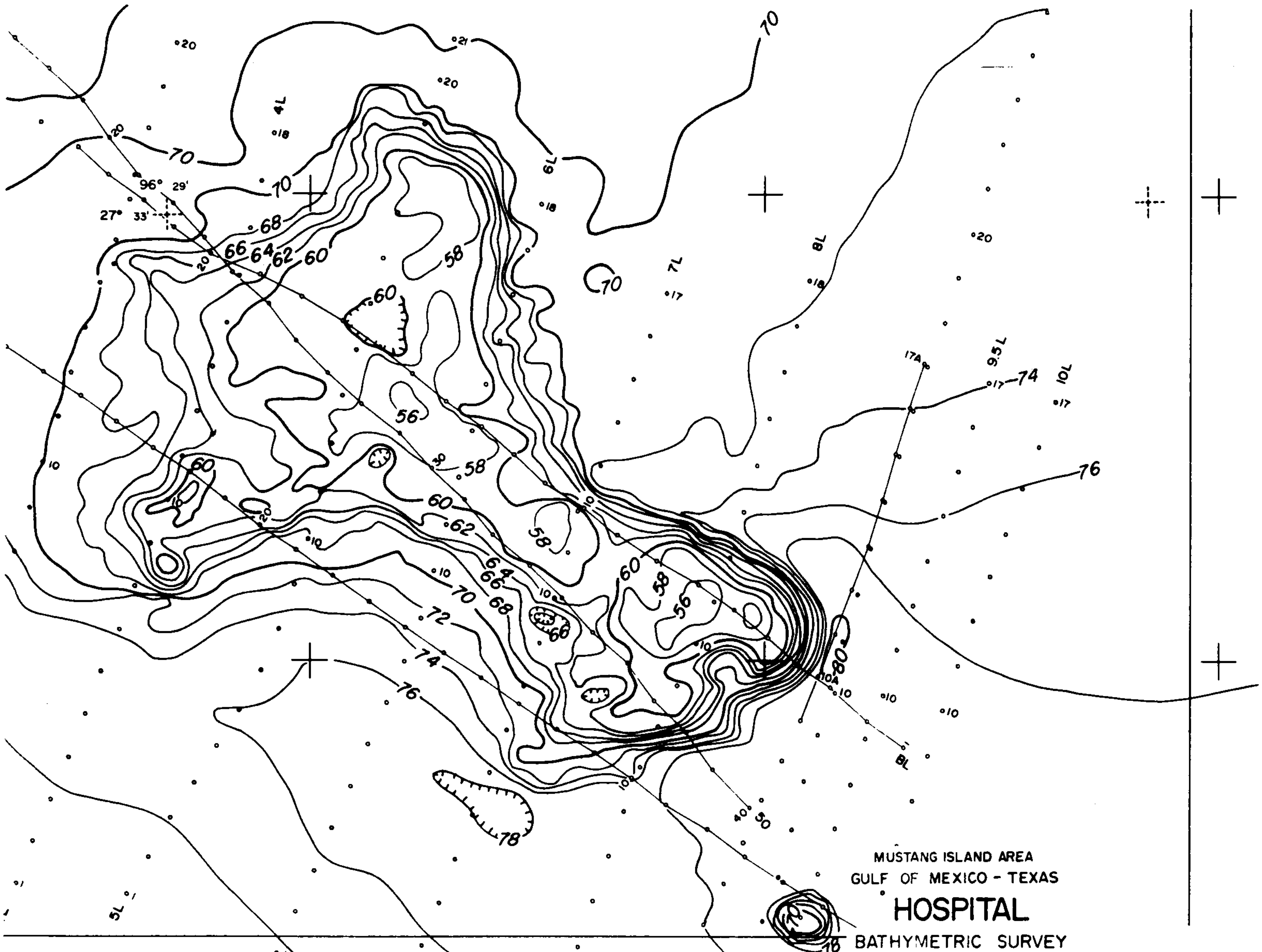
DECCA SURVEY SYSTEMS, INC. & LORAC SERVICE CORP.



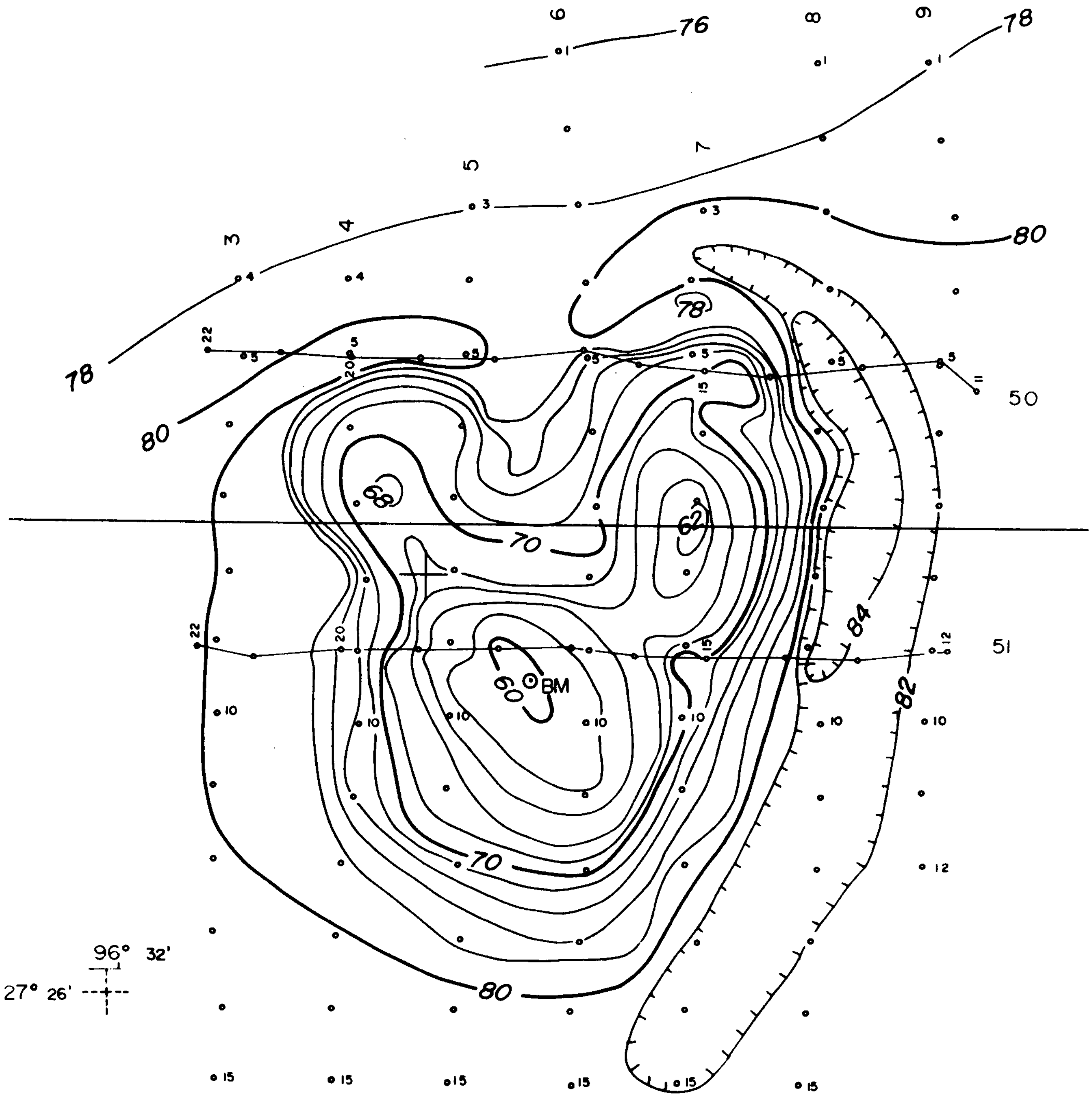
MUSTANG ISLAND AREA
GULF OF MEXICO - TEXAS

HOSPITAL

BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
SURVEYED BY
DECCA SURVEY SYSTEMS, INC. & LORAC SERVICE CORP.

DETAILED BATHYMETRY OF HOSPITAL FROM BATHYMETRY OF HOSPITAL ROCK PREPARED BY SOUTHWEST RESEARCH INSTITUTE (1969).

CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK



CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK

MUSTANG ISLAND AREA
GULF OF MEXICO - TEXAS

SOUTHERN

BATHYMETRIC SURVEY

FOR

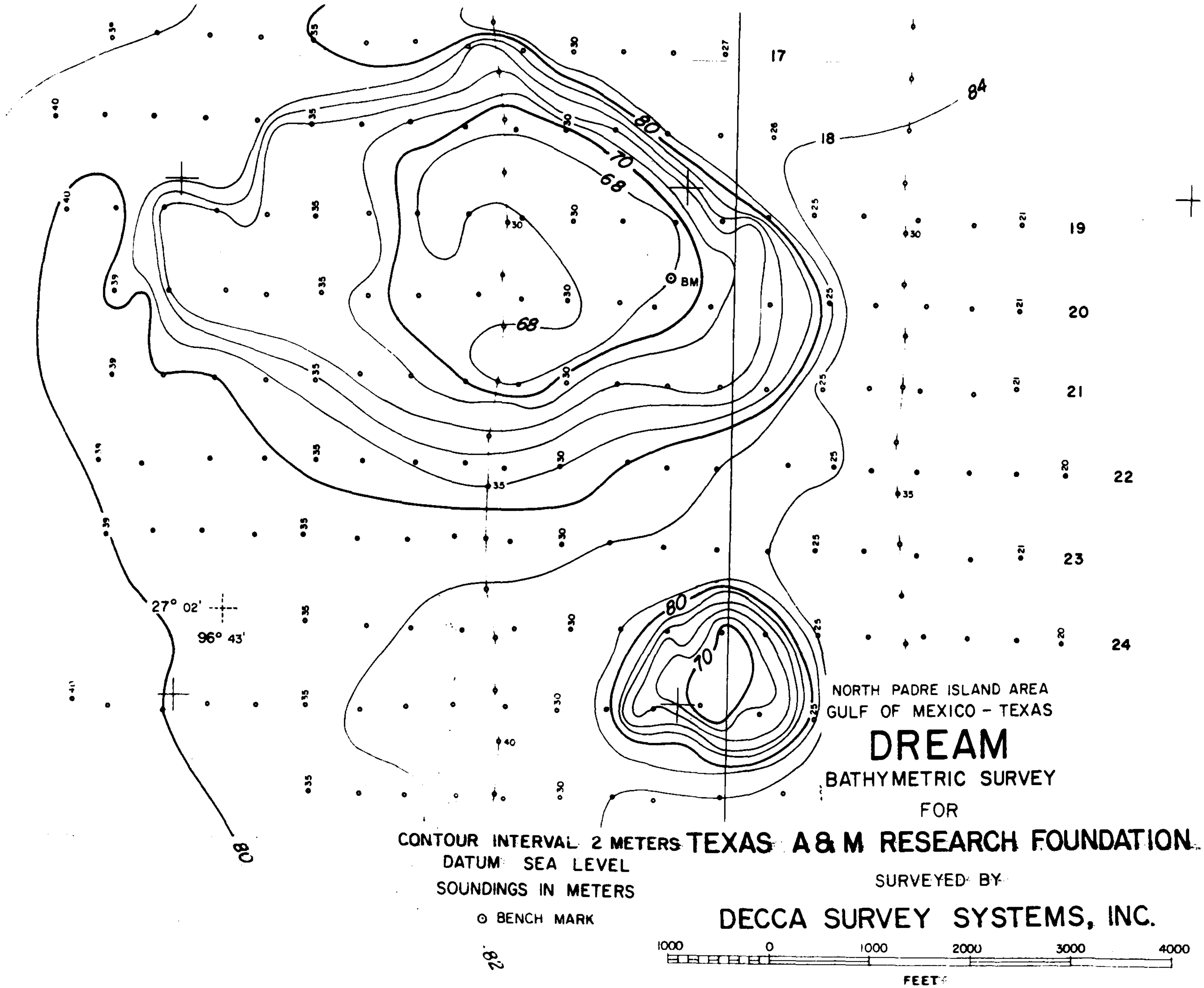
TEXAS A&M RESEARCH FOUNDATION

SURVEYED BY

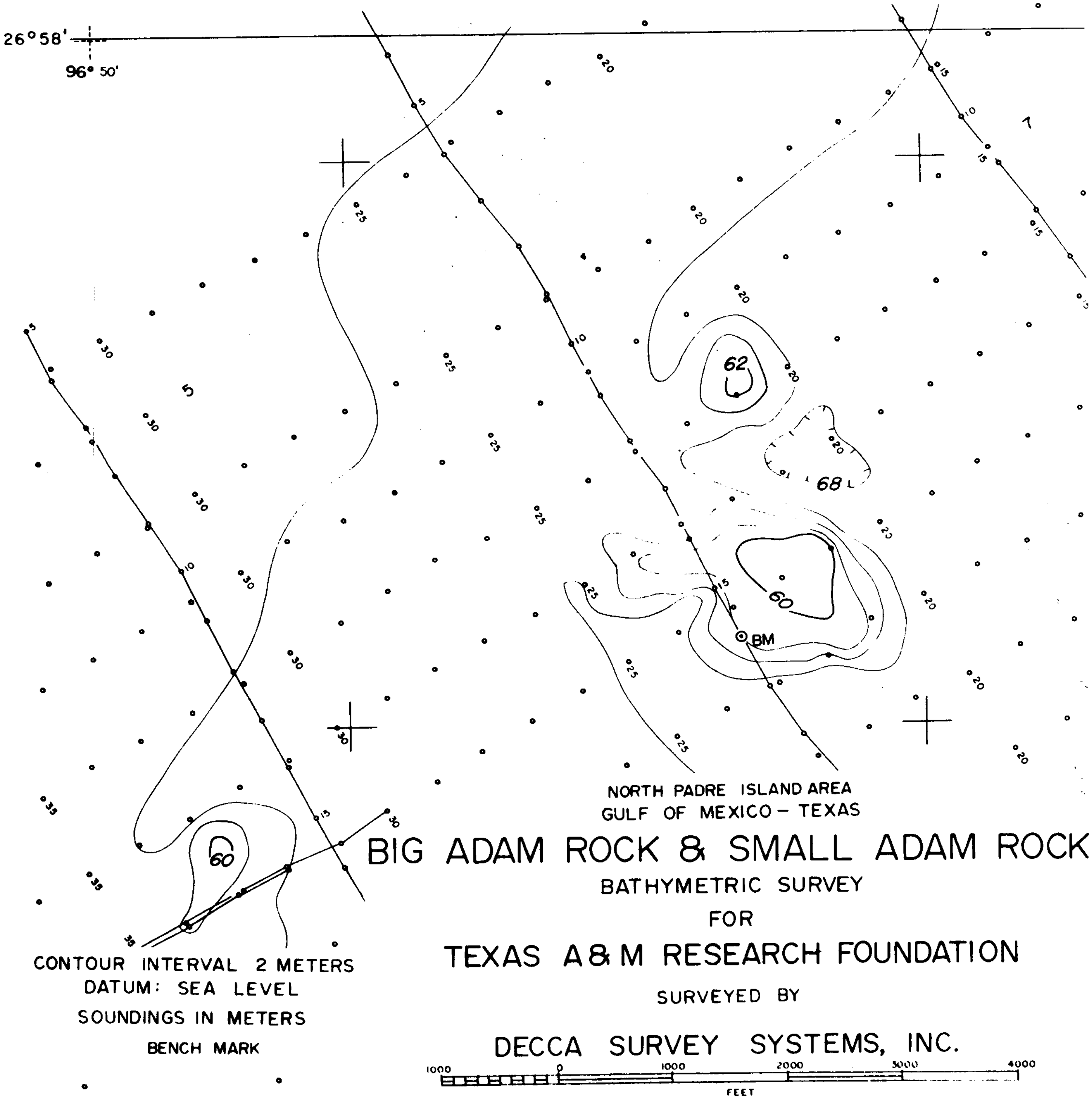
DECCA SURVEY SYSTEMS, INC.

1000 0 1000 2000 3000 4000

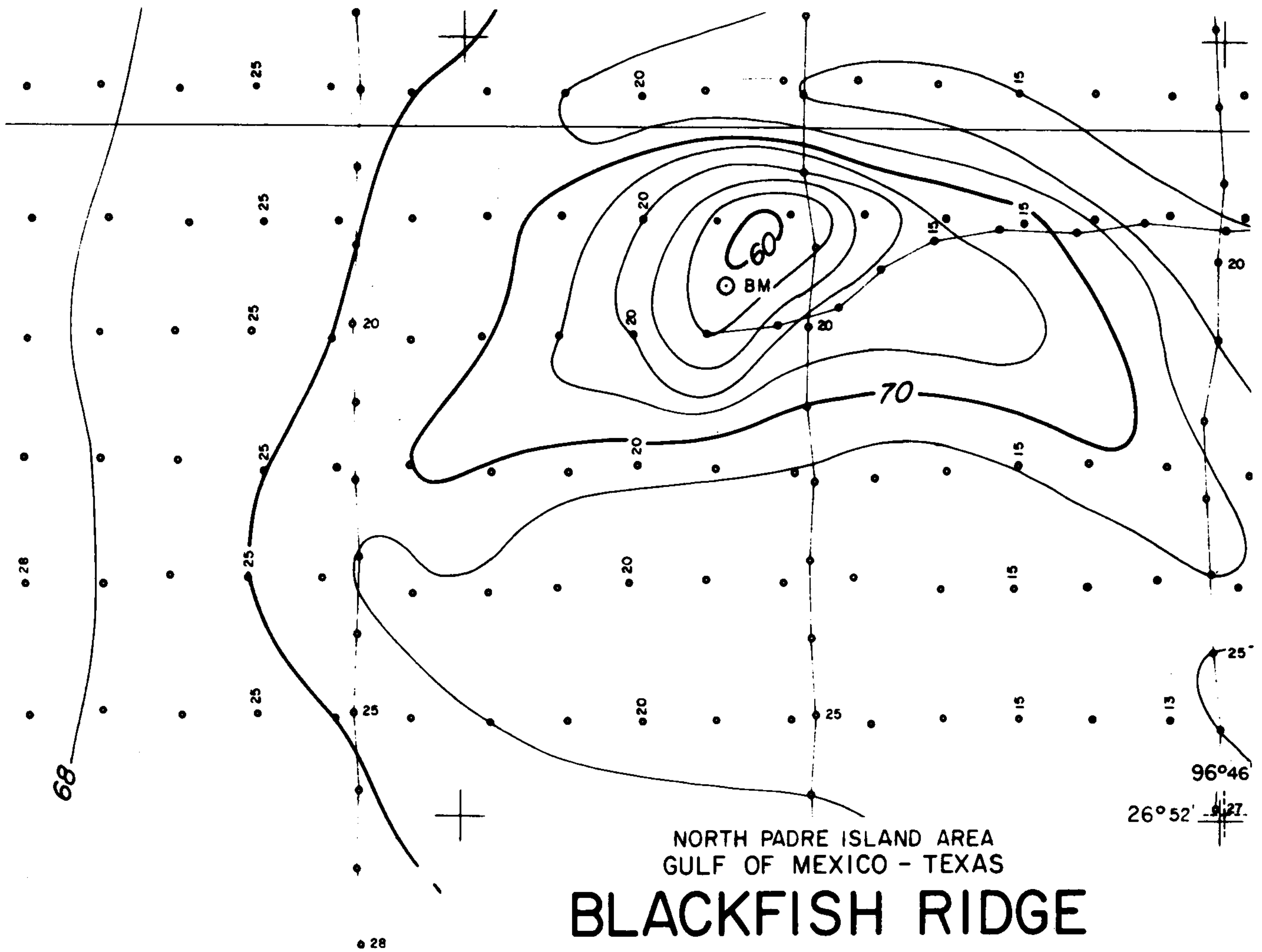
FEET



NORTH PADRE ISLAND AREA
GULF OF MEXICO - TEXAS
DREAM
BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
SURVEYED BY
DECCA SURVEY SYSTEMS, INC.
CONTOUR INTERVAL 2 METERS
DATUM SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK
1000
0
1000
2000
3000
4000
FEET
27° 02'
96° 43'
BM
84
80
70
68
17
18
19
20
21
22
23
24



26°58'
96° 50'
NORTH PADRE ISLAND AREA
GULF OF MEXICO – TEXAS
BIG ADAM ROCK & SMALL ADAM ROCK
BATHYMETRIC SURVEY
FOR
TEXAS A&M RESEARCH FOUNDATION
SURVEYED BY
DECCA SURVEY SYSTEMS, INC.
CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
BENCH MARK
BM
62
68
60
60
1000
0
1000
2000
3000
4000
FEET



NORTH PADRE ISLAND AREA
GULF OF MEXICO - TEXAS

BLACKFISH RIDGE

BATHYMETRIC SURVEY

FOR

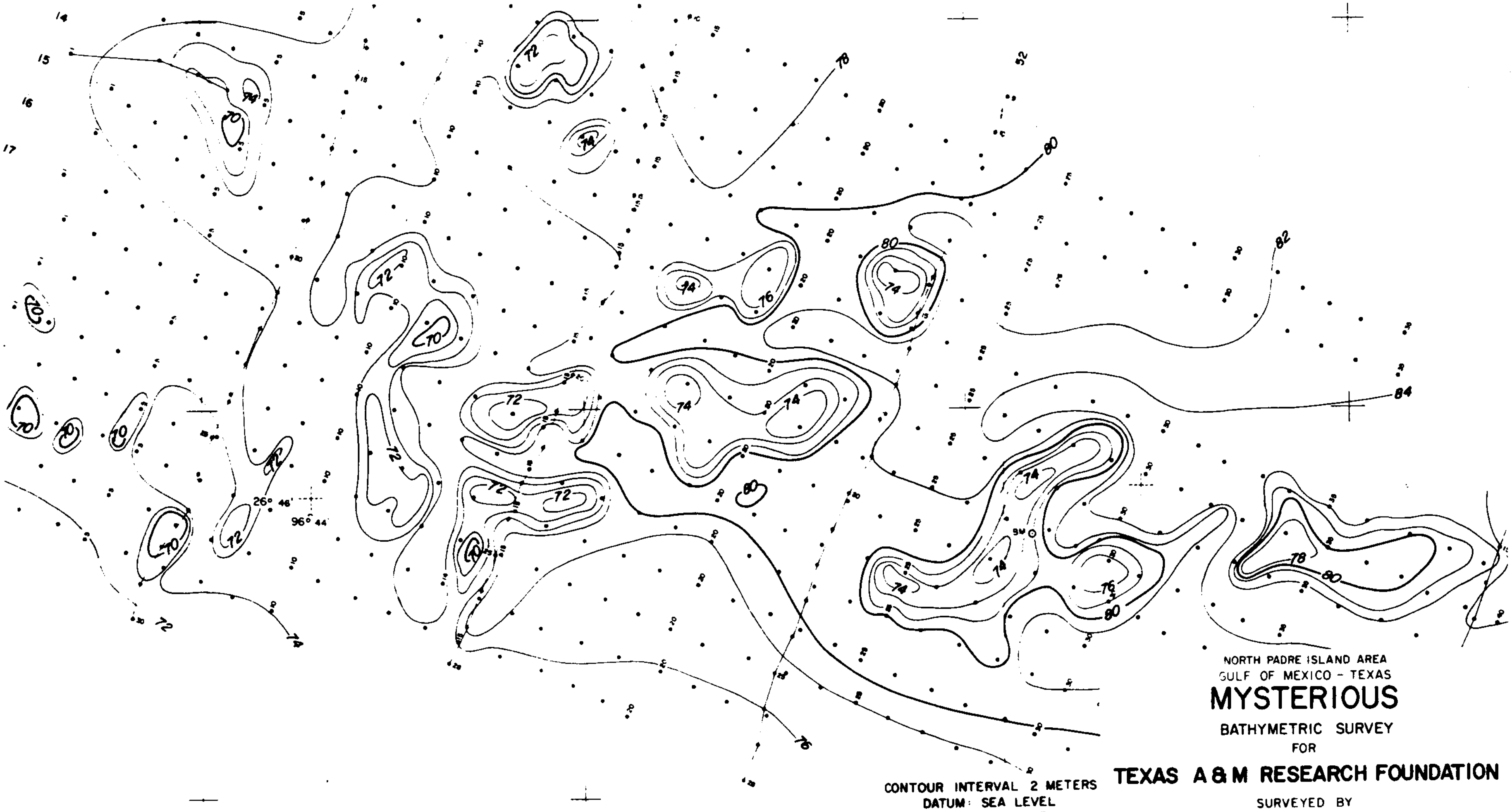
TEXAS A&M RESEARCH FOUNDATION

SURVEYED BY

DECCA SURVEY SYSTEMS, INC.

CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
⊙ BENCH MARK

1000 0 1000 2000 3000 4000
FEET



NORTH PADRE ISLAND AREA
GULF OF MEXICO – TEXAS

MYSTERIOUS

BATHYMETRIC SURVEY
FOR

TEXAS A & M RESEARCH FOUNDATION

SURVEYED BY

DECCA SURVEY SYSTEMS, INC.

CONTOUR INTERVAL 2 METERS
DATUM: SEA LEVEL
SOUNDINGS IN METERS
O BENCH MARK

CHAPTER IV

GEOLOGY

GEOLOGY OF SELECTED SUBMARINE BANKS ON THE SOUTH TEXAS CONTINENTAL SHELF

A. H. Bouma, W. R. Bryant and R. Rezak

INRODUCTION

The existence of topographic highs (banks) on the continental shelf of Texas and Louisiana has been known for many years. However, until recent years very little detailed work has been conducted to determine the origin and structure of these banks.

Many of the early references dealing with the origin of the banks were based upon limited field studies and were speculative. Trowbridge (1930) suggested that the banks resulted from diastrophic events. Carsey (1950) proposed that not only salt intrusion but also volcanic activity might be responsible for the prominences. Goedicke (1955) used the presence of numerous faults to support a tectonic origin for the highs. He also considered differential erosion as a factor in shaping the pinnacles. Stetson (1953) discounted the idea that the banks were erosional remnants and favored the idea that the topographic highs were possibly old biohermal structures or salt domes. Nettleton (1957) presented data in support of the early idea that salt intrusions were responsible for the locations of the banks. Gravity surveys over several banks revealed gravity anomalies.

Neumann (1958) classified the banks into three categories: 1) near shore, 2) shelf, and 3) shelf edge. Near shore banks have irregular forms that extend, at times, over large areas. These features are low in profile and occur out to about 28 Km from shore in depths of 5.5 to 18.3 meters. Relief is ordinarily 4.6 to 7.6 meters.

Shelf banks are steep sided features that cover a small area of the sea floor. These banks are located 85 to 113 Km offshore in depths of 45.7 to 73.2 meters. Their shallowest peaks occur 18.3 to 64 meters below sea level.

Shelf edge banks are concentrated along the shelf edge and upper slope. The depths at which they occur varies from 91.4 to 365.8 meters, but most are located at depths between 91.4 and 182.9 meters. Relief on the shelf edge banks ranges from 18.3 to over 61 meters.

Curray (1960) grouped the shelf banks into two divisions based upon relief and origin. The first division included banks that have 3.7 to 5.5 meters of relief. He considered this group to be the result of salt intrusions. The banks have been modified by the growth of an organic cap and also modified by erosion during a lowered sea level. Banks in the second division have less than 3.7 meters of relief and were considered to be cemented remains of shoreline deposits from the early Holocene or Pleistocene.

The classification that best fits the majority of the banks in the N.W. Gulf of Mexico is the one by Neumann (1958). However, the banks on the South Texas shelf certainly would fall into Neumann's shelf bank category requiring a change of the near shore limits of this group to about 64 Km.

Studies by Texas A&M University during the past 5 years indicate that origin of the banks can be added to Neumann's classification. The banks may be grouped geologically into three categories: 1) Tertiary bedrock exposed due to salt tectonics, as in Stetson and Claypile Banks; coral reefs and banks growing on salt domes, as exemplified by the Flower Gardens and Twenty-eight Fathom Banks; and 3) drowned coral reefs and banks not associated with salt domes, such as: Baker, Southern, Dream and all other banks of the South Texas Shelf. North of 27° 46' N. Lat. all of the banks and reefs are associated with shallow salt domes. South of this line, the drowned reefs and banks appear to have grown on a buried carbonate shelf.

PHYSIOGRAPHY

GENERAL

The banks of the Texas outer continental shelf may be divided into two main groups. Those banks north of 27° 46' N. Lat. are associated with salt domes in the subsurface and their distribution is generally the same as the distribution of shallow salt domes. The banks south of 27° 46' N. Lat. are not associated with any shallow subsurface structures and their distribution is most probably controlled by an ancient shoreline at about 60 meters depth. See Figs. 1 and 2.

The South Texas banks are classified as shelf banks using Neumann's (1958) classification, and as such have considerably less relief than the shelf edge banks to the north and east. The shelf edge banks (Little Sister, West Flower Garden, East Flower Garden, and Twenty-eight Fathom Bank vary in relief from 110 to 175 meters. The South Texas shelf banks vary in relief between 8 and 24 meters. The northern shelf banks including Twenty-nine Fathom Bank, Stetson, Claypile, and Thirty-two Fathom Bank relief varying from 6 to 20 meters.

Reasons for the great differences in relief between the shelf edge and the shelf banks are: 1) greater initial depth of bank at shelf edge and 2) varying degrees of burial of shelf banks by Holocene and Recent sediments.

Many of the banks are partially surrounded by a moat one to four meters deep. Whether these depressions are due to scour by currents or subsidence of the bank is not known at this time.

Bathymetric charts with overlays showing sample stations, survey tracks, and submersible transects are included as Figures 3-8. Figures 9-14 are bathymetric charts of the banks not included in the submersible investigations.

PERSPECTIVE DIAGRAMS

In order to create a better visual image of the bank physiography, computer produced perspective diagrams were constructed. An attempt was made to preserve the interpretation of the manually drawn contour maps. This was accomplished by digitizing contour lines at irregular closely spaced points. This data was then converted to a form compatible with the SYMAP program.

SYMAP is a computer program which portrays quantitative data in a map form. Data consists of coordinate locations of randomly spaced points and, for the present study, the elevations of the bank at these points. Other data specifies the map size, the contour interval, and the symbols which represent the intervals. SYMAP interpolates between data points in order to find the elevation of the bank at regularly spaced grid points. The program then determines the contour interval to which each grid value belongs and assigns each point the appropriate contour symbol. A map which consists of these symbols is then printed.

The concept, overall design and mathematical model was developed in 1963 by Howard T. Fisher (Northwestern Technological Institute). It was programmed by

Mrs. O. G. Brown of the Northwestern University Computing Center. Since then many changes have been made in the program. Our study used version number 5. Many of these changes were accomplished by Robert A. Russel and Donald S. Shepard at the Laboratory for Computer Graphics and Spatial Analysis, Harvard University.

The printer type contour maps were produced and checked for conformity with the manually produced charts. The gridded contour values from these maps were then fed from tape into the SYMVU program.

SYMVU is a computer program which plots three dimensional displays of data. It was developed by Frank J. Rens, under the direction of Prof. Howard T. Fisher, at the Laboratory for Computer Graphics and Spatial Analysis, Harvard University. The data from SYMAP was later used by SYMVU in order to obtain perspective views of the banks. Plotting was performed by using a Systems Engineering Laboratory plotter. The diagrams are included as Figures 15-28. Captions on the diagrams require definition, Azimuth refers to the direction the observer is facing when viewing the bank. Altitude refers to the height of the observer in degrees relative to the crest of the bank. Width and Height are arbitrarily chosen figures that control the scale of the diagram. The vertical scale on the right side of the diagram is a depth scale after foreshortening.

DESCRIPTIONS OF BANKS

Baker (See Figs. 3 and 15)

Baker is a NE-SW trending bank 2700 meters long and 775 meters wide at its widest part. The bank rises from a depth of about 74 meters to a terrace of about 60 meters. Rising above this terrace are 8 peaks varying in depth from 58 to 64 meters. The 58 meters peak at the NE end of the bank was examined using the submersible. The crest of the peak is a large, relatively flat surface composed of hard rock covered by a thin film of fine sediment. Just below the crest of the peak large blocks of reef rock lie scattered on the slope. Fine sediment over the reef rock increases with depth. A discontinuous moat surrounds the bank.

A nepheloid layer lies around the bank. The surface of the nepheloid layer is approximately at the crest of Baker. Suspended sediment in the upper part of the nepheloid layer is less concentrated permitting visibility of 6-10 meters. With increasing depth, concentration of suspended matter increases and visibility near the base of the bank is reduced to about two feet.

<u>South Baker</u> (See Figs. 4 and 16)

South Baker consists of two small peaks rising from depth of 82-84 meters. The larger, northern peak is 675 meters long and 450 meters wide, trending in a NW-SE direction. On the north, east and south sides the slopes are uniformly steep but the northwest slope is more gentle. The surface of the bank is less smooth than Baker having boulders strewn around as at comparable depths at Baker.

The southern peak is nearly circular and rises from a depth of 82-84 meters to a crest at 78 meters. No visual observations were made on this peak.

The nepheloid layer completely covers the main peak reducing visibility at the crest. See Chapter 3, Figures 27, 28 and 32.

<u>North Hospital, Aransas, Hospital Rock</u> (See Figs. 5, 17, 18 and 19)

These three banks lie in close proximity to each other. North Hospital and Aransas were surveyed during Phase I of this investigation. Hospital Rock was not surveyed as a detailed chart had been prepared by Southwest Research Institute in 1969. During the submersible phase of this investigation, we found that Hospital Rock was erroneously charted 1006 meters west of its actual position by the Southwest Research Institute. A subsequent survey showed the details of the 1969 chart to be accurate so the earlier bathmetry was placed on its proper location on the present chart.

Aransas is a small (1000 X 675 meters) bank with uniform slopes in all directions, rising from a depth between 70 and 72 meters to a crest at 58 meters.

North Hospital is elongate in a N-S direction. It is about 1775 meters long and 900 meters wide. A narrow, steep walled canyon cuts into the west side of the bank. The north, east, and west sides of the bank are quite steep with a gentle slope on the west side.

Hospital, the largest of the three banks, is 2550 meters long and bone shaped with the widest part 2050 meters and the narrowest part 650 meters. No submersible transects were made on Hospital. However, one hour and thirty minutes of underwater TV coverage was made on deck during a period when the ship was anchored. The TV tapes showed the bottom to be similar to South Baker and Southern. The rest of the bank is relatively level with large boulders scattered about on the surface.

<u>Southern</u> (See Figs. 6 and 20)

This bank is nearly circular in plan with a diameter of 1275 meters. It rises from a depth of 80 meters to a terrace at about 70 meters. Three peaks rise above this terrace with crests at 60, 62 and 68 meters. The east side of the bank is very steep with a more gentle slope to the north and south. A moat up to 4 meters deep is located on the east side of the bank.

The crest of the highest peak is relatively flat with scattered boulders of rock on the surface. In some areas of the crest the reef rock appears to have been weathered into pinnacles such as are commonly seen on rocky shores just above high tide mark. See Figure 9, Chapter III.

On the flanks of the peak are three levels of boulder accumulations that encircle the peak. These occur at 65, 70 and 75 meters and may represent either rock shorelines or minor reef growth during short period sea level stands during the latest transgression.

<u>Dream</u> (See Figs. 7 and 21)

This is an oval shaped bank with a small circular satellite reef to the southeast. The main bank is 2000 meters long and 1475 meters wide trending in an easterly direction. The bank rises from depths of 80-84 meters to a crest at 70 meters. The slopes around this peak are fairly uniform. Small terraces occur 72-74 meters on the satellite and a large terrace occurs on the main bank at the same depth.

The crest of the main bank is similar to the others, described above, but may have a slightly heavier deposit of fine sediment covering the reef rock.

Big Adam and Small Adam Rock (See Figs. 8 and 22)

Big Adam Rock is a small bank, 825 meters long and 450 meters wide, trending in a NW-SE direction. It rises from a depth of 68 meters to a crest at about 60 meters. To the north is a depression and north of the depression is another small bank that rises to 62 meters. The slopes in Big Adam are fairly gentle except for the northeast side of the bank where they steepen. During the one submersible transect at Big Adam, the crest was found to be deeply immersed in the nepheloid layer. Visibility was only 1/2 to 1 meter and no photographs were taken. However, boulder fields were encountered close to the crest of the bank similar to those described from the other banks.

Small Adam Rock is a very small feature, 300 meters long and 150 meters wide, trending in a N-S direction. It rises from a depth of 62 meters to a crest at 60 meters. This bank was not observed with a submersible because of the very poor visibility encountered at Big Adam.

Blackfish Ridge (See Figs. 9 and 23)

This is an arcuate ridge 1400 meters long and 725 meters wide trending in a E-W direction. The bank rises from a depth of 72 meters to a crest at 60 meters. The steepest slopes are to the north. No submersible observations were made on this bank.

Mysterious (See Figs. 10 and 24)

This is a complex of small banks covering an area 3.8 nautical miles long by 1.6 nautical miles wide and trending in a NW-SE direction. The individual banks vary in size from 100 meters in diameter to 1250 meters in diameter. Relief on the banks varies from less than one meter to as much as 8 meters. No submersible observations were made on these banks.

NEPHELOID LAYER

All of the banks examined during this study are associated with a nepheloid layer. Ewing and Thorndike (1965) introduced the term "nepheloid" to designate a turbid layer of water near the bottom in the North Atlantic. Nepheloid layers are known to exist in many areas of the world ocean. In the deep ocean basins they vary in thickness from 200 meters to 3000 meters. On continental shelves, the nepheloid layer may be one a few meters in thickness while in some areas it may occupy the entire water column.

The nepheloid layer on the Texas continental shelf has been observed at each bank examined during the present study. It varies in thickness from 15 to 20 meters. Hospital Rock is the only bank that rises some distance above the nepheloid layer. The remaining banks either rise up to the top of the nepheloid layer or are deeply immersed in it. Big and Little Adam Rocks, having low relief are deeply immersed in the nepheloid layer and as a consequence must have a very restricted flora and fauna.

The mineral composition of the nepheloid layer is predominantly illite with lesser amounts of montmorillonite and kaolinite (Charles Holmes, USGS, personal communication). The bottom sediments on the shelf are primarily montmorillonite with lesser amounts of illite and kaolinite. The origin of the nepheloid layer will be studied during the coming year. Speculation on the basis of the limited evidence at hand seems to indicate that the nepheloid layer is a relatively recent phenomenon and may be due to dredging of ship channels along the coast where Pleistocene clays rich in illite occur.

CLAY MINERALOGY

One of the first problems recognized by investigators in semi-quantitative clay mineral studies is that mineral determinations are very sensitive to sample preparation procedures and interpretation techniques. The general preparation technique that has been used by a number of recent investigators at this institution--Hagerty (1969), Scafe and Kunze (1971), Appelbaum (1972), and Hall (1973)--is that of Jackson (1956). Most workers attempting to make quantitative measurements of clay percentages have used the peak area method which uses illite as an internal standard. This procedure was devised by Johns et al. (1954). Harlan (1966) compared clay mineral estimates by using peak area and peak height calculations from twenty duplicate samples. He concluded that comparable results in the relative abundance of clay minerals can be obtained using either method. Scafe and Kunze (1971) used the semi-quantitative form factor method of Bradley, Johns et al. (1954) which used peak heights for clay mineralestimates.

To date, there have only been two investigations discussing the minerals of the Gulf of Mexico on a regional basis. Pinsak and Murray (1960) showed that the regional patterns of clay minerals in surficial sediments can be related to source and environment. They found montmorillonite and kaolinite accumulations greatest in the abyssal plain while illite concentrations increased on the continental slope. Also, minor amounts of chlorite and mixed-layer minerals were ubiquitous in samples examined. In a recent study, Devine et al. (1972a, b, and 1973) applied the quantitative X-ray diffraction technique of Moore (1968) to the upper 5 cm of cores from the Gulf of Mexico. Their results differed substantially from those of Pinsak and Murray (1960). In weight percentages, illite was found to be consistently more abundant than smectite (montmorillonite) both in bulk sediments and in the less than two-micrometer fraction of sediment samples. Chlorite was found to be more abundant than kaolinite in mean weight percentage in all samples.

Since Grim and Johns' (1954) early work in the Texas Coastal area, in which montmorillonite, illite, chlorite, and kaolinite were first identified, numerous other investigators have examined clay mineralogy in other local parts of the Gulf of Mexico. In a recent study of part of the area that Grim and Johns discussed, Hall (1973) showed that kaolinite was present in larger quantities than originally reported. The Sigsbee Deep was examined by Murray and Harrison (1956), Harlan (1966), and Scafe and Kunze (1971). These authors reported approximately twice as much montmorillonite as chlorite and illite, and trace amounts of kaolinite in their samples. The recent sediments of the Mississippi Delta have been discussed by Johns and Grim (1958) and by McAllister (1964). Both studies showed that montmorillonite comprised the bulk of the material. McAllister (1964) showed the presence of hallyosite, montmorillonite and kaolinite, but failed to find chlorite as identified by Johns and Grim (1958). Griffin (1962) discussed the relationship between weathering products and the regional clay-mineral facies in the northeast Gulf of Mexico. Hagerty (1969) examined the clay minerals in the less than two-micrometer fraction of surface sediments and adjacent river outlets in the southwestern Gulf of Mexico. He showed that within the southwest Gulf of Mexico, montmorillonite is the predominant clay mineral, and that the clay mineral suite is remarkably homogenous due to mixing by current systems. He also showed that the clay mineral suites found at the mouth of ten river systems fall into four natural geographical groups which are apparently controlled by parent rock rather than climate.

Huang and Goodell (1970) studied the sediments of the eastern Mississippi Fan and found no major lateral clay mineral variations. Appelbaum (1972), in his study of the continental slope in the northwest Gulf of Mexico, showed a uniform relative distribution of clay minerals due to mixing of source materials. He showed that illite, in the 5 to 2 μm fraction, montmorillonite and illite comprised 55 percent and 33 percent, respectively.

Harlan (1966) stated that montmorillonite and kaolinite are the most abundant clay minerals in sediments deposited during the interglacial periods in the Gulf of Mexico, whereas illite and chlorite are most abundant in sediments deposited during glacial stages. Scafe (1968) suggested from the relative uniformity (lateral and vertical), in the mineralogy of the clay-size fraction, that currents in the western Gulf of Mexico were sufficient, during and since Pleistocene time, to transport and evenly distribute clay materials. His evaluation of cores also indicates that the source and supply has been constant since the Pleistocene.

PROCEDURES FOR CLAY MINERAL ANALYSES

Clay mineral analysis was performed on samples from the 23 master stations. The procedure for fractionation and dispersion of the sample for clay mineral analyses followed that of Dixon (personal communication, 1975) which is a modification of Jackson (1956). This modified method is used by the soil mineralogy and geological oceanography laboratories of TAMU.

The carbonates are removed from the sample by treating the sample with a pH 5 N NaOAc (sodium acetate) and heated on a steam bath. Extensive bubbling occurred during heating. In some samples the bubbling did not abate after 2 fresh solutions of pH 5 N NaOAc solution was added and further heating. To these samples Ph 4 N NaPAc solution was added with continued heating. The evolution of a few small bubbles during heating indicates that the carbonates have been removed. The samples were then centrifuged and the supernatant decanted off. The organic matter and $Mn\ 0_2$ were then removed by addition of a 30 percent solution of $H_2 0_2$ (hydrogen peroxide) to the centrifuge cake and heated. This procedure was repeated twice for all samples. They were again centrifuged and the supernatant was decanted off. Finally the samples were fractionated by multiple centrifugations into sand and silt (72 μm) and clay (<2μm) size fractions.

The <2μm sediment was prepared for X-ray diffraction analysis by saturating 0.5 grams of each sample with Mg^{+2} and K^{+}. The magnesium saturated samples were treated with ethlene glycol. The magnesium saturated and glycolated samples were sedimented onto petrographic glass slides. X-ray diffraction was run on the magnesium saturated and glycolated samples at room temperature (25°C). The potassium saturated samples were sedimented into Vycor glass slides which resist breakage on heating to high temperature. Then after heating to 555°C for 1 hour, the samples were cooled for analyses. A Phillips X-ray diffraction unit was employed using a Cu K alpha radiation source at a scanning rate of 1 degree 2θ per minute at 30 kV and 20 Ma. W. F. Bradley form factor values were used to calculate clay mineral percentages.

SUMMARY

Figure 29 shows the X-ray diffraction patterns for sediments from station 41 taken from Southern Bank. It shows the patterns of the magnesium saturated and glycolated clay fraction run at a temperature of 25°C and patterns for the clay potassium saturated and heated to 25°C, 350°C and 550°C. From X-ray diffraction patterns similar to those shown in Figure 1 the relative percentages of the clay minerals, montmorillonite, chlorite, illite and kaolinite were determined.

Table 1 shows the relative percentage of the various clay minerals for stations on the five banks. Examination of this table will readily indicate that there is little, if any, variation of clay mineral distribution within or between Baker, South Baker, Southern, Dream and Little and Big Adam Banks.

Montmorillonite is the predominant clay mineral on all banks. The percentage present ranges from a low of 58.7 percent to a high of 66 percent. Illite is the second most prominent clay mineral present on the banks. It ranges from a high of 30.0 percent to a low of 22.1 percent. Chlorite and kaolinite appear in about equal amounts and are only minor constituants of the clay mineral assemblage.

SEDIMENT SIZE

PROCEDURES FOR GRAIN SIZE ANALYSIS

Subsamples of the unconsolidated sediment from the shortcore tubes and sample bags were analyzed to determine various parameters of the surface sediment.

Grain size determination were conducted following Folk's method (1968). Approximately 15 grams of sample were first dispersed by adding 20 percent Calgon (sodium hexaphosphate) solution and then vigorously agitated on a shaking table for two hours. The sand fraction was separated from the silt and clay fractions of the sample by wet sieving through a 4 phi (230 μm mesh) screen. After drying in an oven overnight at 110°C, the sand was sieved using one-half phi Allen-Bradley sieves over the interval of -1.5 phi to 4 phi, for five minutes on a Sonic Sifter. The silt and clay fractions were determined by pipette analysis using Folk's method (1968). Draws were taken at 0 times, 7, seconds, 31 minutes, 2.03 hours, 4:05 hours and 28 hours which correspond to 4, 6, 7, 8, 9, 10.2 phi size intervals.

GRAIN SIZE PARAMETERS

Grain size results were plotted as cumulative curves to obtain the necessary percentile values needed to determine the following statistical parameters of grain size:

- Median Diameter
- Graphic Mean
- Inclusive Graphic Standard Deviation
- Inclusive Graphic Skewness
- Graphic Kurtosis

The Median Diameter is the diameter corresponding to the 55 percent mark on the cumulative curve. The measure determines that size in which half of the particles by weight are coarser than the median and half are finer.

The Graphic Mean corresponds very closely to the mean as computed by the method of moments. It is computed by the formula

$$\text{Graphic Mean} = (\phi 16 + \phi 50 + \phi 84) \;/\; 3$$

The Inclusive Graphic Standard Deviation is a measure of sorting and is determined by the formula

$$\frac{\phi 84 - \phi 16}{4} = \frac{\phi 95 - \phi 5}{6.6}$$

This formula includes 90 percent of the distribution and is considered the best overall measure of sorting.

Folk (1968) has suggested that the following verbal classification scale for sorting is the most useful:

Values less than .35ϕ, very well sorted

.35 - 0.50ϕ, well sorted

0.50 - 0.71ϕ, moderately well sorted

0.71 - 1.0ϕ, moderately sorted

1.0 - 2.0ϕ, poorly sorted

2.0 - 4.0ϕ, extremely poorly sorted

Inclusive Graphic Skewness is a skewness measure that is geometrically independent of the sorting of the sample. It measures the degree of asymmetry as well as the "sign" of the curve. This determines whether a curve has an asymmetrical tail on the left or the right (Folk, 1968). The following formula is used to determine the Inclusive Graphic Skewness:

$$\frac{\phi16 + \phi84 - 2\phi50}{2(\phi84-\phi16)} + \frac{\phi5 + \phi95 - 2\phi50}{2(\phi95-\phi5)}$$

Folk (1968) suggests the following verbal classification of values of Inclusive Graphic Skewness (Sk_I):

Symmetrical Curves $Sk_I = 0.00$

+1.00 to +0.30, strongly fine-skewed
+0.30 to +0.10, fine-skewed
+0.10 to -0.10, near-symmetrical
-0.10 to -0.30, coarse-skewed
-.30 to -1.00, strongly coarse-skewed

Graphic Kurtosis is determined by the formula:

$$\frac{\phi95 - \phi5}{2.44\ (\phi75-\phi25)}$$

This measure is used to determine the departure of the frequency curve from that of a normal probability curve. The following verbal limits are suggested by Folk (1968):

Values under 0.67, very platykurtic
0.67 - 0.90, platykurtic (flat peaked)
0.90 - 1.11, mesokurtic (normal peaked)
1.11 - 1.50, leptokurtic (excessively peaked)
1.50 - 3.00, very leptokurtic
over 3.00, extremely leptokurtic

DISTRIBUTION OF GRAIN SIZE PARAMETERS

Baker

The sediment apron surrounding Baker consists of a large variety of sediment types. Clayey sands are found at three locations; stations 2, 5, and 29,

(Fig. 30). In general, there is a large sand size fraction in most of the sediments in this area.

Figure 31 shows the range and size limits for all samples within the Baker area. Figures 32 through 38 are the individual cumulative size frequency distribution curves for the various stations on Baker.

All sediment samples analyzed were found to consist of very poorly sorted, fine to strongly fine-skewed platkurtic material except stations 30 and 32 which contained mesokurtic and leptokurtic material (see Table 2).

South Baker

All sediment around the bank consist of fine grain material mostly muds and clays. The Graphic Mean size of the sediment is spread over a very narrow range of from 0.0007 mm to 0.0018 mm (Table 2). The sediment is very poorly sorted (Inclusive Graphic Standard Deviation ranges between 2.41 to 3.78 phi units) but the distributions are not skewed and display a near symmetrical configuration. The Graphic Kurtosis value for all the sediments fall under the mesokurtic classification.

Examination of Figure 40 displays the degree of similarity of the sediment size distributions. They are all contained in a narrow band on the size frequency distribution curve. The individual size frequency distribution curves are shown in Figures 41 through 43. Unlike Baker, South Baker sediments contain only very limited amounts of sand size material. Station 13A, on the southeastern sediment apron flanking the bank, had the highest sand size material. Station 13A, on the southeastern sediment apron flanking the bank, had the highest sand content, 12.7 percent.

Southern

Southern is similar to Dream and Baker Banks in that there is a wide variation of sediment types found within the area. Figure 45 shows the range of the cumulative size frequency distribution curves for the Southern Bank area. Individual size frequency curves are shown in Figures 46 through 51. Most of the fine grain sediments are located around the flanks of the bank.

These sediments are mostly muds and clays whose Graphic Mean range from 0.0210 mm to 0.0009 mm (Table 3). The coarser grained sediments, station Nos. 36 and 39 (Fig. 44) are found in close proximity to the bank. Sediments from station 36 have a Graphic Mean of 1.500 mm. This station is located some distance up in the bank proper.

All the sediments samples (both fine and coarse grained) are very poorly sorted. Sediments from station No. 39, 41 and 44 are strongly fine-skewed while sediments from station 42 consist of coarse-skewed material. The remaining sediments have a symmetrical sediment size distribution, skewed neither to the fine nor to the coarse fractions.

The majority of the sediments are characteristically platykurtic to mesokurtic. Samples from stations 39 and 41 are very leptokurtic and leptokurtic respectively.

Dream

The sediments, stations 60, 65 and 75 (see Fig. 24), on the east and south flanks of the major structure of Dream are coarse grained clayey sands. These sediments have median diameters of 0.435 to 0.500 mm. All the remaining sediments samples collected from the Dream area consist either of muds or clays. These muds and clay sediments are very poorly sorted, (see Table 4), are near symmetrical to coarse-skewed and their size frequency distributions are platykurtic to mesokurtic in character. Figure 53 shows the range of the size frequency distribution curves and Figures 54 through 56 display the individual size frequency distribution curves for all sediment samples.

Big Adam and Small Adam Rock

All sediment samples taken from this area, except from station 86 (see Fig. 57), consist of either muds or clays. Sediments from station 86 are sandy muds with a sand fraction that amounts to 16.8 percent of the total amount. The muds and clays of this area are very fine grained with an average median diameter and a Graphic Mean of around 0.0015 mm. All the sediments of the area are very poorly sorted, and their size frequency distribution curves are near-symmetrical to coarse-skewed and all are platykurtic in character (Table 5).

Figure 58 shows the extremely narrow band of the sediment size frequency distribution curves when their boundaries are plotted altogether. Figures 59 through 63 display the individual size frequency distribution curves for all sediment, (except station 86) from Big Adam Rock and Small Adam Rock.

SUMMARY

The surficial sediments around the banks Baker, South Baker, Southern, Dream and Big Adam Rock and Small Adam Rock are in general fine grained sediments present in the areas surrounding the banks but they are definitely in the minority and generally consist of muddy sands. All these surficial sediments are derived mostly from the Rio Grande River and perhaps some from the Colorado River. The heavy mineral assemblages of these sediments consist solely of Rio Grande and weathered Rio Grande material. From all indications the seasonal currents in this area are incapable of eroding or transporting sediment particles above the fine sand size (about 0.1 to 0.2 mm in diameter) range. No current data is available for the areas around the banks nor is there any indication of bottom current activity, such as ripples or other sediment structures, that would indicate current strengths or directions. The nepheloid layer observed below the 60 meters depth level would indicate that a certain amount of current activity is present in the area. An educated guess would be that currents on the order of about 5cm/sec. (at one meter above the bed) exist in the area during normal wave activity (wave heights of less than 1.2 meters).

Bottom currents in excess of 20cm/sec are necessary for erosion of fine sands and unconsolidated silts and clays (see Fig. 64). Storm waves of long period and great wave heights are the most likely mechanism for the erosion and transportation of sediments from the banks and those that comprise the sediment aprons around the banks. An example of the wave conditions that can occur in the Northwest Gulf of Mexico on the continental shelf is given by the hindcasting of hurricane generated waves from hurricanes Carla, Betsy and Hilda, as determined by Patterson (1971), see Table 6.

The eye of hurricane Carla moved almost directly over the Stetson Bank area which is about 220 Km east of the banks covered by this report. If Pattersons's calculations are correct, we would expect wave heights somewhere between 9 to 12 meters (at a water depth of 61 meters) during the passage of a hurricane similar to Carla. Figure 65 shows the relationship between the erodible particle size, water depth, and maximum wave current velocity for different wave fields common to Gulf of Mexico. Curves C and D on Figure 37 are for wave fields of 9.8 to 13.7 meters respectively. If these tables, curves and hindcasts are anywhere near correct they would indicate that sediment particles in excess of 80 mm in diameter (Curve D) would be eroded from the banks under conditions similar to the largest of the projected waves of hurricane Carla. A piece of gravel 80 mm in diameter is a large sediment size for sediment found in the Gulf. However, examination of Figure 36 indicates that the velocity capable of eroding gravel sized sediments is necessary to erode consolidated fine silts and clays. The degree of consolidation of the surficial sediments around Baker, South Baker, Southern, Dream and Big Adam Rock is unknown but it is suggested that they fall in the categories somewhere between underconsolidated to normally consolidated material. It is more realistic to consider that the wave velocities from a large hurricane would best be represented by curve C in Figure 65 in which case particles up to 15 mm in diameter could be eroded along with unconsolidated silts and clays. However, silts and clays that have a fairly low degree of consolidation would not be affected. Waves created under conditions other than hurricanes are also capable of transporting fairly large sediment particles and unconsolidated silts and clays. Curve B on Figure 65 is for wave height of 13 feet (3.96 meters) a length of 350 feet (106.68 meters) and a 8.2 second period in 180 feet (54.86 meters) of water. Such wave conditions as this are not infrequent during the winter months in the Gulf of Mexico. These storm wave conditions are capable of moving sand sized particles of up to 2.5 mm in diameter and unconsolidated silts and clays but are not capable of moving fine silts and clays which have been consolidated to any degree. It is not surprising that there is a little sediment cover on any of the banks except those found in depressions. In general, it seems that storm wave conditions are the major mechanisms that keep the banks clean of sediments.

Underconsolidated fine silts and clays are eroded at a velocity of around 20cm/sec while consolidated fine silt and clays are extremely difficult to erode, velocities ranging from 400 to 500 cm/sec are required. Since the degree of consolidation of the fine silts and clays on the flats adjacent to the banks would fall somewhere within the underconsolidated to partially consolidated category it would take current velocities in the range of from 30 to 70 cm/sec for erosion to take place. Examination of Figure 64 shows that any fine grained material put in suspension, whether by erosion or by discharging from a river source, can be maintained in suspension and transported great distances by extremely low velocity currents.

Once material like that found in the nepheloid layer around the bank area is in suspension it may take months to years before it will finally settle to the sea-floor.

CARBONATE ANALYSES

TECHNIQUES

Total Carbonate

Total $CaCO_3$ in the sediment was determined by Scheibler method as described by Bouma (1969). Three grams of sample are placed in a bottle together with 15 ml distilled water and a small plastic beaker containing 7 ml HCl (25 percent). After the bottles are sealed, the acid and the sample are mixed by shaking the bottle and the volume of gas evolved is measured in a water-filled burette to which the bottle is connected by plastic tubing. The accuracy of this method may be checked by analyzing duplicate samples. According to Bouma (1968, p. 48), if there is less than 2 percent $CaCO_3$, the duplicates may not differ by more than 0.20 percent. For over 5 percent $CaCO_3$, less than 0.5 percent difference should result.

X-Ray Diffraction

The coarse fractions (<62μm) of the grain size analyses were recombined and thoroughly mixed. These samples were then divided into two parts on a microsplitter. One-half was retained to prepare scatter mounts for particle type identification and the other half, when there was a sufficient amount, was prepared for X-ray diffraction. The sample was hand-ground in an agate mortar and pestle. The sample was then seived through a 270-mesh (53μm) seive using a Sonic Sifter. The 53μm sample was then pressed into the window (1.5 x 1.0 cm) of an aluminum powder sample holder.

A Phillips X-ray diffractometer was used with a source of Cu Ka radiation at 30 KV and 20 MA. The goniometer scanning rate was 1° 2 θ per minute and the recorder speed was 2° per inch. The 3.35 Å quartz peak was located manually as an internal standard and the sample was then scanned from 27° to 31° 2 θ (.30 - 2.88 Å).

A series of 24 known mixtures of quartz, calcite, and aragonite (Table 7) were run in order to establish a basis for quantitative determinations. The resulting peaks were cut out and weighed on a Sartorius balance. (See Table 7). A regression analysis was conducted on the weight of the peaks against the known percent carbonate. This yielded a formula in the form of:

$$Y = mX + b$$

Y = percent calcite in the sample

X = Peak weight (gms) of unknown

The values of m and b were found to be 326.35 and -0.9043 respectively (See Fig. 66).

A regression line for aragonite was not prepared as the 3.396 Å aragonite peak area was too small, even at concentraction of 40 percent, to give reliable results. Milliman (1974, p. 27) indicates that the 3.40 Å peak is 0.35 as intense as the (211) calcite (oyster peak). This would account for the extremely low intensity argonite peaks. Milliman (personal communication) has stated that the 3.48 Å figure on page 27 is a typographical error and should read 3.40 Å.

Particle Type Identification

The portion of the recombined coarse fraction (>62μ) retained for scatter mounts was mounted on 1 x 3 inch (2.5 x 7.6 cm) glass slides and examined using a Zeiss petrographic microscope. Grain counts were made on each slide in order to determine gross composition. A Swift point counter was used and 200 grains were identified on each slide. Ten components were selected as compositional parameters based upon relative abundance in the samples. These are: quartz, planktonic foraminifera, benthic foraminifera, echinoderms, molluscs, coral, algae, pelletoids, rock fragments, and miscellaneous. The miscellaneous category includes heavy minerals and unidentified skeletal fragments.

RESULTS

Total Carbonate Analysis

Total carbonate in surface sediment samples varies from 2.3 to 78.4 percent. It is difficult to correlate these figures with the X-ray diffraction analyses as the total carbonate analyses were run on whole samples while the X-ray diffraction analyses were run on the >62μm fraction. Some samples probably contain large amounts of calcareous nannoplankton which would not be included in the X-ray results because of their small size. The results of the total Carbonate analyses are shown on Table 8.

X-Ray Diffraction

Only 21 samples contained enough $CaCO_3$ in the coarse fraction to permit X-ray diffraction analysis. These samples are listed in Table 9. Three kinds of calcite were found in the samples. These were: 1) low Mg calcite containing 0.0 to 5.5 mole percent $MgCO_3$, and 2) intermediate high Mg Calcite containing 7 - 12.5 mole percent $MgCO_3$, and 3) high-high Mg Calcite with 13.5-31 mole percent Mg CO_3. Percentages of $MgCO_3$ were derived from the curve published by Goldsmith and others (1961). The highest concentration of $MgCO_3$ is seen in sample 22 and probably represents a fragment of coralline algae. The point count results for sample 22 do not show the presence of coralline algae. The X-ray analysis shows this to be only 0.4 percent of the total coarse fraction so it is not surpdrising that coralline algae are missing from the point count for this sample. The intermediate high Mg calcite peaks probably are due to the presence of molluscs, echinoderms and foraminifera. The low Mg calcite is probably due to the presence of molluscs and foraminifera.

Summary of Partical Type Identification

Fourteen samples contained too little calcareous material in the coarse fraction to be counted. Table 10 includes the counts for all samples plus the sand, silt, clay ratios for each sample. Increases in the amounts of molluscs, coral, and lithoclasts occurring in the sediment indicates proximity to a bank.

SEDIMENT CORES

Of the 23 cores taken at master stations, 22 were analyzed. One core was totally disturbed due to flow-in. The lithologies of cores were described and color coded. The cores were radiographed and featues depicted on the radiographs described 53 sediment samples taken from the cores and subjected to total $CaCO_3$ analysis and grain size analysis. The information from all these analyses is presented in Appendix A.

Nine of the cores contained significant amounts of coarse carbonate sediment. These are listed in Table 11 with the depths of the coarse intervals and the distance of the core from the bank.

High resolution sub-bottom profiling reveals a transparent interval beneath the late Holocene and recent clays of the interbank areas, covering large areas of the South Texas continental shelf. The clay cover of this zone thins towards the banks and the transparent zone appears to surface immediately adjacent to the banks. This transparent layer has been interpreted to be a sheet of carbonate sand. The coarse carbonate sediments found at depth in the cores substantiates this interpretation.

PETROLOGY OF BANK ROCKS

Rocks were obtained from Baker, South Baker, Southern, Dream, Big Adam and Small Adam by piston coring, dredging, box coring, and Van Veen grab. The rocks consisted entirely of dead coral and coralline algae nodules. The algal nodules recovered from the surface of the banks were generally stained black with iron and manganese. Nodules that occur at some depth in the cores are unstained and appear rather fresh when the enclosing mud is washed from them. The dead coral from the bank surfaces was generally quite extensively bored by worms and molluscs. Corals recovered from cores were quite fresh in their appearance.

One sample of coral from Dream, taken from a depth of 68 meters, was unweathered and contained very few borings. X-ray diffraction analysis showed the coral to be 100 percent aragonite. The radiometric age of this coral is 10,580 $\pm$ 155 years B.P.

A coralline algal nodule from Dream, taken from a depth of 69 meters, appeared to be extensively bored and weathered. X-ray diffraction analysis showed the nodule to consist primarily of high-Mg calcite containing a substantial amount of quartz and a minor amount of aragonite. No C_{14} date has been obtained on this sample as yet.

A sample of coralline algae dredged from Southern at a depth of 73 meters yielded a C_{14} age of 18,900 + 370 years B.P. No X-ray analyses have been conducted on this sample as yet.

X-ray analyses were run on two samples of coralline algae from Baker. One sample, collected by a Van Veen grab sample at a depth of 62 meters appears extensively bored and weathered. It consists primarily of high-Mg calcite containing small amounts of quartz, low-Mg calcite and aragonite. The sample was found in a core 30 cm below the sediment surface. The core was taken in water depth of 75 meters. The nodule appeared to be unweathered and to have a minimal amount of boring. It consisted primarily of high Mg calcite with minor amounts of quartz and aragonite.

INTERPRETATION

The few samples that have been analyzed to date have yielded important information regarding the Holocene history of the Texas continental shelf. However, the interpretations presented here are primarily speculative and await further detailed sampling on a single bank before they can be substantiated.

The two C_{14} dates seem to fit the USGS paleogeographic model developed by Henry Berryhill (personal communication). Dream is situated on the north flank of a roughly east-west trending late Pleistocene trough. Southern Bank lies about 48 Km to the north. During a regression the shoreline in this area would migrate southward and during a transgression the shoreline would migrate northward. The reef at Southern probably grew during the regression at about 18,000 years ago. As sea-level rose during the following transgression, a reef developed at the site of Dream and continued to grow until about 10,000 years ago.

The absence of low-Mg calcite in most of the samples analysed indicates that the banks were never exposed sub-aerially at anytime after their growth. The sample from Baker is the only one that showed appreciable amounts of low-Mg calcite.

The presence of unrecrystallized aragonite in the coral from Dream indicates the Dream has not been above sea-level for at least the past 10,580 years. Silica, present in most of the weathered algal nodules is probably a submarine replacement of skeletal material.

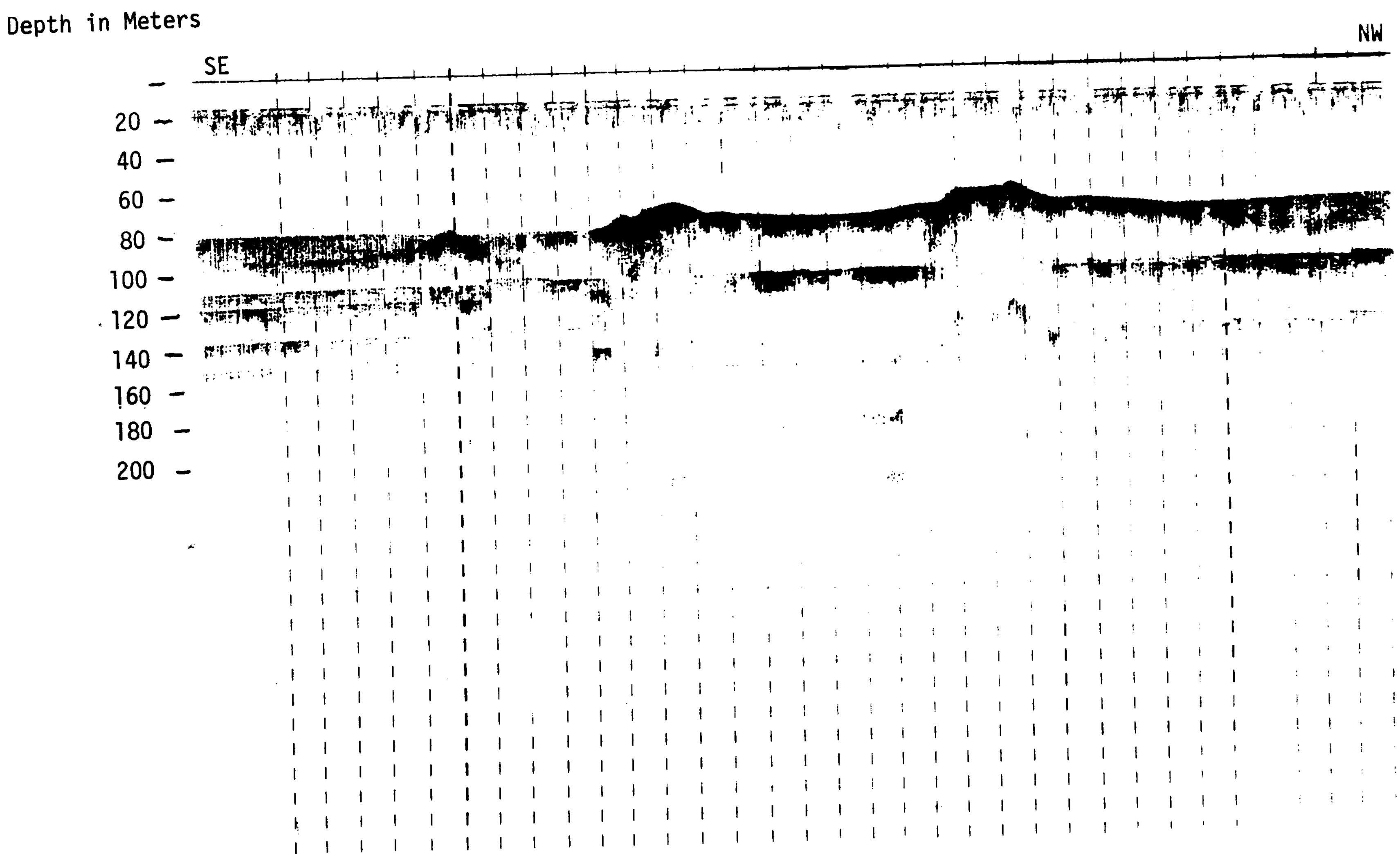


Fig. 1 Sub-bottom profile along Line A of Hospital Bank
Space between vertical lines is 500 ft.

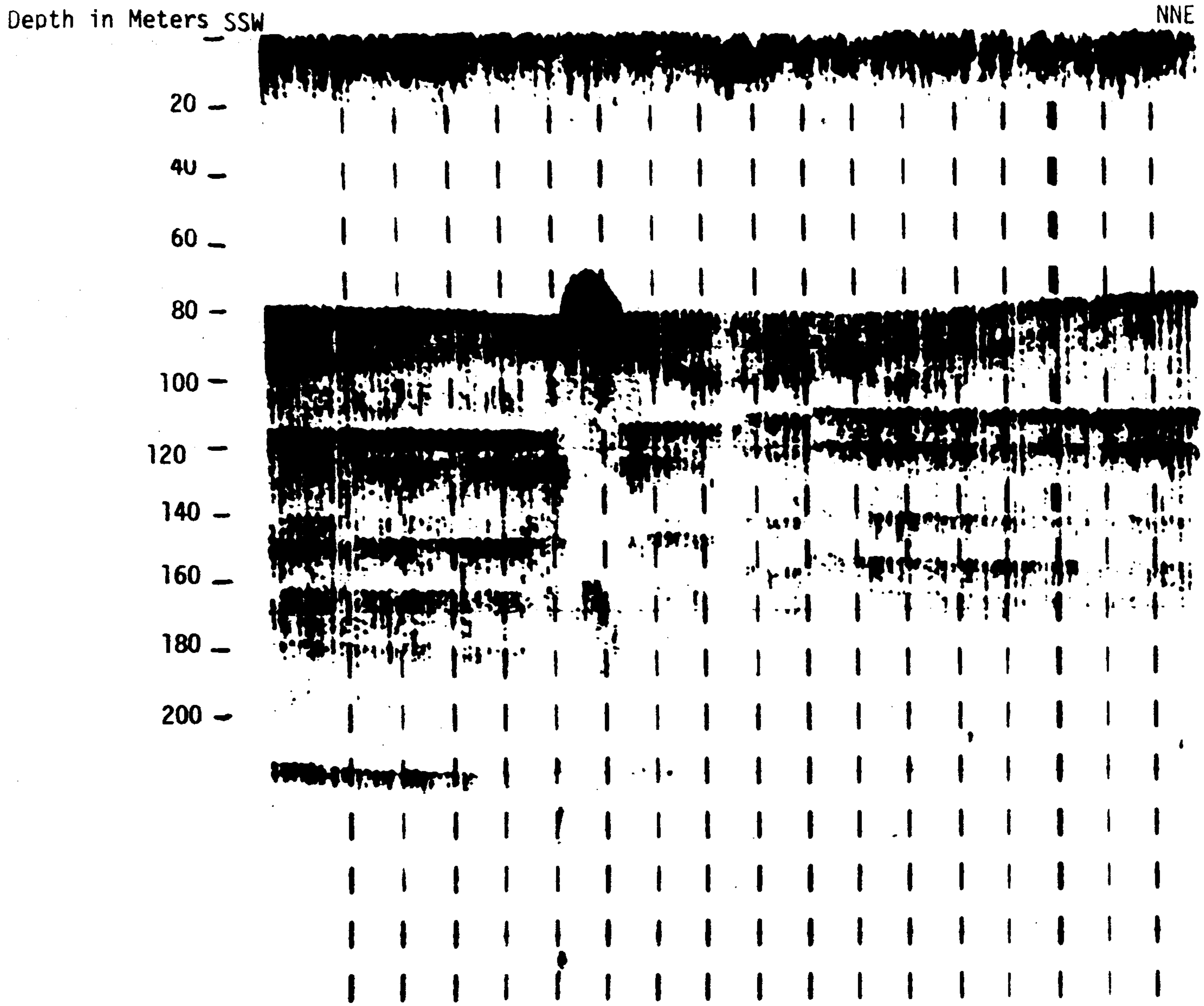


Fig.2 Sub-bottom profile along Line 9.5 of Hospital Bank
Vertical Lines are 500 ft. apart.

