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NORTHWESTERN GULF OF MEXICO
TOPOGRAPHIC FEATURES
STUDY

EXECUTIVE SUMMARY
OF THE
FINAL REPORT

SUBMITTED TO THE

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

OUTER CONTINENTAL SHELF OFFICE

NEW ORLEANS, LOUISIANA

CONTRACT NO. AA550-CT7-15

APRIL 1979

RESEARCH CONDUCTED BY THE

COLLEGE OF GEOSCIENCES

TEXAS A&M UNIVERSITY COLLEGE STATION, TEXAS

Through The
TEXAS A&M RESEARCH FOUNDATION

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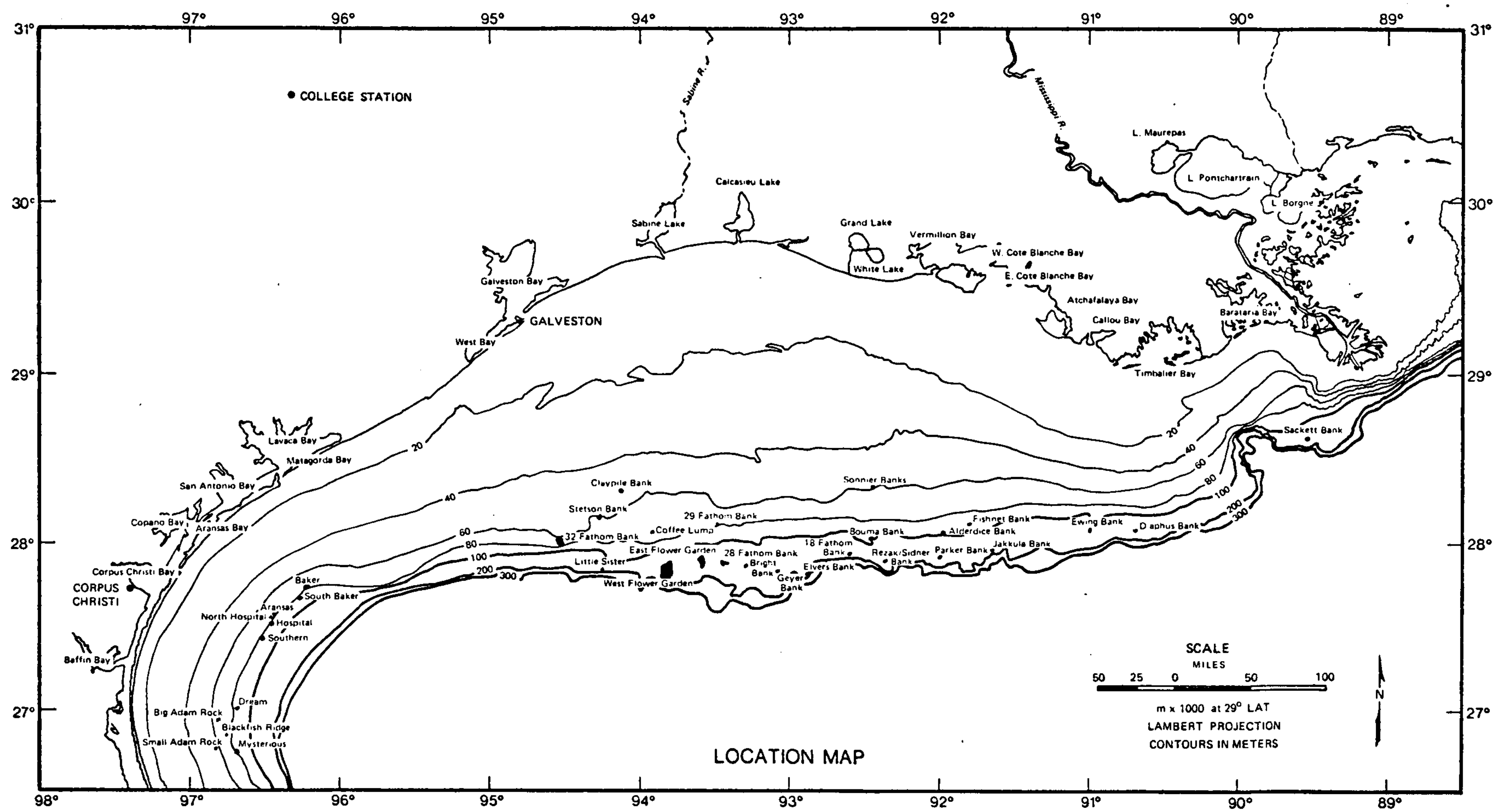


Figure I-1. Major topographical features on the Texas-Louisiana Outer Continental Shelf.

I. INTRODUCTION

During 1977 detailed bathymetric charts were produced for the following banks on the Texas-Louisiana Outer Continental Shelf: 1) Bouma, 2) Bright, 3) Claypile, 4) 18 Fathom, 5) Ewing, 6) Parker, 7) Sonnier and 8) Sackett. The locations of these banks are shown in Figure I-1.

Descriptive reconnaissance studies were completed for Bouma, Bright, Ewing, Parker, Sackett, Sonnier and 18 Fathom Banks. The reconnaissance studies include the geology and biology of the banks as observed from the submersible. In addition, at the East Flower Garden, Sonnier, Bright and Sackett Banks, the study included: the size distribution and mineralogy of the surrounding sediments; hydrography in the vicinity of the banks; chemical analyses of sediments and selected faunal components for trace metals and heavy molecular weight hydrocarbons; chemical analyses of the water column for nutrients, dissolved oxygen, and low molecular weight hydrocarbons; and temperature, salinity, transmissivity and current velocity profiles of the water column.

A monitoring study was initiated within the living coral portion of the East Flower Garden Bank. Through the use of long and short term time lapse camera systems, the spread of pathological conditions and the effect of physical damage to reef coral were observed. The brine lake discovered in 1976 was visited and further observations of this phenomenon were made.

Also at the East Flower Garden, a study of very near-bottom current magnitude and turbulence was made using a dye emission apparatus observed from the submersible.

The study of the composition and density of meiofaunal and macroinfaunal populations living on or around the flanks of the East Flower Garden Bank and Sonnier Banks was continued.

Also continued was the study of the distribution of reworked fossil coccoliths on the South Texas Outer Continental Shelf initiated during 1976. This study has resulted in a much more detailed map of the transport pathways of suspended sediment.

CHARACTERIZATION OF BANKS

II. CHARACTERIZATION OF BANKS

INTRODUCTION

Descriptions of the physiography of the banks are based upon the bathymetric surveys and submersible observations. The sediments are characterized by: 1) clay mineralogy, 2) grain-size distribution, 3) total carbonate percent, 4) bulk mineralogy, and 5) particle type identification of the coarse fraction.

Hydrography on Bright, Parker, Sackett and Sonnier Banks is based upon a single visit to each bank during which four stations were occupied on each bank to measure the distribution of temperature, salinity, transmissivity and current veolocity with respect to depth.

Current profiles at these stations indicate extreme variability in direction and velocity of currents in the water column. Salinity and temperature profiles augmented by submersible observations demonstrate the presence of interval waves having a maximum amplitude of about 10 m and periods that vary from 12 hours to 10 minutes.

Descriptions of the zonation, structure, species composition and relative population levels of epibenthic biotic communities occupying 18 Fathom, Bright, Bouma, Parker, Ewing, Sackett and Sonnier Banks were derived from data and samples taken using the Texas A&M research submersible in September, 1977.

All of the banks are associated with shallow subsurface salt structures. Bright, Bouma, 18 Fathom, Ewing, Parker and Sackett Banks are shelf-edge features while Sonnier is a mid-shelf bank. Due to the shallower water depths at the mid-shelf banks, lower winter temperatures and higher turbidity throughout the year probably inhibit the growth of hermatypic corals. Consequently, the mid-shelf banks in the study area are primarily composed of Tertiary bedrock that has been elevated above the normal mid-shelf depths due to salt tectonics.

Sedimentological studies indicate that Sonnier Banks are the only anomalous banks of those studied during 1977. The sediments surrounding the banks contain an abundance of quartz, low Mg calcite, lithoclasts, and calcite rhombs which taken together indicate exposure of the banks during Pleistocene time with the resulting conversion of high Mg calcite and aragonite to low Mg calcite and erosion of the exposed Tertiary bedrock.

Biotically, the banks fall into three categories (Bright et al., 1978). 18 Fathom, Bright, Bouma, Parker and Ewing Banks support active, diverse, reefal communities dominated by anthozoan corals and/or coralline algae. Sonnier Banks (category 2) are comprised of siltstone outcrops encrusted with populations of hydrozoan fire coral, sponges and other epifauna similar to that found on Stetson Bank (see Bright et al., 1978). Sackett Bank (category 3 or 4), possibly because of its close proximity to the Mississippi River and the probable chronic stress associated with variations in turbidity and salinity due to the river outflow, is not occupied by extensive, thriving coral or coralline algal communities, although drowned remnants of previously active coralline algae reefs are present and small populations of coralline algae occur as scattered nodules and crusts.

BOUMA BANK
(Figures II-1-3)

Geology

Bouma Bank (28°02'N, 92°27'W) is a nearly circular feature about 5.5-5.8 km in diameter. Maximum relief is 47 m and occurs in the southern portion of the bank. The two major peaks rise to depths of 60 m and 65 m. To the north of the 65 m peak, a large depression signals the early stages of collapse of the crest of the bank. The rough topography on the northwestern and northern sides of the bank (Figures II-1- 2) indicates that those parts of the bank have already collapsed and the peaks in those areas are partially buried beneath recent sediments. The three valleys, located on the north, southwest, and south sides of the bank, appear to be erosional features but are most likely structurally controlled.

The sediments on the bank are described on the basis of submersible observations only. The upper portion of the bank is covered by large coralline algal nodules lying on top of coarse carbonate sand. Between 62 and 65 m depth the nodule cover is 80-90%. The amount of nodules decreases to 15-20% at 68 m, 10-15% at 72 m, and they are absent below 75 m depth. As the nodules decrease in abundance with depth there is an increase in the amount of fine silt and clay in the bottom sediment. In addition to the nodules, actively growing coralline algal reef patches and ledges occur from the crest of the bank to at least 70 m depth. Small, drowned, reefal structures occur at greater depths but live coralline algal cover on them is comparatively slight. Flatish crusts of coralline algae occur on the sand and bridge overgroups of nodules in places above 68 m depth. Continued growth of these crusts will stabilize the particulate bottom sediment and provide a hard substrate for continued reef growth.

Biology

Bouma Bank bears clear water carbonate reefal communities dominated by coralline algae populations typical of the ALGAL-SPONGE ZONE, with a community composed of plants, invertebrates and fishes found in corresponding zones at the West Flower Garden, East Flower Garden, 28 Fathom, 18 Fathom, Ewing, and Parker Banks (see Figure II-3). Whereas the species composition of all the ALGAL-SPONGE ZONE communities on all the banks listed is basically the same, differences in relative abundances of some of the more conspicuous species are apparent from bank to bank. Bouma Bank has especially large populations of gorgonocephalan basket stars and the anemone, Condylactis sp.

Leafy algae populations on the crest of Bouma Bank do not appear to be as substantial as those found on some of the other banks, though considerable amounts of Caulerpa sp. and Microdictyon sp. are associated with the algal nodules. Leafy algae populations are undoubtedly subject to seasonal variations and are rather ephemeral. Such is strongly indicated by massive accumulations of loose algal detritus on the lower flanks of the bank. Algal detritus must contribute substantial amounts of food to epibenthic and infaunal communities on and adjacent to the bank.

Natural gas seeps were encountered in the ALGAL-SPONGE ZONE at 62 and 68 m depth. Except for white patches several centimetres in diameter at the points of gas emission, there was no visually detectable

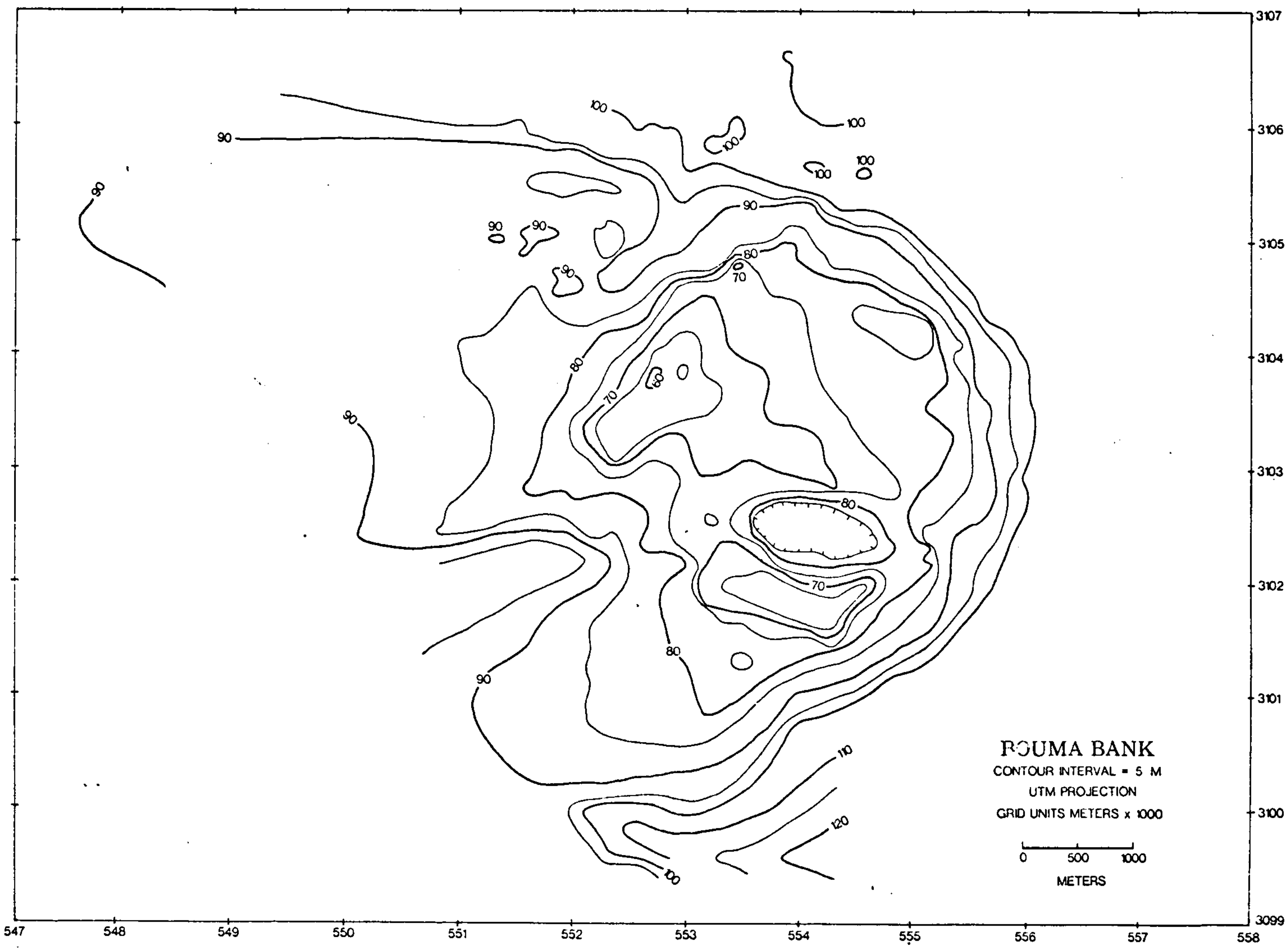


Figure II-1. Bathymetric map of Bouma Bank.

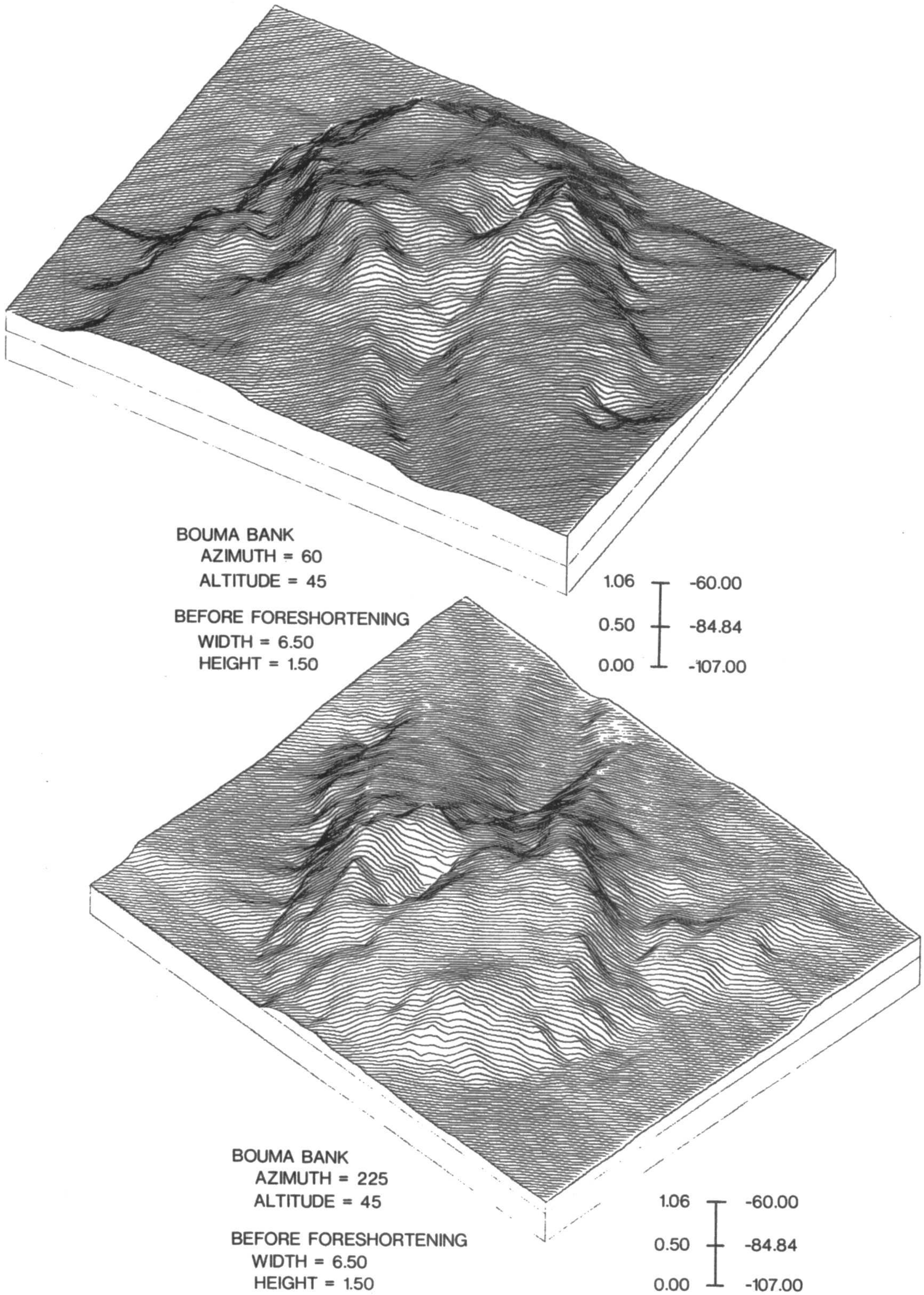
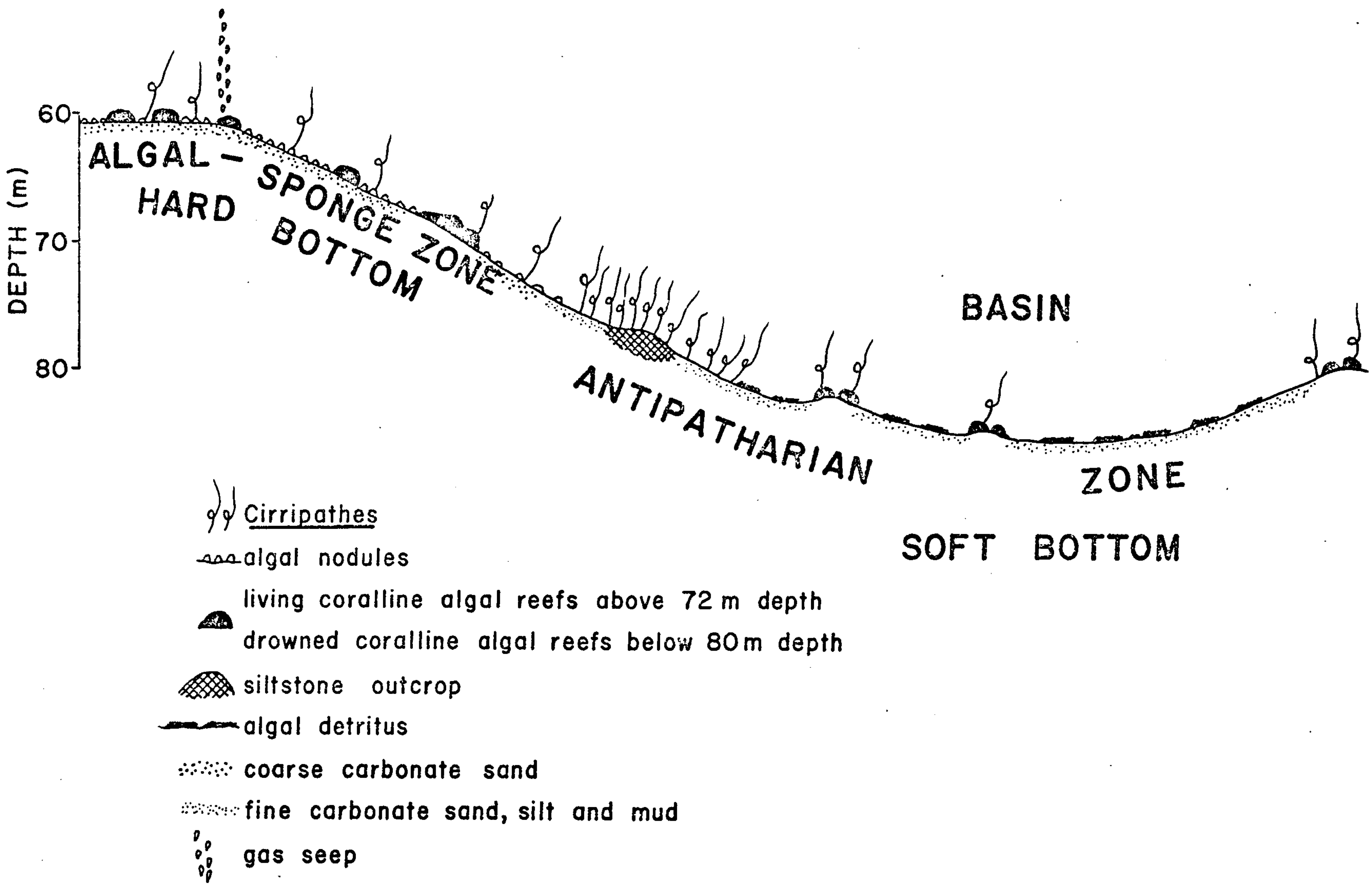


Figure II-2. Three dimensional perspective views of Bouma Bank: 60° and 225° azimuth.

