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ENVIRONMENTAL STUDIES AT THE FLOWER GARDENS AND SELECTED BANKS: NORTHWESTERN GULF OF MEXICO, 1979-1981

EXECUTIVE SUMMARY

Northern Gulf of Mexico Topographic Features Study

Contract No. AA851-CT0-25

Submitted to the
U.S. Department of the Interior
Minerals Management Service
Outer Continental Shelf Office
New Orleans, Louisiana

Technical Report No. 82-8-T

Research Conducted Through
the Texas A&M Research Foundation

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TEXAS A&M UNIVERSITY

COLLEGE OF GEOSCIENCES

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CHAPTER I

INTRODUCTION

D. McGrail, Program Manager
S. Herrig, Assistant Program Manager

This report summarizes the Final Report (McGrail, Rezak, and Bright, 1982) on Gulf of Mexico studies performed in 1979-1981 by Texas A&M oceanographers for the U.S. Department of the Interior, Minerals Management Service (MMS). Formerly known as the New Orleans Outer Continental Shelf Office of the Bureau of Land Management (BLM), MMS is the new title of the government agency which has funded continuing Gulf of Mexico studies directed by Richard Rezak and Thomas J. Bright since 1975 and by Drs. Bright, Rezak, and David W. McGrail since 1977 (Bright and Rezak, 1976, 1978a,b; Rezak and Bright, 1981a).* These studies built upon previous investigations and were motivated by concerns about the environmental effects of oil and gas lease sales on the Outer Continental Shelf (OCS) of the Gulf of Mexico.

BACKGROUND ON PREVIOUS STUDIES

The U.S. Department of the Interior, Bureau of Land Management, held public hearings in 1973, 1974, and 1975, prior to Texas OCS oil and gas lease sales. The hearings were held because of concerns about the possible environmental impact of oil and gas drilling and production operations on coral reefs and fishing banks in or adjacent to lease blocks to be sold. Concerns were articulated by government agencies, such as the National Marine Fisheries Service, by university scientists, and by private citizens. As a result of these hearings, certain restrictive regulations were established for drilling operations in the vicinity of the well documented coral reefs at the East and West Flower Garden Banks.

At that time, very little was known about the geology and biology of the South Texas OCS banks lying in or near lease blocks to be offered for sale in 1975. To fill this information gap, BLM contracted with Texas A&M oceanographers for what became a series of Gulf of Mexico studies. Dates and types of data obtained since the original 1975 study are summarized in Table I-1.

1975 Studies

The initial Texas A&M investigation for BLM provided baseline biological and geological information required to facilitate judgements as to the need for and nature of protective regulations to be imposed on drilling operations near these banks. During the latter part of 1974 and early 1975, Texas A&M contracted to map 17 banks using precision navigation, precision depth recorder, and side-scan sonar. It was found that three of the areas mapped exhibited no topographic expres-

*Any references in the present report to leasing and resource management by BLM are presently administered by the newly created MMS.

TABLE I-1
SUMMARY OF DATA GATHERED IN PREVIOUS
TAMRF-BLM TOPOGRAPHIC FEATURES STUDIES, 1974-80

BANK NAME (abbrev.)	CONTRACT YEAR(s) STUDIED	MAPPING CRUISE	§SUB. OBS. (geo/bio/ hydro)	ROCK SAMP-LES	SEDIMENT SAMPLING	SIDE-SCAN SONAR	SUB-BOTTOM SEISMIC PROFILES	HYDRO-GRAPHIC MEASURE-MENTS	SPECIAL STUDIES
Adam:									
Big Adam (BAD)	CT-5	Jun 75	Jun 75 (geo)	X	X	X			
Small Adam (SAD)	CT-5	Nov 74	none	X		X			
Little Adam (LAD)	CT-5	Nov 74	(no topographic expression)						
Alderdice (ALD)	CT-8	Sep 78 (geo/bio)	Oct 78	X	X	X**	X**(S/I;R)	X	
Applebaum (APL)	CT-5	May 75	none	X	X	X			
(Little Sister)	CT-8		none			**			
Aransas (ARA)	CT-5	Nov 74				X			
	CT-6		Sep 76 (bio)						
Baker (BAK)	CT-5	Oct 74	May 75	X	X	X			
South Baker (SBA)	CT-5	Oct 74	May 75						
	CT-6		Sep 76	X	X	X			††PDE
Blackfish (BLA)	CT-5	Nov 74				X			
	CT-6		TV only						
Bouma (BOU)	CT-7	May 77	Sep 77 (bio)	X		X	X		
	CT-0					**	**(S/I;R)		
Bright (BRI)	CT-7	May 77	Sep 77 (bio)		X	X	X	X	
	CT-0					**	**(R)		
Claypile (CLA)	CT-6		Sep 76 (bio)	X					
	CT-7	Jun 77				X	X		
Coffee Lump (COF)	CT-8	Sep 78	Sep/Oct 78	X	X	X**	X**(S/I;R)	X	
Diaphus (DIA)	CT-8	Sep 78	Oct 78	X	X	X**	X**(S/I;R)	X	
Dream (DRE)	CT-5	Nov 74	Jun 75	X	X	X			

† : Chart prepared in 1969 by Southwest Research Institute; revised by TAMU in 1974.
* : Sediment distribution map constructed.
** : Interpreted; S/I = structure/isopach map; R = seafloor roughness map; M = side-scan sonar mosaic.
†† : PDE = post-drilling environmental assessment.
Eco = quantitative ecological study of relationship of nepheloid layer to epibenthic community distribution and abundance.
X : Studies conducted, as indicated in column heading.
§ : Unless otherwise indicated, geological, biological, and hydrographic observations were made from the submersible.