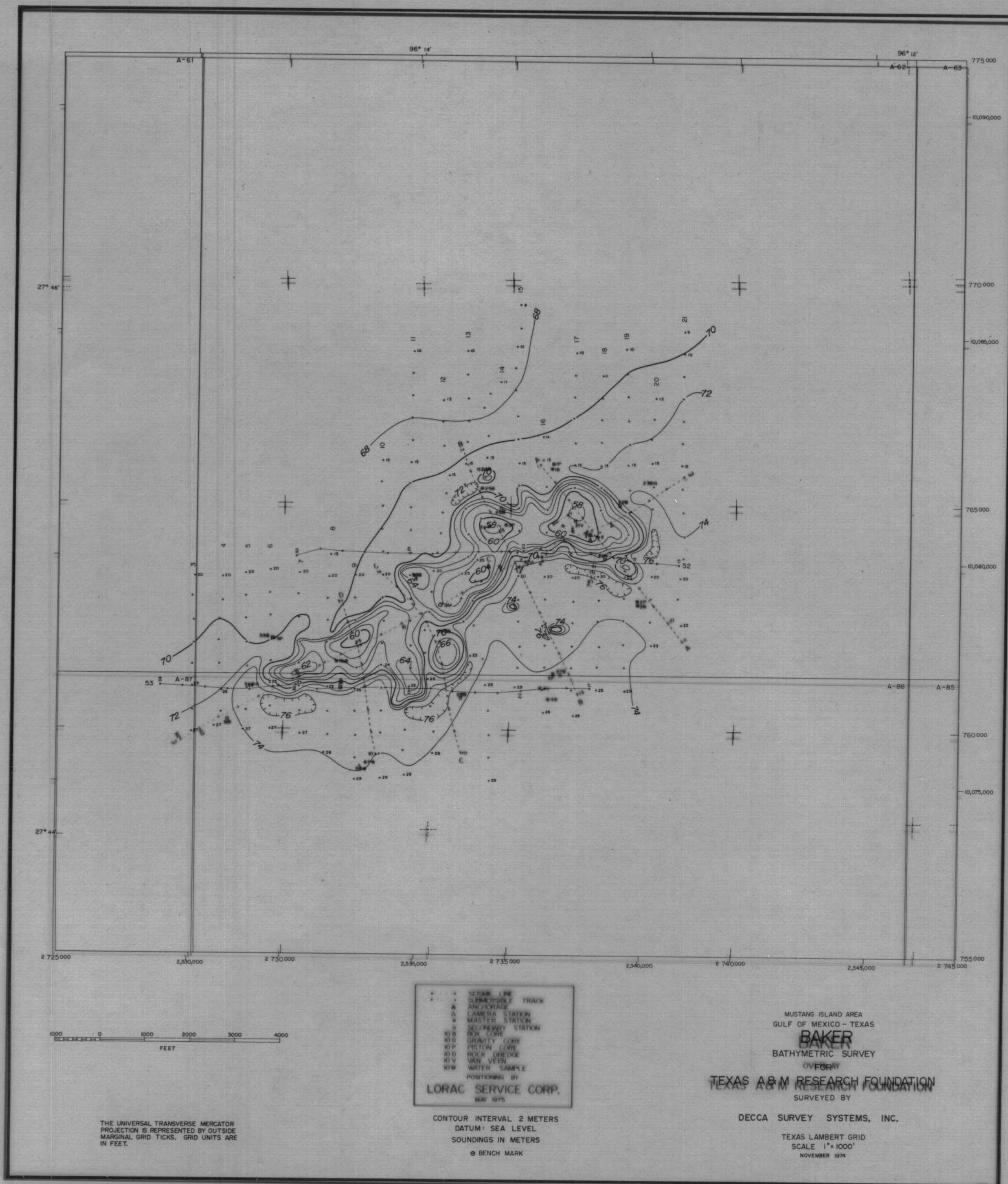


Fig. 3. Bathymetric Chart of Baker Bank

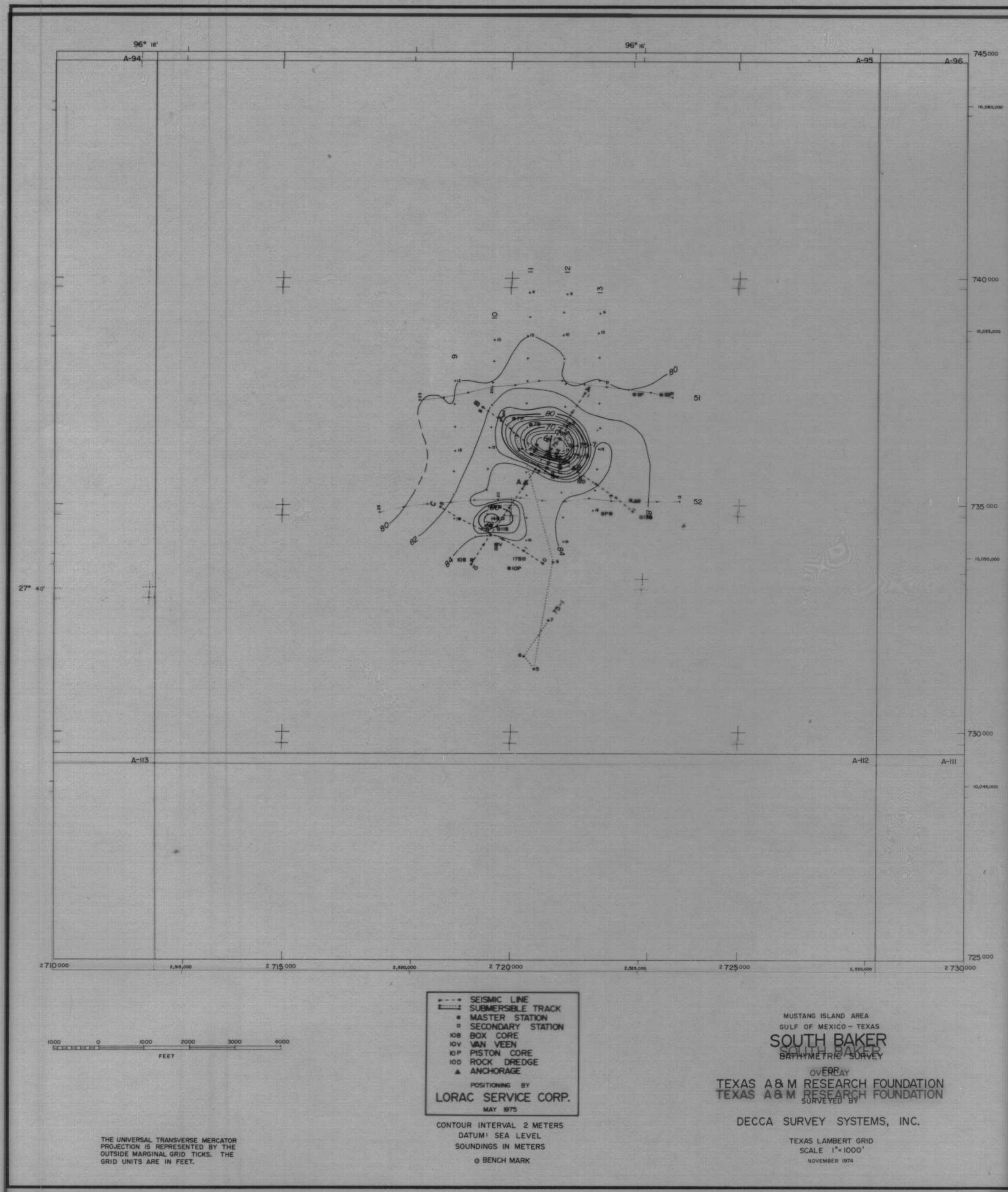


Fig. 4. Bathymetric Chart of South Baker Bank

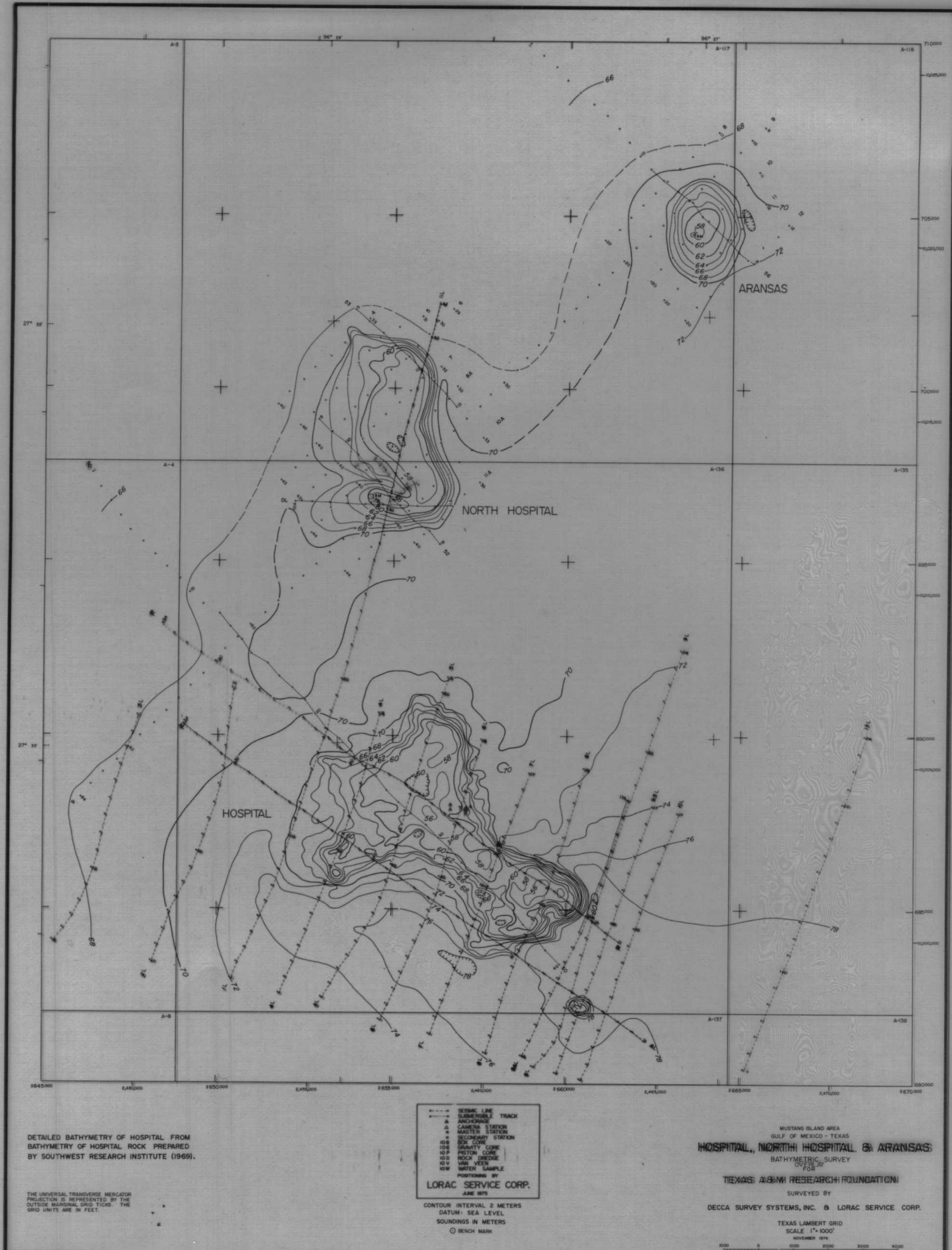


Fig. 5. Bathymetric Chart of Aransas, North Hospital and Hospital Banks

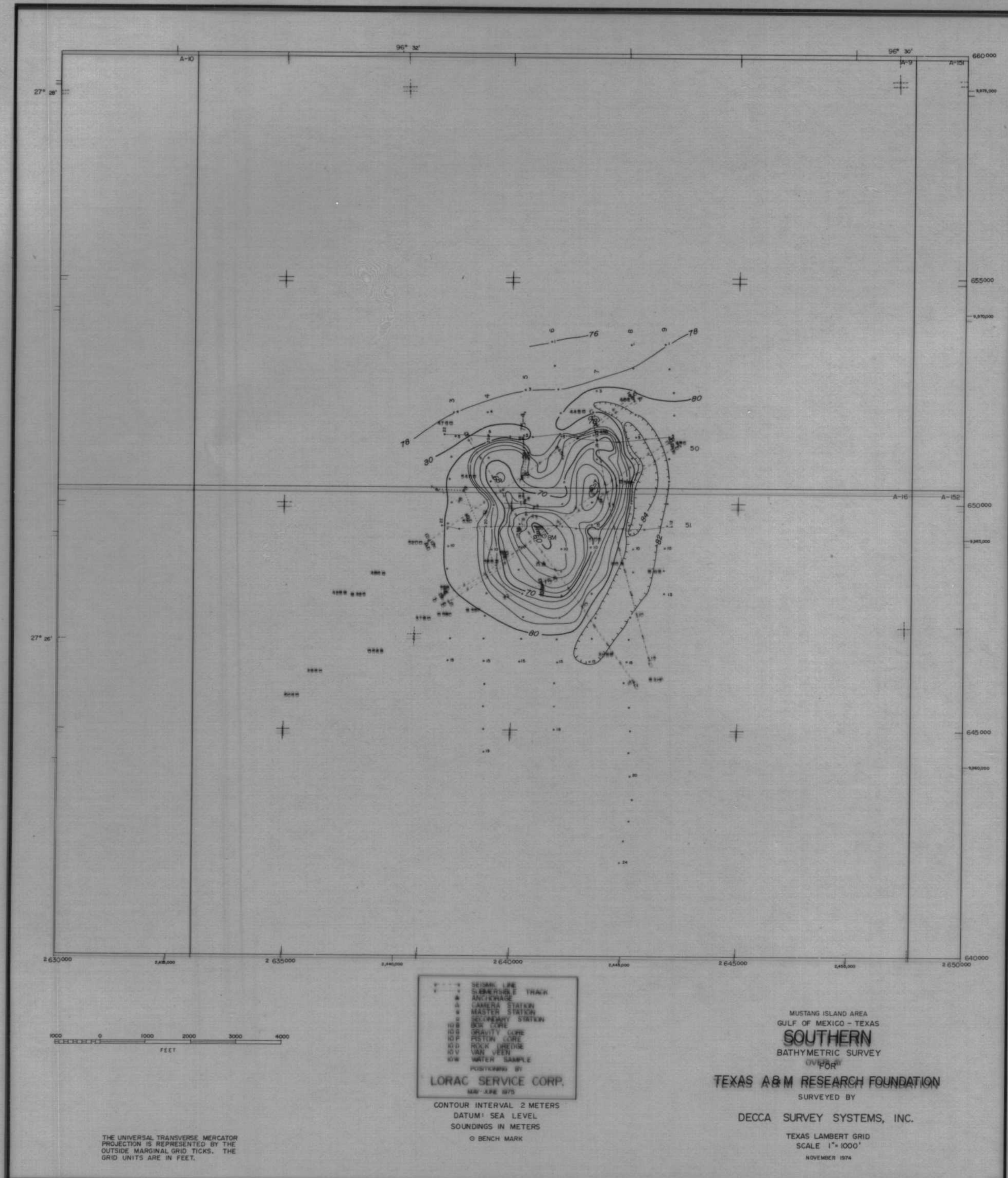
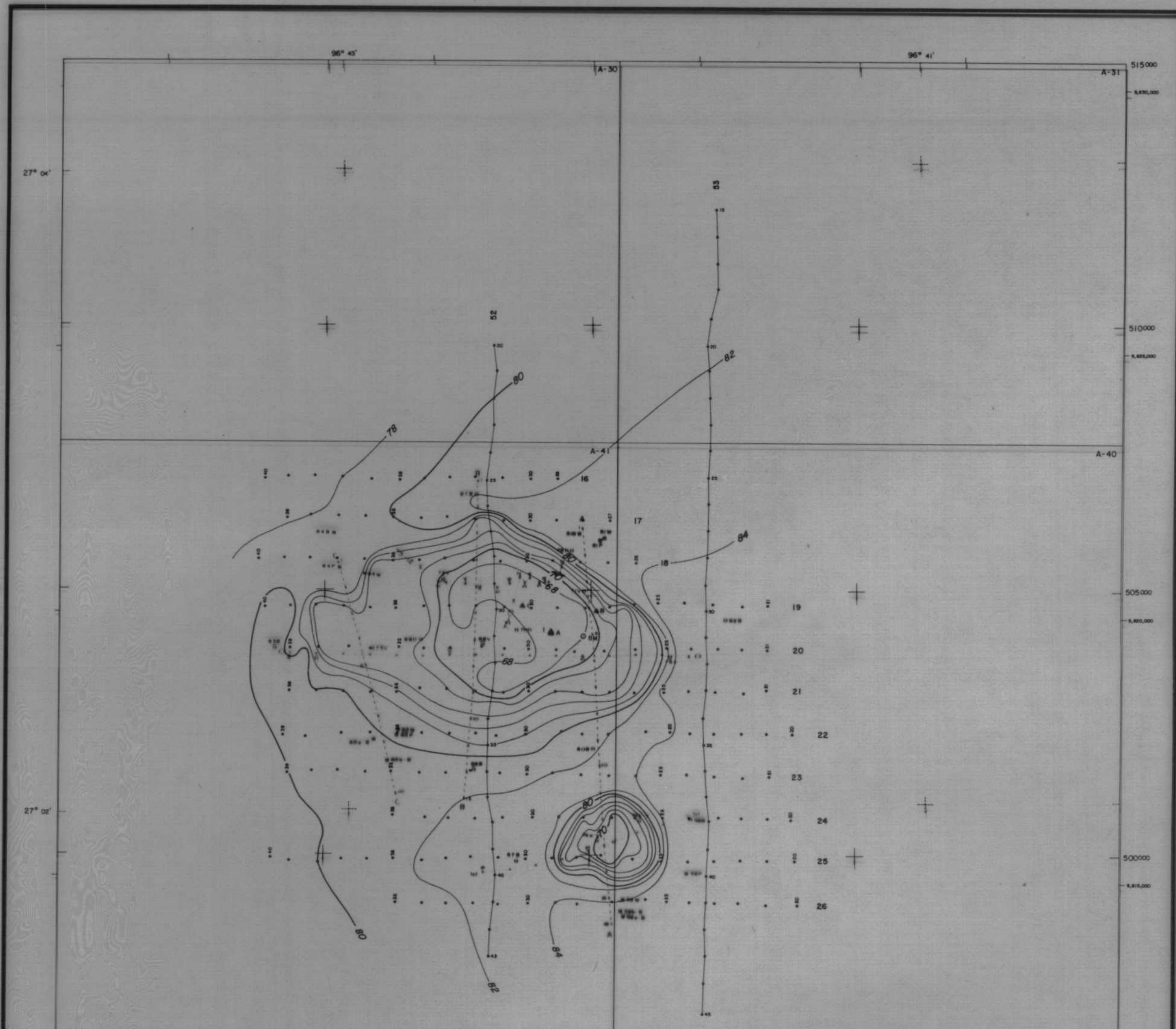


Fig. 6. Bathymetric Chart of Southern Bank


96° 43'
96° 41'
A-30
A-31
A-41
A-40
27° 04'
27° 02'
515000
510000
505000
500000
52
53
78
80
82
84
68
16
17
18
19
20
21
22
23
24
25
26

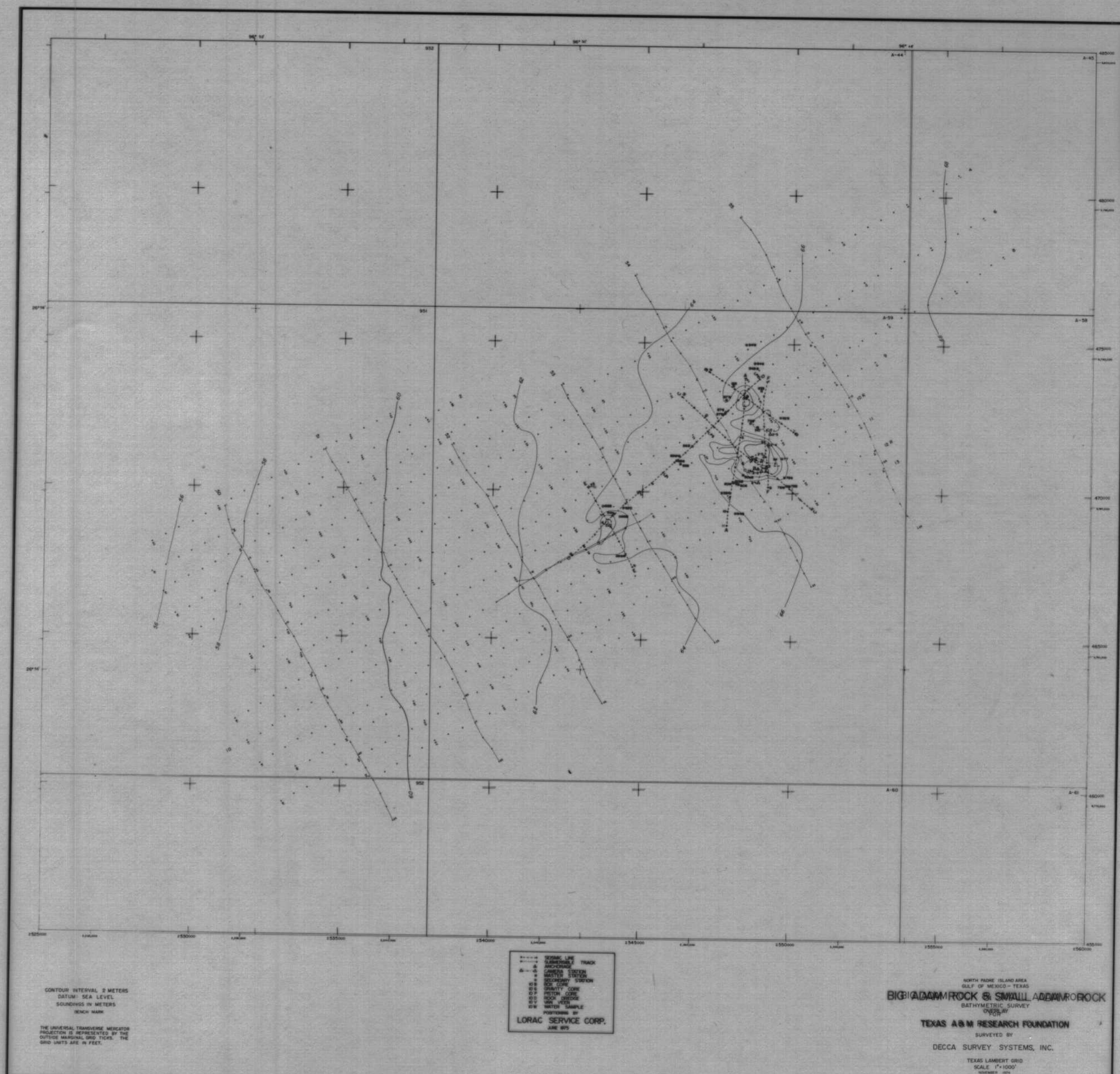


Fig. 8. Bathymetric Chart of Big Adam and Small Adam Rocks

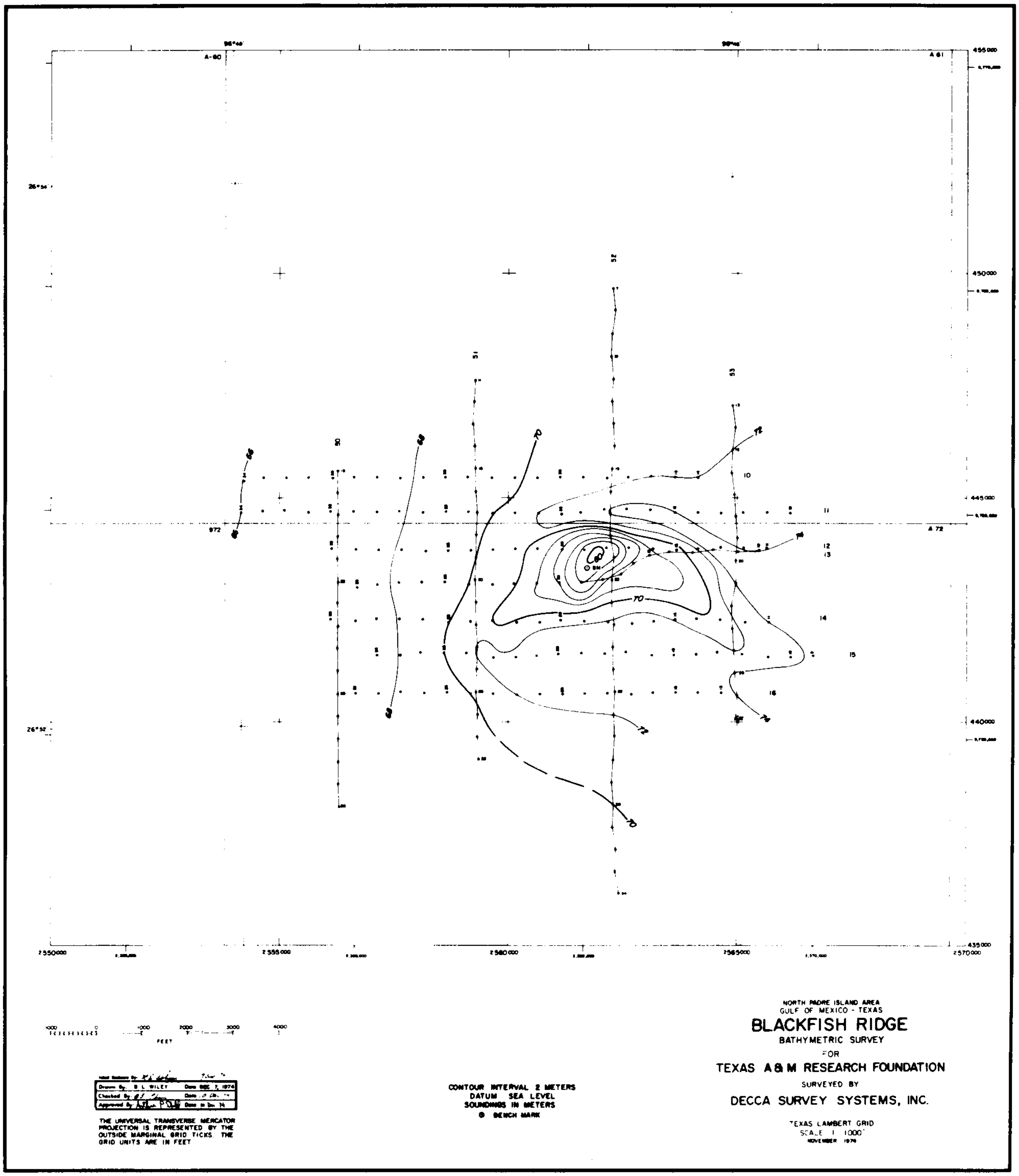


Fig. 9. Bathymetric Chart of Blackfish Ridge

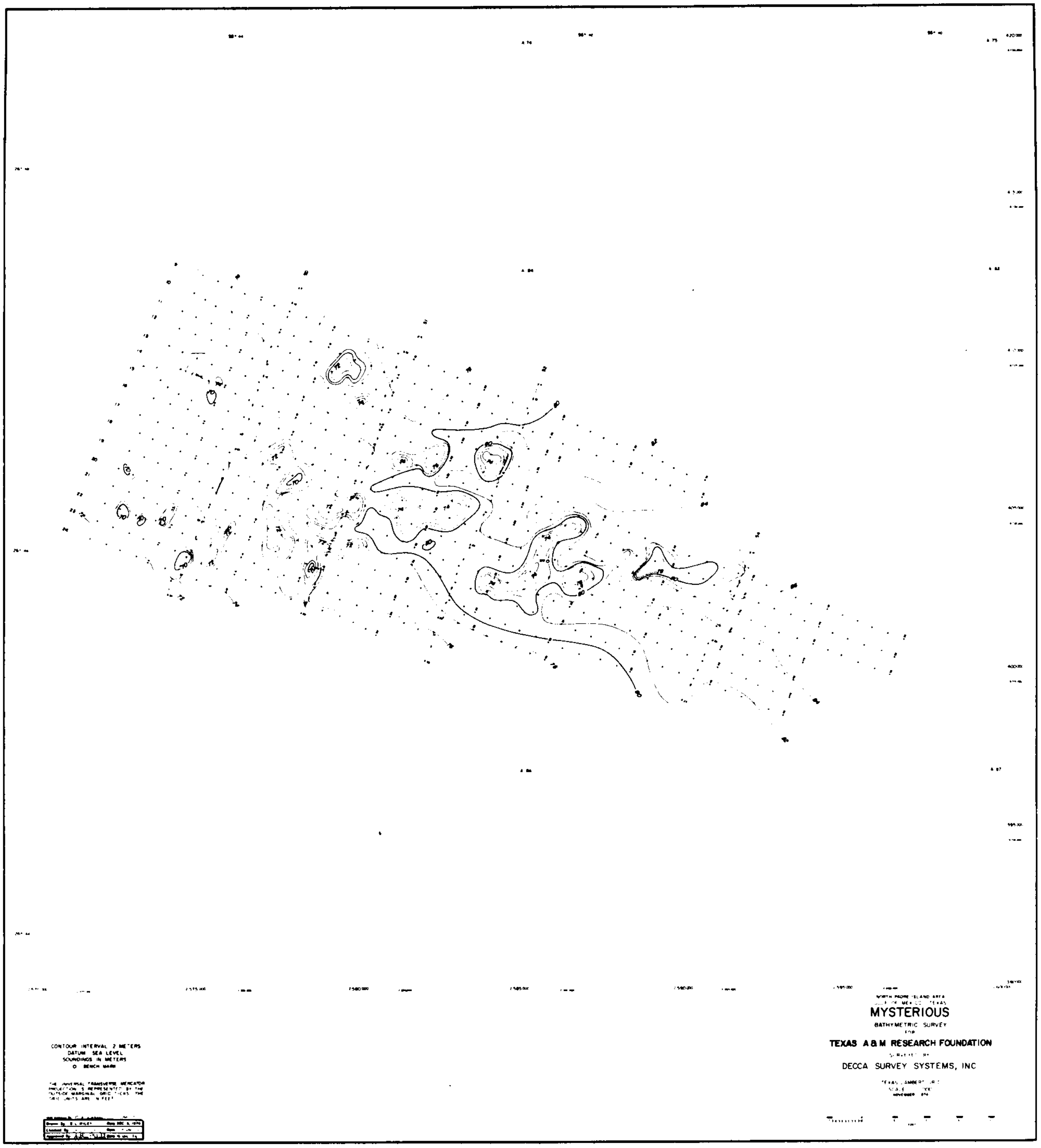


Fig. 10. Bathymetric Chart of Mysterious Bank

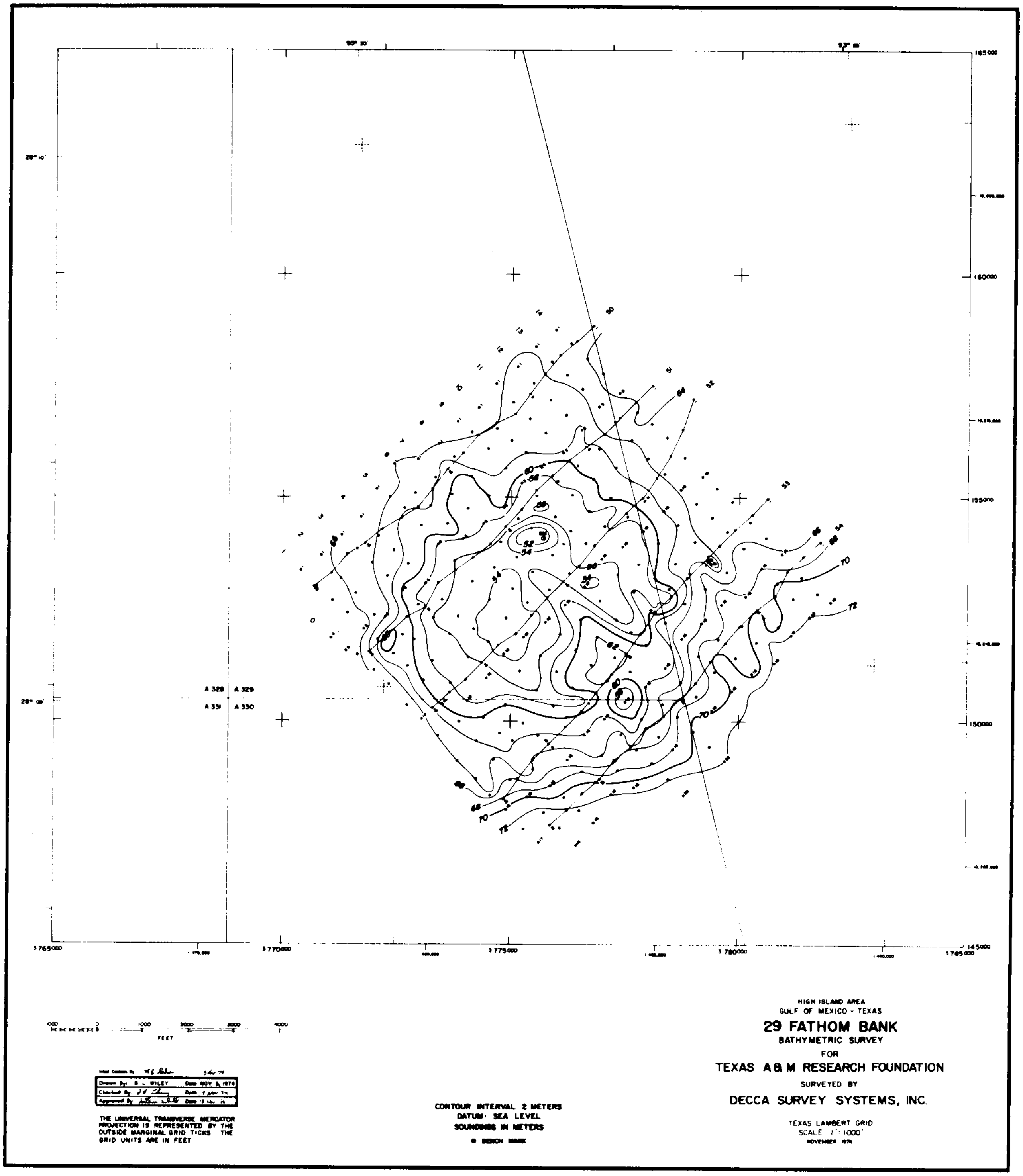


Fig. 11. Bathymetric Chart of 29 Fathom Bank

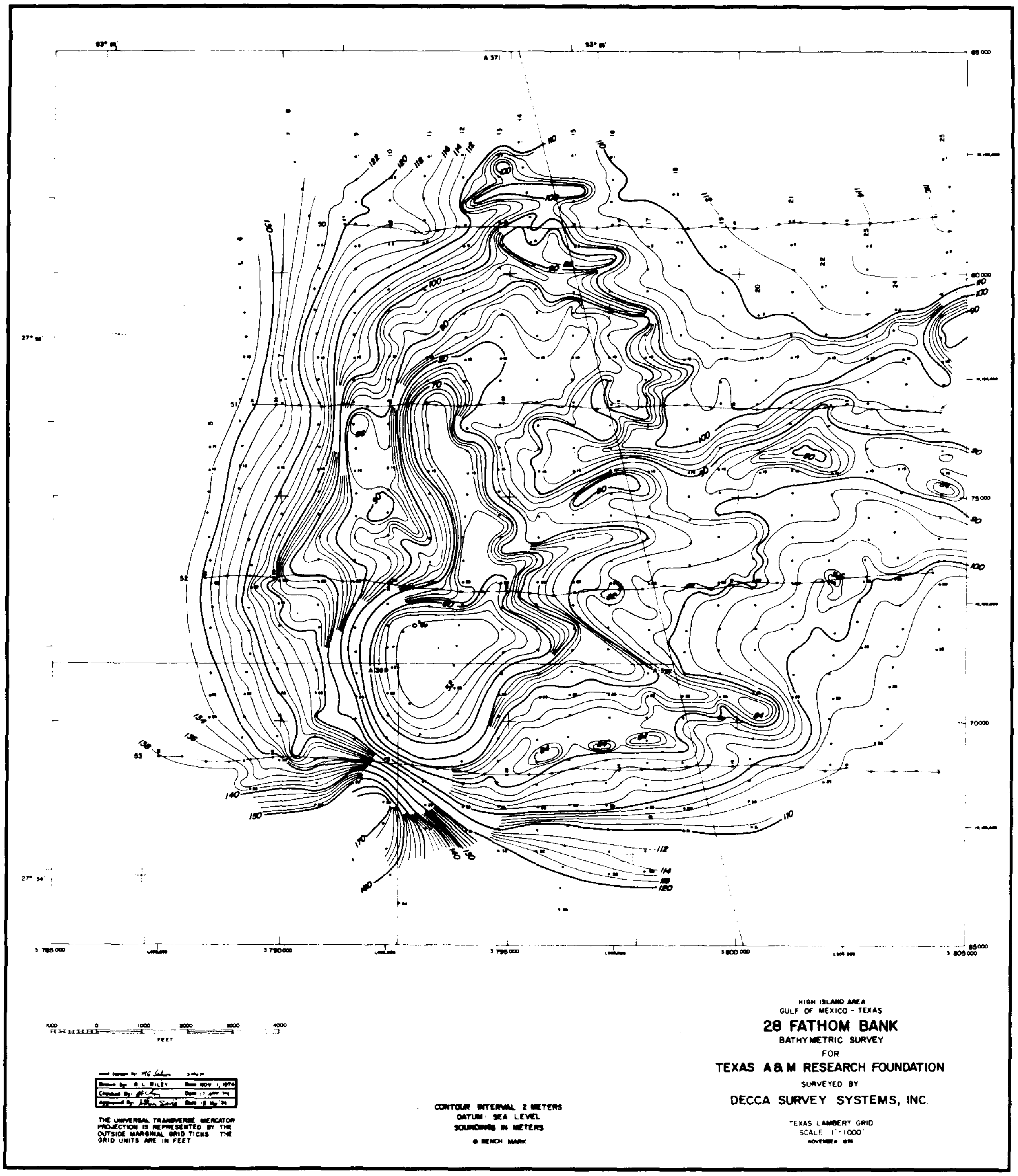


Fig. 12. Bathymetric Chart of 28 Fathom Bank

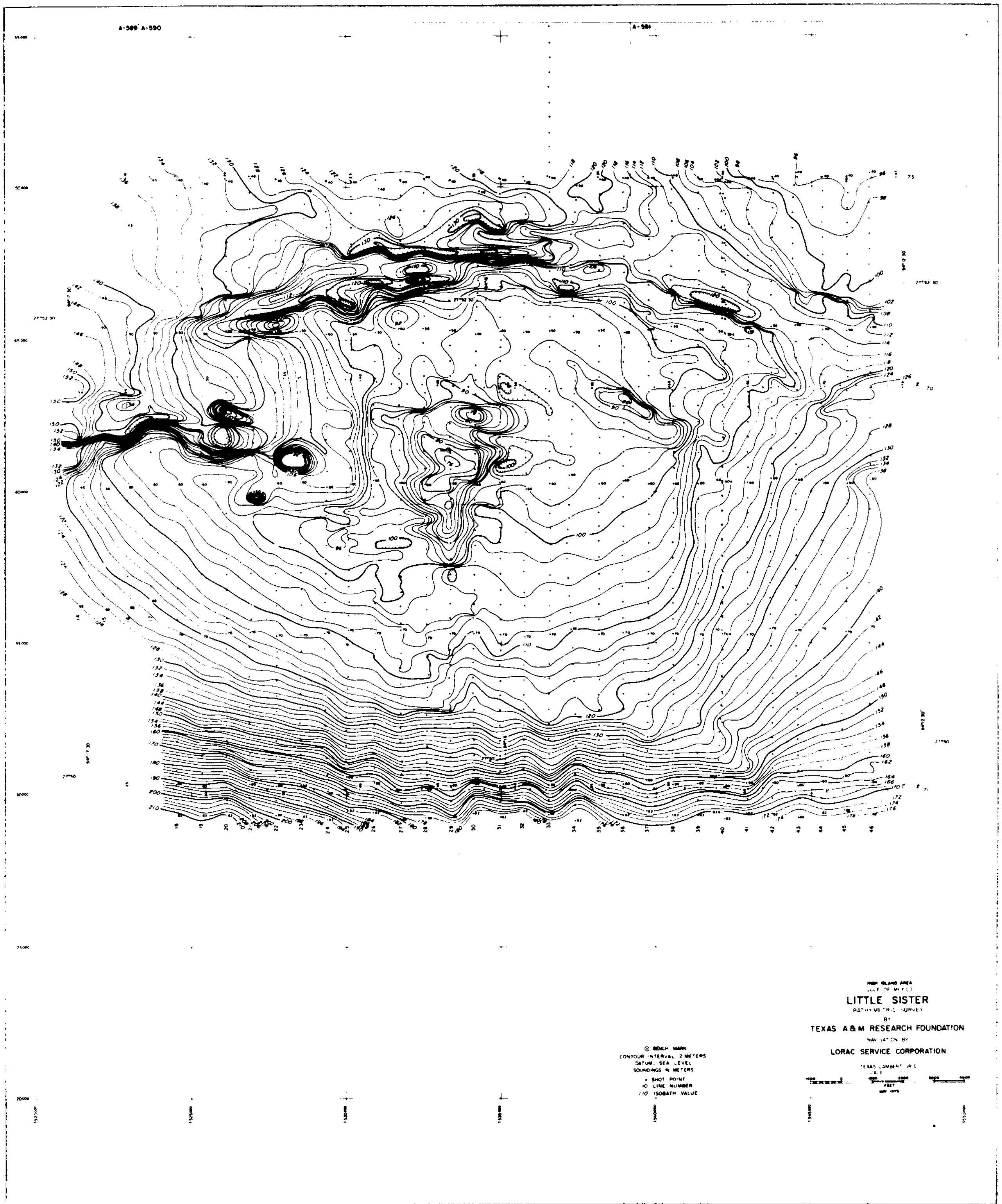


Fig. 13. Bathymetric Chart of Little Sister Bank

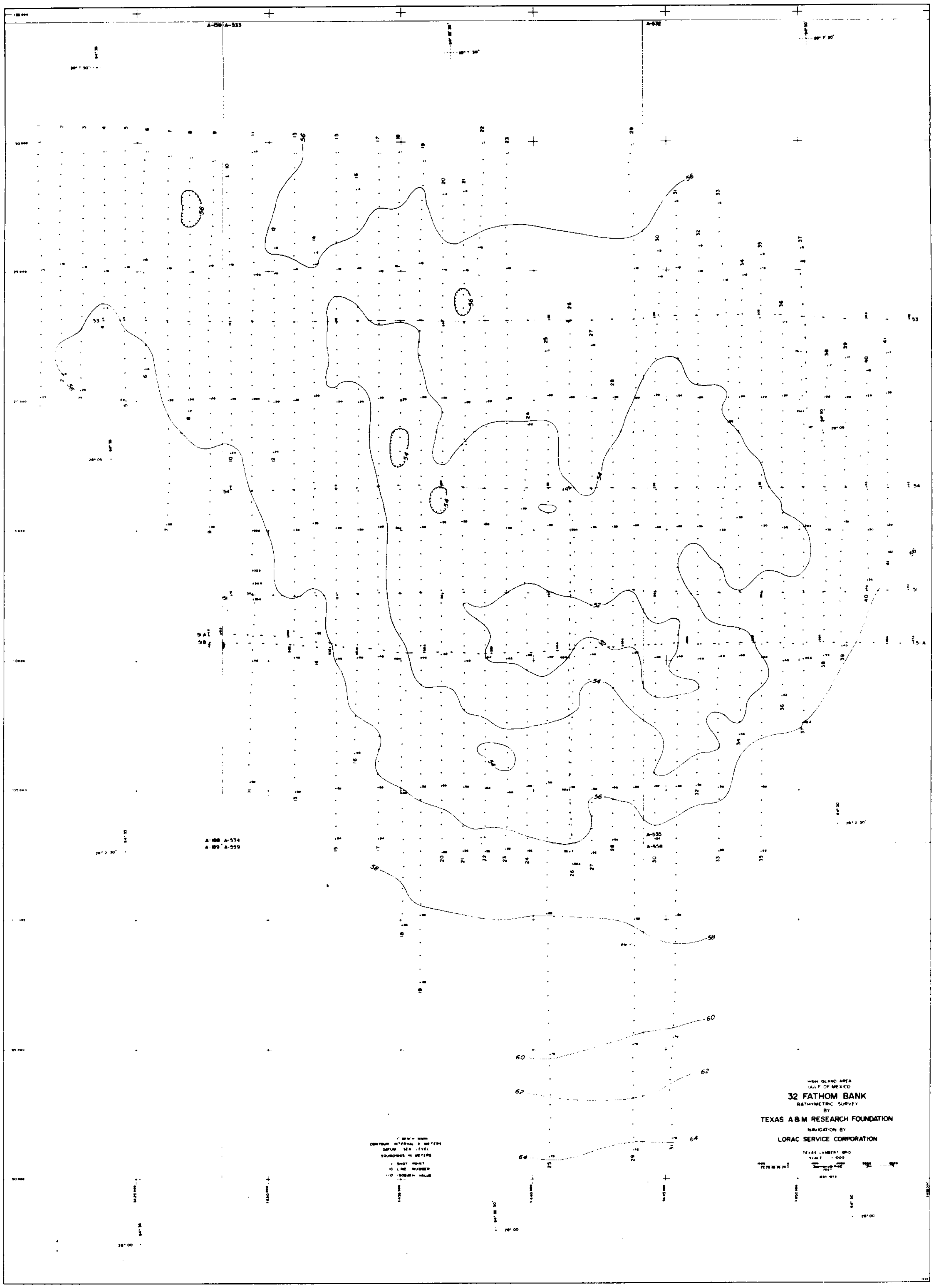
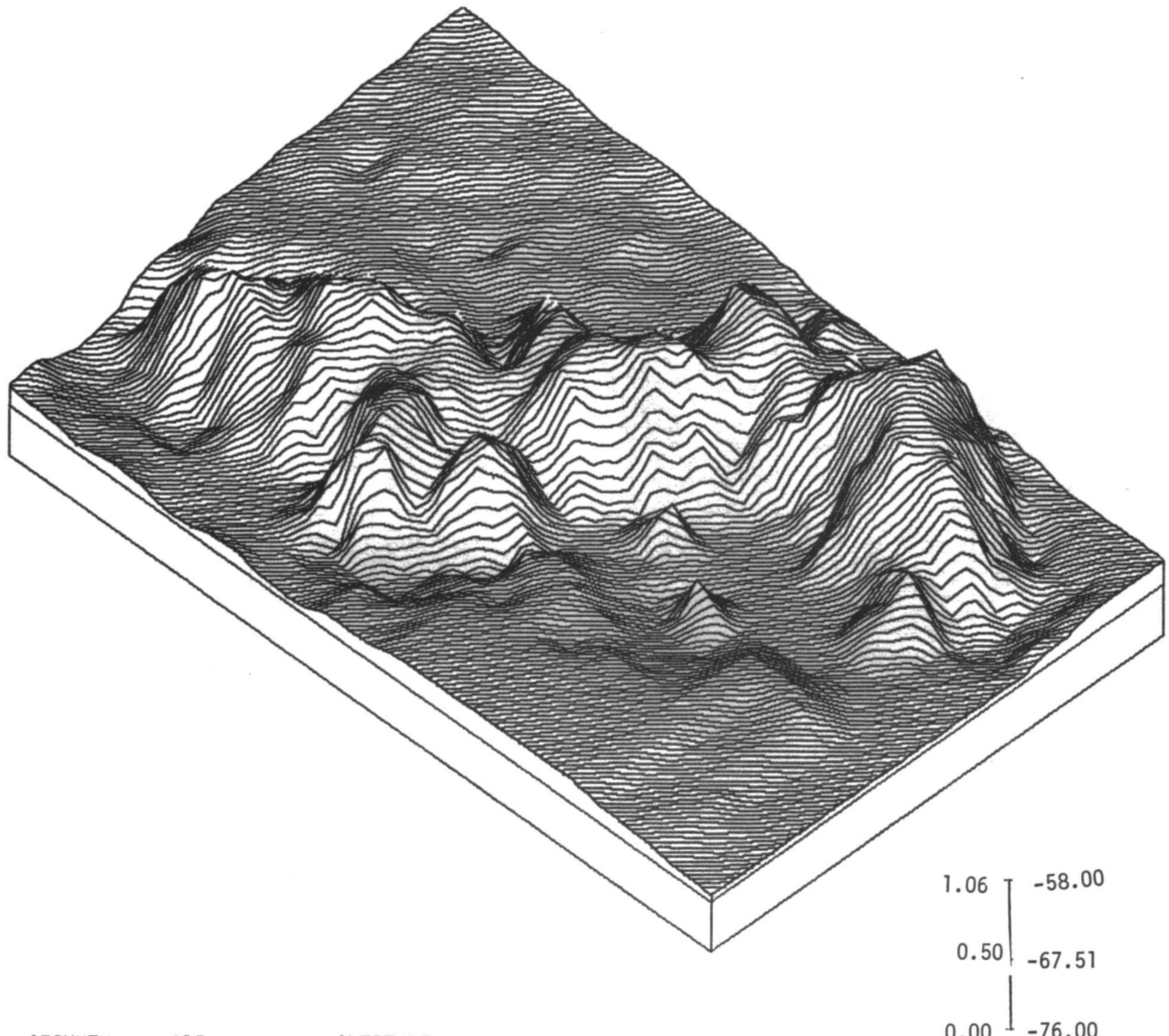


Fig. 14. Bathymetric Chart of 32 Fathom Bank



AZIMUTH = 315   ALTITUDE = 45
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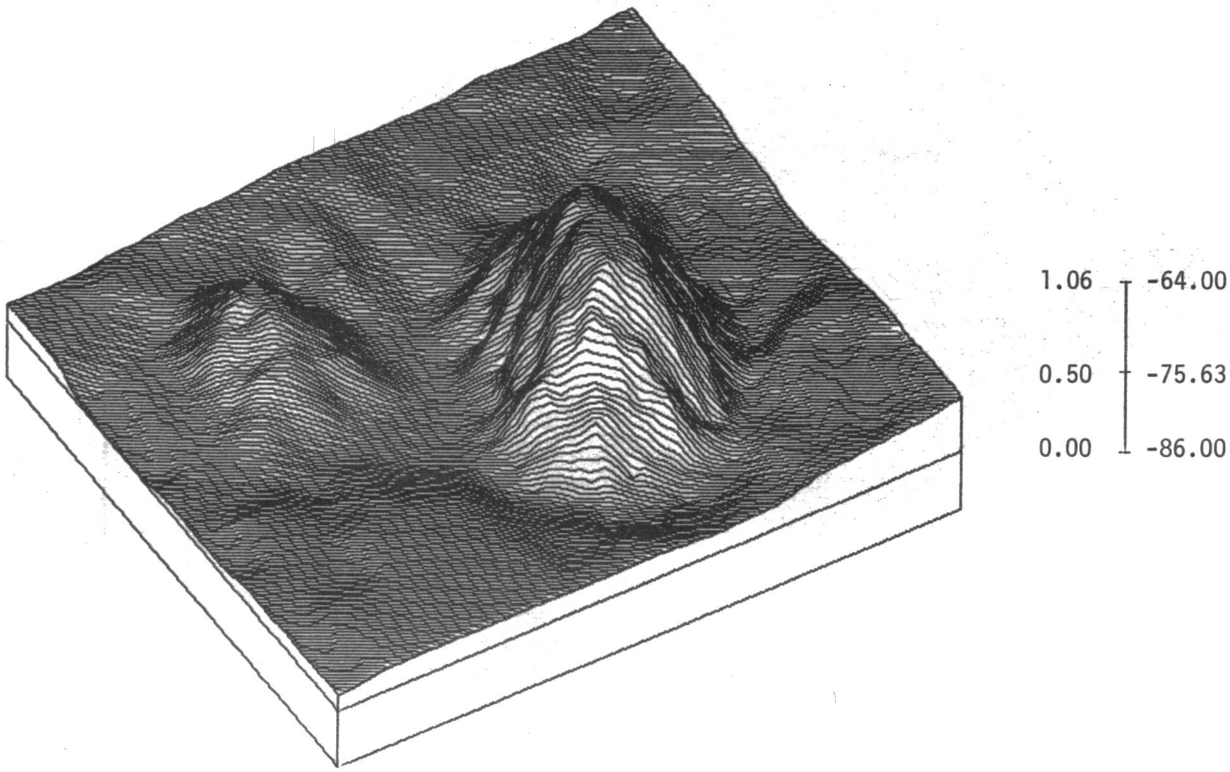
* BEFORE FORESHORTENING

Fig. 15. Perspective Diagram of Baker Bank



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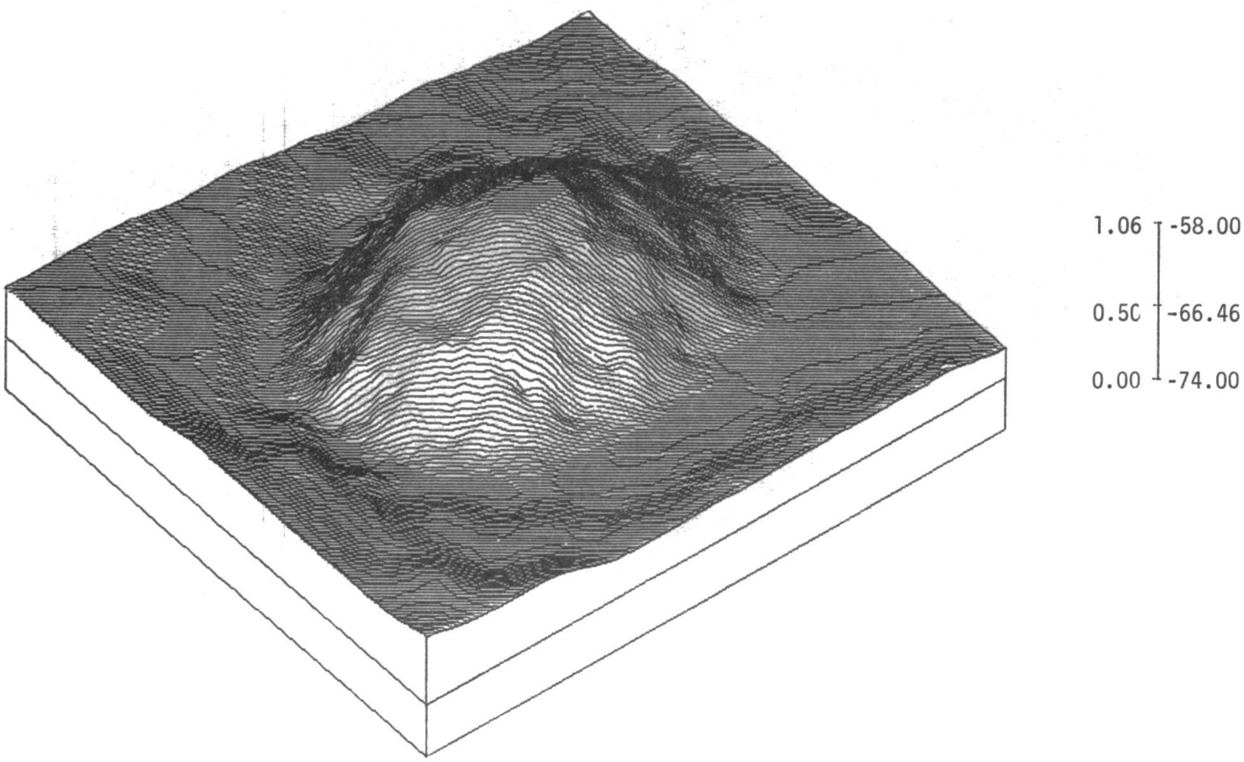
* BEFORE FORESHORTENING

Fig. 16. Perspective Diagram of South Baker



AZIMUTH = 129   ALTITUDE = 45
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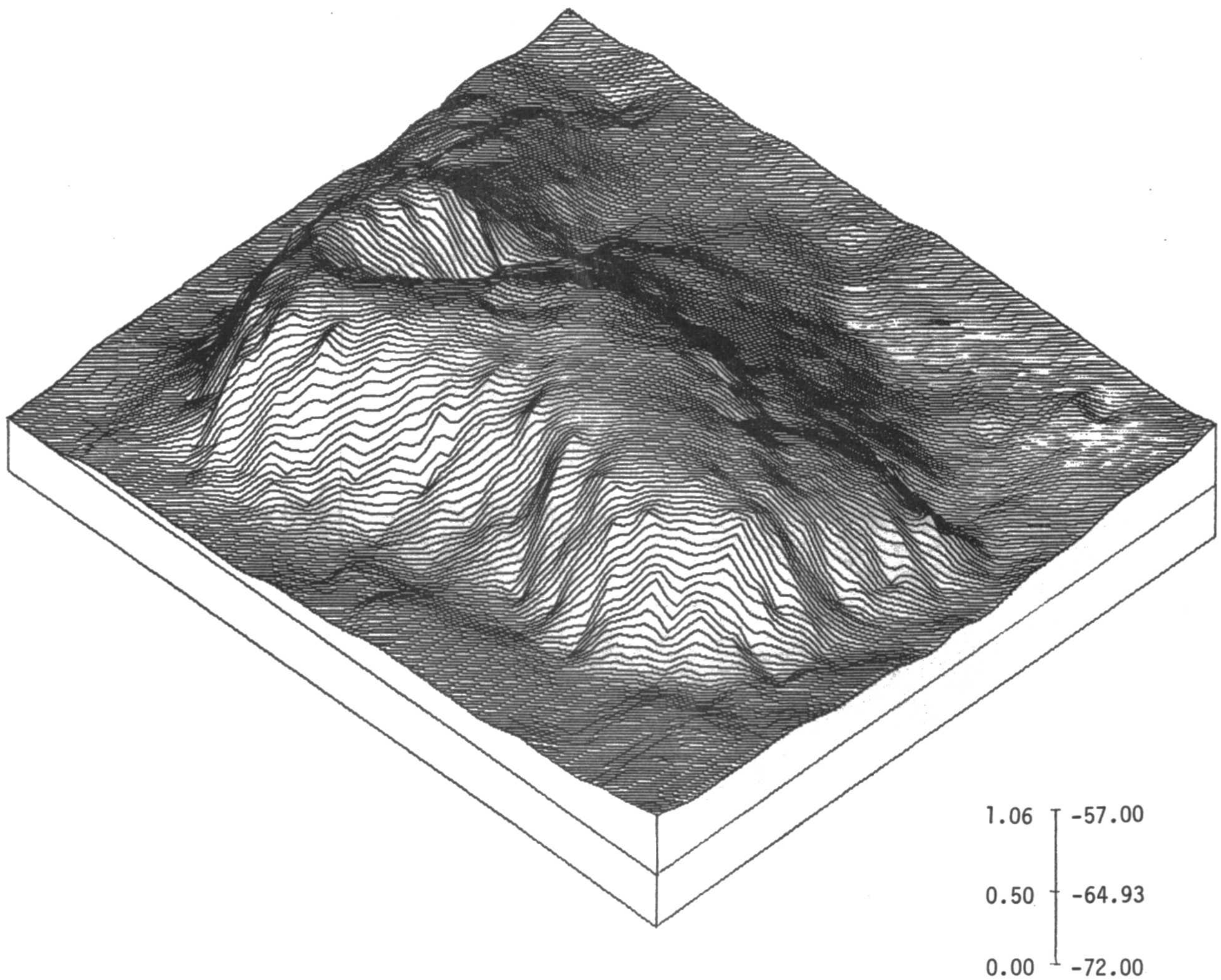
* BEFORE FORESHORTENING

Fig. 17. Perspective Diagram of Aransas Bank



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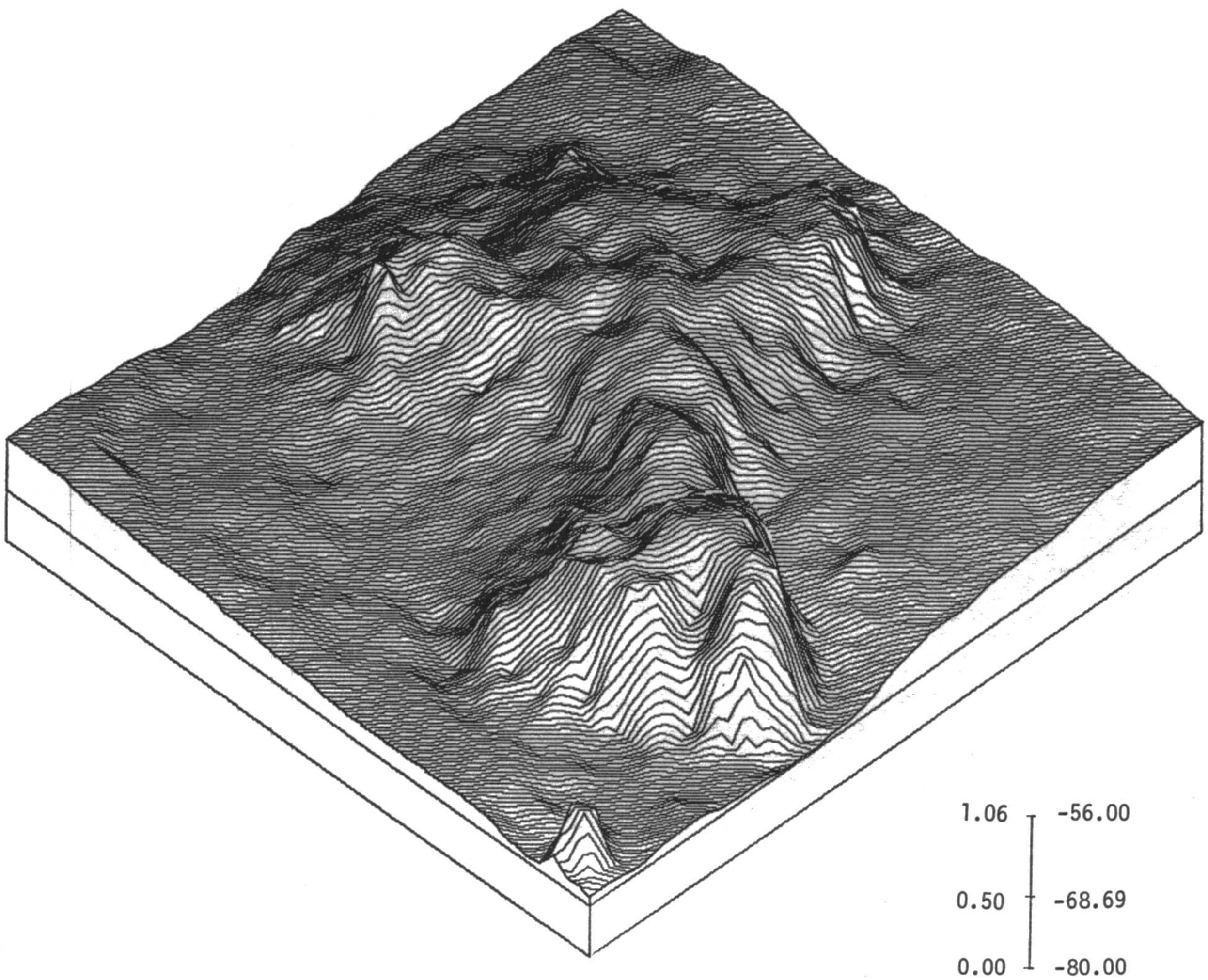
* BEFORE FORESHORTENING

Fig. 18. Persepctive Diagram of North Hospital Bank



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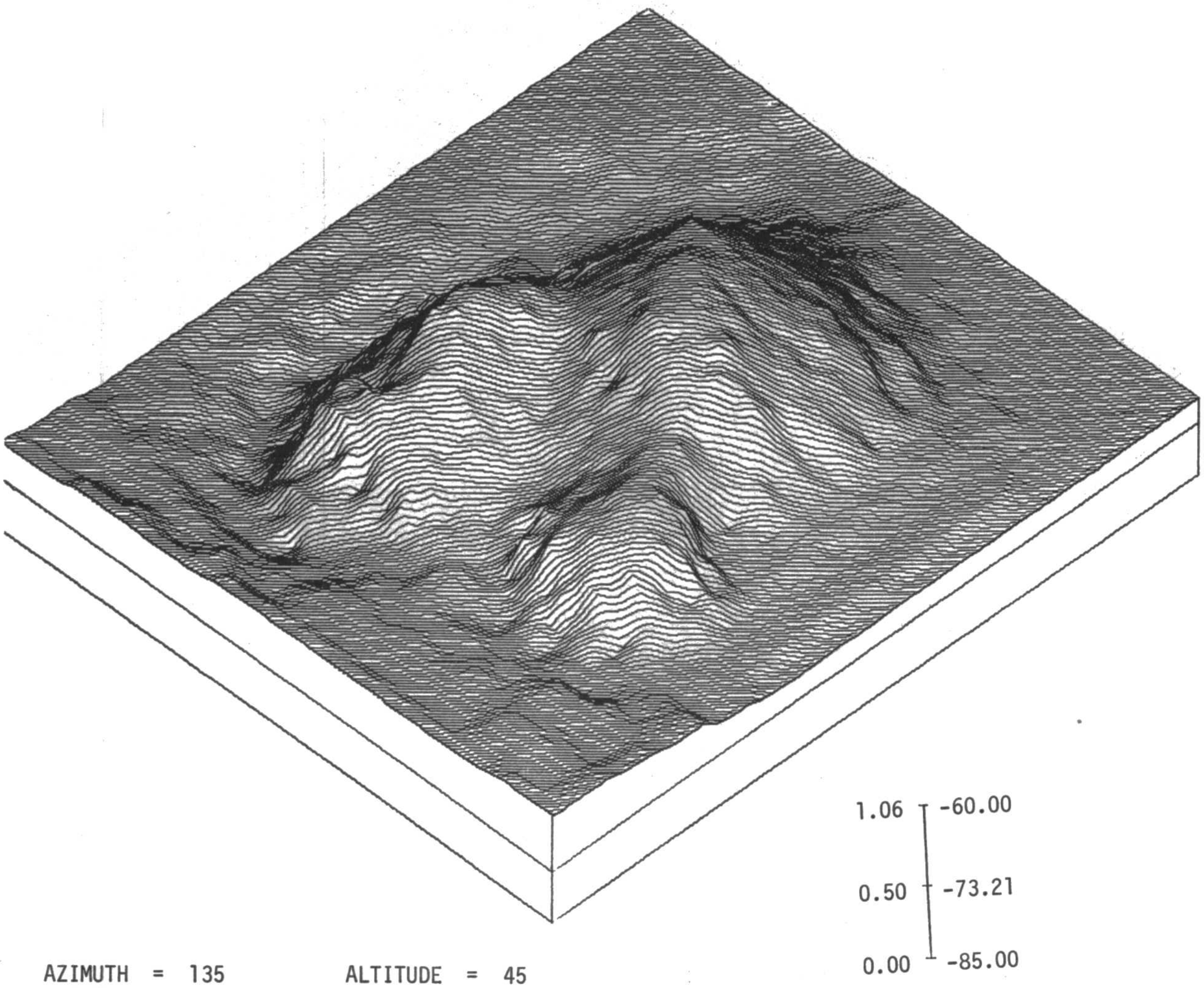
*WIDTH = 5.70 *HEIGHT = 1

* BEFORE FORESHORTENING

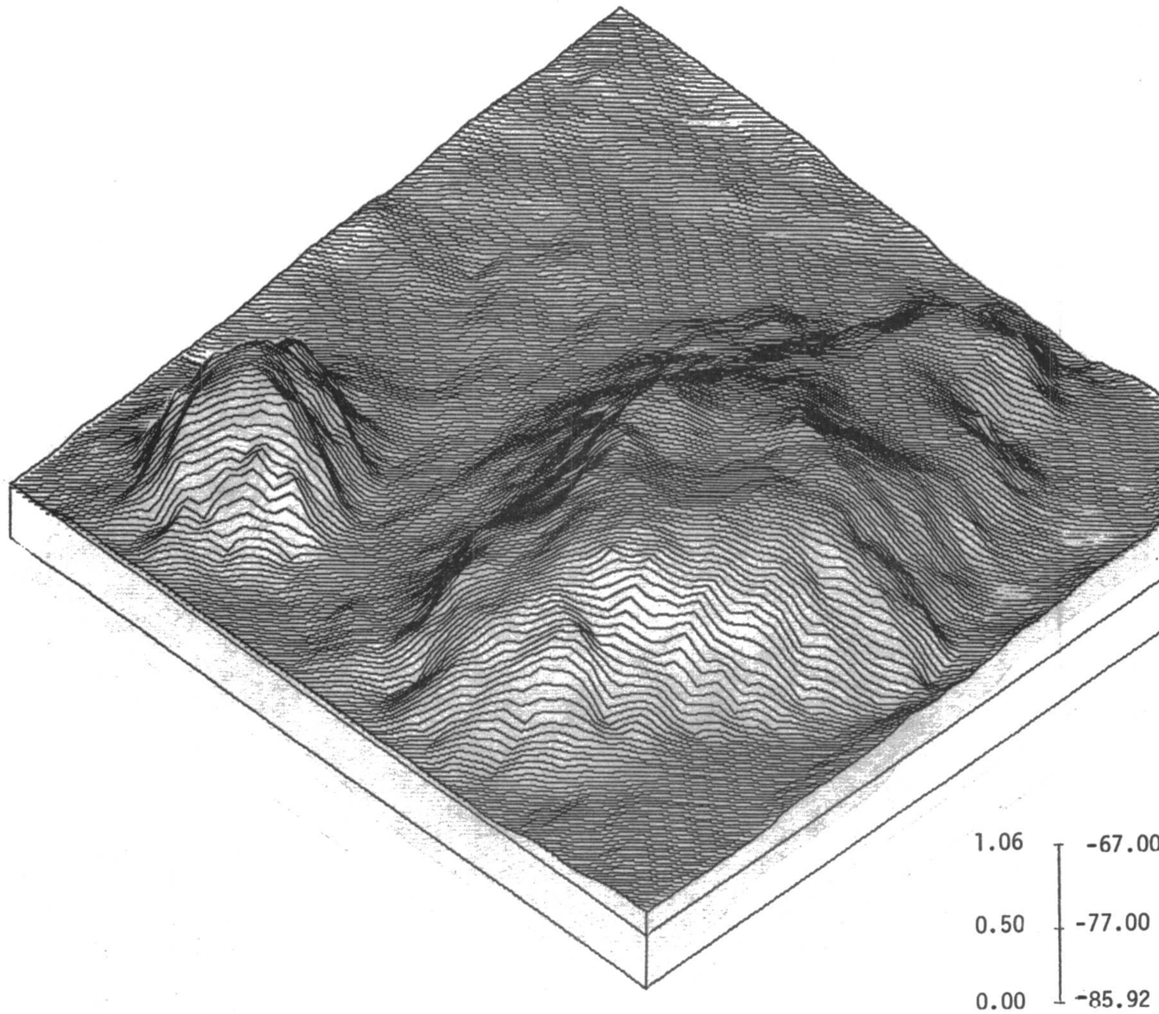
Fig. 19. Perspective Diagram of Hospital Bank



AZIMUTH = 135   ALTITUDE = 45
*WIDTH = 5.40   *HEIGHT = 1.50

* BEFORE FORESHORTENING

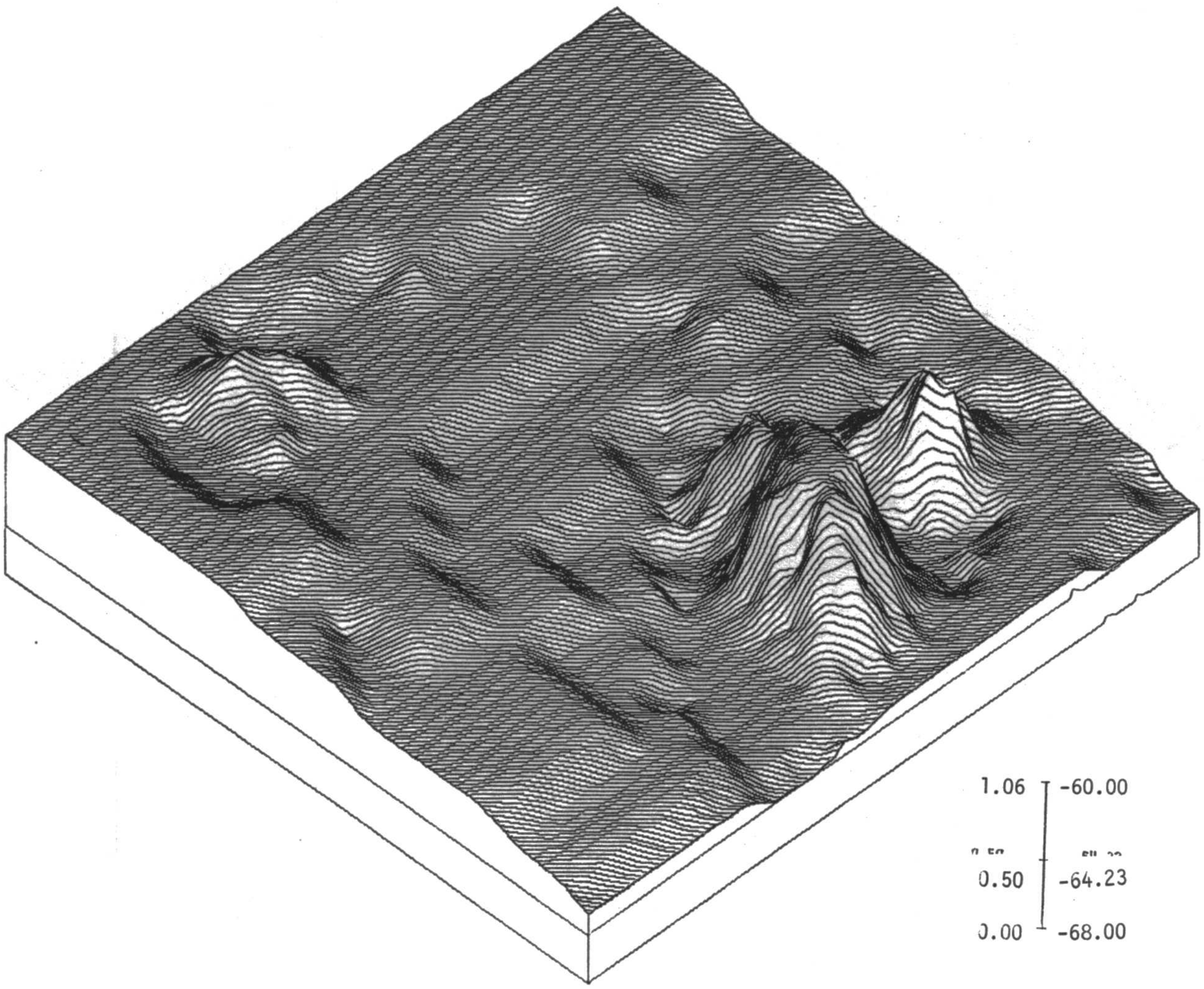
Fig. 20. Perspective Diagram of Southern Bank



AZIMUTH = 225 ALTITUDE = 45
*WIDTH = 5.70 *HEIGHT = 1.50

*BEFORE FORESHORTENING

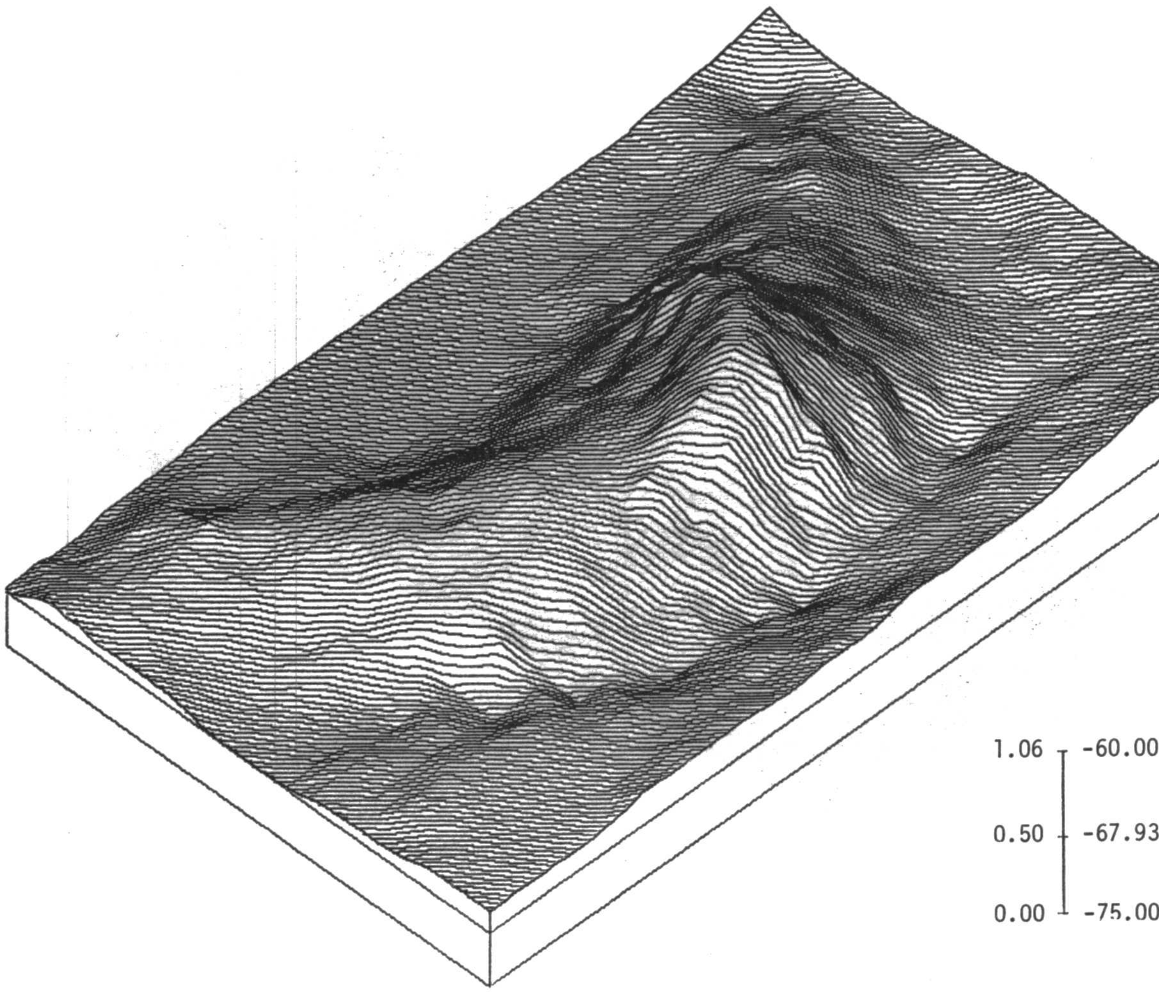
Fig. 21. Perspective Diagram of Dream Bank



AZIMUTH = 315 ALTITUDE = 45
*WIDTH = 6.00 *HEIGHT = 1.50

* BEFORE FORESHORTENING

Fig. 22. Perspective Diagram of Big and Small Adam Rocks



AZIMUTH = 225 ALTITUDE = 45
*WIDTH = 7.00 *HEIGHT = 1.50

*BEFORE FORESHORTENING

Fig. 23. Perspective Diagram of Blackfish Ridge

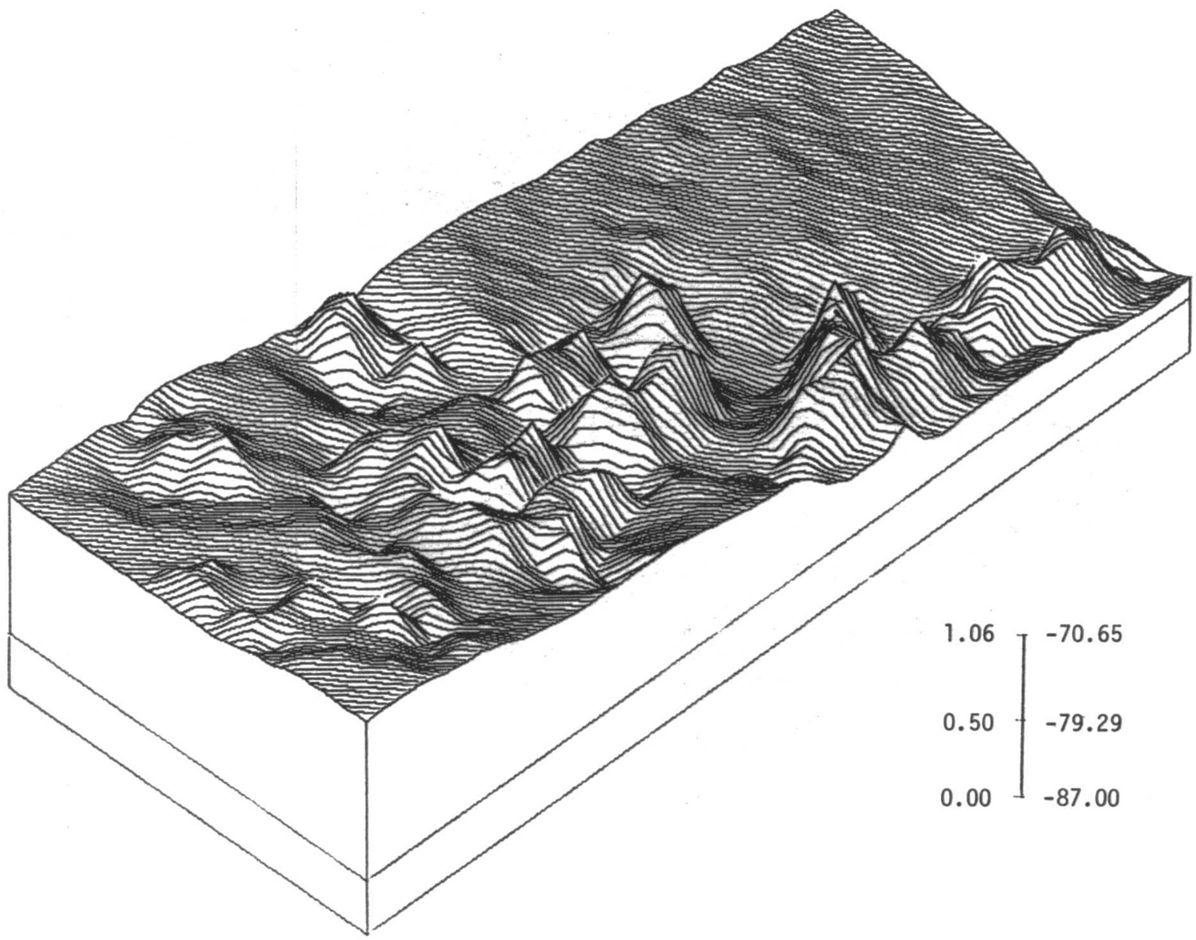


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Fig. 24. Perspective Diagram of Mysterious Bank

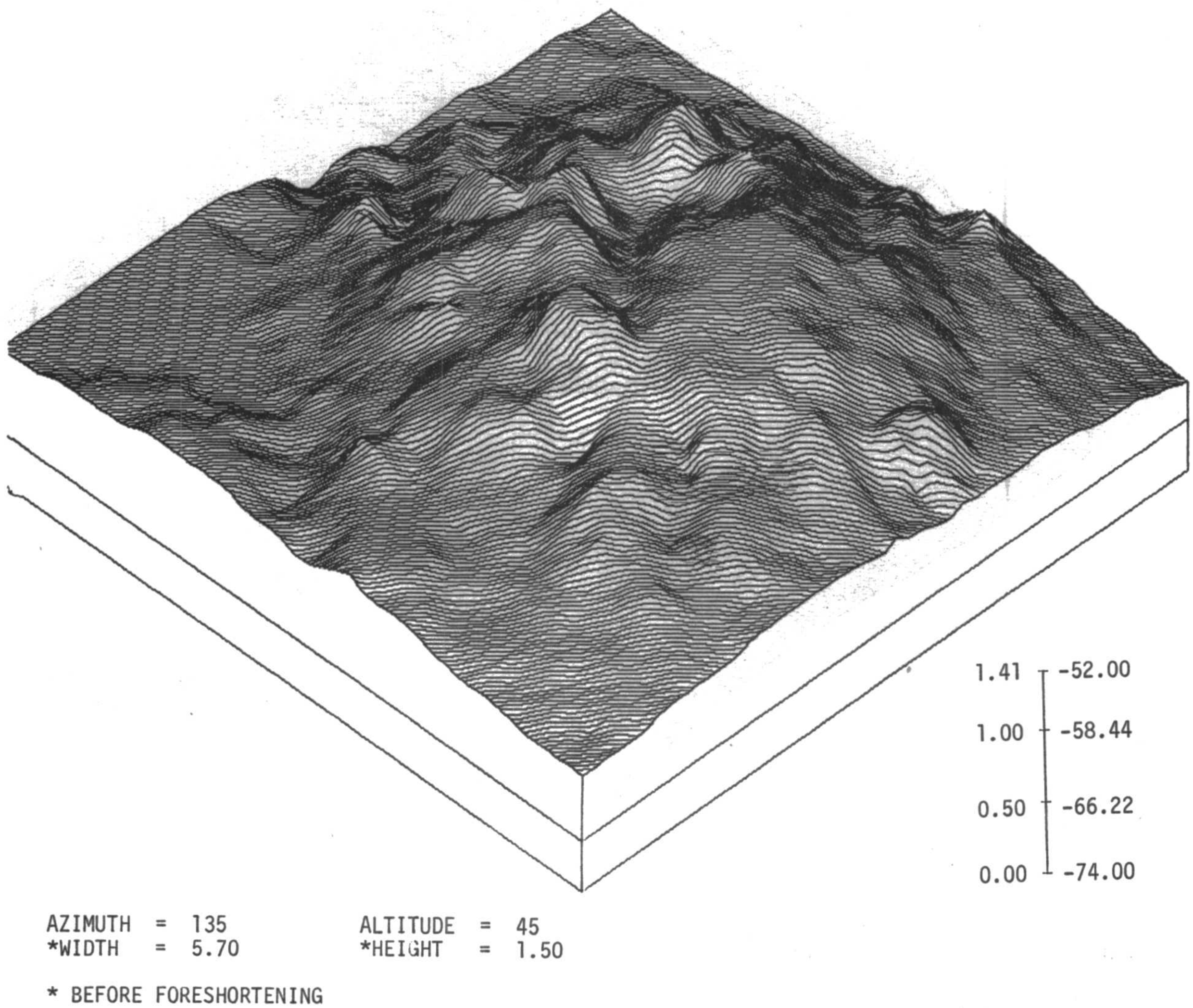
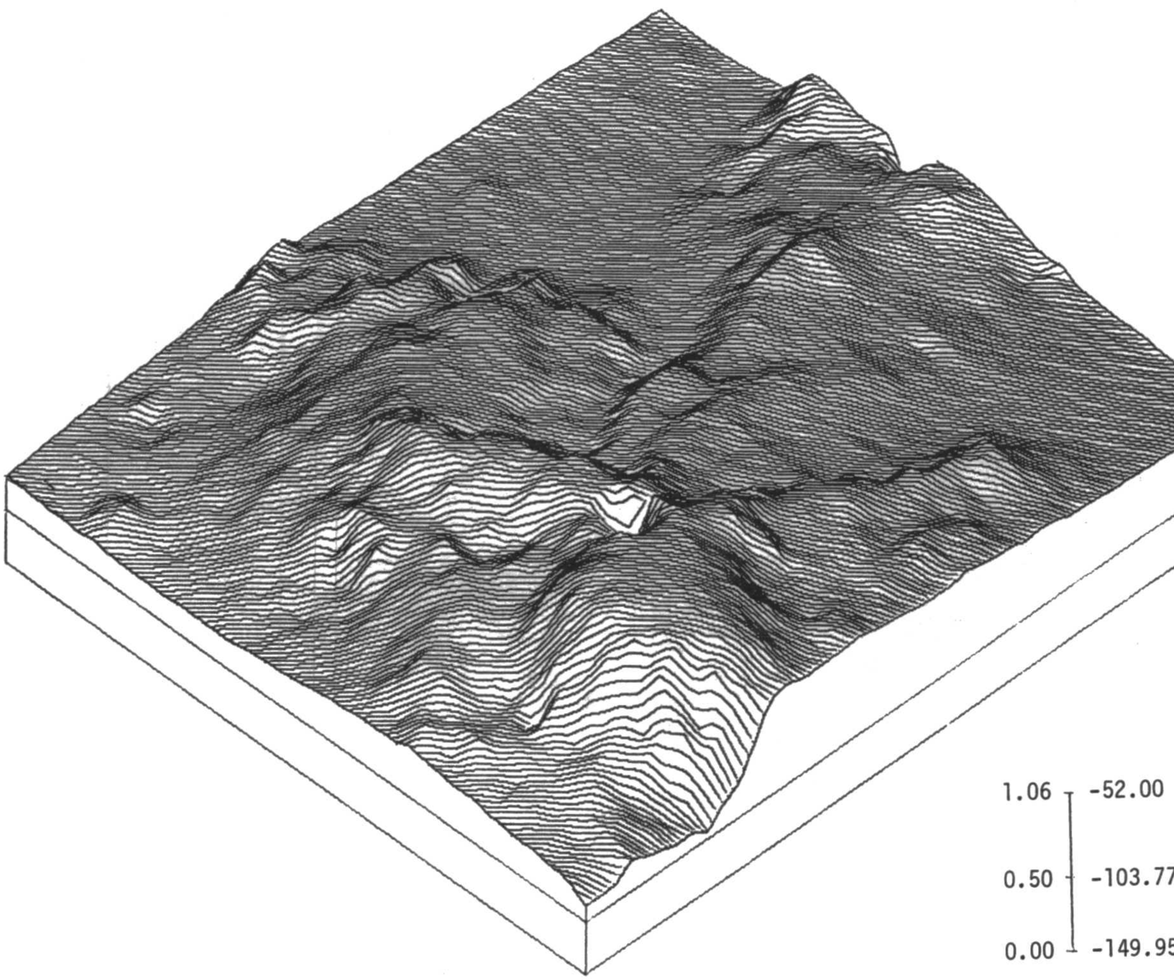