Figure II-3. BOUMA BANK



difference in the coralline algal crusts at the seeps when compared to crusts some distance away.

Drowned carbonate reef patches covered with thin veneers of fine sediment occur on slight rises at 79, 82, 83 and 84 m depth. Small amounts of live coralline algae, less than 5% cover, are present on these structures. They also house populations of sessile and mobile invertebrates and fishes typical of the ANTIPATHARIAN ZONE.

The predominant, conspicuous benthic invertebrates occupying the surrounding soft bottom are Cirripathes sp. and several species of echinoderms. A very large population of small comatulid crinoids occurs between 80 and 82 m depth.

Bouma Bank should be classified, along with 28 Fathom Bank and other similar features, as a first priority bank for purposes of environmental protection.

BRIGHT BANK
(Figures II-4-6)

Geology

Bright Bank (27°53'N, 93°18'W) is 6.3 km wide in an east-west direction and 5.8 km long in a north-south direction. Maximum relief is about 70 m on the east side of the bank. The crest of the bank between 50 and 55 m is a broad surface of very low relief. Scattered over this surface are outcrops of Pleistocene(?) reef rock. The relief on the reef rock appears to be 45 to 60 cm. The rock is jointed and large areas of coarse sand, coral and algal nodules lie between the joint blocks.

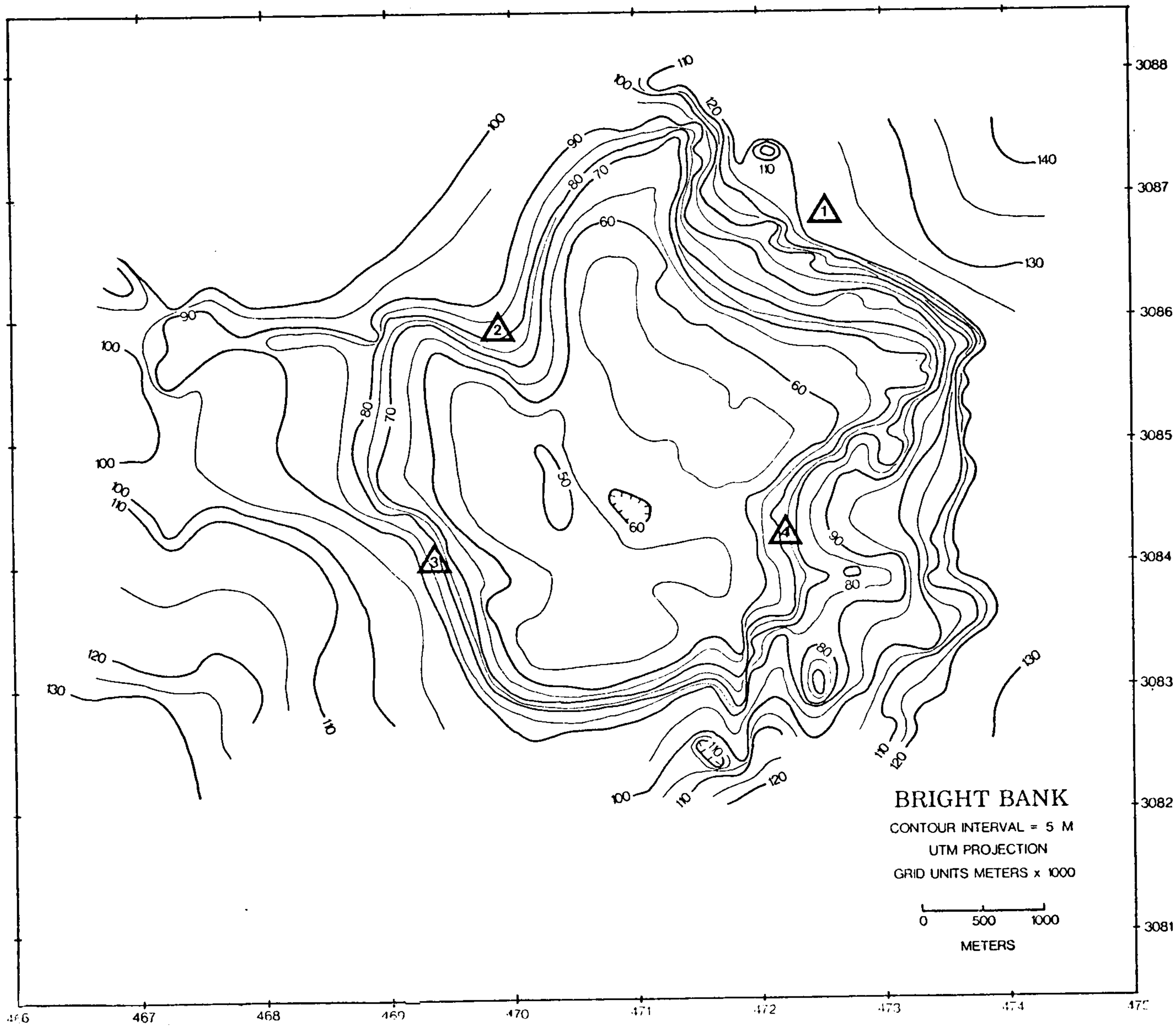


Figure II-4. Bathymetric map of Bright Bank showing sampling station locations.

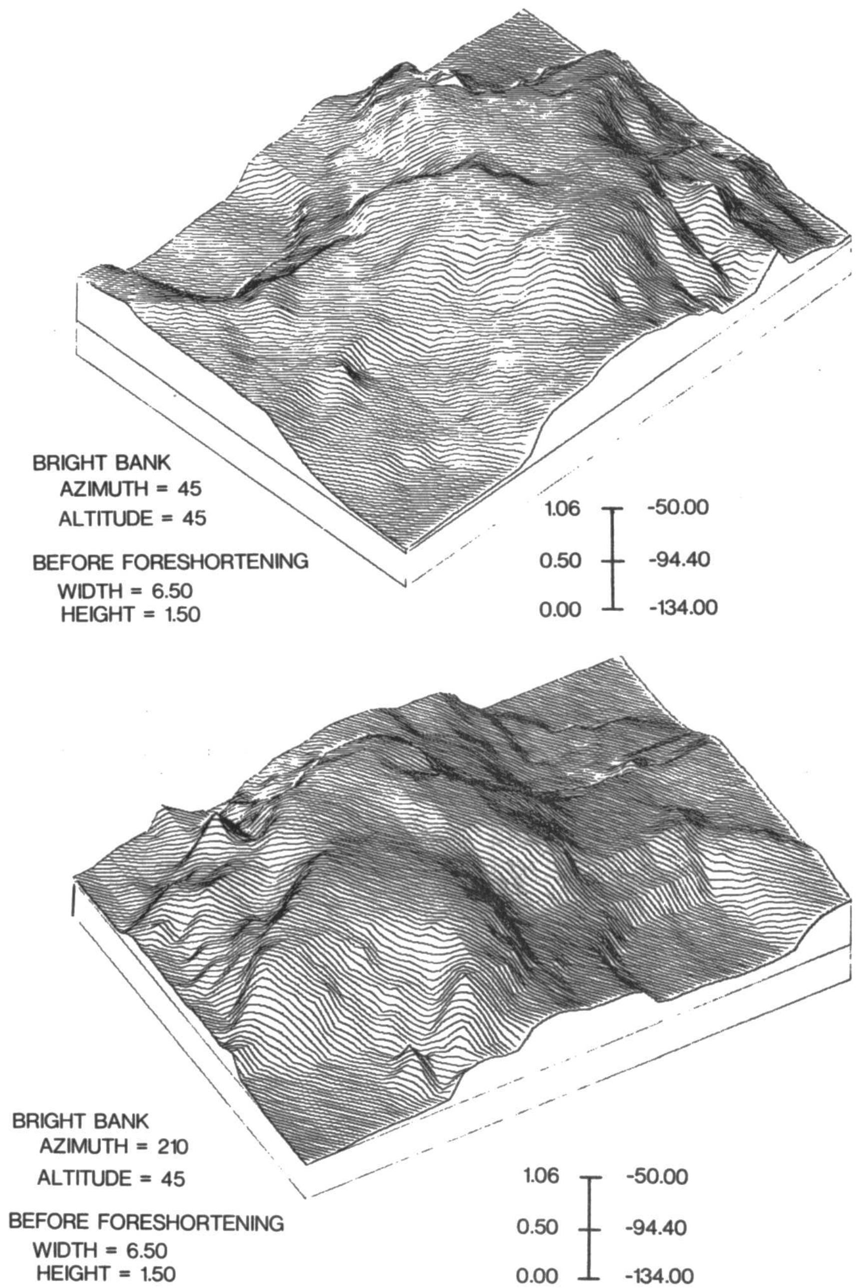


Figure II-5. Three dimensional perspective views of Bright Bank: 45° and 210° azimuth.

Three lineations on the bank appear to be fault controlled (Figures II-4-5). A north-south lineation at grid coordinates 472 x 3082 to 3083.5 may represent a radial fault. Another possible radial fault lies between grid units 467 and 470 at 3086. The steep scarp which lies between grid units 3086 to 3088 and 470.5 to 473 is a peripheral fault scarp.

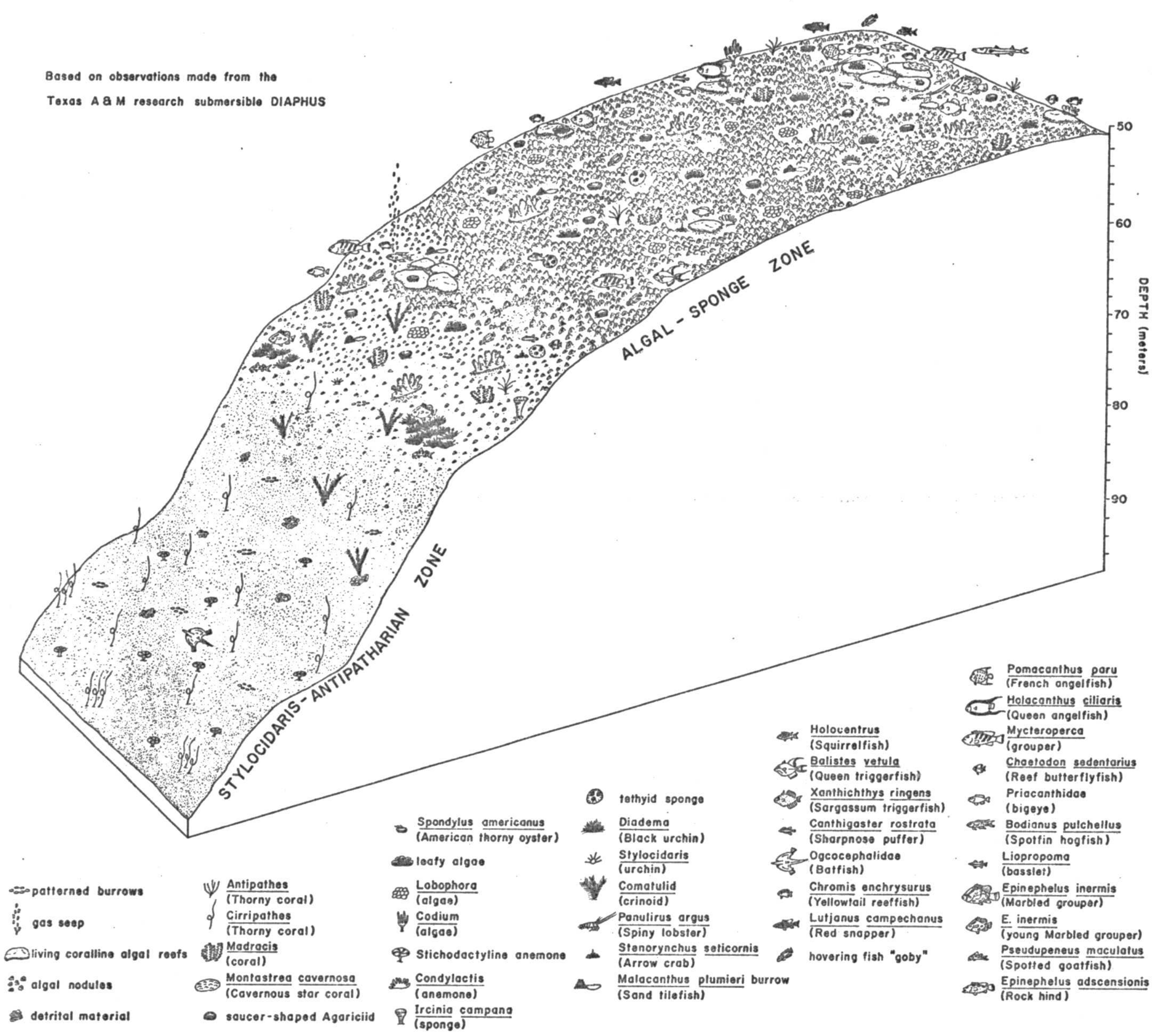
Biology

Bright Bank is occupied by clear-water benthic communities similar to those comprising the ALGAL-SPONGE and ANTIPATHARIAN ZONES of 28 Fathom Bank and the Flower Garden Banks (Figure II-6). The dominant epibenthic organisms on the upper portion of Bright Bank (52-68 m depth) are coralline algae. Algal nodules and living coralline algal reefs are conspicuous and abundant. The reefal structures are typically boulder-like, 1.5 m or less in height and 1 or 2 m in diameter. They occur singly or clustered into reef patches of various sizes. Some reef patches are 50 m or more in diameter and attract a variety of reef fishes and large mobile invertebrates. Natural gas seeps were detected adjacent to some of these structures.

Several species of leafy algae are abundant on the reef patches. *Montastrea cavernosa*, a reef-building coral, occurs on the coralline algal reefs near the crest of the bank, but it is probably not a substantial contributor to substrate production.

The existence of a significant population of spiny lobsters is indicated by two sightings of *Panulirus* sp. at a reef patch near the crest of the bank. It is doubtful that population levels are presently large enough to be considered "exploitable" from a fishery standpoint.

Figure II-6. BRIGHT BANK



As at most of the other shelf-edge carbonate banks in the Northwestern Gulf of Mexico, the predominant conspicuous fishes around reefs in the ALGAL-SPONGE ZONE are Chromis enchrysurus (Yellowtail reeffish), Chaetodon sedentarius (Reef butterflyfish), Bodianus pulchellus (Spotfin hogfish) and Mycteroperca phenax (Scamp). Surrounding the reef patches, there are usually localized bands of bare to rubble-strewn coarse carbonate sand. These are undoubtedly due to the bioturbating activities of fishes and invertebrates frequenting the reefs.

A large population of leafy algae is associated with the coralline algal nodules. In places, Lobophora variegata becomes almost totally dominant, overgrowing the nodules entirely. Two sightings of the alga Codium taylori at 54 m depth are significant insofar as this is a species which was not known to occur in the Western Atlantic until the 1950's. It was possibly introduced from Europe, arriving here attached to the hull of a ship. Judging from observed standing crops of leafy and coralline algae within the ALGAL-SPONGE ZONE of Bright Bank and other shelf-edge carbonate banks, benthic primary production above 70 m depth on these structures must be phenomenal.

Stony coral populations among the algal nodules are substantial down to 62 m depth. Saucer-shaped colonies of Agaricia sp. are most conspicuous. Atypically, a significant percentage of these colonies were upside-down when we observed them in September 1977. Upon turning some of them upright, they were found to still have healthy coloration indicating that they had only recently been disturbed, possibly by the passage of hurricanes Anita and Babe several weeks earlier. Small branching colonies of Madracis sp. are abundant throughout the

ALGAL-SPONGE ZONE, especially at 61-63 m depth. The agariciid and Madracis sp. undoubtedly contribute significant amounts of carbonate sediment to the substratum of the bank and thereby are important constructional elements of the benthic community.

At about 65 m depth the algal nodule cover begins to decrease, and the nodules are more or less gone at 70 m depth. The transition of the substratum with increasing depth below the ALGAL-SPONGE ZONE is distinct, as follows:

65-69 m depth: Coarse carbonate sand. Number of small nodules and rubble decrease with increasing depth.

69-70 m depth: Very shallow and broad ripple marks in carbonate sand. Leafy algal detritus in depression.

70-74 m depth: Carbonate sand with scattered coralline algal rubble and leafy algal detritus. Tracks and trails, burrows, mounds.

74-76 m depth: Nearly total carbonate sand bottom with abundant leafy algal detritus, tracks and trails, burrows, mounds.

77-95 m depth: Fine carbonate sand, tracks and trails, burrows, mounds.

The occurrence of large amounts of leafy algal detritus in the upper SOFT BOTTOM-ANTIPATHARIAN ZONE is an important indication of the probable contribution of the benthic primary producers higher on the bank to the nutriment of surrounding soft-bottom communities.

Bright Bank harbors a diverse and highly productive clear-water benthic community comparable to those of other shelf-edge carbonate banks of similar depth in the Northwestern Gulf of Mexico. From the standpoint of environmental protection, it should be considered one of the highest priority Outer Continental Shelf biotopes.

EWING BANK
(Figures II-7-9)

Geology

Ewing Bank (28°06'N, 91°00'W) is roughly triangular in shape and extends for 7700 m in an east-west direction and 6500 m in a north-south direction. Maximum relief is about 61 m with two high peaks at about 55 m. The peaks lie at grid coordinates 692.6 x 3109 and 696 x 3108 (Figure II-7). A broad triangular shaped terrace at 80 m depth lies on the north side of the bank. Another broad terrace at 90 m depth lies just to the east of the eastern peak. These terraces may have been caused by wave action. However, the surrounding topography is so rough that late collapse features seem to dominate the physiography of the bank (Figure II-8).

No Tertiary bedrock was observed on this bank. A coarse cobble gravel of coralline algal nodules covers most of the shallow portions of the bank. The nodules are underlain by coarse carbonate sand which becomes the predominant sediment below 70 m depth. A sharp break in slope at about 72 m depth is marked by a ledge of algal reef-rock which extends down to 80 m. Below this ledge, the sediment becomes finer, grading into a silty mud around 100 m depth.

Biology

Ewing Bank is a typical Northwestern Gulf of Mexico shelf-edge carbonate bank harboring clear-water reefal communities similar to those occupying 28 Fathom Bank (Figure II-9). The dominant organisms above 70 m depth are coralline algae, nodules of which cover most of the upper part of the bank. Small, growing, coralline algal reef patches of low relief occur here and there on the upper platform of the bank and at ledges.

The ALGAL-SPONGE ZONE at Ewing Bank (56-70 m depth, approximately) is typical, and basically the same as those described for the Flower Garden, 28 Fathom, 18 Fathom, Bright, Bouma and Parker Banks.

A transition to a deep-water epibenthic community is apparent below 67 m depth. On the 67 to 72 m depth terrace, algal dominance is diminished and an abundant population of tubular, branching bryozoans (Stylopoma sp.) is conspicuous. Comatulid crinoids and antipatharians (Cirripathes sp.) are only moderately abundant above 70 m depth, but they become very numerous from 70 and 80 m depth downward.

Ewing Bank is a typical shelf-edge carbonate bank bearing highly productive and diverse clear-water reefal communities. Coralline algal reef building is active above 70 m depth. From the standpoint of environmental protection, Ewing Bank should be considered one of the highest priority Outer Continental Shelf biotopes.