TABLE I-1 (Continued)

BANK NAME (abbrev.)	CONTRACT YEAR(s) STUDIED	MAPPING CRUISE	§SUB. OBS. (geo/bio/ hydro)	ROCK SAMP- LES	SEDIMENT SAMPLING	SIDE- SCAN SONAR	SUB-BOTTOM SEISMIC PROFILES	HYDRO- GRAPHIC MEASURE- MENTS	SPECIAL STUDIES
East (EAS)	CT-5	Nov 74	(no topographic expression)						
East Flower Garden	CT-5		Jun 75	X	X				††PDE
Garden (EFG)	CT-6	Jul 76	Sep 76	X	X	X	X	X	††Mon
	CT-7		Sep 77	X	X			X	††Mon
	CT-8		Oct 78	X	X*	**	**	X	††Mon
	CT-0		Sep 79 & Oct 80	X	X*	**	**(S/I;R)	X	††Mon
Elvers (ELV)	CT-8	Sep 78	Oct 78 (bio)			X**	X**(S/I;R)		
Ewing (EWI)	CT-7	May 77	Sep 77			X	X		
	CT-0					**	**(S/I;R)		
Fishnet (FIS)	CT-8	Sep 78	Oct 78	X	X	X**	X**(S/I;R)	X	
Four Rocks (4RO)	CT-5	May 75	(no topographic expression)						
Geyer (GEY)	CT-8	Sep 78	Oct 78 (bio)	X		X**	X**(S/I;R)		
Hospital (HOS)	CT-5	†	TV only						
	CT-6		Sep 76		X	X		X	††Eco
North Hospital (NHO)	CT-5	Nov 74	Jun 75			X			
Jakkula (JAK)	CT-8	Sep 78	Oct 78 (bio)	X	X	X**	X**(S/I;R)	X	
MacNeil (MAC)	CT-0	Aug/Sep 80	none			X*(M)	X**(S/I)		
Mysterious (MYS)	CT-5	Nov 74	TV only			X			
Parker (PAR)	CT-7	May 77	Sep 77 (geo)		X	X	X	X	
	CT-0					**	**(S/I;R)		
Rezak-Sidner (RSI)	CT-8	Oct 78	Oct 78	X	X	X**	X**(S/I;R)		
Sackett (SAC)	CT-7	May 77	Sep 77 (bio)		X	X	X	X	
Sonnier (SON) (Three Hickey Rock)	CT-7	May 77	Sep 77	X	X	X	X	X	

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* : Sediment distribution map constructed.
** : Interpreted; S/I = structure/isopach map; R = seafloor roughness map; M = side-scan sconar mosaic.
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TABLE I-1 (Continued)

BANK NAME (abbrev.)	CONTRACT YEAR(s) STUDIED	MAPPING CRUISE	§SUB. OBS. (geo/bio/hydro)	ROCK SAMPLES	SEDIMENT SAMPLING	SIDE-SCAN SONAR	SUB-BOTTOM SEISMIC PROFILES	HYDROGRAPHIC MEASUREMENTS	SPECIAL STUDIES
Southern (SOU)	CT-5	May 75	Jun 75						
	CT-6		Sep 76	X	X	X		X	††PDE/Eco
Stetson (STE)	CT-5	(Included data obtained on previous contract with Signal Oil)							
	CT-6	Jul 76	Sep 76 (bio)	X	X	X		X	††PDE
	CT-0					**(S/I)			
West Flower Garden (WFG)	CT-5				X	X			
	CT-8	Jul 79	Sep 79	X	X	X**	X	X	††Mon
	CT-0		Oct 80	X	X*	**(M)	**(S/I)	X	††Mon
18 Fathom (18F)	CT-7	May 77	Sep 77 (bio)			X**			
	CT-0					**(S/I;R)			
28 Fathom (28F)	CT-5	Oct 74				X			
	CT-6		Aug 76 (bio)	X				X	
28 Fathom, SW Peak	CT-6	Jul 76	Aug/Sep 76			X	X	X	
29 Fathom (29F)	CT-5	Oct 74	none			X			
32 Fathom (32F)	CT-5	May 75	none	X		X			
	CT-8					**			

† : Chart prepared in 1969 by Southwest Research Institute - revised by TAMU 1974.
* : Sediment distribution map constructed.
** : Interpreted; S/I = structure/isopach map; R = seafloor roughness map; M = side-scan sonar mosaic.
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sion and were not studied further. Six of the seventeen banks were examined and sampled using the Texas A&M submersible DRV DIAPHUS. All seafloor observations were documented using 35 mm color still photography and black and white video recordings. Surface samples (grabs and cores) were taken at five of the banks. Results of this field work were reported in January 1976 (Bright and Rezak, 1976).