Fig. 25. Perspective Diagram of 29 Fathom Bank



AZIMUTH = 45 ALTITUDE = 45
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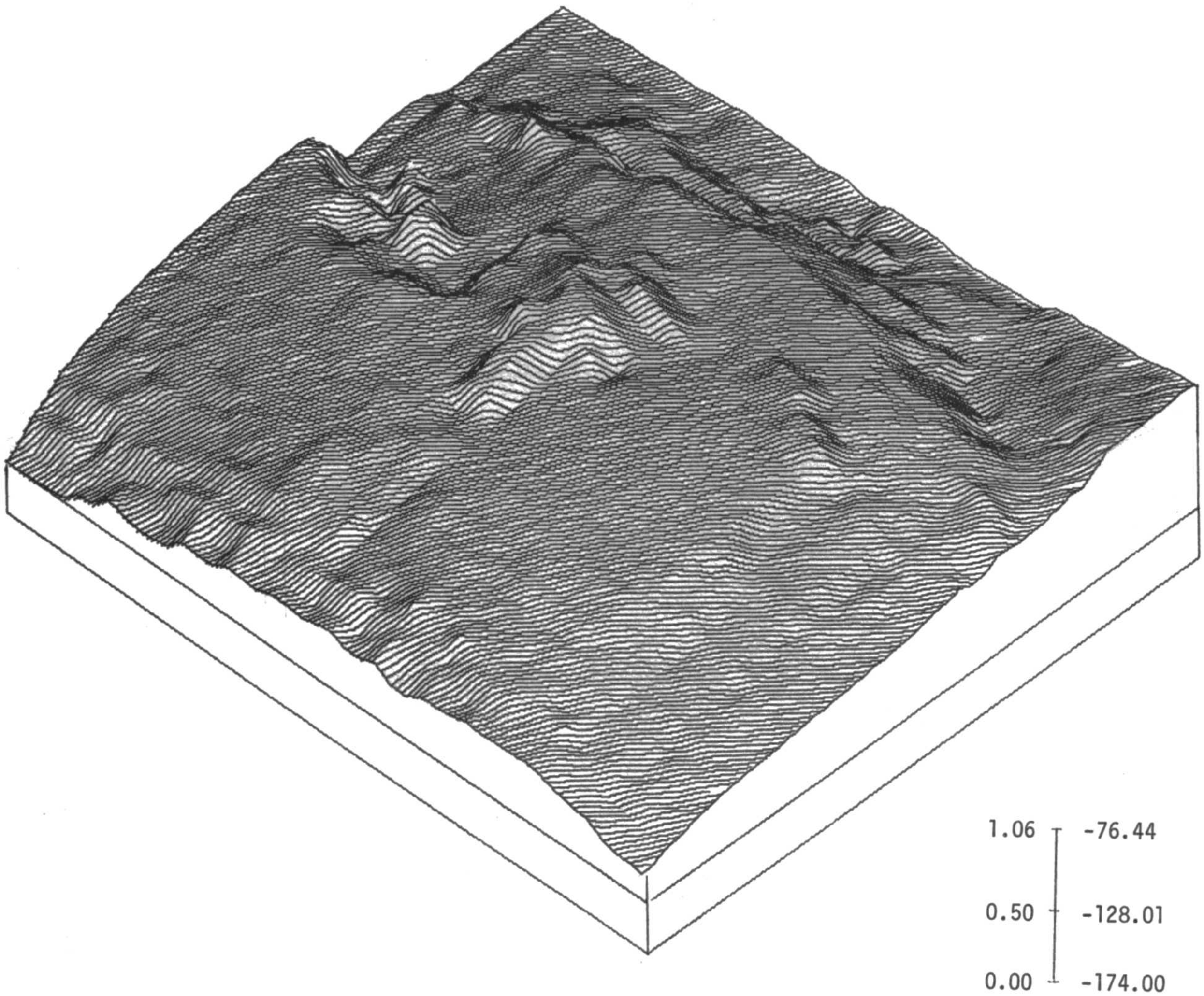
Fig. 26. Perspective Diagram of 28 Fathom Bank



AZIMUTH = 315 ALTITUDE = 45
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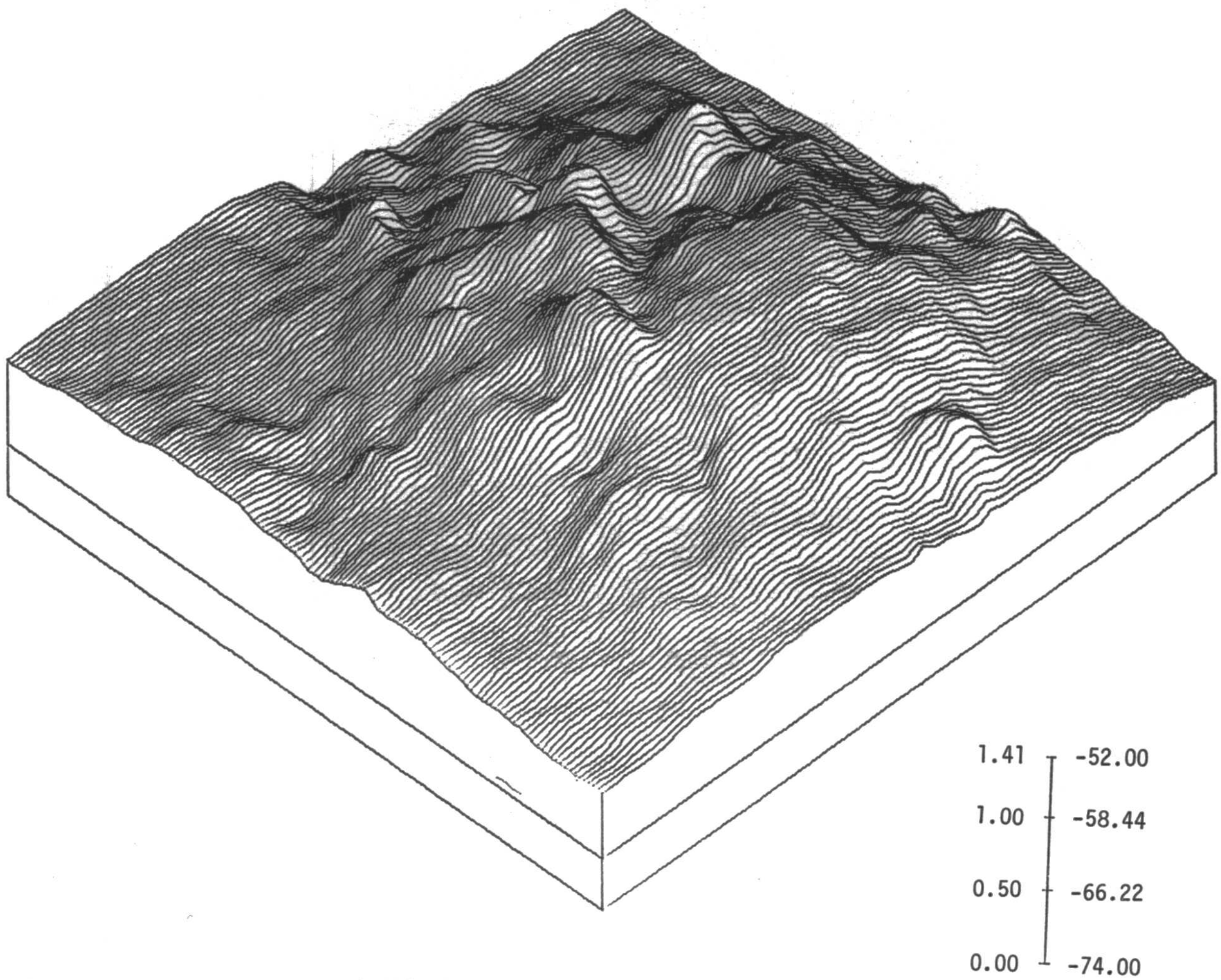
* BEFORE FORESHORTENING

Fig. 27. Perspective Diagram of Little Sister Bank



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* BEFORE FORESHORTENING

Fig. 28. Perspective Diagram of 32 Fathom Bank

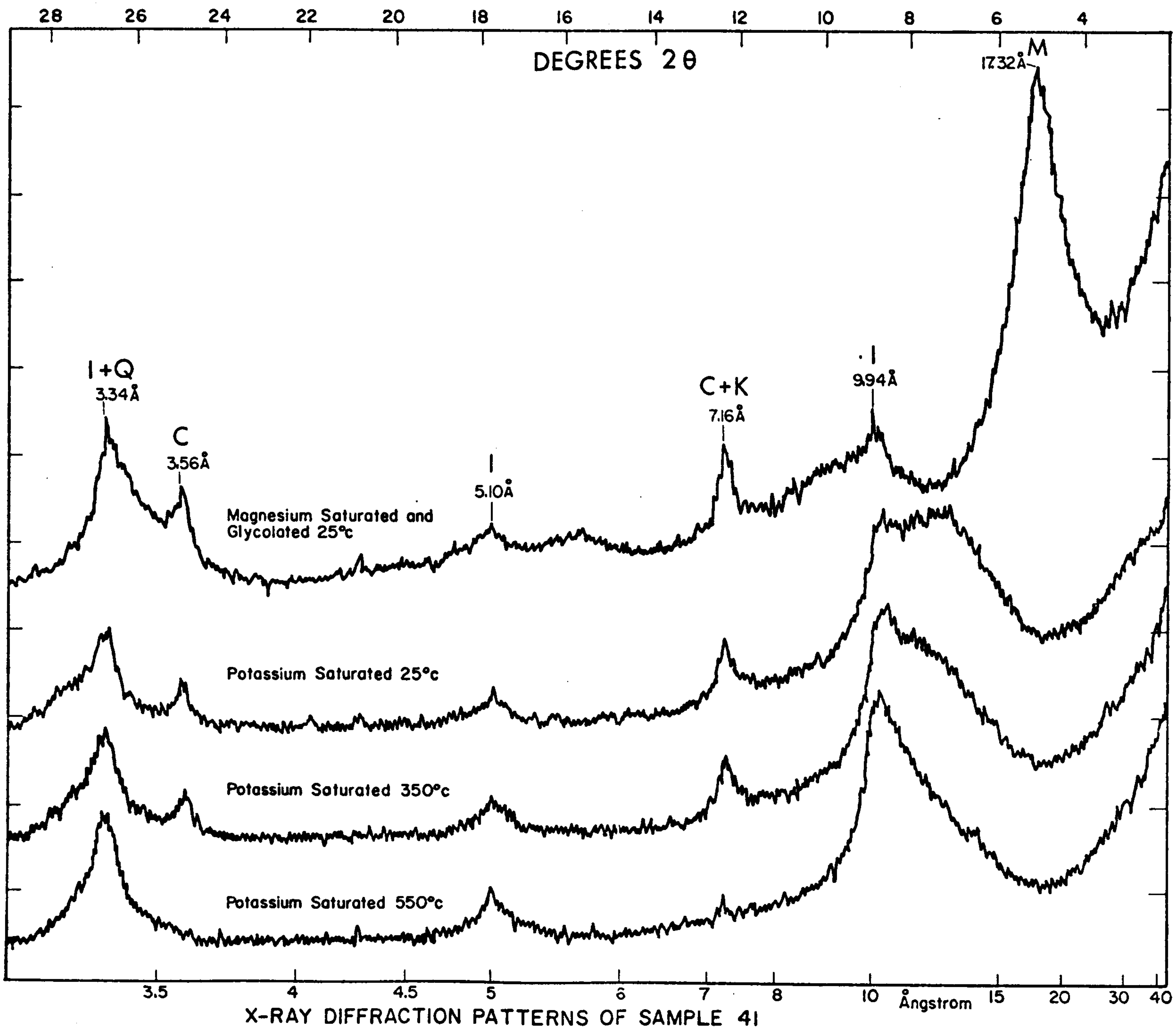


Figure 29. X-Ray Diffraction Patterns of clays from sample station 41.
M= montmorillonite, I= illite, C= chlorite, K= kaolinite,
Q= quartz

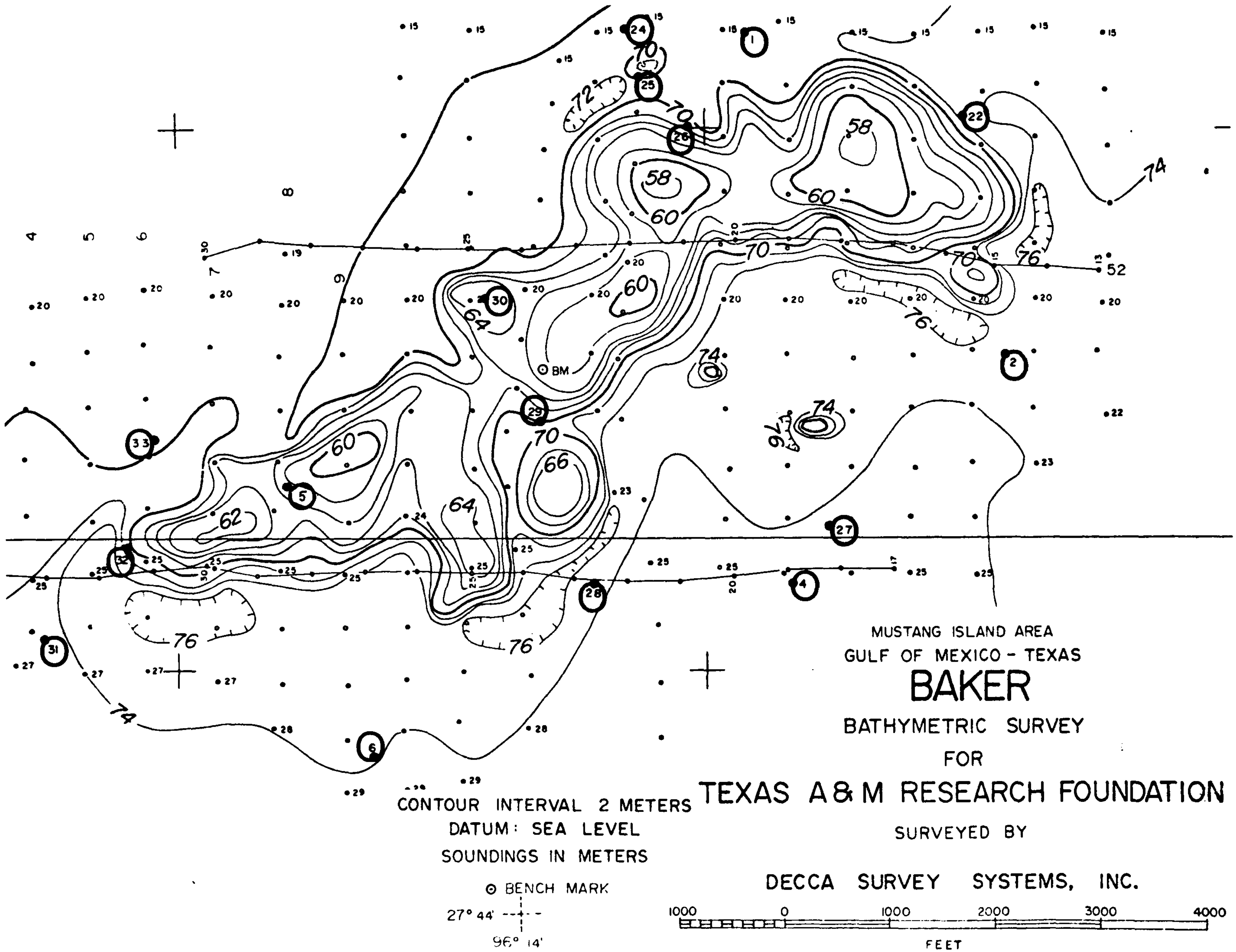


Figure 30. Sediment sample locations on Baker Bank

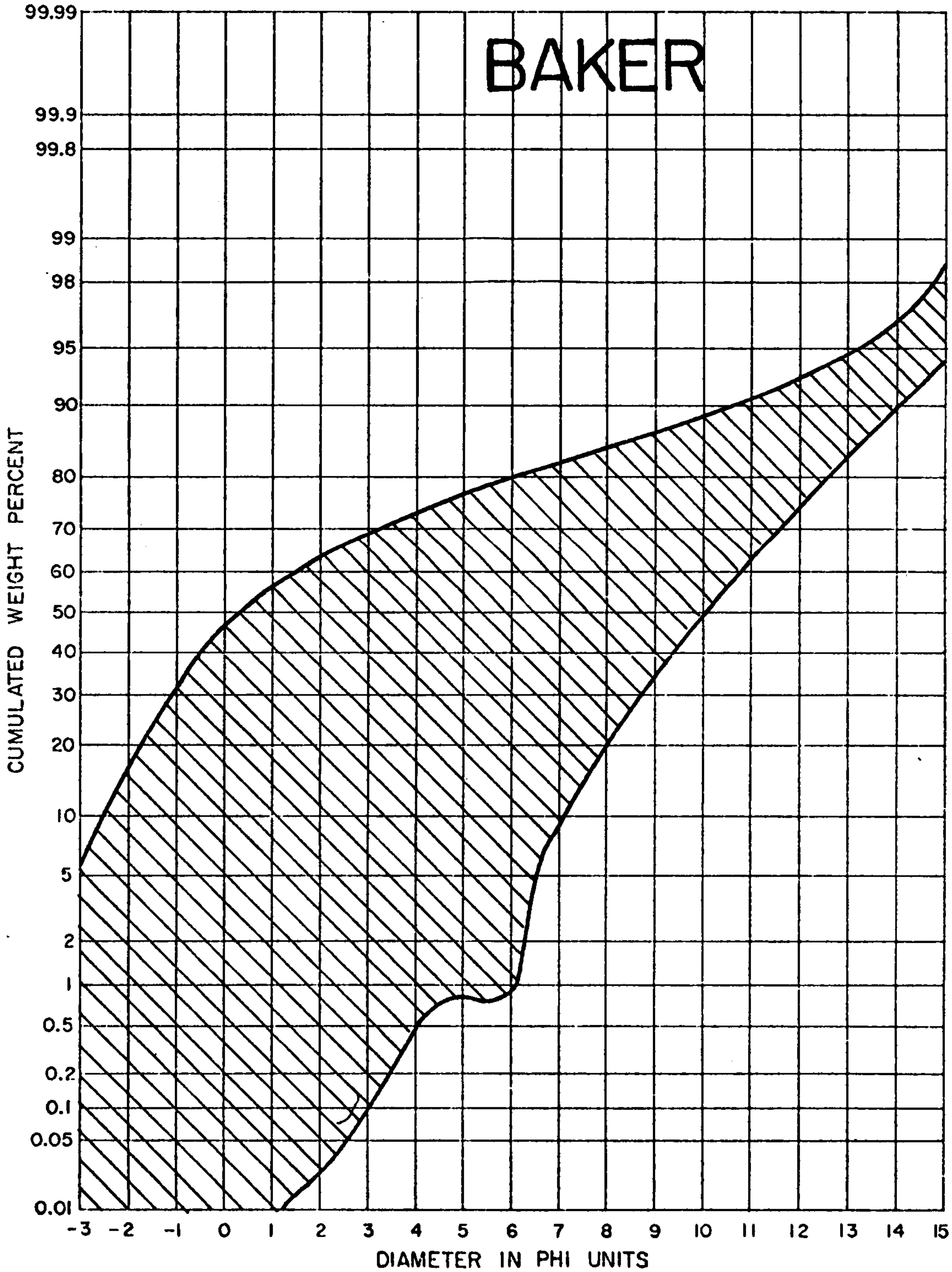


Figure 31
Range of Size Frequency Distribution of Baker Bank.

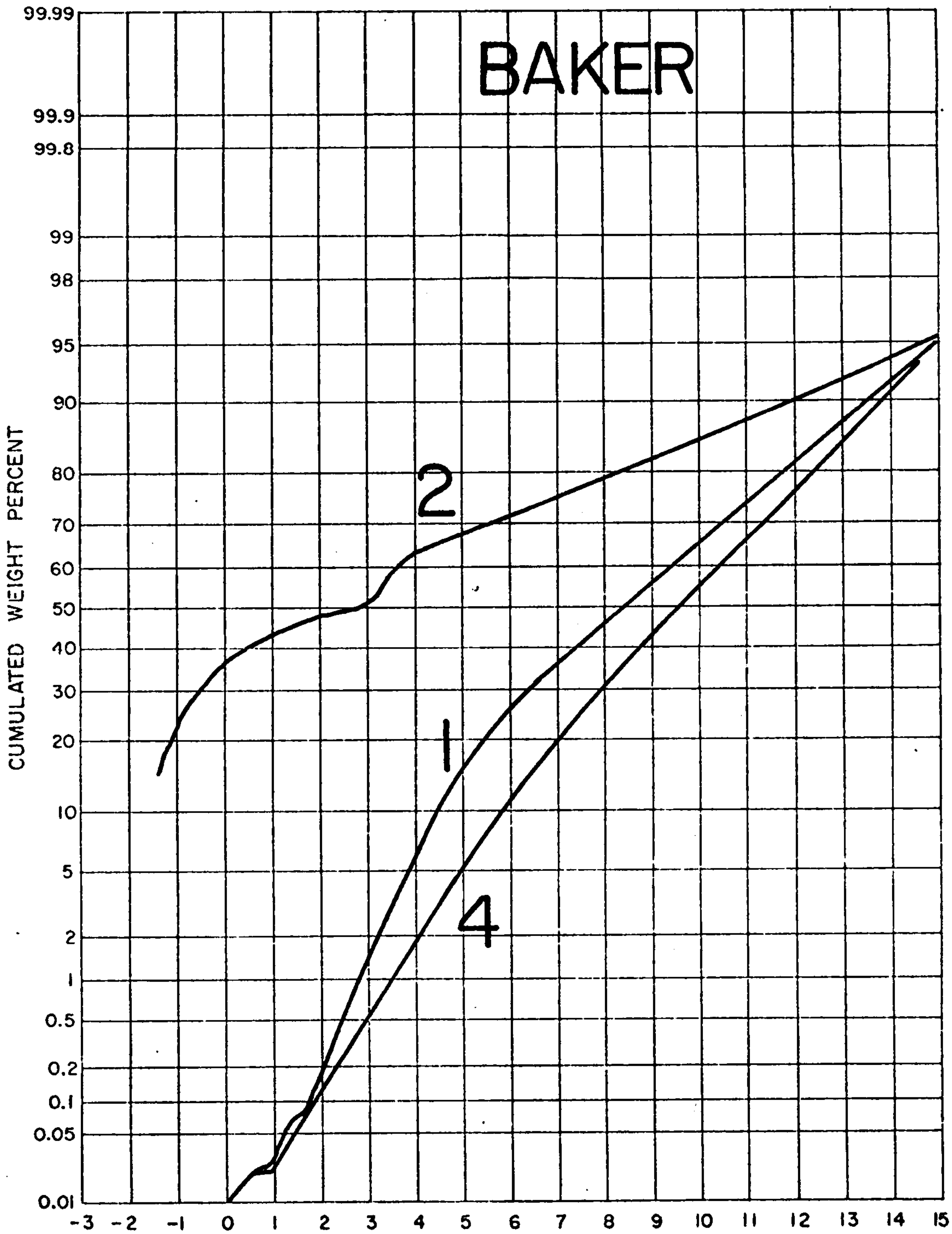


Figure 32
Sediment Size Frequency Disbribution Curves for Baker
Samples 1, 2 and 4.

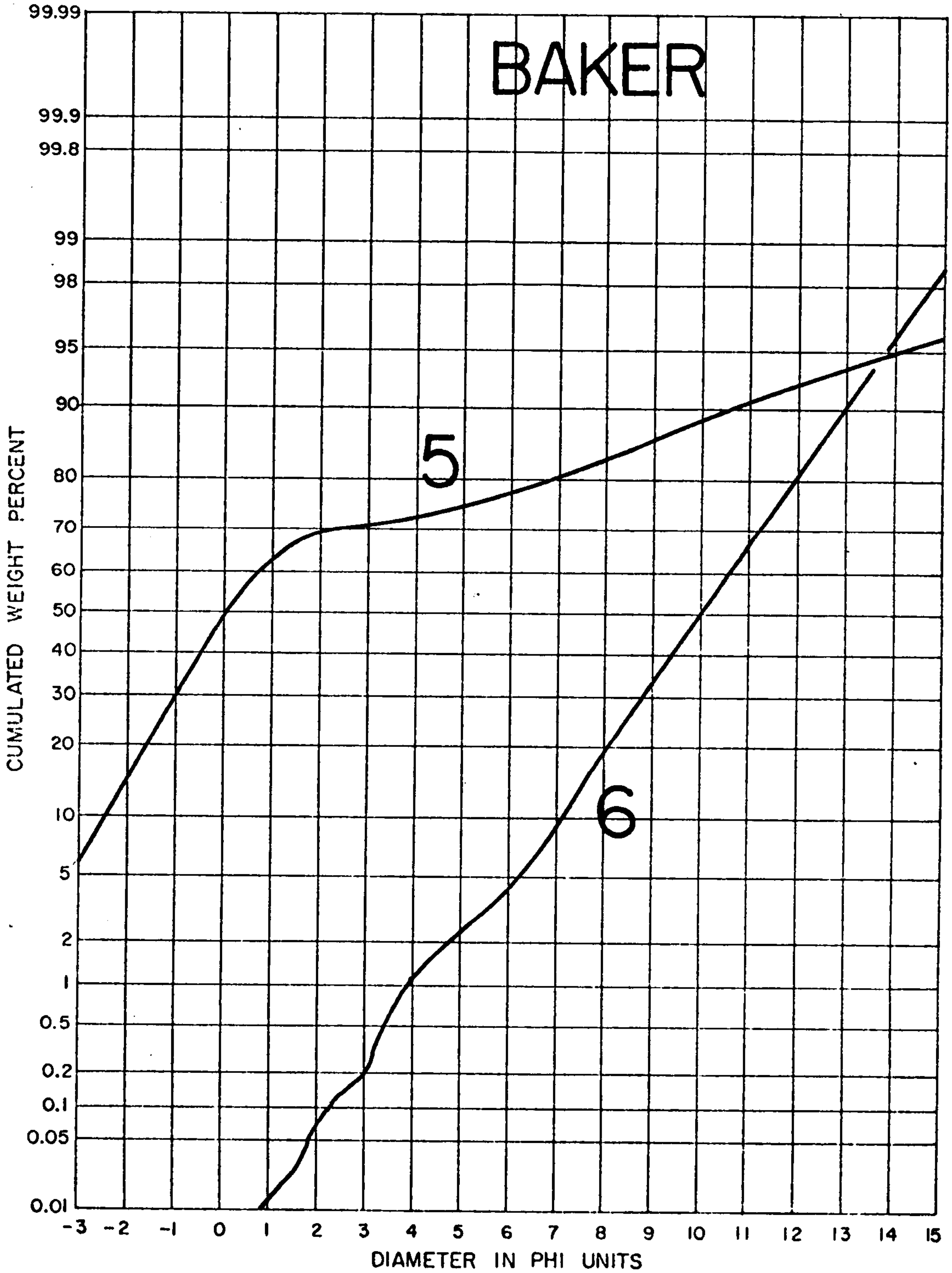


Figure 33
Sediment Size Frequency Distribution Curves for Baker Samples 5 and 6.

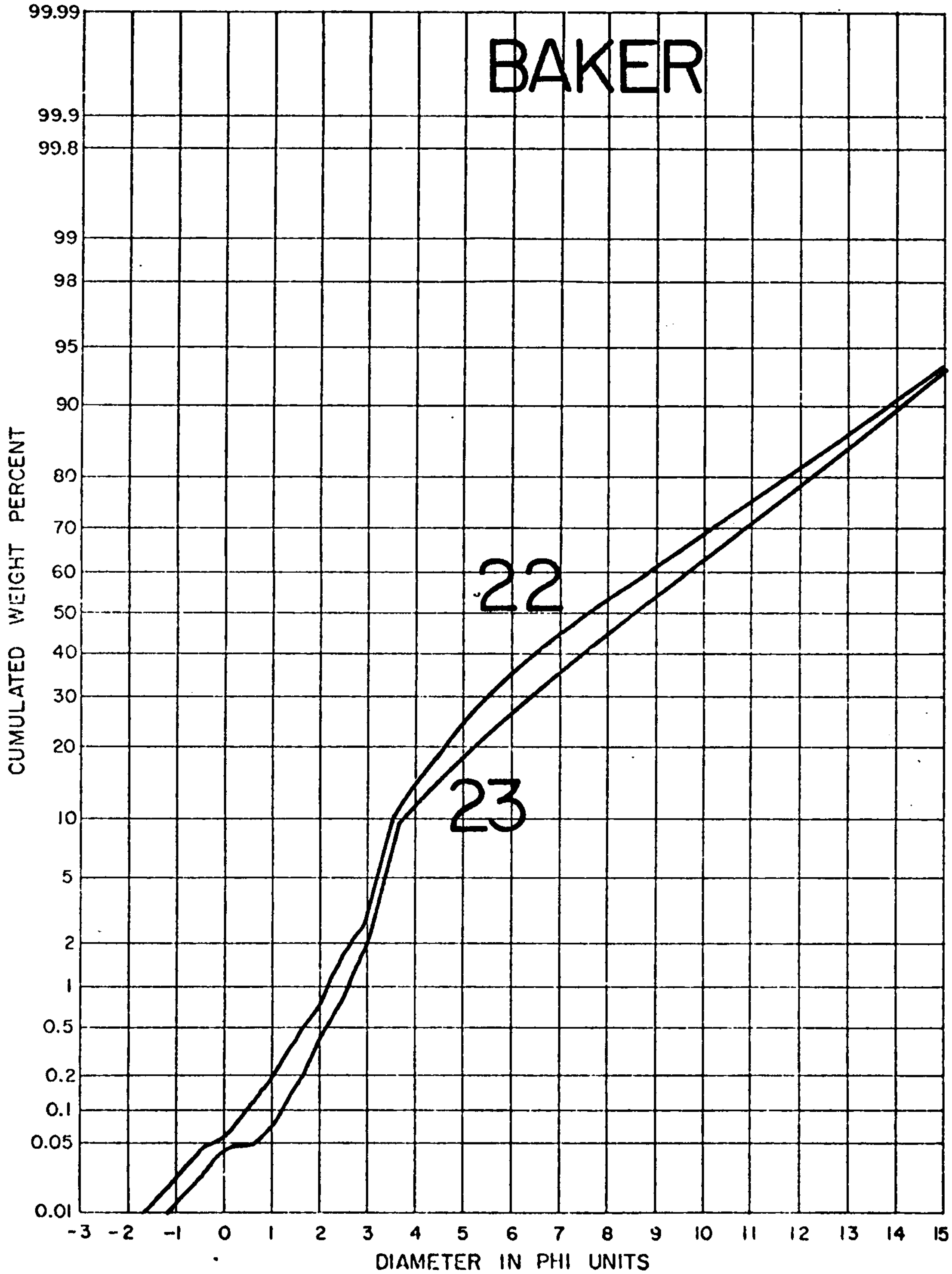


Figure 34
Sediment Size Frequency Distribution Curves for Baker Samples 22 and 23.

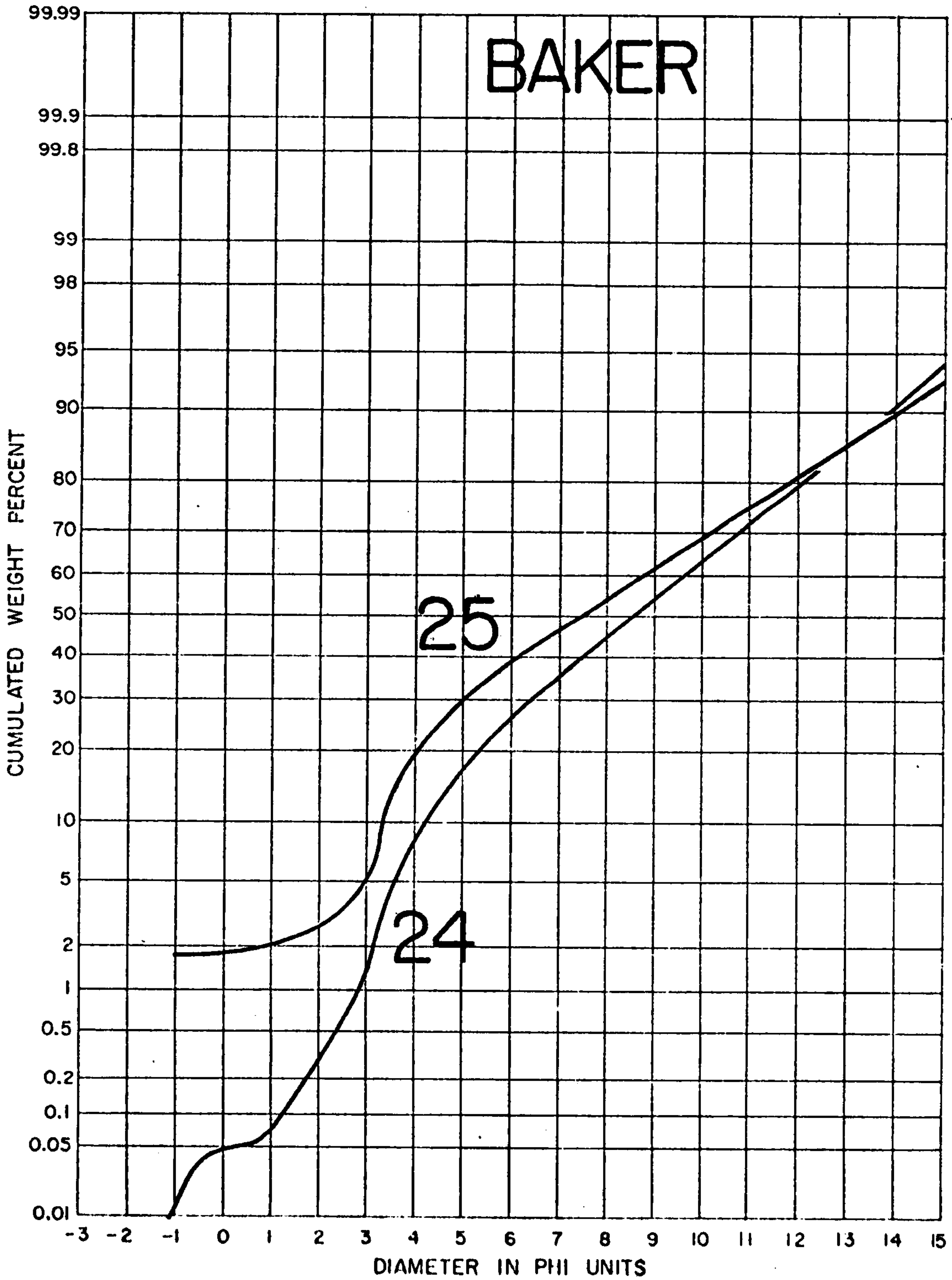


Figure 35
Sediment Size Frequency Distribution Cruves for Baker Samples 24 and 25.

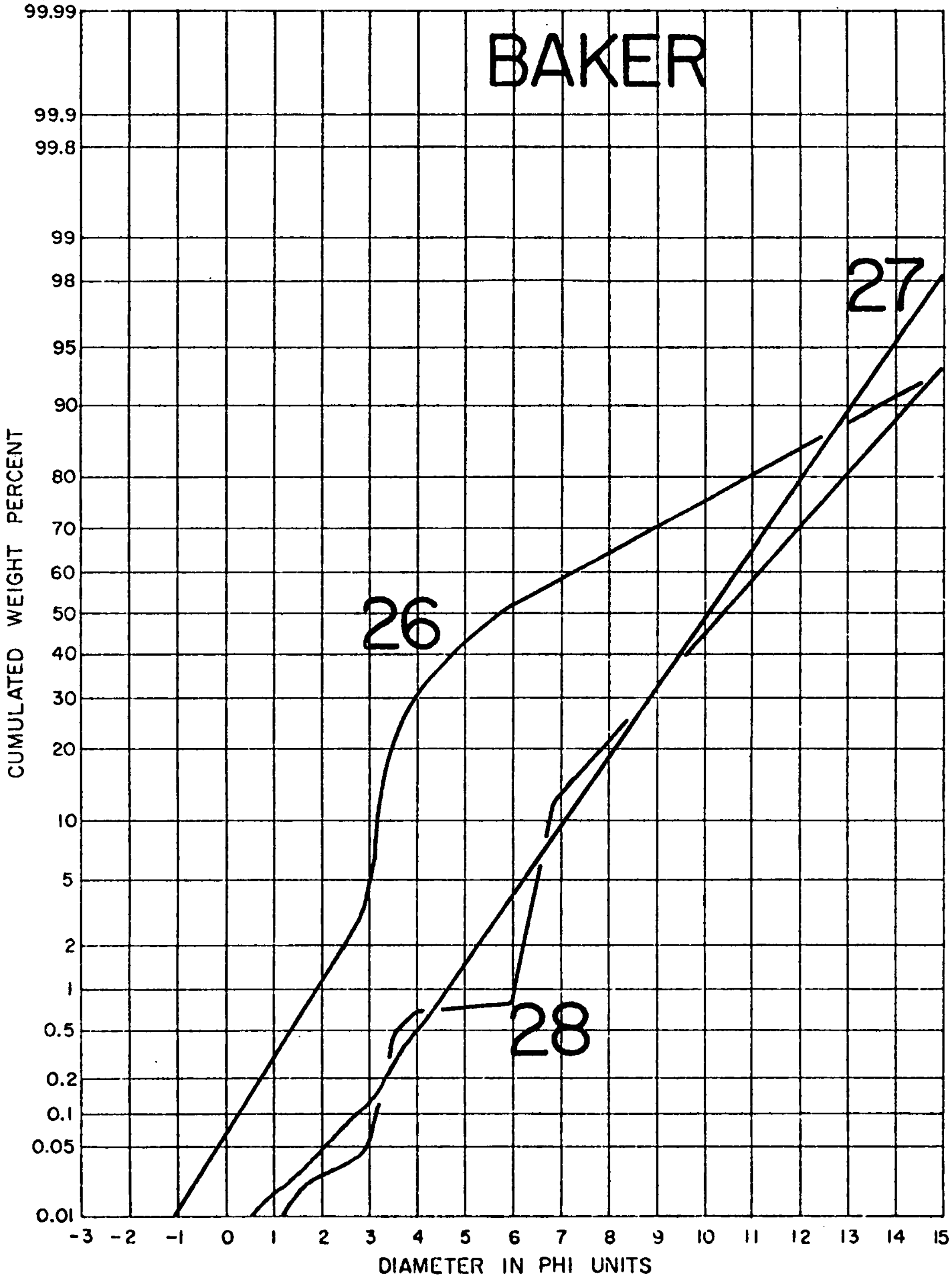


Figure 36
Sediment Size Frequency Distribution Curves for Baker Samples 26-28.

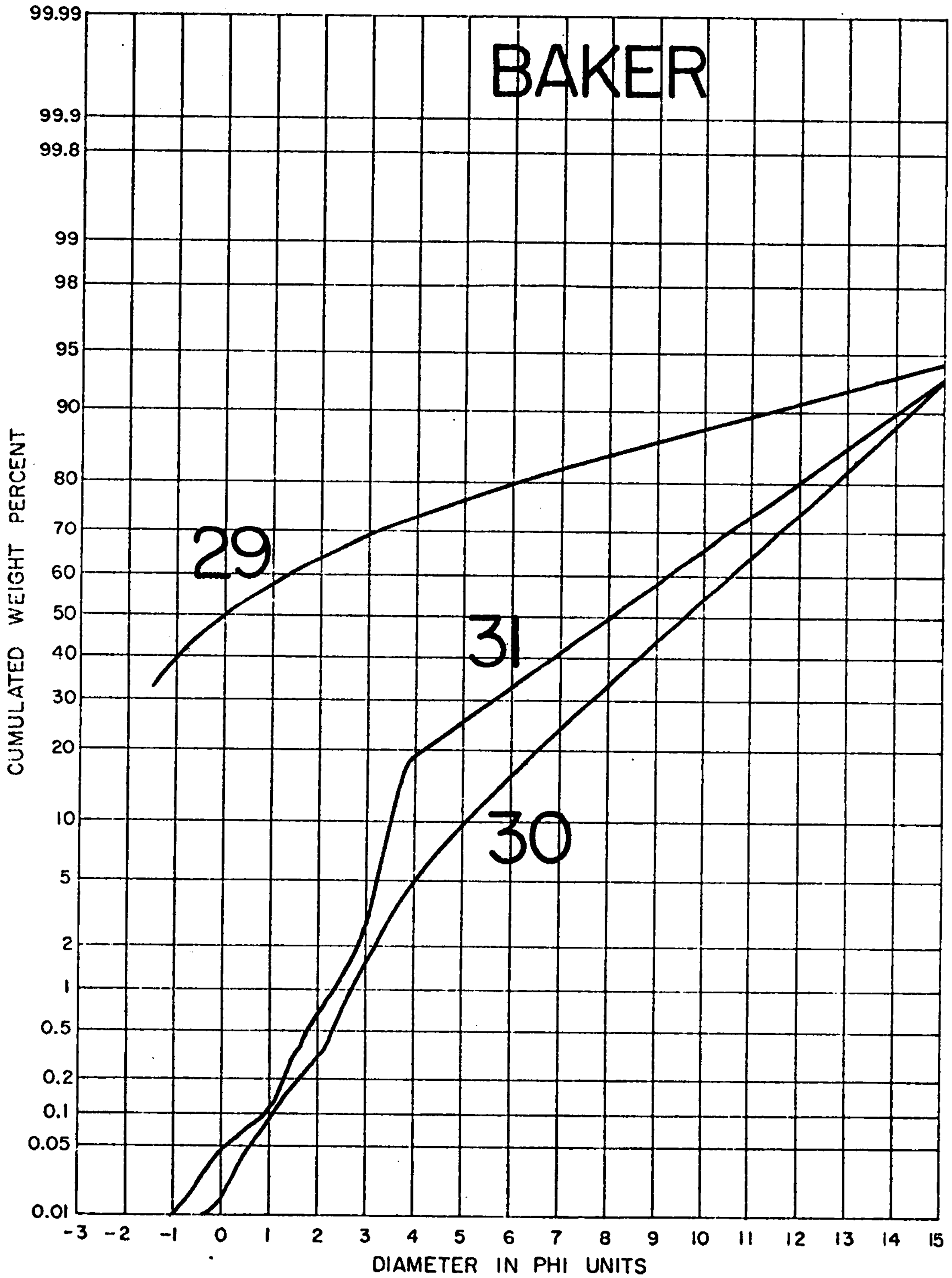


Figure 37
Sediment Size Frequency Distribution Curves for Baker Samples 29-31.

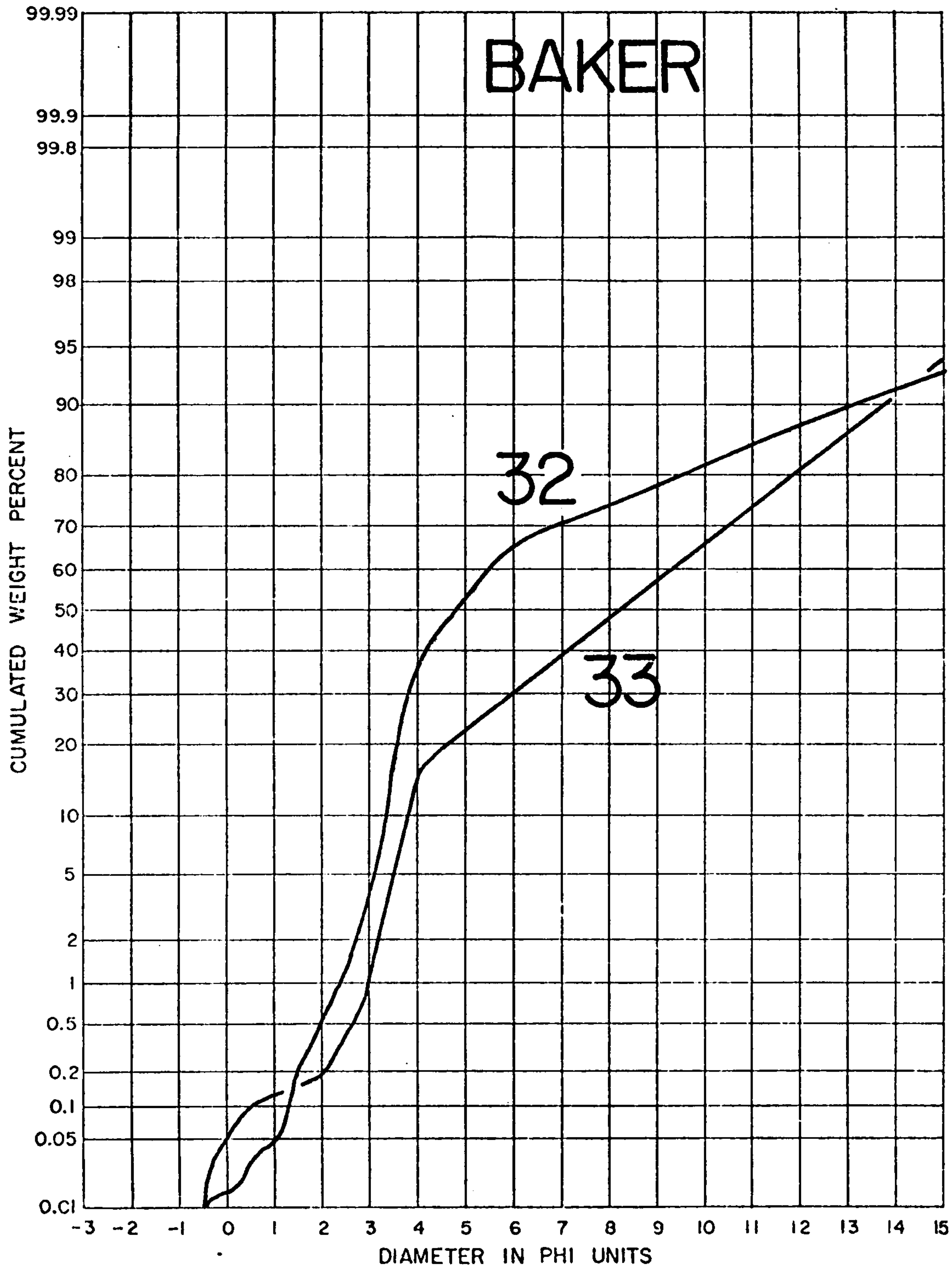


Figure 38
Sediment Size Frequency Distribution Curves for Baker Samples 32 and 33.

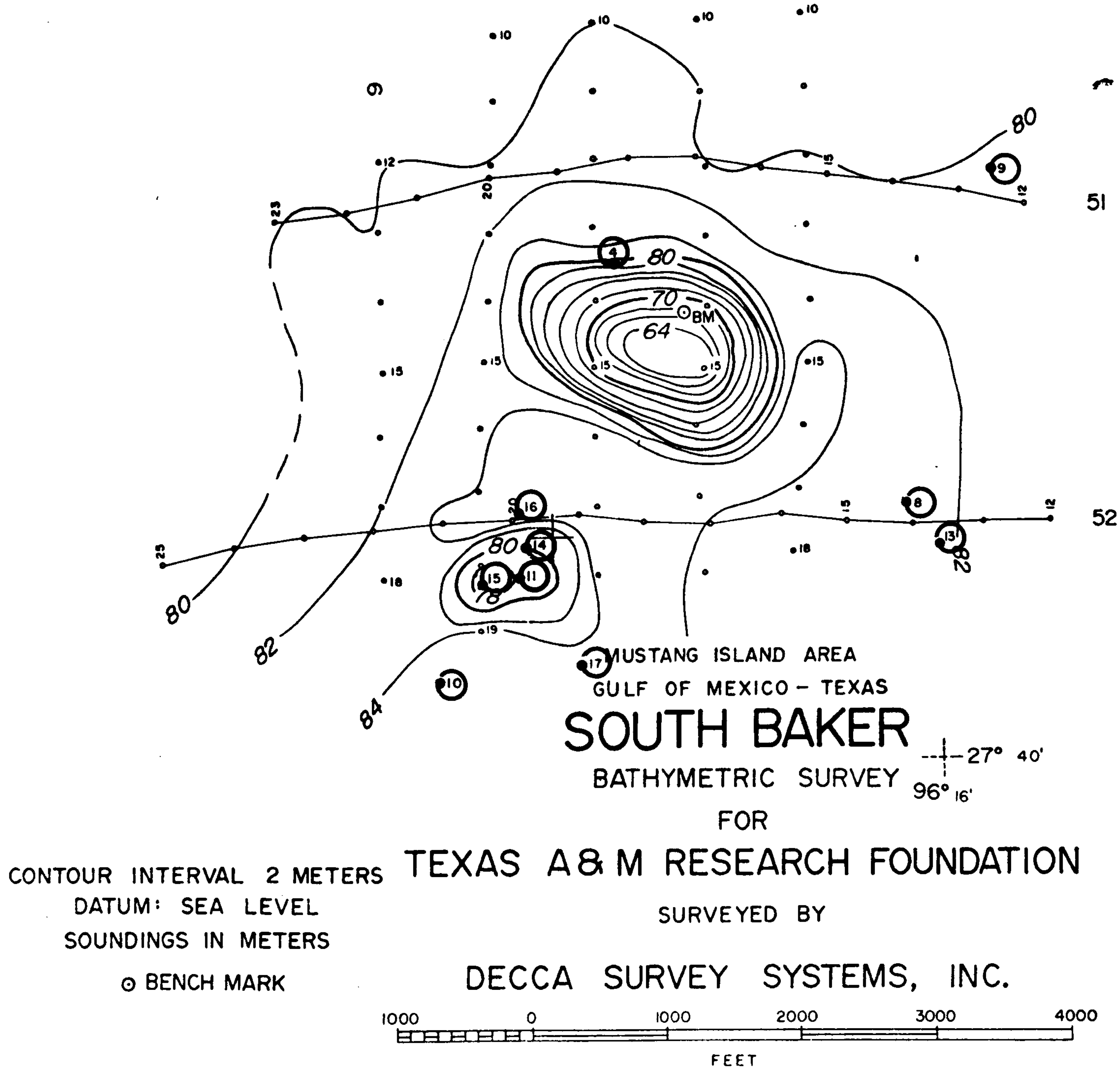


Figure 39. Sediment Sample Locations on South Baker Bank.

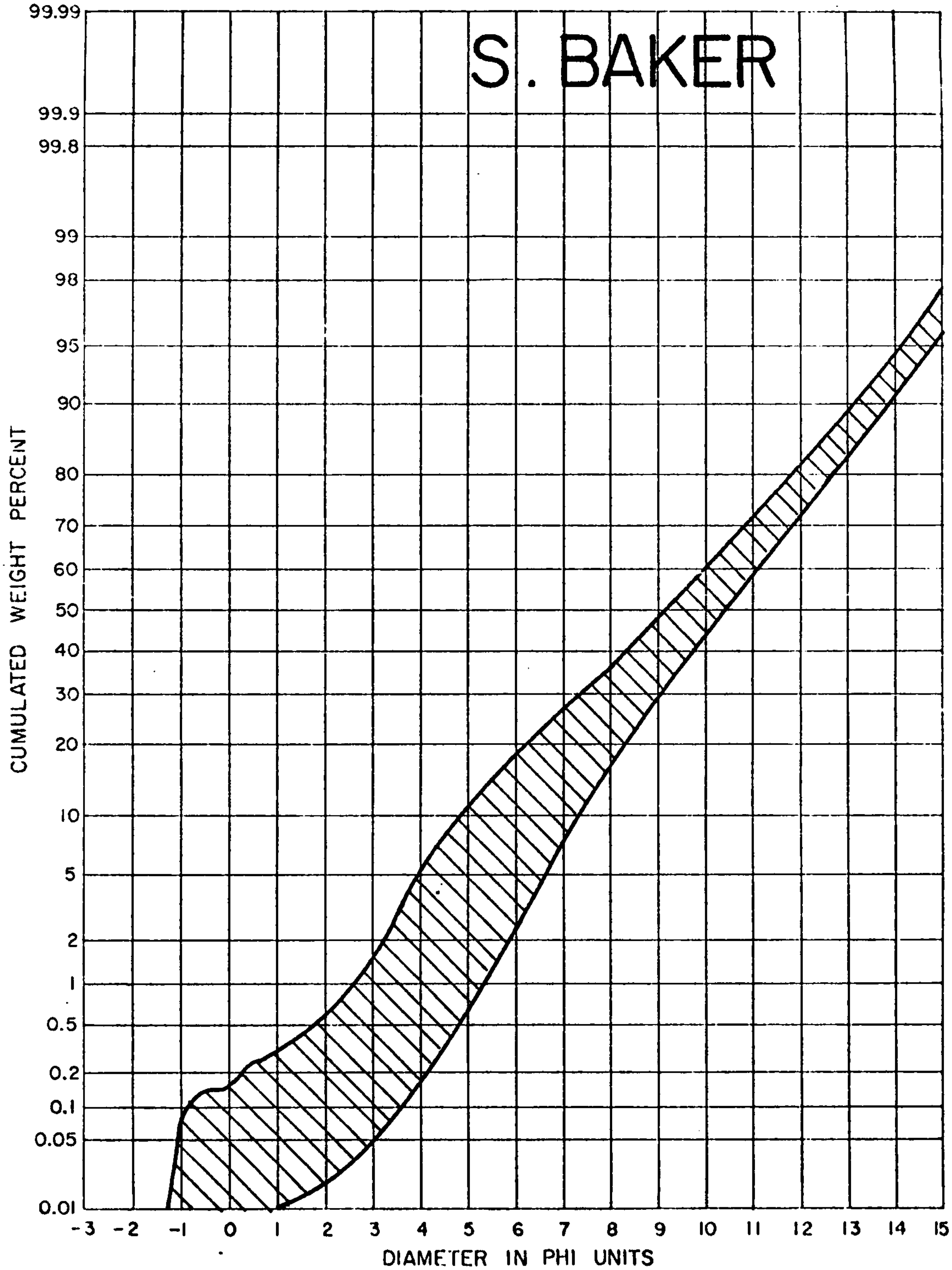


Figure 40

Range of Size Frequency Distribution at South Baker Bank

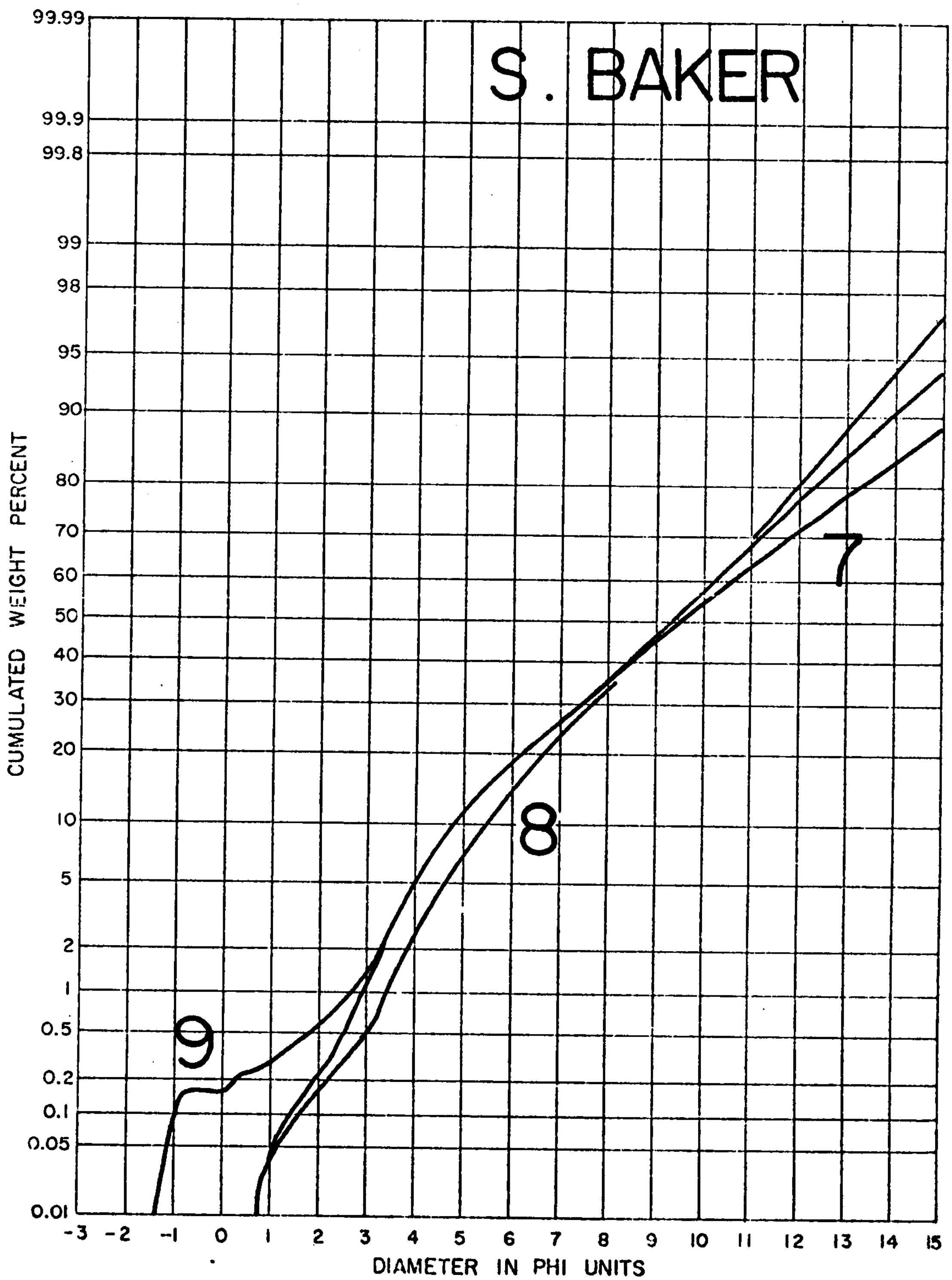


Figure 41

Sediment Size Frequency Distribution Curves for South Baker Samples 7-9.

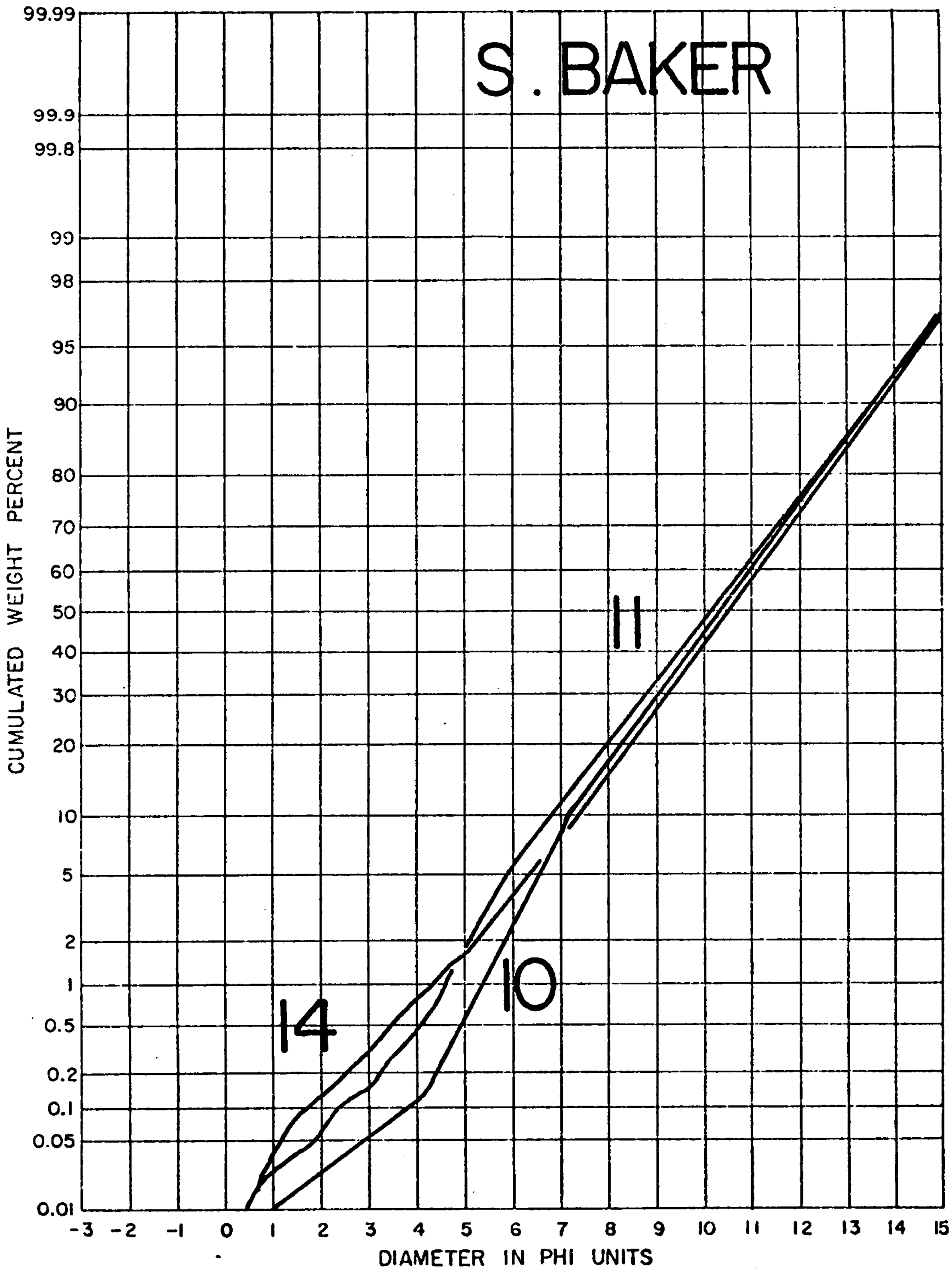


Figure 42
Sediment Size Frequency Distribution Curves for South Baker Samples 10, 11 and 14.

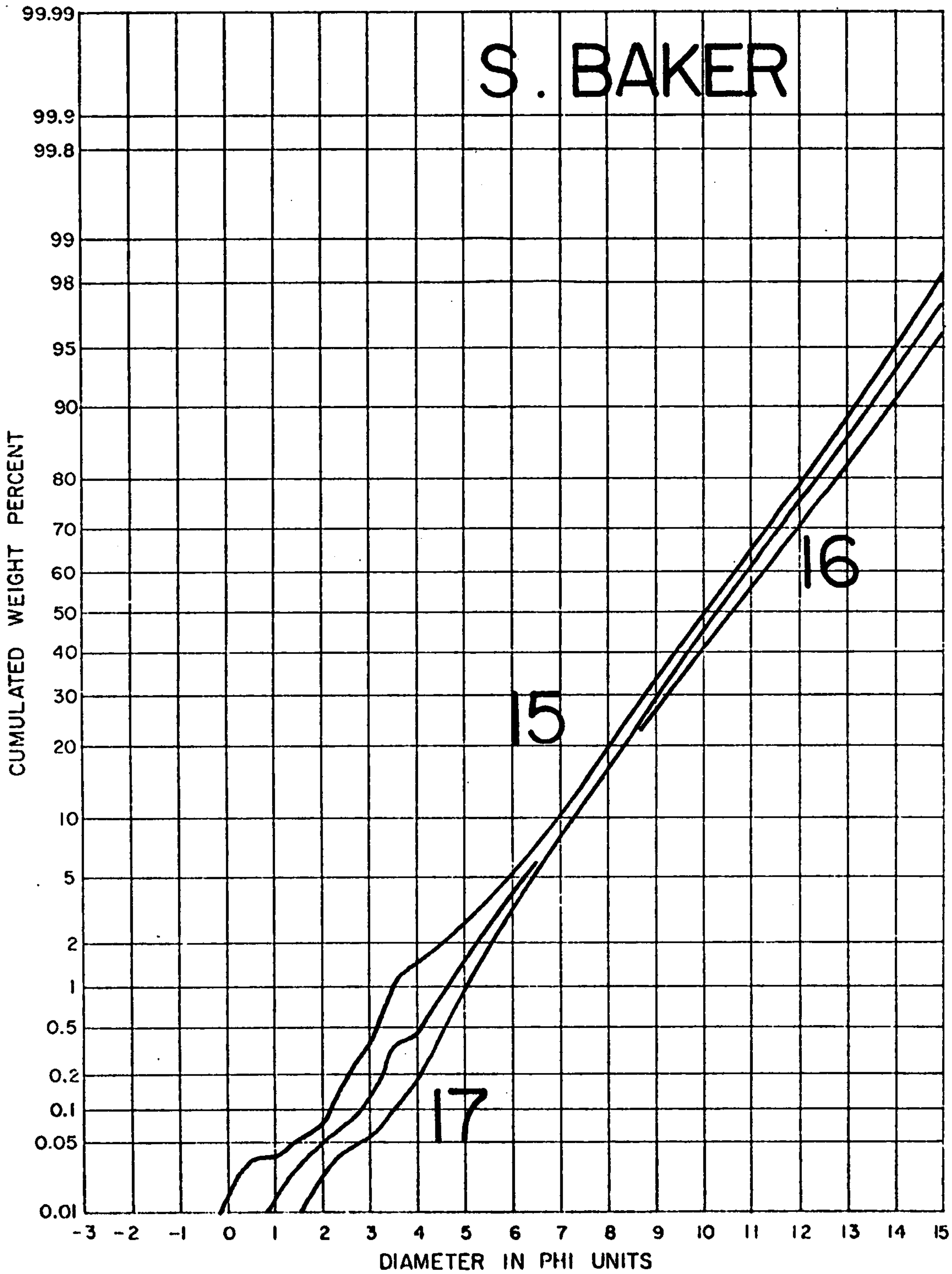


Figure 43
Sediment Size Frequency Distribution Curves for South Baker Samples 15-17.

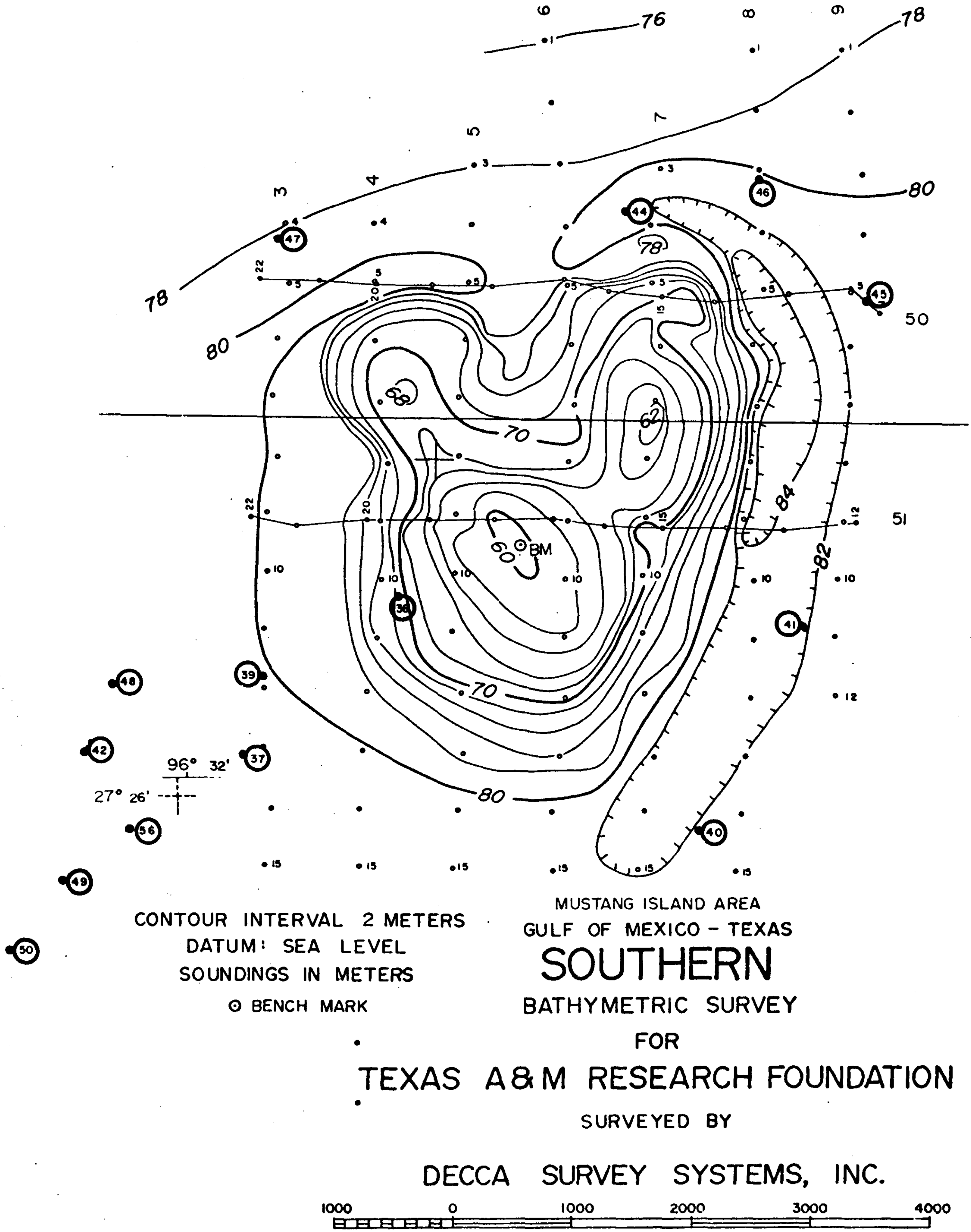


Figure 44. Sediment Sample Locations On Southern Bank.

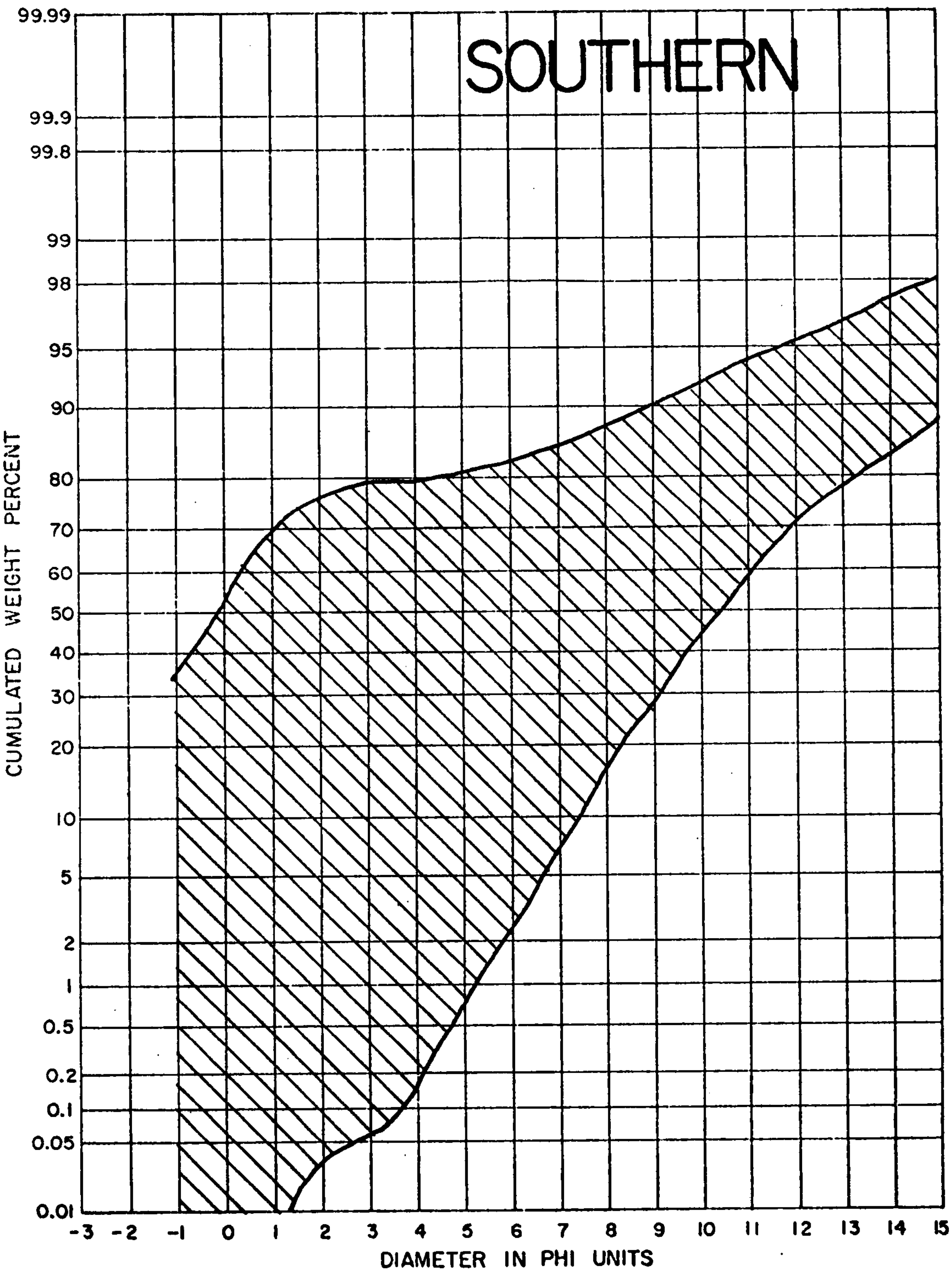


Figure 45

Range of Size Frequency Distribution Curves at Souther Bank.

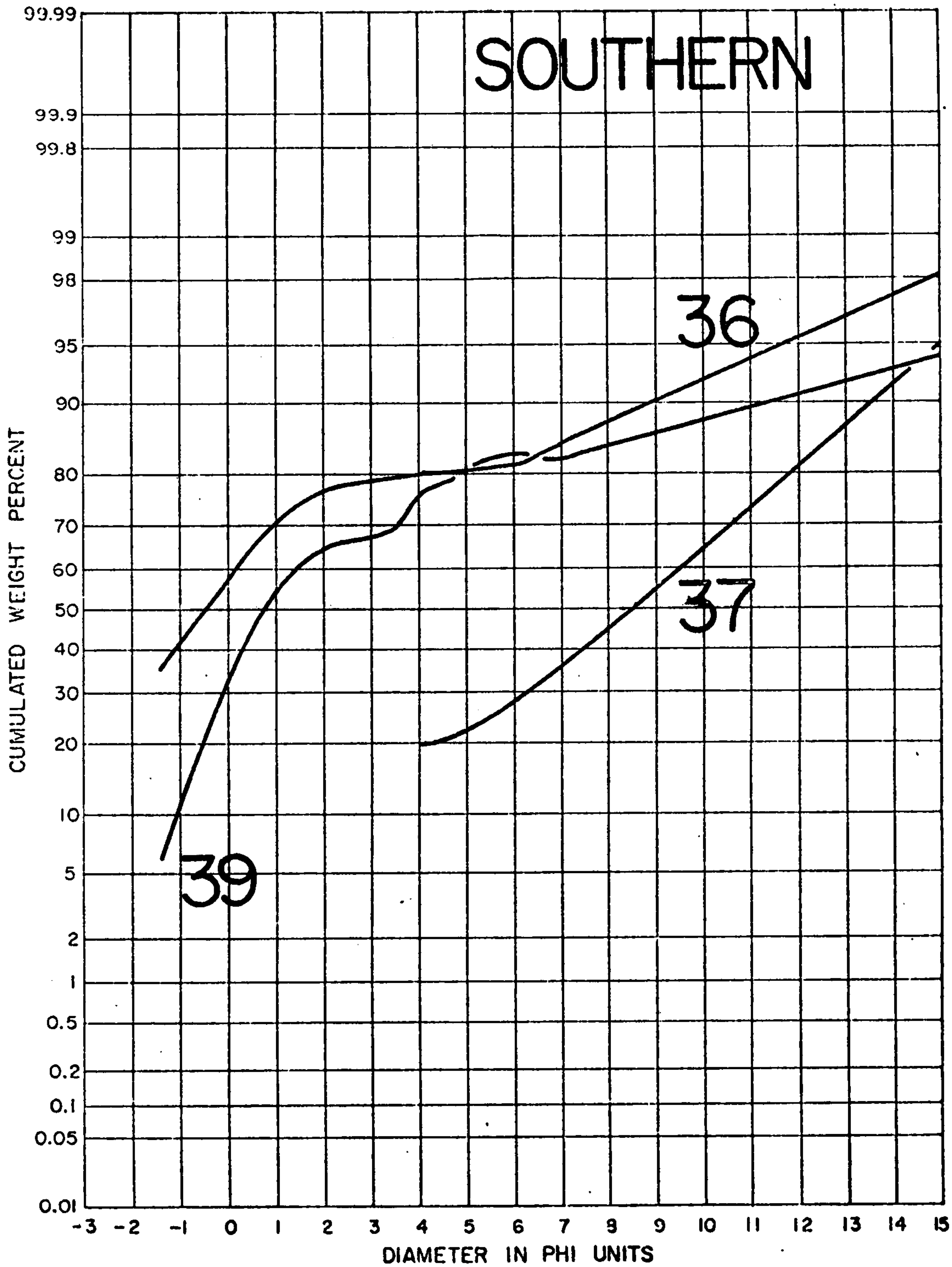


Figure 46
Sediment Size Frequency Distribution Curves for Southern Samples 36, 37 and 39.

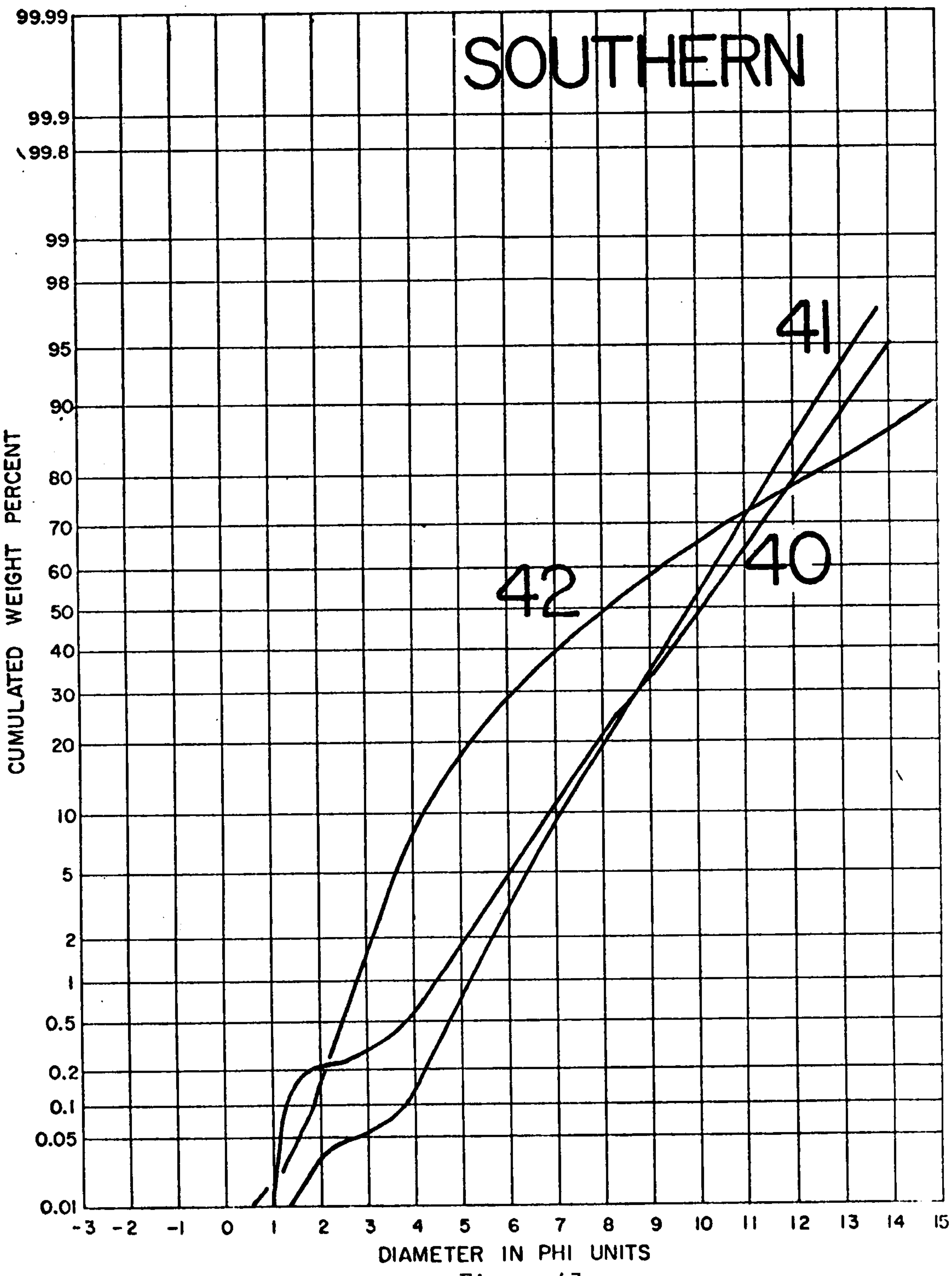


Figure 47
Sediment Size Frequency Distribution Curves for Souther Samples 40-42.