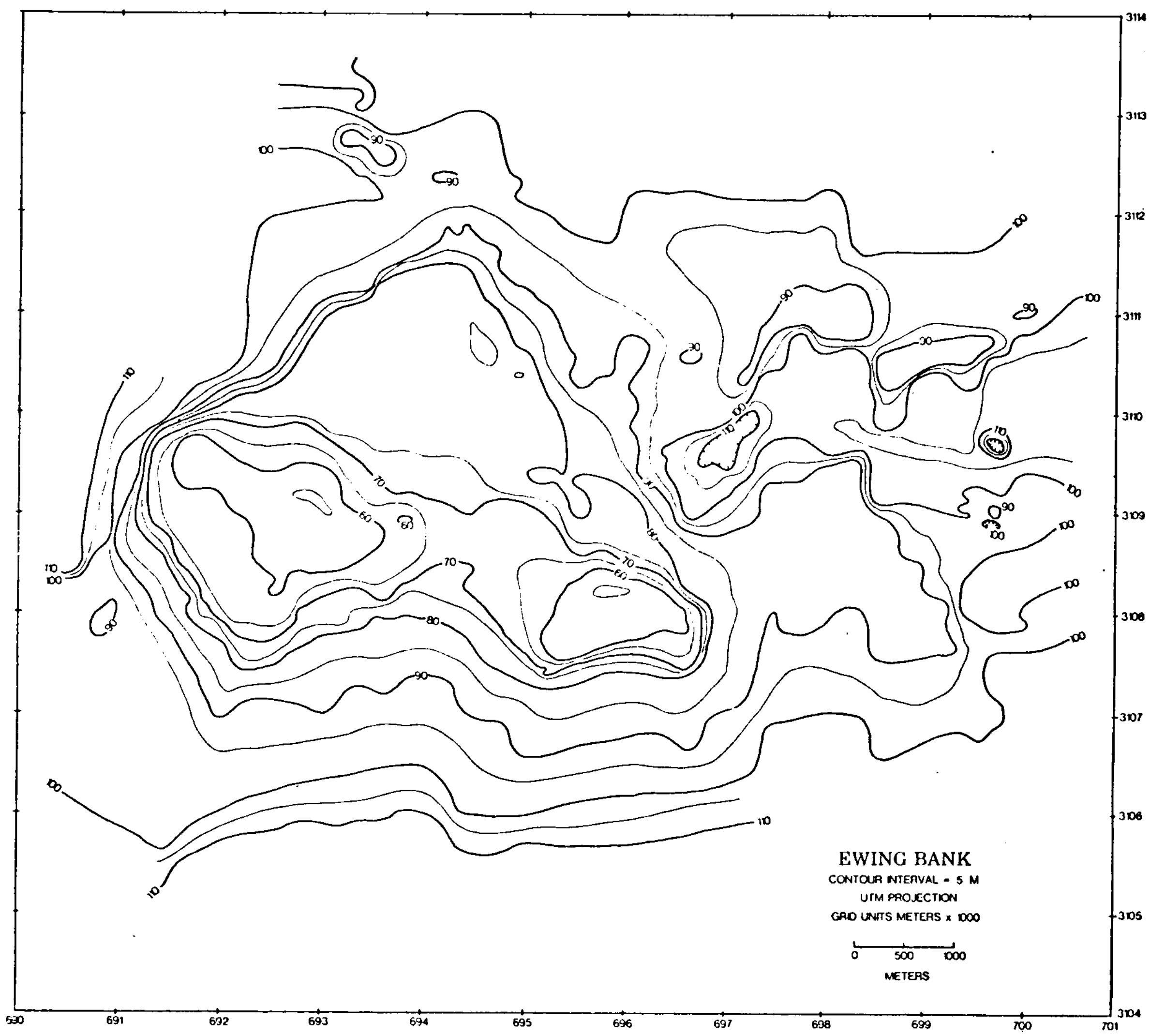


Figure II-7. Bathymetric map of Ewing Bank.

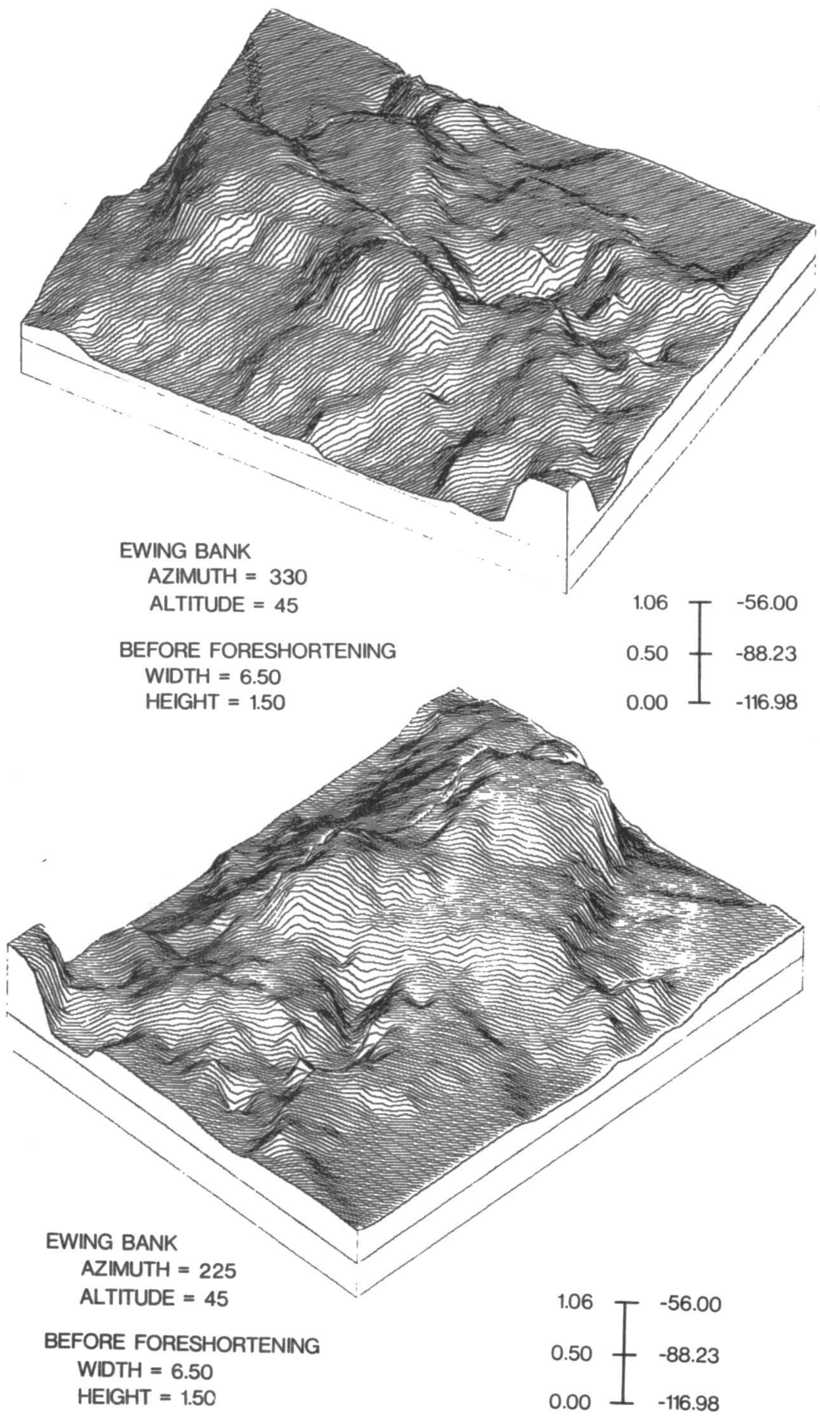


Figure II-8. Three dimensional perspective views of Ewing Bank: 330° and 225° azimuth.

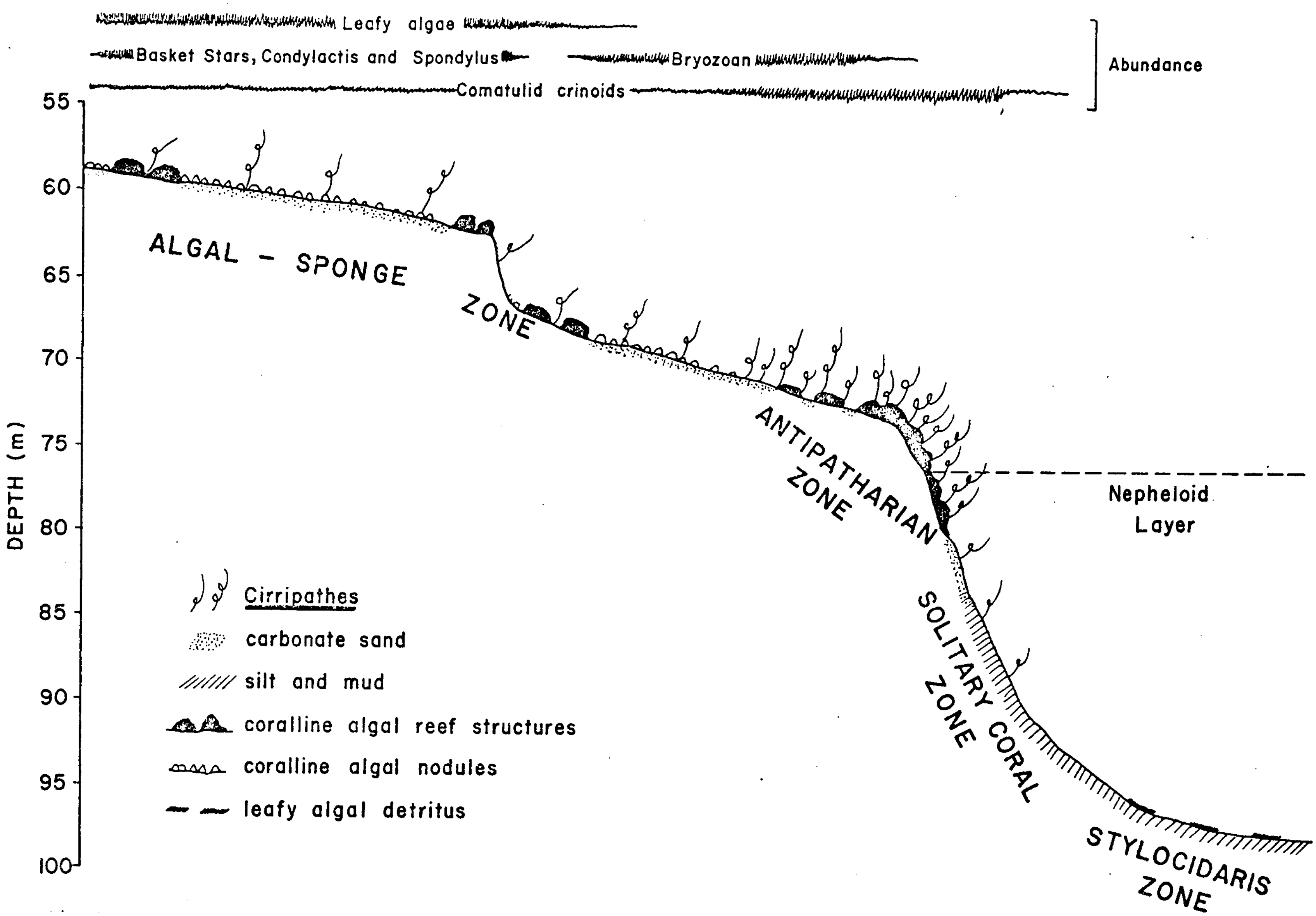


Figure II-9. EWING BANK

CLAYPILE BANK
(Figures II-10-11)

Geology

Claypile Bank (28°20'N, 94°10'W) is approximately 4000 m long and 2100 m wide, trending in a northwest-southeast direction. Local relief is about 17 m. The crest of the bank is a north-south oriented ridge that divides the bank into two parts: 1) a gentle southeastern slope and 2) a northwestern basin that is circumscribed by steeply dipping Tertiary bedrock. The basin appears to be due to a salt spine at that location that was dissolved during Late Pleistocene subaerial exposure of the bank. Collapse of the overlying bedrock created the basin. No sampling nor geological submersible observations were conducted at Claypile. However, T. J. Bright (pers. comm., 1978) has stated that the steeply dipping Tertiary beds resemble the siltstones and claystones observed at Stetson Bank (Figures II-10-11).

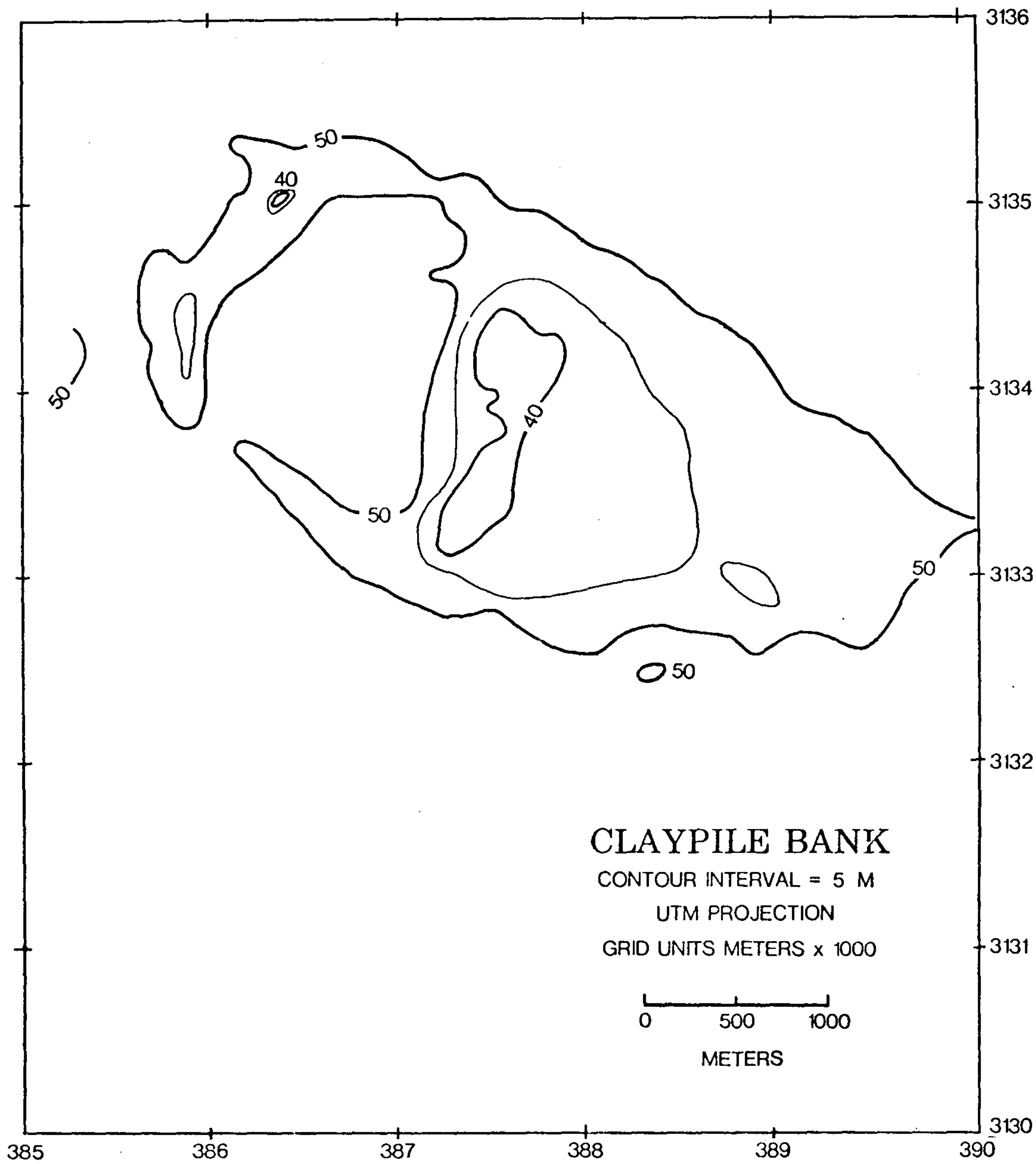


Figure II-10. Bathymetric map of Claypile Bank.

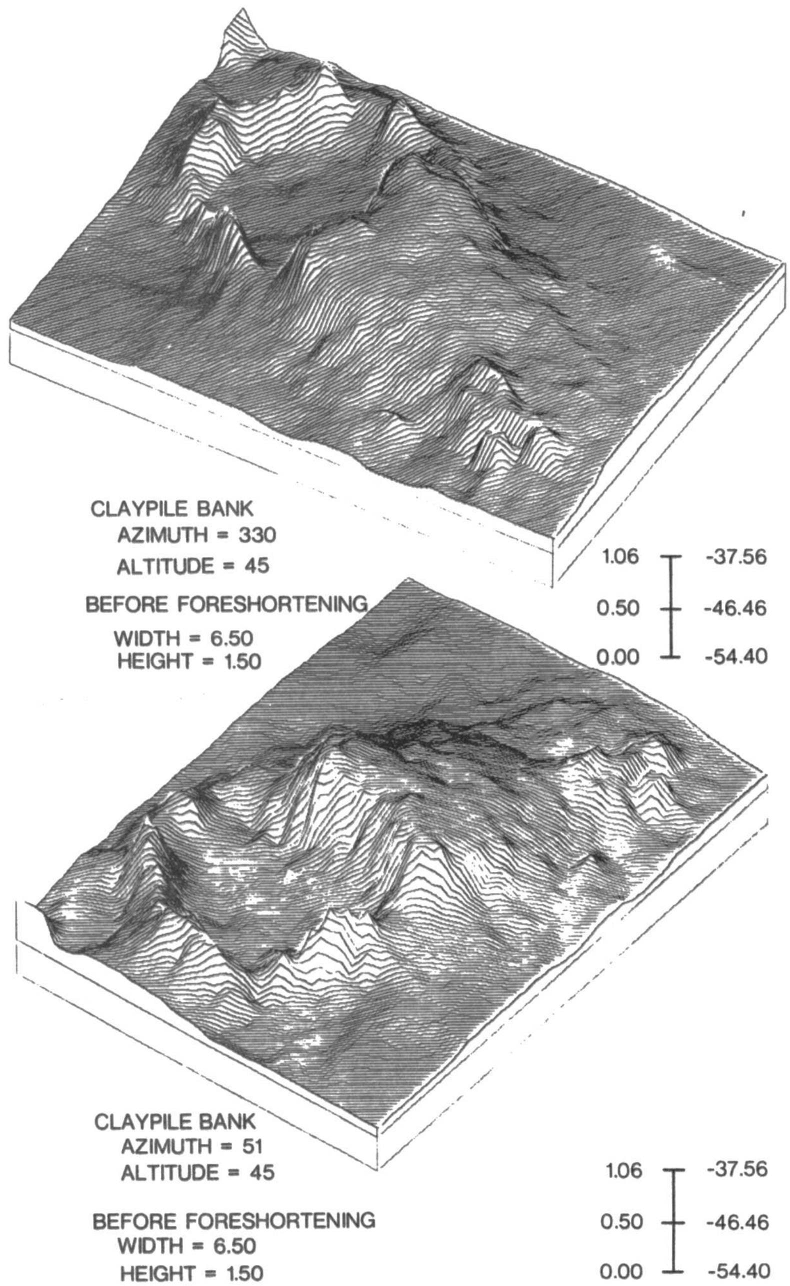


Figure II-11. Three dimensional perspective views of Claypile Bank: 330° and 51° azimuth.

PARKER BANK
(Figures II-12-13)

Geology

Parker Bank (27°57'N, 92°00'W) is nearly circular with a diameter of 7000 m in an east-west direction and 5500 m in a north-south direction. The maximum relief on the bank is 73 m. The highest peak is at 57 m and is located in the east central part of the bank. A broad, deep valley cuts into the bank from the east and trends westward almost to the western limit of the bank. This valley must have been eroded during a Late Pleistocene low sea level stand. Its original outlet was towards the southeast across the 100 meter sill at grid coordinates 599 x 3092 (Figures II-12-13). A later outlet developed towards the northeast across the 110 meter sill at grid coordinates 598.8 x 3093.2.

Two submersible transects on the western crest of the bank revealed no Tertiary bedrock. Pinnacles in that area are patch reefs of Pleistocene coralgal rock. The surrounding areas are covered by coralline algal pavements and the normal bank sediments of the Northwestern Gulf of Mexico.

Biology

Parker Bank was not examined directly by the author from the submersible. However, video tapes made during a geological reconnaissance dive were reviewed and form the basis of the following description.

Above approximately 75 m depth, the bank is occupied by coralline algal nodules and leafy algae with large populations of comatulid crinoids, sponges, Cirripathes sp. and other invertebrates and fishes typical of the ALGAL-SPONGE ZONES found at similar shelf-edge banks in the Northwestern Gulf of Mexico. Sand tilefish burrows (Malacanthus plumieri) are conspicuous on the upper part of the bank.

Coralline algal reefs of substantial size occur near the top of the bank, and carbonate ledges were observed in the vicinity of 73 m depth. Large schools of Creolefish (Paranthias furcifer) congregate around the algal reefs, along with numerous groupers (Mycteroperca spp.), Reef fish A, Chromis enchrysurus, and other resident bank fishes. Between 73 and 80 m depth, the algal nodule cover thins considerably and is replaced by coarse carbonate sand and rubble. At 84 m depth the bottom is mostly fine carbonate sand with numerous burrows and ripple marks. The sediment grades to an easily stirred soft mixture of fine carbonate sand, silt and mud at 87 m depth.

Parker Bank is undoubtedly a shelf-edge carbonate feature bearing clear-water reefal communities dominated by coralline algae above 80 m depth. It should therefore be classified along with 28 Fathom Bank as a first priority bank from the standpoint of environmental protection.