An important discovery made in 1975 was the presence of a layer of turbid water that blanketed the continental shelf surrounding all of the banks examined on the South Texas OCS. This layer of turbid water is associated with increased sedimentation and limited light, both of which have a profound influence on the biota of the banks and the sediments on and around them. The phenomenon is similar to the turbid layer identified by Ewing and Thorndike (1965) in the North Atlantic, for which they coined the term "nepheloid layer." Subsequent Texas A&M studies for BLM have investigated the origin and effects of the nepheloid layer.

1976 Studies

A second investigation initiated for BLM in 1976 (Bright and Rezak, 1978a) extended the mapping program to three more banks and included additional submersible observations of four banks. At four of the seven banks investigated, studies included post-drilling environmental assessments and at two banks scientists examined the quantitative ecological relationship between the nepheloid layer and epibenthic community population dynamics.

An important discovery during the course of this investigation was the existence of a high salinity brine lake at the East Flower Garden Bank. Through subsequent submersible observations (1977-1980), the brine lake has provided a unique opportunity for the study of effects of natural brine discharges. These data should prove useful in assessing the effect of brines which may be discharged from an offshore oil or gas platform over years of production. The presence of the brine lake also provided information on the nature of salt tectonism at the East Flower Garden Bank.

1977 Studies

Studies of the nepheloid layer at various banks and studies of the brine lake at the East Flower Garden Bank were continued in 1977 (Bright and Rezak, 1978b). Additional mapping studies in 1977 provided physiographic and sub-bottom data on eight more banks, seven of which were observed from the submersible. A biological monitoring study was also initiated for the first time within the living coral portion of the East Flower Garden Bank.

1978-1980 Studies

Biological monitoring of the East Flower Garden coral reef was continued in 1978 (Rezak and Bright, 1981), as were studies of the nepheloid layer at selected banks. Both mapping and submersible studies were also undertaken at nine banks not previously observed. Among these was the West Flower Garden Bank, where monitoring studies identical to those at the East Flower Garden Bank were initiated in 1980.

During the 1978-1980 study, several technological changes were made. Provision for seismic and side-scan sonar equipment on mapping cruises made possible the preparation of a series of seafloor roughness and structure/isopach maps for several of the banks. Color video recordings were made of the submersible observations, and the biological monitoring study at the Flower Garden Banks instituted several experimental techniques that permitted quantitative statistical analyses.

Significant advances were made during 1978-1980 in the instrumentation used for hydrographic studies of the nepheloid layer. The deployment of current meter moorings and the development of a sophisticated new system for simultaneous hydrographic measurements have created a very large data base from measurements of turbidity, current velocities, temperature, and salinity in the region of the Flower Garden Banks.

GOALS OF THE PRESENT STUDY

The present study focused on biological and hydrographic monitoring of the East and West Flower Garden Banks, as well as geological analysis and interpretation of sub-bottom, side-scan, and sedimentological data from these two banks. Sub-bottom and side-scan data for seven selected banks were also analyzed and interpreted; with one exception, these data had been acquired in previous studies. Specific goals for the various types of studies are given below. Chapter numbers refer to both McGrail, Rezak, and Bright (1982) and to this Executive Summary. Chapter names and numbers are identical in the two reports.

Flower Garden Banks Region (Chapters II-V)

Geology (Chapter II)

Geological studies at the Flower Garden Banks produced a sediment distribution map for the Flower Gardens region and examined the relationship of sediment facies to biotic zones. Analysis of side-scan and sub-bottom data, as well as submersible observations, permitted construction of maps identifying faults on the two banks and interpreting the structure of the banks. For purposes of display, a side-scan sonar mosaic was prepared for the West Flower Garden Bank, and a seafloor roughness map for the East Flower Garden Bank.

Biology (Chapter III)

Biological investigations at the Flower Garden Banks continued to be directed toward assessment of the health of biotic communities at the two banks. Biotic zonation maps were developed from direct observations and data gathered in the course of the continuing monitoring program. Identical coral ecology studies were carried out at the East and West Flower Garden coral reefs, and the results were compared.

Water and Sediment Dynamics (Chapter IV)

Investigations of water and sediment dynamics at the Flower Garden Banks had three goals: 1) to study the hydrographic climate (salinity, temperature, turbidity, and currents) in which the banks exist; 2) to develop an understanding of the dynamics of the nepheloid layer, particularly as it impinges on these shelf-edge banks; and 3) to ascertain the nature of the shelf-edge flow, including the driving mechanisms.

Chemical Analyses (Chapter V)

Chemical analyses of organisms and sediment samples from the Flower Garden Banks were performed to determine the significance of petroleum-derived hydrocarbons in the samples. These analyses were interpreted in part by comparison with baseline data from previous studies (1975-1978).

Studies of Selected Banks (Chapter VI)

The six banks selected for analysis and interpretation of existing sub-bottom and side-scan records were: Bouma, Bright, 18 Fathom, Ewing, Parker, and Stetson. Existing data are summarized in Table I-1. Similar investigations were carried out at MacNeil Bank, which was mapped for the first time in 1980. The purpose of these studies was to characterize the banks and identify possible geohazards.