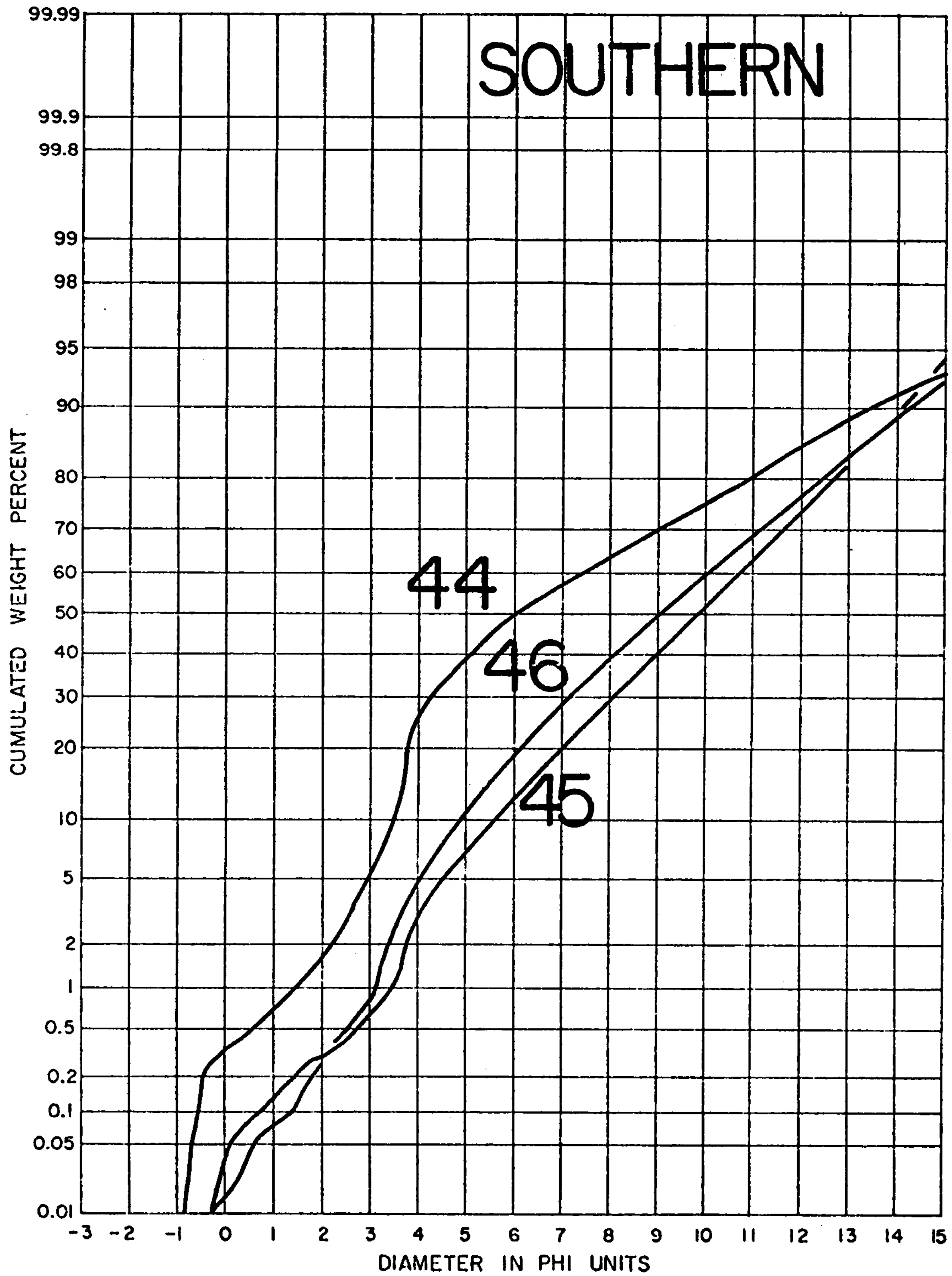


Figure 48
Sediment Size Frequency Distribution Curves for Southern Samples 44-46.

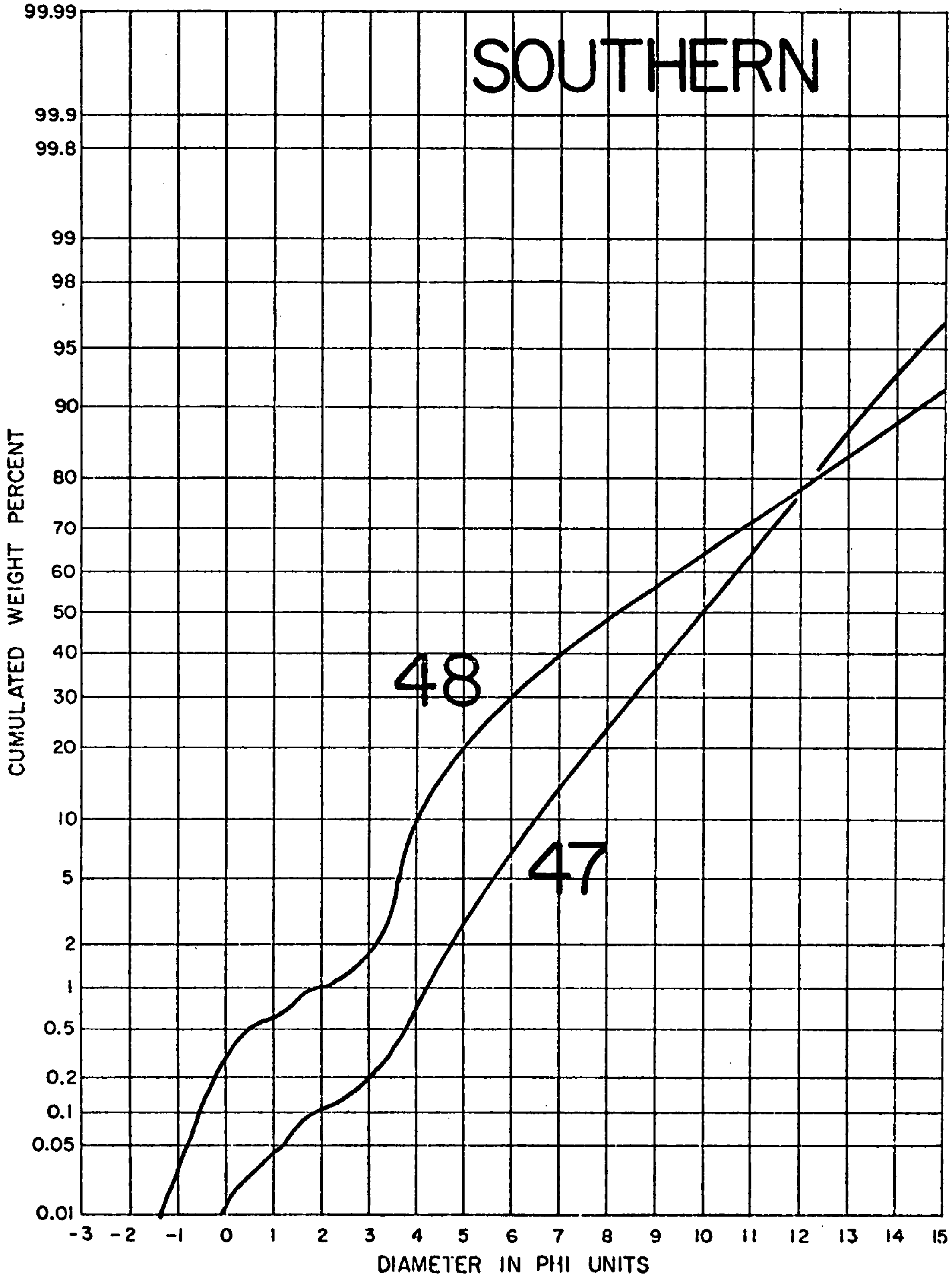
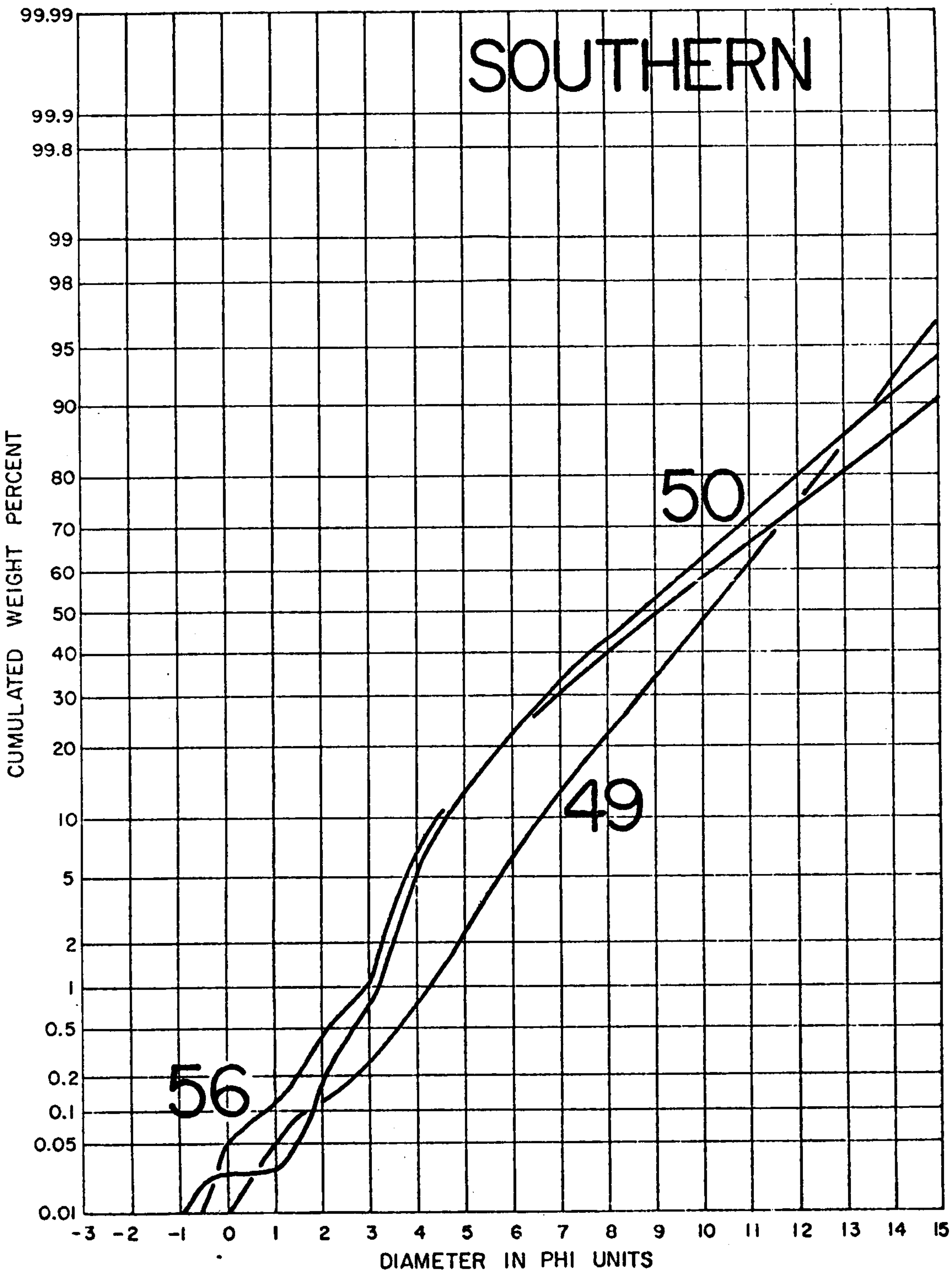


Figure 49
Sediment Size Frequency Distribution Curves for Southern Samples 47 and 48.



Sediment Size Frequency Distribution Curves for Southern Samples 49, 50 and 56.

Figure 50

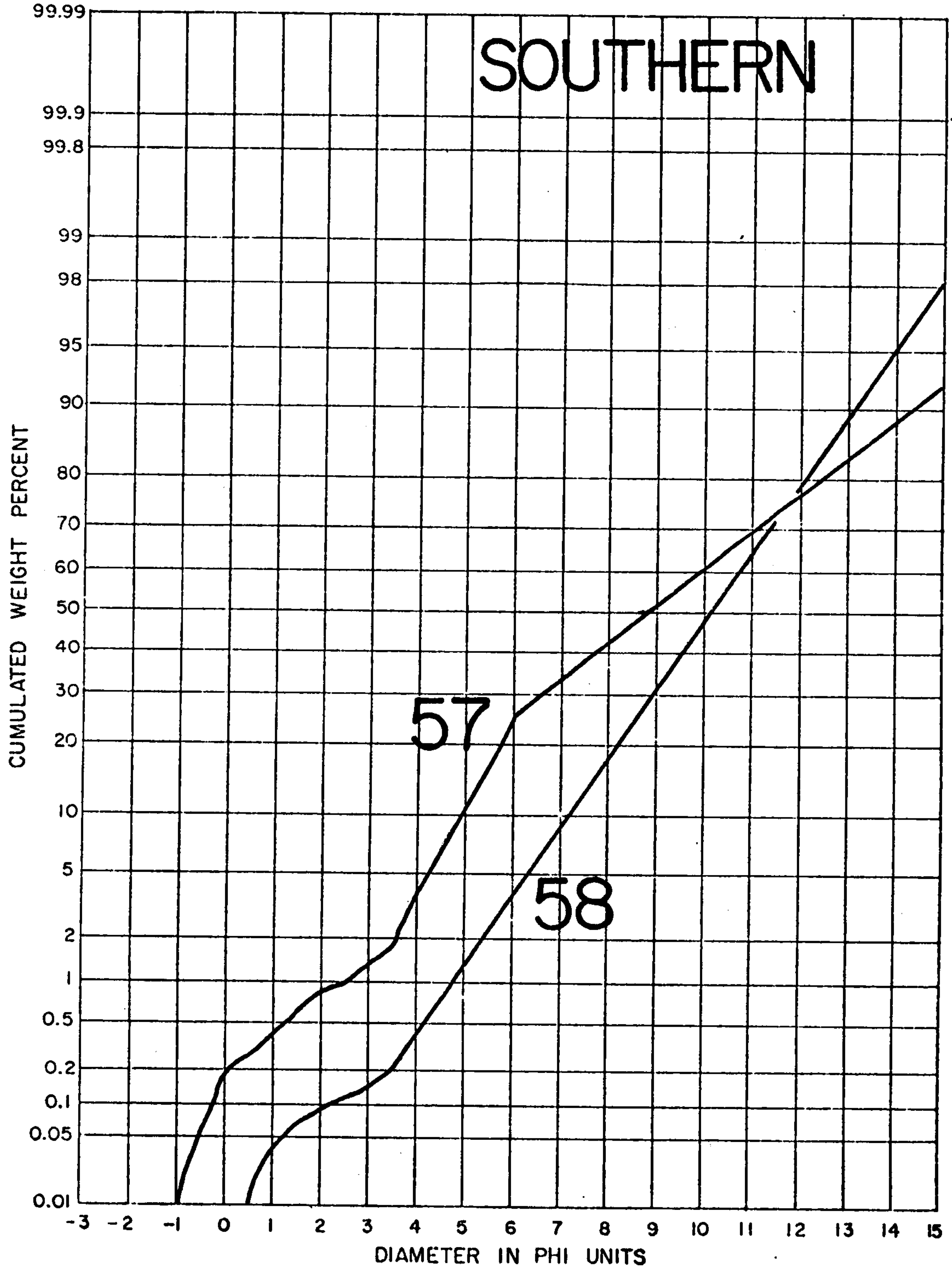


Figure 51
Sediment Size Frequency Distribution Curves for Southern
57 and 58.

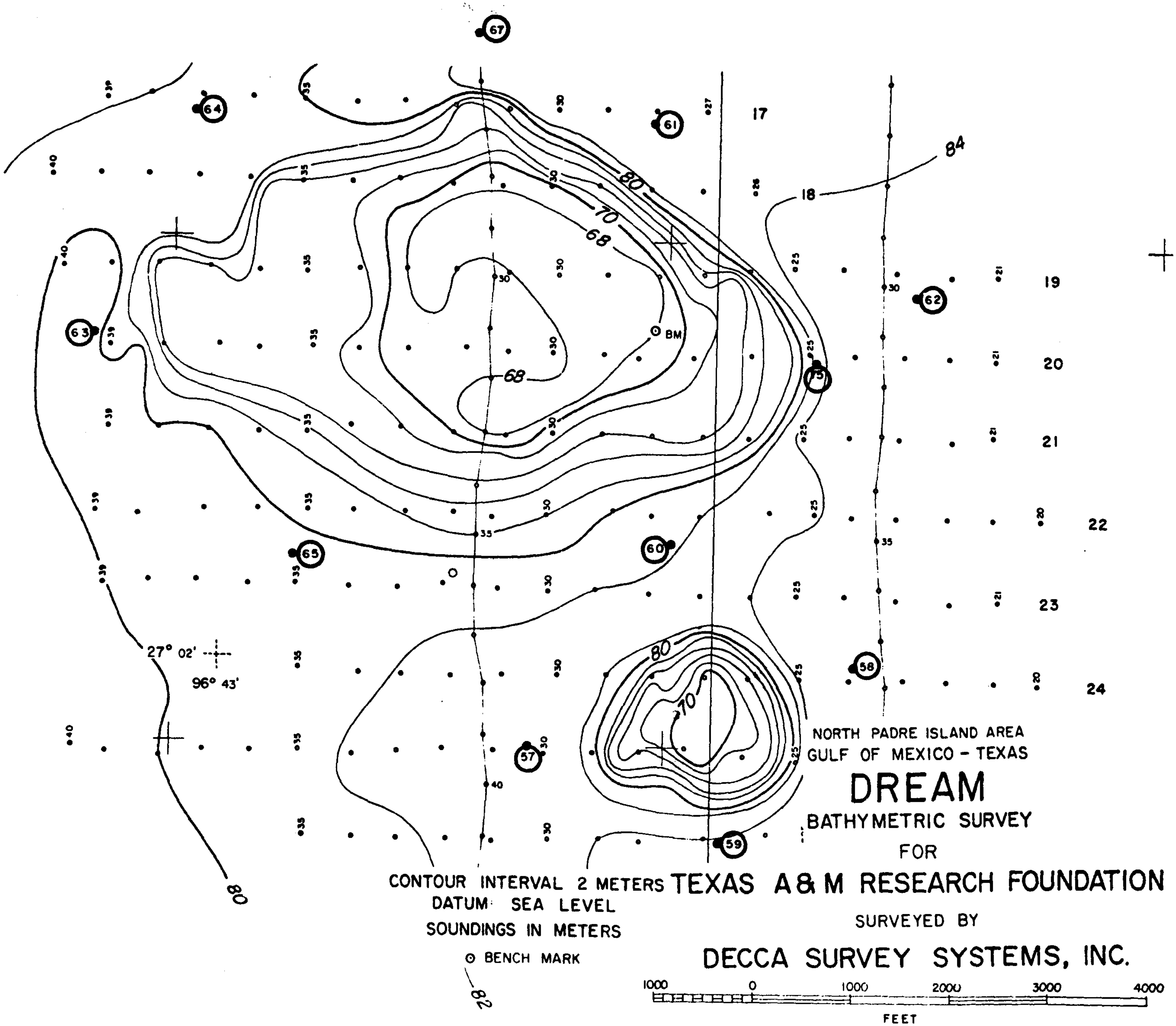


Figure 52. Sediment Sample Locations at Dream Bank.

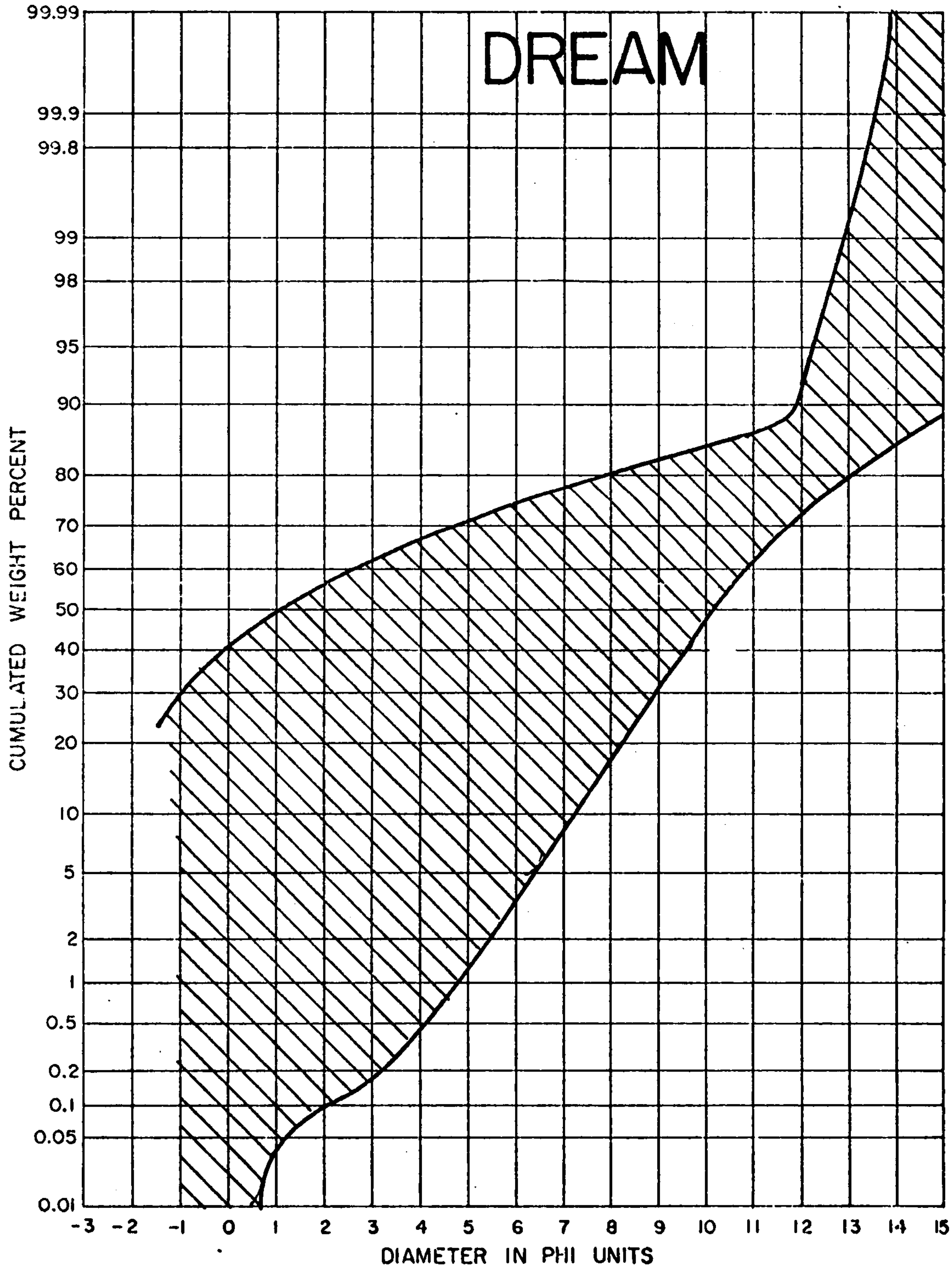


Figure 53
Range of Size Frequency Distribution Curves at Dream Bank.

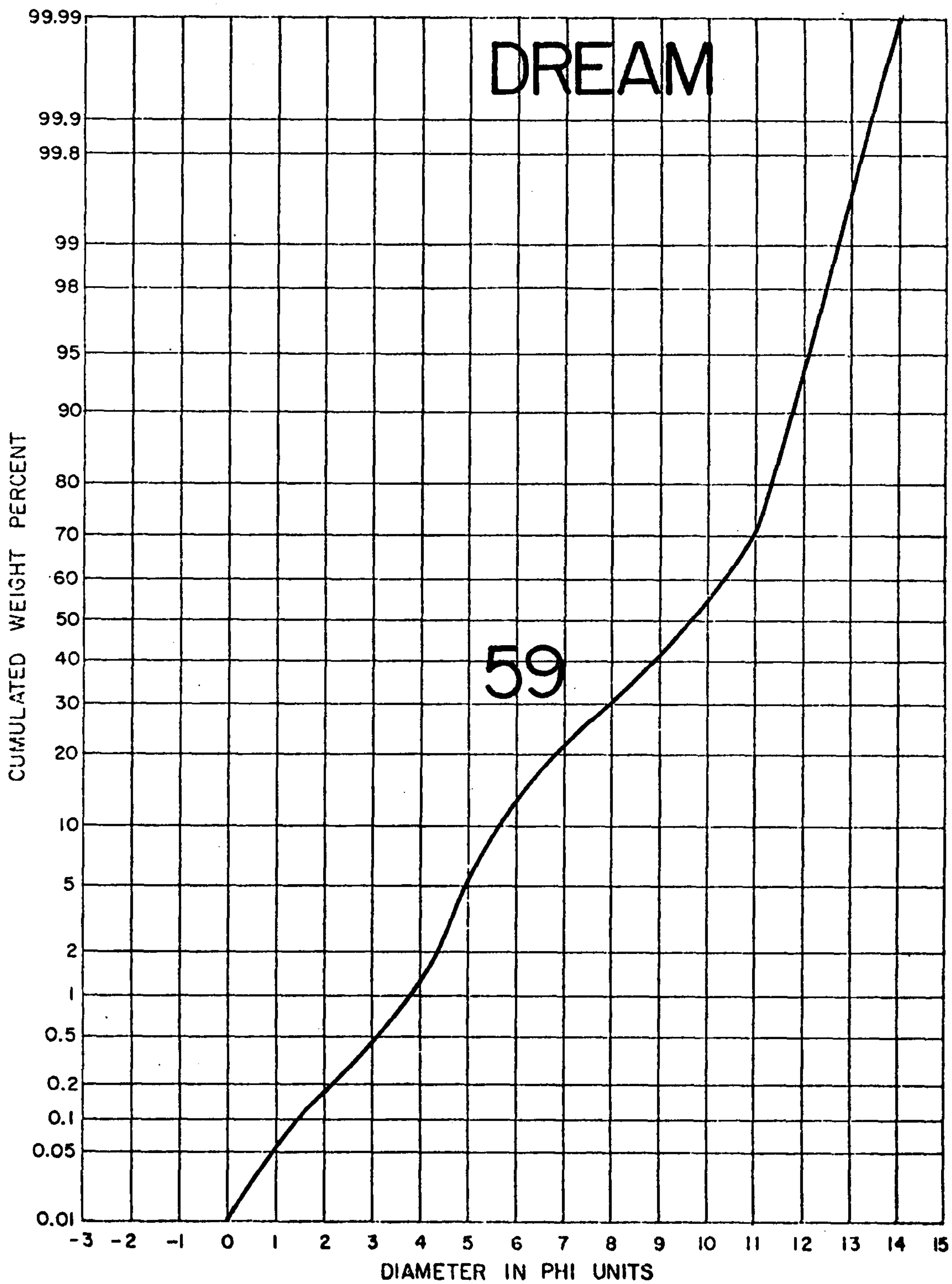


Figure 54
Sediment Sample Locations on Big Adam and Small Adam Rocks.

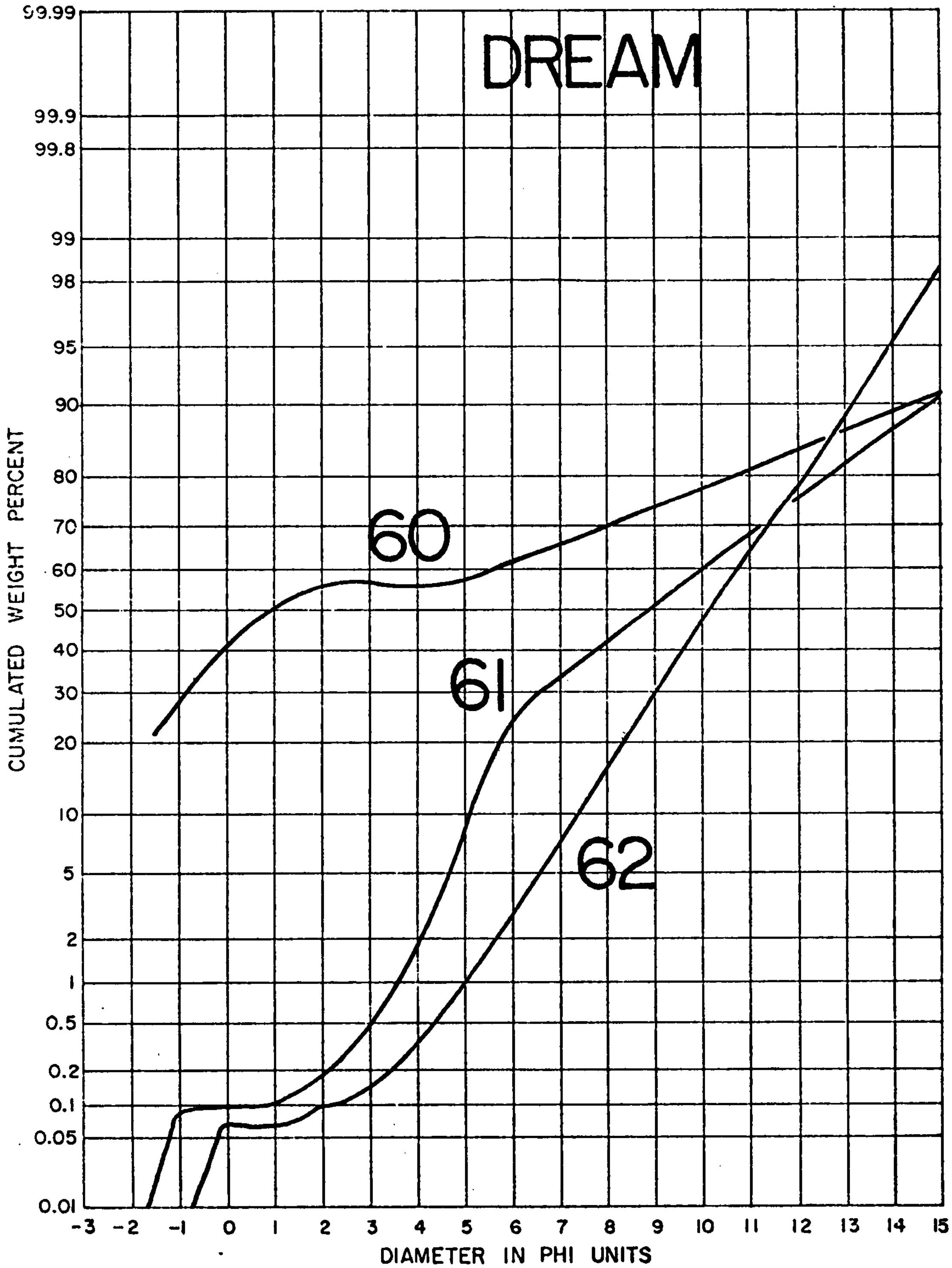


Figure 55

Sediment Size Frequency Distribution Curves for Dream Samples 60-62.

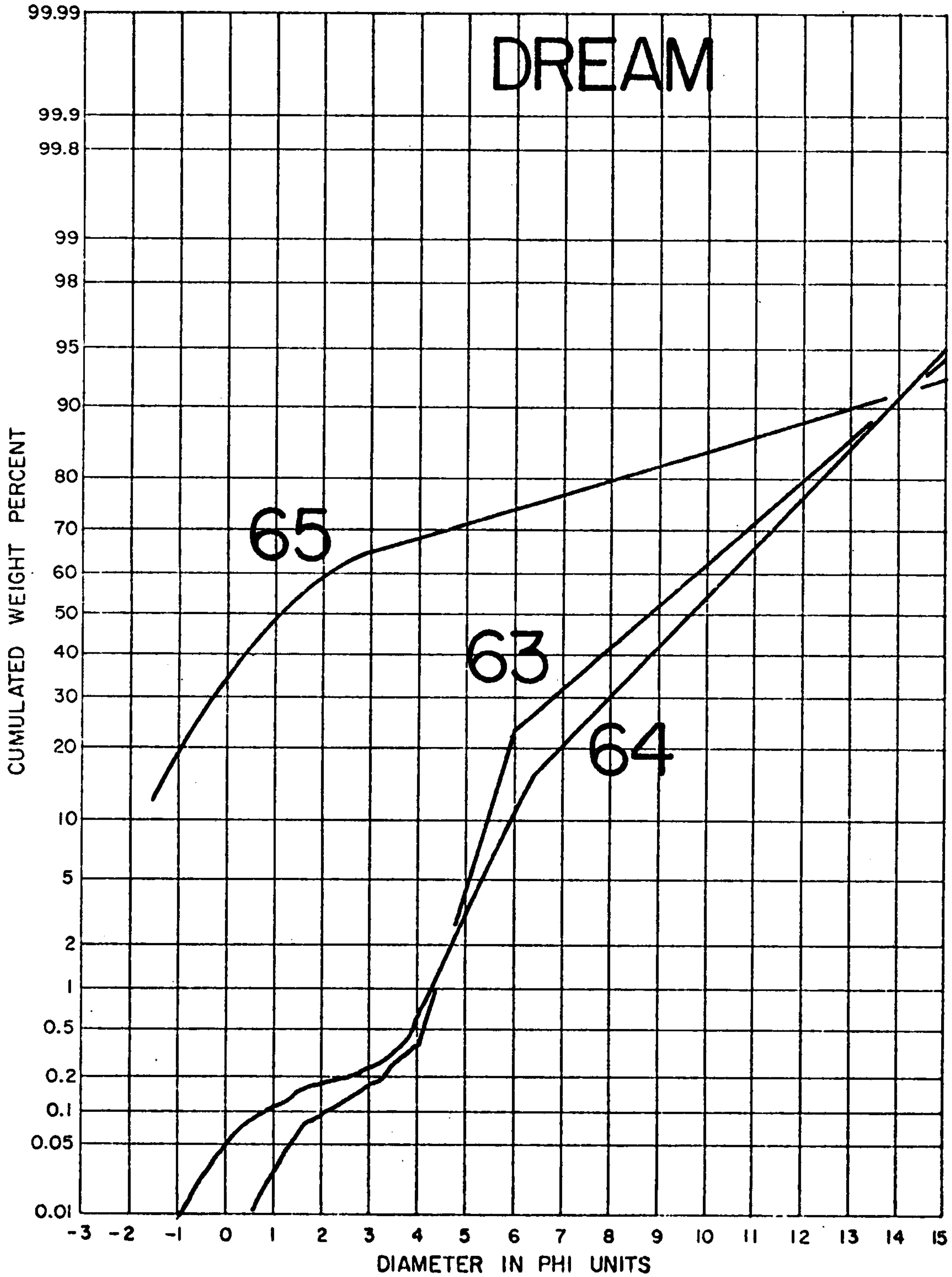


Figure 56
Sediment Size Frequency Distribution Curves for Dream Samples 63-65.

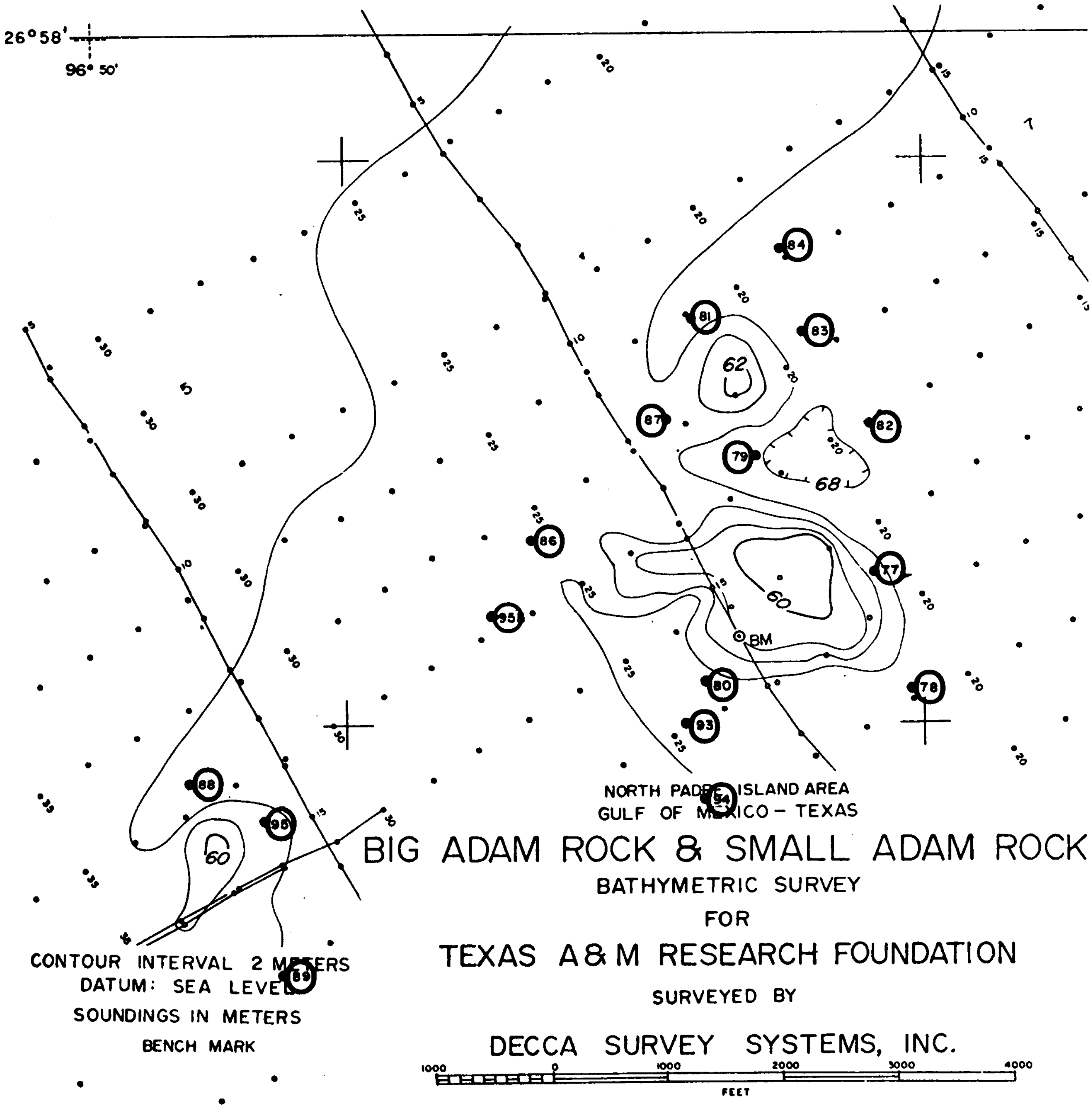


Figure 57. Sediment Sample Locations on Big Adam and Small Adam Rocks.

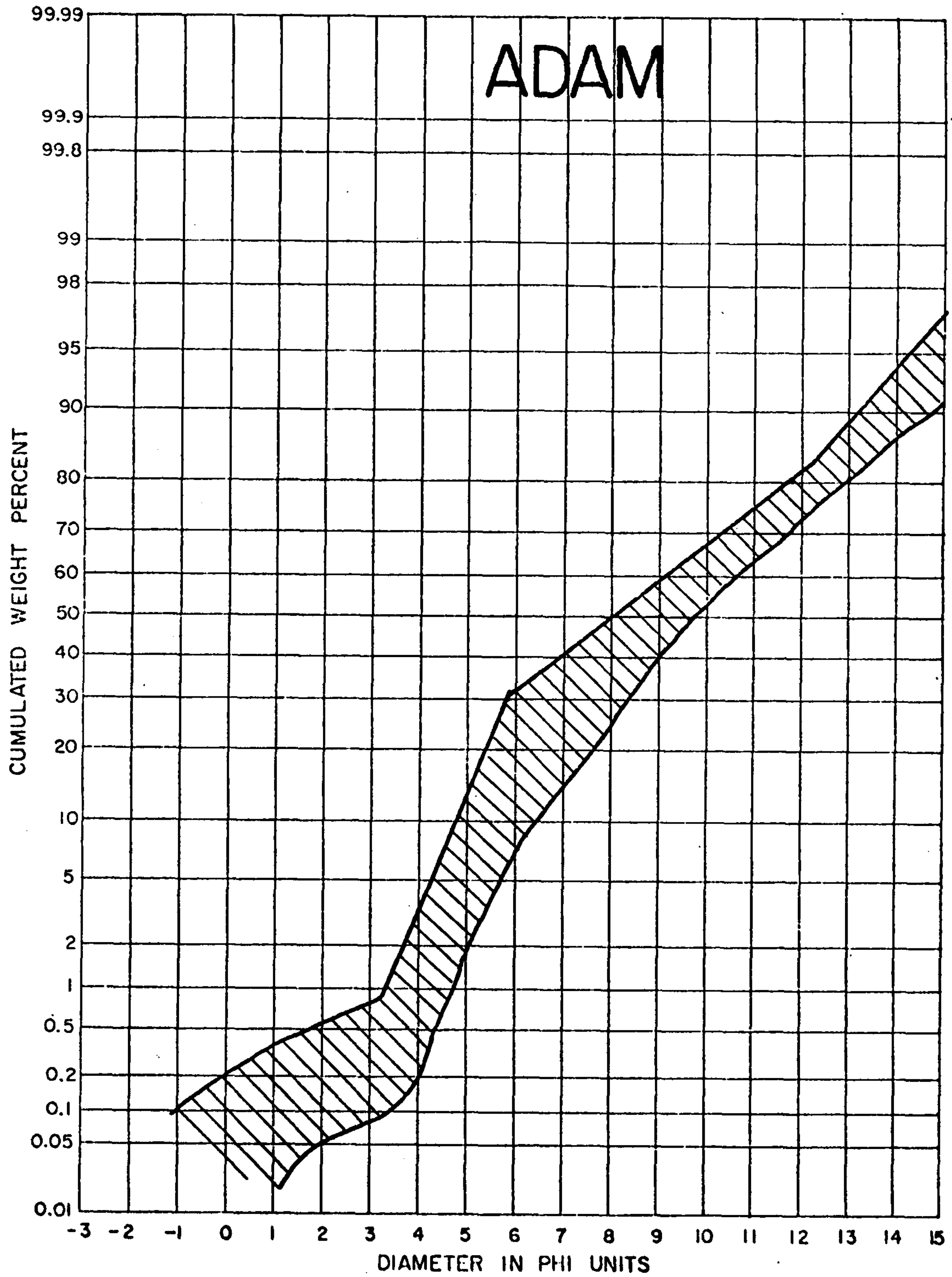


Figure 58

Range of Size Frequency Distribution Curves at Big Adam and Small Adam Rocks.

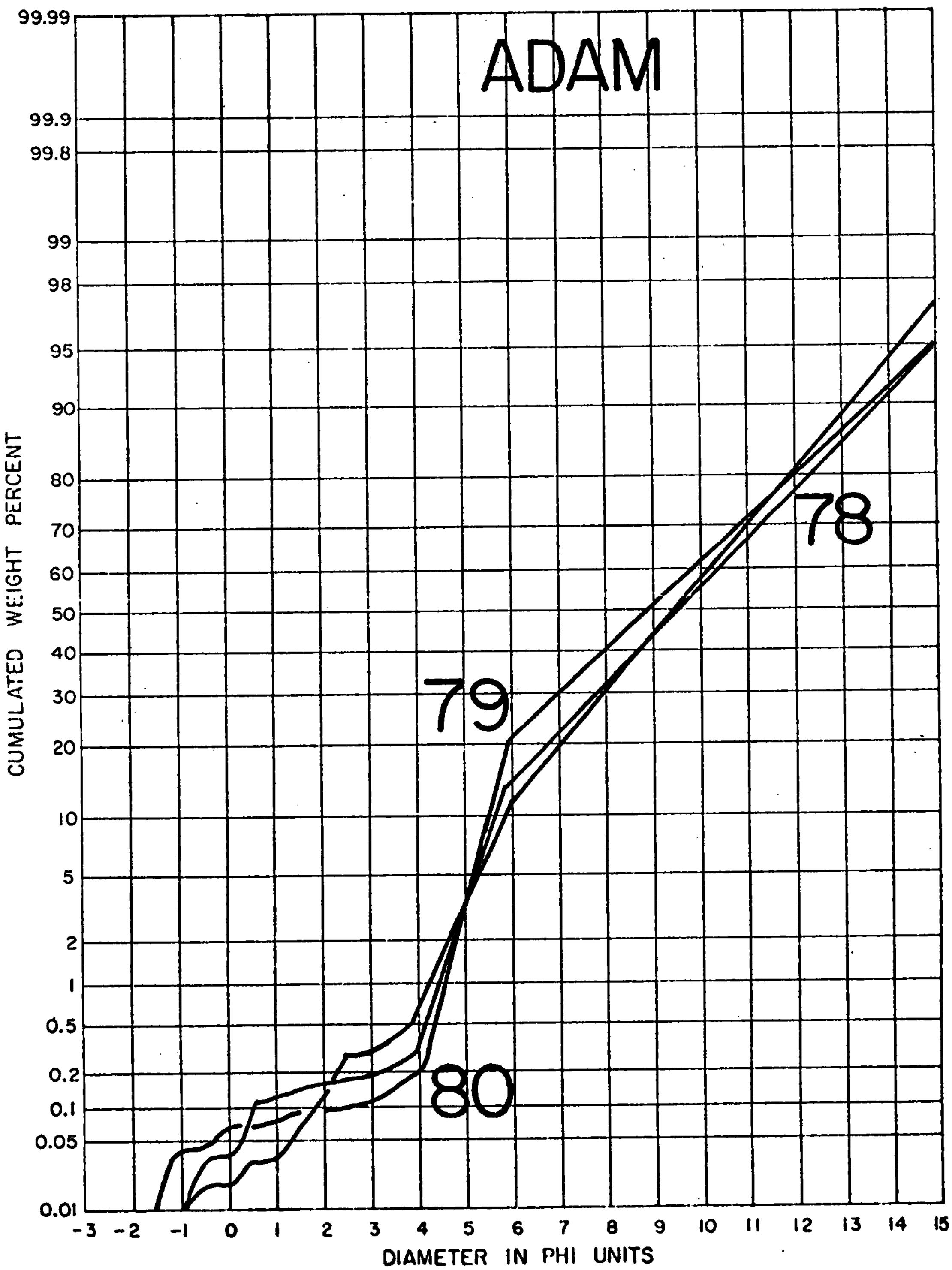


Figure 59
Sediment Size Frequency Distribution Curves for Adam Samples 78-80.

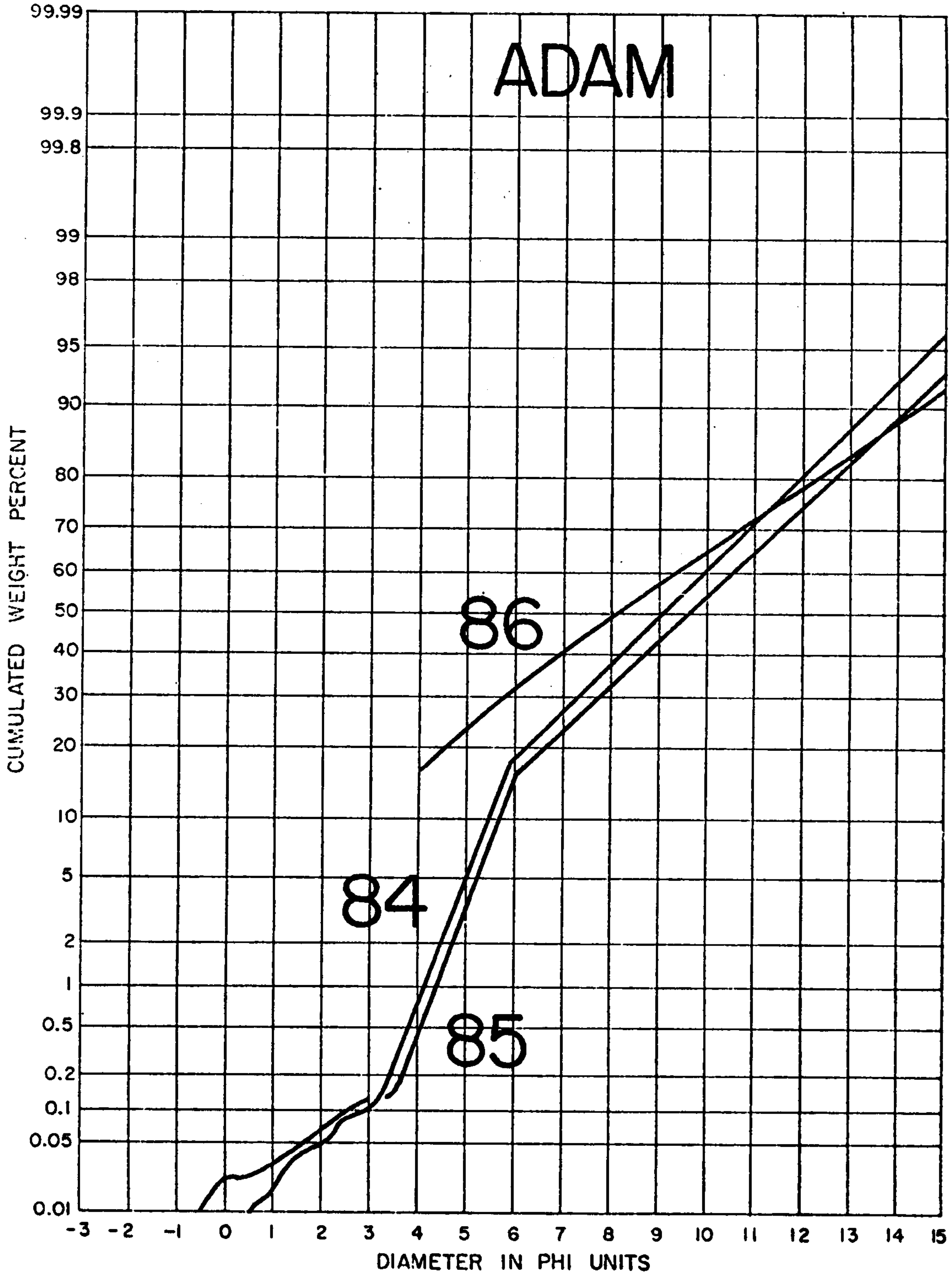


Figure 60
Sediment Size Frequency Distribution Curves for Adam Samples 84-86.

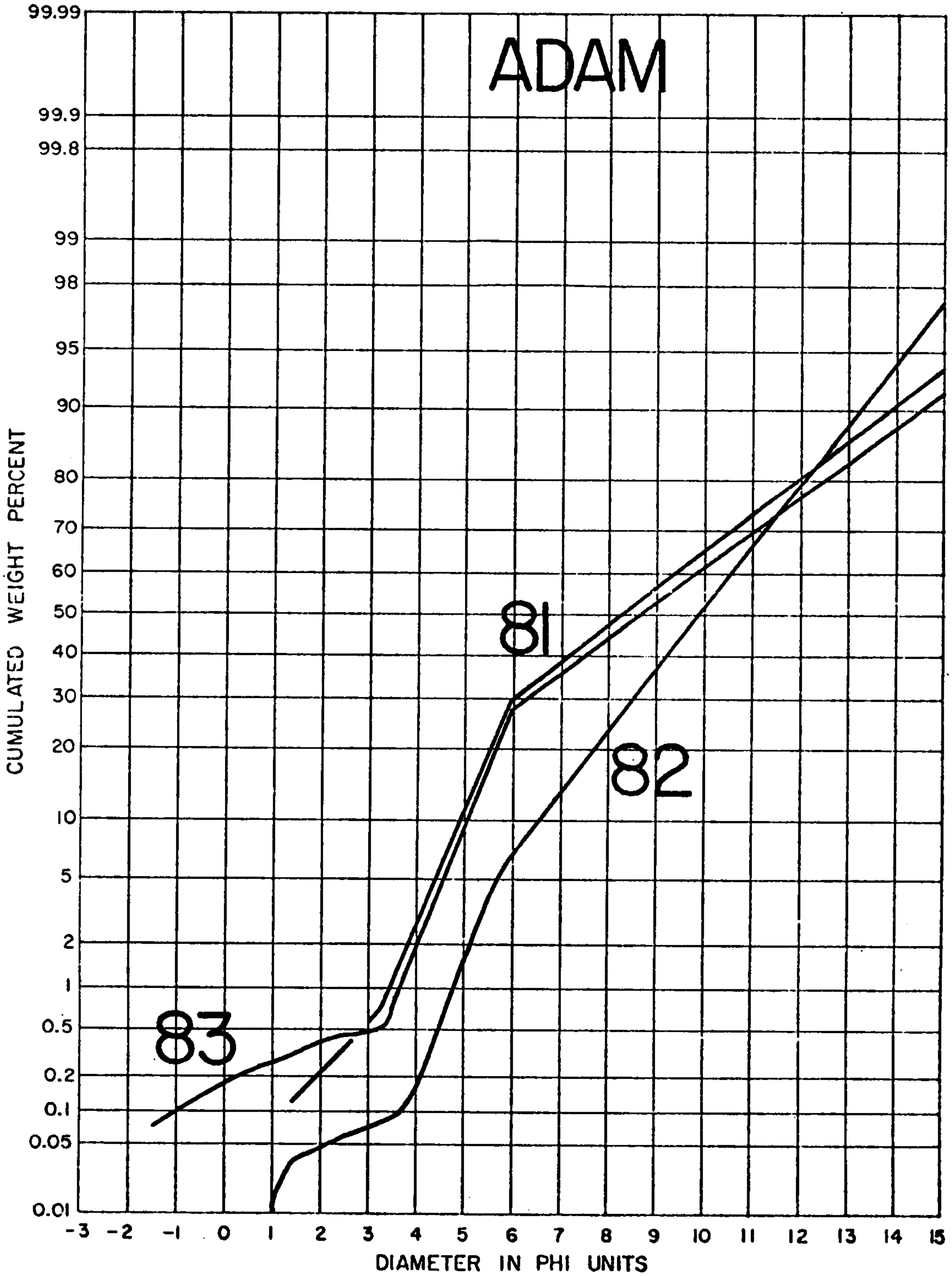


Figure 61
Sediment Size Frequency Distribution Curves for Adam Samples 81-83.

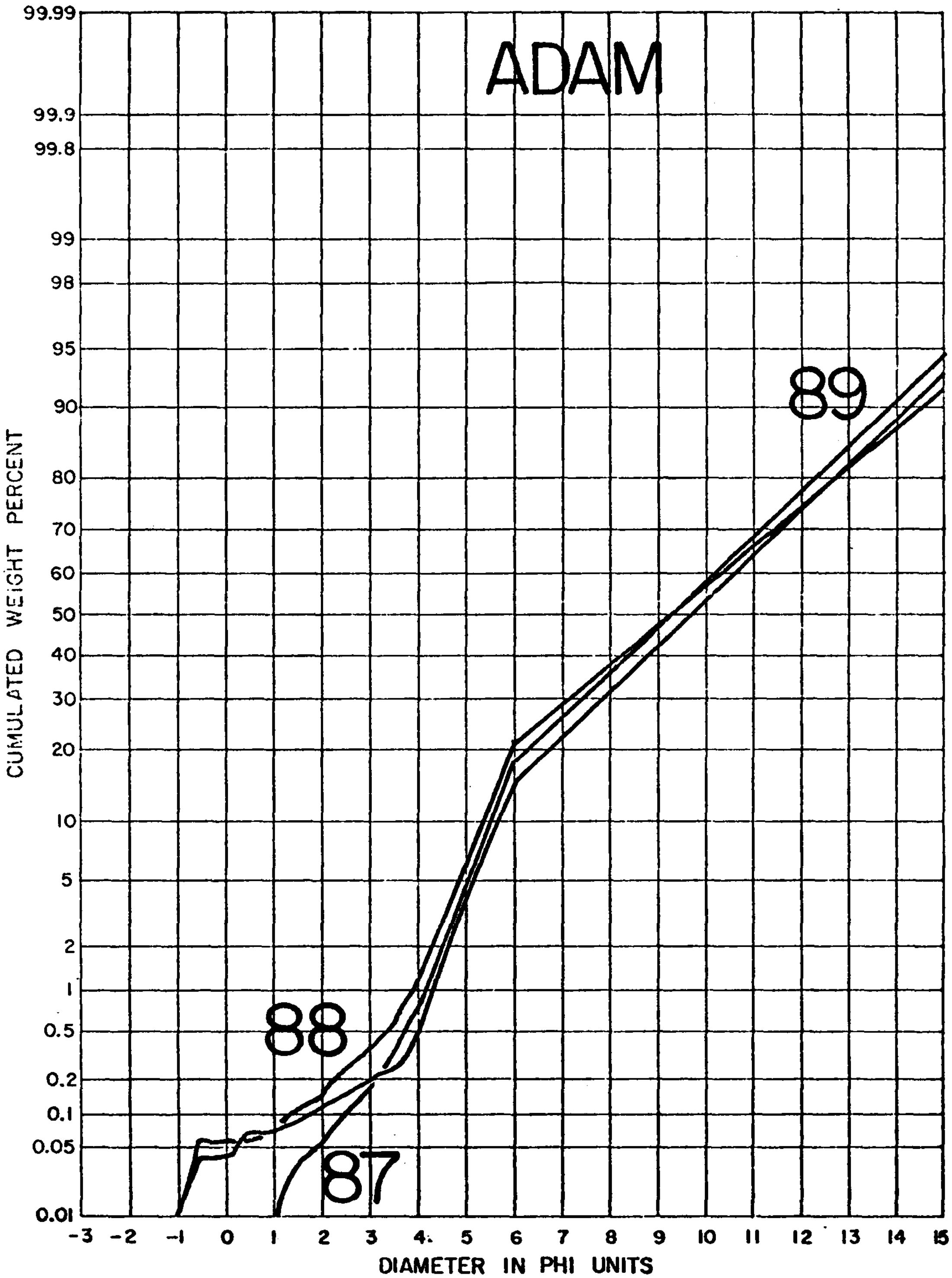


Figure 62
Sediment Size Frequency Disbribution Curves for Adam Samples 87-89.

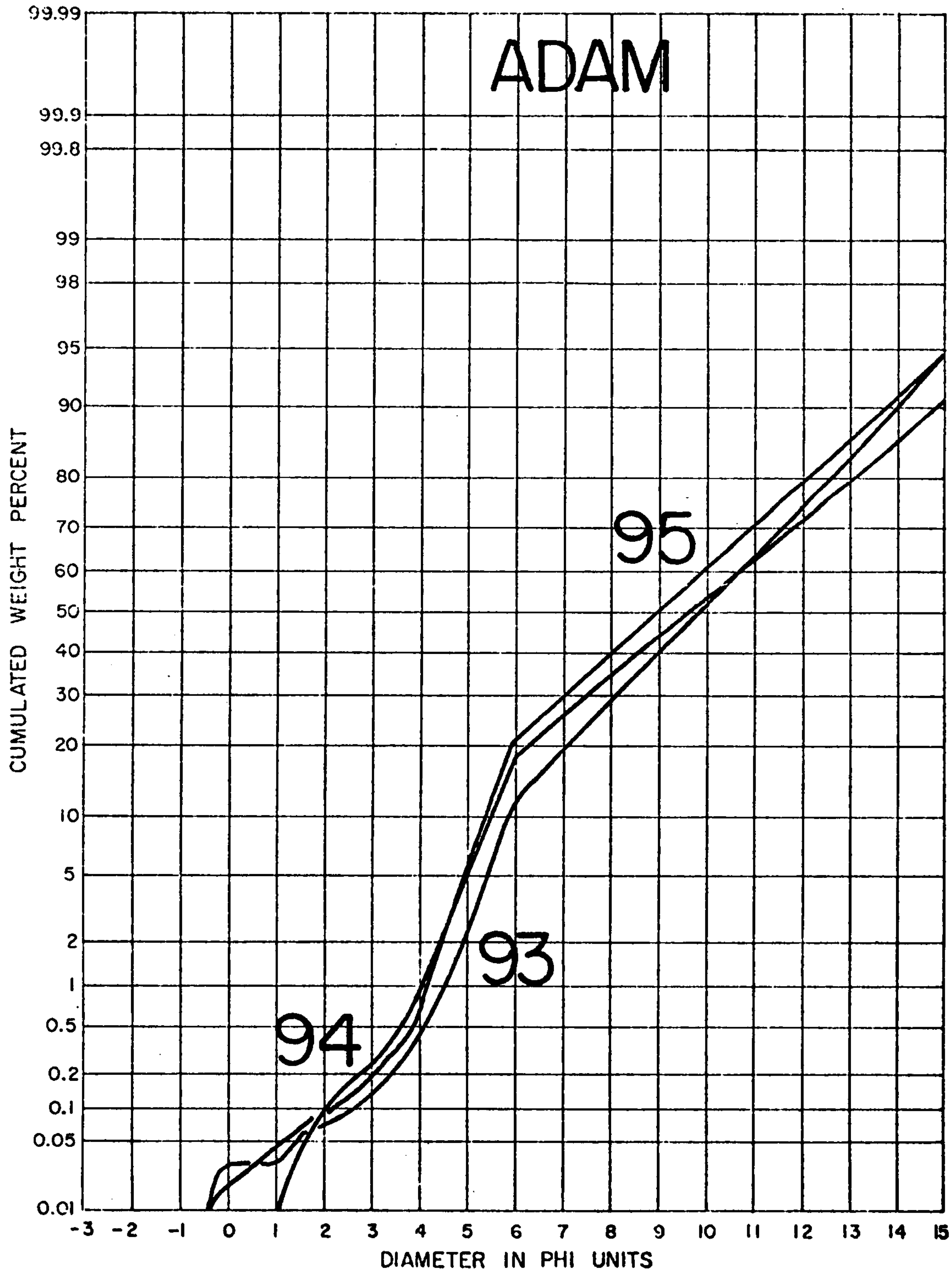


Figure 63

Sediment Size Frequency Distribution Curves for Adam Samples 93-95.

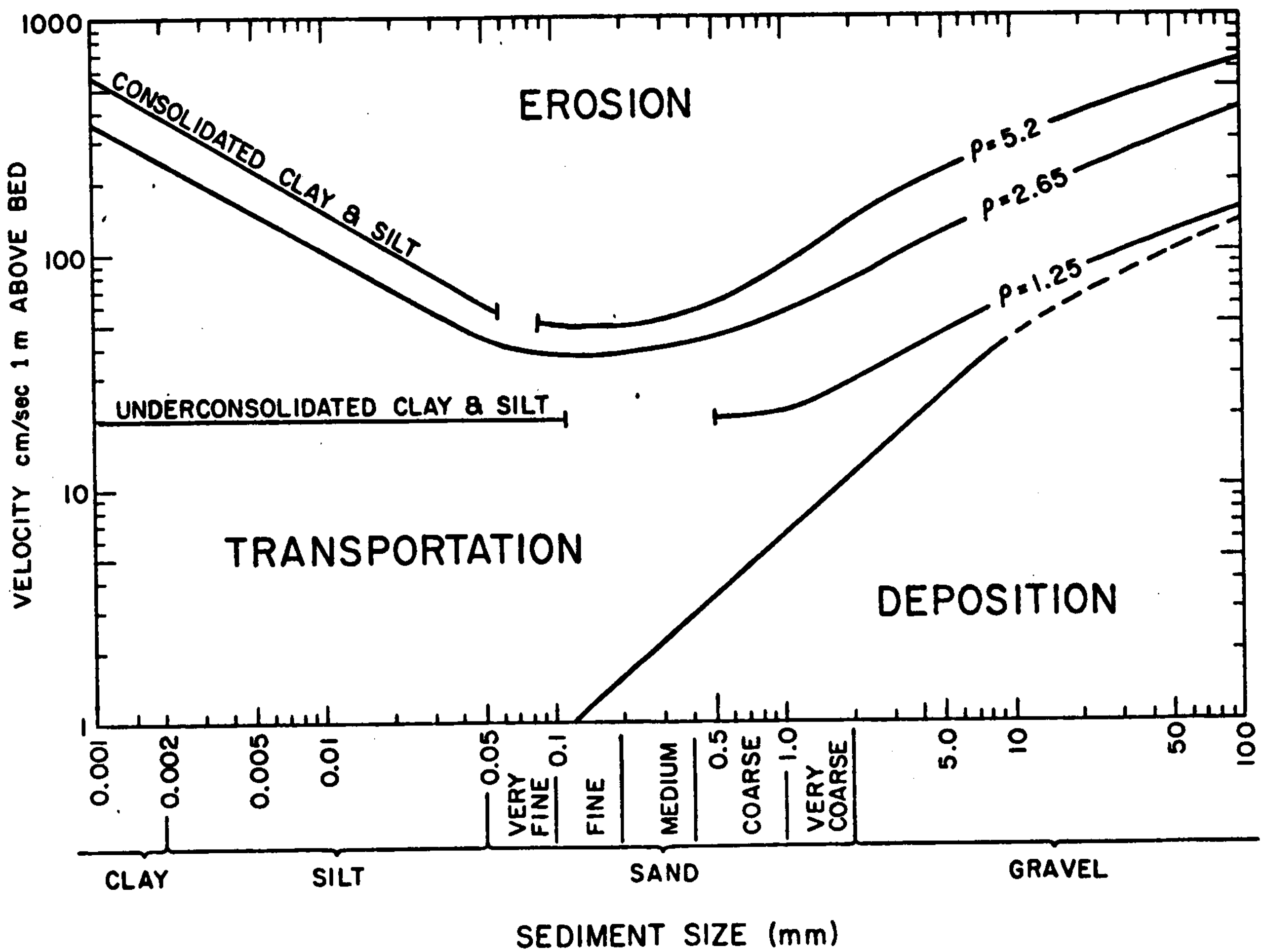
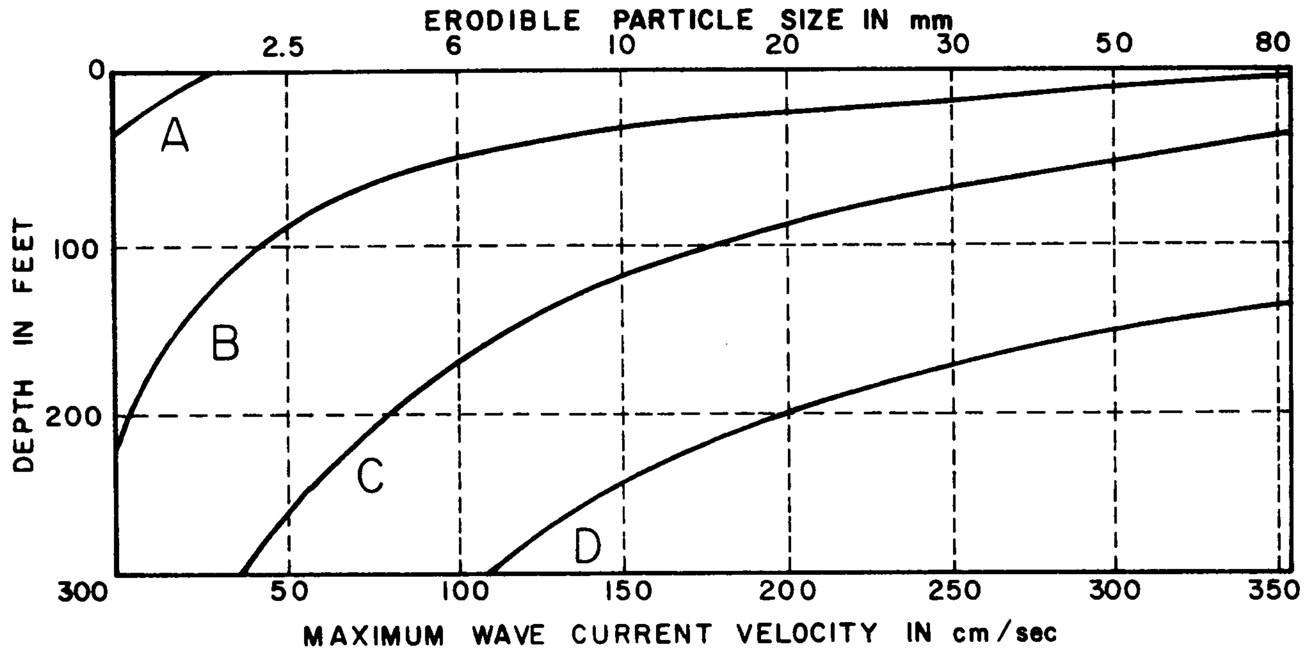


Figure 64. Relationship between current velocity, sediment size, erodibility, transportability, and depositional characteristics of sediments. (Modified from Sundborg, 1956)



WAVE FIELD

	PERIOD	LENGTH	HEIGHT
A	4.0 sec.	82 ft.	4 ft.
B	8.2 sec.	350 ft.	13 ft.
C	12.0 sec.	373 ft.	32 ft.
D	14.4 sec	1067 ft.	45 ft.

Figure 65. Relationship between water depth, erodible particle size, and maximum wave current velocity for various wave fields. (Modified from Logan et al., 1969)

Figure 66. Regression Line for Artificial Mixtures of Quartz, Calcite and Aragonite.

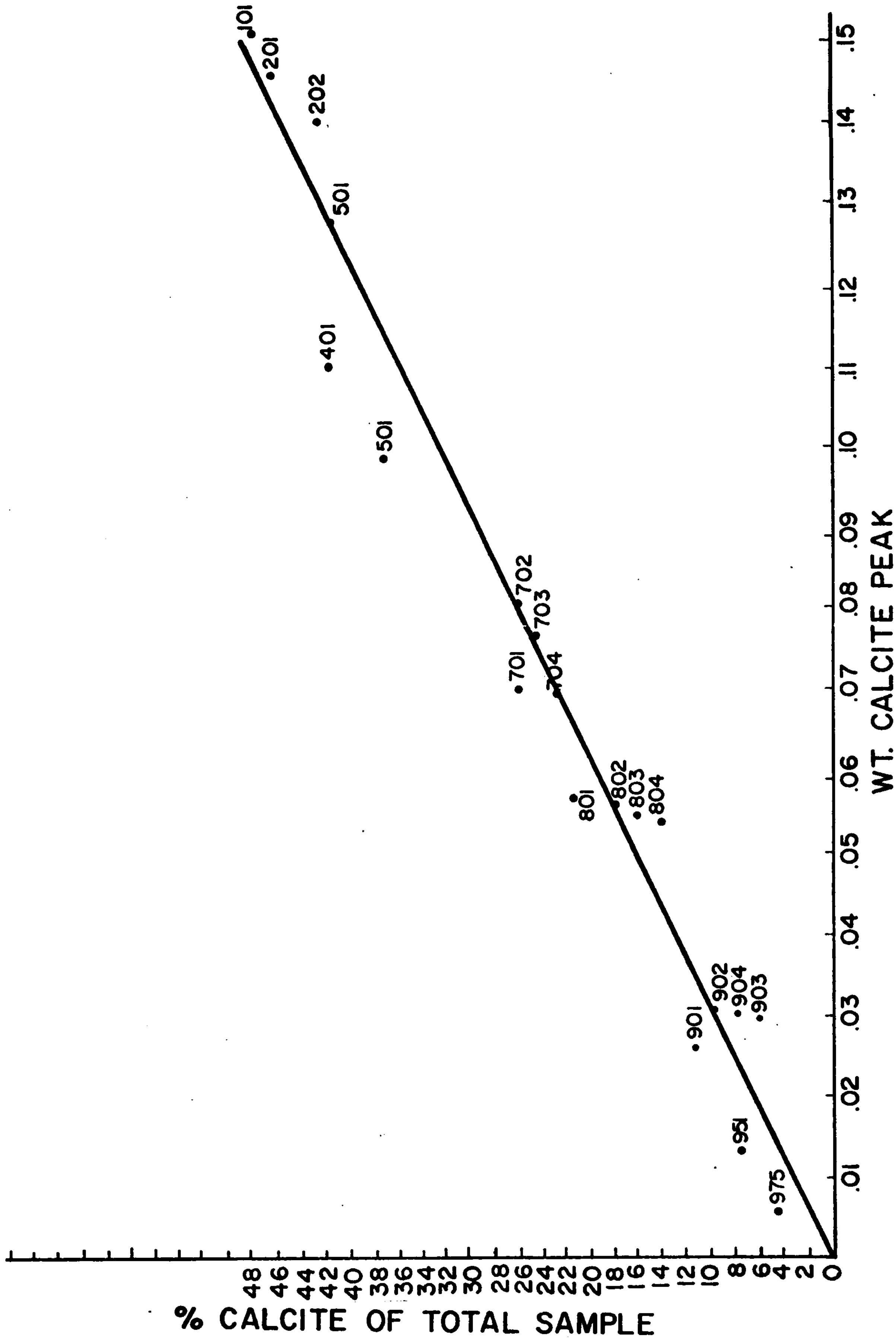


Table 1.

Clay Mineralogy

	Station	Percent Montmorillonite	Percent Chlorite	Percent Illite	Percent Kaolinite
Baker	1	60.4	3.1	29.2	7.3
	2	66.3	2.3	28.3	3.1
	4	63.7	4.3	26.3	5.7
	6	58.7	3.6	30.0	7.7
	25	64.2	6.0	22.7	7.1
	33	64.7	5.2	24.9	5.2
South Baker	7	63.9	5.0	22.1	9.0
	8	66.0	4.5	23.2	6.3
	9	65.9	3.6	26.0	4.5
	10	65.2	5.5	24.7	4.6
Southern	39	64.9	4.4	22.7	8.0
	40	63.7	4.8	27.7	3.8
	41	64.0	4.7	24.7	6.6
	42	61.2	6.2	24.5	8.1
Dream	59	56.7	7.4	27.3	8.6
	61	60.2	5.2	27.1	7.5
	64	62.1	6.8	23.2	7.9
	65	66.8	3.4	22.9	6.9
Little Adam and Big Adam	78	60.2	5.8	25.1	8.9
	80	62.6	3.4	24.8	9.2
	84	62.6	3.7	25.8	7.9
	85	61.6	6.3	24.7	7.4
	87	61.3	3.6	28.7	6.4

Table 2.

BAKER

SEDIMENT SIZE PARAMETERS

STATION NO.	MEDIAN DIA (MM)	GRAPHIC MEAN (MM)	GRAPHIC MEAN (Phi Units)	INCLUSIVE GRAPHIC STANDARD DEVIATION (Phi Units)	INCLUSIVE GRAPHIC SKEWNESS	GRAPHIC KURTOSIS	PERCENT SAND	PERCENT SILT	PERCENT CLAY	TEXTURE CLASSIFICATION
1	0.0027	0.0023	8.77	3.69	0.14	0.90	7.538	36.944	55.518	Mud
2	0.1767	0.0927	-	-	-	-	65.261	13.545	21.195	Muddy Sand
4	0.0012	0.0012	9.70	3.15	0.02	0.95	2.414	28.448	69.138	Clay
5	1.0000	-	0.00	-	-	-	72.631	11.076	16.293	Muddy Sand
6	0.00085	0.00086	10.17	2.26	-0.02	0.99	.988	20.569	78.443	Clay
22	0.0048	0.0034	8.17	3.94	0.22	0.88	13.898	38.066	48.036	Sandy Mud
23	0.0025	0.0023	8.77	2.89	0.10	0.88	11.937	30.834	57.229	Sandy Mud
24	0.0024	0.0021	8.87	3.63	0.09	0.91	7.456	33.879	58.665	Mud
25	0.0055	0.0042	7.90	4.11	0.21	0.81	22.530	30.069	47.401	Sandy Mud
26	0.0206	0.0080	6.97	4.11	0.54	0.88	33.726	32.072	34.202	Sandy Mud
27	0.0009	0.0009	10.10	2.40	- .01	0.98	0.491	19.359	80.150	Clay
28	0.0007	0.0007	10.47	2.86	0.05	0.88	0.674	19.514	79.812	Clay
29	1.0000	-	0.00	-	-	-	74.329	10.297	15.374	Muddy Sand
30	0.0013	0.0013	9.57	3.45	-0.01	1.02	5.319	27.314	67.366	Clay
31	0.0039	0.0034	8.20	3.08	0.16	0.51	18.300	30.610	51.090	Muddy Sand
32	0.0335	0.0113	6.47	3.84	0.69	1.24	36.595	34.353	29.051	Sandy mud
33	0.0034	0.0032	8.27	3.87	0.11	0.84	10.572	35.361	54.067	Sandy Mud

SOUTH BAKER

STATION NO.	MEDIAN DIA (MM)	GRAPHIC MEAN (MM)	GRAPHIC MEAN (Phi Units)	INCLUSIVE GRAPHIC STANDARD DEVIATION (Phi Units)	INCLUSIVE GRAPHIC SKEWNESS	GRAPHIC KURTOSIS	PERCENT SAND	PERCENT SILT	PERCENT CLAY	TEXTURE CLASSIFICATION
7	0.0013	0.0012	9.67	3.78	0.06	0.90	4.172	30.537	65.290	Clay
8	0.0017	0.0018	9.10	2.96	0.002	0.93	2.444	34.076	63.480	Mud
9	0.0018	0.0018	9.07	3.41	0.01	0.95	6.631	30.740	62.628	Clay
10	0.0007	0.0007	10.43	2.46	-0.02	0.96	0.101	16.888	83.011	Clay
11	0.0008	0.0008	10.20	2.52	0.00	1.01	0.344	19.693	79.963	Clay
13A	-	-	-	-	-	-	12.709	42.488	44.803	Sandy Mud
14	0.0007	0.0007	10.50	2.41	0.00	0.96	0.629	15.445	83.926	Clay
15	0.0009	0.0009	10.03	2.45	-0.03	0.98	1.457	20.267	78.276	Clay
16	0.0006	0.0007	10.47	2.46	-0.05	1.00	0.388	17.023	82.589	Clay
17	0.0007	0.0007	10.53	2.46	0.04	0.99	0.156	17.125	82.720	Clay

Table 3.

SOUTHERN

SEDIMENT SIZE PARAMEMTERS

STATION NO.	MEDIAN DIA (MM)	GRAPHIC MEAN (MM)	GRAPHIC MEAN (Phi Units)	INCLUSIVE GRAPHIC STANDARD DEVIATION (Phi Units)	INCLUSIVE GRAPHIC SKEWNESS	GRAPHIC KURTOSIS	PERCENT SAND	PERCENT SILT	PERCENT CLAY	TEXTURE CLASSIFICATION
36	1.500	1.500	-0.5	-	-	-	79.705	8.181	12.114	Muddy Sand
37	0.0027	0.0027	8.5	-	-	-	19.545	22.510	57.945	Sandy Clay
39	0.6597	0.1988	2.33	4.65	0.71	1.71	76.992	7.690	15.318	Muddy Sand
40	0.0009	0.0009	10.20	2.50	0.04	0.98	0.460	22.050	77.490	Clay
41	0.0032	0.0010	10.00	3.13	0.74	1.28	0.099	21.754	78.147	Clay
42	0.0010	0.0021	8.93	3.26	-0.34	0.67	8.328	42.503	49.168	Mud
44	0.0167	0.0069	7.17	4.08	0.50	0.88	28.961	34.338	36.701	Sandy Mud
45	0.0011	0.0011	9.77	3.30	0.003	0.95	3.225	25.786	70.988	Clay
46	0.0015	0.0014	9.43	3.73	0.04	0.90	5.741	30.087	64.172	Clay
47	0.0009	0.0009	10.07	2.66	-0.01	1.00	0.695	21.797	77.507	Clay
48	0.0030	0.0022	8.77	3.69	0.14	0.90	9.846	35.700	54.453	Mud
49	0.0008	0.0008	10.27	2.75	-0.01	1.01	0.672	23.991	75.336	Clay
50	0.0210	0.0020	9.03	3.59	0.09	0.89	5.459	35.006	59.535	Mud
56	0.0160	0.0014	9.43	3.97	0.09	0.87	6.103	32.692	61.204	Mud

Table 4.

DREAM

SEDIMENT SIZE PARAMETERS

STATION NO.	MEDIAN DIA (MM)	GRAPHIC MEAN (MM)	GRAPHIC MEAN (Phi Units)	INCLUSIVE GRAPHIC STANDARD DEVIATION (Phi Units)	INCLUSIVE GRAPHIC SKEWNESS	GRAPHIC KURTOSIS	PERCENT SAND	PERCENT SILT	PERCENT CLAY	TEXTURE CLASSIFICATION
57	0.0022	0.0018	9.10	3.70	0.17	0.86	3.509	39.329	57.163	Mud
58	0.0009	0.0009	10.20	2.22	0.00	1.01	0.306	17.741	81.953	Clay
59	0.0014	-	9.50	-	-	-	0.358	15.548	84.064	Clay
60	0.5000	-	1.00	-	-	-	55.886	13.794	30.319	Clayey Sand
61	0.0020	0.0014	9.53	3.90	0.23	0.80	1.929	38.151	59.919	Mud
62	0.0007	0.0009	10.10	1.98	-0.14	1.00	0.227	17.672	82.102	Clay
63	0.0019	0.0017	9.20	3.31	0.16	1.03	3.348	38.416	58.236	Mud
64	0.0011	0.0011	9.80	3.10	0.05	1.19	0.464	30.900	68.636	Clay
65	0.4352	0.0930	3.43	-	-	-	66.779	10.834	22.388	Clayey Sand
67	0.0013	0.0017	9.17	2.35	-0.28	0.77	1.506	30.916	67.578	Clay

Table 5.