SACKETT BANK
(Figures II-14-16)

Geology

Sackett Bank (28°38'N, 89°33'W) is nearly circular and has a diameter of about 3000 m. The crest is broad and relatively flat at a depth of 63 m. The relief on the bank is 45 m. The crest of the bank is mainly algal nodules with scattered drowned patch reefs up to 3 m

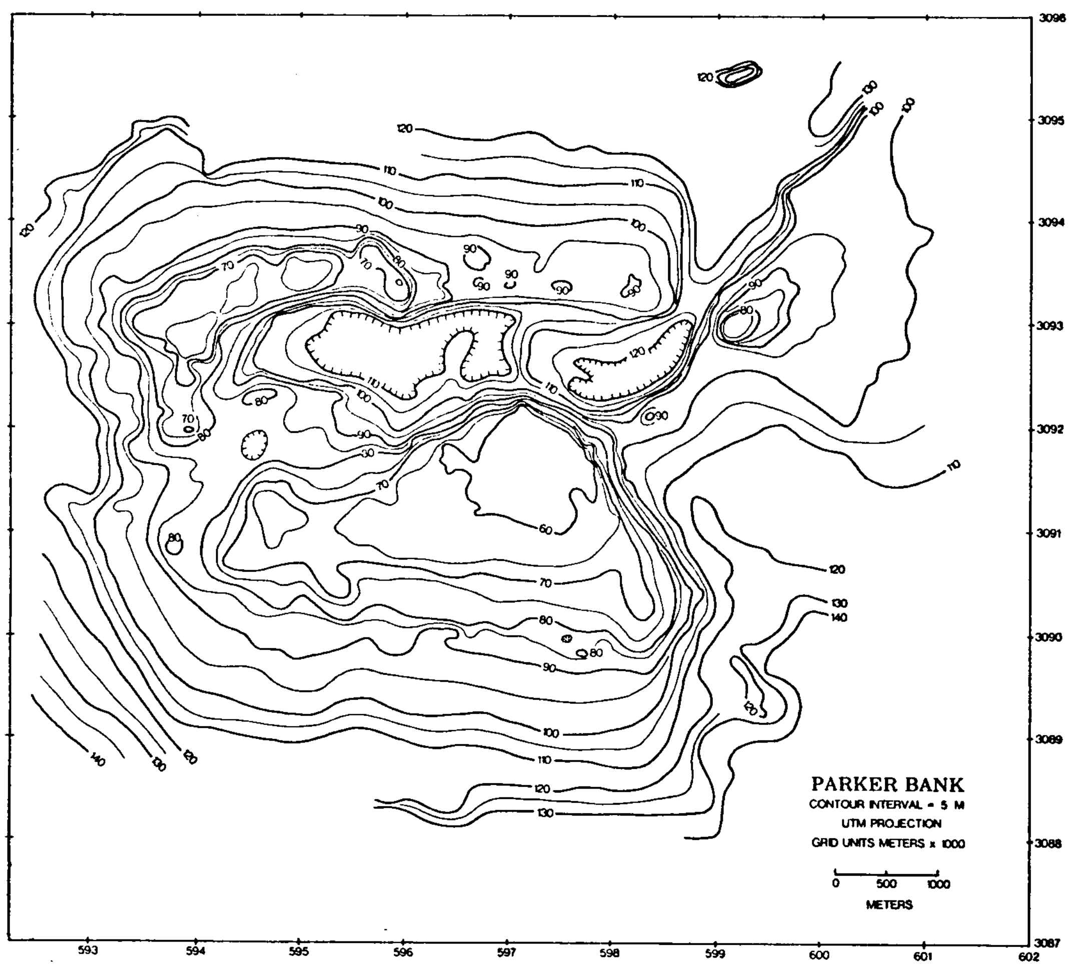
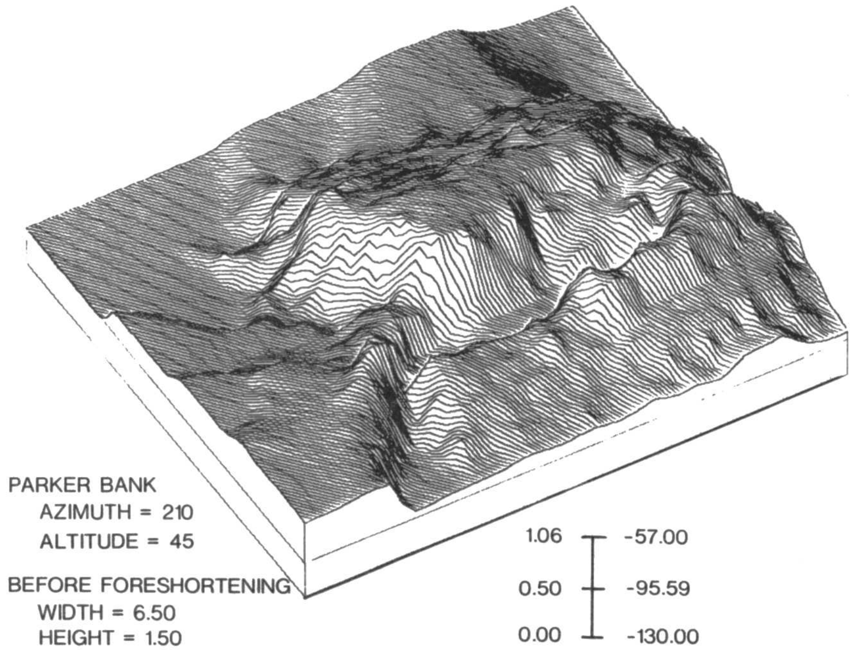
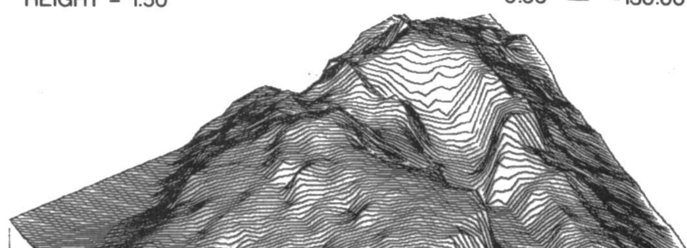


Figure II-12. Bathymetric map of Parker Bank.


PARKER BANK
AZIMUTH = 210
ALTITUDE = 45
BEFORE FORESHORTENING
WIDTH = 6.50
HEIGHT = 1.50
1.06
0.50
0.00
-57.00
-95.59
-130.00



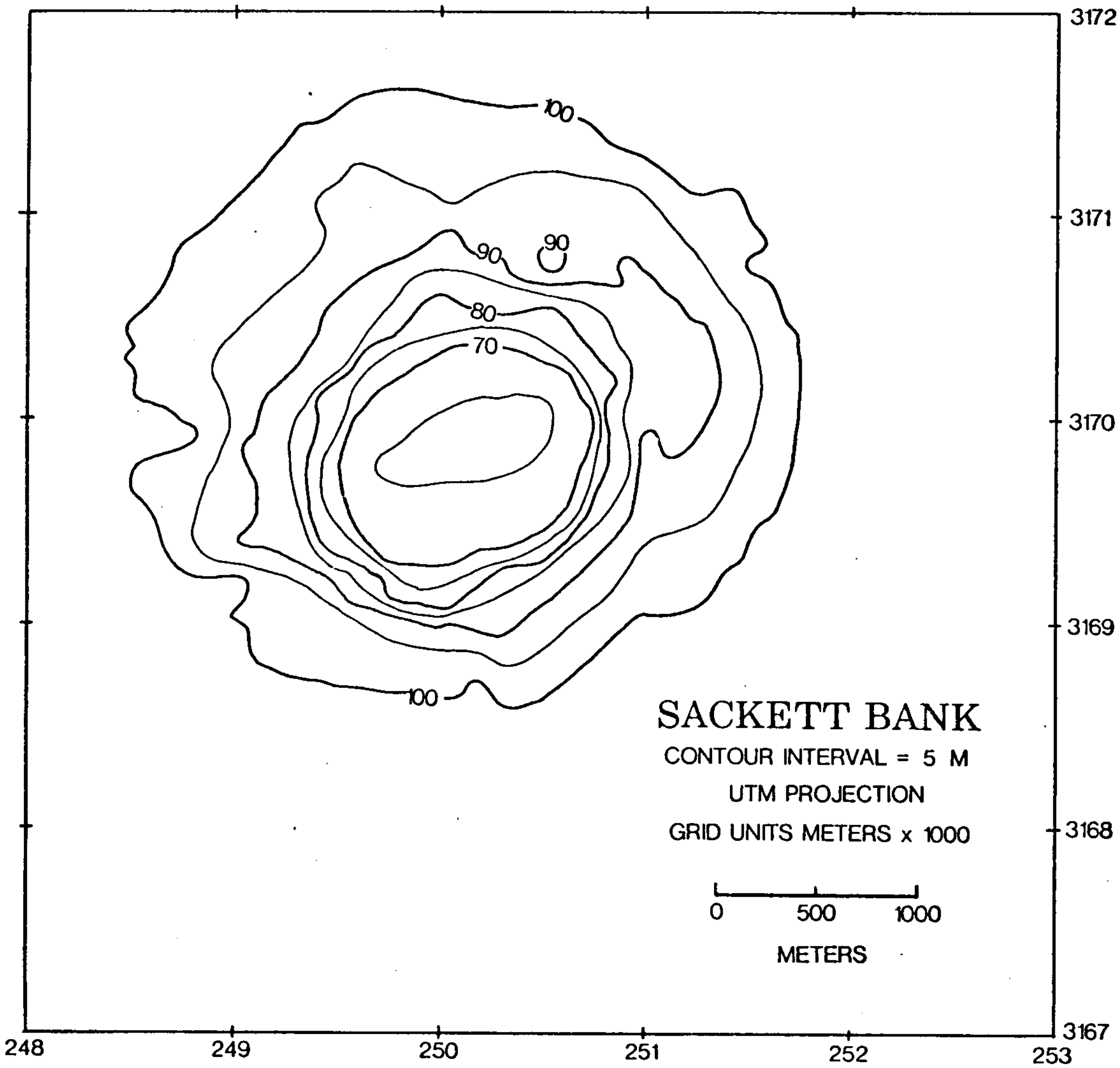


Figure II-14. Bathymetric map of Sackett Bank.

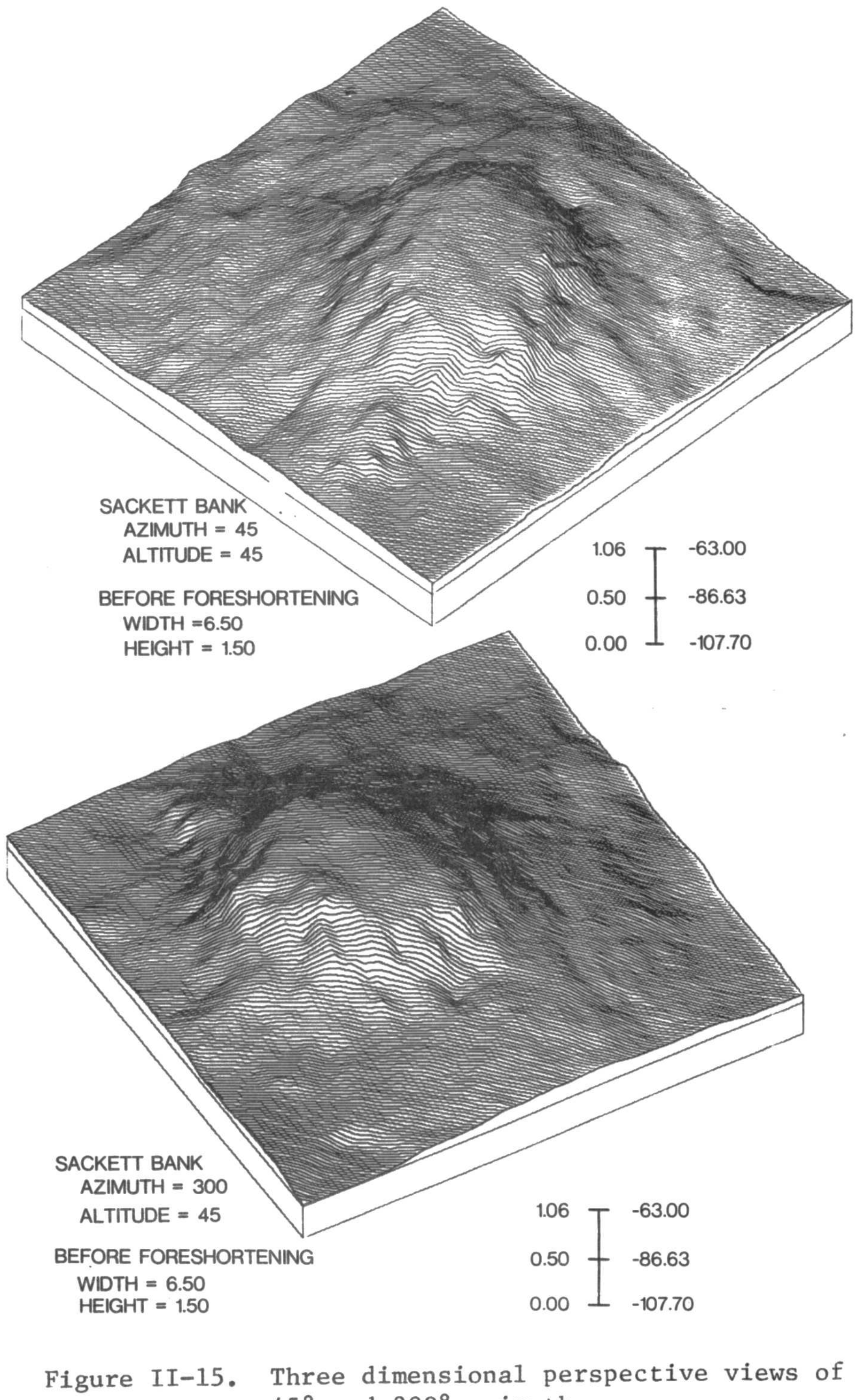


Figure II-15. Three dimensional perspective views of Sackett Bank: 45° and 300° azimuth.

high and 12 m in diameter. At a depth of 73 m there is an outcrop of Tertiary claystone. The surface of the bedrock has been bored by clams and looks like the claystones that occur on Stetson, Claypile and Sonnier Banks (Figures II-14-15).

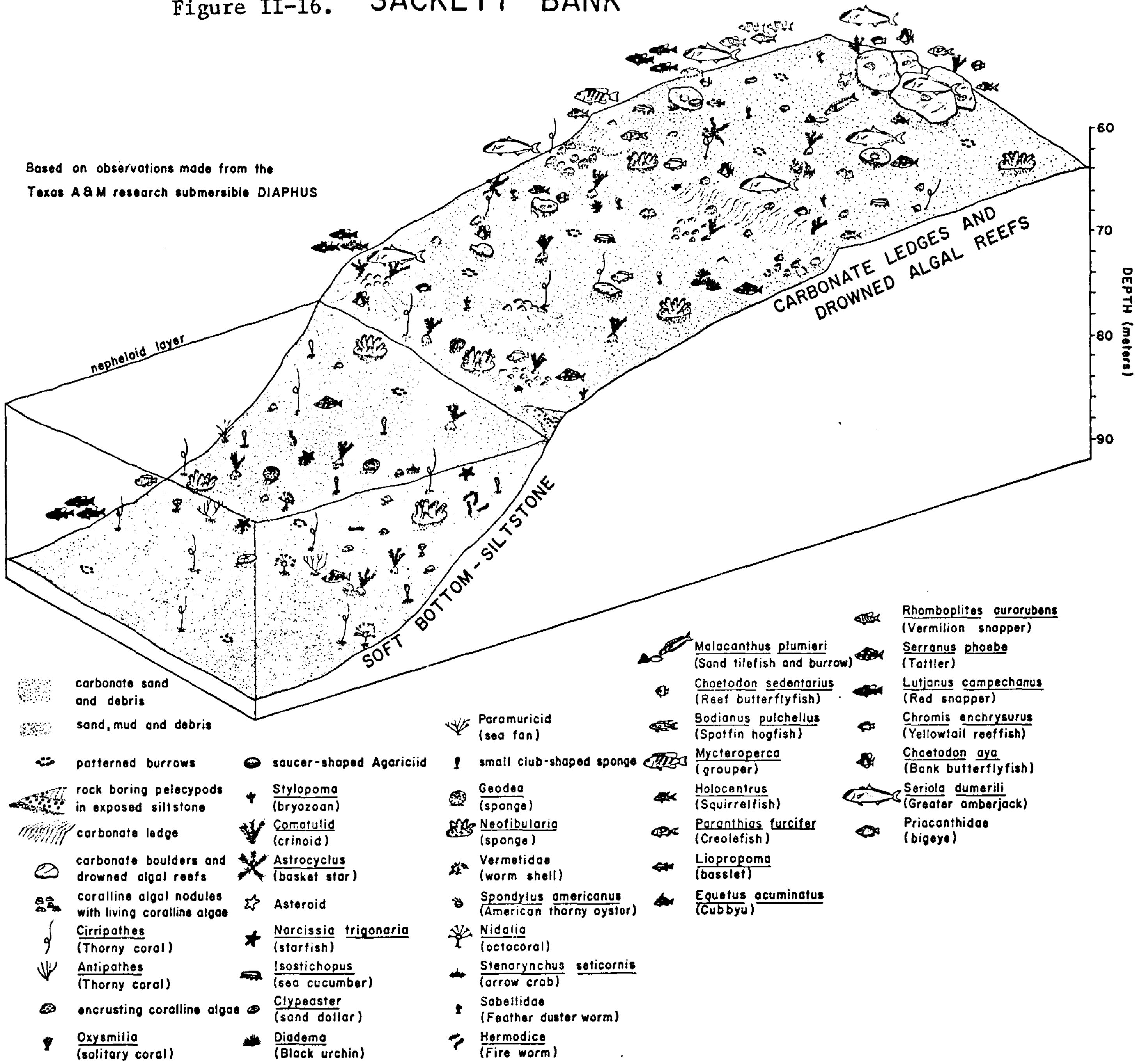
This appears to be a relatively young bank that may have begun its growth during the last rise in sea level. There is no evidence of collapse such as was seen at Sonnier, Claypile, 18 Fathom or the West Flower Garden Banks.

Biology

Sackett Bank is a shelf-edge topographic feature capped by carbonate sediments, including sand, debris, algal nodules, rock ledges and drowned algal reefs (Figure II-16). Whereas these sedimentary components are basically the same as those comprising the substrata of the other shelf-edge carbonate banks, they exist in very different proportions on the upper parts of Sackett Bank. Biotic communities, though composed of species found commonly on the other shelf-edge banks in the Northwestern Gulf, are much less diverse, and less abundant than are those of the other banks. In terms of community structure, the epibenthic biota of Sackett Bank seem to occupy a position somewhere between those of the South Texas Fishing Banks (such as Southern and South Baker Banks) and those of the other shelf-edge carbonate banks in the Northwestern Gulf of Mexico (such as 28 Fathom and Ewing Banks).

The crest of Sackett Bank (64-65 m depth) is rather flat and sandy, with carbonate rubble, a few scattered coralline algal nodules and drowned coralline algal reef patches. On this upper terrace,

Figure II-16. SACKETT BANK



limited amounts of live coralline algae occur on the reef patches, tops of pieces of rubble, and nodules. However, the present degree of carbonate production of coralline algal populations on Sackett Bank does not appear to be substantial.

Some of the drowned reef patches are quite large, up to 3 m high and 12 m across (the largest has a crest of 61 m depth). All are covered with thin veneers of fine, easily stirred sediment and harbor surprisingly sparse populations of epibenthos and fishes.

The predominantly sandy bottom occupying most of the upper platform of the bank above 65 m depth, houses a relatively depauperate assemblage of macroepifauna compared to those occurring at similar depths on other shelf-edge banks in the Northwestern Gulf. Small mounds of "tangled" vermetid gastropod tubes were seen on the upper terrace (64 m depth). These organisms were observed also on 18 Fathom Bank. They may be important contributors to carbonate sediment on Sackett Bank.

Burrows produced by the Sand tilefish, Malacanthus plumieri, are interesting in terms of what they may indicate concerning the nature of the surficial sediments covering the top of Sackett Bank. These conical burrows of about 1 m in diameter were seen in what appeared to be basically sandy bottom with some rubble and few nodules. Adjacent to the apparently sandy burrows, however, were piles of algal nodules, presumably removed from the burrows by the fishes during construction. This would imply that, even though the visible sediment surface is mostly sand, there are significant amounts of coarse material and dead algal nodules buried just beneath. Considering this, and the fact that fair-size drowned reefs are present on the uppermost part of the bank, it is speculated that in the past Sackett Bank must have supported a rather active reef-building community dominated by coralline algae.

Actually, living coralline algal nodules are most abundant near the base of small carbonate ledges and on low mounds on a 67-73 m depth terrace bordering the upper platform. The carbonate ledges, 1 to 2 m high, separate the upper platform from the terrace in places.

The substratum of the 67-73 m depth terrace is basically a rubble-strewn sandy bottom with significant amounts of silt and clay. Very few algal nodules were found on the central part of the terrace. Clusters of them occur more frequently on small mounds around 70-72 m depth. In general the conspicuous soft bottom epifaunal populations are similar to those on the upper platform.

At approximately 72 m depth the slope increases considerably. At this depth we encountered a small outcrop of siltstone similar in appearance to the rocks at Stetson and Sonnier Banks, and to the outcrop seen in the basin at Bouma Bank. These rocks are generally rather soft, and probably disintegrate rapidly where they are exposed directly to water.

When Sackett Bank was explored with the submersible, the top of the nepheloid layer was roughly coincident with the break in slope at 72-74 m depth. A substantial change in the composition of the benthic epifaunal community is apparent between 73 and 76 m depth. Below 90 m depth almost nothing was visible on the mud surface, the conspicuous epifaunal organisms having nearly disappeared.

Epibenthic communities on the upper part of Sackett Bank are poorly developed compared to those on shelf-edge banks to the West. Were it not for the proximity of the Mississippi River, topography, depth and location would seem to favor development of clear-water carbonate reefal communities. Indeed, the presence of large drowned coralline algal reefs and large numbers of dead algal nodules buried under carbonate sand indicates that a substantial, active reef building community existed on the bank some time in the past, dominated by coralline algae.

The small population of living coralline algae existing on the bank suggests that environmental conditions do not now altogether preclude limited carbonate substratum production. It is hypothesized, however, that the conditions of water quality, hydrography and turbidity associated with Mississippi River outflow are responsible for limiting the contemporary development and growth of substantial carbonate reefal communities at Sackett Bank.

Such communities, which are basically dependent on photosynthetic organisms, require adequate levels of light throughout the year (even corals require light to support useful symbiotic plants in their tissue). The water overlying Sackett Bank was much more turbid during observations than the water above any of the other shelf-edge banks. The upper 10 m of the water column (above the thermocline) was very green and contained an enormous amount of organic matter in the form of plankton and seston (floating non-living organic material, often mucus-like). At the thermocline (approximately 10 m depth) we observe large "sheets" of mucus-like white organic matter. Mucus "strands," accompanied by very large zooplankton populations, extended down past 30 m depth. All this suspended material, substantially the result of enormous phytoplankton and zooplankton productivity, effectively decreases the penetration of light, even though the water between the organically turbid surface layers and the bottom nepheloid layers may be quite clear. It is possible, therefore, that the benthic reefal communities of Sackett Bank are held in check by the tremendous productivity of nutrient rich near-surface marine waters in the vicinity of the Mississippi Delta. Long term observations of light penetration, salinity, temperature, nutrients, suspended organics and water column productivity at Sackett Bank and Ewing Bank (the closest shelf-edge bank supporting substantial ALGAL-SPONGE ZONE populations) could reveal much concerning the environmental factors limiting development of clear-water carbonate reef-building communities in the northwestern Gulf of Mexico.