CHAPTER II

GEOLOGY OF THE FLOWER GARDEN BANKS

R. Rezak
Principal Investigator

INTRODUCTION

The East and West Flower Garden Banks are similar in origin, general structure, and sediment distribution but differ in the details of structure, physiography, and sedimentology. This chapter focuses on the specific differences in the geology of the two banks.

Texas A&M oceanographers began studying the geology of the Flower Garden Banks in 1961 and have continued to the present time. Funding for this work has been provided by Texas A&M University, the Texas A&M Sea Grant Program, the National Oceanographic and Atmospheric Administration, as well as the Minerals Management Service (formerly Bureau of Land Management).

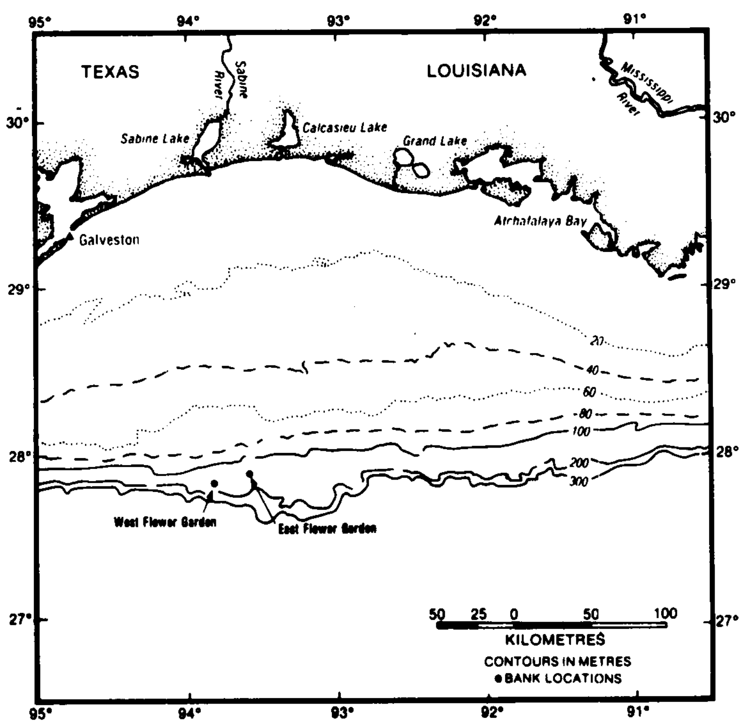

Figure II-1. Flower Garden Banks location map.

GENERAL DESCRIPTION

West Flower Garden Bank

The West Flower Garden Bank is located 107 n.m. due south of Sabine Pass at latitude 27°52'27"N, longitude 93°48'47"W (Figure II-1) in Lease Blocks A-383-85, A-397-99, and A-401 of the High Island Area, East Addition, South Extension, and Lease Block GB-134 of the Garden Banks Area (Figure II-2). It is a large bank covering about 137 km^2. The bank is oval-shaped and oriented in a northeast-southwest direction. The crest of the bank lies at a depth of approximately 15 m. Surrounding depths vary from 100 m to the north, to 150 m to the south. Total relief on the bank is approximately 130 m.

East Flower Garden Bank

The East Flower Garden Bank is located at 27°54'32" latitude and 93°36'W longitude in Lease Blocks A-366, A-367, A-374, A-375, A-388, and A-389 of the High Island Area, East Addition, South Extension (Figures II-1 and 3). The bank is pear-shaped and covers an area of about 67 km^2. Steep slopes occur on the east and south sides of the bank, with gentle slopes on the west and north sides. The shallowest depth on the bank is about 15 m in the northeastern part of Lease Block A-388. The surrounding water depths are about 100 m to the west and north and about 120 m on the east and south sides. An elongate depression in the north-central part of Lease Block A-389 has a depth of 136 m.

PHYSIOGRAPHY AND STRUCTURE

General

Both banks are the surface expression of salt diapirs capped by living coral reefs at their crests. The West Flower Garden is classified as a mature salt dome and the East Flower Garden is a rejuvenated salt dome. A discussion of the development and classification of salt diapirs is presented in Rezak and Bright (1981a, Vol. 1, pp. 23-31).

West Flower Garden Bank

The structure of the West Flower Garden Bank is typical of a mature salt diapir in which crestal faulting has occurred. The trough running from the southeast corner of Lease Block A-399 to the southeast corner of Lease Block A-384 (Figure II-2) is a crestal graben as displayed by the bathymetry. Evidence for recent movement along faults at the West Flower Garden Bank is presented in a sub-bottom profile reproduced in the final report of this study (Rezak, 1982a, Figure II-7). The numerous bathymetric prominences on the bank (Figure II-2) represent fault blocks that stand above the surrounding graben.

The living reef lies in the north-central portion of Lease Block A-398. It rises from depths of 40-50 m to a crest at about 20 m.