BIG ADAM ROCK AND SMALL ADAM ROCK

SEDIMENT SIZE PARAMETERS

STATION NO.	MEDIAN DIA (MM)	GRAPHIC MEAN (MM)	GRAPHIC MEAN (Phi Units)	INCLUSIVE GRAPHIC STANDARD DEVIATION (Phi Units)	INCLUSIVE GRAPHIC SKEWNESS	GRAPHIC KURTOSIS	PERCENT SAND	PERCENT SILT	PERCENT CLAY	TEXTURE CLASSIFICATION
78	0.0013	0.0013	9.63	3.08	0.07	0.86	0.249	31.677	68.074	Clay
79	0.0013	0.0013	9.57	2.77	0.02	0.91	0.467	28.574	70.959	Clay
80	0.0020	0.0018	9.10	3.13	0.13	0.80	1.847	37.552	60.601	Mud
81	0.0064	0.0030	8.40	3.40	0.47	0.81	1.725	44.356	53.920	Mud
82	0.0011	0.0011	9.83	2.53	0.03	0.97	0.106	26.566	73.327	Clay
83	0.0224	010017	9.17	3.67	0.21	0.81	1.616	41.456	56.928	Mud
84	0.0018	0.0017	9.17	3.10	0.10	0.87	0.524	36.431	63.045	Mud
85	0.0014	0.0014	9.53	3.31	0.09	0.86	0.260	33.937	65.803	Mud
86	0.0039	-	-8.00	-	-	-	16.837	31.676	51.487	Sandy Mud
87	0.0015	0.0014	9.50	3.46	0.14	0.87	0.634	37.687	61.679	Mud
88	0.0017	0.0015	9.40	3.58	0.15	0.81	0.987	38.616	60.397	Mud
89	0.0013	0.0013	9.63	3.24	0.07	0.87	0.404	33.443	66.153	Mud
93	0.0011	0.0010	9.93	3.11	0.05	0.91	0.308	26.977	72.715	Clay
94	0.0011	0.0011	9.80	3.73	0.08	0.85	0.889	32.523	66.587	Clay
95	0.0018	0.0017	9.23	3.38	0.13	0.82	0.587	36.864	62.549	Mud

Table 6. Hurricane Hindcast Data

(Modified from Patterson, 1971)

Distance from Eye Nautical Miles	Wave Height Feet	Wave Height Meters	Wave Period Seconds	Wave Celerity Knots	Wave Length Feet	Wave Length Meters
<u>Carla</u>						
180	31	9.1	15.1	49	1,160	353.3
120	32	9.4	15.2	50	1,190	362.4
60	43	13.1	14.6	45	1,098	334.9
30	35	10.7	15.2	49	1,188	361.8
0	41	12.5	14.7	46	1,105	336.5
30	42	12.8	13.6	41	945	288.0
60	45	13.7	14.2	43	1,039	316.9
120	45	13.7	14.4	44	1,043	318.1
180	43	13.1	14.3	44	1,061	323.6
240	39	11.9	13.9	43	944	287.7
420	31	9.4	12.6	39	809	246.5
<u>Betsy</u>						
30	47	14.3	14.5	44	1,076	328.2
<u>Hilda</u>						
30	25	7.6	11.1	34	631	192.3

TABLE 7

X-Ray Diffraction Standards

Sample	% Quartz	% Calcite	% Aragonite	Weight of Calcite Peak (in grams)
901	90	9	1	0.02663
902	90	8	2	0.02815
903	90	6	4	0.02911
904	90	7	3	0.02837
801	80	18	2	0.05369
802	80	16	4	0.05281
803	80	14	6	0.05245
804	80	12	8	0.05210
701	70	24.3	4.5	0.07085
702	70	24.4	8.6	0.07759
703	70	22.9	6.1	0.07344
704	70	21.3	7.6	0.06744
951	95	5	0	0.01428
975	97.5	2.5	0	0.00671
501	50	35	15	0.09819
401	40	40	20	0.10929
301	30	40	30	0.12486
201	20	45	35	0.14375
202	20	40	40	0.13670
101	10	47.5	42.5	0.14960

TABLE 8

Scheibler Analyses

Sample No.	Percent Calcium Carbonate	Sample No.	Percent Calcium Carbonate	Sample No.	Percent Calcium Carbonate
1	5.8	33	5.5	79	5.0
2	53.6	36	78.4	80	5.3
4	5.0	37	6.1	81	4.9
5	79.7	39	71.2	82	4.6
6	2.8	40	3.4	83	4.8
7	6.0	41	3.1	84	5.0
8	5.9	42	5.8	85	4.6
9	5.7	44	8.2	86	4.6
10	2.5	45	5.7	87	4.5
11	2.4	46	5.7	88	4.3
13	7.4	47	4.0	89	4.5
14	2.3	48	6.8	93	5.5
15	2.4	49	4.1	94	4.8
16	3.2	50	5.5	95	4.3
17	2.3	56	5.2		
22	7.3	57	5.6		
23	6.1	58	4.4		
24	5.9	59	4.3		
25	6.0	60	63.9		
26	7.1	61	4.8		
27	2.7	62	4.5		
28	2.7	63	9.9		
29	59.8	64	4.5		
30	3.3	65	70.1		
31	6.9	67	4.7		
32	10.6	78	4.8		

TABLE 9

Carbonate

X-Ray Diffraction Analyses

Bank	Station	Low Mg Location °2 θ	Low Mg Mole % $MgCO_3$	Low Mg % of Coarse Fraction	Intermediate Mg Location °2 θ	Intermediate Mg Mole % $MgCO_3$	Intermediate Mg % of Coarse Fraction	High Mg Location °2 θ	High Mg Mole % $MgCO_3$	High Mg % of Coarse Fraction
	2	29.43	1.5	2.78				29.85	16	15.04
	5				29.63	7	3.23	29.97	19	19.30
	22	29.99	1.4	8.61				30.21	31	0.41
	23	29.49	2.5	5.65						
	24	29.44	1.5	3.82				29.82	13.5	0.37
Baker	25	29.45	1.5	6.23	29.77	12	1.56			
	26	29.36	0.0	11.45				30.20	28	0.36
	29				29.76	12	6.21	30.04	22	9.81
	31	29.46	2	9.13						
	32	29.54	3.5	21.28						
	33	29.45	1.5	3.89	29.65	7	1.56			
South Baker	13	29.49	2.5	5.31						
	36	29.56	5	7.50				29.88	16.5	35.41
	39	29.45	1.5	7.56	29.78	12.5	27.03			
Southern	42	29.53	4	6.93				29.99	20	1.42
	44	29.46	2	12.42						
	48	29.54	4	7.28				29.91	16.5	5.61
	50							30.02	21	7.12
	60	29.58	5.5	5.39				29.94	17	29.97
Dream	64							29.90	16.5	11.25
	65	29.50	3	8.06				29.88	16.5	28.91

Table 10

Particle Type Counts

Bank	Station	% Sand	% Silt	% Clay	Quartz	Benthic Forams	Planktonic Forams	Echinoderms	Molluscs	Coral	Algae	Pelletoids	Lithoclasts	Miscellaneous
Baker	1	7.538	36.944	55.518	167	8	3	0	1	3	2	13	3	13
	2	15.261	13.545	21.195	133	40	5	1	5	7	0	0	6	3
	4	2.419	28.448	69.138	135	35	6	2	5	2	0	6	5	4
	5	72.631	11.076	16.293	160	13	1	1	12	2	0	2	3	6
	6	0.988	20.569	78.443	136	28	3	4	2	5	3	4	7	8
	22	13.898	38.066	48.036	195	26	0	2	3	4	0	9	5	6
	23	11.937	30.834	57.229	166	15	2	2	1	3	0	3	5	3
	24	7.456	33.879	58.465	139	22	1	0	2	2	0	5	5	4
	25	22.530	30.069	47.401	157	14	4	4	0	1	0	9	6	5
	26	33.726	32.072	34.202	154	13	1	3	4	4	2	10	5	4
	27	0.091	19.359	80.150	Too little $CaCO_3$ in coarse fraction									
	28	0.674	19.514	79.812	166	14	3	1	1	3	1	2	4	4
	29	74.329	10.297	15.344	132	21	6	4	6	4	1	9	7	10
	30	5.319	27.314	67.366	116	19	11	3	6	5	2	8	25	6
	31	18.300	30.610	51.090	136	19	5	4	1	4	0	10	4	7
	32	36.595	34.353	29.051	104	23	13	4	8	9	2	13	17	2
	33	10.572	36.361	54.067	144	14	5	0	4	9	2	4	14	4
South Baker	7	41.072	30.537	65.290	150	25	3	2	5	1	1	11	6	4
	8	2.444	34.076	63.480	122	32	6	2	5	2	1	13	9	8
	9	6.631	30.740	62.628	149	18	2	0	1	3	2	9	7	9
	10	0.101	16.888	83.011	Too little $CaCO_3$ in coarse fraction									
	11	0.349	19.693	79.963	114	44	12	4	4	5	0	9	4	8
	13A	12.079	42.488	44.803	151	19	3	2	1	4	1	7	5	3
	14	0.629	15.445	83.926	147	25	1	0	6	5	2	3	5	10
	15	1.457	20.267	78.276	132	29	5	3	3	5	2	10	7	5
	16	0.388	17.023	82.589	146	20	8	3	5	1	1	3	7	6
	17	0.156	17.125	82.720	Too little $CaCO_3$ in coarse fraction									

Table 10 Cont'd.

Particle Type Counts

Bank	Station	% Sand	% Silt	% Clay	Quartz	Benthic Forams	Planktonic Forams	Echinoderms	Molluscs	Coral	Algae	Pelletoids	Lithoclasts	Miscellaneous
	36	79.075	8.181	12.114	127	35	6	3	10	4	0	1	8	6
	37	19.545	22.510	57.945	Too little $CaCO_3$ in coarse fraction									
	39	76.992	7.690	15.318	133	30	7	1	6	11	0	0	7	5
	40	0.460	22.050	77.490	Too little $CaCO_3$ in coarse fraction									
	41	0.099	21.754	78.147	Too Little $CaCO_3$ in coarse fraction									
	42	8.328	42.503	49.168	144	16	8	0	4	6	3	8	6	5
Southern	44	28.961	34.338	36.701	124	28	0	15	6	11	3	3	9	2
	45	3.225	25.786	70.989	100	41	7	5	5	10	5	8	10	7
	46	5.741	30.084	64.172	Too little $CaCO_3$ in coarse fraction									
	47	0.695	21.797	77.507	113	28	9	1	3	9	6	7	16	8
	48	9.846	35.700	54.453	118	33	5	5	3	7	0	10	13	6
	49	0.672	23.991	75.336	119	27	7	2	2	6	5	11	11	10
	50	5.495	35.006	59.535	116	38	2	5	3	9	2	7	10	8
	56	6.103	32.692	61.204	129	24	6	1	2	3	2	13	14	6
	57	3.059	39.329	57.163	124	20	2	0	3	8	1	11	20	11
	58	0.306	17.741	81.953	Too little $CaCO_3$ in coarse fraction									
	59	0.358	15.578	84.064	Too little $CaCO_3$ in coarse fraction									
	60	55.886	13.794	30.319	116	40	9	3	10	7	2	3	5	5
	61	1.929	39.151	59.919	97	49	6	1	2	11	3	13	14	5
Dream	62	0.227	17.672	82.102	Too little $CaCO_3$ in coarse fraction									
	63	3.348	38.416	58.326	96	42	4	3	2	5	1	16	21	10
	64	0.464	30.900	69.636	126	32	6	6	5	8	1	8	5	3
	65	66.779	10.834	22.388	142	29	3	0	7	6	0	1	5	7
	67	1.506	30.916	67.578	123	52	7	1	1	9	1	7	6	2
	75	52.861	14.829	32.310	Too little $CaCO_3$ in coarse fraction									

Table 10 Cont'd.

Particle Type Counts

Bank	Station	% Sand	% Silt	% Clay	Quartz	Benthic Forams	Planktonic Forams	Echinoderms	Molluscs	Coral	Algae	Pelletoids	Lithoclasts	Miscellaneous
	77	39.632	24.513	35.855	Too little $CaCO_3$ in coarse fraction									
	78	0.299	31.677	68.074	Too little $CaCO_3$ in coarse fraction									
	79	0.467	28.579	70.959	103	41	5	12	3	6	1	11	3	13
	80	1.847	37.532	60.601	112	48	7	3	3	6	0	9	8	4
	81	1.725	44.356	53.920	140	34	3	1	0	10	1	9	7	6
	82	0.106	26.566	73.327	Too little $CaCO_3$ in coarse fraction									
	83	1.616	41.456	56.932	131	39	4	1	1	3	0	6	7	8
Adam	84	0.524	36.431	63.045	121	33	2	2	2	7	1	18	7	7
	85	0.260	33.937	65.803	Too little $CaCO_3$ in coarse fraction									
	86	16.837	31.676	51.487	Too little $CaCO_3$ in coarse fraction									
	87	o.634	37.692	61.679	118	35	4	5	0	6	1	20	9	2
	88	0.987	38.616	60.397	113	32	6	10	1	7	1	20	7	3
	89	0.404	33.493	66.153	Too little $CaCO_3$ in coarse fraction									
	93	0.308	26.977	72.715	Too little $CaCO_3$ in coarse fraction									
	94	0.889	32.523	66.587	115	31	7	1	2	8	0	19	10	5
	95	0.587	36.864	62.549	115	34	0	3	9	7	0	14	10	8

TABLE 11

Coral-Algal Gravels in Cores

Core No.	Bank	Depth (cm)	Distance From Bank (feet)
2 P	Baker	0-60 80	675
3 P	Baker	50-57	350
4 P	Baker	140	900
8 P	S. Baker	390-421 40-45	1950
39 P	Southern	240-248	2140
59 P	Dream	280-360	1570
61 P	Dream	306-352	1900
78 G	Big Adam	80-85	1150
80 G	Big Adam	60-66	1250

APPENDIX A

CORE DESCRIPTIONS

Legend

 Burrows

 Shell Fragments

 Coral Fragments and Coralline Algae Nodules

 Sand Laminae

Sand

Fine Mud

SSC Sand-Silt-Clay Ratio

Cruise 75-G-7II Core No. 1P-A No. Sections 5 Date 9/26/75

Position ________ Station Baker 1 Total Length 545 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	fine mud shell frag?				
20 cm	lt olive gray ↓				
A 40 cm	dk greenish gray	burrowed bioturbated very fine sand and silt some shell frag.			
56					
60	burrows?	mottled, few burrows thin sand laminae			
80					
100	uniform		100		fine mud; ssc 4.2/43.2/52.56 5.1 % $CaCO_3$
B 120	fine sed.				
140	dk greenish gray				
160					
178					
180					
200		fine sand or silt layer			
220	sandy feel	burrowed sand			
C 240	uniform				
260	fine sed.				
280	dk greenish gray 5GY4/1	bioturbated sand laminae			
300		sand laminae			
301	sand patch	sandy layer	313		sand ssc 26.7/36.7/36.8 5.5 % $CaCO_3$
320					
340	shell frag.	large burrow			
D	sand patch				
360	dk greenish gray				
380					
400	patches of sand				
420	sand globule				
423					
440					
460	slight color change brownish sand layer	heavily bioturbated sand and silt	445		sand was top 1 cm w/clay below ssc 31.1/29.7/39.2 6.7 % $CaCO_3$
E 480	sand				
500	sand layer	fine sand laminae with bioturbated sand above	508		mud above sand ssc 3.5/41.4/55.0, 4.5% $CaCO_3$
520			517		sand layer, ssc 21.1/57.2/21.8, 4.9 % $CaCO_3$
			528		mud below sand, ssc 7.6/41.2/51.2 7.7 % $CaCO_3$
540					
545cm					

CORE DESCRIPTIONS   Page 2

Cruise 75-G-7II   Core No. 2P   No. Sections 1   Date 9/27/75

Position ______   Station Baker 2P   Total Length 105 cm   Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	lt olive gray 5Y5/2				
	large coral chunks	large algal nodules some shell fragments			
10 cm					
	shell frag and watery mud				
20					
30	lt olive gray 5Y6/1		30 cm		Radiocarbon Sample (Coralline Algae)
	broken rock frag & watery mud				
40	large rock algal chunk				
50 cm		coarse sand matrix			
	sand and shell frag matrix				
60	coarse sand				
	color change greenish gray 5G8/1				
70	and shell frag zone				
80	large algal nodule frag				
90	lt olive gray 5Y6/1				
	coarse sand & shell frag				
100cm	lg black frag broken coral & shell				
105cm					

CORE DESCRIPTIONS

Page 3

Cruise 75-G-7II Core No. 3P No. Sections 1 Date 9/27/75

Position ______ Station Baker 3P Total Length 57 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
0	dk greenish gray 5GY4/1 fine sed.				
10 cm	sand				
		burrowed bioturbated shell & sand & mud			
20 cm					
30	coarse sand				
	watery sed. depression	burrow, lg			
40	sample missing	large shell frag ↓			
50	large lithoclasts dense shell frag	crustose coralline algae			
57 cm					
60					

Cruise 75-G-7II Core No. 4P No. Sections 5 Date 9/27/75

Position ______ Station Baker 4 Total Length 538 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	fine grain sed				Core dividing plane surface is disturbed by splitting
20	burrowed	burrowed			
40	dk greenish gray 5GY4/1				
A			55		fine mud above shell frag ssc 0.3/18.3/81.4 3.3 % $CaCO_3$
60	shell frag	shell frag & fine sand and silt			
	burrowed		70		shell layer ssc 30.4/32.6/37.0 18.6 % $CaCO_3$
80	large void	heavily burrowed large dia.			
100	fine sed				
118					
120	fine sed				
140	lg coral frag	large coral and shell frag	146		coral and shell layers (matrix), ssc 2.4/35.9/61.7, 4.8 % $CaCO_3$
	fine sed				
160	watery depression	burrowed			
B					
180	burrows	fine sand laminae			sand
	dk fine grain sand	sparse shell frag	191		ssc 14.6/43.3/42.2 7.1 % $CaCO_3$
200	dk greenish gray 5GY4/1	dk hole-burrow?			
220		fine sand layer			
240	burrows				
	burrows 5GY4/1	thin sand and silt			
260	sand	shell frags & burrows			
	fine mud	shell frags			
280					
C					
300					
320					
340	watery depression	small shell zone			
		fine sand laminae			
360	shell sandy	shell frag	360		sand, ssc 13.2/62.1/24.7 3.2 % $CaCO_3$
362	shell frag				
380		fine shell frag			
400	lump shell frag 5GY4/1				
420	shell frag	shelly	420		fine mud and shell ssc, 16.1/38.4/45.5 18.0 % $CaCO_3$
D			434		mud, ssc 6.1/44.5/49.5 5.3 % $CaCO_3$
440	fine mud				
460	dense shell frag	shell zone shell zone			
480	large shell	fine shell frag			
484	large shell frag	shelly			sandy & mud, ssc 6.6/48.7/44.6, 10.7 % $CaCO_3$
500	fine mud predom.	fine sand laminae shelly	504		
E			519		dense shell zone, ssc 39.7/27.7/32.6, 38.7 % $CaCO_3$
520	sandy	large shell frags			
	dense shell frag.				
540	lg.coral frag.	coral			
	538 cm				
560					

CORE DESCRIPTIONS

Cruise 75-G-7II Core No. 5P No. Sections 5 Date 9/27/75

Position ______ Station Baker 5P Total Length 524 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	sandy				no color change at top thin sandy layer?
	burrows				
20		highly bioturbated			
	dk greenish gray 5GY4/1				
40					
A					
	fine gr. mud				
60					
80					
100		indistinct sand laminae			
112		bioturbated sand			
120	uniform 5GY4/1 fine mud	mottled			
		bioturbated			
140					
B					
	sand layer				
160		sand laminae			
180					
200	sand				
		lg shell (whole)			
220					
	sand				
234					
240		bioturbated sand			
260					
C					
280		bioturbated sand & silt			
300					
	sandy				
320					
	sandy				
340					
356					
360					
	sandy	bioturbated sand			
380					
	sandy				
400					
D					
420		bioturbated sand			
440					
460					
	sandy				
478					
480		lg burrow			
E		lg burrow			
500					
	sandy	bioturbated sand			
520					
524					
540					

Cruise 75-G-7II Core No. 6P No. Sections 5 Date 9/27/75

Position ________ Station Baker 6 Total Length 565 cm Described by P.E.L.

Depth (cm)	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	very fine mud				No color change at top
20		sparse shell frags			
	disturbed				
40	5GY4/1	burrowed			
A	burrows				
60	fine mud	shelly			
80	shell frag	thin shell zone sand laminae burrows			
100		thin sand laminae			
111		burrowed			
	burrows				
140					
B					sec B top and bottom not indicated. . . assumed in direction of core label, writing and so marked
160	burrow dense shell frag				
180	fine mud	dense shell zone w/sand			
200		sparse shell frag.			
	sand burrow				
220	sparse shell	sand laminae shell zone			
232					
240	sparse shell	fine sand laminae and shell			
260					
C					
280	dense shell fine mud uniform throughout core	dense shell zone			
300	small voids burrows?				
320					
340	sandy (darkens) contact fine mud	thin silt laminae grades to very thin parallel sand laminae			sandy area seems to be gradational downward and ends with slight color change greenish gray 5GY8/1 below and dark greenish gray 5GY4/1 above core is a lighter dk greenish gray normally.
356	sand				
360	burrows	shelly			
380		thin sand laminae			
D					
400	sandy				
420	dense shell	dense shell zone			
440					
460	dense shell frag coral				
478	sparse shell	sparsely shelly			
480					
E					
500	fine mud 5GY4/1	bioturbated and burrowed sandy			
520					
540	sandy				
560		sand laminae			
565					

CORE DESCRIPTIONS

Cruise 75-G-7II Core No. 7P No. Sections 5 Date 9/28/75

Position ____ Station S. Baker 7 Total Length 510 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	dk greenish gray 5G4/1	burrowed and bioturbated			color is somewhere between greenish gray and dark greenish gray, 5GY->5G
20					
40	fine mud				
A					
60		dk slanted zone burrowed and bioturbated	60		fine mud ssc 3.1/39.3/57.6 5.95 % $CaCO_3$
80					
100	sandy		99		sand layer ssc 45.9/26.7/27.4 4.3 % $CaCO_3$
112					
120					
140	fine mud disturbed by splitting	burrowed			
160	burrows				
B					
180					
200					
220					
232					
240		bioturbated			
260	finc mud				
C					
280	sand	burrowed sand			
300					322 small L frag taken
320	sand and shell frag	bioturbated sand layer	324		sand layer, ssc 64.8/14.8/20.3, 7.5 % $CaCO_3$
340	sandy mud		342		sandy mud, ssc 20.5/36.3/43.2, 7.2 % $CaCO_3$
353					
360		large burrow	365		mud ssc 3.5/42.3/54.3 7.3 % $CaCO_3$
380					
400	sandy mud	large burrow	396		sandy mud ssc 31.9/37.2/30.9 7.1 % $CaCO_3$
420	sandy mud				
D					
440	shell frag				
460					
476					
480					
500	fine mud 5GY4/1				
510					

CORE DESCRIPTIONS

Page 8

Cruise 75-G-7II Core No. 8P No. Sections 4 Date 9/28/75

Position ______ Station S. Baker 8 Total Length 421 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	oxidized	burrowed			
	fine mud				
20					
			29		Mud
					ssc 1.8/16.6/81.5
40	sandy				2.8 % $CaCO_3$
A	dk greenish				
60	gray, 5GY4/1		65		sandy mud
					ssc 21.1/35.1/43.8
80					5.5 % $CaCO_3$
		fine thin wavy sand laminae			
100					
	sand	sand laminae	108		sand
117					ssc 9.4/37.4/53.2
120					6.4 % $CaCO_3$
	sandy	sand laminae			
140		bioturbated sand			
B	sand				
		sand			
160	sand				
		very fine sand laminae			
180					
		thin fine sand laminae	187		sand
	sand				ssc 32.1/36.2/31.8
200					2.8 % $CaCO_3$
			207		
		fine sand laminae			mud, ssc 3.8/55.1/41.1
220	sand & shell frag				3.5 % $CaCO_3$
	sandy		237		sand, ssc 19.4/29.1/51.5
238					6.0 % $CaCO_3$
240	sandy	bioturbated sand			
C	sand				
260					
		bioturbated sand			
280			269		sand, ssc 15.9/51.1/33.0
					8.2 % $CaCO_3$
300	sand	thin parallel sand			sandy mud, ssc 6.3/69.0/
		laminae	305		24.6, 5.7 % $CaCO_3$
320	slight brownish		317		oxidized mud, ssc 0.7/32.4/
	tint	dense shell zone			66.9, 3.6 % $CaCO_3$
	dense shell frag		328		dense shell zone, ssc 62.0/
340		shelly			21.9/17.1, 16.7 % $CaCO_3$
	sandy with shell				
	frag				
360		shelly burrows	362		shelly sandy mud, ssc 9.4/
	shell frag				21.4/69.2, 3.5 % $CaCO_3$
D	sandy				
380	shell frag	shelly			
		dense shell	389		dense shell zone, ssc 64.2/
	dense shell frag				17.4/18.4, 29.0 % $CaCO_3$
400	coral		412		sandy coral matrix, ssc
	shell and coral				67.2/13.3/19.5, 47.8 % $CaCO_3$
420	lg. bored				
421	lithoclasts				
500					

CORE DESCRIPTIONS — Page 9

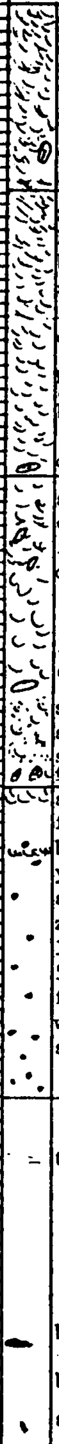
Cruise 75-G-7II Core No. 9P No. Sections 4 Date 9/28/75

Position ______ Station S. Baker 9 Total Length 397cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	burrow	burrowed			core disturbed by splitting
20					
40	shell				
A	watery void				
60	fine mud, dk greenish gray 5GY4/1				
80	sand	indistinct sand laminae			
100		bioturbated			
117	sand				
120	sand	lg shell (whole)			
140	sand				
		bioturbated sand			
160					
B	sand				
180	sand	indistinct sand laminae			
	sandy	bioturbated			
200	sand				
		lg burrow			
220		bioturbated sand			
239	sandy				
240	sandy				
		fine mud			
260					
C					
280	shell frag				
300	sand				
320					
340		shell (whole)			
360					
362					
D					
380	sand				
397					
400					

Cruise 75-G-7II Core No. 39P No. Sections 5 Date 9/29/75

Position ______ Station Southern Total Length 462 cm Described by P.E.L.



Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	dense shell frag 5GY4/1 mud matrix				
20 A		very shelly	28		coarse shell ssc 61.6/12.5/26.0 71.2 % $CaCO_3$
40	coral fine mud	coral chunk			
55					
60	greenish gray here down	very shelly			
80 B	brown shell and coral- line algal no- dules				
100		coarse shell frag			
120	pale brown 5YR5/2 brown spot		130		brown spot in coarse shell ssc 63.8/9.5/26.8, 64.5 % $CaCO_3$
140 149	dense shell lump				
160	shell frag encrusted coral in mud	very shelly large shell frags			
180 C	darker clasts		188		black sandy shell area ssc 91.6/3.4/5.0, 91.5 % $CaCO_3$
200	large algal en- crusted shell				
220	sandy with a few shells		228		shelly sand, ssc 55.7/13.0/ 31.3, 63.2 % $CaCO_3$
240 249	shell & coral frag				dense interval of shell ends
260 D	shell frag fine mud brown, pale yellowish 10YR6/2	shelly fine mud	266		end of shelly zone, ssc 21.8/18.9/59.4, 27.4 % $CaCO_3$ light brown color rather than grayish greenish
280	shell and sand zone	burrowed	290		fine mud
300	lt olive gray 5Y6/1	sparse shell frag			ssc 0.5/18.4/81.1 2.8 % $CaCO_3$
320	fine mud with blackish spots (burrows)				
340					
349		fine mud			
360	thin brown				
380 E					
400					
420	burrow (darker)	thin sand laminae	426		burrowed mud (puncture in wall of liner apparently made from inside)
440	brown zone see	burrowed			ssc 2.6/41.4/56.0
460 462	small frag				5.0 % $CaCO_3$
480					
500					

Cruise 75-G-7III Core No. 40P No. Sections 6 Date 10/1/75

Position ______ Station Southern 40 Total Length 593 cm. Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
A	very fine mud dk greenish gray 5GY4/1	burrowed			
20		sand laminae			
40					
43					
60		burrowed			
80	same	thin sand laminae partly disturbed by burrowing			
100					
B, 120	sand	thin sand laminae (burrowed)			
139					
140		bioturbated sand			
160					
180		burrowed			
200	same				
C					
220					
240					
252					
260	sand	bioturbated sand			
280	shell frag	shell frag (whole)			
300	sand	thin sand laminae			
320	very fine mud 5GY4/1				
D, 340					
360	sand	bioturbated sand burrowed			
366					
380	sand	sand laminae			
400	sand	bioturbated sand lens			
	sand	sand laminae			
420	same				
E, 440					
460					
480					
F	same				
500	see next page				

Cruise 75-G-7 III Core No. 40P No. Sections 6 Date 10/2/75

Position ______ Station Southern 40 Total Length 593 cm. Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
500	sand very fine mud	fine sand laminae			
520					
540	sandy	bioturbated sand and shell frag			
560	sandy slight brown tint olive gray 5Y4/1				
580					
593					
600					

CORE DESCRIPTIONS

Cruise 75-G-7 II Core No. 41G No. Sections 1 Date 10/2/75

Position ______ Station Southern 41 Total Length 143 cm Described by P.E.L.

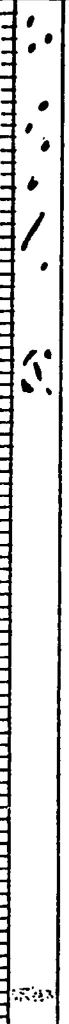
Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
0	brown top	burrowed			
	very fine mud				
	dk greenish				
10	black				
	5G 2/1				
20					
30					
40	transition to greenish gray 5GY6/1 to dk greenish gray 5GY4/1				
50					
60					
	dense shell frag	dense shell zone			
70					
80					
90					
	shell	shell zone			
100					
110					
	sandy				
	lg shell piece				
120	shelly zone	shell zone			
	shell frag				
130					
134					

CORE DESCRIPTIONS

Page 14

Cruise 75-G-7 II Core No. 42 G No. Sections 1 Date 10/2/75

Position ______ Station Southern 42 Total Length 82 cm Described by P.E.L.

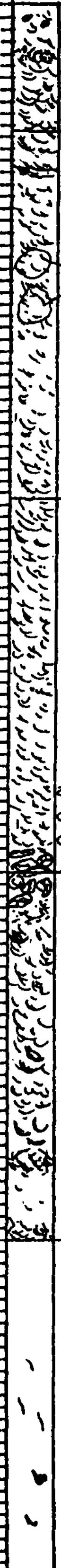


Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	burrowed	burrowed			
10	dk greenish gray 5GY4/1				
20					
30	burrowed	large lump			
40	very fine mud				
50					
60		bioturbated			
70					
80	sand	indistinct sand laminae			
82					

CORE DESCRIPTIONS

Cruise 75-G-7 Core No. 59 P No. Sections 5 Date 10/2/75

Position ______ Station Dream 59 Total Length 526 cm Described by P.E.L.



Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
A	sandy	burrowed			
20	shelly				
38		very shelly			
40	shell & mud				
	dense shell	very bioturbated shell & mud			
60	very shelly mud				
80	5GY4/1	very shelly			
	mud				
100	dense shell				
120					
B					
	mud				
162	very shelly mud	very shelly			
	lg coral frag				
200					
C					
	algal encrusted coral litho-clasts and lg coral frag				
288					
300	fine shell coarse sandy mud	coarse shell shelly mud			water present in bottom of C and top of D
	very shelly lg lithoclasts	shelly mud with lg shell frag			
D					
	very shelly				
	fine mud				
	very shelly	shell hash fine mud			
408	fine mud	shell hash			
412	very shelly				
420		very fine sand			
	fine mud				
440					
E		shell frag			
	5GY4/1	worm tubes			
	shell frag				
500	shell frag				

Cruise 75-G-7 Core No. 61 P No. Sections 4 Date 10/4/75

Position ______ Station Dream 61 Total Length 427 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	fine mud 5 GY4/1	burrowed bioturbated			
20 A					mud ssc 0.9/35.1/64.0 3.4% $CaCO_3$
40		burrowed	40		
60		sand layer bioturbated			
80	Same	bioturbated sand laminae			
100					
20		mottled, many burrows	121		mottled mud ssc 0.3/23.9/75.8 2.2% $CaCO_3$
B		sand laminae			sand laminae ssc 1.5/50/8/47.7 3.9% $CaCO_3$
			158		
		bioturbated sand laminae	178		sandy mud ssc 1.2/58.0/40.8 0.84% $CaCO_3$
181		parallel sand laminae			
200	burrowed & sandy	thin sand laminae			
220			217		sand laminae ssc 4.9/71.7/23.4 5.8% $CaCO_3$
	burrow				
240					
C		some shell frag thin sand laminae			
280					
	shelly	shelly	299		shell zone ssc 18/5/28.6/52.9 18.4 % $CaCO_3$
300 304	lg lithoclasts	very shelly; lg coral frag			
	mud w/shell	very shelly			
320	algal nodules lg coral litho-clasts	coral and shell frag			
340	fine mud w/shell				
	dense shell				
360		dense shell zone	364		shelly sand ssc 27.7/25.2/47.2 14.3 % $CaCO_3$
D	fine mud	shelly mud			
380	shell sand				
400	shelly mud	shell hash	406		shelly ssc 19.0/36.1/44.9 9.3% $CaCO_3$
	fine mud or shell	worm tubes			
427					
500					

CORE DESCRIPTIONS

Cruise 75-G-7 Core No. 64G No. Sections 1 Date 10/5/75

Position ________ Station Dream 64 Total Length 65 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
0	fine mud with shell frag	shelly bioturbated ↓			
15	dense shell				
20		very shelly ↓			
25	very shelly mud				
58	very shelly				
65					

Cruise 75-G-7 Core No. 65G No. Sections 1 Date 10/5/75

Position ______ Station Dream 65 Total Length 26 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	rock & shell frag. fine mud				top of core with rock and shell frag was moderate yellowish brown (10YR5/4)
10	very shelly mud	very shelly			
20	5GY4/1				
26					

Cruise 75-G-7 Core No. 78G No. Sections 1 Date 10/5/75

Position ______ Station Big Adam Total Length 85 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
0	very fine mud darker	burrowed			
10	shell frag	fine sand layer shell zone fine sand layer	9		shell and sand laminae ssc 0.5/30.8/68.7 3.5 % $CaCO_3$
20					
30	dense shell frag	dense shell zone	31		dense shell zone ssc 35.8/24.0/40.2 58.0 % $CaCO_3$
	very fine mud 5GY4/1				
40					
50		shelly	50		mud ssc 0.57/36.6/62.9 2.2 % $CaCO_3$
60		very shelly with large shell frag (↓ to 85)			
70	very shelly mud encrusted shell frag. algal lithoclast frag.		73		shelly zone ssc 42.0/17.2/40.9 25.8 % $CaCO_3$
80					
85					

CORE DESCRIPTIONS

Cruise 75-G-7 Core No. 80G No. Sections 1 Date 10/5/75

Position ______ Station Big Adam 80 Total Length 66 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
	shelly, burrowed mud 5GY4/1	bioturbated sand layer			
10		shell frag (whole)			
		very thin sand laminae, partially burrowed			
20					
30	large void	large coral frag			
40		very shelly			
50	very shelly mud	large shell frags ↓			
60	large shell frag algal nodule				
66					

CORE DESCRIPTIONS

Cruise 75-G-7 Core No. 84G No. Sections 1 Date 10/5/75

Position ________ Station Big Adam 80 Total Length 126 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
10	very fine mud 5GY4/1 with scattered shell frag and burrows	burrowed fine mud			
20					
30					
40					
50		bioturbated sand laminae			
60					
70					
80	burrow				
90					
100					
110					
120					
126					
130					

CORE DESCRIPTIONS

Cruise 75-G-7 Core No. 85G No. Sections 1 Date 10/5/75

Position ______ Station Big Adam 85 Total Length 116 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
0–30	very fine mud 5GY4/1 burrowed and occasional shell frag	burrowed			
70		bioturbated sand layer burrowed			
80		burrowed			
90		bioturbated sand laminae			
110		bioturbated sand			
116					

CORE DESCRIPTIONS

Cruise 75-G-7 Core No. 87G No. Sections 1 Date 10/5/75

Position ________ Station Sm. Adam 87 Total Length 132 cm Described by P.E.L.

Depth	Lithology & Color	Radiography	Samples	Smear Slides	Miscellaneous Remarks
0–10	very fine mud 5GY4/1 with occasional burrows and shell frag	burrowed			
20	burrow				
50		sparse shell frag			
70		sparse shell frag			
100	shell	sparse shell frag			
110	shell	sparse shell frag			
120		shell frag			
132					

CHAPTER V

MEIOFAUNA

Meiofauna-Sediment Correlations on Samples From Submarine Banks in the Gulf of Mexico

D. Gettleson and W.E. Pequegnat

INTRODUCTION

DEFINITION

The term meiobenthos was coined by Mare in 1942 to describe a group of benthic metazoans that were intermediate in size between the larger, traditionally collected, macrobenthos and the smaller microbenthos, which Mare considered to consist of bacteria, diatoms, and most protozoans. This concept of the meiofauna is not rigid, and is often based on sieve mesh sizes utilized by investigators. Within the meiofauna, as defined by sieve size, are two importantly different classes of animals: permanent and temporary. The permanent meiofauna (e.g., nematodes, harpacticoid copepods, foraminiferans and kinorhynchs) remain within the meiofauna their entire life, while the temporary forms (polychaetes, mollusks, sipunculids, etc.) are actually juvenile forms of macrobenthos. The permanent meiofauna can be characterized as a group of animals which differ from the macrofauna not only in size, but by number, generation time, and morphological adaptations to their environment (McIntyre, 1969). The meiofauna, if considered to pass 1.0 to 0.5 mm. mesh sizes and be retained by 100 to 70 micron meshes, (as used by Gerlach, 1971) generally is equal to only 3 percent of macrofaunal biomass. Even though the turnover rates of these two groups differ markedly, it appears that the meiofauna, because of its faster turnover, equals almost 15 percent of the macrofaunal biomass if examined over a period of one year.

ECOLOGIC NICHE

The role of the meiofauna in the marine ecosystem is only known in a very general fashion, and even at this level contradiction exists. Meiofaunal sized organisms feed on detritus, benthic diatoms, bacteria, and occasionally on one another. McIntyre (1964,1969) believes that there might be competition between the macrofauna and meiofauna for organic matter, and that the primary role of the meiofauna is to recycle nutrients. The most important question regarding the meiofauna is its relationship to the macrofauna and demersal fishes as a food source, and it is in this function that the role of the meiofauna is debated. Rees (1940), Perkins (1958), Tietjen (1966), and Coull (1968) report that polychaetes, which are often the numerically dominant macrofaunal taxa on soft bottoms, use the meiofauna as a food source. McIntyre and Murison (1973) and others do not believe that the meiofauna is a significant food source for higher levels in the food chain. On the other hand polychaetes are important in the diet of many macrourid and ophidiid demersal fishes. Hence if Tietjen and others are correct (as stated above), then the meiofauna is important in food webs even though one step removed from some fishes. Rayburn (1975) reports that foraminiferans are commonly found in the stomach of Halosaurus guntheri, Dicrolene intronigra, Nezumia hildebrandi, and Cariburis zaniophorus, all of which are deep-water demersal fishes in the Gulf of Mexico.

INDICATORS OF ENVIRONMENTAL CHANGE

Disregarding the trophic position of the meiofauna, they are still of great importance because of their intimate relationship with sediment particles, their large numbers, and their short lives. These characteristics make them potentially very effective environmental indicators. Work is only beginning on the taxonomy of many of these organisms, but preliminary surveys have demonstrated their use as indicators of environmental perturbations (Pequegnat, 1975; Rogers and Darnell, MS 1973; NMFS, 1972).

PREVIOUS STUDIES

GULF OF MEXICO

In only one known instance has the sublittoral meiofauna (down to 62 microns) been examined in the Gulf of Mexico (Pequegnat and Gettleson, 1974). This study reported on the number of individuals in major meiofaunal taxa at four stations in the vicinity of Stetson Bank. A significant finding was that the ratio of numbers of individuals between the macrofauna and the meiofauna is sufficiently definitive as to be useful as a baseline parameter for judging some environmental impacts that affect sediment cover.

Nematodes are the dominant group in the meiofauna, but only six papers have been published that deal with the Gulf of Mexico and all are concerned with the littoral zone. Hulings (1967) reviewed ostracod research in the Gulf of Mexico, and other than the foraminiferans no published reports on the permanent meiofaunal groups have been found.

Extensive work has been done by Phleger and Parker (1951) and Phleger (1956) on both living and dead foraminiferan assemblages on the continental shelf in the central and west Gulf. Unfortunately the method used to differentiate living from dead forms in the 1951 work was not reliable and thus our work is not directly comparable. However, twenty-four of Phleger's 1956 stations were in the immediate vicinity of some of our stations and the methods are relatively similar so that comparisons may be made. Phleger found over 52 species of living foraminiferans within the areas sampled in this investigation, and based on living forms he delineated a general facies or community boundary at 50 to 70 meters, which is within the depths sampled in this investigation. He set up facies of 50 to 70 meters and greater than 50 to 70 meters and mentioned certain species which characterized each zone. It is important to emphasize that the boundaries were not sharp but gradual. Buzas (1967) analyzed Phleger's data by canonical variate analysis and determined that a transition in biofacies occurred at 60 meters. Murray (1973) reviewed then current knowledge of living benthic foraminiferans and stated that average values for continental shelf environments ranged from 50 to 200 individuals per 10 cm^2. He also cautioned against comparing values without taking seasonal variation into account.

OUTSIDE THE GULF OF MEXICO

McIntyre (1969 and 1971) reviewed the existing literature dealing with meiofauna and concluded that the information on subtidal meiobenthos was very sparse, and that is still the case today. There have been a few general meiofaunal investigations conducted at approximately the same depth as this study, but due to differences in collection and sorting methods most are not comparable. Two exceptions may be Wigley and McIntyre (1964) and Tietjen (1971). However, in considering both studies only seven stations were in approximately the same water depth, and only one sample was taken in sediment similar to the sediment found in this study.

MATERIALS AND METHODS

STUDY SITES

Meiofaunal samples were taken at twenty-four stations with a specially constructed box sampler (Jonasson and Olausson, 1966). Table 1 reports on the positions of the stations, depth of water, and dates of collection. Figure 1 shows the locations of the submarine banks on the continental shelf in the northwest Gulf, and figures 2 through 6 indicate the more precise station positions in relation to the bathymetry of the banks.

SUBSAMPLES

The material within the samples was subsampled by pushing a length of clear plastic tubing (I.D. 3.5 cm) at least 15 cm into the sediment. On most occasions there was a quantity of water overlaying the sediment, and when it exceeded a few cm it was siphoned off before subsampling. A single sub-sample per box was gently extruded from the core tubes, cut into 5 cm increments to examine vertical variations, preserved in 5 percent buffered formalin, and transported to the lab for extraction.

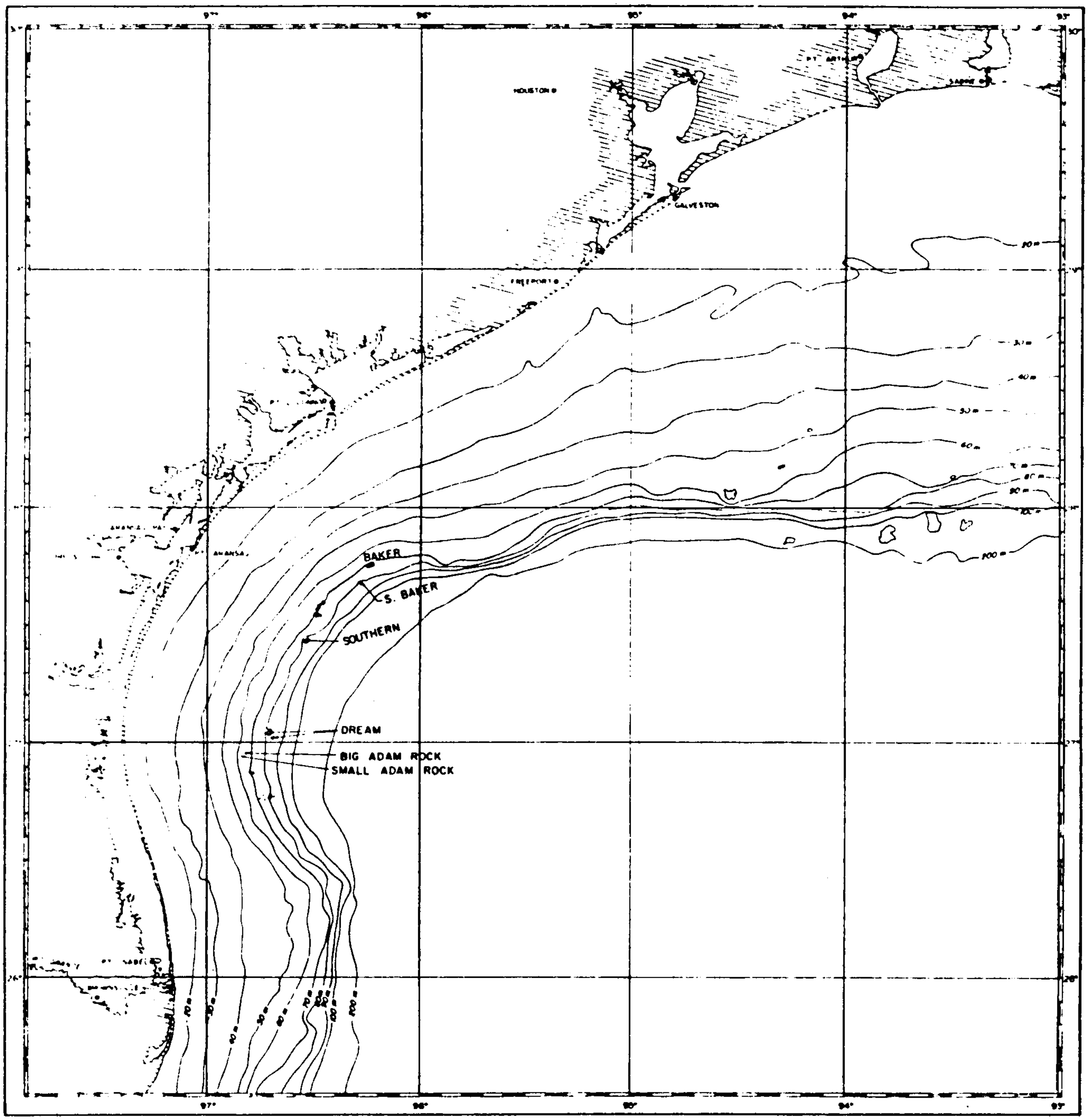


Fig. 1. Map of the northwest Gulf of Mexico showing the positions of the five submarine banks considered in this study.

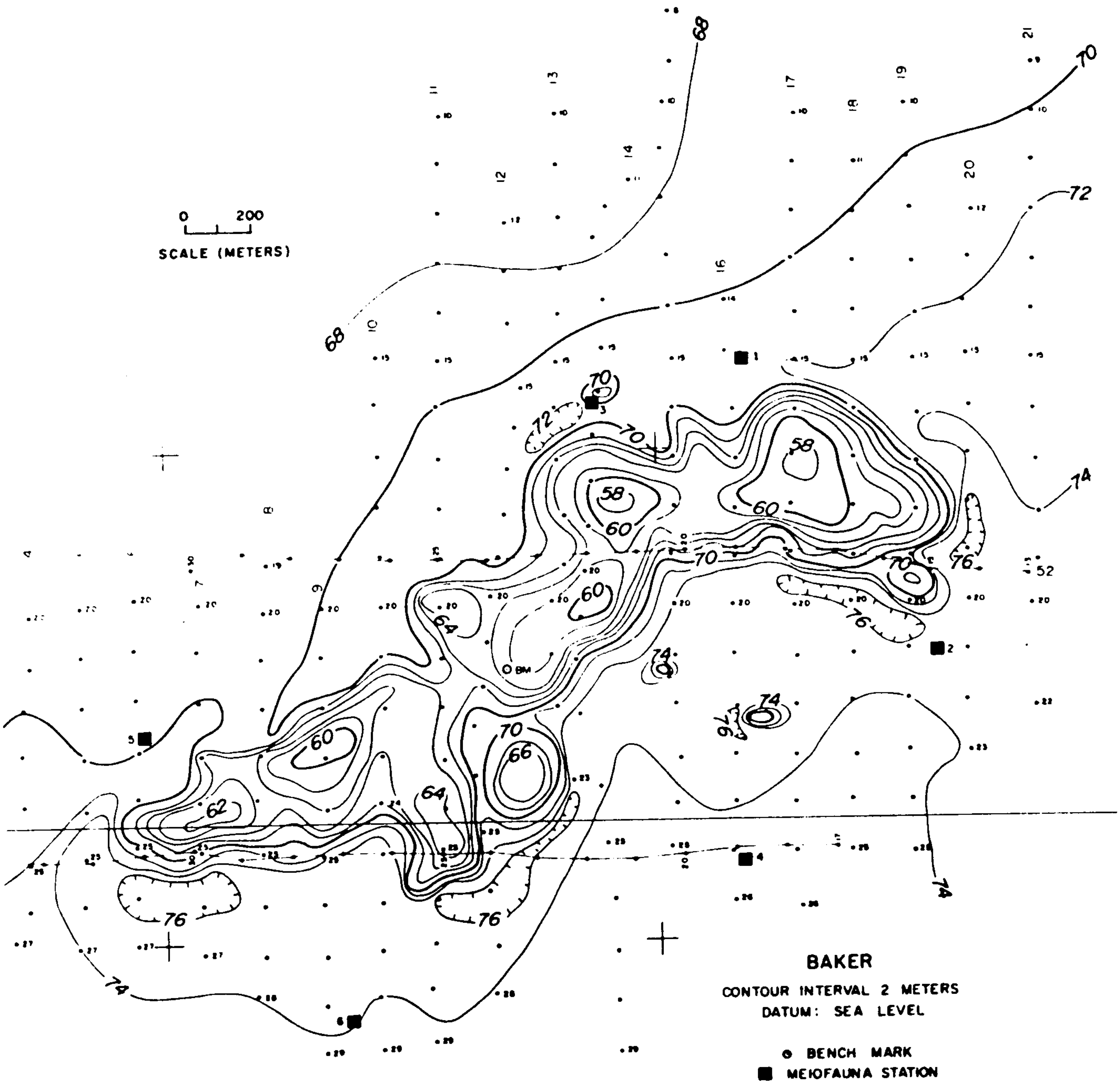


Fig. 2. Meiofauna station positions in relation to the bathymetry of Baker Bank.

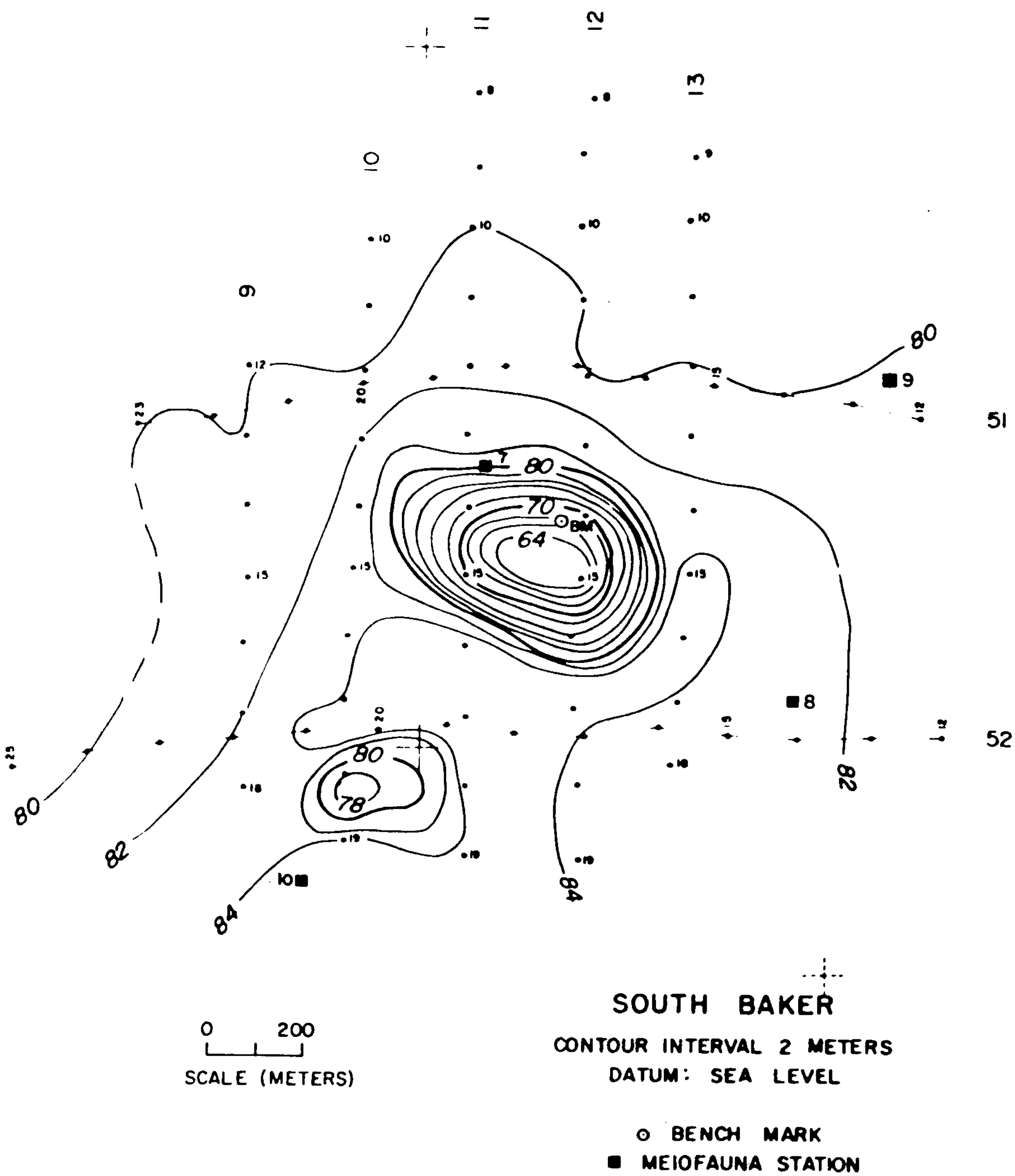


Fig. 3. Meiofauna station positions in relation to the bathymetry of South Baker Bank.

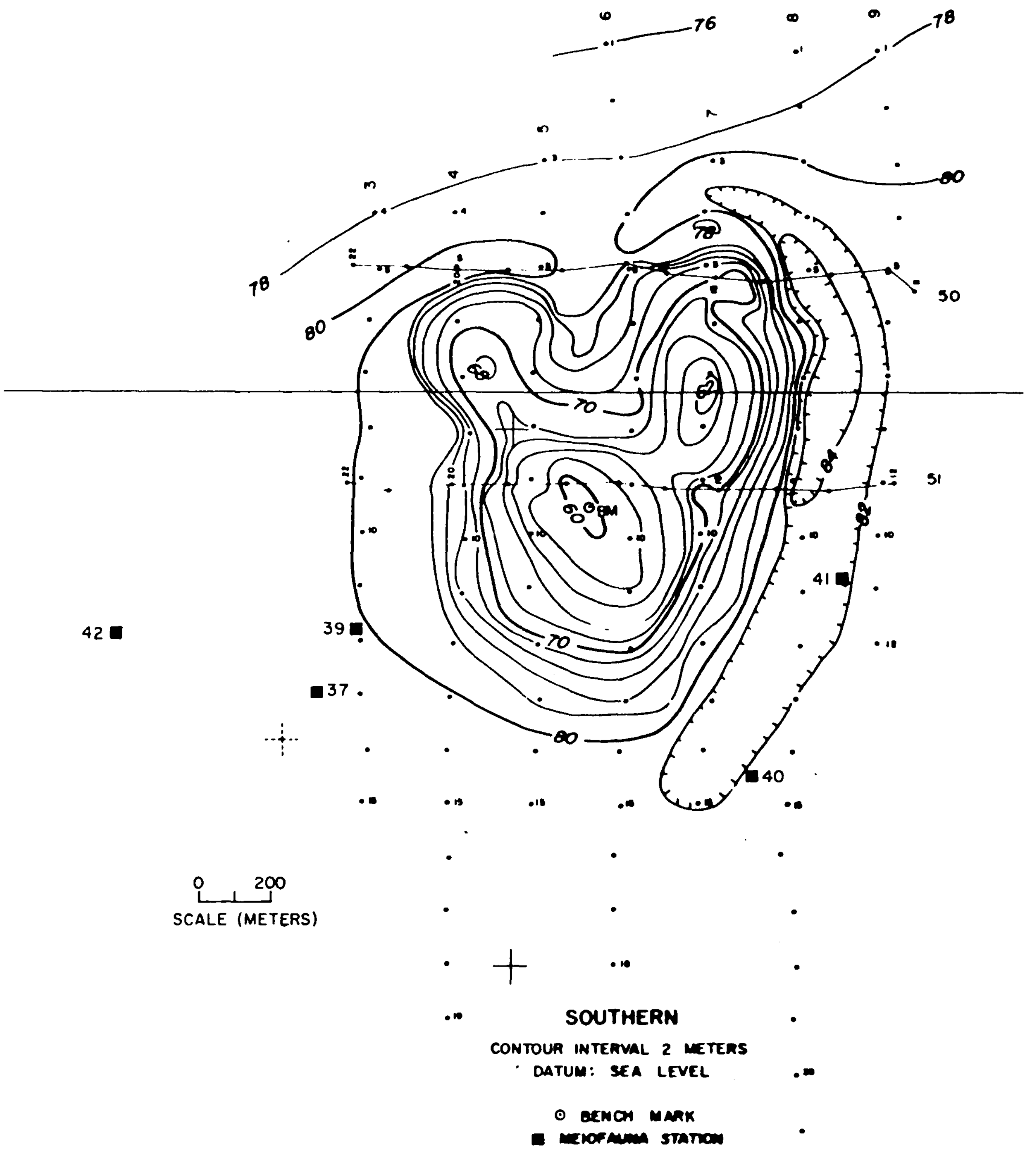


Fig. 4. Meiofauna station positions in relation to the bathymetry of Southern Bank.

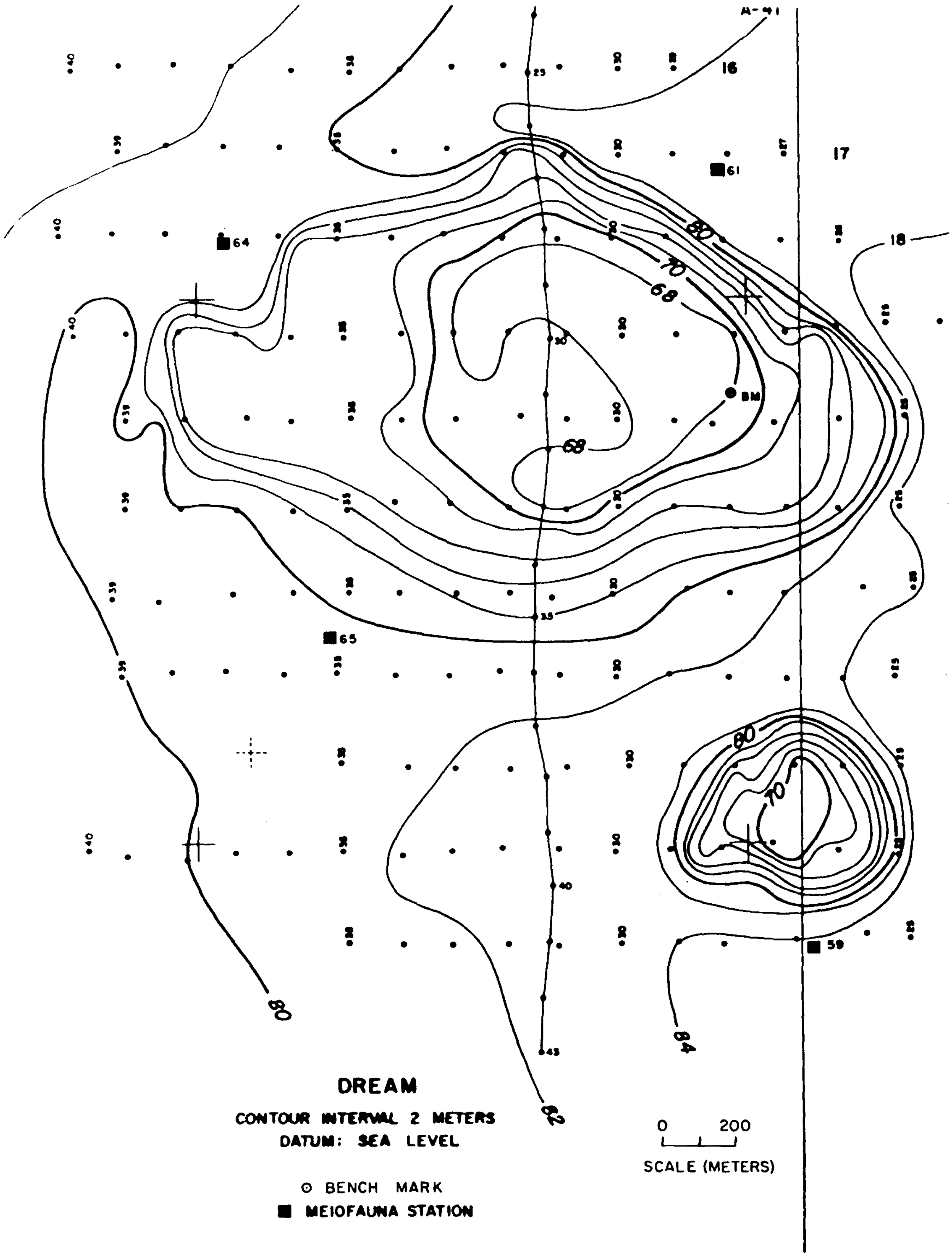


Fig. 5. Meiofauna station positions in relation to the bathymetry of Dream Bank.

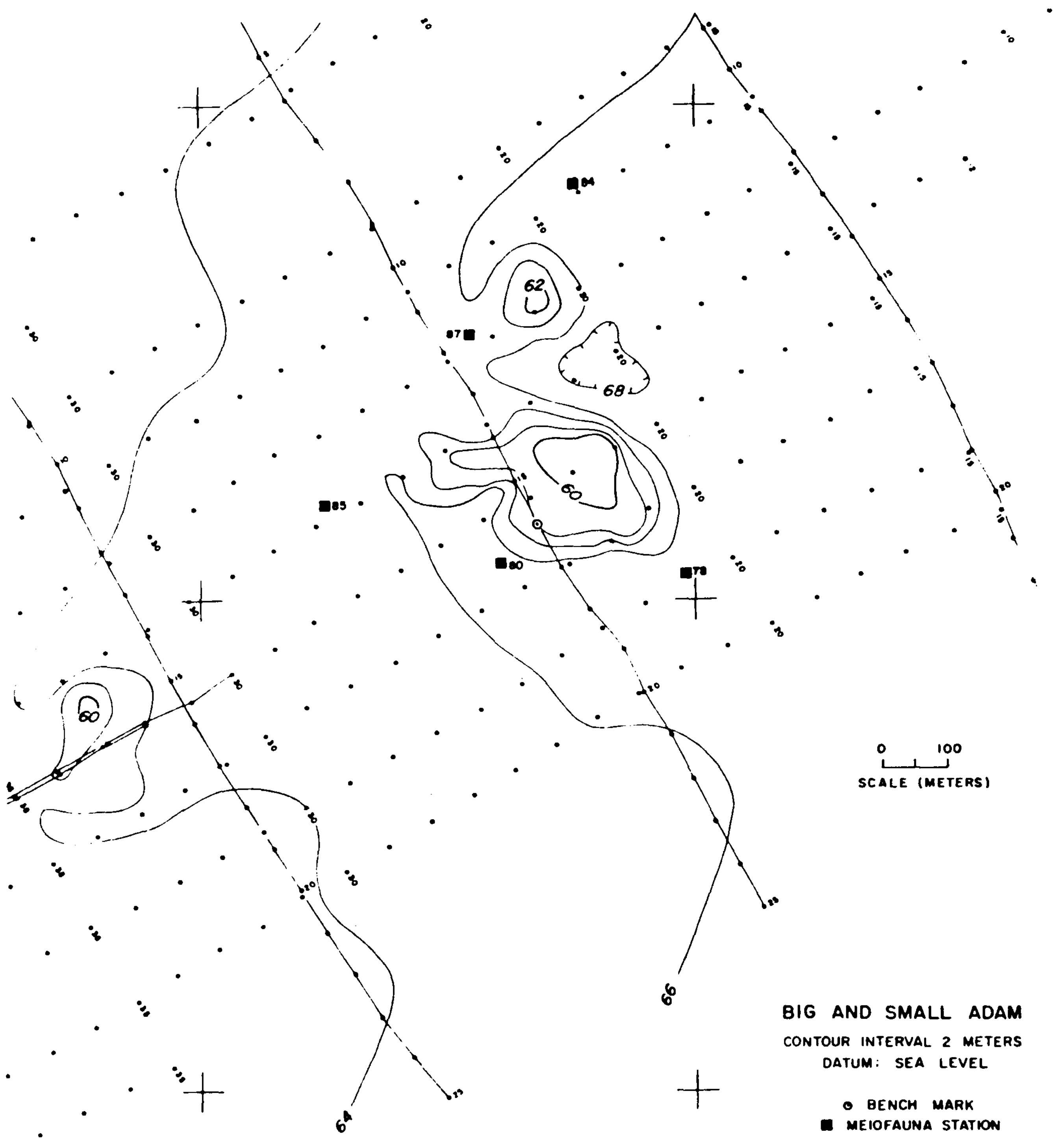


Fig. 6. Meiofauna station positions in relation to the bathymetry of Big and Small Adam Banks.

Other subsamples of sediment were taken from the box sampler at twenty-three of the meiofaunal stations for grain size analyses, which were performed by the geologists associated with the study. (Note: The geologist's station 25 corresponds to our 3, and their 33 to our station 5.) The results of the analyses are presented in Table 2, and the sand fractions have been combined for reasons which will be explained later.

EXTRACTION OF MEIOFAUNA

As explained by Uhlig et al. (1973), separation of meiofauna from the sediment involves two different procedures: concentration and then sorting and counting. The concentration of the meiofauna was accomplished by sieving and decantation, which according to Uhlig et al. (1973) is one of the best methods for separating the total fauna. Each sample was washed through a 500 μ and then a 62.5 μ sieve. Those organisms which passed the coarser screen, but were retained by the finer one were considered meiofaunal. De Bovée et al. (1974) demonstrated that the 62.5 μ screen was suitable for a quantitative survey of both the numbers and biomass of muddy bottom meiofauna, with over 90 percent of the fauna being retained. The upper limit of 500 μ has been utilized by other investigators (Tietjen, 1966; Coull, 1968; McIntyre and Murison, 1973) and we believe that this size more adequately separates the taxa involved than larger sieve sizes. In many samples over 90 percent of the sediment washed through the screens (composed of silt and clay) and the remaining organisms, detritus, and sand was placed in a solution of 5 percent formalin, rose bengal, and aqueous phenol for at least 24 hours to ensure proper staining (Walton, 1952; Uhlig et al. 1973). In those samples in which a large quantity of material was left on the sieve another extraction and concentration procedure had be utilized. In this procedure a sucrose solution was used to float the organisms from the sediment (Heip et al. 1974). This was performed by simply pouring the sucrose solution onto the material, decanting the solution from the sediment, and pouring it through a 62.5 μ sieve. This was generally done three to five times to give adequate separation. This fraction was likewise immersed for at least 24 hours in the formalin, rose bengal aqueous phenol solution. To test the extraction efficiency of the sucrose method the remaining sand fraction was examined in all cases after staining. Table 3 indicates that this method extracted over 90 percent of the fauna, but selected against the heavier foraminiferans, ostracods, and mollusks. After rinsing the material free of excess stain the organisms were identified and counted at 25X magnification, using Wild M-5 dissecting microscopes.

STATISTICAL ANALYSIS

Multiple linear regression was used in an attempt to account for the between station variability in the meiofauna. A least squares regression of the dependent variable y (nematodes in 0-5 cm section transformed using ln (x + 1)) was first determined on a set of 3 independent variables (x_1, x_2, x_3) in which the percentage by weight of sand, silt, and clay in Table 2 were utilized as independent variables. In an attempt to increase the correlation coefficients, an arcsin $\sqrt{x}$ transformation was applied to the grain size data (Steel and Torrie, 1960). This, however, did not significantly increase the correlation coefficients. Transformed counts (Ln x + 1) of each major taxa (nematoda, foraminifera, copepoda, and polychaeta) and the total meiofauna in 0-5 cm and 0-15 cm vertical sections were then used individually as the dependent variable. They were regressed against the seven grain size classes in Table 2. The sand fractions were combined into percent sand (x_1), since the percentage sand had the lowest correlation with the nematodes in the 0-5 cm section. The three classes of silt and three of clay in Table 2 were the other six independent variables (x_2, ..., x_7). An arcsin $\sqrt{x}$ transformation was made on all seven grain size classes, and the nematodes (0-5 cm) were regressed against the transformed grain sizes. This again gave lower correlations and the transformation was not used again. The calculations were made on a Hewlett-Packard 9830 A calculator with a multiple linear regression statistical package.

RESULTS

POPULATIONS

Appendix I, Figure 7, and Table 4 give the numbers of individuals counted

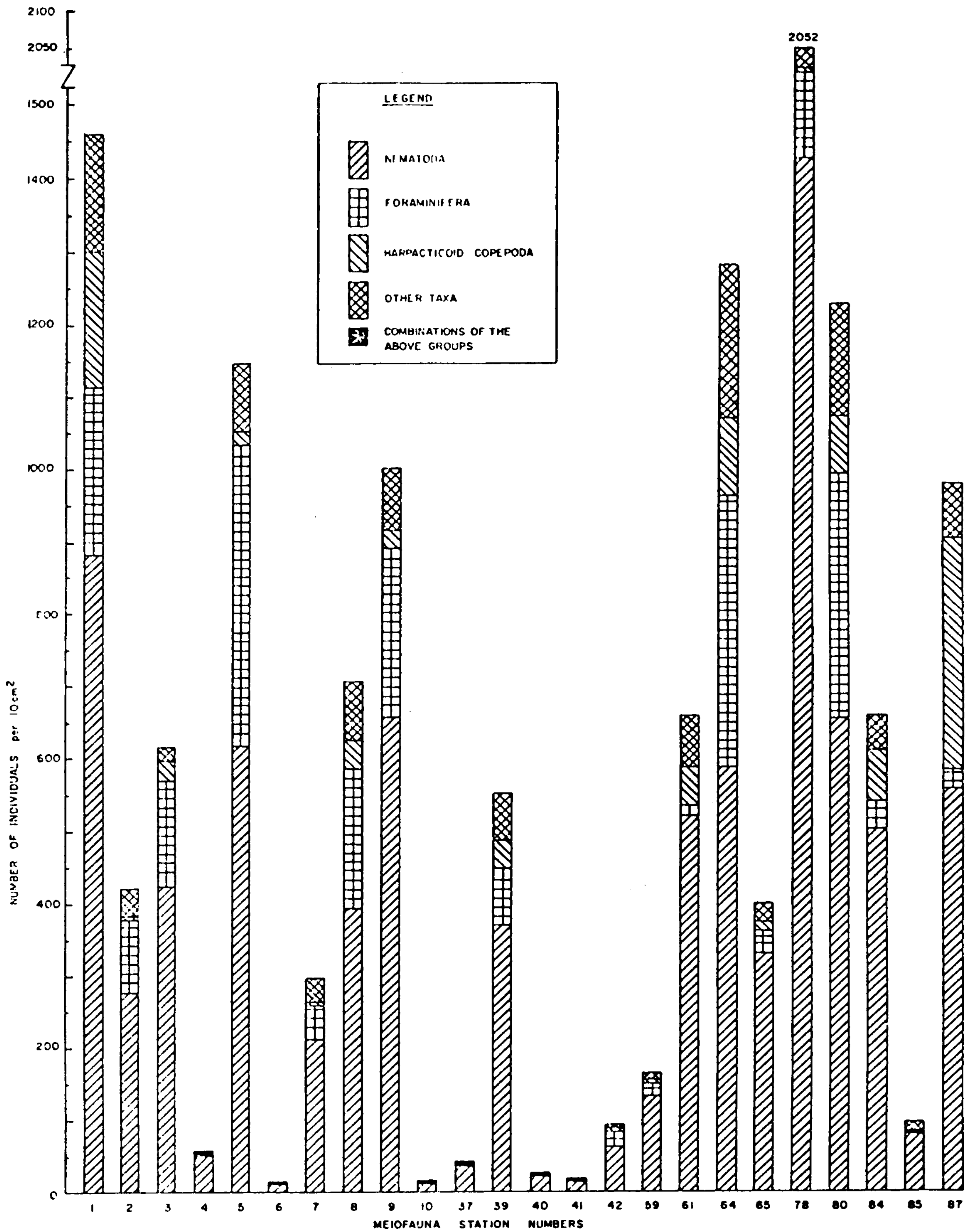


Fig. 7. Number of individuals of the dominant meiofauna taxa found at the twenty-four stations utilized in this study.

in each taxon along with their vertical distributions, and their means. The total number of individuals per 10 cm^2 ranges from 15 at station 10 to a high of 2052 at station 78, the average being 577. The numbers of individuals generally fall into three classes. The nine stations with the lowest number of individuals average 55 organisms/10 cm^2; another group of 8 stations which have numbers ranging from 280 to 679 individuals averages 532/10 cm^2; while the remaining seven stations average 1299 individuals/10 cm^2. If the data are examined with regard to banks it is obvious that the meiofauna population surrounding Southern is the most depauperate with an average of only 141/10 cm^2 while Big Adam's population averages 992/10 cm^2. This variation may not be due to the banks per se, but is a function of the sediments surrounding them. It would be interesting to compare the current regime between Southern and Big Adam, and at each of these banks to look at the amount of organic material in the sediment. The level of organics in the sediments could be related to production on the banks, and the downstream stations (if any) might be expected to have larger meiofaunal populations.

The nematodes are the numerically dominant meiofauna taxon averaging 363 individuals/10 cm^2 and this is 63 percent of the total. This is a lower percentage than normally encountered in other studies, but it is partly because the foraminiferans have rarely been included in previous studies. Ignoring the foraminiferans the nematodes account for 77 percent of the total individuals within the 15-cm column.

DISTRIBUTION IN SEDIMENT COLUMN

The vertical distribution shows that 74.37 percent of the total meiofauna are found within the 0 to 5 cm section, while 92.81 percent reside in the top 10 cm.

The temporary meiofauna (polychaeta, bivalvia, gastropoda, and sipunculida) average only 40 individuals/10 cm^2 with the polychaetes averaging 26/10 cm^2. The tremendous number of sipunculids at station 78 particularly in the 5-10 cm section is noteworthy. However, even without this group the meiofauna is very rich at this station, especially in the lower sections, which may be an indication of a disturbed sample, which will be noted again later.

Table 5 demonstrates the large variability or small scale patchiness of the meiofauna. All three replicates were taken from a single box sample. The values for the other 23 stations should be examined with this in mind.

INTERTAXA RATIOS

Table 6 shows the ratios between the dominant, permanent meiofaunal taxa. Parker (1975) found that the ratio between benthic copepods to nematodes was a possible index of pollution. In most environments, particularly muds, nematodes predominate, but Parker found in portions of Galveston Bay and Brazos River Estuary that copepods "far outnumbered" nematodes. He attributed this unusual condition to pollution. If proper sampling and extraction methods are used and the type of sediment is taken into account this ratio may have some meaning as Parker maintains. As can be seen from Table 6 the ratios fluctuate substantially and depend to a great extent on the number of individuals in the sample.

MEIOFAUNA-SEDIMENT CORRELATIONS

Tables 7 and 8 show the results of the multiple linear regression in which meiofaunal groups (dependent variables) are regressed against the sediment grain size classes. The relationships between the independent x variables are depicted for both the grain size percentages and the transformed percentages. In general, the sand is negatively correlated with the silt and clays, and the fine silt and clays are positively correlated to each other. These relationships are reasonable when considered with other data. Table 8 indicates that the transformed sediment percentages lead to lower multiple correlation coefficients, but that transforming counts of individuals results in higher correlations. This was demonstrated for the nematodes (0-5 cm) and followed in other regressions. The percent silt has almost twice the positive correlation coefficient as does percent sand when only the three major classes are considered. The percent clay has nearly the same coefficient as does the silt, but it is negative. This led to a decision to concentrate on the silt and clay fractions in other regressions. The table shows that the coarse and medium silt has the highest correlation in all cases to the number of individuals. The fine and very fine clay has the second highest correlation, but it is negative, whereas the coarse and medium silt is positively correlated. The correlations between these two fractions and the various dependent factors are significant to highly significant (0.001 level) even though the partial correlation coefficients are not particularly high. The coarse and medium silt seems to definitely have an influence on the meiofaunal variations between stations. The multiple correlations are significant for the nematodes, polychaetes, and total meiofauna, but only at the (0.05 level). As can be seen from the table, the polychaetes are most highly correlated to the sediment, the nematodes second, and the total meiofauna is also correlated to a significant degree. The harpacticoid copepods have the lowest multiple correlation coefficient and the foraminiferans are also not very highly correlated to the sediment. An interesting fact is that the grain size percentages were determined only from a surface sample but that the total sample is more highly correlated in each case than are the counts for the 0 to 5 cm section.

VALUE OF THE NEMATODE/HARPACTICOID RATIO

An interesting consideration emerges from the above observations which argues that if harpacticoid copepod populations are not highly correlated with sediment fractions and nematode populations are, then any activity that changes sediment characteristics (e.g. drilling for oil) at a known point will have a profound effect on the nematode: harpacticoid ratio. And by the same token, if sediment structure is held constant and this ratio is observed to change in a previously studied area, then one can assume that it would be worthwhile to look for another kind of environmental perturbation.

DISCUSSION

VERTICAL DISTRIBUTION IN SEDIMENTS

Elmgren (1973) has demonstrated that subsampling a grab type box sampler is a reliable method for sampling meiofauna quantitatively. He has further reported that the box sampler is the only sampling device that obtains the needed undisturbed sample. It must also be recognized that most extraction techniques, including the one used here, probably yield minumum estimates of the soft-bodied taxa such as gastrotrichs, protozoans, and turbellarians as special techniques must be followed if these organisms are to survive the extraction procedure.

McIntyre (1961), Weiser and Kanwisher (1961), and Tietjen (1966), and McIntyre (1969) have shown that most meiofaunal organisms are confined within the upper 2 cm of sediment, with the majority of nematodes in the upper 4 cm, but extending to a lower limit of 6 to 8 cm. This study indicates that the vertical penetration of the meiofauna exceeds these referenced depths and that relatively low numbers of nematodes may even be encountered below 15 cm. The presence of living foraminiferans in the 10 to 15 cm section is doubted although they are recorded in this layer (Appendix I). It is possible that the rose bengal stained other than the living foraminiferans (Boltovskoy, 1966, Martin and Steinker, 1973). Teitjen (1966) investigated the factors controlling the vertical distribution of the meiofauna and found that decreasing water content, O_2, and food are probably the main parameters which limit the vertical penetration of the meiofauna into the sediment.

POPULATION SIZE VARIABILITY

This study indicates the tremendous variation which can occur in subtidal meiofaunal populations over a relatively homogeneous sediment type. The factors which may be responsible for these changes are numerous, but it is doubtful that either salinity or temperature play an important role since they are very nearly the same between the 64 and 86 meters isobath in which these stations are situated (Harrington, unpublished). However, temperature has been shown to be important in temporal fluctuations in population levels. The numerical variation in the permanent meiofauna of the littoral zone and very shallow water oscillated widely over an annual cycle (Tietjen, 1966), but little information is available on the fluctuations of offshore populations. Studies by McIntyre (1964) and Warwick and Buchanan (1971) in approximately 100 meters of water have indicated that statistically significant monthly variations in the permanent meiobenthos do not occur, although the temporary meiobenthos were more numerous in late autumn and winter. Etter and Cochrane (in press) have shown an annual variation of 3 to 6°C in bottom water temperature for the area encompassed by this study, while Harrington (unpublished), based on less data, has indicated an 11°C change and almost constant salinity. This low variability probably led to little seasonal variation in the study area. The granulometry of sediment and the associated factors are probably the most influential in determining spatial variations in the meiofauna. Ward (1975) reported that silt and clay percentages of 15 percent or more in sediments would effectively fill the interstices between large particles and provide a more or less uniform environment for the meiofauna. Almost all of the meiofaunal organisms present in this study are either burrowers or live on the sediment surface. The most commonly measured parameter in benthic studies is grain size, but as Jansson (1967) has pointed out grain size _per se_ does not affect meiofaunal distributions; it is the size of the interstices which result from the size, shape, sorting, and packing of the sediment particles. The porosity, permeability, and oxygen content of the sediment are highly correlated with the pore size and are also very important. The amount of organic matter, measured as total carbon, and the number of bacteria present are often highly negatively correlated to grain size and very influential in determining spatial variations in meiofaunal populations (Gray and Johnson, 1970; Tietjen 1971; Dale, 1974).