The structure and abundance of biotic communities at Sackett Bank is intermediate between those described for shelf-edge carbonate banks (such as 28 Fathom Bank) and South Texas fishing banks (such as Southern Bank). Living coralline algae populations at Sackett Bank are more substantial than those found on the South Texas banks. It is difficult, therefore, to fit Sackett Bank into the classification scheme for banks in the Northwestern Gulf proposed by Bright et al. (1978). In terms of precautions to be taken to protect Sackett Bank, it is recommended that it be considered a second priority bank, along with Stetson and Sonnier Banks.

SONNIER BANKS
(Figures II-15-17)

Geology

Sonnier Banks (28°21'N, 92°27'W) consist of eight separate banks or peaks associated with a salt dome. The peaks are nearly conical features with a maximum relief of about 30 m. Each peak consists of steeply dipping Tertiary sandstones, siltstones and claystones. The strike of the bedding planes on the one peak that was observed from the submersible varies from 300 to 330° and the dip varies from 45 to 90°. The constancy of the strike within a single peak and the arrangement of the peaks leads to the conclusion that each peak represents an individual fault block caused by the collapse of the beds overlying the salt along radial and annular faults.

The bases of the peaks lie at a depth of 52 m. With increasing distance away from the peaks, boulders become smaller and give way to a mud bottom with partially buried siltstone boulders and cobbles, all covered with a veneer of fine sediment. At 58 m depth mud is predominant with only a few scattered cobbles.

Biology

The epibenthic communities occupying Sonnier are basically similar to, but better developed than, those found at Stetson Bank (Figure II-17). The crest of Sonnier (20-21 m depth) is almost entirely encrusted with fire coral (*Millepora* sp.) and the sponges (*Neofibularia nolitangere* and *Ircina* sp.).

The fire coral population extends downward to 40 m depth, but is severely diminished below the crest of the bank. Dead branches and broken pieces of fire coral occur abundantly in the unconsolidated sediment at the bases of the shallower outcrops along with siltstone chips and fine silt and clay-sized particles. The coral must, therefore, contribute significantly to the sediment which is produced on the bank and ultimately transported to the surrounding level-bottom.

Heads of the hermatypic anthozoan coral Stephanocoenia sp. were seen at 36, 38 and 41 m depth. None of these heads was over 1 m in diameter. The only other stony coral encountered at Sonnier Banks was the saucer-shaped agariciid (seen at 52 m depth).

Encrusting coralline algae occur at Sonnier Banks down to 47 m depth. Populations are moderate above 40 m, becoming sparser with increasing depth. Populations of fishes and conspicuous, mobile invertebrates are diverse and abundant above 45 m depth and are very comparable to populations at Stetson Bank. The molt of a spiny lobster, Panulirus sp., was seen at 27 m depth.

A correlation between the depth distribution and abundance of epibenthic communities and patterns of chronic turbidity at Sonnier Banks is probable. In September 1977, water turbidity was greater below 42 m than above, although a highly turbid nepheloid layer was not encountered above 52 m depth. The abundance of Millepora, sponges, coralline algae and most of the other encrusting epifauna is greatly reduced below 40 m depth.

Although certain species which are abundant on the bank extend some distance out onto the surrounding level bottom, benthic communities occupying this turbid water, rock strewn soft-bottom, differ considerably from those found on the bank. Conspicuous organisms

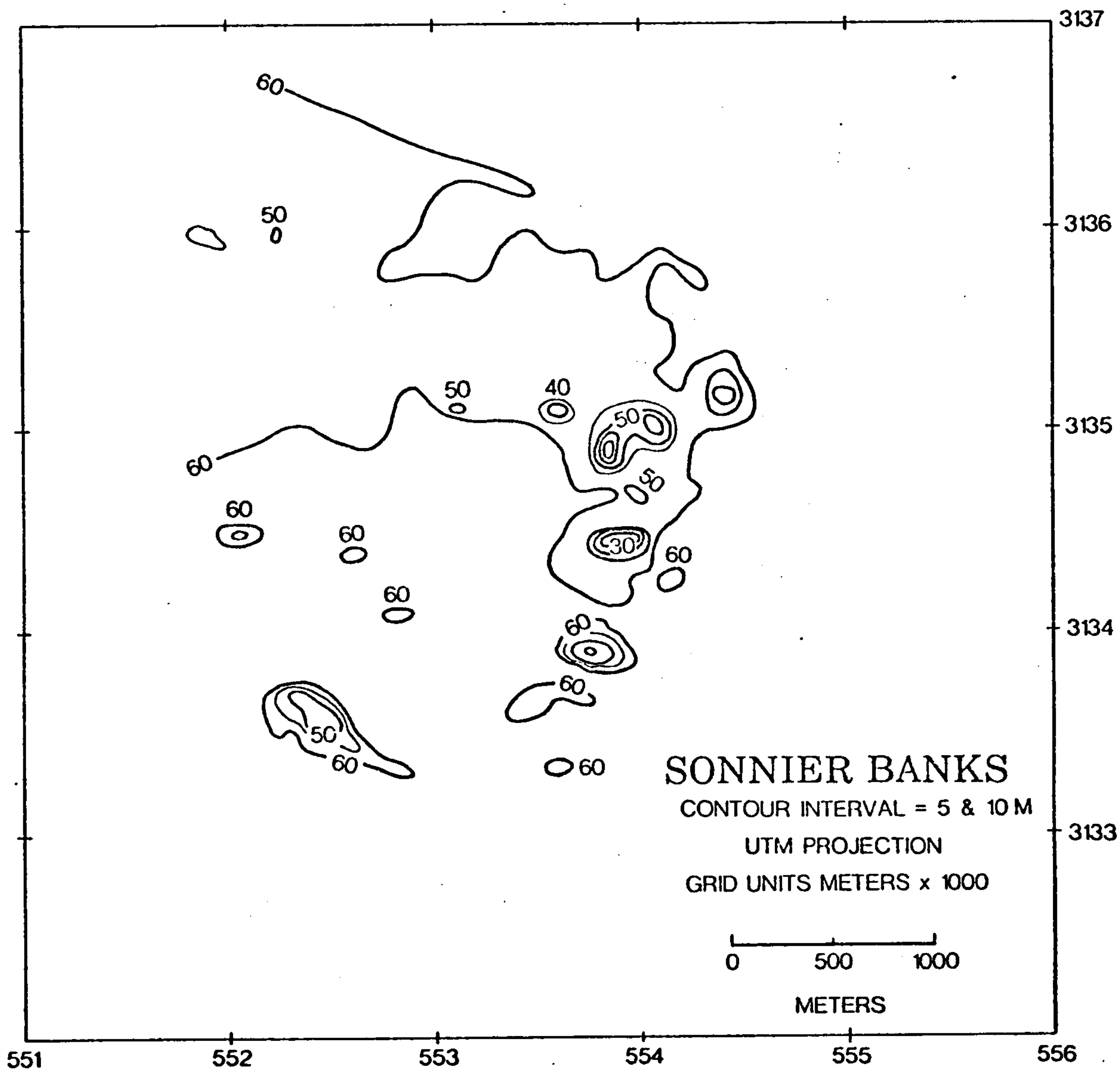


Figure II-17. Bathymetric map of Sonnier Banks.

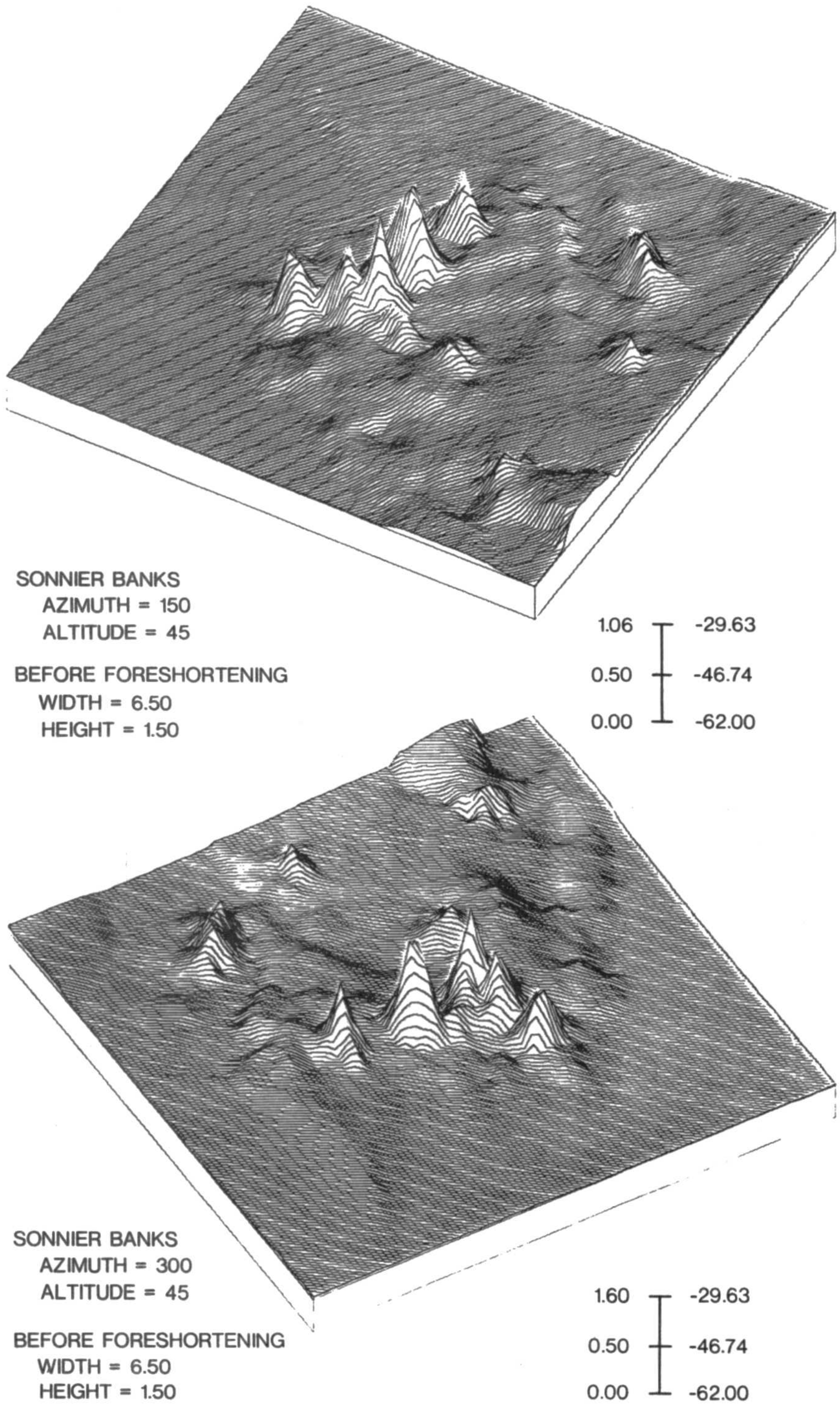
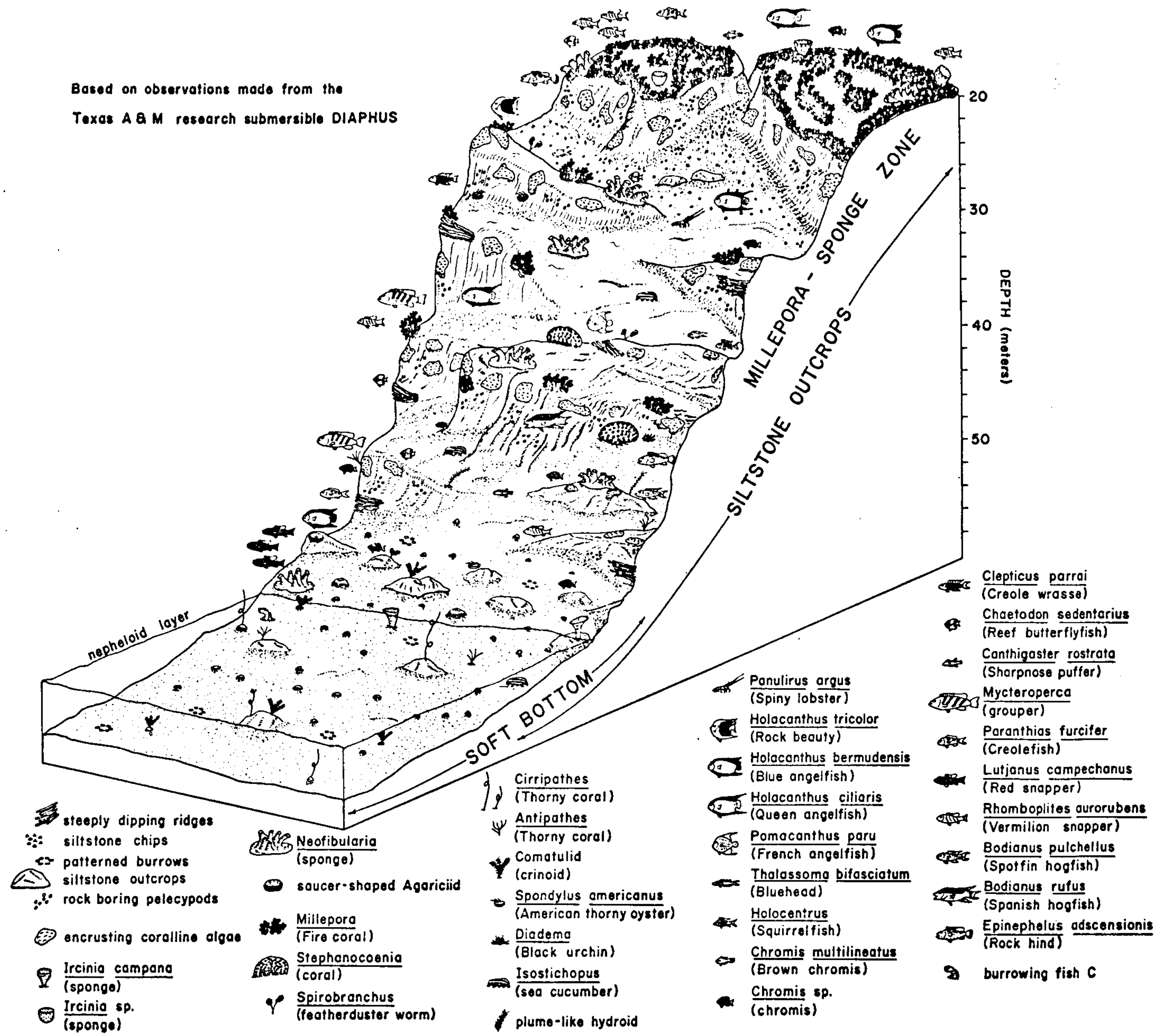


Figure II-18. Three dimensional perspective views of Sonnier Banks: 150° and 300° azimuth.

Figure II-19. SONNIER BANKS



present adjacent to the bank, but not on it, include the antipatharians Cirripathes sp. and Antipathes sp., comatulid crinoids, and the sponge Ircinia campana. Abundant burrows, tracks and trails in the mud attest to a substantial population of large infaunal organisms.

Because of the striking similarity in their structure, environment and biota, Sonnier and Stetson Banks should be classed together in terms of measures to be taken in protecting them from possible effects of oil and gas activities. It is pointed out however, that there have already been 9 exploratory wells drilled wihtin 4.6 to 9.2 kilometers of Sonnier Banks. Because they were drilled before any concerted attempts by the federal government to assure protection of fishing bank communities, there were no restrictions on the discharge of effluents such as those currently imposed on drilling activities near such banks. It is therefore assumed that all drill effluents from these wells were discharged at or near the sea surface. Such circumstances must be taken into consideration in assessing the effects of offshore petroleum industry operations on sensitive marine habitats.

In view of the above, it is significant that epibenthic communities at Sonnier Banks appear to be very healthy at present, and there is no evidence of past mass mortalities or large scale deleterious environmental effects attributable to any cause. In fact, the condition of epifaunal populations at Sonnier Banks seems generally better than that of the similar populations at Stetson Bank, around which no drilling had occured prior to 1975 (we examined Stetson Bank in 1974 and 1976).

18 FATHOM BANK
(Figures II-20-22)

Geology

18 Fathom Bank (27°58'N, 92°36'W) is an arcuate pair of northeast-southwest trending ridges separated by a valley. The bank appears to be a small part of a large salt dome that lies to the southwest. Local relief is about 90 m with the crest of the southeastern ridge lying at a depth of about 50 m. The northwestern slope of the outer ridge is considerably steeper than the southeastern slope giving the impression of a resistant Tertiary formation dipping steeply away from the salt dome. The inner ridge is less resistant and has much lower relief. The valley between the two ridges represents a Tertiary unit that was easily eroded during Late Pleistocene exposure. A breech through both ridges at grid coordinates 538 x 3094 may represent a Pleistocene drainage feature (Figures II-20-22).

A drowned fringing reef was encountered during one of the submersible dives. The reef appears as a massive ledge. Its crest lies at a depth of 78 m and its base is at 90 m (see Figures II-20a, b). The upper surface of the reef was covered with knobby protuberances about 60 cm high. These protuberances appear to be the same as those seen on Southern Bank (Bright and Rezak, 1977) and are interpreted to be intertidal erosional features. Cutting through the reef at right angles to its trend are several large channels filled with sand. These are interpreted to be surge channels between reef buttresses.

The face of the reef has a very sharp overhang about 2 to 3 m thick and about two metres wide. In one location a chimney was found to penetrate the overhang. The overhang may have been caused by the outward growth of an emergent reef community or it could be a dissolution feature such as is commonly seen in carbonate rocks that are exposed at sea level. All evidence points to this reef having been formed at or near sea level.

Biology

18 Fathom Bank has a comparatively shallow crest depth (43 m). Of the shelf-edge carbonate banks west of the Mississippi Delta, only the East and West Flower Garden Banks have shallower crests. Like the Flower Gardens, the uppermost part of 18 Fathom Bank is occupied by coral reefs, coralline algal reefs, algal nodules, leafy algae and a diverse array of attached and mobile invertebrates and fishes (Figures II-22a,b).

The coral reefs of 18 Fathom Bank are unique, occurring in patches between 43 and 47 m depth. Biologically, they are much less diverse than the Flower Garden reefs. Only 4 types of coral seem to be important reef builders, compared to 10 or so at the Flower Gardens. At the crest of 18 Fathom Bank, the coral Stephanocoenia sp. forms crusts and rounded heads which may be 1.5 m in height. Smaller heads of Stephanocoenia sp. were seen on coralline algal reef patches, ledges and hard bottoms down to a depth of 54 m. The fire coral, Millepora sp., is very conspicuous above 54 m depth, encrusting on coralline algal reefs and other hard substrata. Montastrea cavernosa occurs in the same depth range, primarily as flat crusts up to 1 m or so in diameter. A species of the coral genus Agaricia occurs as crusts and small masses on the coral reefs and coralline algal reefs down to at least 49 m depth.

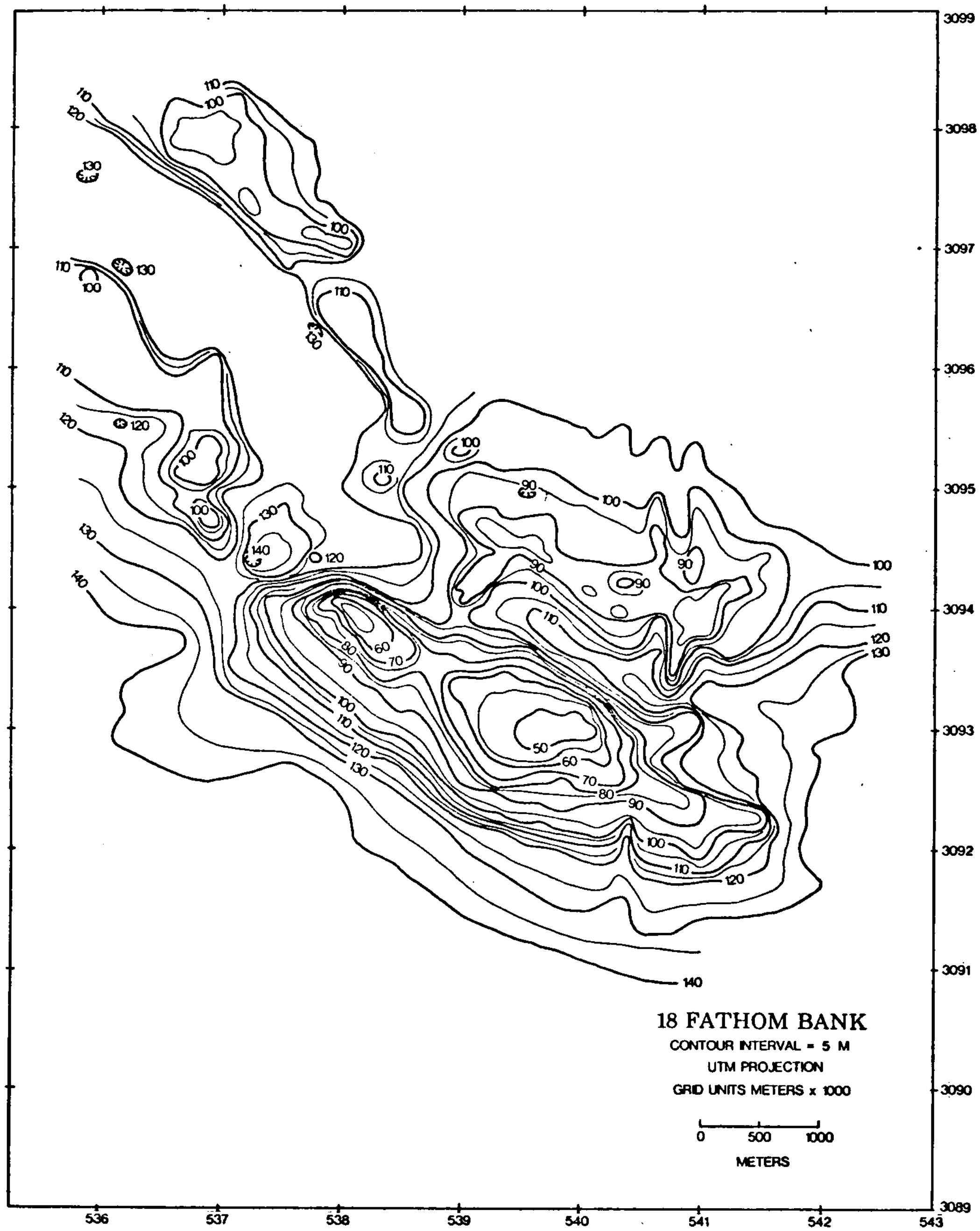


Figure II-20. Bathymetric map of 18 Fathom Bank.