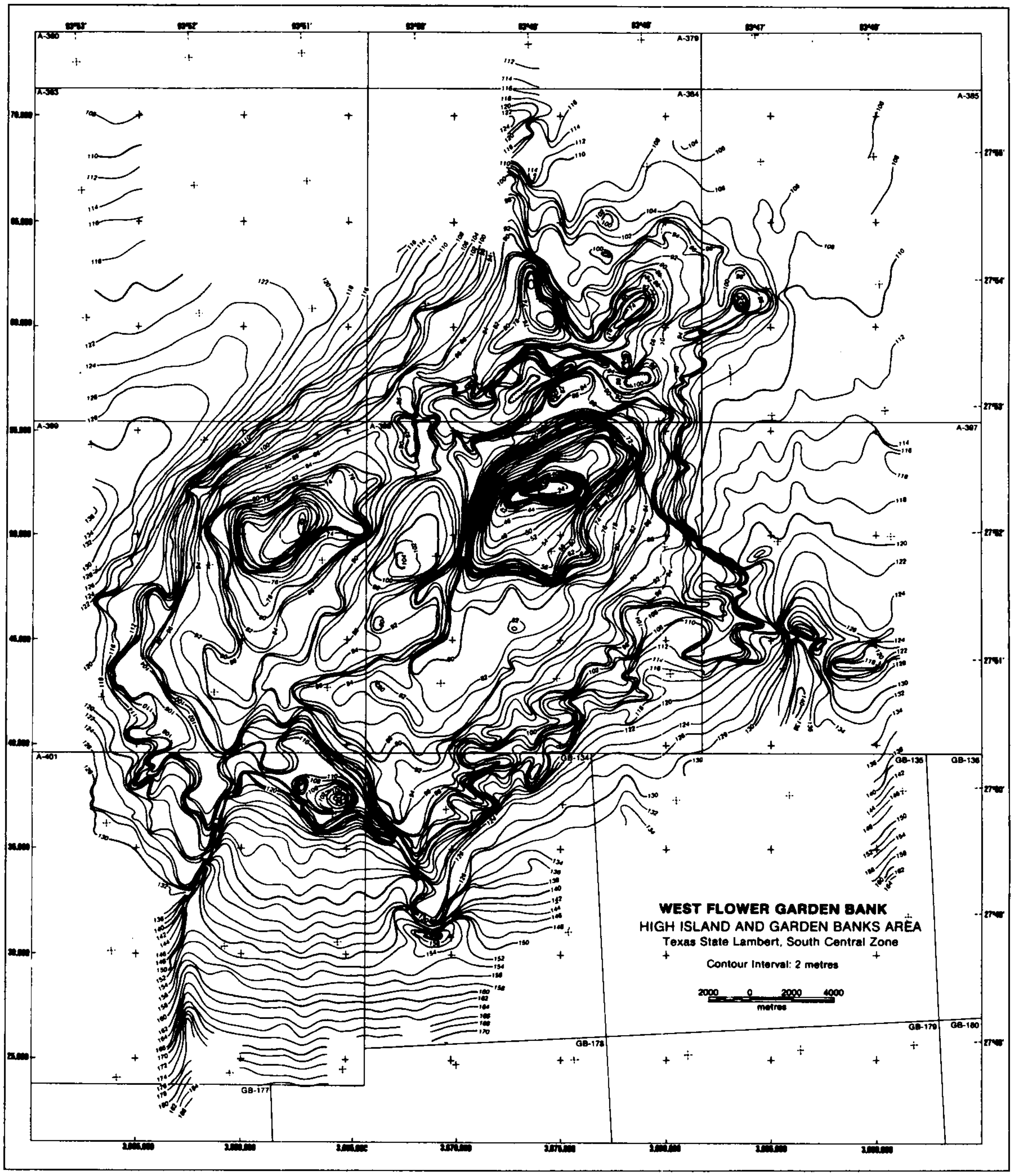

Figure II-2. Bathymetric map of the West Flower Garden Bank.