When considering which environmental parameters may be of most importance in influencing spatial distributions it is necessary to define the area and spatial scale of the distribution. Most of the ecological studies of ostracode and foraminiferans have been concerned with broad areas such as the entire continental shelf, or major differences in habitat such as a coarse sand and a fine clay sediment (Kornicker, 1958 and Parker, 1960 for example). In these types of "macro-distributions" temperature, salinity, water masses, and water depths prove to be very significant. Obviously, salinity and temperature would be of much greater significance in estuaries than in the subtidal zone. When considering distributions over a narrow depth zone on the continental shelf, even though its sediment type may be considered homogeneous, (predominately silt/clay), it seems likely that very small substrate differences and biotic interactions are exerting major influences on meiofaunal distributions.

Ward (1973), among others, has shown that the meiofauna which inhabit sediment with low median grain sizes and corresponding high percentages of silt and clay are of low diversity compared to those of sandy substrates. It is believed that coarse sediments, because of their interstices provide a greater number of habitats for the meiofauna and this leads to higher diversity.

Attempts to correlate foraminiferans with median grain size have not been markedly successful (Shelton, 1957), and for this reason the meiofauna in this study were regressed against the individual grain size classes. Multiple linear regression is a measure of the degree to which variables vary together or a measure of the intensity of association between the dependent and independent variables. It has been utilized in a number of marine studies to relate faunal distributions to selected environmental factors (Buzas, 1969; Oviatt and Nixon, 1973 for example). Analyses do not prove causality between dependent and independent variables even when the correlation coefficients are significant. The independent factors may be highly correlated with some other factor that has not been included in the regression analyses. Hartzband and Hummon (1974) have adequately demonstrated the point. Interrelationships between the independent variables are also common, as in this study, and this leads to further difficulties in interpretation of the results. Another consideration is the fact that the relationship between dependent factors and independent factors may not be linear.

Tietjen (1966), while working in two New England estuaries, found that meiofaunal populations showed a significant positive relationship with water content and some correlation between the major meiofaunal taxa and temperature and organic matter. Gray (1971), in perhaps the most significant study of this kind to date, found that only grain size parameters showed significant positive or negative correlations to meiofaunal numbers. His study centered on five beach areas and temperature, salinity, oxygen availability, Eh-pH, depth of redox discontinuity, and beach slope were also used as independent variables. Rogers and Darnell (1973) studied the effects of dredging on meiofaunal taxa in those parts San Antonio Bay subjected to shell-dredging. They demonstrated that dredging was an important environmental perturbation in that it reduced the population of meiofauna almost 70 percent. Of equal importance was the finding that "in general, the higher the silt fraction in the sediments the higher the meiobenthic population". Only six stations were used to support this claim, but it is probably still valid and it indicates the same relationship that was found in this study.

The degree of correlation between fauna and certain environmental parameters, depends, to a great degree, on the habitat(s) in which the relationship is established. For example, if ten stations are utilized and a certain species is regressed against grain size it would make a great deal of difference if the stations were in the same habitat or spread between two. In other words, a higher correlation would be expected between a species and grain size if the species only occurred in fine silt and five of the stations were located in a nearby sandy area in which the species was not present, than if all of the stations were within the fine silt area. This indicates that correlation coefficients must be interpreted with great care and that the not particularly high values in this study are not unexpected. Other factors which have probably contributed to the somewhat low correlation coefficients are small scale patchiness of the meiofauna and failure to differentiate species. The three replicates at station four (Table 5) indicate that more than one sample of the size utilized in this study is needed to predict with confidence the numbers of meiofauna in a small area. The lack of replication and the subsequent poor estimate of the population leads to low correlations. Each species occupies its own niche and responds to the environment in its own way. This is reflected in the distribution pattern of a species, and since correlations were not derived for individual species the correlations obtained are averages for all those species contained in each taxa. It is also possible that the meiofauna is responding to certain biologically important physical variables which were not measured, and that biotic interaction such as intra-specific gregariousness, predation, or bacterial attractiveness (food) are responsible for distributions (Gray and Johnson, 1970). Combinations of all these parameters make the problem extremely complex.

It is obvious that the meiofauna is highly dependent on grain size, but in this study only 39 percent (r^2) of the spatial variance is accounted for by grain size. An ecological interpretation of the highly significant positive correlation between coarse and medium silt and all meiofauna taxa is difficult. It may be related to food supply as Dale (1974) found bacteria were highly correlated to grain size with low grain sizes (silt and clay) harboring the highest numbers of bacteria. The significant negative correlation between fine and very fine clay and all meiofauna taxa is probably due to available oxygen and pore water. The predominance of very fine clays results in very little interstial space and because of this water and oxygen have difficulty penetrating very far below the sediment surface.

SUMMARY AND CONCLUSIONS

The present study demonstrates that meaningful data on the meiofauna of deep water is obtainable only with a sampler having the capability of taking an undisturbed sediment section possessed by a grab-type box corer. This conclusion is supported by the present study which shows that substantial numbers of meiofauna are living as deep as 10-15 cm in deep-water sediments, often without the sharp reduction of individuals below the 5 cm level frequently shown by the data of others. In fact, our data show that when total meiofaunal populations are large in deep-water areas (e.g. station 78 at Big Adam Bank), there is a correspondingly large proportion of the population in the 10-15 cm section of the sediment column. This probably explains also why correlations between populations and grain size were higher for the whole sample than for any section even though grain size percentages were determined only from a surface sample.

One may speculate that a likely explanation of the sharp reduction of populations beyond the first few centimeters, as found by others, is that they lost the upper 5 to 10 cm at the moment of sampling (pressure wave before a grab) or during retrieval of the sampler (winnowing) to the surface. It follows from this that regional comparisons of meiofaunal data are of little value unless the same type of sampler is used in both regions.

As was indicated earlier, the meiofauna has great potential in the role of environmental indicators, provided certain precautions are taken in sampling and in interpreting the data. Thus, an adequate number of replicates must be taken with a reliable sampler in order to warrant making estimates of the populations at each designated location. As we have demonstrated in this study, the natural variation in the populations of permanent meiofauna is large both spatially and probably temporally. Hence, in order to serve as useful and very sensitive indicators of environmental perturbations, these characteristic variations must be known and even predicted.

We believe that two ratios are of special value in monitoring environmental change. When properly derived and correlated with grain size analysis, the nematode-harpacticoid ratio is responsive to both sedimental and chemical changes. Among its values in practical terms is its short-time span. It will be quick to develop under stress and reasonably quick to respond to removal of stress.

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Table 1. Meiofauna Station Positions, Depths, and Dates of Collection

BANK	STATION	DEPTH in meters	LATITUDE	LONGITUDE	COLLECTION DATE
Baker	1	68	27° 45.33'	96° 13.47'	May 24
	2	73	27° 44.83'	96° 13.12'	May 24
	3	71	27° 45.27'	96° 13.77'	May 26
	4	76	27° 44.49'	96° 13.50'	May 24
	5	69	27° 44.73'	96° 14.63'	May 27
	6	74	27° 44.24'	96° 14.25'	May 24
South Baker	7	82	27° 40.61'	96° 16.44'	May 26
	8	83	27° 40.33'	96° 16.03'	May 26
	9	82	27° 40.71'	96° 15.91'	May 26
	10	86	27° 40.12'	96° 16.68'	May 26
Southern	37	82	27° 26.07'	96° 31.94'	May 29
	39	80	27° 26.16'	96° 31.87'	May 30
	40	84	27° 25.93'	96° 31.19'	May 30
	41	83	27° 26.24'	96° 31.04'	May 30
	42	81	27° 26.16'	96° 32.25'	May 31
Dream	59	85	27° 01.69'	96° 42.06'	June 8
	61	86	27° 02.87'	96° 42.20'	June 7
	64	78	27° 02.87'	96° 43.04'	June 7
	65	81	27° 02.16'	96° 42.87'	June 7
Big Adam	78	67	26° 56.95'	96° 48.65'	June 9
	80	68	26° 57.03'	96° 49.04'	June 12
	84	65	26° 57.67'	96° 48.91'	June 9
	85	65	26° 57.14'	96° 49.38'	June 9
	87	64	26° 57.42'	96° 49.11'	June 9

TABLE 2. GRAIN SIZE ANALYSIS IN WEIGHT PERCENTAGE

STATION	SAND	SILT				CLAY			
	3 mm to 62.5μ	62.5 to 15.6μ	15.6 to 7.8μ	7.8 to 3.9μ		3.9 to 1.95μ	1.95 to 0.98μ	0.98 to 0.24μ	
	Granule to Very Fine	Coarse & Medium	Fine	Very Fine	Total	Coarse	Medium	Fine & Very Fine	Total
1	7.538	20.170	7.789	8.985	36.944	2.618	18.723	34.176	55.518
2	65.261	8.512	3.239	1.794	13.545	3.042	5.807	12.345	21.195
3	22.530	15.424	7.328	7.318	30.069	10.793	7.393	29.215	47.401
4	2.414	10.100	8.982	9.366	28.448	8.098	18.089	42.951	69.138
5	10.572	19.520	8.087	7.754	35.361	7.436	19.838	26.794	54.067
6	0.988	2.588	7.941	10.041	20.569	9.249	13.017	56.178	78.443
7	4.172	13.849	9.086	7.602	30.537	7.883	12.711	44.696	65.290
8	2.444	13.191	10.293	10.592	34.076	11.311	15.809	36.360	63.480
9	6.631	12.243	10.669	7.829	30.740	9.412	13.430	39.786	62.628
10	0.101	2.428	5.763	8.697	16.888	9.371	20.062	53.578	83.011
37	19.545	6.535	7.577	8.398	22.510	9.766	14.978	33.201	57.945
39	76.992	6.083	0.775	0.833	7.690	2.124	5.517	7.678	15.318
40	0.460	4.043	8.428	9.579	22.050	7.186	22.438	47.867	77.490
41	0.099	2.944	8.709	10.101	21.754	8.302	22.521	47.324	78.147
42	8.328	25.014	8.980	8.509	42.503	4.052	5.491	39.626	49.168
59	0.410	3.990	5.090	12.940	22.020	6.980	13.980	34.180	77.570
61	1.929	23.103	7.428	7.620	38.151	8.009	14.003	37.908	59.919
64	0.464	11.140	11.633	8.128	30.900	8.475	7.835	52.326	68.636
65	66.779	5.349	4.257	1.228	10.834	3.029	0.073	19.285	22.388
78	0.249	12.764	9.042	9.872	31.677	9.406	14.450	44.218	68.074
84	0.524	17.660	9.386	9.386	36.431	9.205	15.426	38.414	63.045
85	0.260	15.807	9.890	8.239	33.937	8.869	14.665	42.269	65.803
87	0.634	17.738	11.153	8.796	37.687	8.962	11.038	41.678	61.679

Table 3. Extraction Efficiency of Meiofaunal Groups From Sediment

Taxa	Percentage Extracted
Nematoda	99.63
Foraminiferida	70.94
Harpacticoid Copepoda	100.00
Kinorhyncha	100.00
Ostracoda	80.00
Halicaridae	100.00
Gastrotricha	100.00
Polychaeta	98.38
Mollusca	83.33
Total Meiofauna	92.33

Table 4. Means, Percentages of Total Meiofauna Population, and Vertical Distributions of Dominant Meiofauna Taxa.

TAXA	$\overline{X}$ For All Stations, Individuals /10 cm^2	Percentage of Total Meiofauna	Percentage within Top 5 cm of Sediment	Percentage within Top 10 cm of Sediment
Nematoda	363	62.98	63.28	84.95
Foraminiferida	106	18.32	79.43	93.65
Harpacticoid Copepoda	45	7.87	86.69	98.56
Polychaeta	26	4.54	80.17	95.71
Other taxa	36	6.29	62.29	91.17

TABLE 5. COMPARISON OF REPLICATE SUBSAMPLES FROM STATION 4

Taxa	Sample 1	Sample 2	Sample 3
Nematoda	50	10	28
Harpacticoid Copepoda	1	0	0
Foraminiferida	1	0	0
Polychaeta	3	0	0
Total Individuals	55	10	28

Table 6. Ratios Between Dominant Meiofaunal Groups

Station	Nematoda: Foraminiferida	Nematoda: Harpacticoid Copepoda	Foraminiferida: Harpacticoid Copepoda
1	3.86 : 1	4.90 : 1	1.27 : 1
2	2.56 : 1	65.75 : 1	25.75 : 1
3	3.04 : 1	13.13 : 1	4.32 : 1
4	50.00 : 1	50.00 : 1	1.00 : 1
5	1.48 : 1	25.74 : 1	17.35 : 1
6	----	----	----
7	3.67 : 1	----	----
8	2.04 : 1	11.06 : 1	5.41 : 1
9	2.76 : 1	20.10 : 1	7.29 : 1
10	----	13.00 : 1	----
37	4.80 : 1	12.00 : 1	2.50 : 1
39	4.59 : 1	9.69 : 1	2.11 : 1
40	4.75 : 1	----	----
41	----	----	----
42	3.35 : 1	11.40 : 1	3.40 : 1
59	7.93 : 1	29.75 : 1	3.75 : 1
61	35.07 : 1	10.91 : 1	0.31 : 1
64	1.49 : 1	5.68 : 1	3.80 : 1
65	10.10 : 1	27.55 : 1	2.73 : 1
78	6.65 : 1	13.70 : 1	2.06 : 1
80	1.94 : 1	8.42 : 1	4.35 : 1
84	12.13 : 1	9.10 : 1	0.75 : 1
85	----	----	----
87	26.05 : 1	1.62 : 1	0.06 : 1
$\bar{x}$	9.41 : 1	18.08 : 1	4.89 : 1

Table 7 . Correlation Coefficients Between Independent Variables

	1	2	3	4	5	6	7
1	1.000						
2	-.232	1.000					
3	-.800	.406	1.000				
4	-.925	.069	.640	1.000			
5	-.679	-.024	.642	.634	1.000		
6	-.676	-.103	.357	.674	.426	1.000	
7	-.869	-.070	.711	.748	.614	.529	1.000

	1	2	3	4	5	6	7
1	1.000						
2	-.199	1.000					
3	.350	-.125	1.000				
4	-.645	.192	-.328	1.000			
5	-.715	-.012	-.301	.490	1.000		
6	-.723	-.002	-.136	.552	.513	1.000	
7	-.908	-.094	-.396	.594	.677	.558	1.000

Sediment data transformed (arc sin $\sqrt{X}$)

1--Sand
2--Coarse and Medium Silt
3--Fine Silt
4--Very Fine Silt
5--Coarse Clay
6--Medium Clay
7--Fine and Very Fine Clay

Table 8. Partial and Multiple Correlation Coefficients Between Meiofaunal Groups and Grain Size Classes

TAXA	VERTICAL SECTION (cm)	PARTIAL CORRELATION COEFFICIENTS			MULTIPLE CORRELATION COEFFICIENTS	TEST OF SIGNIFICANCE (F)			
		SAND	SILT	CLAY	TOTAL SAND, SILT, CLAY	SAND	SILT	CLAY	TOTAL SAND, SILT, CLAY
[1]Nematoda	0-5	.197	.348	-.430	.4745	1.4084	15.3358**	.3358	5.7182**
[2]Nematoda	0-5	.238	.417	-.453	.3954	1.7772	5.9655*	4.6819*	4.1415**

[1]Only numbers of individuals transformed (ln × + 1)

[2]Both numbers of individuals transformed and grain sizes (arcsin $\sqrt{x}$)

*Significant P≤0.05 but not at P≤0.01

**Highly significant P≤0.01

Table 8 continued.

TAXA	VERTICAL SECTION (cm)	PARTIAL CORRELATION COEFFICIENTS						
		SAND	SILT			CLAY		
		Granule to Very Fine	Coarse & Medium	Fine	Very Fine	Coarse	Medium	Very Fine
[1]Nematoda	0-5	.024	.492	.160	-.086	-.136	-.066	-.210
[1]Nematoda	0-5	.197	.564	.079	-.266	-.157	-.348	-.419
[2]Nematoda	0-5	.238	.488	.178	-.124	-.164	-.302	-.398
[1]Nematoda	total	.226	.645	.025	-.229	-.159	-.299	-.405
[1]Foraminiferida	0-5	.341	.505	-.047	-.281	-.241	-.328	-.450
[1]Foraminiferida	total	.330	.505	-.020	-.236	-.203	-.305	-.444
[1]Harpacticoid Copepoda	0-5	.082	.543	.077	-.097	-.112	-.221	-.243
[1]Harpacticoid Copepoda	total	.103	.561	.078	-.093	-.095	-.219	-.262
[1]Polychaeta	0-5	.077	.681	.162	-.040	-.043	-.037	-.291
[1]Polychaeta	total	.241	.654	.078	-.220	-.160	-.228	-.405
[1]Total Meiofauna	0-5	.240	.630	.029	-.239	-.177	-.311	-.402
[1]Total Meiofauna	total	.223	.647	.046	-.218	-.153	-.298	-.397

[1]Only numbers of individuals transformed $(\ln x + 1)$

[2]Both numbers of individuals transformed and grain sizes ($\arcsin\sqrt{x}$)

Table 8 continued.

TAXA	VERTICAL SECTION (cm)	MULTIPLE CORRELATION COEFFICIENTS	TEST OF SIGNIFICANCE (F)		
		TOTAL SAND, SILT, CLAY	Coarse & Medium Silt	Fine & Very Fine Clay	Total Sand, Silt, Clay
Nematoda	0-5	.3233	5.7964*	0.1934	1.0239
[1]Nematoda	0-5	.5743	13.8298**	3.4892	2.8904*
[2]Nematoda	0-5	.4233	7.7625*	0.5075	1.5727
[1]Nematoda	total	.6312	17.8510**	4.5127	3.6673*
[1]Foraminiferida	0-5	.4765	8.0830*	2.0641	1.9508
[1]Foraminiferida	total	.4945	8.3494*	2.4280	2.0961
[1]Harpacticoid Copepoda	0-5	.4224	7.8760*	1.9904	1.5669
[1]Harpacticoid Copepoda	total	.4255	8.4690*	1.7591	1.5870
[1]Polychaeta	0-5	.6102	18.2032**	3.8340	3.5390*
[1]Polychaeta	total	.6472	19.2765**	4.8161*	3.9316*
[1]Total Meiofauna	0-5	.6047	15.9799**	3.9462	3.2783*
[1]Total Meiofauna	total	.6280	17.8357**	4.5788*	3.6170*

*Significant $P \leq 0.05$ but not at $P \leq 0.01$

**Highly significant $P \leq 0.01$

[1]Only numbers of individuals transformed ($\ln x + 1$)

[2]Both numbers of individuals transformed and grain sizes ($\arcsin \sqrt{x}$)

APPENDIX I. Number of Individuals per 9.62 cm^2 Surface Area.
(0-5, 5-10, 10-15 = Vertial Section of Core in cm)

SPECIMENS	STATIONS											
	BAKER 1				BAKER 2				BAKER 3			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	804	33	15	852	152	91	20	263	333	60	14	407
FORAMINIFERIDA	216	4	1	221	95	6	2	103	120	6	8	134
HARPACTICOID COPEPODA	172	2		174	2	2		4	28	3		31
CYCLOPOID COPEPODA												
POLYCHAETA	76	2	4	82	8	8	1	17	10		1	11
BIVALVIA	12			12	5	5	1	11	4			4
GASTROPODA	1			1								
KINORHYNCHA	43			43					1		1	2
OSTRACODA	3			3								
HALICARIDAE	5			5					1			1
GASTROTRICHA	9			9								
PROTOZOA												
SIPUNCULIDA	3			3								
UNKNOWN					6			6				
TOTAL ALL PHYLA				1405				404				590

APPENDIX I. (cont'd)

SPECIMENS	STATIONS											
	BAKER 4				BAKER 5				BAKER 6			
	0-3	3-8	8-13	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	27	15	8	50	489	87	16	592	12			12
FORAMINIFERIDA	1			1	324	47	28	399				
HARPACTICOID COPEPODA			1	1	22	1		23				
CYCLOPOID COPEPODA					4			4				
POLYCHAETA	1	1	1	3	58	11	5	74				
BIVALVIA					2			2				
GASTROPODA												
KINORHYNCHA					8			8	2			2
OSTRACODA									2			2
HALICARIDAE												
GASTROTRICHA												
PROTOZOA												
SIPUNCULIDA												
UNKNOWN												
TOTAL ALL PHYLA				55				1102				16

APPENDIX I. (cont'd)

SPECIMENS	STATIONS											
	SOUTH BAKER 7				SOUTH BAKER 8				SOUTH BAKER 9			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	146	42	10	198	244	122	10	376	452	144	27	623
FORAMINIFERIDA	38	8	8	54	155	28	1	184	199	20	7	226
HARPACTICOID COPEPODA					26	8		34	27	4		31
CYCLOPOID COPEPODA					1	1		2				
POLYCHAETA	23	3	2	28	57	6		63	51	6	2	59
BIVALVIA					1			1	7			7
GASTROPODA												
KINORHYNCHA					11			11				
OSTRACODA					2			2	4			4
HALICARIDAE												
GASTROTRICHA												
PROTOZOA					3			3	6	4	3	13
SIPUNCULIDA												
UNKNOWN					1	2		3	2			2
TOTAL ALL PHYLA				280				679				965

APPENDIX I. (cont'd)

SPECIMENS	STATIONS											
	SOUTH BAKER 10				SOUTHERN 37				SOUTHERN 39			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	9	2	2	13	14	7	3	24	281	67	1	349
FORAMINIFERIDA						5		5	75		1	76
HARPACTICOID COPEPODA	1			1		2		2	36			36
CYCLOPOID COPEPODA												
POLYCHAETA					2	1		3	26	1		27
BIVALVIA									19			19
GASTROPODA									2			2
KINORHYNCHA									1			1
OSTRACODA									7			7
HALICARIDAE												
GASTROTRICHA												
PROTOZOA												
SIPUNCULIDA									1			1
UNKNOWN									3			3
TOTAL ALL PHYLA				14				34				521

APPENDIX I. (cont'd)

SPECIMENS	STATIONS											
	SOUTHERN 40				SOUTHERN 41				SOUTHERN 42			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	14	5		19	12	2	3	17	36	11	10	57
FORAMINIFERIDA	1	2	1	4					10	4	3	17
HARPACTICOID COPEPODA									4	1		5
CYCLOPOID COPEPODA												
POLYCHAETA					1			1	4			4
BIVALVIA												
GASTROPODA												
KINORHYNCHA												
OSTRACODA												
HALICARIDAE	1		2	3								
GASTROTRICHA												
PROTOZOA												
SIPUNCULIDA												
UNKNOWN												
TOTAL ALL PHALA				26				18				83

APPENDIX I. (cont'd)

SPECIMENS	STATIONS											
	DREAM 59				DREAM 61				DREAM 64			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	75	37	7	119	282	106	103	491	420	117	14	551
FORAMINIFERIDA	8	4	3	15	10	1	3	14	281	64	24	369
HARPACTICOID COPEPODA	3	1		4	27	18		45	85	12		97
CYCLOPOID COPEPODA					1			1				
POLYCHAETA	3	1		4	12	5		17	35	4	2	41
BIVALVIA					3			3	8	1		9
GASTROPODA					1			1	1			1
KINORHYNCHA					1			1	6			6
OSTRACODA						7		7	22	3		25
HALICARIDAE												
GASTROTRICHA					4			4	2			2
PROTOZOA	1	1	3	5	39	6	1	46	92	17		109
SIPUNCULIDA												
UNKNOWN									7			7
TOTAL ALL PHYLA				147				630				1217

APPENDIX I. (cont'd)

SPECIMENS	STATIONS											
	DREAM 65				BIG ADAM 78				BIG ADAM 80			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	238	58	7	303	611	344	429	1384	380	230	13	623
FORAMINIFERIDA	29		1	30	91	67	50	208	239	78	5	322
HARPACTICOID COPEPODA	11			11	77	11	13	101	56	18		74
CYCLOPOID COPEPODA												
POLYCHAETA	1	16		17	33	3	4	40	31	10		41
BIVALVIA		1		1	2	1		3	4	1		5
GASTROPODA		2	1	3	2			2	1		1	2
KINORHYNCHA					8		1	9	7			7
OSTRACODA	1			1	21	1	2	24	16	4		20
HALICARIDAE					1			1	1			1
GASTROTRICHA					6			6	1			1
PROTOZOA									26	23	10	59
SIPUNCULIDA					16	162	18	196				
UNKNOWN	2			2					6	3		9
TOTAL ALL PHYLA				368				1974				1164

APPENDIX 1. (cont'd)

SPECIMENS

	BIG ADAM 84				BIG ADAM 85				BIG ADAM 87			
	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL	0-5	5-10	10-15	TOTAL
NEMATODA	294	131	48	473	52	11	11	74	365	102	54	521
FORAMINIFERIDA	33	1	5	39					14	2	4	20
HARPACTICOID COPEPODA	51	1		52					312	9	1	322
CYCLOPOID COPEPODA												
POLYCHAETA	30	10		40	4	1		5	22	5	1	28
BIVALVIA	6			6					2			2
GASTROPODA	3			3								
KINORHYNCHA	1			1					3			3
OSTRACODA	3			3					7		4	11
HALICARIDAE												
GASTROTRICHA	1			1								
PROTOZOA	3	2		5	1			1	13	1	2	16
SIPUNCULIDA												
UNKNOWN		1	2	3		2	1	3				
TOTAL ALL PHYLA				626				83				923

APPENDIX I. (cont'd)

SPECIMENS	TOTAL	AVERAGE
NEMATODA	8391	350
FORAMINIFERIDA	2441	102
HARPACTICOID COPEPODA	1048	44
CYCLOPOID COPEPODA	7	1
POLYCHAETA	605	25
BIVALVIA	85	4
GASTROPODA	15	1
KINORHYNCHA	94	4
OSTRACODA	108	5
HALICARIDAE	11	1
GASTROTRICHA	23	1
PROTOZOA	257	11
SIPUNCULIDA	200	8
UNKNOWN	38	2
TOTAL ALL PHYLA	13324	

APPENDIX II. Some dominant genera and species of the meiofauna found on the outer continental shelf off Texas.

Phylum Nematoda

Sabatiera sp.

Vastoma spp.

Cheironchus sp.

Metachromadora spp.

Spirinia sp.

Desmodoia sp.

Quadricoma spp.

Tricoma spp.

Linhomoeus sp.

Sphaerolaimus spp.

Phylum Protozoa

Order Foraminiferida

Cancris oblonga (Williams, 1858)

Fursenkoina pontoni (Cushman, 1932)

Hanzawaia strattoni (Applin, 1925)

Bolivina striatula Cushman, 1922

Bolivina fragilis Phleger & Parker, 1951

Bigenerina irregularis Phleger & Parker, 1951

Angulogerina bella Phleger & Parker, 1951

Cibicides cf. *floridanus* (Cushman, 1918)

Elphidium discoidale (d'Orbigny, 1839)

Eponides antillarum (d'Orbigny, 1839)

Nonionella opima Cushman, 1947

Proteonina difflugiformis (H.B. Brady, 1879)

Pseudononion atlanticus (Cushman, 1947)

APPENDIX II. (cont'd)

Phylum Kinorhyncha

Echinoderes spp.

Pycnophyes sp.

Semnoderes sp.

Phylum Mollusca

Class Gastropoda

Caecum sp. (protoconch)

Phylum Sipunculida

Golfingia trichocephala (Sluiter)

Phylum Arthropoda *

Class Ostracoda

Philimedes sp.

Sarsiella spp.

* Harpacticoid copepod identifications will be forthcoming in a supplemental report.

CHAPTER VI

EPIBENTHOS

AND

GROUNDFISHES

Epibenthos and Groundfishes

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The concern expressed by interested parties in recent BLM public hearings into possible environmental impacts of oil and gas drilling on Texas Outer Continental Shelf Fishing Banks has been for the well-being of the banks' fishes and epibenthic communities. It is appropriate, therefore, that a great deal of our project effort has been directed toward a descriptive assessment of these components of the biota associated with the topographical features studied. Prior to our investigation very little was known of the benthic invertebrate populations and fishes, other than commercial and sport varieties, inhabiting the South Texas Fishing Banks. Bright and Pequegnat (1974) described the biota of the West Flower Garden Bank off Galveston and therein list references to past publications dealing with biological aspects of some of the South Texas Banks.

The following people contributed importantly to the production of the Epibenthos and Groundfish section of this report: Robert Abbott, Bart Baca, John Bennington, Greg Boland, Ronald Britton, Dr. Elenore Cox, Charles Giammona, Arthur Leuterman, Glen Lowe, Dr. Linda Pequegnat, Dr. Richard Rezak, Jack Thompson, all from Texas A&M University, and Joyce Teerling of Ecosystems Inc., New Orleans, Louisiana.

SOUTH TEXAS BANKS

The South Texas banks sampled and examined with the submarine (see Chapter II) are Baker, South Baker, North Hospital, Southern, Dream and Big Adam (Fig. 1 in Chapter III). The crest of Hospital Rock was viewed using the towed underwater television. All of the banks are composed of carbonate substrata overlain by fine sediment veneers of varying thicknesses. Carbonate blocks up to 1.5 or 2 meters high, grossly resembling reefal structures, occur on the banks and are seemingly clustered at particular depths (Fig. 1, see also Geology section of this report). It is on these blocks, which provide at least some local relief above the generally flat sediment-covered carbonate rock bottom of the bank, that the epifaunal communities are best developed. And it is around these blocks that the

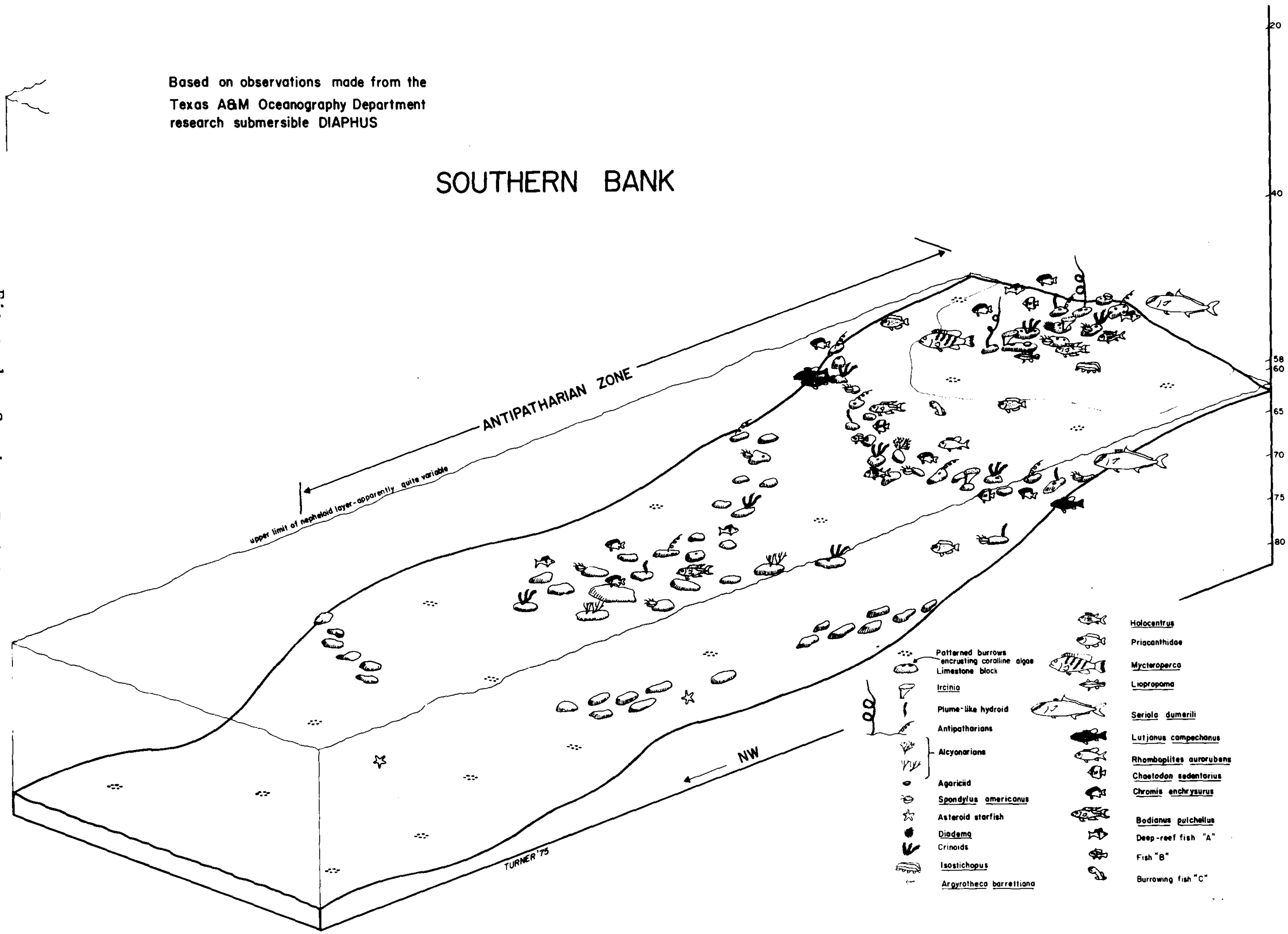


Figure 1. Southern Bank block diagram.

greatest number of fishes congregate.

Virtually all of the banks examined are inhabited by the same fishes and epibenthic communities and bear a hard-bank biota typical of what we are calling the Antipatharian Zone (Fig. 1) because of the conspicuousness and abundance of the large, white, spiraled sea whip-like coelenterates of the Order Antipatharia. In all cases this zone is the only one recognizable on the South Texas banks from their crests to their bases. There appear to be, however, variations in population levels of the organisms with depth on each bank, decreasing downward, and from bank to bank. The Antipatharian Zone is, interestingly, also present on the lowermost portions of the East and West Flower Garden Banks below about 75 meters, which is considerably deeper than the crests of the South Texas banks, about 58-60 meters in most cases. The most conspicuous and predominant organisms inhabiting the Antipatharian Zone are listed in Table 1 of Chapter III in the columns including depths greater than 76 meters. As will be pointed out, we feel that the vertical and lateral variations in distribution of organisms of the Antipatharian Zone along the Texas coast are at least in part related to water turbidity, sedimentation, and the nepheloid layers (Fig. 1) of the region.

Insofar as we have been informed that exploratory drilling will occur first adjacent to Southern Bank (Fig. 2, Table 1), it seems appropriate that its biota be described in some detail as representative of all of the banks. The remaining banks (Fig. 3-7, Tables 2-6) will be discussed to the extent by which they differ from or are similar to Southern Bank.

SOUTHERN BANK

The most conspicuous epifaunal organism on Southern Bank (Fig. 1) is the large white bedspring-shaped antipatharian sea whip which we think is *Cirripathes* sp. (Fig. 8, 9, 10). Because the same is true on all of the South Texas banks studied, we have used "Antipatharian" to designate the only hard-bank biotic zone definable on them. An almost equally conspicuous macrobenthic organism is the white, somewhat vase-like sponge *Ircinia campana* (Fig. 10), which, interestingly, is not particularly noticeable within the Antipatharian Zone, or any other zone, at the East and West Flower Gardens. Comatulid crinoids (Fig. 12) are abundant and easily seen everywhere on the upper portion of the bank.

Fish Observations

Symbol	
2	*Holacanthus bermudensis*
4	*Chaetodon sedentarius*
8	*Chromis enchrysurus*
11	*Bodianus pulchellus*
16	*Sphyraena barracuda*
18	*Gobiosoma* sp.
21	*Holocentrus* sp.
22	*Liopropoma* sp.
23	*Paranthias furcifer*
24	*Priacanthus arenatus*
25	*Malacanthus plumieri*
27	*Seriola dumerili*
28	Labridae
29	*Haemulon melanurum*
30	*Equetus acuminatus*
31	*Equetus lanceolatus*
32	*Balistes vetula*
33	Balistidae
35	*Calamus* sp.
38	*Canthigaster rostrata*
41	Deep-reef fish "A"
42	Fish "B"
43	Burrowing fish "C"
44	Holocentridae
45	*Equetus* sp.
46	*Apogon* sp.
47	*Rhomboplites aurorubens*
48	*Plectrypops retrospinis*
49	Carcharhinidae
50	Rajiformes
●	*Lutjanus campechanus*
◑	*Mycteroperca* sp.

Observations Other Than Fish

Symbol	
B	Patterned burrows
C	Encrusting coralline algae
E	*Ircinia campana*
G	*Neofibularia* sp.
H	*Argyrotheca barrettiana*
I	*Spondylus americanus*
J	Bryozoans
M	Hermit crab
N	*Stenorynchus* sp.
O	*Diadema* sp.
Q	Asteroidea
R	*Narcissia trigonaria*
S	Basket stars
T	*Isostichopus* sp.
U	Comatulid crinoids
a	Plume-like hydroid
j	Antipatharia
m	Large antipatharia
n	*Hypnogorgia* sp.
q	Brown-orange sea fan

Figure 2a. Legend for Figures 2-7

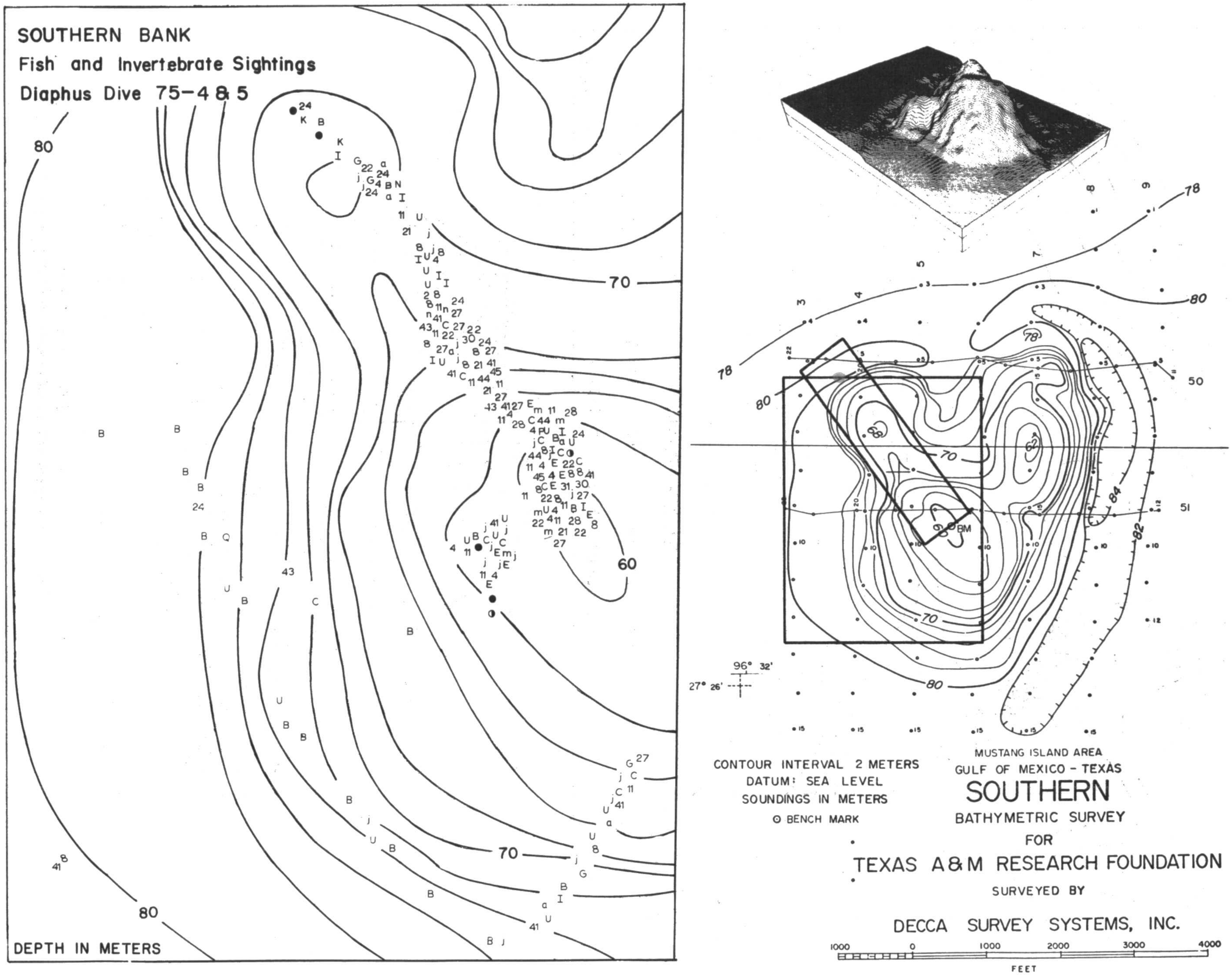


Figure 2b. Southern Bank.

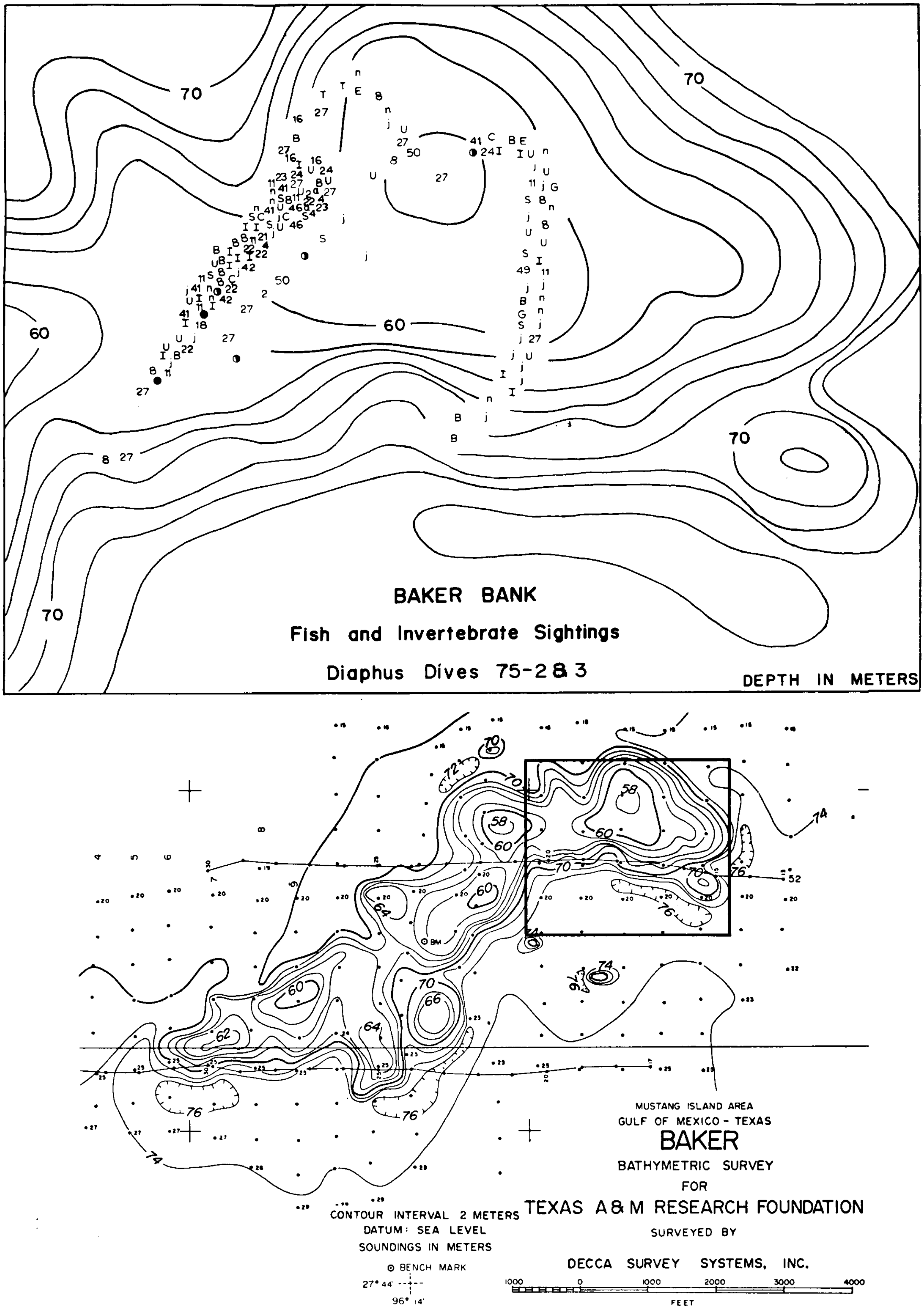


Figure 3. Baker Bank.

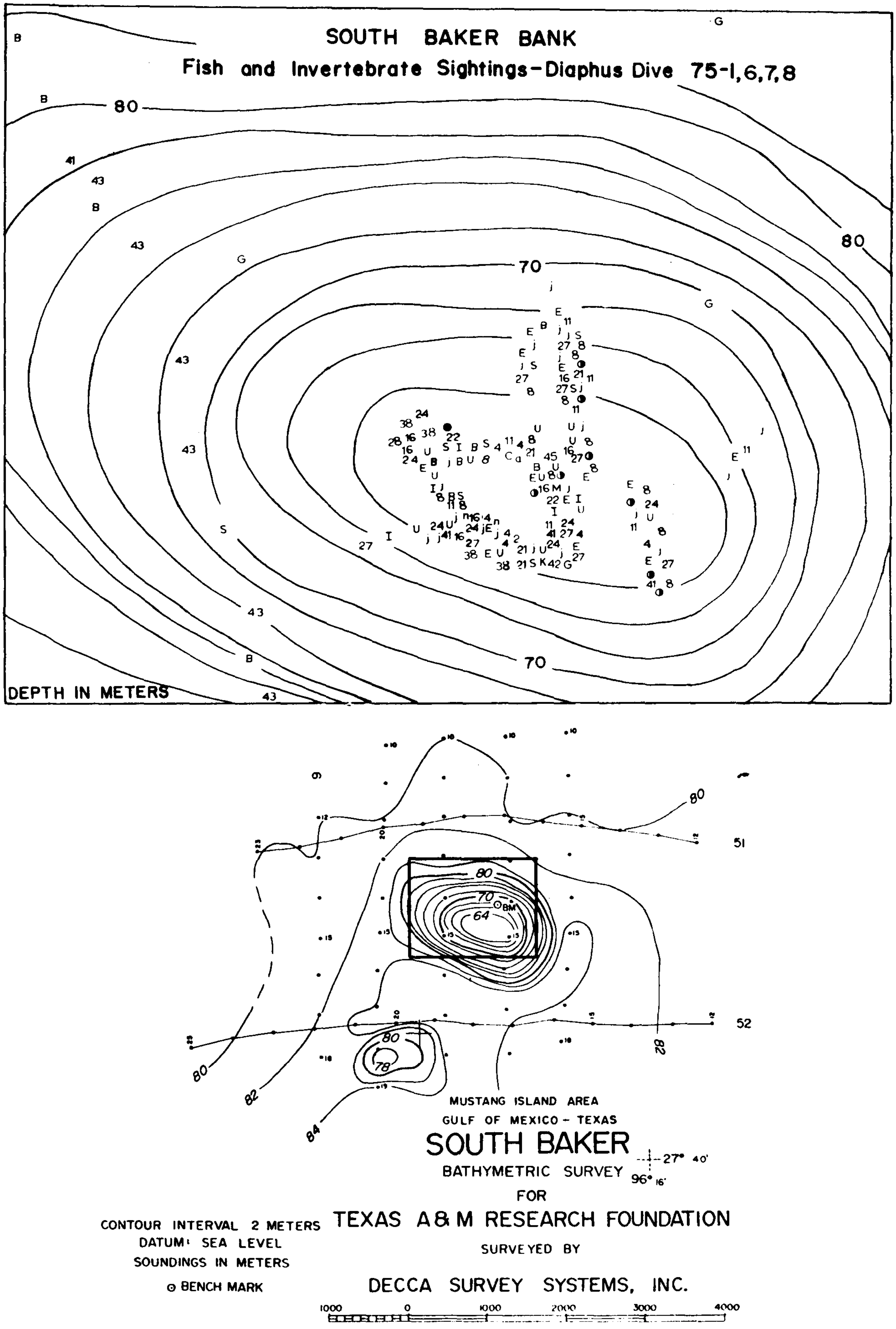
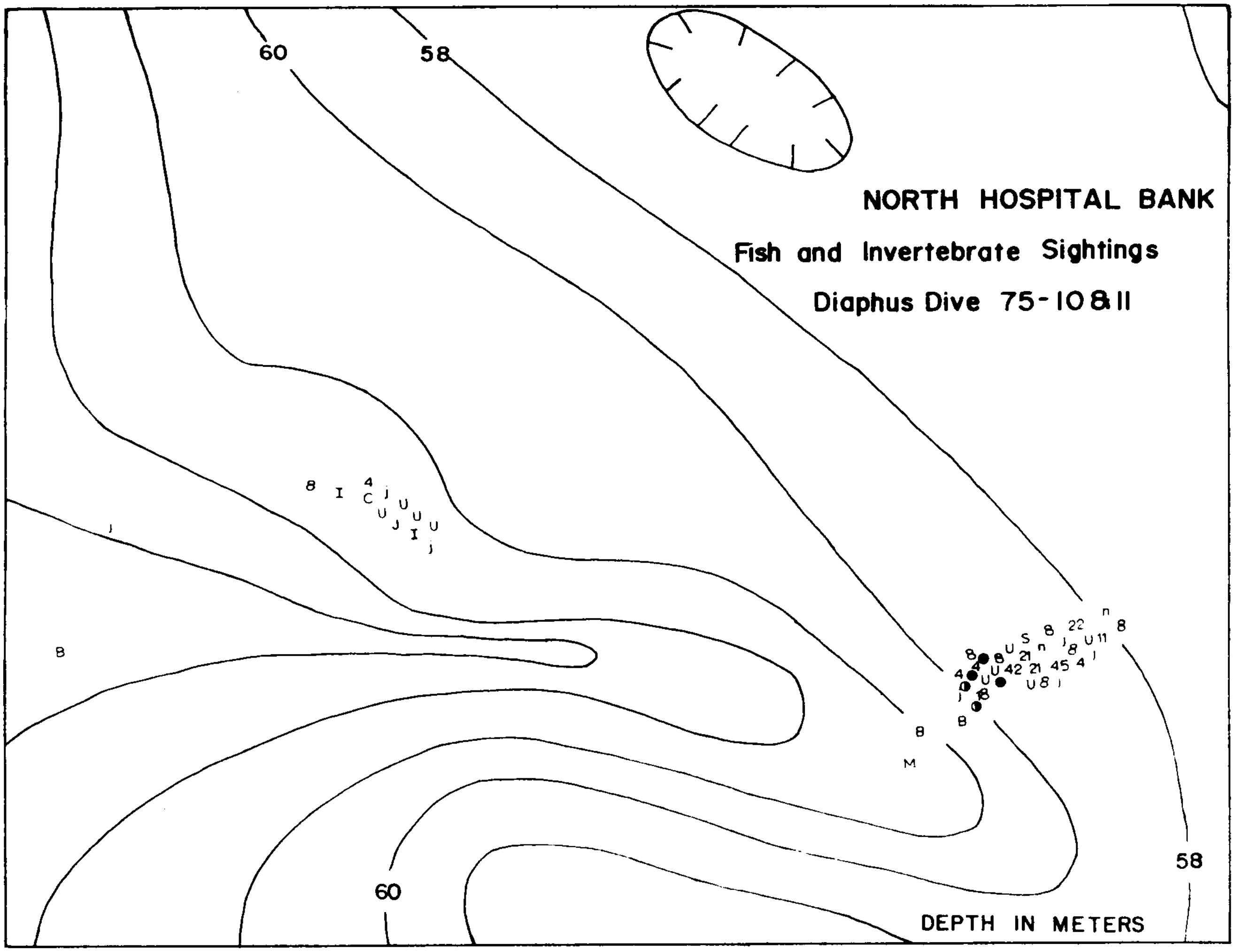


Figure 4. South Baker Bank.



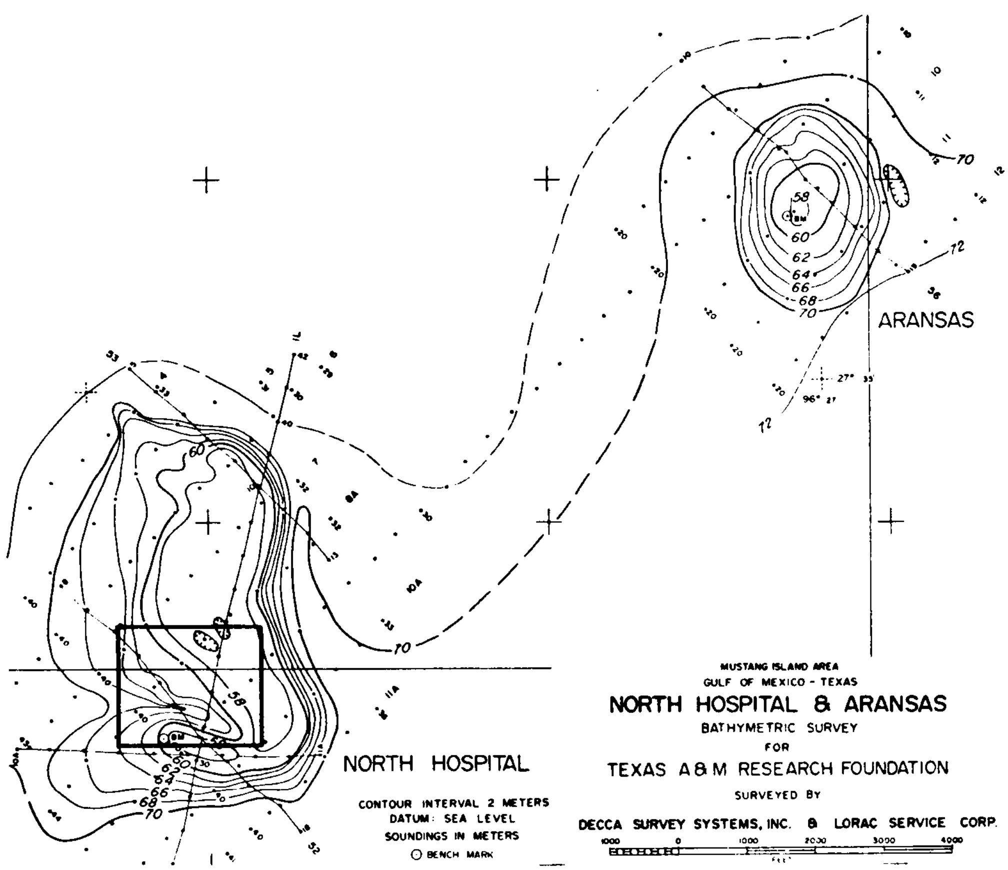


Figure 5. North Hospital Bank.

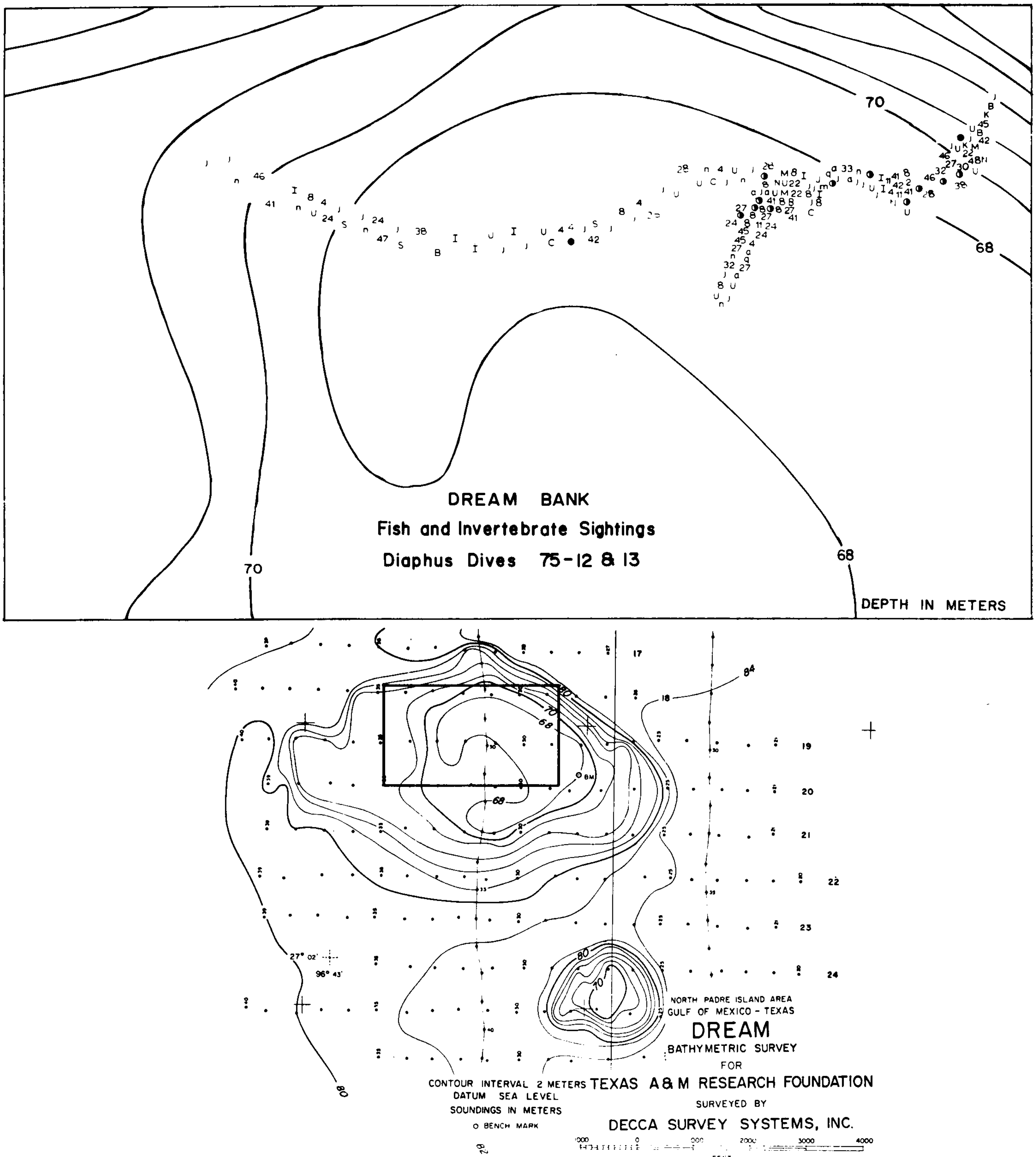


Figure 6. Dream Bank.

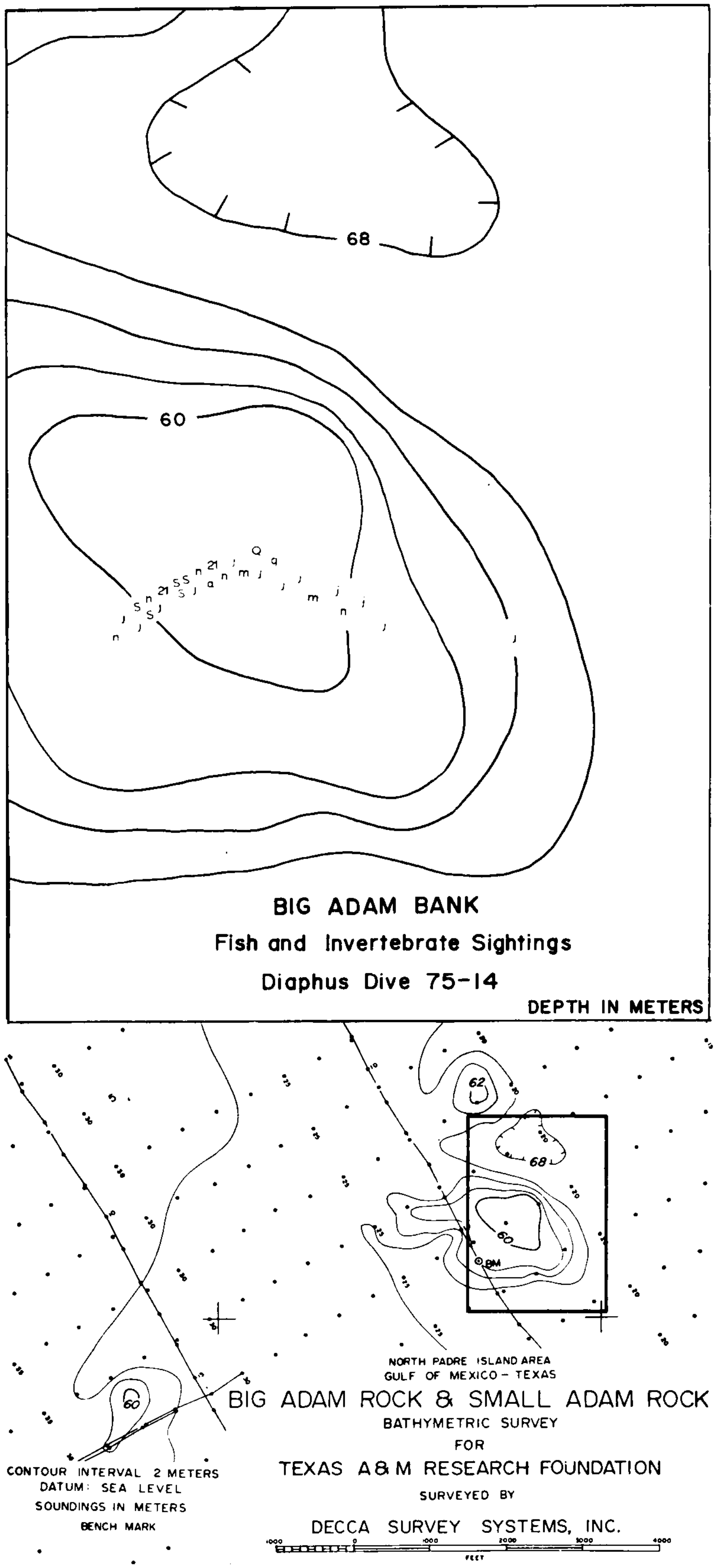


Figure 7. Big Adam Bank.

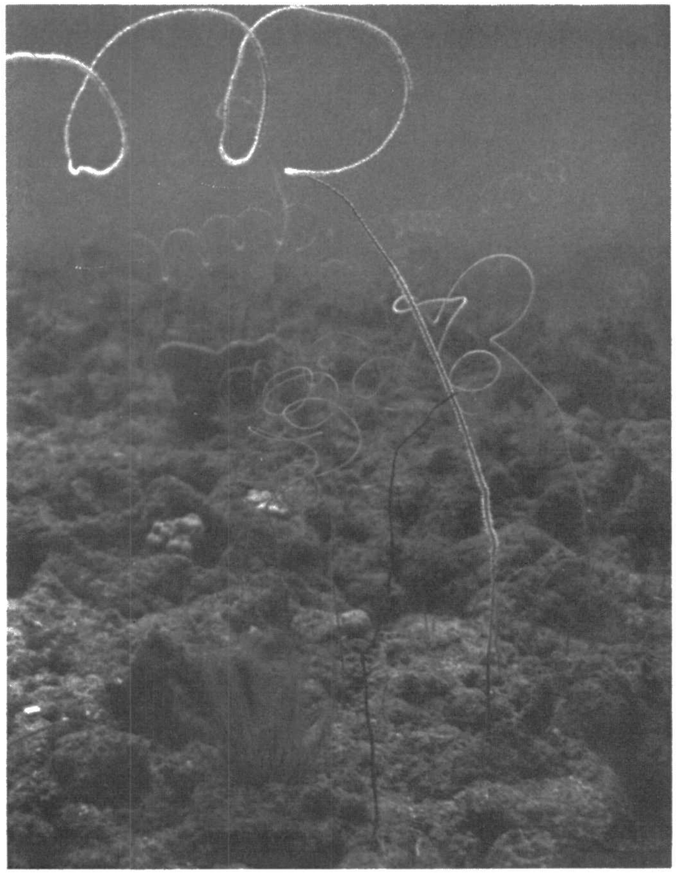


Figure 8. Epifauna on rocks at crest of Southern Bank, bedspring-shaped antipatharians, crinoids in foreground, Ircinia near center (58 meters).

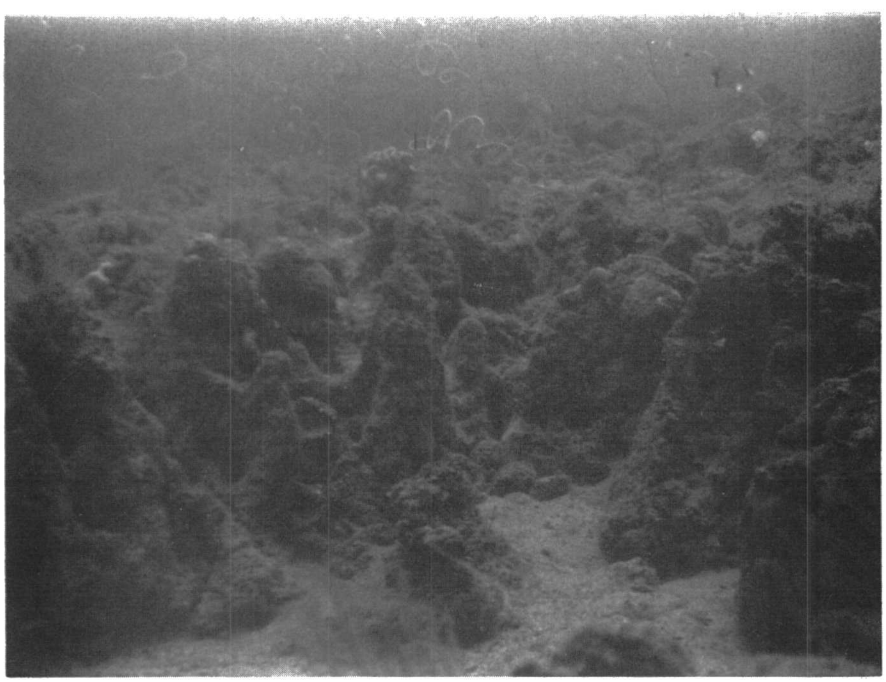


Figure 9. Pinnacle-like structures about 3/4 meter high at 58 meters depth on Southern Bank.

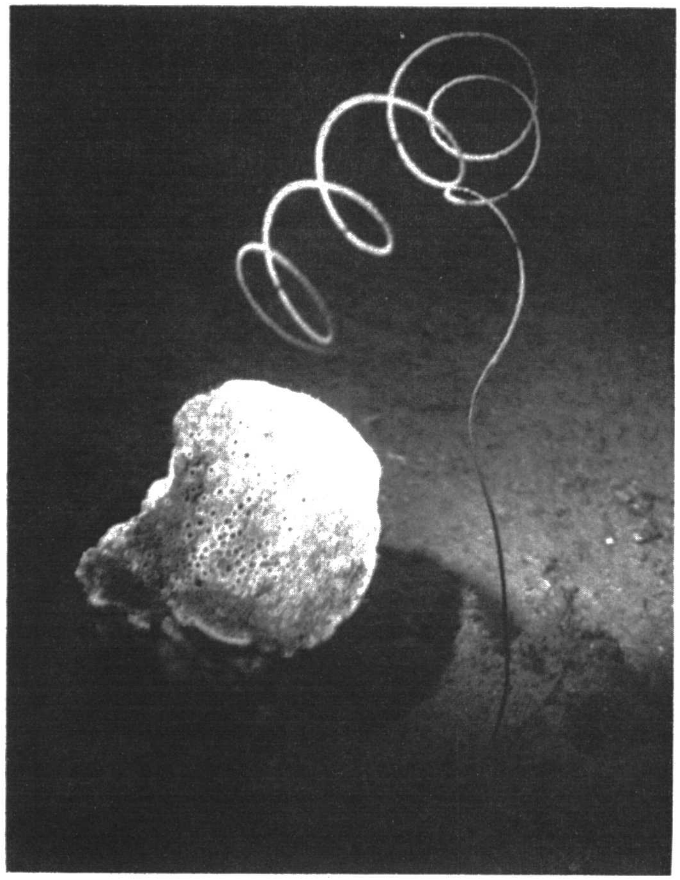


Figure 10. Ircinia and antipatharian at Southern Bank (64 meters).

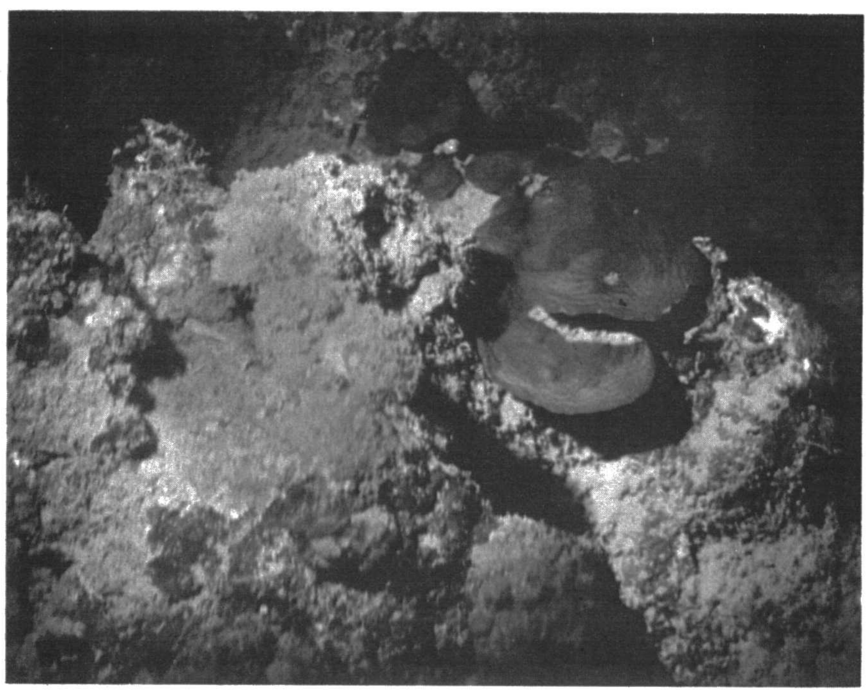


Figure 11. Saucer-shaped agariciid coral and some coralline algae attached to rock at Southern Bank (61 meters).

A large white sea fan Hypnogorgia (Table 1), though apparently less abundant than the organisms mentioned above, was frequently seen because of its size. Other deep-water alcyonarians occur on Southern and other South Texas banks (Tables 1-6) and on drowned reefs of the deepest parts of the West Flower Garden Bank, and also presumably the East Flower Garden (see Table 1 of SUMMARY of entire report). Surprisingly, there are virtually no populations of shallow-water alcyonarians on the coral reefs at the Flower Gardens. Alcyonarian fans in particular seem to be restricted to the Antipatharian Zone and deeper in the Northwestern Gulf of Mexico.

The only noticeable stony coral present on Southern Bank was a saucer-shaped agariciid (Fig. 11) observed by us only near the top of the bank in relatively clear water (visibility 10 meters or so at 60-64 meters depth, decreasing to nil at 70 meters depth). These small coral patches were not particularly abundant, but we did encounter them several times during our dives (Table 1). Two other corals were collected (Table 1)--the small, branching Madracis brueggemanni and a number of specimens of a solitary species we have designated "A," but these were not noticed from the submarine. We speculate that there may be a moderate population of the solitary corals, but they are individually quite small. There is an encrusting coralline algae population on Southern; Lithophyllum has been identified, but it is sparse, occurring more extensively at the very crest of the bank where it not only forms isolated patches on the carbonate blocks but also encrusts the tops of pieces of rubble on the sediment-covered bottom between the blocks (Fig. 14). At best, the carbonate substratum-producing capacity of these limited populations of corals and coralline algae is feeble and possibly rivaled by that of Spondylus americanus, the American thorny oyster (Fig. 13), which we found to be, surprisingly, as abundant as populations of the same species at similar depths on the East and West Flower Gardens.

Spondylus americanus appears to thrive not only in the clearer waters at the crests of the banks but also within the nepheloid layer farther down. It was observed in apparent good health attached to sediment-covered hard bottoms, itself bearing a significant veneer of fine sediment. The sizeable populations of these large, filter feeding pelecypods on the South Texas banks, and at the Flower Gardens and banks farther east, lead us to

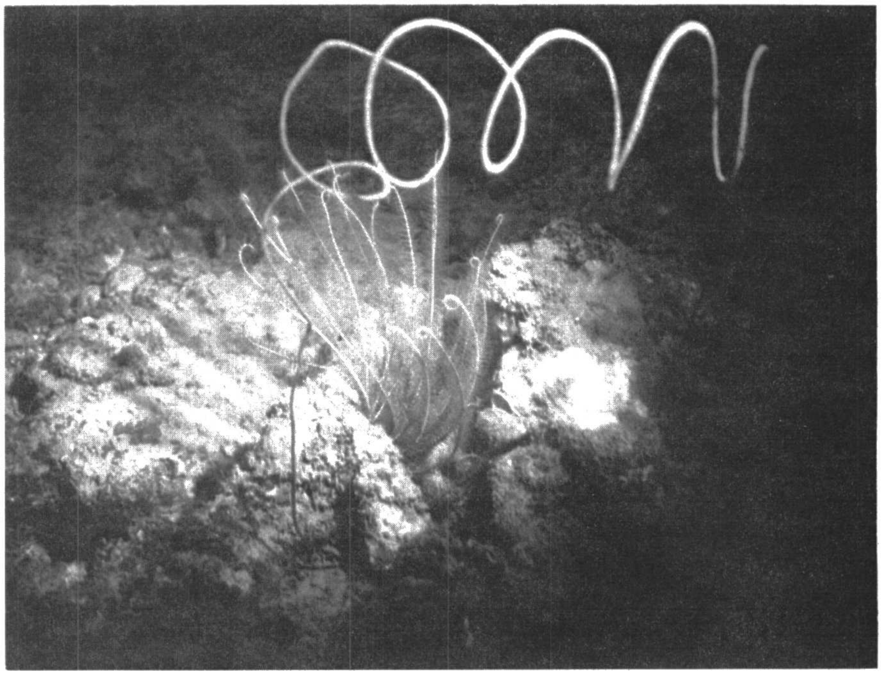


Figure 12. Antipatharian and crinoid at Southern Bank (61 meters).

Figure 13. Rock covered with sediment at 64 meters on Southern Bank. Spondylus americanus in lower right, crinoids and antipatharians visible.

Figure 14. Sediment bottom between carbonate blocks (rocks) at 61 meters on Southern Bank. The larger pieces of coarse rubble are partly encrusted with coralline algae.

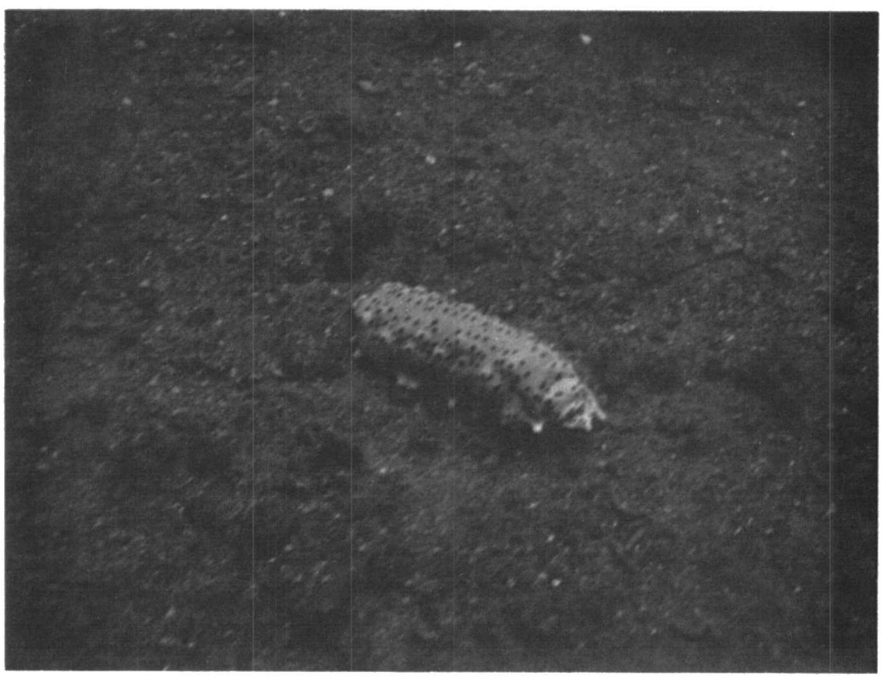


Figure 15. Isostichopus on sediment bottom between carbonate blocks at Southern Bank (58 meters).

suggest that the species might be considered useful as an "indicator" species for such things as petroleum hydrocarbon and heavy metal uptake. It may also serve as a likely subject for certain comparative physiological studies relating to effects of supposed "contaminants" on neritic marine organisms (those inhabiting the continental shelf), particularly since such studies have been carried out on similar organisms, *Crassostrea* and *Rangia*, from estuarine environments.

Another very small species of calcium carbonate secreting organism, the brachiopod *Argyrotheca barrettiana*, is present cemented to the rocks, but due to its size is certainly not a major substratum builder.

Leafy algae, though present at least at the very crest of Southern Bank (Table 1), are exceedingly inconspicuous. We did not detect them from the submarine and became aware of their limited presence only after collecting a piece of rock which happened to bear a small amount of very short filamentous green algae and juvenile blades of a brown algae. We did not find leafy algae on any of the other South Texas banks but presume that very small populations do exist on most.

Among the larger mobile benthic invertebrates we were able to recognize from the submarine were the Arrow crab, *Stenorynchus seticornis*; a hermit crab in a whelk (*Busycon*) shell; the urchin *Diadema*; the sea cucumber *Isostichopus* (Fig. 15); and fireworms, *Hermodice* sp. (Fig. 16) which we feel are fairly abundant on the banks. Other varieties of attached and mobile invertebrates collected or observed are listed in Table 1, along with the numbers of specimens or sightings, which will give a rough indication of relative abundances.

Burrows in the sediment on all parts of the bank and adjacent to it are obviously of biological origin, though the nature of the organisms responsible is unknown. The distinctive clusters of holes which we have called "patterned burrows" (Fig. 1) have a form which may indicate involvement of a mobile species, but we have no observations which would confirm it.

The groundfish populations at Southern Bank, and all the South Texas banks, are strikingly similar in composition and apparent magnitude per unit area

Figure 16. Fireworm on fine sediment at 67 meters on Southern Bank.

Figure 17. Deep-reef fish species "A" (64 meters at Southern Bank).

Figure 18. School of Chromis enchrysurus with a few deep-reef fish species "A" at 61 meters on Southern Bank.

Figure 19.
Bodianus pulchellus
(64 meters,
Southern Bank).

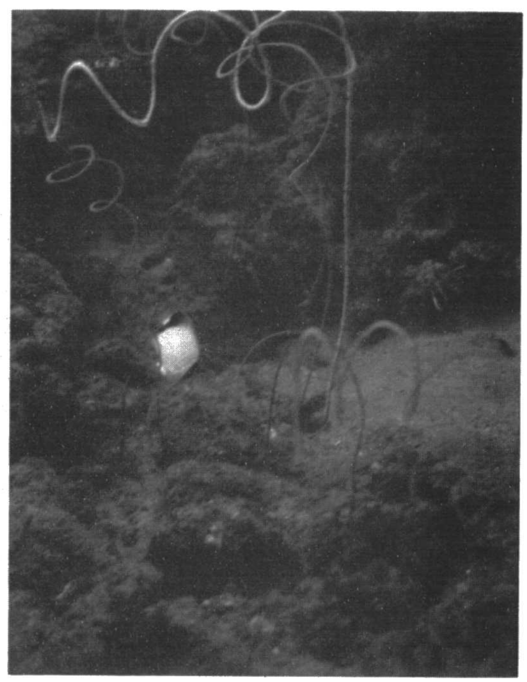


Figure 20.
Chaetodon sedentarius
(61 meters,
Southern Bank),
Spondylus in
right center.

to those frequenting the Antipatharian Zones at the East and West Flower Gardens. The most characteristic conspicuous resident species are Chromis enchrysurus, deep-reef fish species "A," Bodianus pulchellus, Chaetodon sedentarius, Liopropoma sp., Priacanthidae, fish "B," the burrowing fish "C," and Holacanthus bermudensis, in apparent order of abundance (Fig. 17-20, 26, 29, 30, 33; Table 1).

Chromis enchrysurus, the Yellowtail reeffish, is particularly abundant, occurring in schools of up to a hundred or more (Fig. 18), but also in small groups and singly. Deep-reef fish species "A" is perhaps most characteristic of the Antipatharian Zone because it has not been observed in any of the shallower hard-bank zones found on topographical highs farther north and seems to be strictly a deep-bank variety. All of the other fishes mentioned above, except possibly fish "B," are also fairly abundant on the coral reefs and in the Algal-Sponge Zones at the Flower Gardens. Fish "B," which may be the young of some species of Pomadasyidae (grunts), has not been encountered by us on the northern group of Texas Outer Continental Shelf banks, but it seems to be moderately abundant on the South Texas banks. The population of large groupers of the genus Mycteroperca (Fig. 33) was surprisingly small on Southern and the other banks, and species of Epinephelus appear to be lacking or very scarce.