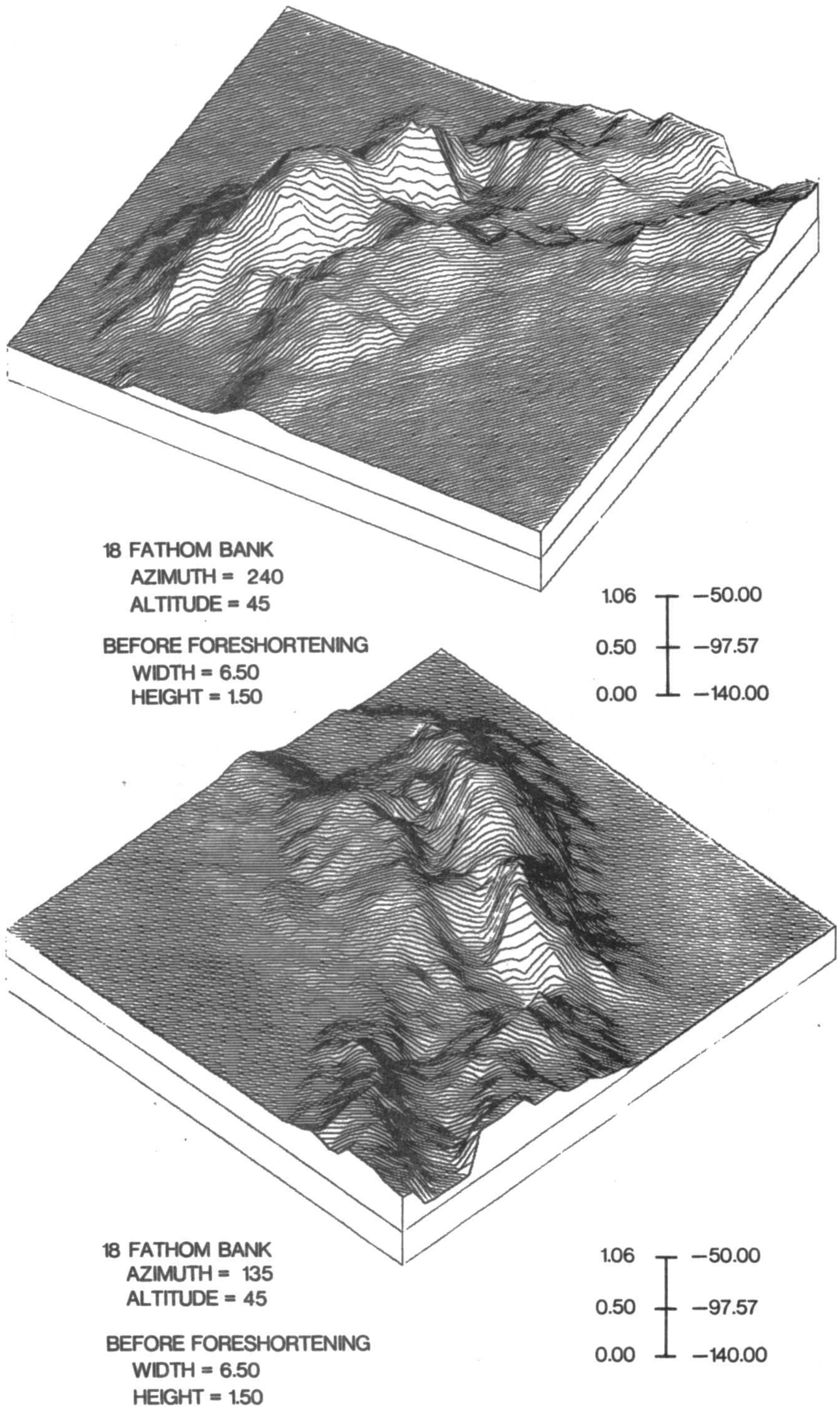


Figure II-21. Three dimensional perspective views of 18 Fathom Bank: 240° and 135° azimuth.

Figure II-22a. Legend for Figure II-22b.

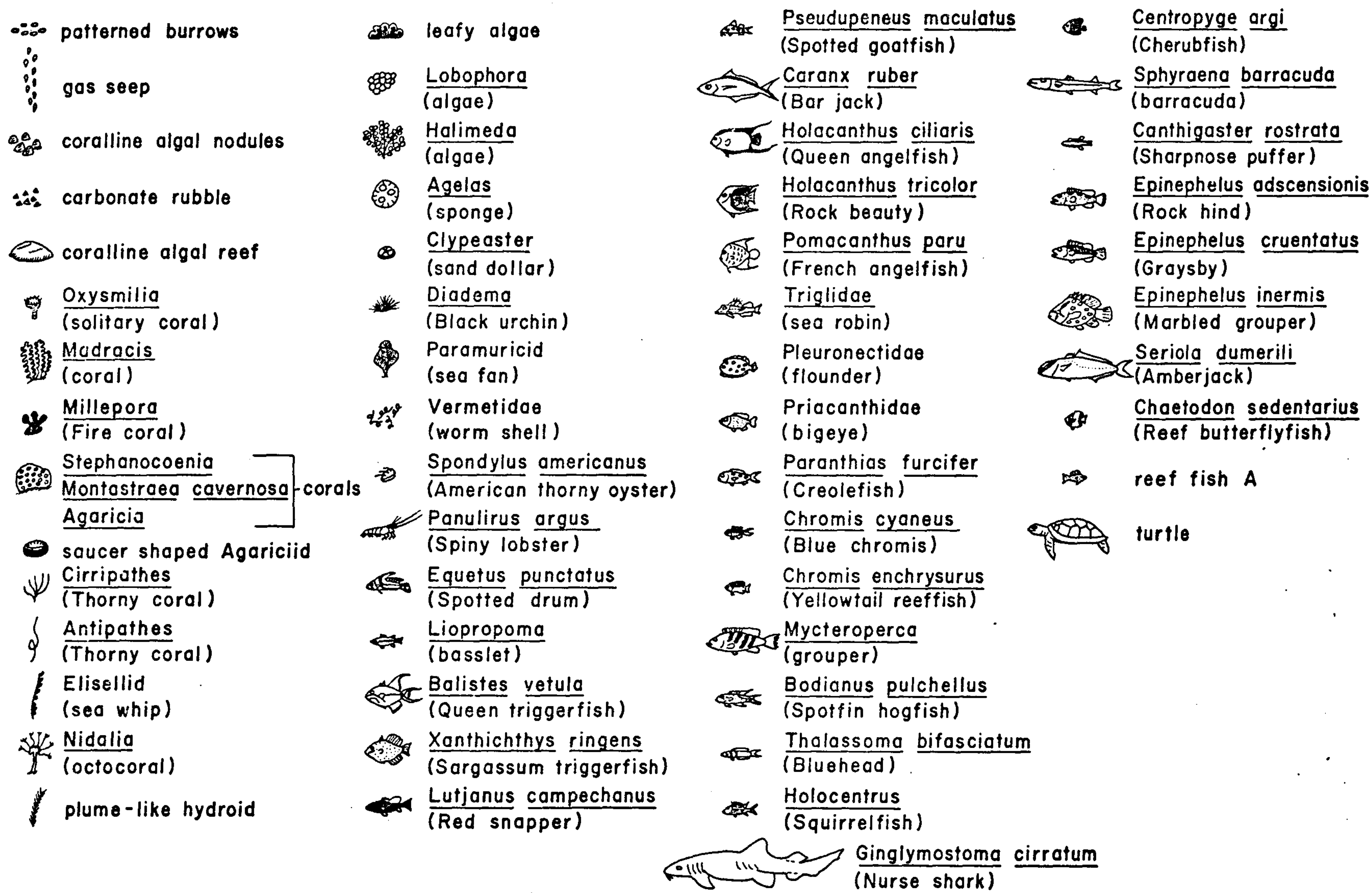
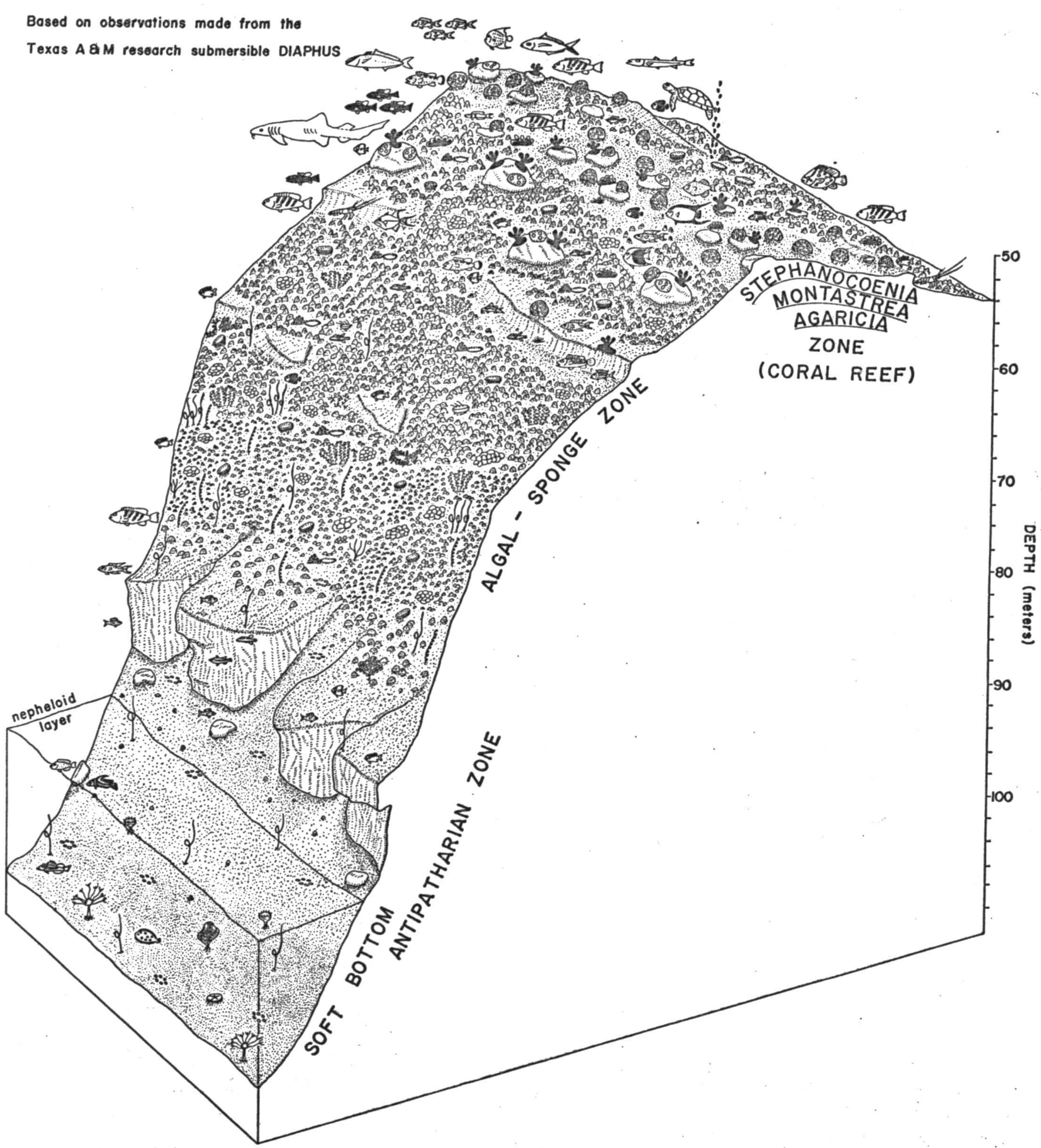


Figure II-22b. 18 FATHOM BANK



In recognition of the unique nature of these coral reefs, the depth range wherein sizeable colonies of hermatypic corals of the genera Stephanocoenia, Montastrea and Agaricia are abundant has been designated the STEPHANOCOENIA - MONTASTREA - AGARICIA ZONE. It is pointed out, however, that coralline algal reefs are probably at least as widespread wihin the zone as are the coral reefs.

In general, from the standpoints of coral, fish, algae and invertebrate populations, the shallowest reefs at 18 Fathom Bank are comparable to deep coral reefs reported from 43 to 55 m depth at the East Flower Garden. This overlap of comparable coral reef communities from one bank to another, and the nearly perfect correlation of their depth distribution, is significant evidence that depth-related factors, probably light penetration, largely control the distribution of biotic communities on the upper portions of the clear-water, shelf-edge carbonate banks in the northwestern Gulf of Mexico. That the influence of such factors may be offset by proximity to the Mississippi River has been discussed in relation to Sackett Bank (pp. 38-39).

Away from the reef patches, between 45 and 76 m depth, the bottom is generally covered with coralline algal nodules and harbors large populations of leafy algae and sponges. The nodules become less abundant below 76 m depth and are not significant below 82 m depth. The biotic community associated with the algal nodules is probably the most diverse on the bank in terms of invertebrates and algae.

The leafy algae population is large everywhere in the ALGAL-SPONGE ZONE. Lobophora variegata is the most abundant leafy alga, in places covering 70 to 80 percent of the bottom. Abundant populations of small hermatypic corals are associated with the nodules.

Large coralline algal reefs up to 2.5 m in height and 6 m or so in diameter occur on the algal nodule platform between 46 and 48 m. North of the crest of the bank, these reefs are spaced 30 to 50 m apart They are actively growing, with extensive covers of living coralline algae. Millepora sp. and the sponge Agelas dispar are abundant on the algal reefs. Heads of Stephanocoenia sp. and Montastrea cavernosa are present, along with a significant population of Spondylus americanus. Fishes congregating around the algal reefs are the same types as were seen on the nearby coral reefs.

The area of the bank which bears coral reefs and large coralline algal reefs (43-48 m depth) is bounded to the north and south by carbonate ledges, the tops of which are at 48-49 m depth and the bases of which are at 53-59 m depth. These ledges are heavily encrusted with coralline algae and are occupied by the same types of corals, sponges, invertebrates and fishes described above for the large coralline algal reefs. The bases of the ledges are bordered by bands of bare carbonate sand, indicating a substantial amount of localized bioturbation. A significant population of the common black urchin Diadema sp. occurs on the ledges, and Spiny lobsters, Panulirus sp., live along the undercut bases of the ledges. A natural gas seep was seen at one point on one of these ledges, and a sea turtle was encountered.

The algal nodules begin to thin out at 62 m depth and give way to smaller nodules, rubble and a very substantial cover of Lobophora variegata. Between 68 and 70 m depth this alga covers almost 90 percent of the bottom in places. Lobophora variegata was not seen below 79 m depth. Large antipatharians (Cirripathes sp.) were seen from 58 m depth downward and were most abundant from 68 to 80 m depth.

From 80 m depth, a large, spectacular carbonate ledge drops vertically ten metres. This ledge marks the edge of the bank in the area examined. It also marks the downward transitions from constructional, clear-water communities, dominated by coralline algae and coral, to the deep water bank-edge community typical of the flanks of shelf-edge carbonate banks in the Northwestern Gulf of Mexico. The top of the ledge has a significant cover of encrusting coralline algae, and a scattering of rather large coralline algal nodules. The lower sides of the ledge support less living coralline algae. Smaller carbonate structures near the base of the ledge are more-or-less "drowned" (without substantial crusts of living coralline algae).

18 Fathom Bank is extremely interesting biotically and ecologically. The coral reefs at its crest parallel the deepest coral reefs found at the East Flower Garden. Their presence implies the possibility that any of the shelf-edge carbonate banks in the Northwestern Gulf could become future sites for coral reef development, providing the reef-building activities of the deeper-living coralline algae continue to decrease crest depths of the banks in the coming centuries.

It seems critical, therefore, that the productivity and constructional capabilities of coral and coralline algal populations on these banks not be subject to interference. 18 Fathom Bank must be included in the group of shelf-edge topographical features classified as first priority from an environmental standpoint.

SPECIAL STUDIES

III. SPECIAL STUDIES

SEDIMENT AND BOUNDARY LAYER DYNAMICS

Purpose

The purpose of this study was to develop an understanding of the constituents of the nepheloid layer, why it occurs where it does, and what causes its variability in time and space. In order to accomplish this goal an investigation was launched to study the processes which initiate and modify the turbidity in the shelf waters.

The work consisted of three integrated parts. Foremost among these parts was the seasonal monitoring of temperature, salinity, transmissivity and current structure around the East Flower Garden Bank. This provided valuable, however sparse, information on the long term variability of the measured parameters. The second part of the study, carried out during the September seasonal sampling cruise, was the dye emission study. This was accomplished from the submersible DR/V DIAPHUS using a 3 m high dye-emitting stand emplaced from the R/V GYRE. Its purpose was to examine the short term phenomena, such as turbulence, and their relationship to the turbidity in the water column. The third part of the work was comprised of a single visit reconnaissance of Sackett, Bright, Parker, and Sonnier Banks. At each of these banks at least four stations were occupied to measure the distribution of temperature, salinity, transmissivity, and current velocity with respect to depth. The third portion of the study provided, therefore, a measure of the spatial variability of the measured parameters.

Significant Findings

It is quite clear from the work done this year that the nepheloid layer is an integral part of the bottom boundary layer (BBL). The amount of suspended sediment and its penetration height above the bottom are a function of the local sediment type and the intensity of the turbulence present, and degree of stratification of the water column. The reason for this relationship is rather straightforward.

When water flows over a bounding surface, it adheres to the surface by means of molecular friction (viscosity). This produces a very thin layer near the bounding surface in which there is a sharp velocity gradient wherein the velocity drops from the mean speed of the flow to zero at the bottom. The adherence to the bottom causes a momentum transfer to the material on the bottom in the form of tangential stress. That is, the flow pulls on the bottom material in a plane parallel to, and in the direction of, the flow. If this shearing stress exceeds the shear strength of the bottom material (sediment in the case of interest) the flow will cause erosion and begin tearing pieces of material from the bottom. Viscosity is, however, an inefficient mechanism for momentum transfer in water, and laminar flow (nonturbulent) is rarely capable of exerting sufficient stress on the bottom to cause any erosion.

As a matter of fact, laminar flow is rarely, if ever, observed in the marine environment. Rather, the adherence of the water at the bottom causes deformation of the flow over the bottom leading to the turbulence outside of a thin (5 m - 20 m) boundary layer. This could be seen from the existence of a layer mixed with respect to temperature and salinity which extended from the sediment/water interface up to the onset of a sharp thermocline. In stratified waters the turbulent eddies must do work in displacing waters of different densities as they transport momentum. When the eddies are sufficiently intense to cause the displacement, the water becomes homogeneous with respect to temperature and salinity. Away from the bounding surface, the eddies are less intense and reach a point where they can no longer mix the water. At stations where both turbidity and the mixed layers were present, the turbidity did not extend above the mixed layer. The reason is quite clear; the extinction of turbulence by the stratification precludes the transport of sediment up beyond the top of the mixed layer.

At some stations near the banks there were isolated spikes of turbidity and mixed layers separated from the bottom mixed layer by clear, stratified waters. This is related to the second effect of stratification. In this case the top of the bank represents a new bounding surface well up in the stratified waters. Rapid flow over the bank leads to the formation of a narrow mixed layer. More importantly the presence of the bank induces internal waves much akin to the riffles that form over rocks on the bottom of a fast flowing stream.

These internal waves have very little surface expression, but rather are manifest in the vertical displacement of isotherms and presence of a layer at the height of the bank where the velocity undergoes minimum and maximum inflections. Where the waves impinge on the bottom they stir up the sediment and it becomes entrained in the flow over the bank. The sediment appears as a spike in the transmissivity profile on the downstream side of the bank in such a case. This was observed at the East Flower Garden Bank particularly.

Topographic excitation is only one way that internal waves are generated on the continental shelf in the Gulf of Mexico. Some appear to have a tidal origin. These are caused by break up of the barotropic tide on the shelf edge. The waves of this type seem to travel as packets. Waves of high amplitude and low frequency travel at the head of the packet; those of low amplitude and high frequency travel at the tail of the packet. These waves affect the whole water column and contribute large quantities of turbulence to the bottom boundary layers. This, in turn, leads to intermittent suspension of dense clouds of sediment as the waves pass over the bottom.

Implications for Management

The nepheloid layer is a transient feature in a state of almost constant change. It does, however, represent sediment trapped near the bottom by stratification of the water column. An artificial turbid layer such as the effluent of drilling mud from a rig could be expected to behave in much the same manner. That is, once shunted to the bottom it would be unlikely to rise again to the level of the living reefal communities on the East Flower Garden or other banks. Dumped on the surface, this effluent might travel long distances before sinking to safe depths. The variability of directions and speed of the surface currents suggest that it is unwise, therefore, to permit surface dumping near these banks.