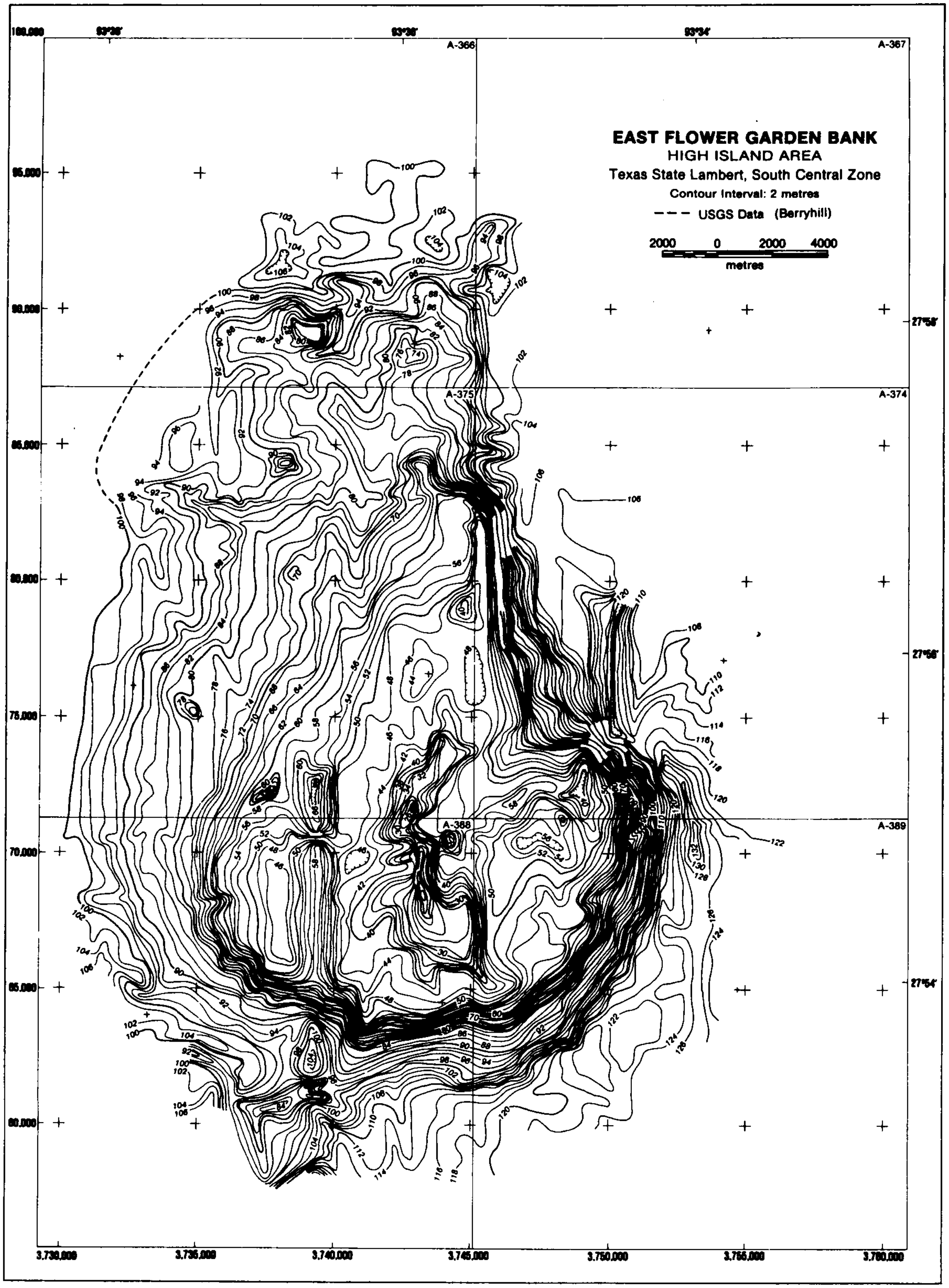

Figure II-3. Bathymetric map of the East Flower Garden Bank.

Extending from near the base of the reef towards the northeast and the south is a broad terrace that reaches depths of about 60 to 70 m (Figure II-2). The surface of this terrace is characterized by large waves of sediment consisting primarily of the gravels of the Gypsina-Lithothamnium Facies. The gravel waves are oriented normal to the isobaths. Below these depths are numerous lineations (faults and outcrops of Tertiary bedrock covered by drowned reefs) and patch reefs scattered to depths as great as 170 m. Most of the patch reefs above 90 m appear to have formed during the last rise of sea level.

East Flower Garden Bank

The structure of the East Flower Garden Bank is typical of either a young or a rejuvenated salt dome. Figure II-3 shows that there is little evidence for faulting on the gentle western slope of the bank. The major faults are peripheral faults on the southern and eastern margins of the bank. Numerous shallow depressions on the central and eastern part of the bank (Figure II-3) probably represent the early stages of crestal collapse.

A large depression between the living reef and the southeastern margin of the bank has been identified as a young graben with a total relief of 10 m. Evidence for recent collapse of this structure has been presented in Rezak and Bright (1981a,b). It is expected that continued removal of salt from the crest of the East Flower Garden Bank diapir will result in continued deepening of this depression. A large part of the living reef lies within this fault block, and continued crestal collapse could eventually displace the living reef into water depths that are unfavorable for reef growth.

Side-scan sonar records show an abundance of drowned patch reefs up to 3 m in height below a depth of approximately 50 m. These patch reefs appear to have developed during the last rise of sea level following the last low stand of sea level about 18,000 years ago.

SEDIMENTOLOGY

The carbonate facies at the two Flower Garden Banks are identical in their composition and bathymetric distribution. The sediment facies at the West Flower Garden Bank are described in detail by Edwards (1971), and the facies at the East Flower Garden Bank are described by Rezak and Bright (1981a, Vol. 3). Figure II-4 shows the distribution of sediments in the Flower Garden Banks area. This map is based upon 139 sediment samples.

The sediments of the two banks differ completely from the sediments of the open shelf surrounding the banks. Bank sediments are all derived from the skeletons of organisms that are living on the banks. On the other hand, the open shelf sediments in the area of the banks are sands and muds that have been eroded from the North American continent and mechanically transported to the Gulf of Mexico by streams such as the Mississippi, Trinity, Sabine, and Brazos Rivers. These sands