Most of these fishes prefer to congregate around the clustered carbonate blocks (Fig. 1). The bigeyes, however, seem also to favor locations on the flatter portions of the bank, particularly over small potholes in the bottom into which they can retreat (Fig. 29). The burrowing fish "C" likewise favors the leveller sediment-covered bottom where it apparently digs a hole which it occupies when not hanging suspended in the water directly above.

Larger migratory fishes which cannot be considered residents of any particular bank occur at Southern and the others, and include the most important game and commercial fishes: schools of Red snapper and Vermilion snapper, Lutjanus campechanus and Rhomboplites aurorubens; the Greater amberjack, Seriola dumerili; the Great barracuda, Sphyraena barracuda; and small (one-meter) carcharhinid sharks. The Cobia, Rachycentron canadum, was caught on other South Texas banks and is presumed to also visit

Southern Bank. The migratory game fishes are responsible, more than any of the truly resident varieties, for the importance of these banks in the commercial snapper fishery and head-boat industry. The low populations of large groupers on these relatively small banks may indeed reflect some degree of overfishing, which seemingly would have a greater impact on the more-or-less sedentary, resident, or semi-resident species than on those fishes which travel frequently from bank to bank.

BAKER BANK

Baker Bank (Fig. 3, 21-26) bears essentially the same epibenthic biota as does Southern (compare Tables 1 and 2). The most conspicuous epifaunal organisms are antipatharians (Fig. 25), sponges such as Ircinia campana and Spongia barbara (Fig. 22), large hydroids (Fig. 22), alcyonarian fans including Hypnogorgia sp. (Fig. 23), a sizeable population of Spondylus americanus (Fig. 24), comatulid crinoids (Fig. 21, 22), and gorgonocephalan basket stars (Fig. 25). Encrusting coralline algae are sparsely represented and patterned burrows occur over the entire bank.

The resident groundfish population is dominated by Chromis enchrysurus, Chaetodon sedentarius, Bodianus pulchellus, Priacanthidae, Liopropoma sp. (Fig. 26), and Mycteroperca spp. The migratory fish population is basically the same as that observed at Southern with the schooling Red and Vermilion snappers, the Greater amberjack, and Great barracuda. The Cottonwick, Haemulon melanurum, was caught frequently on hook-and-line at Baker and is presumed to frequent all of the South Texas Banks in schools on a migratory basis.

The considerable population of basket stars seen at Baker may represent a slight variation in community structure from bank to bank within the Antipatharian Zone, insofar as the only other banks on which basket stars were detected were South Baker and Big Adam (Tables 1-6). The typical daytime posture of the basket stars seen by us was that pictured in Figure 25, contracted into a ball clinging to an antipatharian or, less frequently, some other elevated structure.

Figure 21. Carbonate block (rock) at 61 meters on Baker Bank, extensive fine sediment cover with crinoids and some coralline algae.

Figure 22. Spongia barbara, yellow in color with antipatharian, crinoids and hydroids (63 meters on Baker Bank).

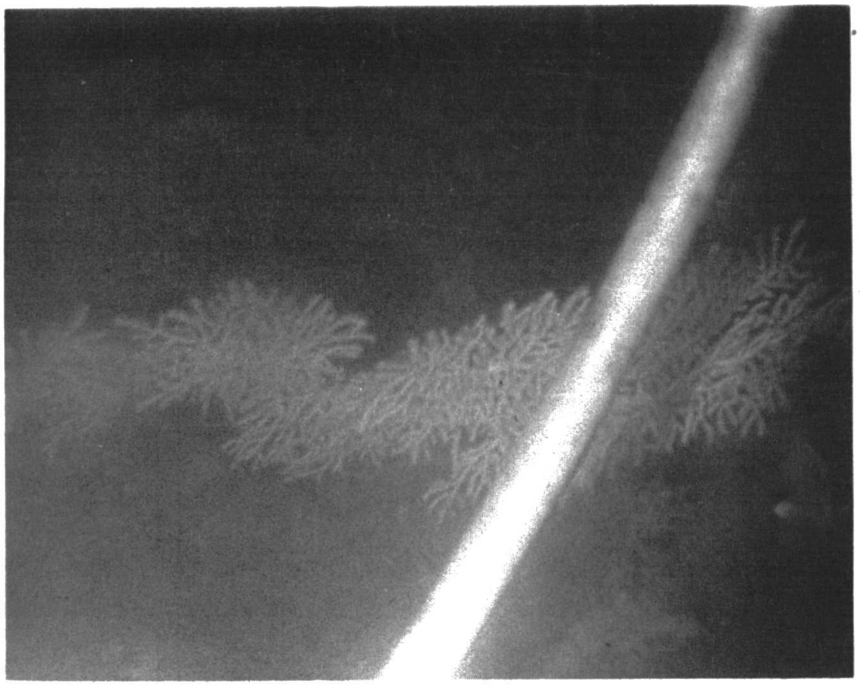


Figure 23. Large white sea fan, probably Hypnogorgia, at 63 meters on Baker Bank.

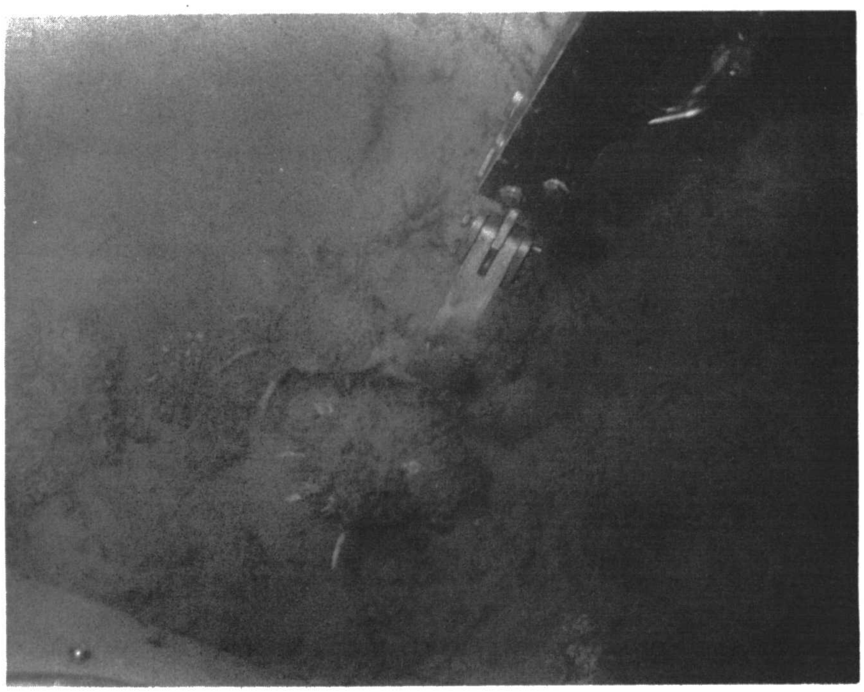


Figure 24. Two Spondylus americanus heavily covered with fine sediment at 63 meters on Baker Bank.

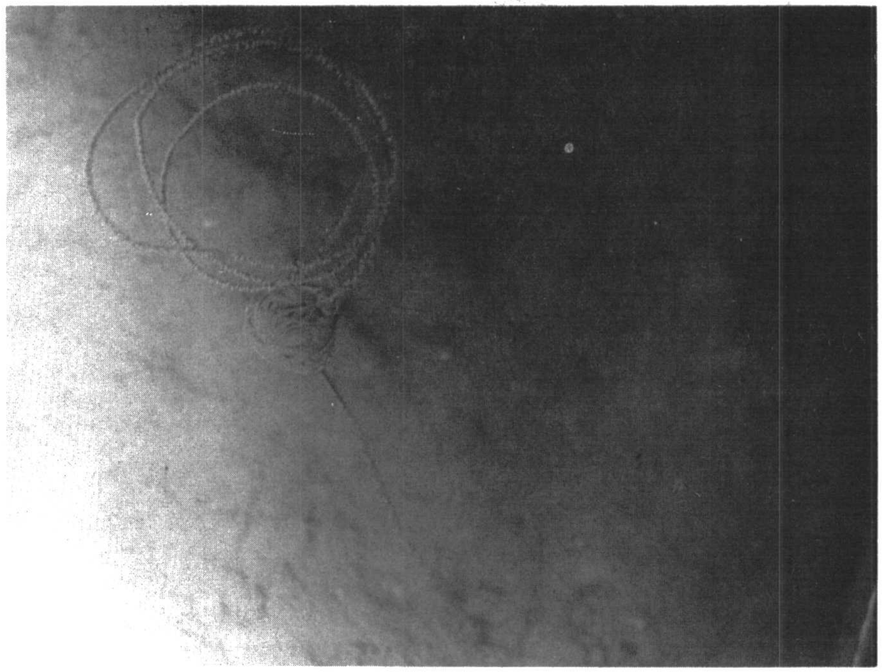


Figure 25. Basket star balled up and clinging to an antipatharian at 63 meters on Baker Bank.

Figure 26. Liopropoma at 63 meters on Baker Bank.

SOUTH BAKER BANK

South Baker Bank (Fig. 4, 27-35) is biotically similar to Southern Bank (Table 3) with a predominance, among the large epifauna, of antipatharians (Fig. 27, 31, 33); sponges, including Ircinia campana (Fig. 31, 33) and Spongia barbara (Fig. 28); alcyonarian fans (Fig. 32); Spondylus americanus; comatulid crinoids (Fig. 27, 28); and, as at nearby Baker Bank, a sizeable population of gorgonocephalan basket stars. Encrusting coralline algae are present.

A very interesting sighting of a spanish lobster, Scyllarides sp., was made at South Baker. This species has been found by us on the shallow coral reef at the West Flower Garden, and we speculate that its range includes most banks of the Texas Outer Continental Shelf. In view of the scarcity of the commercial spiny lobster, Panulirus, on the banks off Texas, repeated sightings of a large edible species such as Scyllarides, which may have some economic potential, are significant.

Patterned burrows occur over the entire bank and in the very soft sediment adjacent to it (Fig. 34, 35).

The resident and migratory fish populations are the same as those at Southern and the other banks, as can be determined from Table 3 and Figures 29, 30, 31, and 33. Figure 33 is interesting in that the reflection from the eye of the bigeye is directed in such a way as to give a visual impression of the sediment suspended in the water column.

On the soft sediment adjacent to the bank (80 meters depth), even though visibility was nil, we observed a large population of small slender bottom fish, possibly 8-10 cm long, scurrying away as the submarine approached. Frequently these fish would dive into the many burrows in the soft bottom. Several times on this same bottom we sighted medium-sized flatfishes, Order Pleuronectiformes, 30 or so cm in length which, likewise, scurried away quickly in the murky water in front of the submarine.

Figure 27. Epifauna on rock at 64 meters on South Baker Bank, antipatharians and crinoids.

Figure 28. Spongia barbara and crinoids at 65 meters on South Baker Bank.

Figure 29.
Bigeye (64 meters,
South Baker Bank).

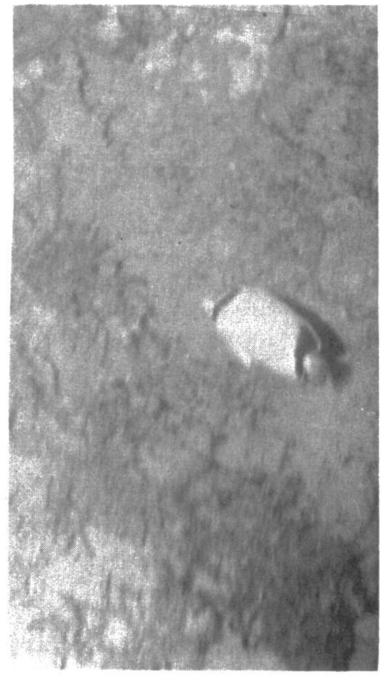


Figure 30.
Chaetodon sedentarius
(64 meters, South
Baker Bank).

Figure 31. Antipatharians, Ircinia, Bodianus pulchellus at 68 meters on South Baker Bank.

Figure 32. Hypnogorgia (73 meters, South Baker Bank).

Figure 33. Mycteroperca, bigeye, antipatharians, Ircinia and Hypnogorgia at 73 meters on South Baker Bank.

Figure 34. Soft sediment adjacent to South Baker Bank at 80 meters, plowed up by front of submarine.

Figure 35. Patterned burrow cluster in soft sediment adjacent to South Baker Bank (80 meters).

NORTH HOSPITAL BANK AND HOSPITAL ROCK

These banks were not specified as primary study sites by BLM because they are not in or near lease blocks offered for sale in 1975. We visited them, however, to round out our reconnaissance effort under the provision of the contract which allowed us to do so if time were available.

Our biological observations are less complete on these two banks than on the others; Hospital Rock was examined only with the towed underwater television. It is obvious, however, that the epibenthic and fish communities on both of these banks are essentially the same as those occupying the banks already discussed (Fig. 5, 36, Table 4).

DREAM BANK

It is apparent, from a comparison of the depths listed in Table 5 with the bathymetric map of Dream Bank in Figure 6, that the submarine encountered depths on the bank shallower than any represented on the map. Although the source of this seeming discrepancy is not clear to us, it is obvious that the biotic communities of Dream Bank are similar in content and abundance to those occupying the banks farther north, which crest at a somewhat shallower depth (Fig. 6, 37-43, Table 5).

Notably, however, it did appear that the alcyonarian fan population, particularly *Scleracis* sp. (Fig. 43), was greater on Dream Bank than on the others. Also, it is worth noting that where the fans grew side by side, they were most often all oriented in the same plane (Fig. 43), in precisely the fashion such fans orient perpendicularly to the prevailing directions of local currents or wave travel in shallower waters. Indeed, there was a striking resemblance between the general appearance of certain very flat and level, hard carbonate bottom areas on Dream Bank and hard carbonate sublittoral platforms studied by us seaward of living bank barrier reefs in Florida and the Caribbean. In both cases alcyonarians, by no means the same species, are abundantly affixed to the hard bottom (which is overlain everywhere by a very thin veneer of sediment) and aligned as described above. The resemblance is, of course, superficial insofar as the sediments are

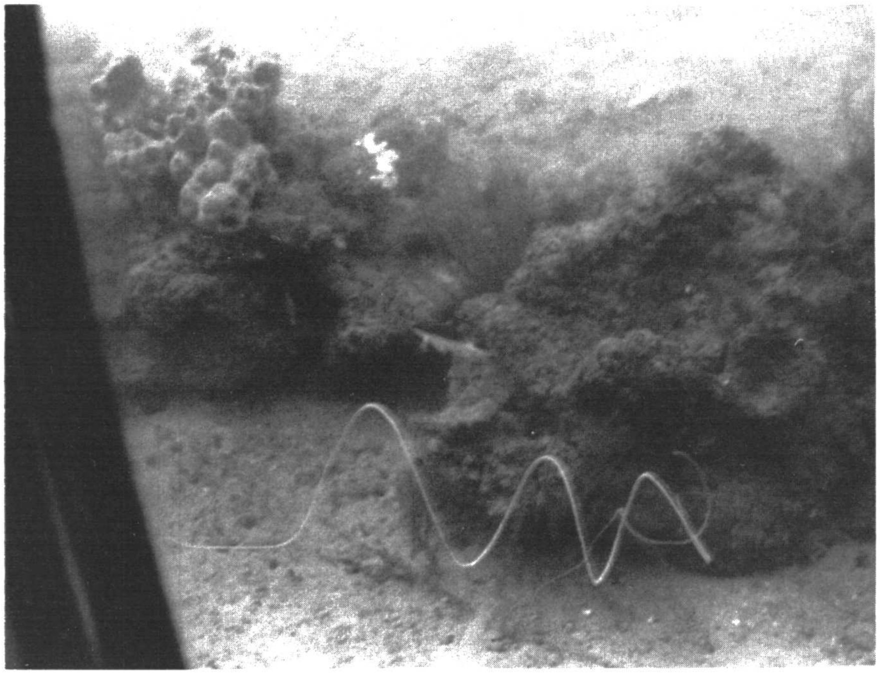


Figure 36. Epifauna (including antipatharians, crinoids and ?Spongia) and Chromis enchrysurus at 59 meters on North Hospital Bank.

Figure 37. Alcyonarian "fans," antipatharians and other epifauna at 67 meters on Dream Bank.

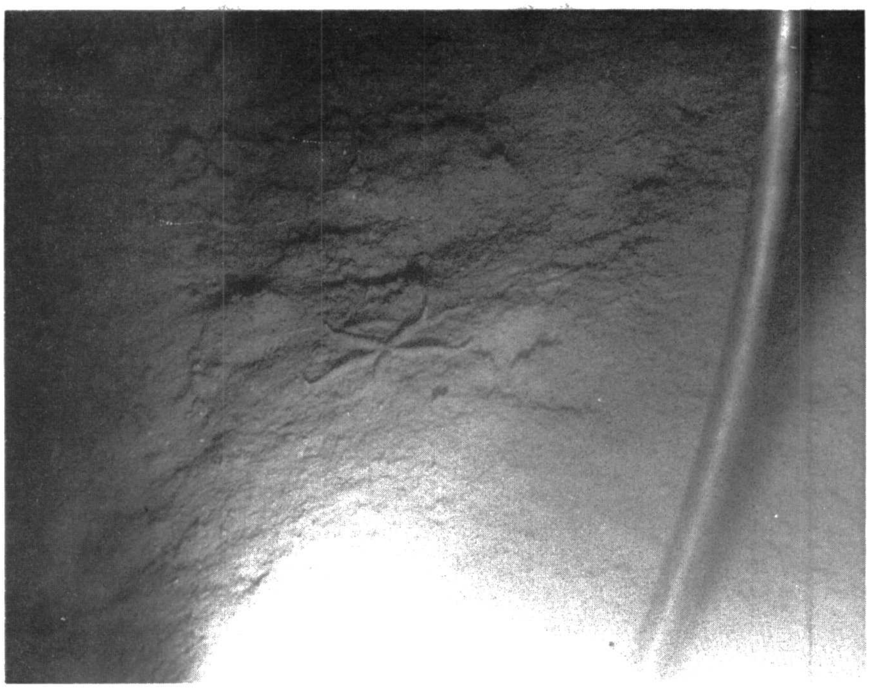


Figure 38. Starfish on fine sediment covered bottom at 66 meters on Dream Bank.

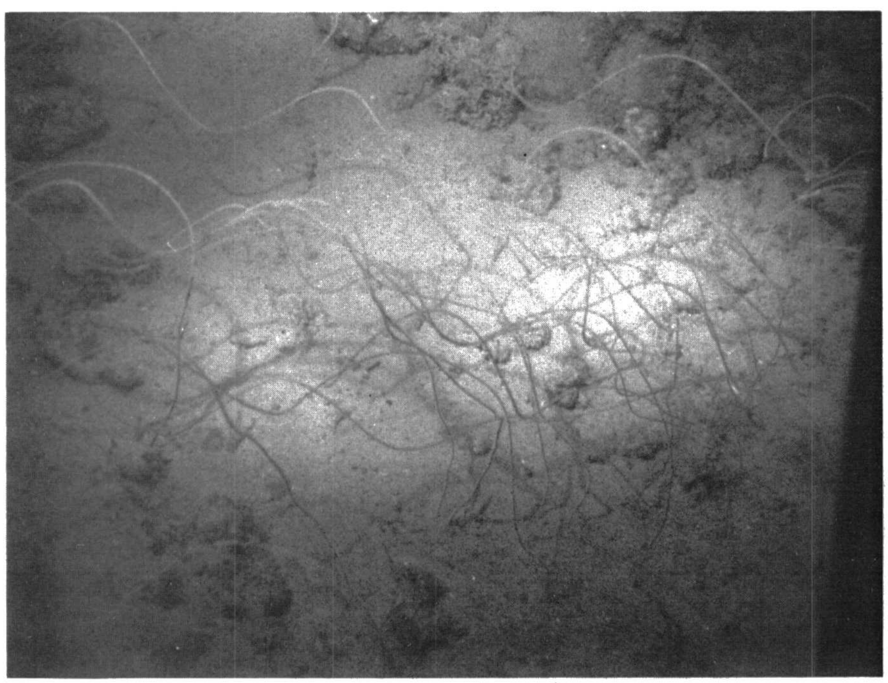


Figure 39. Antipatharians at 67 meters on Dream Bank.

Figure 40. Ircinia species "a" and crinoids at 70 meters on Dream Bank.

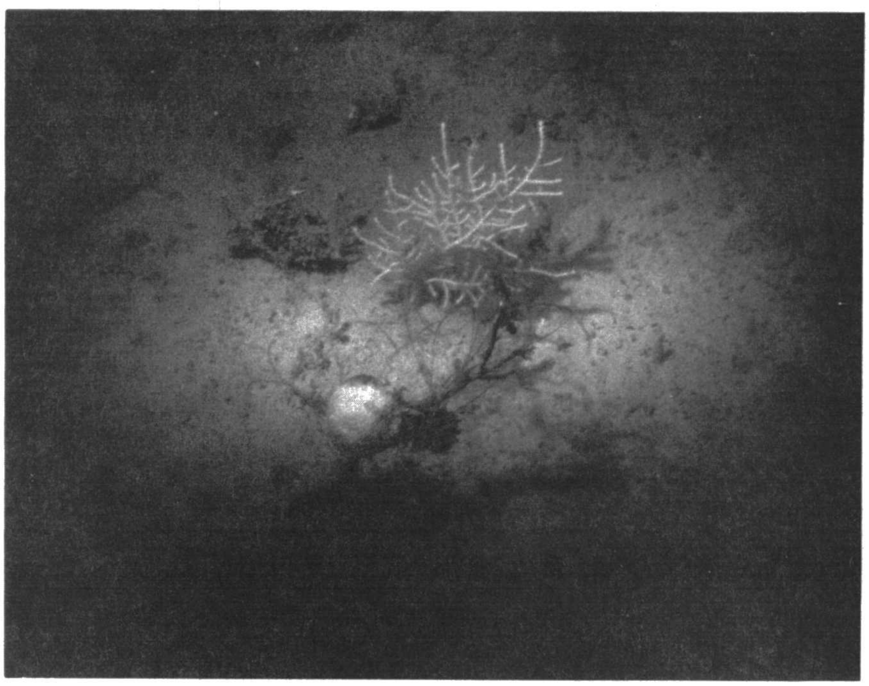


Figure 41. Sea fan (probably Hypnogorgia), ball-shaped sponge and hydroids at 70 meters on Dream Bank.

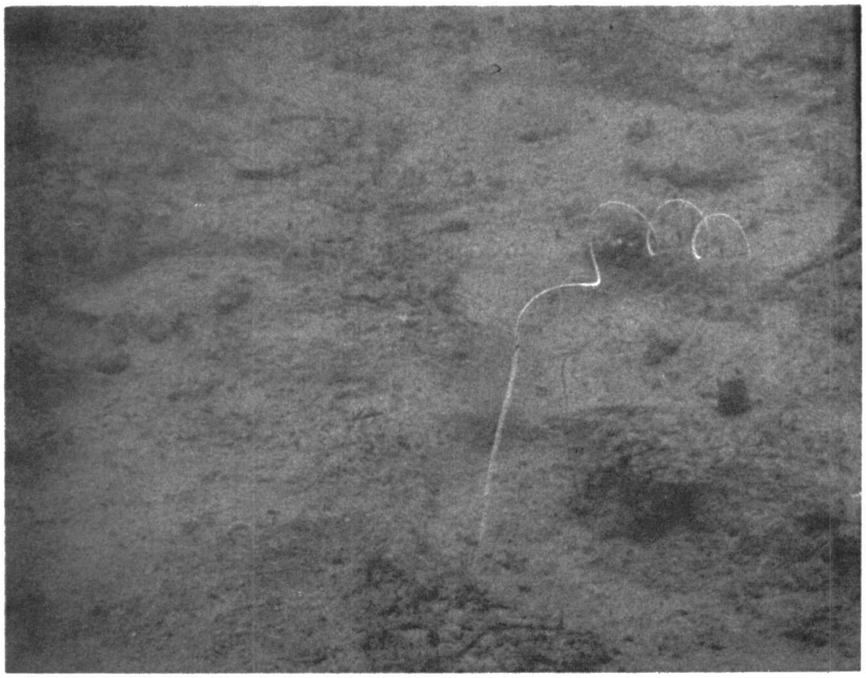


Figure 42. Antipatharian at 72 meters on Dream Bank.

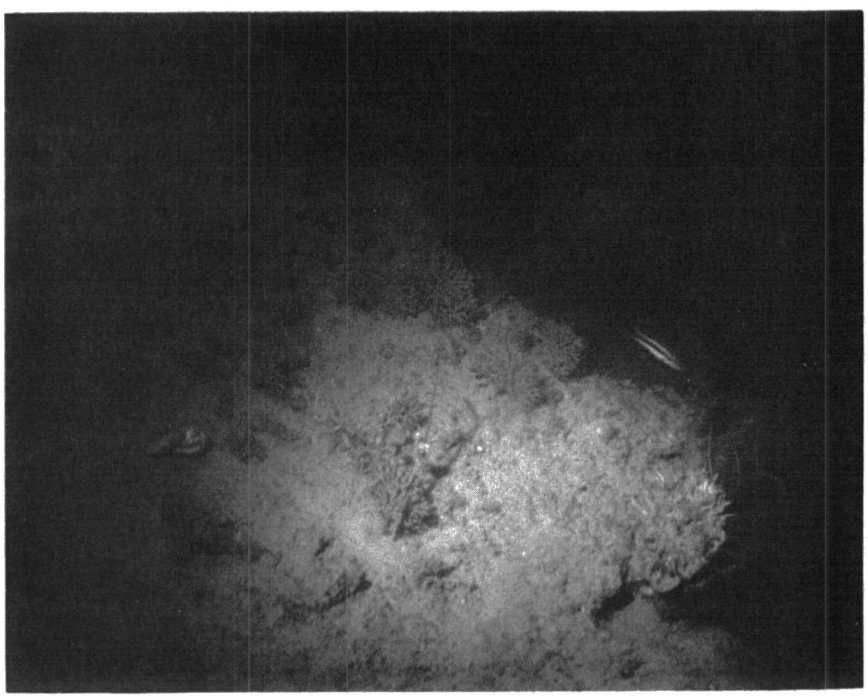


Figure 43. Sea fans (probably Scleracis), crinoids living inside dead Spondylus shell, dead cone shell and Liopropoma at 72 meters on Dream Bank.

vastly different (fine silt at Dream and coarse carbonate in the other localities), and the alcyonarians are deep-water species at Dream, as opposed to shallow-water. The fact that such orientation of sea fans occurs at depths exceeding 65 meters on Dream Bank, however, indicates that there is a prevailing directionality of movement imparted, almost certainly by waves, to the water even at those depths.

That this is probable is indicated by the fact that on several occasions while sitting on the bottom in the submarine at comparable depths on the South Texas banks, we experienced definite wave surge which moved us back and forth ½ meter or so.

BIG ADAM BANK

Big Adam Bank (Fig. 7, Table 6) differs from the banks discussed above in a way which possibly has had a significant influence on the diversity and abundance of epibenthic communities there. Figure 7, when compared with Figures 2-6, shows that Big Adam has very little relief (about 8 meters) above the surrounding soft bottom compared to that of the other banks, usually about 20 meters. As a result, Big Adam, we think, is nearly always covered by the highly turbid nepheloid layer (Fig. 1), and sedimentation on its upper portion is probably much greater than at the tops of the other banks. This situation may well account for the apparently low diversity and abundance of epifauna and groundfishes at Big Adam (Table 6), though those organisms known to be present are distinctly members of the Antipatharian Zone assemblage.

We should point out that our observations at Big Adam were severely hampered by the very high turbidity there and the information in Table 6, on which we in part base the comments made above, is probably quite incomplete.

ENVIRONMENTAL FACTORS

The crests of all of the South Texas banks studied (58-62 meters) fall within a depth range (49-76 meters) which at the East and West Flower Gardens is occupied by Algal-Sponge Zones (Fig. 47), harboring abundant and diverse populations of coralline algae (mostly in the form of nodules), leafy algae,

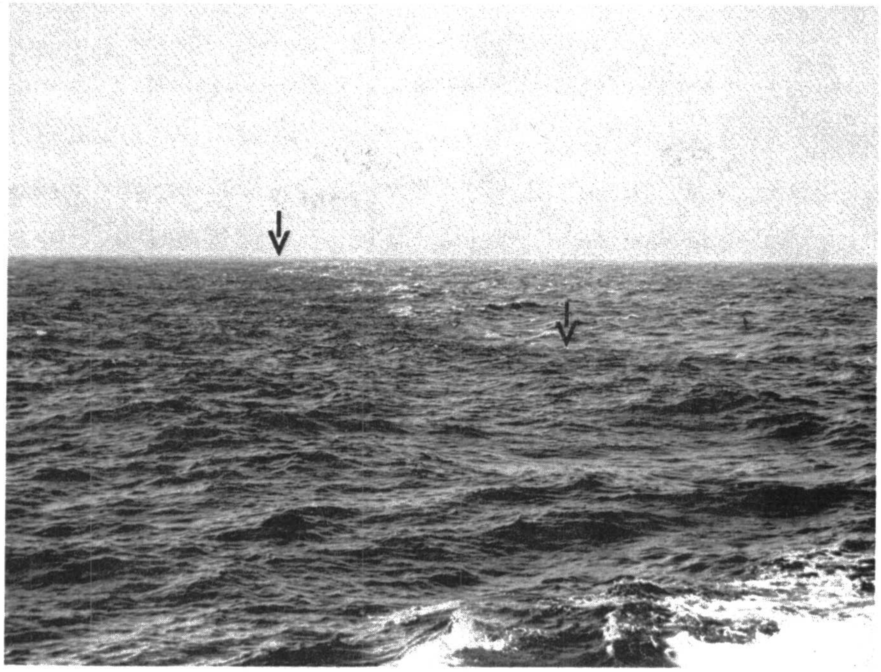


Figure 44. Interface between "blue" water and "green" water north of Baker Bank.

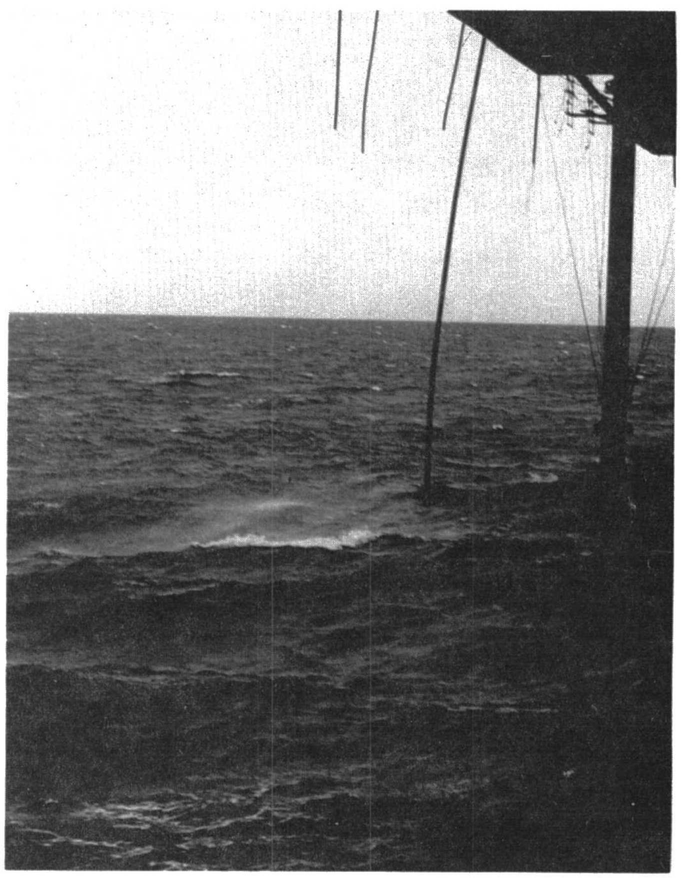


Figure 45. Sediment being dumped at surface from drilling rig off Texas.

sponges, and a large array of attached and mobile epibenthos. Whereas many of the organisms inhabiting the South Texas banks also occur in the Algal-Sponge Zones, there is little similarity between the diversity and abundance of the populations; they are far lower on the southern banks. Moreover, the general level of abundance of populations is higher in the Antipatharian Zones at the Flower Gardens (75-90 meters) than on the South Texas banks, which are directly comparable in terms of biotic content and diversity.

Variations in several rather conspicuous environmental factors observed by us (namely, salinity, temperature, turbidity, sedimentation, and light) would seem to deserve some consideration in attempting an explanation of the obvious discrepancies in depth of distribution, diversity, and abundance of the hard-bank communities mentioned above.

Observations over past years (Bright & Pequegnat, 1974; Abbott, 1975) have shown that the Flower Gardens and other banks occurring at the seaward edge of the Texas-Louisiana Continental Shelf are bathed almost perpetually in oceanic water of high clarity (visibility usually greater than 30 meters) down to depths of over 70 meters. Even below that, to depths of 85 or more meters, water clarity is quite good, and light penetrates well. Only infrequently does the salinity differ much from normal marine (35 parts per thousand), and seasonal bottom temperature variations at the depths in question are generally less than 6° C. On the other hand, bottom temperatures in the vicinity of the South Texas banks can vary 12°-16° C and salinities are abruptly changeable.

Whereas the Flower Gardens are rarely, if ever, subjected to truly coastal water masses, the South Texas banks may experience alternations between the presence of oceanic and coastal water several times in a week. In May and June 1975 we observed several times, in the vicinity of the South Texas banks, sharp sea surface interfaces between blue water of near normal marine salinity and greenish water with salinites more comparable to those nearer shore. For instance, upon sampling surface water on both sides of one such interface (Fig. 44) we found that in the blue water the salinity was 34.3 parts per thousand at the interface and 34.4 parts per thousand 100 meters away; in the green water the salinity was 31.7 parts per thousand at the interface and 31.4 parts per thousand 100 meters away (a gradient of 3 parts per thousand in 200 meters). Obviously, there was some degree of mixing of the two water masses at the convergence, but the distinction between them in terms of color, salinity, and turbidity (the green water was considerably murkier than the clear blue water) was striking, even though temperature differed only by .05° C (25.80° C in the blue water and 25.75° C in the green). While diving on the various banks we noted that from one day to the next the color and clarity of the water would often change, indicating the passage of one of these very abrupt interfaces. We suppose that such constantly recurring fluctuations in certain basic environmental factors at the South Texas banks could be considered a form of stress which is much less pronounced on the banks of the shelf edge farther north.

The nepheloid layers and associated sedimentation are certainly more pronounced on the South Texas banks than at the shelf edge banks (compare Figures 1 and 47). We speculate that most or all of the South Texas banks are frequently totally covered by the nepheloid layer, as we observed to be the case at Big Adam in June 1975, especially during severe wave conditions. At the Flower Gardens a substantial nepheloid layer has not been observed shallower than 90 meters, and usually the water is fairly clear even at that depth. Only over the deeper, level soft bottoms composed of relatively fine sediments does a nepheloid layer apparently develop at the Flower Gardens.

The South Texas banks, however, are generally coated with thin to thick layers of fine sediment, presumably derived from nepheloid layers. Burrowing organisms, of which there are millions on these banks, must continually propel fine sediment into the water where it tends to stay for rather long periods of time. A small amount of water movement is sufficient to cause resuspension of the fine sediments. Although they will eventually resettle, turbidity is temporarily increased. Under these conditions sedimentation becomes an ever-present factor dependent on weather conditions, biological activity, and the nature of the water masses present.

Undoubtedly, the conditions described above, especially with regard to water turbidity and sedimentation are less favorable for the development of healthy clear-water, light-loving communities such as those in the Algal-Sponge Zones at the Flower Gardens.

The relationships between relief above the bottom and possible effects on biotic communities due to the presence of nepheloid layers has been alluded to previously in the case of Big Adam Rock. In this regard it should be pointed out that the local relief of the northern shelf edge banks is considerably greater than that of any of the South Texas banks (60 meters, as opposed to 20 meters).

Because there have been no physiologically oriented studies to determine the effects of environmental contaminants introduced by man on any of the organisms encountered by us, and because no investigations have been completed which would indicate the dispersal rates, settling rates and ultimate fates of contaminants released into the water from drilling rigs and production platforms, it is impossible to predict whether or not dumping of drill cuttings and other substances (Fig. 45) near one of these banks will have a significant impact on the epibenthic communities there. It should be remembered, however, that these banks do not bear lush and abundant populations of marine organisms, and those that are there are possibly already subject to a great deal of natural environmental stress. We would warn against decisions concerning the mechanics of drilling operations which may result in any additional ecological stress. Certain criteria to be considered in making management judgements concerning these banks are presented in Chapter VII, along with some specific recommendations for regulating drilling.

EAST FLOWER GARDEN

The objective of our 21-24 June 1975 reconnaissance of parts of the East Flower Garden Bank was to determine whether, in our opinion, there were detectable effects or environmental impact, due to nearby recent exploratory drilling, on biota of the bank, particularly in the Algal-Sponge and Antipatharian Zones as defined below. To this end we attempted to duplicate a transect made with the submarine on 30 June 1974 from the base of the coral reef out across the bank to a depth of approximately 90 meters (Fig. 46). Although our 1974 and 1975 tracks do not coincide exactly they are close enough to make our conclusions quite valid. Insofar as it is the after drilling condition of the bank that is of interest, all of the photographs presented here are those taken in 1975, except for Figure 73, which was taken in 1974.

ZONATION AND BIOTA

The East Flower Garden is, biotically, the most diversified of the hard banks on the Texas-Louisiana continental shelf. Though its neighbor, the West Flower Garden, is quite similar and more thoroughly documented (Bright and Pequegnat, 1974), it apparently lacks some of the shallower biotic zones found at the East Flower Garden above 45 meters, namely, the Leafy Algae Zone and *Madracis* Zone (compare Fig. 47 with Fig. 2 in the SUMMARY of this report).

Water clarity on the bank is exceptional, with visibility consistently exceeding 15 meters and often 30. The main living coral reef (*Diploria-Montastrea-Porites* Zone) occupies the crest of the bank down to approximately 46 meters depth (Fig. 48 and 49). Most of the reeftop varies in depth from 18 to 28 meters but 14 to 15 meter depths are common and an 11 meter depth has been encountered (Edmond Alexander, personal communication). Table 7 lists the major conspicuous epifaunal organisms and

Fish Observations

Symbol	
1	*Holacanthus tricolor*
2	*Holacanthus bermudensis*
3	*Holacanthus ciliaris*
4	*Chaetodon sedentarius*
5	*Prognathodes aculeatus*
6	*Centropyge argi*
7	*Eupomacentrus partitus*
8	*Chromis enchrysurus*
9	*Eupomacentrus* sp.
10	*Chromis cyaneus*
11	*Bodianus pulchellus*
12	*Halichoeres* spp.
13	*Thalassoma bifasciatum*
14	*Sparisoma viride*
15	*Scarus* sp.
16	*Sphyraena barracuda*
17	*Serranus annularis*
18	*Gobiosoma* sp.
19	*Acanthurus* sp.
20	*Gymnothorax* spp.
21	*Holocentrus* sp.
22	*Liopropoma* sp.
23	*Paranthias furcifer*
24	*Priacanthus arenatus*
25	*Malacanthus plumieri*
26	*Caranx* sp.
27	*Seriola dumerili*
28	Labridae
29	*Haemulon melanurum*
30	*Equetus acuminatus*
31	*Equetus lanceolatus*
32	*Balistes vetula*
33	Balistidae
34	*Acanthostracion* sp.
35	*Calamus* sp.
36	*Pseudopeneus maculatus*
37	*Mulloidichthys martinicus*
38	*Canthigaster rostrata*
39	Diodontidae
40	*Synodus intermedius*
41	Deep-reef fish "A"
42	Fish "B"
43	Burrowing fish "C"
44	Holocentridae
45	*Equetus* sp.
46	*Apogon* sp.
47	*Rhomboplites aurorubens*
48	*Plectrypops retrospins*
49	Carcharhinidae
50	Rajiformes
51	*Pomacentrus paru*
●	*Lutjanus campechanus*
▲	*Petrometopon cruentatum*
■	*Epinephelus adscensionis*
◐	*Mycteroperca* sp.
◩	*Dermatolepis inermis*
◮	*Epinephelus* sp.

Observations Other Than Fish

Symbol	
A	Gas seep
B	Patterned burrows
C	Encrusting coralline algae
D	Thin branching sponge
E	*Ircinia campana*
F	*Callyspongia* sp.
G	*Neofibularia* sp.
H	*Argyrotheca barrettiana*
I	*Spondylus americanus*
J	Bryozoans
K	*Hermodice* sp.
L	*Spirobranchus* sp.
M	Hermit crab
N	*Stenorynchus* sp.
O	*Diadema* sp.
P	*Clypeaster* sp.
Q	Asteroidea
R	*Narcissia trigonaria*
S	Basket stars
T	*Isostichopus* sp.
U	Comatulid crinoids
V	Leafy algae
W	*Agelas* sp.
a	Plume-like hydroid
b	*Condylactis* sp.
d	*Madracis decactis*
e	*Madracis mirabilis*
f	*Madracis asperula*
g	Agariciid
h	*Diploria* sp.
i	*Montastrea cavernosa*
j	Antipatharia
m	Large antipatharia
n	*Hypnogorgia* sp.
q	Brown-orange sea fan
r	Sabellid worm
t	*Udotea* sp.
x	Munida crab

Figure 46 - A, Legend

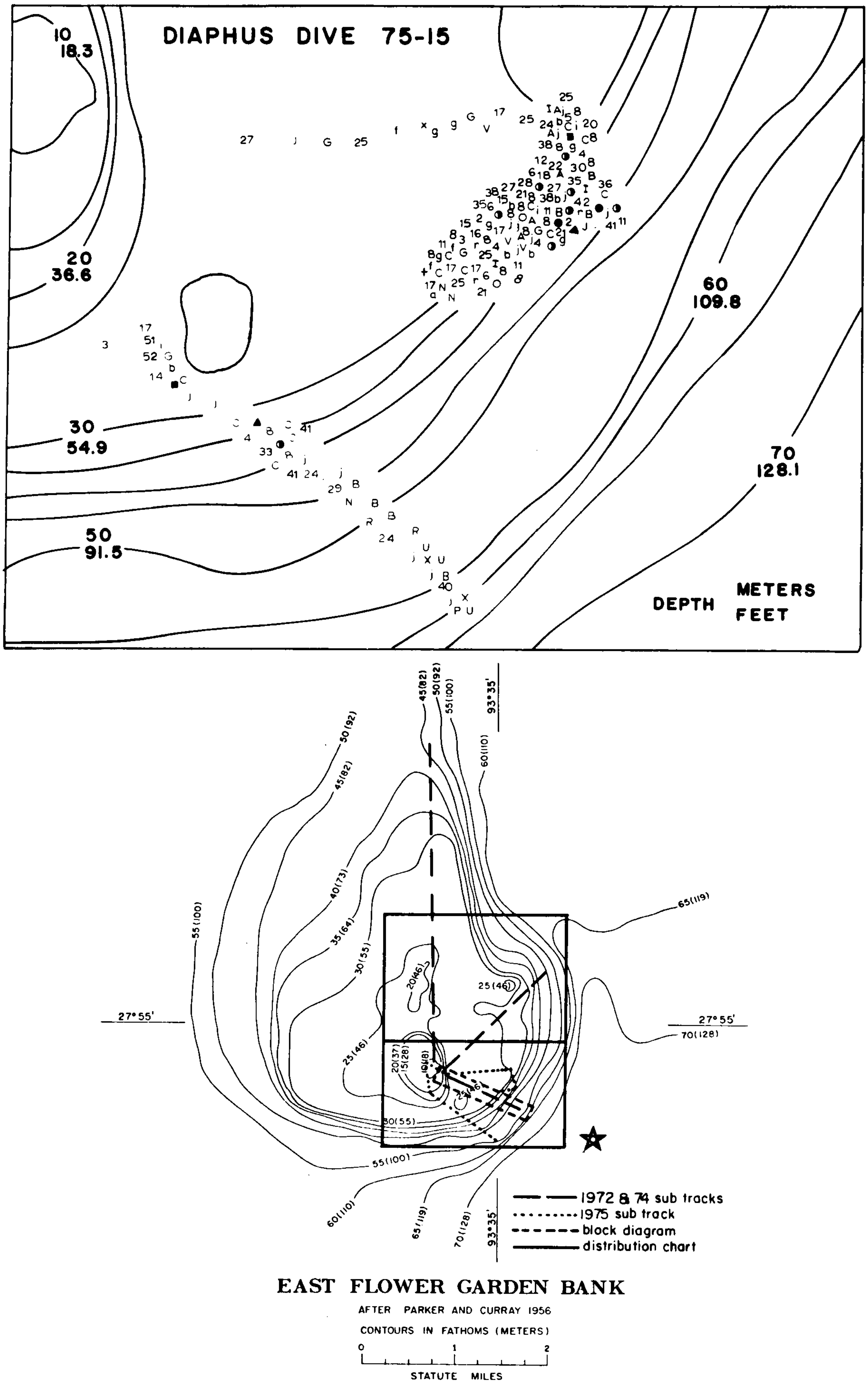


Figure 46- B, Organism sightings and samples 1975. Star indicates approximate Mobil drill site.

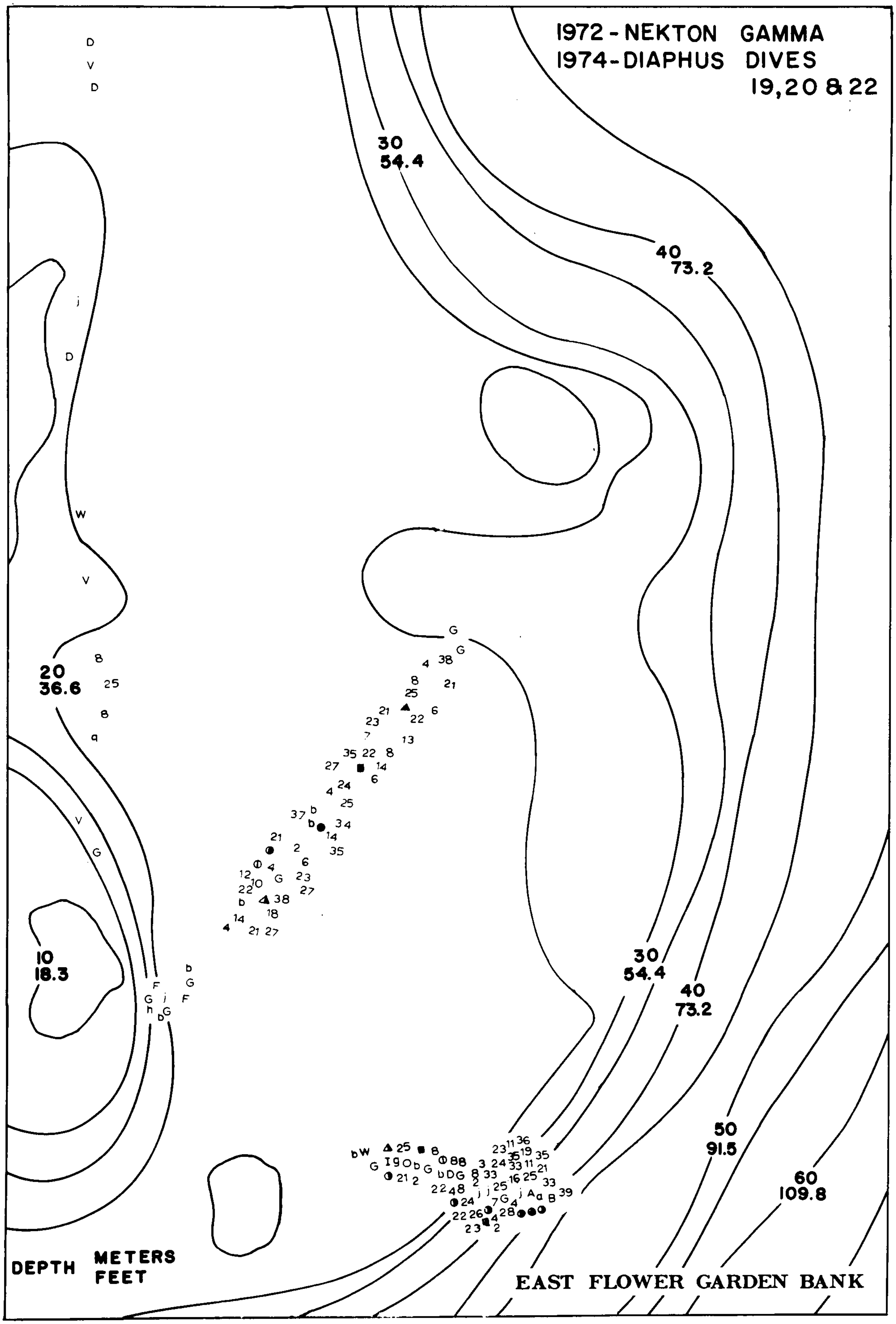


Figure 46- C, Organism sightings and samples 1972 and 1974.

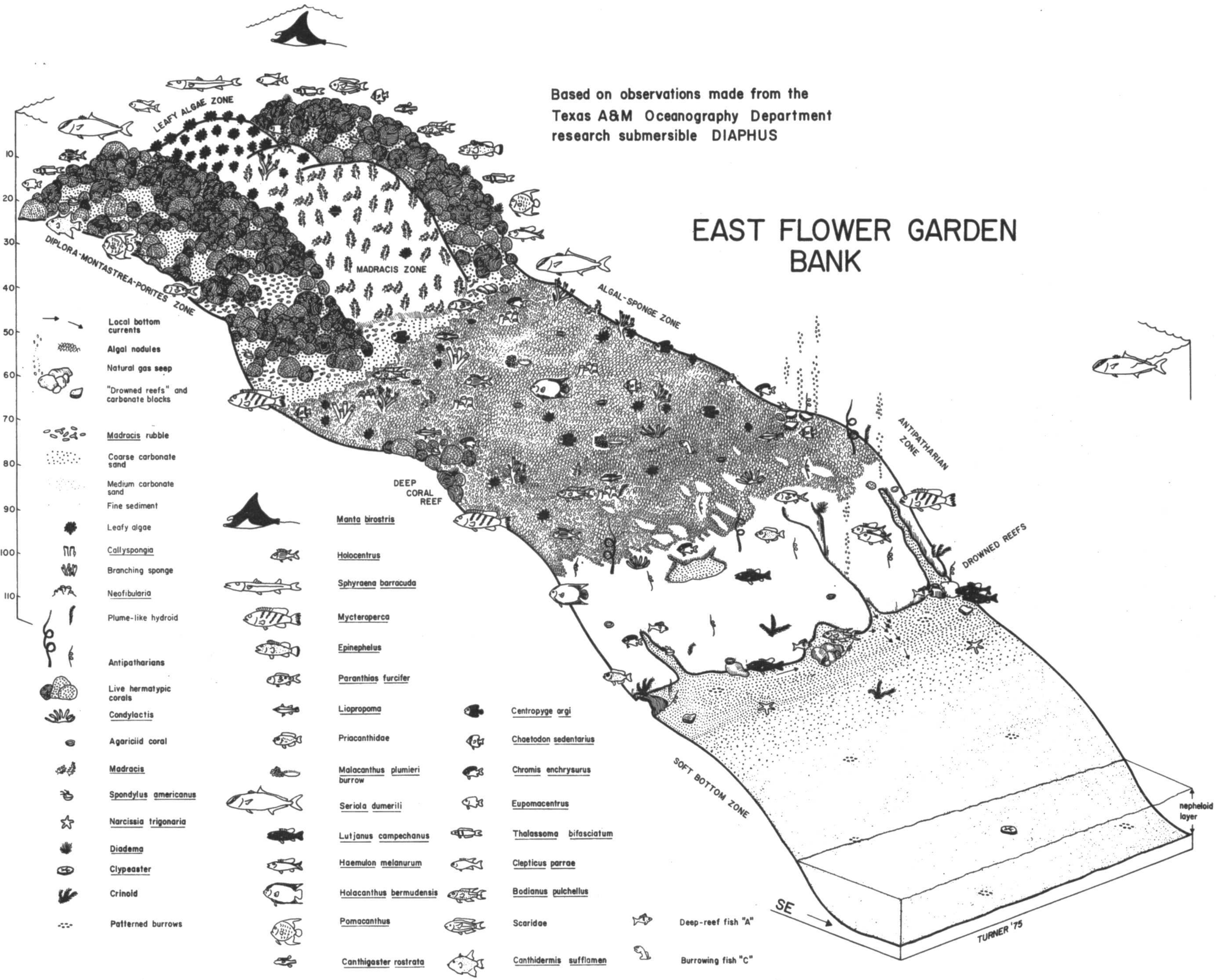


Figure 47. East Flower Garden block diagram.

Figure 48. Coral reeftop at East Flower Garden (18-23 meters).

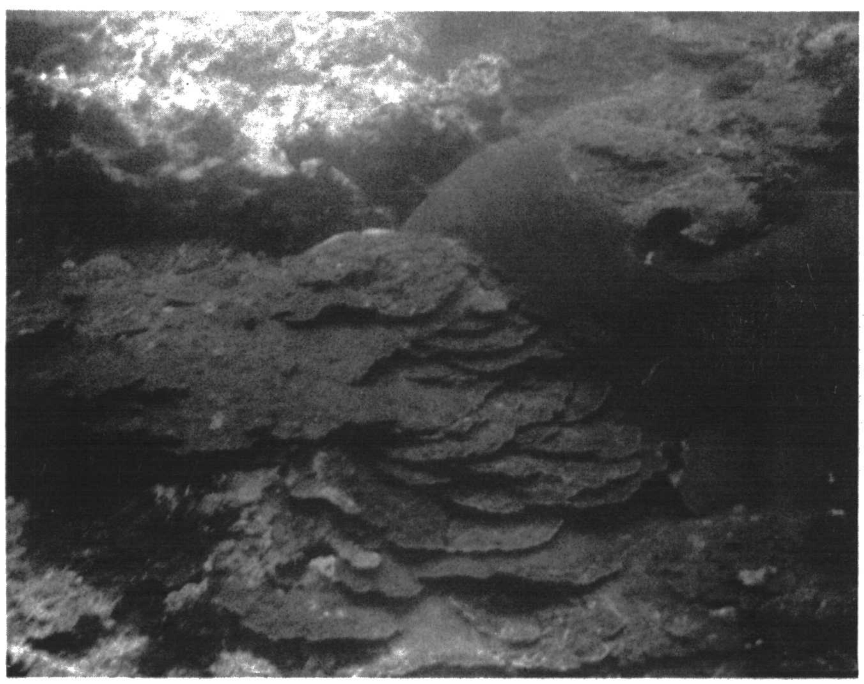


Figure 49. Coral reef flank, East Flower Garden (30-36 meters).

groundfishes seen or collected by us at the East Flower Garden between 1972 and 1974, Table 8 lists results of our 1975 efforts. Living corals cover 30 to 50 percent of the bottom where the reef is developed and, as at the West Flower Garden, the major reef builders are Montastrea, Diploria and Porites, probably in that order of importance. The Fire coral, Millepora alcicornis (Fig. 50), encrusts reefrock throughout the zone as do various species of sponges and other epifauna.

In places the coral heads, which are generally 1.5-3 meters in horizontal and vertical dimensions (Fig. 51), are quite cavernous beneath, being undercut by cavities frequently large enough for a man to enter. Such is hardly ever the case at the West Flower Garden. There also seem to be more and larger beds of coarse calcareous sand between coral heads and, understandably, a larger population of leafy algae on the main coral reef at the East Flower Garden than at the West. As at the West Flower Garden, however, the shallow water alcyonarian population on the main reef is nil.

The north to northeast and southeast faces of the main reef are often quite steep, vertical in places, dropping from 24 - 28 meters down to between 43 and 49. On these vertical faces the corals, especially Montastrea, tend to grow in closely spaced shelf-like extensions from the peripheries of the coral heads (Fig. 49). There is an impression that the coral heads on the north and northeast face of the main reef are not always in their original position, as if some have been tumbled, possibly by storm waves.

The Diploria-Montastrea-Porites biotic zone is not restricted to the main reef at the East Flower Garden. During a 1974 submarine dive which traversed the biostromal bank (Algal-Sponge Zone) on a northeast course from the main reef we encountered a smaller but healthy living coral reef growing out of a depth of 55 meters to a crest at 43 meters. Living corals, mostly Montastrea, Diploria and Millepora, but also others (Table 7)

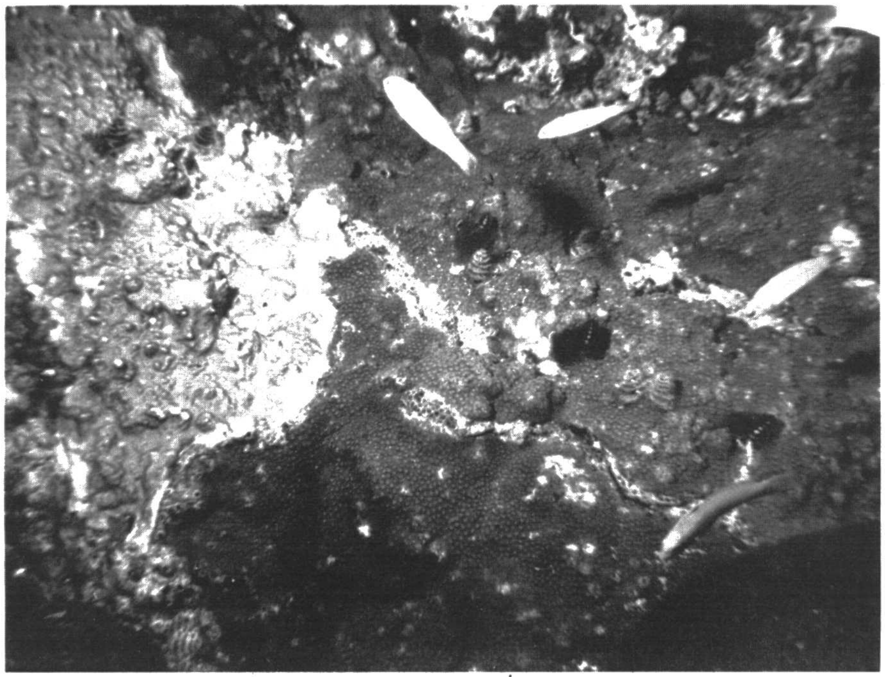


Figure 50. Millepora (upper left), scleractinian coral, Spirobranchus worms and small wrasses (Thalassoma bifasciatum) (20 meters).

Figure 51. Montastrea head with clump of Mussa just above Queen triggerfish, Balistes vetula (20 meters).

covered approximately 30 percent of the bottom. The seemingly lower diversity of the fish population here than on the main reef is possibly due to the fact that most of this reef (30 meters or so wide and of undetermined length) falls within a depth range below the base of the main reef. Interestingly, the population of Spondylus americanus, the American thorny oyster (Fig. 52), much prized as trophies by sport divers, appeared to be exceptionally great on this deep outlying reef. The Common black urchin, Diadema antillarum, was abundant and conspicuous here, as it is on the main reef.

Structurally, the outlying reef is similar to bank barrier reefs existing in much shallower water in the southern Gulf of Mexico and Caribbean. It is linear, roughly parallel to the face of the main reef, relatively narrow, with a fairly steep backreef face of about 2.5 meters relief, a flatish topreef and a gently sloping forereef which changes seaward from rather closely spaced heads 1 to 1.5 meters high to widely scattered heads on a sandy bottom. The reef grades seaward into the Algal-Sponge Zone (also referred to as "algal nodule zone" or "biostromal bank" or "Gypsina-Lithothamnium Facies") from which it arose on its backreef side.

The fish population on the main coral reef at the East Flower Garden (Fig. 50, 51, 53; Tables 7 and 8) is undoubtedly as diverse as that of the West Flower Garden though the number of species sighted by us at the former falls 40 or so short of the 100 or more listed by Bright and Cashman, 1974, on the basis of extensive sampling at the West Flower Garden.

Lateral variability in benthic community structure at the East Flower Garden is apparently greater than that of the West. Knolls at the East Flower Garden are occupied by large fields of Madracis mirabilis (Madracis Zone) (Fig. 47, 54 and 55). Others harbor mixtures of sponges, Madracis, and leafy algae (Fig. 56 and 57). And still others are covered almost totally by lush growths of leafy algae (Leafy Algae Zone) including

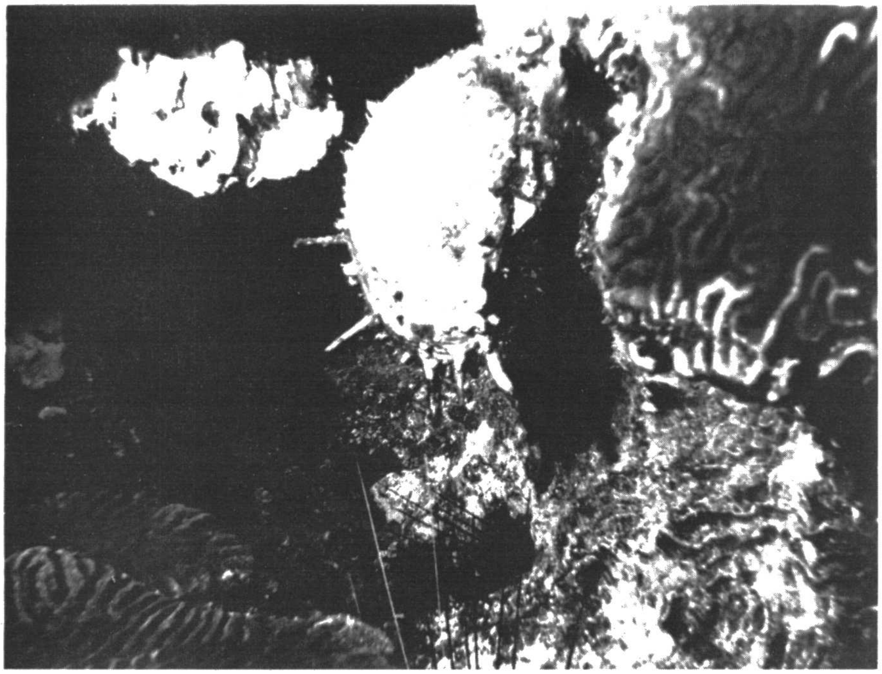


Figure 52. Spondylus americanus, Diadema spines, brain coral and coralline algal encrustation on dead portion of brain coral in lower right (20 meters).

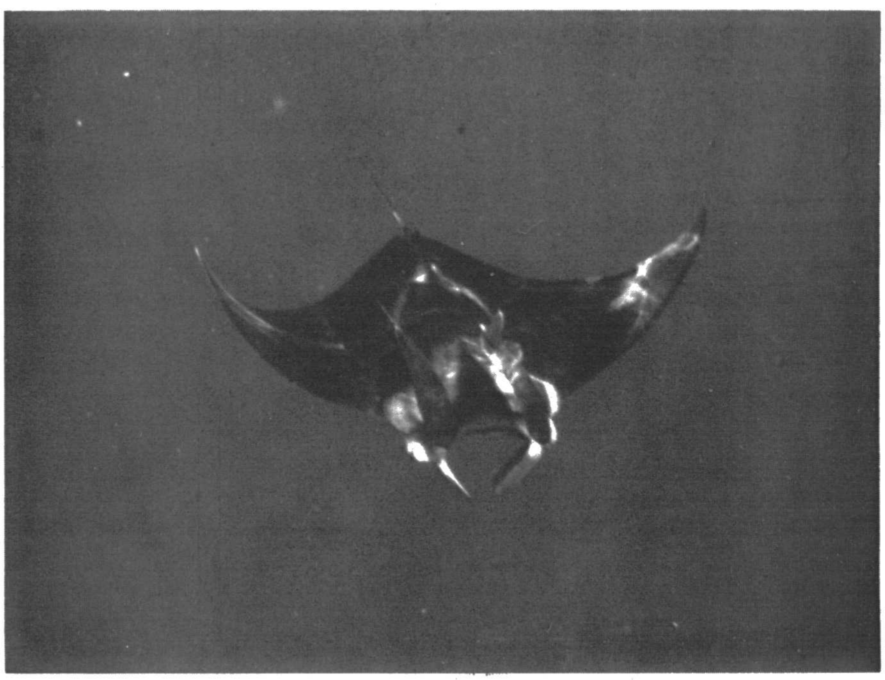


Figure 53. Manta birostris with two sharksuckers (Echeneidae) above eyes.

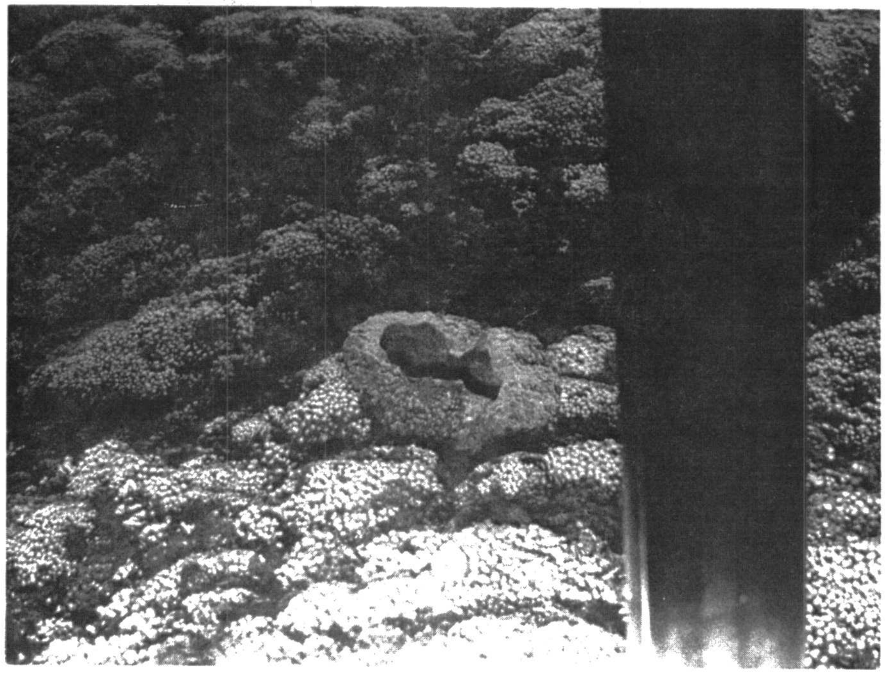


Figure 54. Madracis field at top of East Flower Garden (27-30 meters).

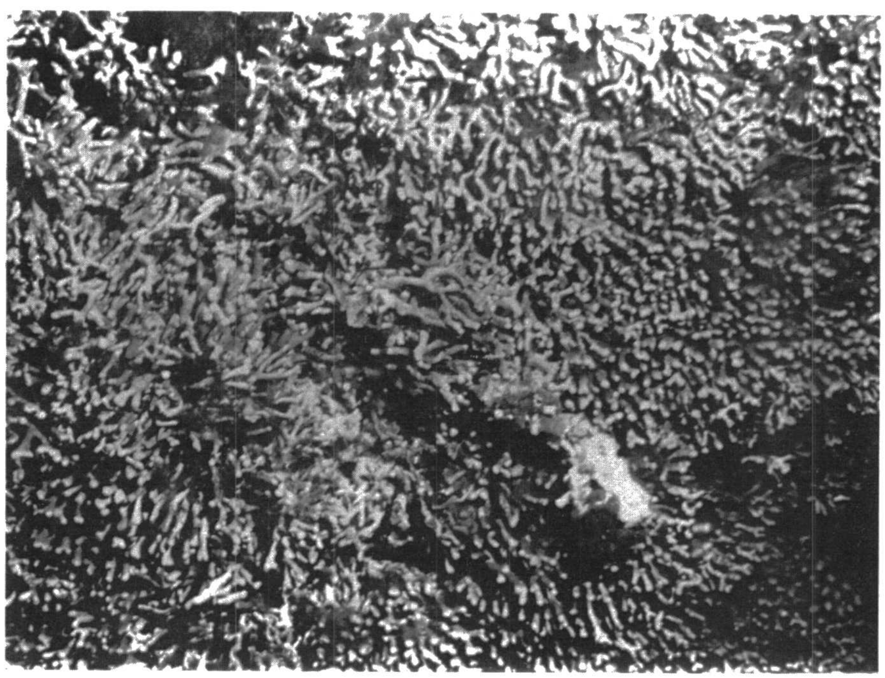


Figure 55. Madracis in the field pictured above (27 meters).

Figure 56. The branching sponge Verongia just below manipulator arm claw, leafy algae and Madracis clumps (25 meters).

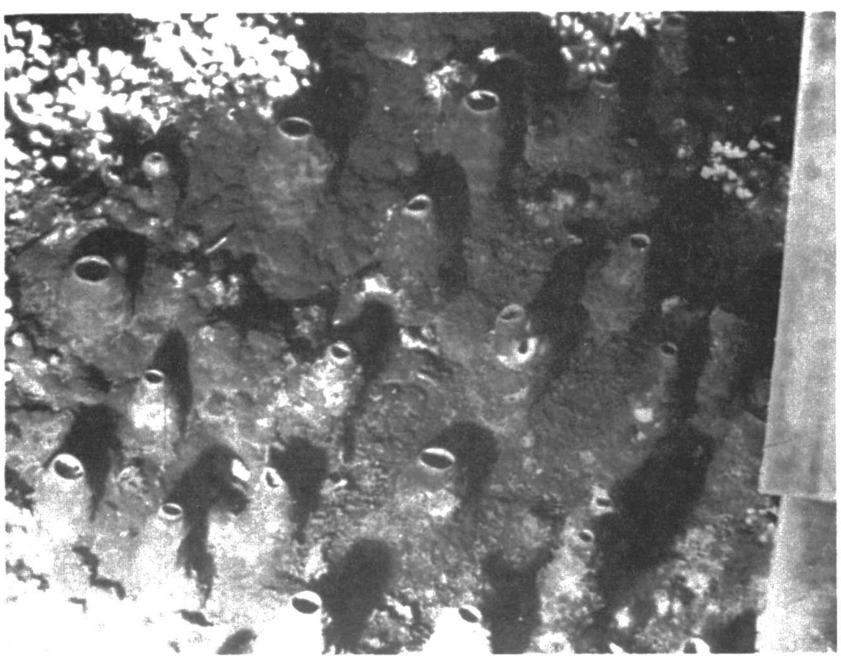


Figure 57. Neofibularia and Madracis clumps (25 meters).

Caulerpa, Chrysymenia, Halymenia, Gloiophloea, Lobophora, Microdictyon and others (Fig. 47, 58 and 59; Tables 7 and 8). Such knolls occur at the crest of the bank alongside the coral reefs of the Diploria-Montastrea-Porites Zone at depths shallower than 45-49 meters.

Skeletal remains of Madracis are locally very important contributors to the sediment in depressions between coral heads and at the base of the reef face (Fig. 47, 82), often to the exclusion of the coarse carbonate sand generally found below the heads and in a band separating the reef rom the deeper Algal-Sponge Zone.

The biotic community inhabiting the Algal-Sponge Zones of the East and West Flower Gardens was described by Abbott, 1975, where it was usually referred to as the algal nodule zone because of the overwhelming presence of nodules formed of, and rubble encrusted by, coralline algae, mostly Lithothamnium, Lithophyllum, Lithoporella and Mesophyllum, and the encrusting formaminifer Gypsina plana (Fig. 47, 60).

The nature of benthic communities inhabiting the Algal-Sponge Zone on all transects made at the East Flower Garden is as described by Abbott. From the base of the main reef outward the substratum is generally coarse calcareous sand, underlain and replaced locally by flat to low outcrops of carbonate rock, drowned reefs, isolated coral heads and at least in one place a living contemporary coral reef. The sand and hard bottom where the relief is rather flat are covered to varying extents with a veneer of rubble, nodules and crusts of coralline algae. The base of the main reef is generally bordered either by a band of nearly bare sand or sand overlain by finger sized pieces of Madracis rubble encrusted with coralline algae. A short distance away from the reef fist sized algal nodules are mixed with the rubble. The nodules tend to predominate seaward, attaining their greatest sizes between 55 and 61 meters and giving way to some extent to coralline algal crusts in the deepest parts of the zone. Sizeable nodules have been seen, however, as deep as 76 meters. The isolated

Figure 58. Field of leafy algae (26 meters).

Figure 59. Leafy algae in field pictured above (26 meters).

Figure 60. Algal nodule covered bottom in Algal-Sponge Zone (50 meters).

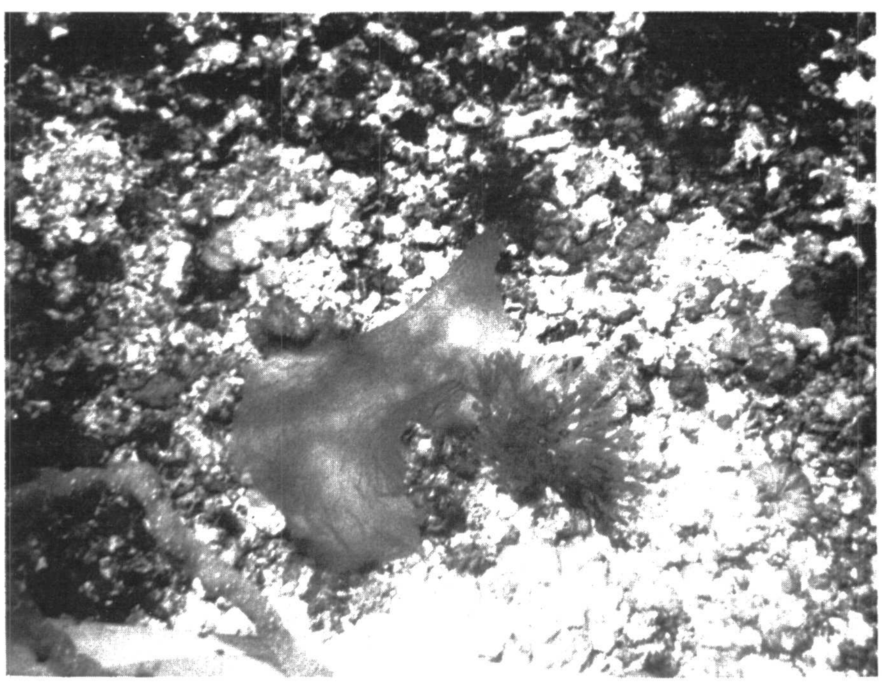


Figure 61. Leafy algae (blade-like Halymenia and bushy Chrysymenia) among algal nodules. Tube sponge Callyspongia in lower left (54 meters).

heads and outcrops in the zone generally bear little living coral and are usually heavily encrusted with coralline algae.

Among the conspicuous components of the Algal-Sponge Zone community are leafy algae (Fig. 61; Tables 7 and 8) and several species of sponges of which encrusting growths of Neofibularia (Fig. 62) are most distinctive. The branching finger sponge Verongia (Fig. 56) is locally abundant and scattered throughout the zone down to at least 55 meters. Enormous massive gray sponges 1 to 1.5 meters in diameter were seen between 55 and 61 meters near the edge of the Algal-Sponge Zone on the northeast and southeast transects. Large plume-like hydroids (Fig. 63) of the family Plumularidae, probably Aglaophenia sp., (Defenbaugh, personal communication) are frequently encountered in the zone, as is Condylactis (Fig. 64), a large olive colored anemone with blue tipped tentacles. The most frequently encountered coral in the Algal-Sponge Zone is an agariciid occurring down to a depth of at least 85 meters in growths the size and shape of saucers (Fig. 65). Sabellid worms (Fig. 66) inhabit the sediment between nodules. The feather duster worm Spirobranchus and the urchin Diadema antillarum occur on the coral reefs and throughout the Algal-Sponge Zone among or on rocks and outcrops (Fig. 50 and 52). The Arrow crab, Stenorynchus seticornis, is frequently seen on all parts of the bank to at least the lower limit of the Algal-Sponge Zone. As at the West Flower Garden, the small Yellowtail reeffish, Chromis enchrysurus, is the most abundant of the conspicuous fishes which generally congregate around irregularities in the Algal-Sponge Zone. Conical burrows a meter across and ½ meter deep produced by the Sand tilefish, Malacanthus plumieri, are scattered about the zone from the base of the main coral reef down to at least 70 meters (Fig. 67).

The nodule-rubble cover within the Algal-Sponge Zone usually exceeds 80 percent except where disturbed by invertebrates, fishes or man. The Sand tilefish mentioned above removes nodules from its burrow and piles them neatly beside it. The activities of organisms living on or under reefrock outcrops and isolated heads everywhere on the bank maintain zones of bare sand at the bases of many such structures.

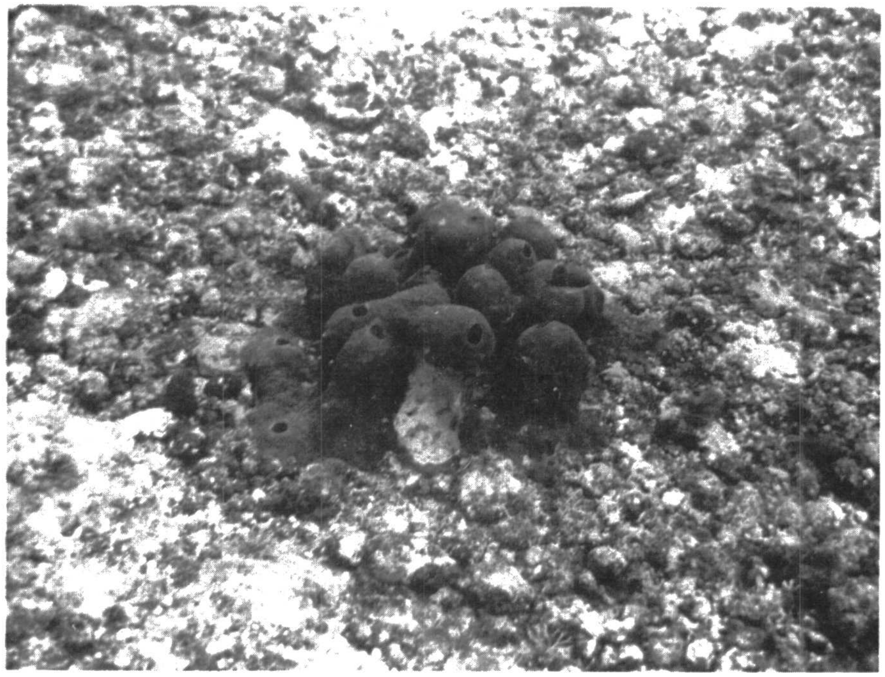


Figure 62. Neofibularia growing on nodules (49 meters).

Figure 63. Plume-like hydroid in Algal-Sponge Zone (55 meters).

Figure 64. The anemone Condylactis (55 meters).

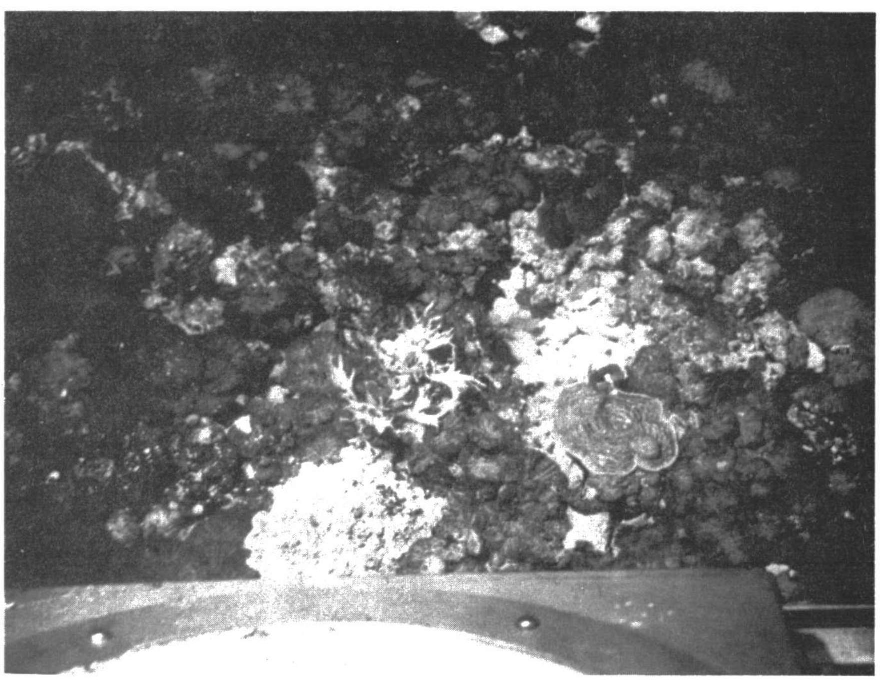


Figure 65. Saucer-shaped agariciid coral (right center), leafy algae (center) and coralline algal crust (white in lower center) (55 meters).