COCCOLITHS AS SEDIMENT TRACERS

Introduction

Coccoliths and related calcareous nannoplankton remains are contributed to the sediment as a steady rain of particles over the entire continental shelf area. These particles are produced in great number, by algae in the photic zone and, although they are quite small--1 to 10 µm--they are distinctive in appearance and, therefore, can be readily identified. Age characteristic nannofossils are found in nearly all marine sediments, including most notably those derived from the wide belt of Cretaceous chalk that is found in a wide belt around the Gulf of Mexico. Streams and rivers flowing over the outcrop areas erode the soft and friable nannofossil bearing sediments and transport them to the Gulf of Mexico along with other fine-grained detrital sediments. These sediments enter the Gulf of Mexico at a series of point sources along the coast where the rivers enter the Gulf, or where the various bays and estuaries open to the Gulf. Because of their small size, coccoliths and other nannofossils are moved essentially as part of the suspended load, being placed in suspension by waves, and dispersed across the continental shelf by prevailing currents.

As these fossil coccoliths are dispersed their numbers are also constantly being diluted by the contribution of modern coccoliths that are produced in the overlying water column, so that at any point on the continental shelf the ratio of redeposited coccoliths to modern coccoliths will reflect the relative proportion of the detrital sediment contribution. The variations in this proportion in turn will reflect the pathways of sediment dispersal. Thus, a high proportion of redeposited specimens would reflect a relatively high amount of detrital contribution; and a tongue of high proportion of redeposited specimens extending across the continental shelf would indicate dispersal direction of detrital sediment.

In a surface sediment sample even the uppermost millimetre may represent several tens of years of sedimentation, owing to mixing by burrowing organisms and other agencies. The relative abundance of redeposited nannofossils in surface sediments, therefore, represents the integrated effect of detrital sediment dispersal over a period of years. In suspended sediment samples, on the other hand, the proportion of redeposited nannofossils will depend entirely on their proportion in the parent sediment. If the suspended sediment originated on the sea floor in the immediate area where it was taken, then the proportion of redeposited nannofossils will reflect this; if, on the other hand, the suspended sediment originated in an area where the proportion of redeposited nannofossils is different, this will be readily apparent. Moreover, given sufficient sampling density, it should be possible to determine the direction of movement of suspended sediment at a particular time.

The justification for the study ultimately is to provide a means of predicting the fate of particulate pollutants that might be introduced to this area through the activities of man.

The greatest concentration of redeposited coccoliths, almost exclusively Cretaceous species, is along the coastline. The lowest concentration is found in samples from the shelf-edge and slope. Intermediate concentrations extend in more or less parallel bands, sometimes parallel to the coast, elsewhere trending across the shelf.

The general pattern of distribution of redeposited nannofossils as established during the previous study remains after the new data have been incorporated. One notable and significant difference is that the more closely spaced samples in the current study have revealed the presence of a narrow tongue of high concentration of redeposited coccoliths extending from offshore of Port Aransas to the south-southeast diagonally across the continental shelf and the upper continental slope. The shoreward end of this tongue merges with the shoreward end of an equally pronounced but somewhat broader tongue extending nearly due east from Port Aransas diagonally across the shelf (Figure III-1). Thus, these two tongues of high concentration of redeposited coccoliths are nearly at right angles to one another, and are separated by a broad area of significantly lower concentrations. In the southern part of the study area the previously constructed map is not altered significantly by the new data. A broad bulge of slightly higher concentration is associated with the mouth of the Rio Grande, and locally higher concentrations of redeposited species may be found.

The data from this study suggest that in the northern half of the South Texas continental shelf there are two pathways by which fine-grained detrital sediments (fine silt and coarse clay-size particles) are dispersed across the continental shelf, and that these pathways are indicated by the tongues of high concentration of redeposited fossil coccoliths (Figure III-1).

EAST FLOWER GARDEN ENVIRONMENTAL MONITORING

Introduction

Environmental monitoring at the East Flower Garden (Figures III-2-3) is desirable to insure that the condition and health of biotic communities

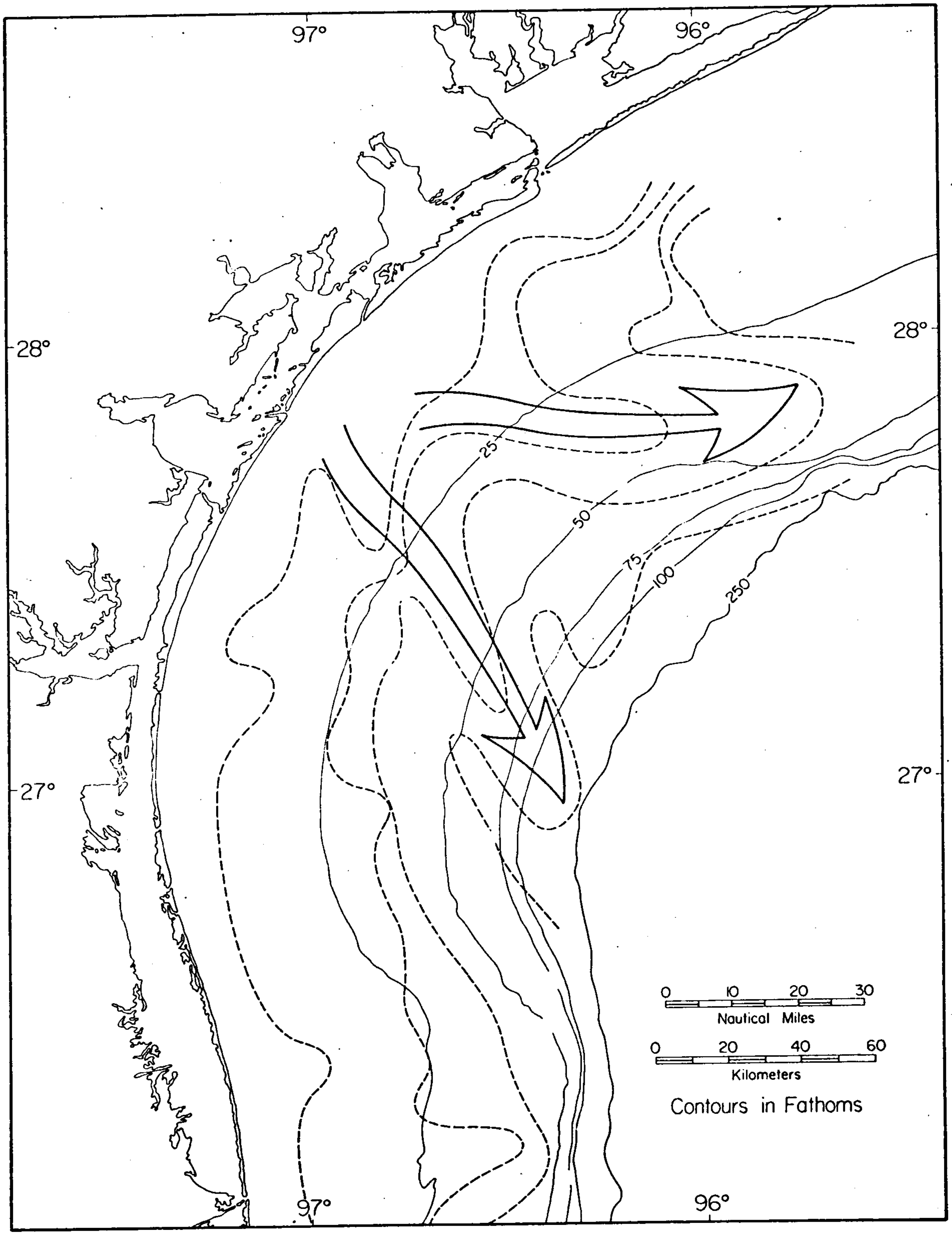


Figure III-1. Inferred direction of seasonal suspended sediment transport based on redeposited coccoliths.

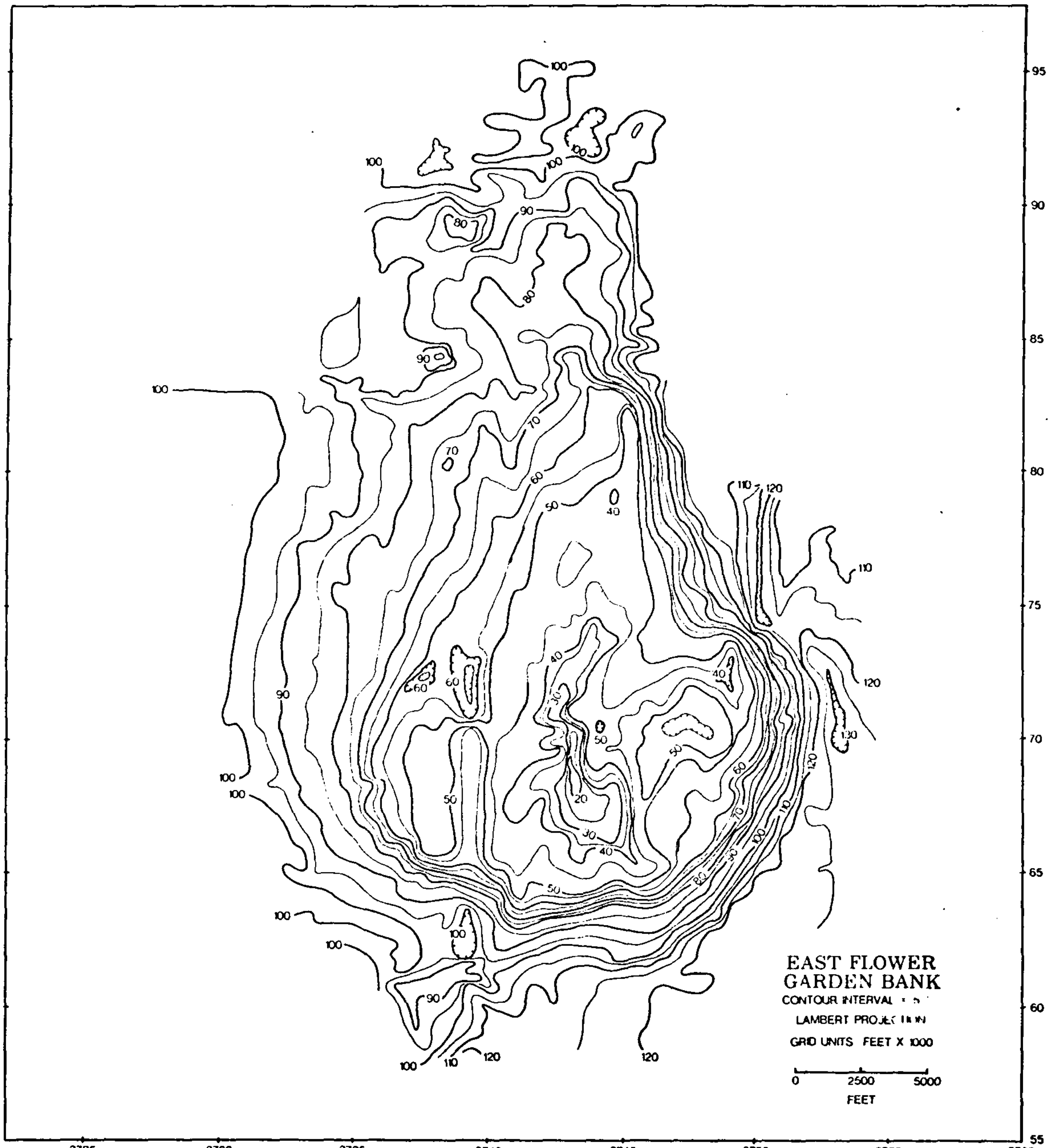


Figure III-2. Bathymetric map of East Flower Garden Bank.

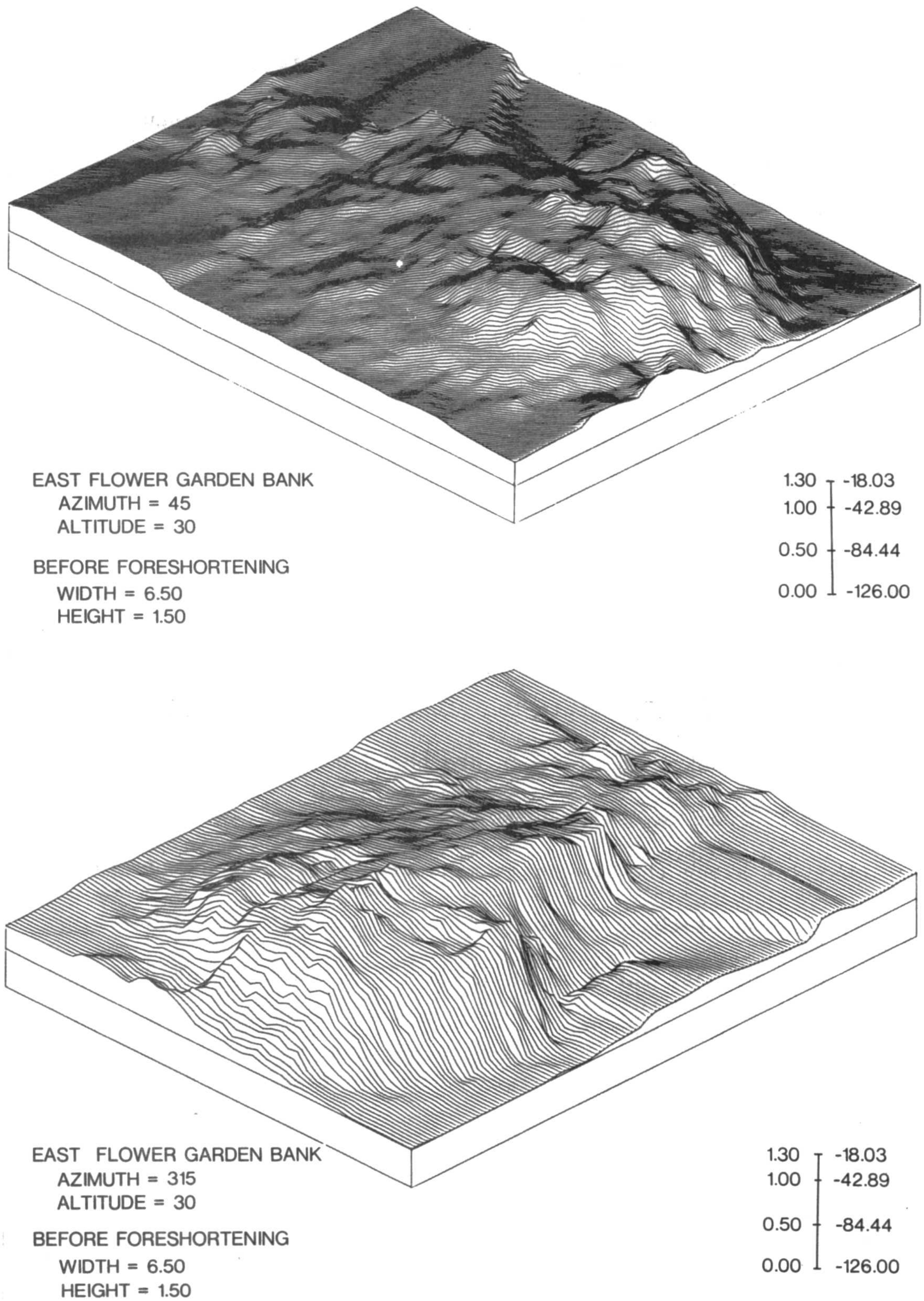


Figure III-3. Three-dimensional perspective views, East Flower Garden Bank: 45° and 315° azimuth on the bank are not degraded as a result of petroleum development and other commercial, sport and scientific activities. Since 1974, we have used a research submersible to perform yearly reconnaissance transects from the coral reef at the crest of the bank to the edge of the hard bank (Bright et al., 1976, 1978). In June, 1977, a long-term monitoring site was established at 26 m depth on the southeastern side of the coral reef. Two additional reef monitoring sites were established by the consulting firm Continental Shelf Associates (CSA) in the course of a monitoring study for Mobil Oil Company (Continental Shelf Assoc., 1978). This work was conducted with CSA during their study and their two monitoring stations have subsequently been used.

The submersible reconnaissance observations have resulted in year-to-year comparative assessments of the general health and condition of biotic communities within the ALGAL-SPONGE ZONE and deeper biotic zones on the bank. Conclusions are based on qualitative judgements made by the principal investigator after direct visual inspection of benthic communities along the reconnaissance transect. No changes in the health and condition of these deeper hard-bank communities southeast of the coral reef over the past three years (1974-1977) are apparent from submersible reconnaissance studies.

The monitoring study initiated at the East Flower Garden coral reef during 1977-78 is directed toward obtaining a base of quantitative and qualitative information concerning the extent and health of coral populations at the reef. Carefully controlled repetitive determinations generating the same type of information from season to season and year

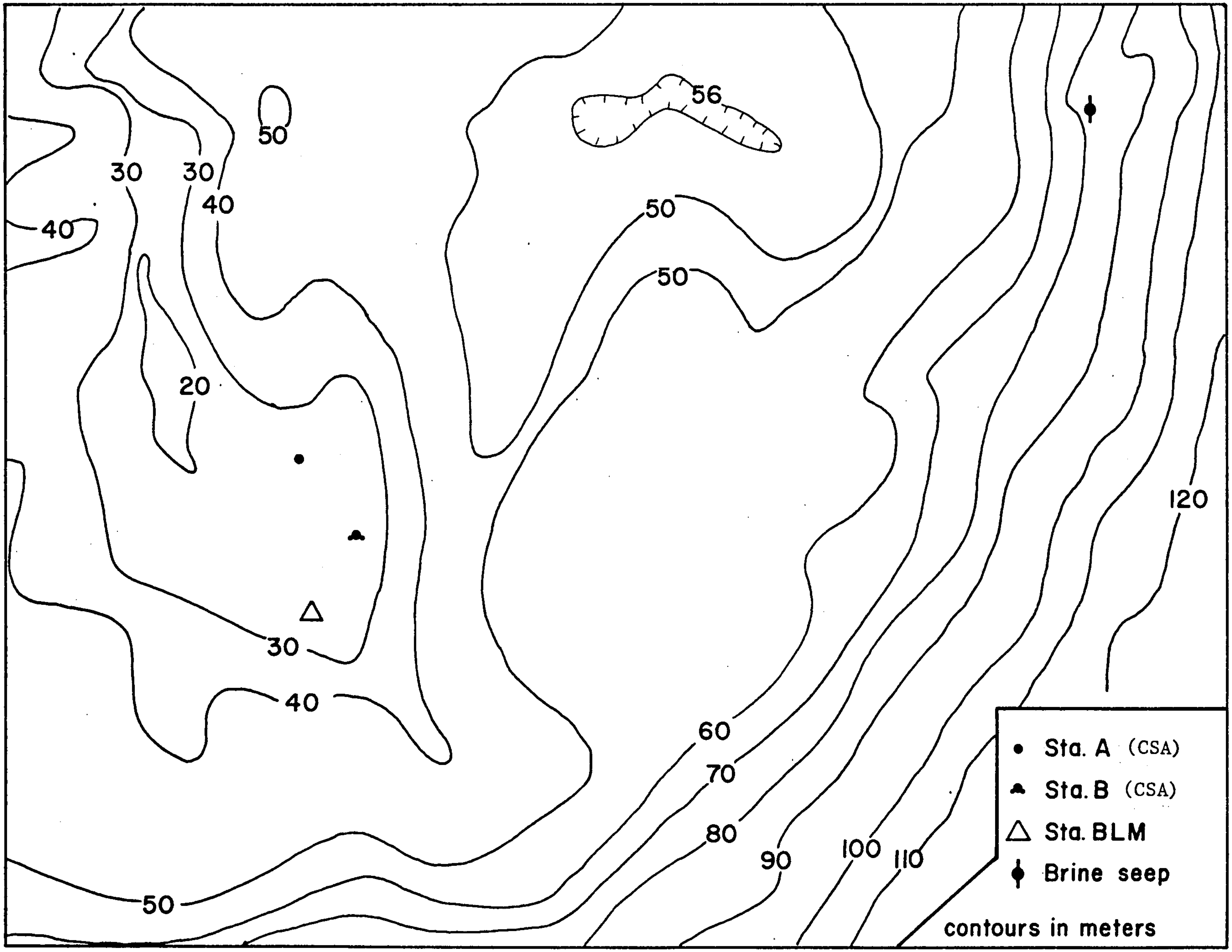


Figure III-4. Locations of three East Flower Garden reef monitoring sites (Sta. A, Sta. B, Sta. BLM) and Brine Seep.

to year will result in an orderly mass of data from which reasonable assessments of the effects of natural and man-induced environmental processes can be drawn.

During the first year, we have concluded that approximately 60-65% of the hard-bottom in the vicinity of our BLM reef monitoring site is covered by living hermatypic coral. This figure cannot be considered representative of the entire reef insofar as the BLM monitoring site is near the edge of the reef. It is suspected that live coral cover may be considerably less on the central part of the reef, where quantitative measurements are yet to be made. At the nearby West Flower Garden reef, measurements indicated 34-40% live coral cover on the reef top in 1972. The East Flower Garden is very similar to the West Flower Garden in terms of depth, physiography, hydrography and coral species composition.

Obvious destructive processes affecting live corals at the East Flower Garden include necrosis of coral tissue; mechanical damage by coralivores, browsers, and grazers; massive loss of zooxanthellae and mechanical damage due to hurricanes; anchor and diver caused damage; and competition for space between encrusting organisms.

Necrosis of coral tissue refers to what is usually perceived as a gradual disintegration and regression of the living tissue at the borders of coral colonies. The cause, or causes, of necrosis are not apparent. In many cases there appear to be spatial correlations between the occurrence of necrosis and filamentous or endolithic algae. It is hypothesized that certain algae may secrete chemical substances which induce necrosis in coral tissue, but we have no reliable evidence that this is so. No cases of coral death due to the known coral pathogen Oscillatoria submembranacea (a blue-green alga) (Antonius, 1977) have been encountered at the East Flower Garden.