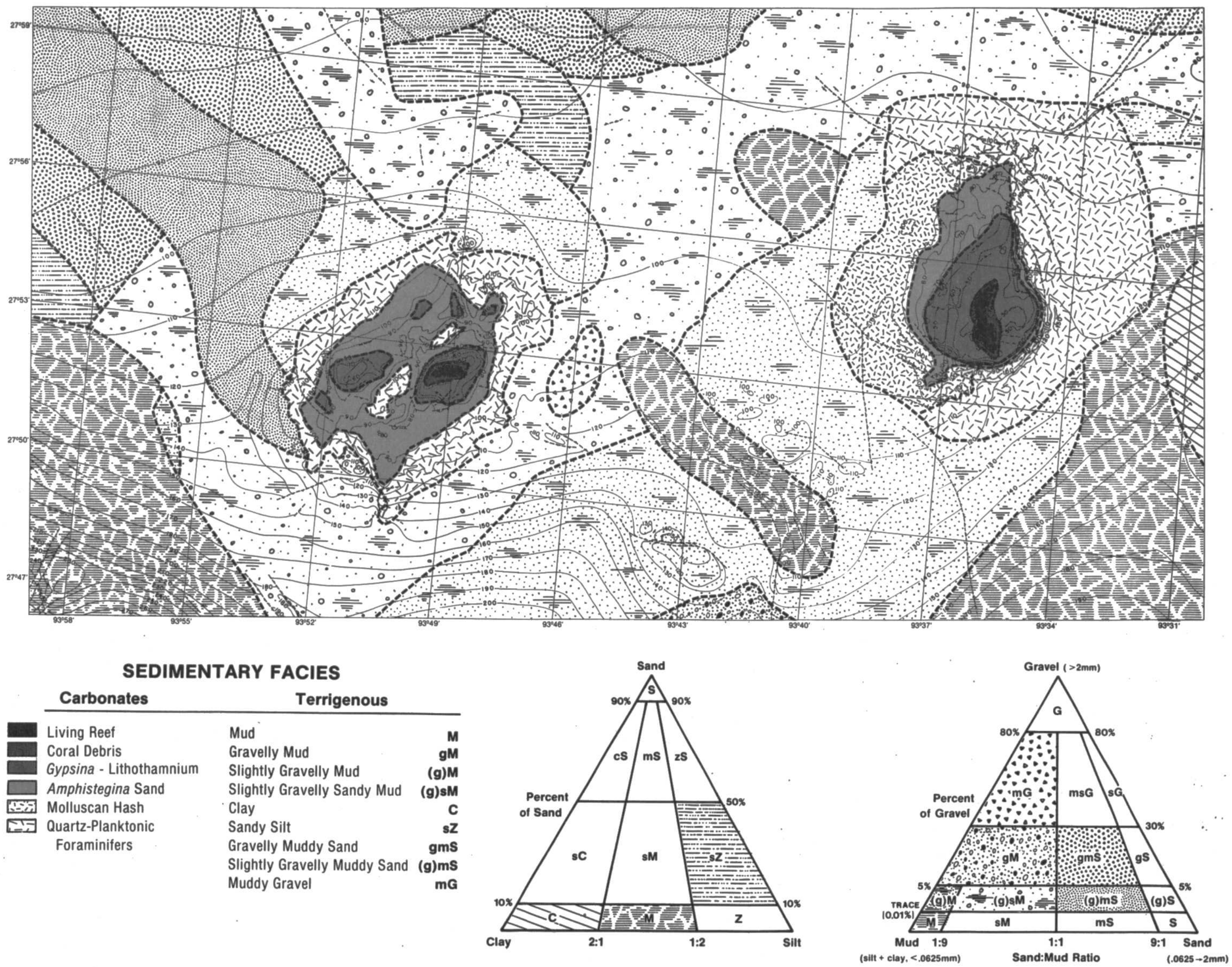

Figure II-4. Sediment distribution map, East and West Flower Garden Banks.

and muds do not occur at depths shallower than 85 m at the Flower Garden Banks. The sediments above the 85 m level are all coarse sands and gravels and the rocky, limestone structure built by the corals and other reef-dwelling organisms.

The loose sediments around the reef reflect the depth zonation of the biological communities that are present on the two banks. Table II-1 illustrates the relationship between the biological zones and the sediment facies.

As may be seen in Table II-1, the sediment facies are intimately related to the biological zonation and hydrological conditions at each bank. However, the sediment boundaries do not coincide with the biotic boundaries. This is partly due to the downslope movement of loose sediment by the force of gravity and partly due to the use of soft-bodied organisms in delineating the biotic zonation. In Table II-1, for example, the lower boundary of the Algal-Sponge biotic zone is based upon the lower depth limit of *Neofibularia*, a colonial, soft-bodied sponge which also grows in the upper part of the *Amphistegina* Sand Facies.

TABLE II-1
RELATIONSHIP BETWEEN SEDIMENT FACIES AND BIOLOGICAL ZONES
AT THE EAST FLOWER GARDEN BANK

SEDIMENT FACIES	DEPTH (m)	BIOLOGICAL ZONE	DEPTH (m)
1. Coral Reef	15-50	1. *Montastrea-Diploria-Porites*	15-36
a. Living Reef (massive limestone)	15-45		
b. Coral Debris (coarse sand and gravel)	25-50	2. *Madracis*	28-46
		3. *Stephanocoenia*	36-52
2. *Gypsina-Lithothamnium* (coarse gravel and massive limestone)	50-75	4. Algal-Sponge	46-88
3. *Amphistegina* Sand (medium to coarse sand, muddy at depths greater than 85 m)	75-90	5. Transition	88-89
4. Quartz-Planktonic Foraminifers (sandy mud)	90 +	6. Nepheloid	89
5. Molluscan Hash (muddy sand)	90 +		

Knowing the distribution of living, lime-secreting, skeletal organisms, one can demonstrate that the direction of sediment transport on the banks is downslope. The Coral Debris Facies accumulates between coral heads and in a narrow band around the base of the living reef. The Gypsina-Lithothamnium Facies consists of coarse gravel and massive limestone that are forming in situ due to the growth of calcareous algae and encrusting calcareous protozoans. However, the Amphistegina Sand Facies is composed of the recently dead skeletons of a small protozoan that lives and grows abundantly in the Gypsina-Lithothamnium Facies. Upon dying, the sand size skeletons of these protozoans are moved downslope by gravity to form the Amphistegina Sand Facies.