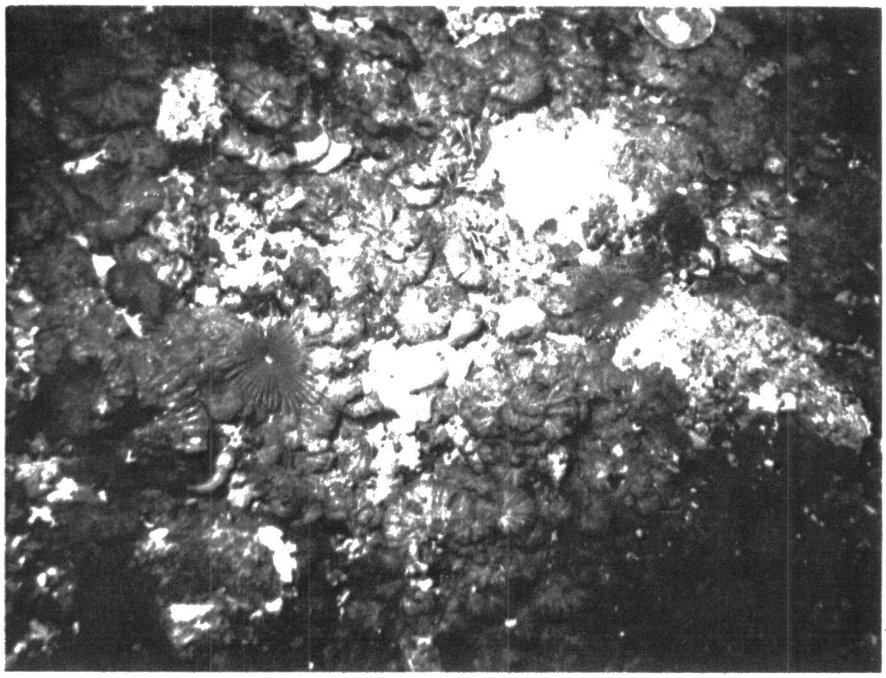


Figure 66. Sabellid worms in Algal-Sponge Zone (55 meters).

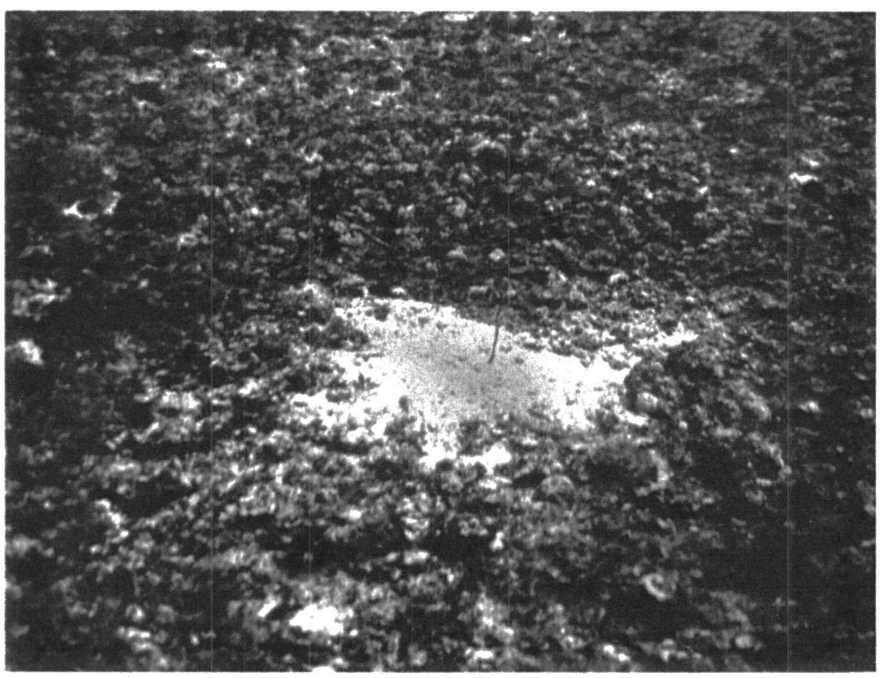


Figure 67. Sand tilefish burrow (52 meters).

White, bedspring-shaped antipatharian sea whips, probably Cirripathes, occur between 52 and over 85 meters at the East Flower Garden and, where they are most abundant (generally around 60 to 85 meters), mark a transition between biotic assemblages which exhibit distinct shallow water affinities (leafy algae, abundant coralline algae, hermatypic corals, sizeable shallow water reef fish populations) and those which are deep-water oriented. This supposed Antipatharian Zone (Fig. 47) blends with the Algal-Sponge Zone in its upper reaches (Fig. 68, 69, 70 and 71) and it is impossible to find any sharp demarcation between the two. One might just as well speak of a lower Algal-Sponge Zone which has a sizeable antipatharian population. With depth, however, algal nodules tend to give way to pavement-like encrustations of coralline algae which thins out downslope (Fig. 72) from nearly 80 percent cover at 75 or so meters to something less than 30 percent near the very base of the bank (85 meters).

Here, the epifauna and fishes (Fig. 74 and 75) exhibit so close a resemblance to the biota encountered on the South Texas banks (Baker, South Baker, Aransas, North Hospital, Hospital, Southern and Dream) that it is reasonable to consider them as representing basically the same biotic zone. Most conspicuously they have in common antipatharians, comatulid crinoids, few if any leafy algae, thin to sparse populations of coralline algae and a distinctly limited fish fauna including deep-reef fish species "A", Bodianus pulchellus, Chromis enchrysurus, Chaetodon sedentarius and Holacanthus bermudensis.

In 1974 on the north and northeast parts of the bank we encountered a distinct but not precipitous break in slope at approximately 61 meters. From there a short traverse seaward brought us to an abrupt transition between the Antipatharian Zone and the upper part of the Soft Bottom Zone (Amphistegina Facies) (Fig. 47). Between 73 and 76 meters the nature of the bottom changes, usually rather abruptly, from algal nodules and crusts to a soft level bottom of mixed coarse calcareous sand (with an abundance

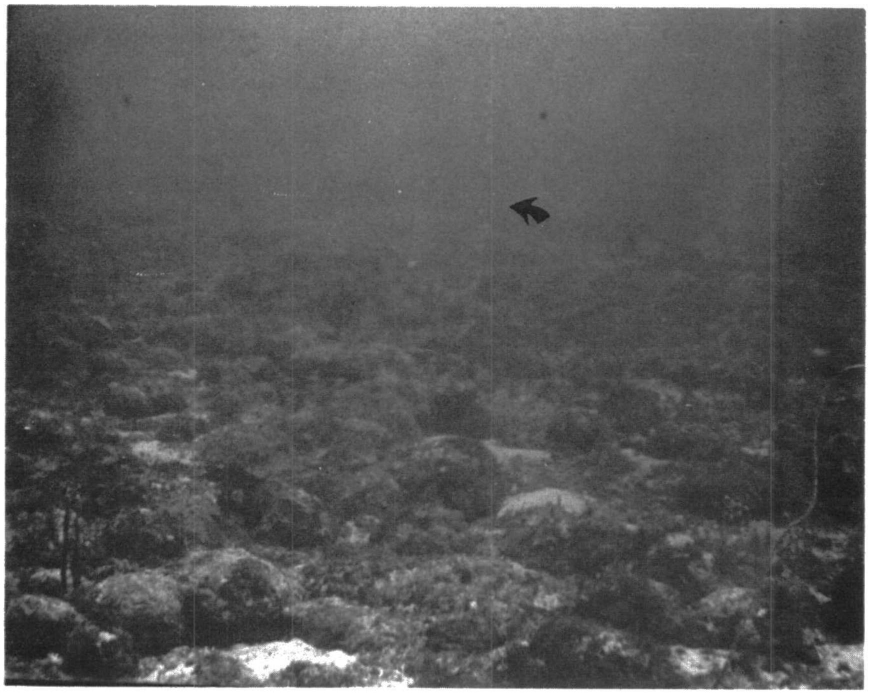


Figure 68. Gas seep in upper Antipatharian Zone (55 meters).

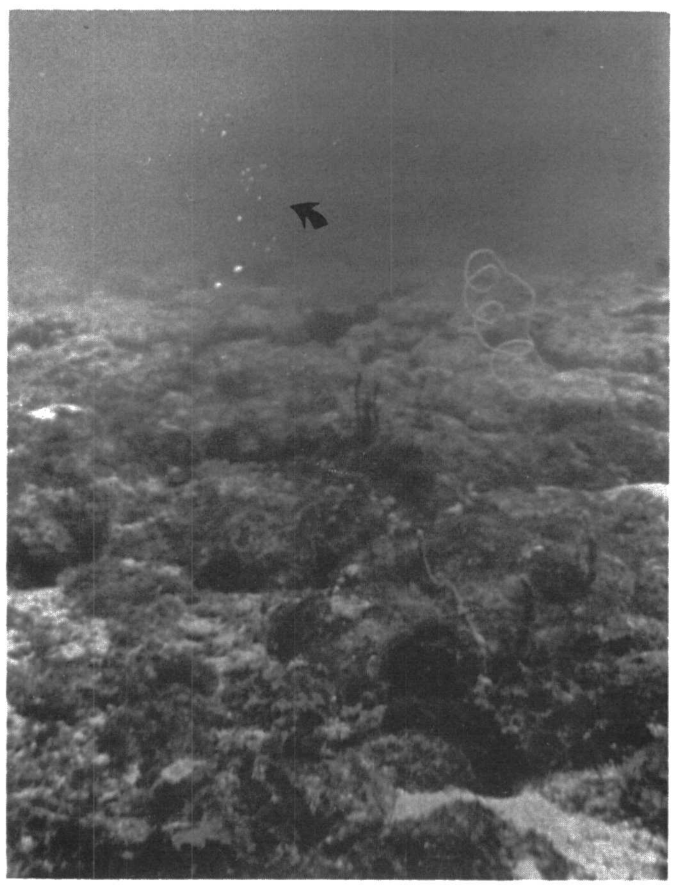


Figure 69. Gas seep near one pictured above.

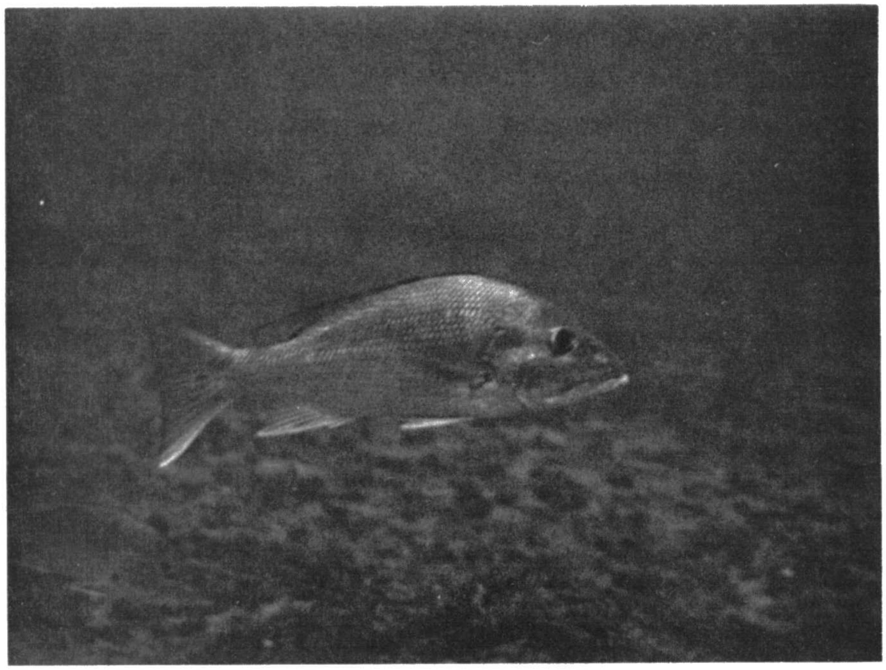


Figure 70. Lutjanus (snapper) at 55 meters.

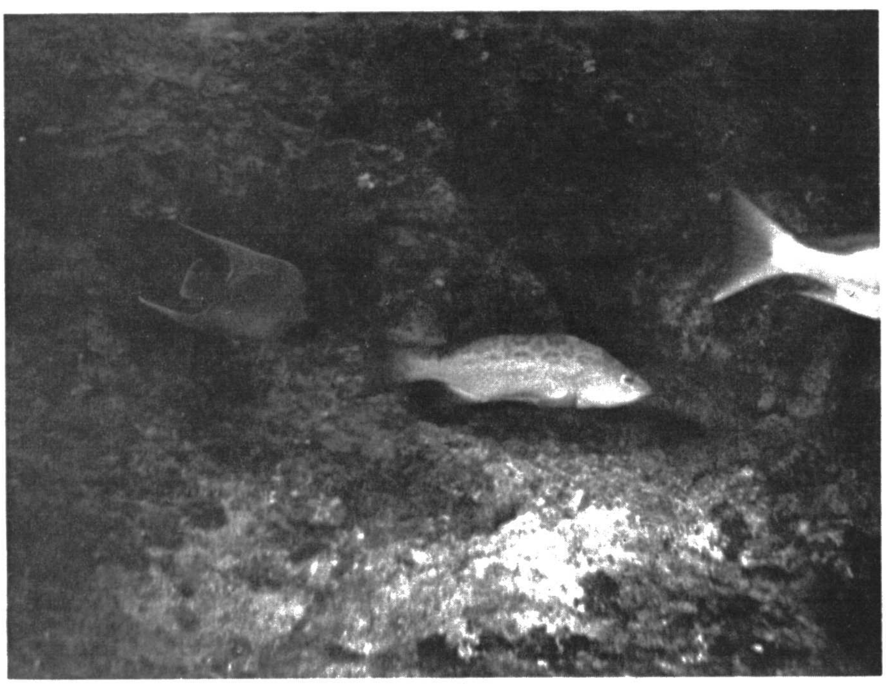


Figure 71. Holacanthus bermudensis, Mycteroperca and tail of Lutjanus at 58 meters.

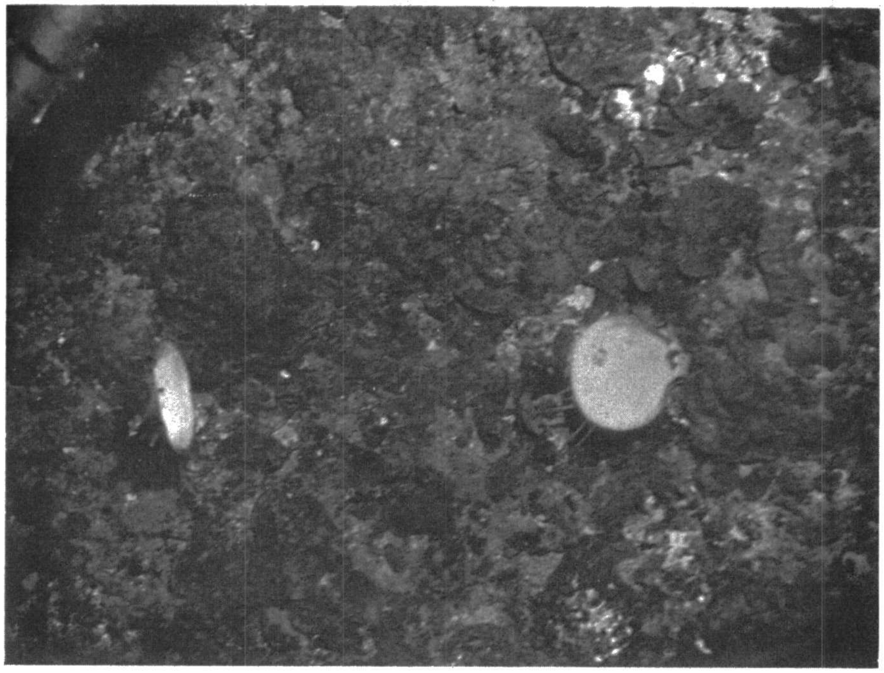


Figure 72. Spondylus shell recently opened and encrusting coralline algae in mid Antipatharian Zone at about 65 meters.

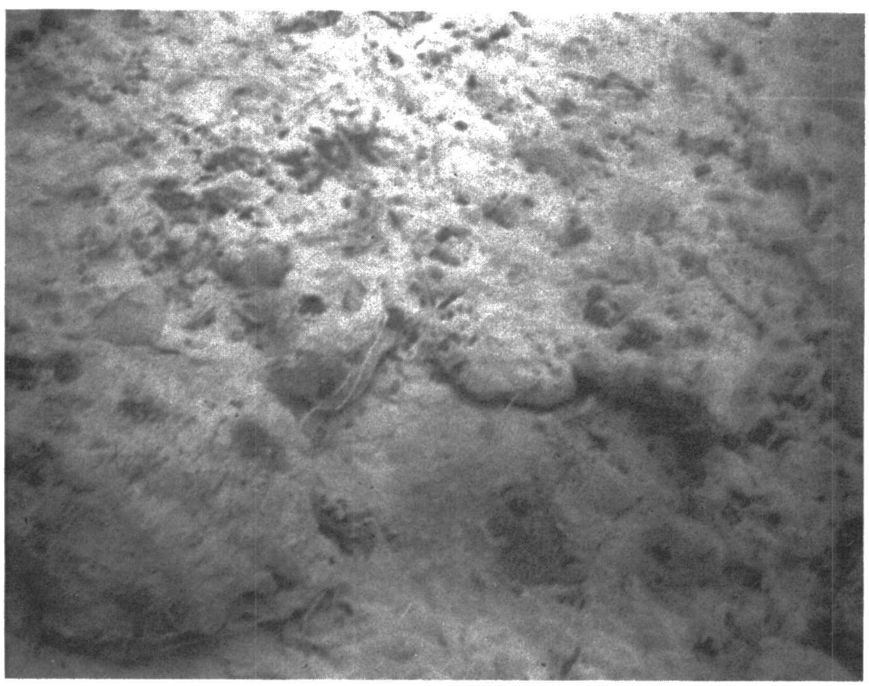


Figure 73. White slimy covering on bottom of "Canyon" (76 meters).

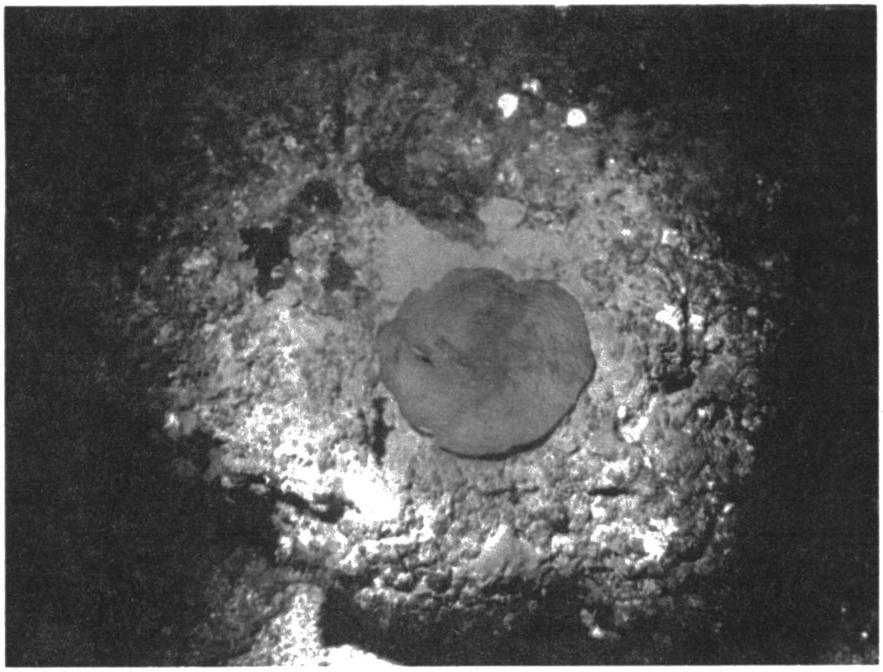


Figure 74. Saucer-shaped agariciid coral and encrusting coralline algae in lower Antipatharian Zone (84 meters).

Figure 75. Deep-reef fish species "A" (84 meters).

of tests of the foraminifer Amphistegina) and fine silt to clay sized particles which are easily stirred up and remain in suspension for a long while. The Amphistegina Facies is characterized by the presence of a conspicuous population of echinoderms, particularly the urchin Clypeaster ravenelli and the asteroids Chaetaster sp. (Fig. 76), Narcissia trigonaria and others (Tables 7 and 8). Also, patterned burrows (6 to 12 burrows in circular arrangements of diameters up to ½ meter or so) are overwhelmingly numerous (Fig. 77).

Certainly, the most spectacular part of the East Flower Garden Bank examined by us in 1974, with the exception of the coral reef above 46 meters, is at the outer edge of the algal nodule terrace southeast of the main reef. Here, at a depth of approximately 61 to 64 meters, manifestations appear of what are obviously the drowned remains of an extensive ancient reef. The top edge of the reef is not elevated above the surrounding nodule strewn bottom but the reef face drops abruptly some 9 meters or so. The reef face, with slopes varying from 15° to 45° is cut by surge channels 3 to 6 meters wide emptying onto a nearly bare sand flat at 73 meters. The coarse calcareous sand there is accompanied by some fine grained material easily stirred up. Coralline algae encrusts the old reef-rock thickly in pancake sized to platter sized growths which are easily crushed by the submarine. A few nodules are present on the sand near the reef and on the reef among the encrustations. Antipatharians are abundant on the reef, Spondylus shells were seen, Diadema is present, Neofibularia encrusts the reef in places, the calcareous alga Halimeda was seen at 61 and 67 meters, Sand tilefish burrows occurred on the sand at 70 meters, Chromis enchrysurus is extremely abundant and other fishes typical of outcrops in the Algal-Sponge Zone and upper Antipatharian Zone are well represented (see Table 7). Interestingly, on following the reef face described above with the submarine, it was found that the sand flat at 73 meters was actually the flat floor of a large basin-like hole 9 meters deep, possibly 46 meters in diameter, bordered all around by the drowned reef face which was cut periodically by the small canyon-like surge channels. On the sand floor of the basin large ripple marks (approximately 1 meter across and several centimeters deep) occurred perpendicular to the reef face.

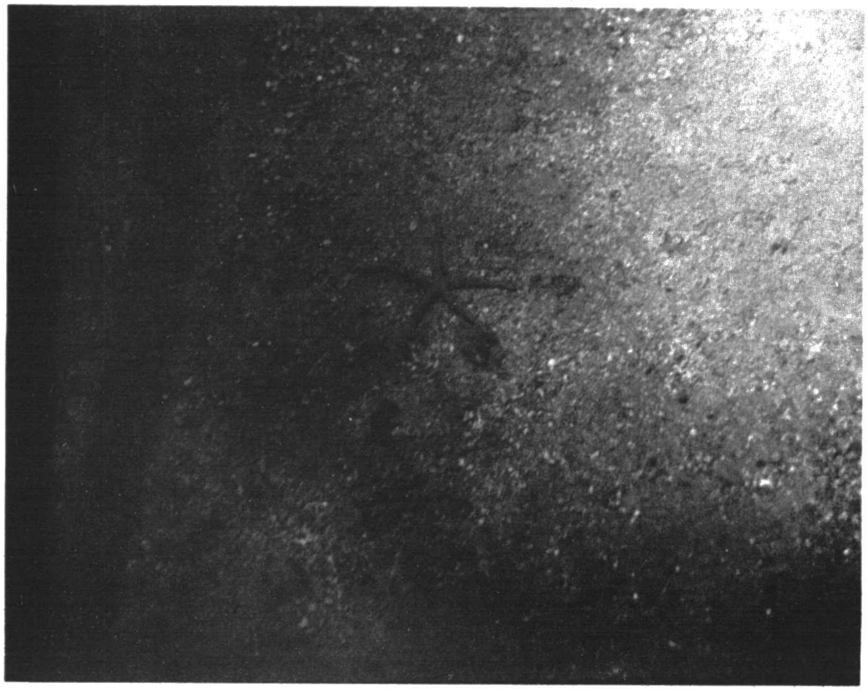


Figure 76. Starfish (Chaetaster) at 85 meters in Soft Bottom Zone.

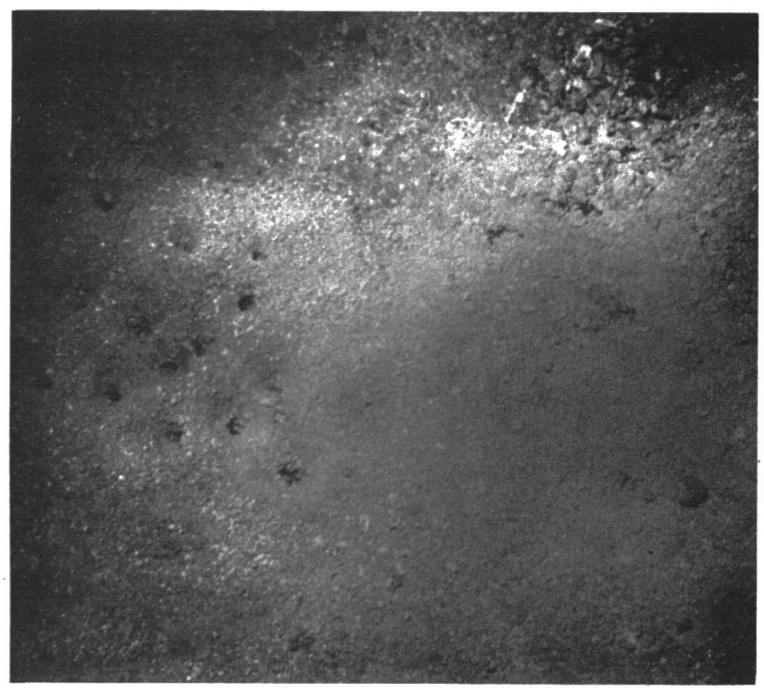


Figure 77. Patterned burrow cluster in Soft Bottom Zone (85 meters).

Leaving the basin on course 110° the submarine immediately encountered, at 67 meters, the rim of a canyon approximately 25 meters wide at the top narrowing to 10 or so meters at the bottom and tending west to east (Fig. 47). The floor of the canyon is coarse calcareous sand with no fines and there are sand channels extending up the canyon walls in places. The mouth of the canyon opens eastward onto the level soft bottom of the *Amphistegina* Facies at 79 meters, which we crossed in the submarine seaward to a depth of 88 meters encountering a sizeable population of sea urchins and asteroid starfishes as described earlier, as well as a small porcupine fish, *Diodon* sp. The canyon thus cuts the nearly vertical face of an ancient drowned reef 12 meters high. Like the reef face bordering the basin nearby, the sides of the canyon and the major reef face it cuts are heavily encrusted by coralline algae.

We were particularly impressed by the population of large game fishes in the vicinity of the basin and the canyon. Schools of hundreds of Cottonwick, *Haemulon melanurum*; large numbers of groupers, *Mycteroperca* spp. and *Dermatolepis inermis* two feet in length; bigeyes, Priacanthidae; and porgys, *Calamus* spp., were present. This would seem to be an excellent hook-and-line fishing locality, though somewhat deep.

The submarine descended into the canyon some distance from its mouth. A bottom current of approximately ½ knot was detected running from the head of the canyon (west) to its mouth (east) (Fig. 47). The water moving in the bottom current was seen to shimmer as water does at a thermocline but we detected no sharp change in temperature (21.7 °C) near the bottom The shimmer may have resulted from high salinity at the bottom, the entire bank is thought to be underlain by a diapiric salt intrusion. The bottom current detected in the canyon continued a short distance out onto the *Amphistegina* Facies, however, ripple marks were observed perpendicular to the northeast-southwest strike of the face of the drowned reef.

Whether these ripple marks are current or storm wave generated is not known. On the floor of the canyon two large drowned reef patches 3 meters high and wide were severely undercut to approximately 1 meter off the bottom. Coarse sand was piled up against the canyon walls on either side of the reef patches, indicating that at least occasionally the current through the canyon must be considerable.

In addition to the above, the central axis of the canyon (about ½ of its width) was coated with a white "slime" a few millimeters thick (Fig. 73). The "slime" did not appear to be alive and is presumed to be a precipitated deposit of some sort. It adhered so loosely to the sand and rocks that efforts to sample it failed insofar as we did not have a proper container associated with the submarine's manipulator arm. Two small gas seeps were seen bubbling intermittently from the sandy bottom of the canyon described above.

Natural gas seeps are common occurrences within the Algal-Sponge and Antipatharian Zones and have been seen by us on the main coral reef. In 1973, seeps were recorded on video tape using towed underwater television within the Diploria-Montastrea-Porites Zone on the western side of the main reef at approximately 36 meters depth. Small streams of gas bubbles issued intermittently from the calcareous sand around the bases of live coral heads approximately 1.5 meters high. The nature of the gas seeps seen there is the same as those seen elsewhere on the bank, periodic serial (1 to several/second) bursts of up to 30 small bubbles which rise in linear groups toward the surface (Fig. 68 and 69). The locality of the seeps observed in 1973 is presumed to be a part of the main coral reef, though the heads are smaller and cover less of the bottom than elsewhere (live coral and skeletal reefrock together covering about 50 percent of the bottom). The gas seeps seemed to arise out of a small patch of moderately close spaced coral heads bordered on the east and west by areas of more sparse coral development. Seaward of this particular seep area the reefrock heads, bearing patches of living coral, cover possibly 25 percent of the bottom for a short distance. This grades into the Algal-Sponge Zone with algal nodules and encrusted rubble over coarse calcareous sand.

Direct observations from the submarine of gas seeps associated with living coral in the Diploria-Montastrea-Porites Zone were not made and the resolution achieved in the video recordings is not sufficient to allow judgments concerning the effects of gas seepage on a major portion of the nearby benthic community. However, there is no visibly apparent difference in the coral cover, "health," and nature of the community there when compared to those seen at other similar sites without seeps on the transect. The other seeps observed at the East Flower Garden in 1974 and 1975 were within the Algal-Sponge Zone northeast of the main coral reef in 43 meters, 50 meters, and 55 meters and in the upper Antipatharian Zone at 55 meters southeast of the main reef (Fig. 68 and 69). These were similar in nature and occurrence to those described for the Diploria-Montastrea-Porites Zone.

No apparent effects on the macrofauna of benthic communities could be detected in either the Antipatharian or Algal-Sponge Zones at the East Flower Garden, using the West Flower Garden, where no seeps were seen, as a control and basis of comparison. Nor were there visually detectable differences in "health," community structure or populations of conspicuous benthic organisms and groundfishes adjacent to points of gas emission. In most cases no evidence whatsoever of the presence of a gas seep, whether it issued from sand or from beneath a coral head or algal nodules, could be detected from the submarine unless the bubbles were seen.

This is not to say that subtler effects on the organisms do not occur. There may be sublethal effects or gas induced modification of populations, distributions and species diversities in those components of the communities too small or too secretive to be detected visually from the submarine. Moreover, the reactions of fishes, which overtly always appeared oblivious of the gas bubbles, are often such that they cannot be easily detected by less than intense and prolonged observation. We can say, however, that on the basis of our observations no fishes appeared to be attracted or repelled by the natural gas issuing from the bottom, though fishermen frequently claim that gas seeps attract such species as the Red snapper, Lutjanus campechanus. In this respect it should be noted that all of the gas seeps observed by us were either in or very close to topographical irregularities which undoubtedly do attract commercial and game fish. Again, however, we know nothing of diel changes in sensitivity and behavior of these fishes relating to their feeding cycle, which in turn of course relates directly to their being caught on hook-and-line. If any of these rather intriguing questions are to be pursued further, more specialized sampling and experimental procedures must be undertaken.

CONDITION OF COMMUNITIES

Comparison of observations made by us in 1974 (before drilling) and 1975 (shortly after drilling) on southeast transects from the main coral reef out to the edge of the bank and into the Soft Bottom Zone indicates no apparent effects of drilling on any of the conspicuous epifauna or groundfish populations. We observed no evidence of recent mortality which could be reasonably attributed to drilling and no signs of undue sedimentation on the bank which may have been associated with the operation. The nature and "health" of the biota within the Algal-Sponge and Antipatharian Zones appeared nearly identical from one year to the next on the basis of observations made by the same personnel, television documentation and color photography. The diversity,distribution and abundance of epifauna and fishes did not differ to an extent which seemed to indicate population changes in the area (Fig. 46, Tables 7 and 8).

It should be pointed out that, considering the requirement for shunting of drilling discharges to below 90 meters, the hard-bank biota most likely to come in contact with effluent from the drilling were those inhabiting the drowned reefs of the lower Antipatharian Zone between 80 and

85 meters. As has been pointed out, this community, though more abundant per unit area at the East Flower Garden, is basically the same as that found on the hard-banks studied by us on the South Texas Outer Continental Shelf. We have speculated, based on observations of the extent of the nepheloid layer on and around these banks, that the community in question is fairly well adapted to withstanding periodic or even possibly chronic conditions of high turbidity and moderate sedimentation.

Even though what could be classified as nepheloid layers at the East Flower Garden have been observed only in depths greater than those at which the drowned reefs occur (Fig. 47), turbidity increases rather steadily below a depth of 75 meters or so. There is reason to believe, therefore, that, at least in the case of possible effects due to sedimentation and turbidity produced by drilling, the epifaunal community most likely to be contacted under current regulations by the "contaminants" may be that which is most adapted naturally to contending with them.

Higher on the bank, however, the predominant epifaunal organisms are encrusting coralline algae and hermatypic corals. These organisms, to a large extent, structure the substrata and contemporary benthic habitats. They are clear water communities, depending heavily upon downwelling light for the massive amount of photosynthetic activity required to maintain them. Therefore, there is good reason to believe that sedimentation and high turbidity are inimical to the health of these most essential and predominant organisms (coralline algae and hermatypic corals) of the upper Antipatharian Zone, Algal-Sponge Zone, Leafy Algae Zone, *Madracis* Zone and *Diploria*-*Montastrea*-*Porites* Zone.

There is some indication, moreover, that the hermatypic corals on the bank suffer a considerable amount of what is presumably "natural" mortality. This could indicate that the reefs are subject to stressful environmental conditions even under normal circumstances.

Figures 78-84 comprise a series of photographs taken within the Diploria-Montastrea-Porites Zone at the East Flower Garden in June 1975. They show a presumed sequence of stages of mortality and deterioration easily observed to some extent on all coral reefs but considerably more conspicuous at the East Flower Garden than on most comparable reefs studied by us in the Caribbean.

Following death of all or part of a coral head (Fig. 81) there is generally at least a temporary invasion of the affected area by "soft bodied" epifauna and/or soft algae (Fig. 80). These initial coatings can be replaced by encrustations of coralline algae (Fig. 52), Millepora (Fig. 50), or re-invasions of still living remnants of the same coral head, as conceivably could have been the case in Figure 79 had not erosion of the dead portion of the head proceeded so far. Occasionally we saw growths of Montastrea on the main reef face which exhibited narrow bands of skeletons of killed polyps around the periphery where new growth should be (Fig. 78). These, however, always gave way inward to healthy polyps which were seemingly in the process of overgrowing the moribund peripheral bands.

It is not clear whether or not the "milky" substance adhering to many of the coral heads at the East Flower Garden (Fig. 82-84) is related in any way to coral mortality. If it is, however, the observed abundance of the substance there is alarming. We estimate that at least 10 percent of the corals seen on the reef bear traces of the substance which seems to be concentrated in depressions and the valleys between coral polyps. Similar but lesser "infestations" were seen at the West Flower Garden in 1972 and 1973. An attempt should definitely be made to determine the nature of the "milky" substance and to assess its significance in terms of "health" of the corals.

Evidences of mechanical damage to the coral reef and Algal-Sponge Zone

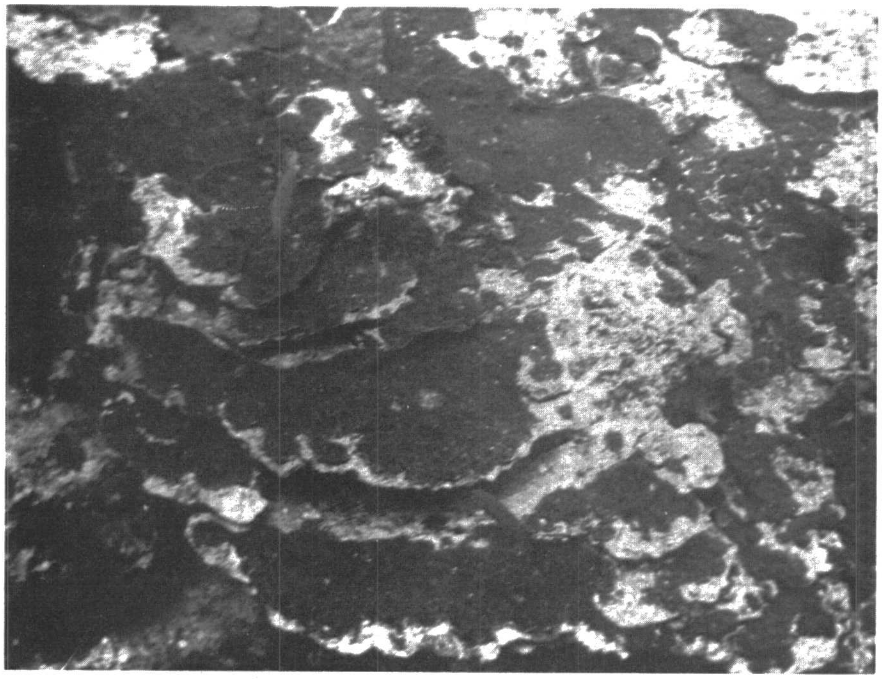


Figure 78. Old mortality of coral polyps around peripheries of shelf-like growths of Montastrea (34 meters).

Figure 79. Old mortality and substantial subsequent erosion of brain coral (20 meters).

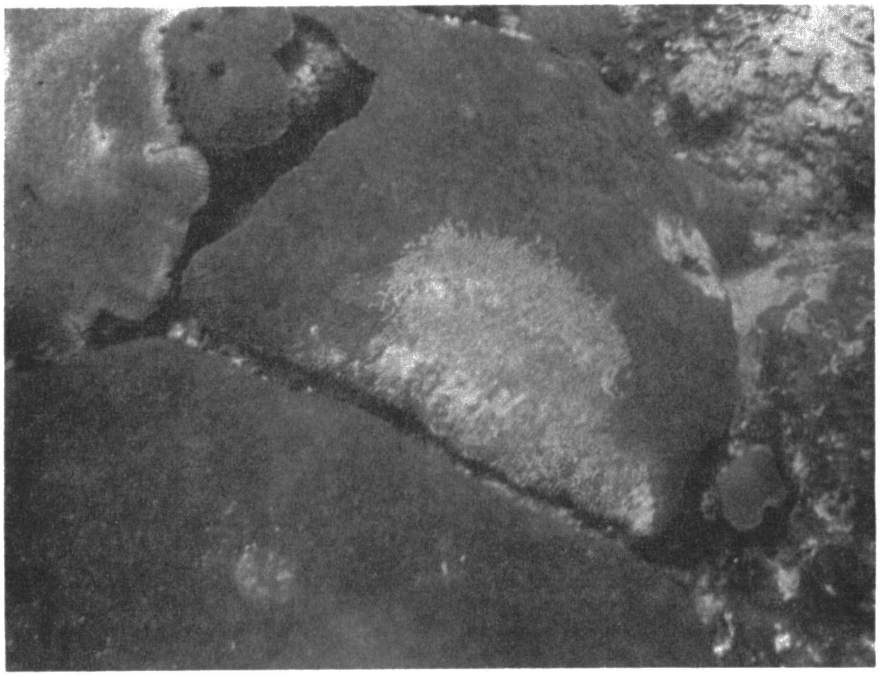


Figure 80. Recent mortality of part of a brain coral head with subsequent colonization of affected area by small amount of epifauna (18 meters).

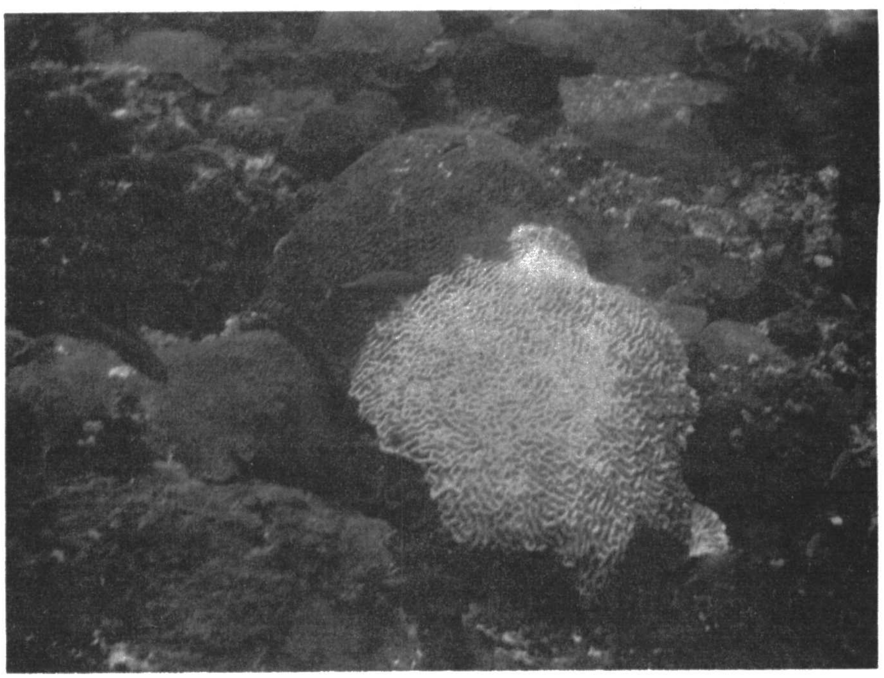


Figure 81. Quite recent mortality of brain coral with no colonization of affected area by epifauna or algae (18 meters).

Figure 82. "Milky" substance on part of Montastrea head (18 meters), note Madracis rubble at bases of heads.

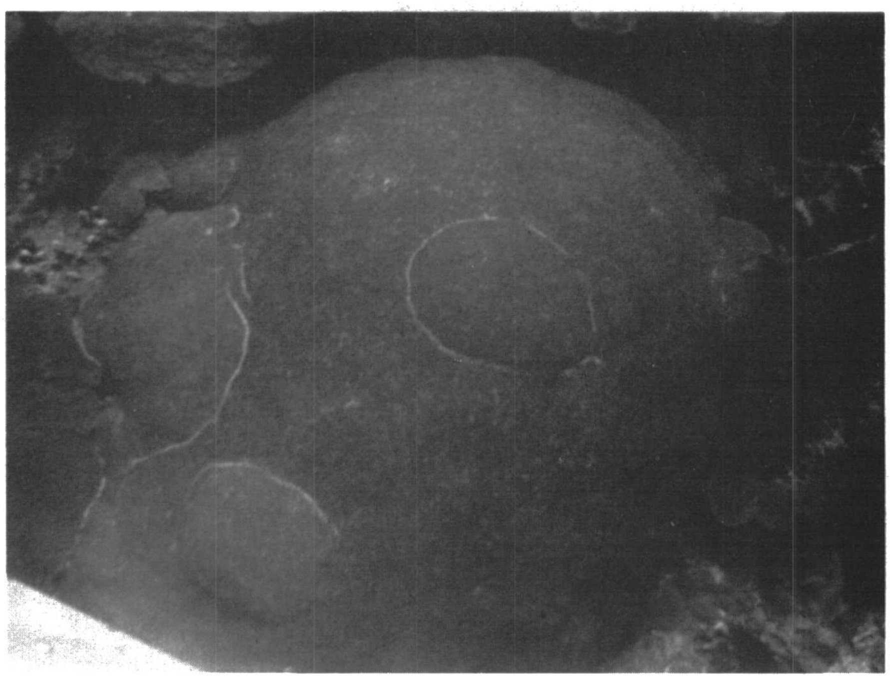


Figure 83. "Milky" substance in linear depressions on Montastrea head (18 meters).

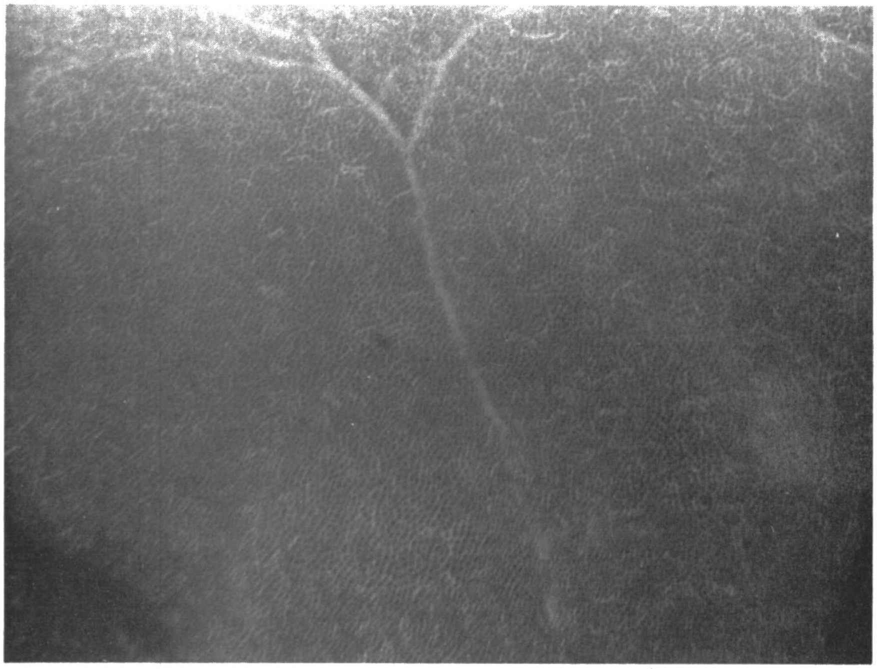


Figure 84. "Milky" substance in linear depressions and valleys between calyces of Montastrea (18 meters).

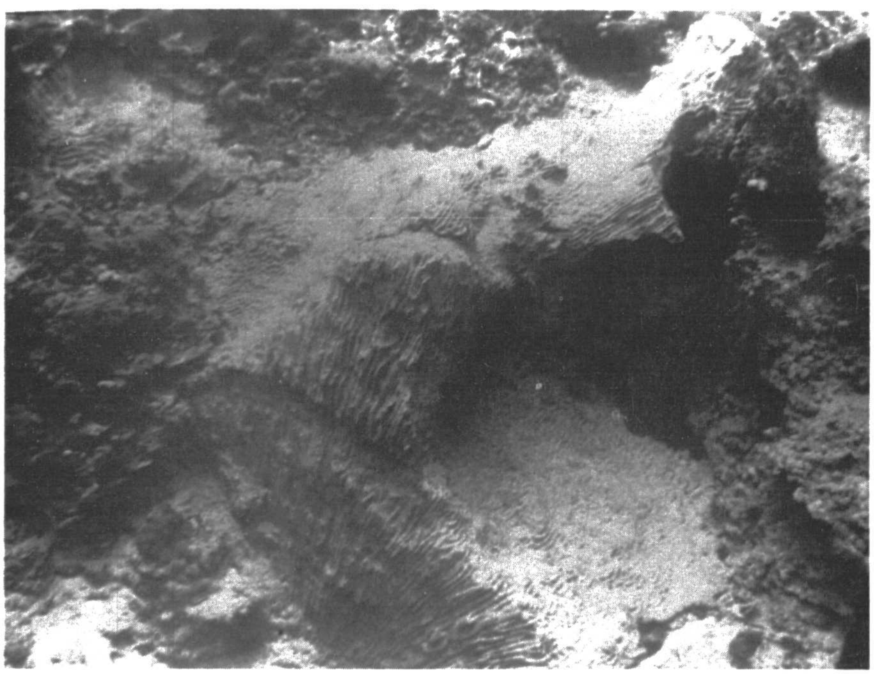


Figure 85. Apparent recent mechanical damage to brain coral head.

were encountered by us during most of the submarine dives. Figure 85 illustrates a brain coral which has apparently been broken recently, possibly by an anchor. Anchor scars are particularly conspicuous on the algal nodule terrace, generally taking the form of more or less circular areas of sand 2 meters or so across, devoid of nodules, where the anchors rested. These sand patches are accompanied by long, denuded grooves ½ meter or so wide where the anchors were dragged. Most of the scars seen have been in the shallower part of the Algal-Sponge Zone near the main reef. In 1974 it was observed that the mooring cable attached to the Coast Guard emplaced navigation buoy was too long and had repeatedly scraped across the bottom in the vicinity of the concrete mooring block thoroughly denuding down to bare rock and sand an area around the block some 30 meters in diameter.

It would appear that more actual damage has so far been done to the bank communities at the East Flower Garden by anchoring and buoy emplacement than by drilling activities. Seemingly, therefore, the restrictions imposed by B.L.M. on drilling at the locality have been adequate so far and should be strictly adhered to in the future. Further recommendations appear in Chapter VII.

Table 1. Southern Bank Species List

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	58-64	7
*Lithophyllum sp.	58	1
FILAMENTOUS GREEN ALGAE		
*Cladophora corallicola	59	1
BROWN ALGAE		
*Fucales	59	1
SPONGES		
No I.D.	59-76	22
Ircinia campana	64	1
*I. fasciculata	?	1
I. strobilina	?	1
I. spp.	59-67	10
I. sp. "A"	?	1
Spongia barbara	?	1
*Haliclona sp.	58	1
Neofibularia sp.	61-66	2
*Callyspongia armigera	?	1
*Thalyseurypon sp.	?	1
*Auletta sp.	58	1
*Suberites sp.	58	1
*Plakortis zyggompha	58	1
HYDROIDS		
No I.D.	61-70	5
Plume-like hydroids	64-70	5
ALCYONARIAN FANS		
Hypnogorgia sp.	68	1
*Thesea sp. "A"	73-76	3
ANTIPATHARIA		
*Cirripathes sp.	58-73	52
ANTHOZOAN STONY CORALS		
*Madracis brueggemanni	58	1
Saucer agariciid	61-64	3
*Ahermatypic solitary sp. "A"	58	4
GASTROPODS		
Busycon sp.	64	1
PELECYPODS		
*Barbatia domingensis	?	1
Pteria sp.	68	1
*Hiatella arctica	?	1
Spondylus americanus	61-70	14
Lima sp.	?	1

Table 1. Southern Bank Species List (continued)

Organism	Observed Depth Range (meters)	No. of Observations
BRACHIOPODS		
*Argyrotheca barrettiana	58	1
POLYCHAETE WORMS		
Hermodice sp.	67	3
*Syllidae	58	5
*Phyllodocidae	?	1
*Nereidae	?	1
*Arabella tricolor	58	1
*Eunice sp.	?	1
CRABS		
*Xanthidae	?	1
Stenorynchus sp.	67	1
HERMIT CRABS		
No I.D.	?	1
SNAPPING SHRIMP		
*Synalpheus townsendi	?	2
AMPHIPODS		
No I.D.	?	9
THALASSINIDS		
No I.D.	?	1
*Axiidae	81	1
STARFISH		
No I.D.	74	1
BRITTLE STARS		
*Ophiothrix angulata	73	1
*Ophiactis savignyi	?	A
*Ophiostigma sp.	73	1
SEA URCHINS		
Diadema sp.	64	1
SEA CUCUMBERS		
*Isostichopus sp.	61	1
CRINOIDS		
Comatulids	61-74	27
FISHES		
Carcharhinidae (requiem sharks)	?	2
Holocentridae (squirrelfish)	61-69	5
Sphyraena barracuda (Great barracuda)	?	1
Mycteroperca sp. (groupers)	57-61	2
Paranthias furcifer (Creole fish)	?	1
Liopropoma sp. (basslet)	61-66	2

Table 1. Southern Bank Species List (continued)

Organism	Observed Depth Range (meters)	No. of Observations
Priacanthidae (bigeyes)	61-75	11
Apogon sp. (cardinalfish)	61	1
Malacanthus plumieri (Sand tilefish)	61	1
Seriola dumerili (Greater amberjack)	58-69	10
Lutjanus campechanus (Red snapper)	59-67	A
Rhomboplites aurorubens (Vermilion snapper)	?	A
Pomadasyidae (grunts)	64	1
Equetus acuminatus (High hat)	61-69	4
E. lanceolatus (Jackknife-fish)	61	1
Chaetodon sedentarius (Reef butterflyfish)	58-69	12
Holacanthus bermudensis (Blue angelfish)	68	1
Pomacentridae (damselfishes)	61	1
Chromis enchrysurus (Yellowtail reeffish)	61-70	19
Labridae (wrasses)	61-64	5
Bodianus pulchellus (spotfin hogfish)	60-69	16
Deep-reef fish "A"	61-70	8
Fish "B"	61-69	8
Burrowing fish "C"	64-66	2

* Specimens archived in Dr. Bright's laboratory.

Table 2. Baker Bank Species List

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	56-61	4
SPONGES		
No I.D.	56-64	26
"U" sponge	61	1
Ircinia campana	?	1
* *I. fasciculata*	61	1
* *I.* sp. "A"	56	1
* *Spongia barbara*	63	1
* *Neofibularia nolitangere oxeata*	56-58	2
Agelas sp.	60	1
* *Auletta* sp.	?	1
* *Epipolasis* sp.	61	1
HYDROIDS		
No I.D.	59	1
Plume-like hydroid	59-61	2
ALCYONARIAN FANS		
No I.D.	56-66	13
* *Hypnogorgia* sp.	61	1
ANTIPATHARIA		
* *Cirripathes* sp.	53-64	23
PELECYPODS		
Spondylus americanus	56-62	18
GALATHEIDS		
Galathea rostrata	69	1
SNAPPING SHRIMPS		
* *Synalpheus townsendi*	61	1
STARFISH		
No I.D.	67	2
BASKET STARS		
No I.D.	56-61	8
Gorgonocephalidae	61	1
? *Astrocyclus caecilia*	61	1
SEA CUCUMBERS		
No I.D.	56	2

Table 2. Baker Bank Species List (continued)

Organism	Observed Depth Range (meters)	No. of Observations
CRINOIDS		
Comatulids	56-64	16
FISHES		
Carcharhinidae (requiem sharks)	58	4
Rajiformes (rays)	57	1
Aulostomus maculatus (Trumpetfish)	60	1
Holocentrus spp. (squirrelfishes)	58-60	2
Sphyraena barracuda (Great barracuda)	0-5	4
Mycteroperca spp. (groupers)	56-60	3
Paranthias furcifer (Creole fish)	60	2
Liopropoma sp. (basslet)	60-61	5
Priacanthidae (bigeyes)	56-60	6
Apogon spp. (cardinalfishes)	60	2
Rachycentron canadum (Cobia)	58	1
Caranx sp. (jack)	60	1
Seriola dumerili (Greater amberjack)	0-60	10
Lutjanus spp. (snappers)	58-64	4
L. campechanus (Red snapper)	56-59	5
Rhomboplites aurorubens (Vermilion snapper)	59	1
Pomadasyidae (grunts)	43-59	3
Haemulon melanurum (Cottonwick)	59	4
Chaetodon sedentarius (Reef butterflyfish)	59-61	3
Holacanthus bermudensis (Blue angelfish)	60	2
H. ciliaris (Queen angelfish)	60	1
Eupomacentrus sp. (damselfish)	60	1
Chromis enchrysurus (Yellowtail reeffish)	43-64	12
Bodianus pulchellus (Spotfin hogfish)	43-64	8
Gobiosoma sp. (sharknose goby)	64	1

* Specimens archived in Dr. Bright's laboratory.

Table 3. South Baker Bank Species List

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	64-67	2
SPONGES		
No I.D.	61-67	41
Ircinia sp.	62-64	6
I. campana	?	1
I. fasciculata	?	1
I. species "A"	?	2
Spongia barbara	65	1
Neofibularia nolitangere oxeata	?	1
Auletta sp.	?	1
Epipolasis sp.	?	1
HYDROIDS		
No I.D.	61-67	2
ALCYONARIAN FANS		
No I.D.	59-64	3
ANTIPATHARIA		
No I. D.		
Thesea sp.	76	1
PELECYPODS		
**Pteria* sp.	76	1
Spondylus americanus	62-67	6
Lima sp.	67	1
POLYCHAETE WORMS		
Hermodice sp.	64	1
CRABS		
**Raninoides lousianensis*	76	1
SPANISH LOBSTERS		
Scyllarides sp.	67	1
HERMIT CRABS		
Paguridae	62	2
BASKET STARS		
Gorgonocephalidae	61-70	13
FISHES		
Carcharhinidae (requiem sharks)	0-73	3
Ophichthidae (snake eels and worm eels)	63	2
Holocentridae (Squirrelfish)	61-67	7
Spyhraena barracuda (Great barracuda)	20-67	11

Table 3. South Baker Bank Species List (continued)

Organism	Observed Depth Range (meters)	No. of Observations
Mycteroperca sp. (groupers)	61-67	25
Paranthias furcifer (Creole fish)	59	1
Liopropoma sp. (basslet)	64-67	2
Priacanthidae (bigeyes)	61-67	4
Apogon spp. (cardinalfishes)	63	1
Malacanthus plumieri (Sand tilefish)	?	1
Echeneidae (sharksuckers)	0	1
Caranx sp. (jacks)	61-63	4
Seriola dumerili (Greater amberjack)	61-64	12
Selene vomer (Lookdown)	58	2
Lutjanus campechanus (Red snapper)	?	3
Rhomboplites aurorubens (Vermilion snapper)	?	3
Equetus spp. (drums)	67	7
Chaetodontidae (angelfishes, butterflyfishes)	61	3
Chaetodon sedentarius (Reef butterflyfish)	61-67	9
Holacanthus bermudensis (Blue angelfish)	63	1
Pomacentridae (damselfishes)	67	2
Chromis enchrysurus (Yellowtail reeffish)	61-67	19
Bodianus pulchellus (Spotfin hogfish)	61-67	11
Labridae (wrasses)	67	3
Tetraodontidae (puffers)	67	1
Canthigaster rostrata (Sharpnose puffer)	63	1
Deep-reef fish "A"	62-76	4

* Specimens archived in Dr. Bright's laboratory.

Table 4. North Hospital Bank Species List

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	61	1
SPONGES		
No I.D.	58-61	11
Ircinia campana	63	1
*I. strobilina	?	1
*I. sp. "A"	61-63	3
*Spongia barbara	58-61	2
*Agelas dispar	58-61	2
ALCYONARIAN FANS		
Hypnogorgia sp.	58	1
ANTIPATHARIA		
No I.D.		
PELECYPODS		
*Chama macerophylla	58	1
*Hiatella arctica	58	1
Spondylus americanus	58-64	4
*NEBALIACEA		
No I.D.	58	1
*TANAIDACEA		
No I.D.	58	1
*ISOPODA		
No I.D.	58	1
AMPHIPODS		
*Gammaridae	58	1
HERMIT CRABS		
No I.D.	58-61	3
GALATHEIDS		
*Galathea rostrata	58	1
CRABS		
*Xanthidae	58	1
SNAPPING SHRIMPS		
*Synalpheus townsendi	58	1
*Synalpheus sp.		
BRITTLE STARS		
*Ophiactis savignyi	58	10

Table 4. North Hospital Bank Species List (continued)

Organism	Observed Depth Range (meters)	No. of Observations
CRINOIDS		
Comatulids	58-61	7
FISHES		
Holocentridae (squirrelfish)	58	1
<u>Mycteroperca</u> spp. (groupers)	61	2
<u>Liopropoma</u> sp. (basslet)	58	1
<u>Lutjanus campechanus</u> (Red snapper)	61	6
Chaetodontidae (angelfish and butterflyfish)	58	1
<u>Chaetodon sedentarius</u> (Reef butterflyfish)	58-61	6
Pomacentridae (damselfish)	61	1
<u>Chromis enchrysurus</u> (Yellowtail reeffish)	58-64	7
<u>Bodianus pulchellus</u> (Spotfin hogfish)	58	3
<u>Gobiosoma</u> sp. (sharknose goby)	61	1
Fish "B"	58	1

* Specimens archived in Dr. Bright's laboratory.

Table 5. Dream Bank Species List

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	62-64	5
SPONGES		
No I.D.	62-66	10
**Ircinia campana*	?	A
**I. fasciculata*	?	1
**I. strobilina*	?	1
**I.* sp. "A"	62-70	4
**Spongia barbara*	?	1
Verongia cauliformis ruta	62	1
**Halisarca* sp.	69	1
**Sigmadocia caerulea*	69	1
**Cyamon vickersi*	69	1
**Microciona* sp.	69	1
**Eurypon clavata*	69	2
**Mycale laevis*	69	1
**M.* sp.	69	1
**Auletta* sp.	69-73	3
A. sp. "A"	69	1
Suberites sp.	?	1
**Terpios fugax*	?	1
**Cliona celata*	62-73	4
**Plakortis zyggompha*	73	1
*?*Timea*	?	1
HYDROIDS		
No I.D.	63	4
Plume-like hydroids	63	2
*Hebellidae	?	1
*Sertularidae	73	1
ALCYONARIAN FANS		
*Paramuriceidae	62	1
**Bebryce* sp.	62	1
Hypnogorgia sp.	62	2
**Scleracis* sp.	63-69	4
**Thesea* sp. "A"	62	1
ANTIPATHARIA		
**Cirripathes* sp.	62-69	22
ANTHOZOAN STONY CORALS		
**Madracis myriaster*	69	1
GASTROPODS		
Cypraea sp.	62	1
Cassis sp.	62	2
Conus sp.	62	3

Table 5. Dream Bank Species List (continued)

Organism	Observed Depth Range (meters)	No. of Observations
PELECYPODS		
*Arca zebra	69	1
*Arcopsis adamsi	69	2
Spondylus americanus	62	8
POLYCHAETE WORMS		
Hermodice sp.	62-67	2
HERMIT CRABS		
No I.D.	62	3
CRABS		
* ?Micropanope sp.	?	1
Stenorynchus sp.	62	6
AMPHIPODS		
*Gammaridae	69	1
BRITTLE STARS		
*Amphioplus sp.	69	1
*Ophiactis sp.		2
*Ophiothrix angulata	69	2
SEA URCHINS		
No I.D.	62	1
CRINOIDS		
Comatulids	62-65	15
FISHES		
Plectrypops retrospinis (Cardinal soldierfish)	62	1
Mycteroperca sp. (groupers)	62	
Liopropoma sp. (basslet)	62	3
Priacanthidae (bigeyes)	62-64	6
Apogon sp. (cardinalfish)	62	3
Echeneidae (sharksuckers)	37	3
Seriola dumerili (Greater amberjack)	27-63	8
Lutjanus spp. (snappers)	62-66	2
Rhomboplites aurorubens (Vermilion snapper)	62	1
Equetus spp. (drums)	62-66	3
Chaeton sedentarius (Reef butterflyfish)	62-64	10
Holacanthus bermudensis (Blue angelfish)	62	1
Chromis enchrysurus (Yellowtail reeffish)	62	3
Labridae (wrasses)	62	3
Bodianus pulchellus (Spotfin hogfish)	62	4
Balistidae (triggerfishes)	62	1
Balistes vetula (Queen triggerfish)	62	1
Canthigaster rostrata (Sharpnose puffer)	62	1
Deep reef fish "A"	62	4
Fish "B"	62	1

* Specimens archived in Dr. Bright's laboratory.

Table 6. Big Adam Bank Species List

Organism	Observed Depth Range (meters)	No. of Observations
SPONGES		
No I.D.	58-60	2
Ircinia sp. "A"	?	1
**Agelas dispar*	?	1
ALCYONARIAN FANS		
No I.D.	58-60	6
ANTIPATHARIA		
**Cirripathes* sp.	58-63	7
BASKET STARS		
Gorgonocephalidae	58	4
FISHES		
Holocentridae (squirrelfish)	58	2
Liopropoma sp. (basslet)	58	2
Priacanthidae (bigeyes)	60	1
Chaetodontidae (angelfish and butterflyfish)	58	1

* Specimens archived in Dr. Bright's laboratory.

Table 7. East Flower Garden Bank Species List, 1972 and 1974

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	15-78	8
Nodules	58-68	7
LEAFY ALGAE		
No I.D.	30-53	7
Chrysymenia	24-53	3
?*Halimeda* sp.	61	1
?*Padina* sp.	49	
ALCYONARIAN FANS		
No I.D.	45	3
ANTIPATHARIA		
Cirripathes sp.	64-73	8
ANEMONES		
Condylactis sp.	43-55	4
HYDROZOAN CORALS		
Millepora spp.	42-55	4
ANTHOZOAN STONY CORALS		
Stephanocoenia intersepta	38	1
Madracis sp.	29-43	2
M. decactis	18-21	2
M. asperula	23	2
Saucer agariciid	18-59	9
Diploria spp.	42-55	2
D. strigosa	18-55	1
Colpophyllia sp.	40-46	2
Montastrea sp.	18-55	4
Scolymia sp.	18-46	1
Mussa sp.	30-43	2
GASTROPODS		
Polinices sp.	23	1
Conus sp.	76	1
Cypraea sp.	20	1
PELECYPODS		
Lima sp. (Flame scallop)	43	1
Cardiidae (cockle)	50	1
Spondylus americanus (American thorny oyster)	37-70	7
CEPHALOPODS		
Octopus sp.	62	1

Table 7. East Flower Garden Bank Species List, 1972 and 1974 (continued)

Organism	Observed Depth Range (meters)	No. of Observations
POLYCHAETE WORMS		
Sabellidae	43	1
Spirobranchus sp.	18-55	3
SHRIMPS		
No I.D.	58	1
Tuleariocaris neglecta	23-24	2
CLEANER SHRIMPS		
No I.D.	55	1
LOBSTERS		
Scyllarides aequinoctialis (Spanish lobster)	18	1
CRABS		
Stenorynchus seticornis (Arrow crab)	49-83	4
Carpilius corallinus	18	1
SEA URCHINS		
Diadema antillarum	18-67	4
Clypeaster ravenelli	82	3
STARFISH		
Astropecten sp.	82	1
Narcissia trigonaria	84	1
?*Ophidiaster guildingii*	82	1
BRITTLE STARS		
Ophiothrix suensonii	67	1
?*Astrocyclus caecilia*	?	2
CRINOIDS		
Comatulids	76	2
FISHES		
Ginglymostoma cirratum (Nurse shark)	40	1
Manta birostris (Atlantic manta)	surface	1
Gymnothorax sp. (moray eel)	49-55	2
G. moringa (Spotted moray eel)	18	1
Aulostomus maculatus (Trumpetfish)	18	
Holocentrus ascensionis (Longjaw squirrelfish)	44	
H. sp. (squirrelfish)	18-76	9
Sphyraena barracuda (Greater barracuda)	18-70	2
Epinephelus spp. (hinds)	49-55	4
E. adscensionis (Rock hind)	31-55	4
Dermatolepis inermis (Marbled grouper)	29-67	2
Mycteroperca spp. (groupers)	31-79	15
Paranthias furcifer (Creole fish)	15-72	5
Liopropoma sp. (basslet)	52-67	4

Table 7. East Flower Garden Bank Species List, 1972 and 1974 (continued)

Organism	Observed Depth Range (meters)	No. of Observations
Priacanthidae (bigeyes)	52-59	3
Apogon sp. (cardinalfish)	18-53	3
Malacanthus plumieri (Sand tilefish)	22-70	10
Caranx spp. (jacks)	33-67	?
C. fusus (Blue runner)	44	1
C. ruber (Bar jack)	40	1
Seriola sp. (amberjack)	44	1
S. dumerili (Greater amberjack)	44-67	5
Coryphaena hippurus (Dolphin)	surface	1
Lutjanus campechanus (Red snapper)	31-55	2
Haemulon melanurum (Cottonwick)	20-67	3
Calamus spp. (porgys)	31-79	8
Equetus lanceolatus (Jackknife-fish)	43-49	2
Mulloidichthys martinicus (Yellow goatfish)	43-49	?
Pseudupeneus maculatus (Spotted goatfish)	43-67	2
Chaetodon aculeatus (Longsnout butterflyfish)	18-46	1
C. ocellatus (Spotfin butterflyfish)	43	1
C. sedentarius (Reef butterflyfish)	18-70	11
Holacanthus sp. (angelfish)	50	1
H. ciliaris (Queen angelfish)	49-60	2
H. bermudensis (Blue angelfish)	49-60	2
H. tricolor (Rock beauty)	18-76	3
Pomacanthus paru (French angelfish)	43-53	2
Centropyge argi (Cherubfish)	49-53	4
Chromis cyaneus (Blue chromis)	43-49	3
C. multilineatus (Yellow-edged chromis)	43-49	?
C. enchrysurus (Yellowtail reeffish)	30-55	14
Eupomacentrus partitus (Bicolor damselfish)	15-52	8
Bodianus rufus (Spanish hogfish)	42	2
B. pulchellus (Spotfin hogfish)	43-67	6
Clepticus parrai (Creole wrasse)	23	1
Halichoeres garnoti (Yellowhead wrasse)	46	1
H. radiatus (Puddingwife)	46	1
Thalassoma bifasciatum (Bluehead)	15-53	2
Scarus spp. (parrotfish)	18-43	4
S. taeniopterus (Princess parrotfish)	15-49	?
Sparisoma viride (Stoplight parrotfish)	40-50	?
Gobiosoma sp. (sharknose goby)	49	1
Acanthurus sp. (surgeonfish)	49-67	3
Balistes capriscus (Gray triggerfish)	46-79	3
B. vetula (Queen triggerfish)	37-52	2
Melichthys niger (Black durgon)	15	1
Lactophrys triqueter (Smooth trunkfish)	18-43	1
Acanthostracion sp. (cowfish)	49-50	1
Canthigaster rostrata (Sharpnose puffer)	18-55	3
Diodontidae (porcupinefishes)	85	1
Ogcocephalus vespetilia (Batfish)	49	1

Table 8. East Flower Garden Bank Species List, 1975

Organism	Observed Depth Range (meters)	No. of Observations
CORALLINE ALGAE		
Encrusting	24-86	18
LEAFY ALGAE		
*?*Gloiophlaea halliae*	24	7
**Galaxaura obtusata*	?	1
**Caulerpa racemosa* var. *macrophysa*	24	6
**Pocokiella variegata*	24-55	2
**Udotea occidentalis*	24-55	6
**Microdictyon boergesenii*	55	2
*?*Halymenia floridana*	50	6
**Chrysmenia halymenioides*	24-50	3
**Jania capillacea*	?	1
**Hypoglossum tenuifolium*	?	1
*?*Nemalion* sp.		
SPONGES		
No I.D.	24-60	19
Ircinia strobilina	24	3
I. species "A"	?	2
Spongia barbara	?	1
**Verongia cauliformes rufa*	26-55	5
Neofibularia nolitangere oxeata	24-57	11
Siphonodictyon coralliphagum	24	2
Agelas dispar	24-57	3
Spirastrella sp.	24	2
HYDROIDS		
*Plumularidae	55	2
ANTIPATHARIA		
Cirripathes sp.	44-104	14
ANEMONES		
Condylactis sp.	45-59	7
HYDROZOAN CORALS		
Millepora alcicornis	15-55	M
ANTHOZOAN STONY CORALS		
Stephanocoenia intersepta	38	S
Madracis decactis	15-21	M
**M. asperula*	55-56	S
**M. mirabilis*	23	A
**M. brueggemanni*	62	R
Saucer-shaped Agariciid	60-73	M

Table 8. East Flower Garden Bank Species List, 1975 (continued)

Organism	Observed Depth Range (meters)	No. of Observations
ANTHOZOAN STONY CORALS (continued)		
Agaricia sp.	15-59	M
A. agricites agaricites	20	1
A. agricites	?	1
Helioseris cucullata	55-62	2
Porites astreoides	21-40	M
Diploria spp.	15-55	M
D. strigosa	15-55	A
Colpophyllia natans	21	M
* *C.* spp.	40-46	?
* *Montastrea annularis*	21	A
M. cavernosa	15-60	M
Scolymia sp.	37	2
Mussa angulosa	30-54	S
PELECYPODS		
Spondylus americanus	39-62	S
POLYCHAETE WORMS		
Sabellidae	55-89	3
Spirobranchus sp.	17-25	M
CRABS		
Stenorynchus seticornis	55-83	3
Munida sp.	92-104	2
CLEANER SHRIMPS		
No I.D.	55	1
STARFISH		
No I.D.	37	1
Narcissia trigonaria	92-113	3
* *Chaetaster nodosus*	85	1
* Spinulosida	?	1
BRITTLE STARS		
* *Ophiothrix angulata*	?	1
* *O. pallida*	?	1
* *Ophiactix savignyi*	?	A
SEA URCHINS		
Diadema antillarum	18-55	6
Clypeaster sp.	67-107	3
CRINOIDS		
Comatulids	92	2

Table 8. East Flower Garden Bank Species List, 1975 (continued)

Organism	Observed Depth Range (meters)	No. of Observations
FISHES		
Ginglymostoma cirratum (Nurse shark)	24	1
Manta birostris (Manta ray)	0-28	3
Gymnothorax spp. (moray eels)	39-55	
Aulostomus maculatus (Trumpetfish)	24	1
Holocentrus spp. (Squirrelfish-large species)	45-61	3
Sphyraena barracuda (Great barracuda)	0-37	A (13)
Epinephelus adscensionis (Rock hind)	30-61	3
Mycteroperca spp.(groupers)	9-85	27
Dermatolepis inermis (Marbled grouper)	24	1
Paranthias furcifer (Creole fish)	24-55	9
Liopropoma sp. (basslet)	55	2
Priacanthidae (bigeyes)	59-92	4
Serranus annularis (Orangeback bass)	45-55	6
Amblycirrhitus pinos (Redspotted hawkfish)	24	1
Malacanthus plumieri (Sand tilefish)	55	3
Sand tilefish burrows	30-55	6
Caranx spp. (jacks)	0-39	9
C. ruber (Barjack)	35	1
Seriola dumerili (Greater amberjack)	55	3
Lutjanus campechanus (Red snapper)	24-85	5
Haemulon melanurum (Cottonwick)	79	1
Calamus spp. (porgys)	24-61	10
Equetus acuminatus (High hat)	61	1
Mulloidichthys martinicus (Yellow goatfish)	30-40	2
Pseudopeneus maculatus (Spotted goatfish)	40-73	4
Chaetodon aculeatus (Longsnout butterflyfish)	55	1
C. ocellatus (Spotfin butterflyfish)	45	1
C. sedentarius (reef butterflyfish)	30-73	8
Pomacanthus spp. (angelfishes)	55	1
P. paru (French angelfish)	30-45	3
P. arcuatus (Grey angelfish)	18-36	2
Holacanthus ciliaris (Queen angelfish)	45-55	3
H. bermudensis (Blue angelfish)	55-61	2
H. tricolor (Rock beauty)	18-25	2
Centropyge argi (Cherubfish)	24-55	6
Eupomarentrus spp. (damselfishes)	28-45	2
E. purtitus (Bicolor damselfish)	24-28	5
Chromis cyaneus (Blue chromis)	24-46	4
C. enchrysurus (Yellowtail reeffish)	18-73	16
Bodianus rufus (Spanish hogfish)	15-40	2
B. pulchellus (Spotfin hogfish)	44-85	5
Labridae (wrasses)	27-55	4
Thalassoma bifasciatum (Bluehead	24-31	6
Clepticus parrai (Creole wrasse)	24	2
Scarus spp. (parrotfishes)	24-55	6
Sparisoma viride (Stoplight parrotfish)	24-46	4
Gobiosoma sp. (sharknose goby)	45-55	2
Acanthurus spp. (surgeonfishes)	40	1
A. coeruleus (Blue tang)	24	2

Table 8. East Flower Garden Bank Species List, 1975 (continued)

Organism	Observed Depth Range (meters)	No. of Observations
Balistidae (triggerfishes)	0-40	9
Balistes vetula (Queen triggerfish)	15-55	5
Melichthys niger (Black durgon)	30	1
Lactophrys triqueter (Smooth trunkfish)	24	2
Canthigaster rostrata (Sharpnosed puffer)	24-55	5
Deep-reef fish "A"	61-85	4
Fish "B"	61-73	2
Burrowing fish "C"	55	1

A--Abundant

M--Moderate

S--Scarce

R--Rare

* Specimens archived in Dr. Bright's laboratory

CHAPTER VII

RECOMMENDATIONS

RECOMMENDATIONS

One of the purposes of this project was to provide information which would be useful in assessing the ecological "value" of the South Texas banks, to aid in determining the degree to which effort should be expended to "protect" them. Toward these ends we can now say that:

1) The South Texas banks do not bear significant living populations of hermatypic corals, nor is it likely that such populations will develop there under prevailing natural environmental conditions.

2) Though less than lush, the epibenthic hard-bank populations are well structured and seemingly in balance with the extant hydrographic and sedimentary conditions.

3) There are relatively few of these banks, and they bear limited epibenthic populations. Therefore, the overall extent of the Texas Outer Continental Shelf hard-bank biota is very small compared to a region such as the Eastern Gulf of Mexico.

4) Although the most important commercial and gamefish populations are migratory, their migrations are probably from bank to bank within the northern Gulf of Mexico, and they may be somewhat dependent on resident forage fish found in fair abundance on the banks.

5) The benthic communities of the South Texas banks appear to be rather adapted to severe conditions of turbidity, sedimentation, and large and rapid fluctuations in salinity and possibly temperature, but may be existing under borderline natural environmental stress.

In view of the above, we recommend a cautious attitude regarding protection of the South Texas banks, at least in the initial phases of regional drilling. It would be wise, initially, to bar drilling activities within 750 meters of the bases of the banks and to impose requirements for shunting to the extent that no sediment plumes would be expected to contact the upper 15 meters or so of any of the banks, except possibly Big Adam Rock. Appropriate and effective monitoring programs should be implemented which include tracking of the sediment plumes and the taking, at least, of current measurements and temperature and salinity observations. Such programs should require <u>real</u> <u>time</u> feedbacks of freshly gathered information to a federal official empowered to make decisions which may result in immediate modification of the drilling operation in the event something environmentally disturbing is detected.

In the case of the East Flower Garden we recommend continuation of all established restrictions on drilling activities. They obviously were adequate for the first well drilled and should under no circumstances be downgraded. Future monitoring programs could be scaled down considerably but as mentioned above, should involve sediment plume tracking, hydrographic observations, and real time feedback of information to responsible federal officials. Moreover, there should be heavy reliance on during-drilling visual monitoring and inspection of the coral reef by qualified reef biologists instructed to look for signs of sedimentation, recent mortality, and deteriorating "health" of members of the reef community. Before and after drilling, visual assessments of the condition of the organisms inhabiting the algal nodule terrace and drowned reefs down to at least 80 meters depth should be made.

Continuing assessment of the environmental relationships between the hardbank communities on Texas Outer Continental Shelf banks and drilling-production activities should involve a better understanding of the influence of natural turbidity and sedimentation on predominant benthic organisms of the various biotic zones, particularly with respect to coralline algae and hermatypic corals. Studies of the fate of drill cuttings and other waste dumped during drilling and production should be encouraged. It would certainly be useful to make pertinent observations on and around any banks (Three Hickey Rock is one, see Fig. 1 of Chapter III) near which drilling has occurred in the past to see if any lasting environmental impact on the local benthic communities could be detected.

Questions raised in this report concerning natural mortality of hermatypic corals at the East and West Flower Gardens should be pursued, with special attention to possible infectious deseases and the nature of the existing balance between coral mortality and growth rates.

Considering the results of our 1975 studies of the South Texas banks and the East Flower Garden, we feel that exploratory drilling and subsequent oil or gas production near the banks are quite compatible with the continued well-being of the banks' biota, as long as reasonable and well planned regulations on drilling and subsequent activities are devised and adhered to.

It is probable that such regulations can be less stringent in relation to the South Texas banks, particularly Big Adam Rock, than those advisable for Stetson Bank, the East and West Flower Gardens, Twenty Eight Fathom Bank, and other banks bearing clear-water biotic communities at the edge of the Outer Continental Shelf off Texas and Louisiana.

Possibly the best "indicator organism" for assessing effects of sedimentation and turbidity on the "health" of these hard-bank communities will be the encrusting coralline algae which occur to some extent in all of them. The percent cover of such algae appears to reflect currently prevailing natural conditions (high percentage cover in clear water and low percentage under chronically turbid conditions). Changes in percent of living coralline algae cover at selected sites over short periods of time could easily be detected visually and documented photographically.

As a potential chemical-physiological "indicator organism" we recommend *Spondylus americanus* (the large American thorny oyster), sizeable attached populations of which have been found on all the South Texas banks and at the Flower Gardens. Not only could the soft parts of this filter-feeding organism be effectively analyzed for petroleum hydrocarbons and heavy metals, but the species is a likely subject for investigations into the mechanisms of incorporation into the tissues of such marine organisms of contaminants and their toxicity and sublethal effects on certain basic physiological processes.

The most obvious and often observed environmental impact of human activity on the hard-bank communities is mechanical disruption due to anchoring and emplacement of large buoys, leaving scars on the algal nodule terraces and broken coral heads at the Flower Gardens and Twenty Eight Fathom Bank. We recommend that some attempt be made to assess possible future effects of anchoring and other mechanical disturbance of hard-bank communities in light of probable increases in the presence of commercial, recreational, industrial, and scientific users.

Perhaps the meiofauna can be utilized to provide insights into subtle sedimental and/or chemical changes resulting from man's activities. To do this it is recommended that microscale measurements of physico-chemical parameters (e.g. Eh, selected metals, hydrocarbon levels, total carbon content) of the meiofaunal habitats in addition to simple grain-size analysis should be made. Also, it is recommended that a reliable box-corer type sampler be used and that a sufficient number of replicates per box-core sample be analyzed to determine the natural spatial variations in the populations of the permanent meiofauna. Finally, the data derived should be presented in such form as to be tested in various combinations by multivariate analyses.

APPENDIX

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The Department of the Interior Mission

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 sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; 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 ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.