Whatever the cause, coral necrosis is one of the most important processes resulting in reduction of live coral cover at the East Flower Garden. Measured rates of linear retreat of live coral borders due to necrosis varied from 0.05 cm/mo to 5 cm/mo, with an average of approximately 1 cm/mo. The maximum rate of retreat measured by us at the East Flower Garden (5 cm/mo) is about half the maximum rate of regression measured by Dustan (1977) for what he calls "plague" at Carysfort Reef off Key Largo, Florida. Dustan's "plague" seems to resemble our necrosis in appearance. Fortunately, most living coral borders at the East Flower Garden are not necrotic. We do not yet have an estimate of the percentage of coral borders which are necrotic.

At the East Flower Garden, mechanical destruction of live coral tissue is attributed to 1. hurricanes which dislodge small coral heads; 2. coral-eating fishes (and possibly invertebrates); 3. incidental damage inflicted by browsers and grazers searching for food directly adjacent to live coral tissue borders; and 4. damage by anchors and diver activity.

Mechanical damage by man and storms occurs swiftly, and it is unlikely that the act of destruction will be detected during the course of a monitoring study. For this reason, it is nearly impossible to identify the exact cause of supposed manifestations of this type of damage, viz., overturned coral heads and obvious large scars on coral tissue. At present, it can be said that such damage occurs at the East Flower Garden. We cannot, however, define the extent of it on the reef, nor can we speculate on the relative amount of damage caused by storm vs. man. Certainly, the impact of man in this respect has been much less at the East Flower Garden than is the case for shallower, more accessible reefs in the Florida Keys (Dustan, 1977).

The destructive impact of coralivores such as the Stoplight parrotfish, Sparisoma viride, may be considerably greater than that currently attributable to man or storms. Such destruction is more easily observed in progress because of its pervasive and continuous occurrence on the reef. Some of the coralivores appear to work "territories," for a period of weeks or longer. Although our observations of coralivore activities are limited, it is suspected that they are of major importance in the balance between destructive and constructive processes affecting coral populations at the East Flower Garden.

Recovery rates of damaged coral are apparently slow, possibly on the order of several years for a damaged patch of coral 10 cm or so in diameter. It is believed that lateral encrusting growth of a damaged colony is the most important recovery mechanism at the East Flower Garden, although recruitment and establishment of new colonies must play a role.

Lateral coral growth, massive growth and recruitment are logically the constructive processes which compensate for and balance the destructive processes discussed above. We have no information on massive growth and recruitment at the East Flower Garden. Measurements of lateral encrusting growth rates of the major anthozoan corals range from 0.037 to 0.25 cm/mo, with an average of approximately 0.15 cm/mo.

It is felt that the numerical balance between the rate of anthozoan coral tissue regression on the reef due to destructive processes and tissue growth due to constructive processes is the critical measure of reef "health." An index of "health" would therefore be $G/R = H$ where G is the rate of lateral tissue growth, R is the rate of lateral tissue regression and H is a value representing "health" of the dominant hermatypic coral population, and presumably the reef. Where H is greater than one it can be assumed that the percent cover of live hermatypic coral is increasing (healthy). A value of H less than one would indicate a decrease in live coral cover (unhealthy). The complexity of this seemingly simple ratio is apparent when one considers the various elements comprising G and R. G is a function of all of the growth rates of all of the important species of anthozoan corals on the reef, with due consideration for their relative abundances. R is a function of the rates of regression for all of the corals, with due consideration for their relative abundances. These rates will vary with location on the reef, hydrography, season, and the nature and rates of processes controlling regression, growth, and recruitment of new coral colonies.

One of the objectives of our future efforts at the East Flower Garden will be to devise a feasible methodology for the determination of a numerical index of the "health" of coral populations which will be useful as a management tool. Until such is accomplished, judgements concerning the condition of the reef continue to be somewhat subjective.

Nevertheless, on the basis of information gathered during 1977-1978, we have found no evidence that drilling activities in the vicinity of the East Flower Garden have had deleterious effects on the reef communities through the spring of 1978.

EAST FLOWER GARDEN BRINE LAKE.

The East Flower Garden (EFG) Bank is one of many salt diapirs which dot the Northwestern Gulf. Salt tectonics on this shelf and slope may result in many such brine outflows, as witnessed by the recent fortuitous discoveries of the EFG brine (Bright, 1977) and the Orca Basin brine (2400 m depth, Northwestern Gulf of Mexico, Shokes _et al._, 1977).

The EFG brine (200 o/oo) has its origin in the evaporite deposits that underlie the reef bank. Molecular and isotopic comparisons of the EFG and Orca basin brines indicate that although these brines both originate from Gulf evaporite deposits, they have different histories. The low $C_1/(C_2 + C_3)$ ratio resulting from appreciable quantities of ethane and propane and the heavy carbon isotope ratio of methane (-40 o/oo) in the EFG brine are indicative of thermocatalytic hydrocarbons in oil field-produced brines in this region. The Orca basin shows typical biologically-produced hydrocarbon compositions with $C_1/(C_2 + C_3)$ ratios in the hundreds and $\delta\ ^{13}C$ ratios around -74 o/oo.

The other major difference between the Orca and EFG brine is in bacterial activity. The extent of bacterial activity in the Orca Basin brine is unknown, although recent measurements indicate that only very low levels exist. The low level of hydrogen sulfide in the

Orca Basin is further evidence for its low bacterial activity. It is uncertain at present why there is such a large difference in bacterial activity in these brines, as their carbon reservoirs and nutrient levels are similar. There may be a threshold salinity above which anoxic, hypersaline bacteria cannot function. The presence of light and H_2S as a hydrogen source may also contribute to higher bacterial levels in the EFG brine. The temperature and pressure difference between 72 and 2400 m may also be a controlling factor.

Further studies are continuing at the EFG brine lake to determine the origin of the brine, the cycling of carbon in the reservoir, and bacterial perturbations of chemical constituents within the pool and overflow canyon. The brine lake is a unique biogeochemical phenomenon and should be recognized as being worthy of environmental protection and preservation for its intrinsic scientific value.

TRACE METALS

Concentrations of selected trace metals have been determined in organisms collected from several topographic highs on the Texas-Louisiana Outer Continental Shelf in order to provide a basis for detecting and evaluating future changes in organismal trace metal levels which could result from increased petroleum exploration and development in this region. Three species of organisms were analyzed for trace metals. They included two macronekton species (fish: *Lutjanus campechanus*, red snapper; *Rhomboplites aurorubens*, vermilion snapper) and one epifaunal species (spiny oyster, *Spondylus americanus*).

Samples were collected primarily during September and October (second season) from six banks. Macronekton samples were taken at Ewing, East Flower Garden, and Sonnier Banks. Spondylus were collected at Bouma, Bright, East Flower Garden, and 18 Fathom Banks. All of the banks sampled during 1977 (except Bouma and East Flower Garden) were farther east than those visited during 1976.

A total of 65 analyses, each for ten trace metals (Al, Ca, Cd, Cr, Cu, Fe, Ni, Pb, V, Zn), were conducted on material from 7 macronekton and 9 spiny oyster samples. In addition, Ba levels in Spondylus were determined.

Although often difficult to collect, Spondylus was a good organism to choose for a baseline study such as this one. Spondylus contains relatively high levels of all the metals of interest and being a sessile organism it should be a fairly sensitive indicator for the levels of biologically available trace metals in the local environment. Lutjanus and Rhomboplites were selected for this study because they are common inhabitants of topographic highs in the Northern Gulf of Mexico. This fact permits a consistency in sampling which is essential for a project where the number of samples is relatively small. Also there are important commercial and sport fisheries for both species in the Northern Gulf. Because of their mobility, trace metals levels in macronekton are probably insensitive to small scale (microenvironmental) changes in ambient trace metal concentrations. However, macronekton probably reflect or integrate trace metal levels existent over a larger geographic area than do sessile organisms. As a result, these levels are probably better indicators of large scale fluctuations in ambient trace metal concentrations.

Conclusions

1. Although 3 of the 4 banks (Bouma, Bright, and Ewing) sampled during 1977 had not been visited in 1976, the levels and variability of trace metals observed for both years were generally similar. This observation is significant when one considers that samples of the three species of marine organisms analyzed were collected from banks scattered along a 450 km stretch of the Texas-Louisiana OCS. No indication of substantial trace metal pollution was observed at any of the topographic highs sampled.
2. Significant differences in trace metal levels between bank stations were observed. However, no consistent geographical trend in metal levels was apparent.
3. *Spondylus* and macronekton liver tissue represent the best sample types for future monitoring because they contain measurable levels of all metals studied during this baseline effort. With sufficient replication of samples ($\geq 5 - 10$) at each collection site, intra-station variability in trace metal concentrations could be reduced to permit meaningful quantitative statistical comparisons among different banks.
4. Rank order relationships of elemental means in macronekton gill and liver tissue are sufficiently consistent to suggest that any future departures will be the result of important environmental changes. The pattern is Fe > Zn > Cu > Pb > Cd for gills and Fe > Zn > Cu > Pb or Cr or Ni for livers.

HIGH MOLECULAR WEIGHT HYDROCARBONS IN MACRONEKTON AND SPONDYLUS SAMPLES

Six samples of macronekton from the East Flower Garden, Ewing, and Sonnier Banks and five *Spondylus* samples from the East Flower Garden and 18 Fathom Banks were analyzed using Gas Chromatography and Gas Chromatography-Mass Spectrometry according to procedures established by BLM. A total of 18 analyses (3 organs per sample--liver, gonads, muscle) were performed on the macronekton samples, and 5 analyses (whole specimens, less shell) were performed on *Spondylus* samples.

The distribution patterns of *n*-alkanes and the absence of aromatic hydrocarbons in the macronekton and *Spondylus* samples imply that very low levels or no heavy hydrocarbons of anthropogenic origins are present in organisms from the study area.

HIGH MOLECULAR WEIGHT HYDROCARBONS IN SEDIMENTS

Nineteen sediment samples from the East Flower Garden, Parker, Sonnier and Bright Banks were analyzed for high molecular weight hydrocarbon (HMWH) content in accordance with procedures established by BLM. In addition, 17 of these samples were analyzed for total organic carbon (TOC) and $\delta\ ^{13}C$.

The TOC values at several stations are higher than the usual 1% for open shelf sediments and represent a higher level of production or lower rate of decomposition. The $\delta\ ^{13}C$ values are similar to open shelf values. No oil is indicated.

The levels of HMWH and the molecular types are consistent with an environment which has vanishingly small levels of petroleum contamination. This is the same picture that has emerged in the open shelf studies of sediment (Parker *et al.*, 1975, 1976, 1977, 1978).

MEIOFAUNA AND MACROINFAUNA

Our studies of Meiofaunal and Macroinfaunal populations in the vicinity of Outer Continental Shelf Banks off Texas and Louisiana lead us to the following conclusions:

1. The meiofauna of the flanks of the hard banks off the Texas coast form a stable community that varies in regard to depth, orientation down-current of the main mass of the bank, sediment grain size and, presumably, in regard to the amount of labile carbon compounds in the sediment.
2. The bank meiofaunal populations are, generally, higher than those on the adjacent level bottoms of the outer continental shelf. This may be a reflection of greater inputs of organic materials into the sediments from the bank debris and detritus, but again, this is as yet untested. The latter is suspected, however, because harpacticoid copepods, which respond positively to organic inputs, are significantly more abundant on the banks than on level bottoms in this area.
3. It is noted that the harpacticoid:nematode ratio is significantly greater at the banks than at transect stations. Also, the ratio differs predictably among banks, appearing to indicate that banks have a signature ratio that will identify its condition of health. Whereas environmental impacts can be measured among the macroepifauna, primarily by death or no death, such impacts can be estimated and predicted by

ratio changes among these two components of the meiofauna. Further work would be required to note signature ratios.

4. The macroinfauna of the flanks of the hard banks off the Texas coast also form a stable community that varies less than the meiofauna in the depth range of this study. However, as in the case of the meiofauna, it is more abundant downstream of the bank proper, and it is significantly more abundant on the bank flanks than on the level bottoms of the transects.
5. The meiofaunal annual production in the Gulf is believed to be two to five times greater than the macroinfauna.
6. The true meiofauna:macroinfauna ratio is considered to be another important signature marker of individual banks. It appears to be stable from year to year.
7. Both the meiofauna and the macroinfauna respond to changes in the characteristics of the sediment bed. However, it appears that the usual division of sediments into gravel, sand, silt and clay is too gross. Rather, the individual grain sizes should be divided into at least 16 categories and percentages for each derived.

CONCLUSIONS AND RECOMMENDATIONS

IV. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Biological and geological reconnaissance efforts in September, 1977, resulted in the characterization of seven topographical features in the Northwestern Gulf of Mexico. In addition, monitoring studies of the biological health of the reef and physical oceanographic parameters of the water column were conducted at the East Flower Garden Bank. A sediment net transport study using fossil coccoliths as tracers has demonstrated two relatively restricted avenues of basinward sediment transport on the South Texas outer continental shelf.

All of the banks in the present study are associated with shallow subsurface salt structures. The shapes of the banks are dependent upon a number of factors, such as:

1. The age of the salt dome, i.e. was the dome subaerially exposed during the Pleistocene or has its topographic expression developed since the last rise in sea level?
2. The nature of the rocks that have been penetrated by the salt.
3. The amount of dissolution of salt and collapse of the overlying sedimentary rocks.
4. The degree of faulting associated with the salt structure.
5. The amount of reef growth during Late Pleistocene to Recent time.

Reef growth has modified the surficial characteristics of the banks. Young reefs tend to accentuate the original local relief, while older reefs tend to mask the original local relief.

18 Fathom Bank (27°57'N, 92°35'W) is a shelf-edge carbonate bank bearing clear water epibenthic communities. Depauperate coral reefs (Stephanocoenia-Montastrea-Agaricia Zone) occupy the crest of the bank. An Algal-Sponge Zone extends downward to approximately 82 m depth, with healthy populations of coralline algae forming algal nodules and algal reefs. In terms of the bank classification scheme presented in Bright and Rezak (1977), 18 Fathom Bank is a category #1 bank, with living coral reefs (highest environmental priority).

Bright Bank (27°53'N, 93°18'W), Bouma Bank (28°03'N, 92°28'W), Parker Bank (27°56'N, 92°00'W) and Ewing Bank (28°05'N, 90°59'W) are all carbonate banks with biotic communities and zonation similar to 18 Fathom Bank except that they lack living coral reefs. They are, therefore, category #1 banks without coral reefs.

Sackett Bank (28°38'N, 89°33'W) is only 21 miles from the Mississippi Delta. The crest of the bank is carbonate reef rock that was probably produced during the Late Pleistocene when the outflow of the Mississippi River was to the west of the bank. Limited amounts of live coralline algae are present on the bank as crusts and nodules. Most of the carbonate substrate, however, is covered by a thin veneer of sediment or occupied by sparse epifauna.

Benthic communities in general are not as well developed on Sackett Bank as they are at comparable depths on other shelf-edge banks. It is hypothesized that this condition results from unfavorable and variable hydrographic conditions related to the Mississippi River outflow (high turbidity, sedimentation, changeable temperature and salinity, etc.). Biologically and structurally, Sackett Bank could be classified as a very depauperate and regressing category #1 bank. In terms of environmental priority, however, it is closer to category #3.

Sonnier Banks (28°20'N, 92°27'W) are mid-shelf features comprised of 8 separate peaks. Each peak consists of steeply dipping sandstones, siltstones and claystones of Tertiary age. The constancy of the strike of the beds in each peak and the arrangement leads to the conclusion that the peaks represent individual fault blocks caused by the collapse of the beds overlying the salt plug along radial and annular faults. The crest of the largest of these peaks is occupied by a nearly total cover of hydrozoan corals and sponges. Biotically, it is similar to Stetson Bank and is appropriately classified as a category #2 bank. We detected no evidence of serious, lasting environmental effects on Sonnier Banks due to the drilling of 9 exploratory wells between 4.6 and 9.2 kilometers distance from the banks in the mid 1960's.

Three biological monitoring sites were established on the coral reef at the East Flower Garden Bank. Substantial mechanical destruction of coral tissue by coral-eating reef animals was documented. It is suspected that the dislodging of coral heads, expulsion of zooxanthellae by corals and disruption of leafy algae populations may have resulted from water movements and temperature variations associated with the passage of two hurricanes in August and September 1977. Slow death (necrosis) of anthozoan coral heads due to disease-like factors was followed at 14 specific stations. Where necrosis occurred it appeared to result in the lateral regression of living coral tissue at a rate of approximately 1 cm/month, on the average.

Lateral growth rates of anthozoan corals at 7 specific stations averaged approximately 0.1 cm/month. Growth rates of the hydrozoan coral (Millepora) and encrusting coralline algae are substantially higher.

Information concerning the numerical balance between lateral regression and growth of anthozoan corals in terms of area vacated or newly occupied by living coral tissue is to be pursued in the coming year. It is felt that knowledge of this balance will allow us to create a numerical index of reef "health." We have demonstrated that mechanical damage to coral tissue, necrotic death of corals and lateral coral growth are measureable and can be quantified at the East Flower Garden Bank over periods of time less than a year. We hope to develop our techniques to a level which will result in a numerically valid method of monitoring the health and condition of populations of corals and coralline algae, which are the most appropriate "indicator" organisms on the reef. Neither the studies related to coral health nor submersible reconnaissance observations made in the southeast quarter of the East Flower Garden have revealed undue changes in rates of coral growth and death or apparent conditions of benthic communities between 1976 and 1978.

Hydrographic cruises were conducted during June and September 1977 and February-March 1978 to obtain profiles of temperature, salinity, transmissivity, and current velocity at stations at the East Flower Garden Bank. It is quite clear from the data collected that the nepheloid layer is an integral part of the bottom boundary layer. The amount of suspended sediment and its penetration height above the bottom are a function of the local sediment type and the intensity of the turbulence present. Stratification in the water column precludes the transport of sediment above the top of the mixed layer.

The presence of banks on the outer continental shelf induces internal waves similar to the riffles that form over rocks on the bottom of a fast flowing stream. Where the internal waves impinge on the bottom they stir up the sediment and it becomes entrained in the flow over the bank. Some internal waves appear to have a tidal origin. These waves are caused by break-up of the barotropic tide on the shelf edge. They affect the whole water column and contribute large quantities of turbulence to the bottom boundary layers. This, in turn, leads to intermittent suspension of dense clouds of sediment as the waves pass over the bottom.

Mapping of the distribution of redeposited Cretaceous coccoliths in the surface sediments of the South Texas continental shelf has provided an overview of the dispersal pattern of fine silt and clay-sized particles that are introduced along the shoreline. In general, the proportion of redeposited coccoliths decreases with distance from the shoreline, as would be expected. Important exceptions to this generalization are found in the northeastern part of the study area (Figure III-1) in the region south and east of Matagorda Bay, where a westward onshore transport is suggested by the very low number of land-derived redeposited specimens. Immediately south and west of this area of onshore transport are two well-defined tongues of offshore transport extending diagonally across the continental shelf, one nearly due east, the other approximately due south from St. Joseph's Island-Matagorda Island. These two tongues of offshore transport of fine silt and coarse clay-sized sediment appear to be related to seasonal shifts in the wind driven surface currents, although the precise relationship is not yet totally clear.

Farther south on the South Texas continental shelf, offshore transport of coccolith size (fine silt and coarse clay) does not seem to be confined to specific pathways as in the northern part of the area. Rather, dispersal seems to occur broadly across the shelf in a manner more or less analogous to diffusion.

It is useful to bear in mind that the dispersal pattern deduced from surface sediment represents an integrated picture of sediment transport over a period of years and decades, not an instantaneous state of sediment transport. The latter can be best deduced from sediment in suspension, and this problem, too, was addressed in this study, albeit less successfully. Coccoliths--both modern and redeposited species--were found in suspended sediment and most notably in near-bottom suspended sediments, their occurrence was found to be sporadic, depending very probably on the amount of turbulence and resuspension that was occurring at the time the samples were taken.

It is reasonable to conclude that if a particulate pollutant with particles in the fine silt and clay-sized range were introduced to the South Texas continental shelf area, the particles would be distributed in the same fashion as are the redeposited coccoliths. If such particulates were known to have harmful effects, a maximum impact would be produced in the area of greatest concentration, that is, the area where the particles are swept across the continental shelf in narrow bands.

RECOMMENDATIONS

Insofar as drilling for and production of petroleum is increasing in the immediate area, it is recommended that environmental and hydrographic monitoring studies at the East Flower Garden be continued. The studies should be directed, in part, toward refining *in situ*, nondestructive methods to monitor the health and condition of reef corals and coralline algae as indicator organisms. A numerically valid index of reef "health" should be developed using as its basis the quantitative relationship between rates of coral death and lateral encrusting coral growth. Natural and man-induced ecological processes affecting the growth and death of coral tissue and coralline algae should be investigated further to establish cause and effect relationships.

The nepheloid layer is a transient feature in a state of almost constant change. It does, however, represent sediment trapped near the bottom by stratification of the water column. An artificial turbid layer such as the effluent of drilling mud from a rig could be expected to behave in much the same manner. That is, once shunted to the bottom it would be unlikely to rise again to the level of the living reefal communities on the East Flower Garden or other banks of the same type. Dumped on the surface, this effluent might travel long distances before sinking to safe depths. The variability of directions and speed of the surface currents suggest that it is unwise, therefore, to permit surface dumping near these banks.

It is suggested that BLM monitoring studies at the East Flower Garden Bank would be greatly facilitated by the establishment of an on-site monitoring station on a production platform directly adjacent to the bank. Bathymetric mapping during the past year was limited to a pre-determined depth contour based upon the probable existence of sensitive biotic elements above these depths. As a result, on some banks the entire geological structure of the bank was not mapped. We recommend that the limits of mapping for each bank be determined by the geological structure as delineated by the subbottom profiles during the mapping process. This will insure complete coverage of the bank and permit a more realistic assessment of the geological hazards at each bank. In addition, two lines, a north-south line and an east-west line on each bank should be extended a distance of at least 5 nautical miles beyond the bank margin so that the structural details of the bank may be related to the regional structural picture that is being developed by the U.S. Geological Survey.

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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.