At depths less than 85 m, the sediments of the banks are medium to coarse calcareous sands and gravels. The living reef and the Gypsina-Lithothamnium Facies are natural sediment traps due to their highly irregular surfaces. Any fine sediments, such as occur below the 85 m depth, would be trapped in the irregular topography of these facies if they were ever carried to the top of the reef by either physical or biological processes. The surface irregularities would act as baffles that retard the velocity of the currents and cause deposition of the fine sediment in nooks and crannies on the reef and in the Gypsina-Lithothamnium zone. This process is analogous to a snow fence that traps snow away from highways and railroad tracks.

As indicated above, there is no land-derived mud in the bottom sediments above a depth of 85 m. This fact substantiates the conclusion that the nepheloid layer rarely rises to depths of 85 m (Rezak and Bright, 1981a, Vol. 3). If the nepheloid layer were able to cover more of the bank, then one would find land-derived muds mixed with coarser sediments at shallower depths. Moreover, the 80 m isobath is a major boundary in the biological zonation. That depth separates the turbid water faunas below from the clear water faunas and floras above. If the nepheloid layer were able to rise to shallower depths, the lower limits of the clear water assemblages would also be raised by the same number of metres (Bright and Rezak, 1978b; Rezak and Bright 1981a, Vol. 3).

CONCLUSIONS AND RECOMMENDATIONS

The conclusion that it is impossible for suspended sediments in the bottom boundary layer to be transported to the top of the reef is corroborated by three geological findings, as follows:

1. There are no land-derived muds in the bottom sediments above a depth of 85 m. If the nepheloid layer ever reached the top of the reef, even only occasionally, there would be evidence of its presence in the bottom sediments.

2. The distribution of sediments around the reef indicates a downslope movement due to gravity. There is absolutely no evidence for upslope transport of bottom sediments.

3. The vigorous growth of corals on the living reef, and other reef-building organisms such as coralline algae at depths shallower than 75 m, attests to the fact that the nepheloid layer never envelops the reef. If it did, these organisms could not possibly survive (Rezak and Bright, 1981a; Rezak, 1977; Bright and Rezak, 1978b).

Therefore, the established restrictions on drilling appear to be sufficient to protect the reefs from damage due to drilling activities.

The danger of catastrophic collapse of the seafloor both on the hard bottoms of the banks and on the soft bottoms immediately surrounding the banks is very real. Pre-drilling hazard surveys should be undertaken prior to emplacement of seafloor structures. Areas of faulting should be avoided even though there is no evidence for recent displacement of the seafloor.

CHAPTER III

BIOLOGICAL MONITORING AT THE FLOWER GARDEN BANKS

T. Bright
Principal Investigator

INTRODUCTION

Biological monitoring of the coral reef at the East Flower Garden Bank was initiated in 1977 (Bright and Rezak, 1978b) and continued in the present study. An identical monitoring study was established at the West Flower Garden Bank in 1980. These investigations have resulted in data on biotic zonation, coral populations, coral growth/mortality, and coral recruitment.

GOALS

The chief purpose of environmental monitoring at the Flower Garden Banks has been to track the condition of biotic communities before, during, and after episodes of human activities which may induce ecological stress. In the current case, the "episode" involves exploration for and development of petroleum.

The concept of environmental monitoring does not necessarily involve determination of cause-and-effect in the event of environmental degradation. Rather, it need only detect the degradation, or lack of it, to be of value to informed managers and regulators charged with the responsibility of protecting the ecosystem.

In the best of worlds, monitoring would not only result in quantitative, statistically supportable information on causes and effects, but also continuous data revealing the health and condition of all components of the biotic community under scrutiny. In view of realistic financial and logistical limitations, such an effort is not feasible. A serious compromise was necessary for the Flower Gardens effort, resulting in the approach described below.

EXPERIMENTAL DESIGN

Aspects of population ecology, behavior, physiology, and survival of indicator species are frequently employed as gauges of environmental impact. Choice of a suite of indicator species for the Flower Garden coral reefs was not difficult. Hermatypic corals are the community dominants above 50 m depth. They build the reef framework, and, as living tissue, occupy 60 to 70% of the hard bottom. Coralline red algae are secondarily important carbonate frame-builders on the coral reefs and, between 50 and 80 m, are the dominant substratum producers.

Reef monitoring efforts have been directed toward describing and monitoring coral populations and their dynamics above 30 m at the two

Flower Garden Banks. This assured that determinations were pertinent to the well-being of the shallow reef community, which would disintegrate if the dominant corals died. The coral study required all of the time and resources available for enviromental monitoring. No additional indicator organisms have been employed, but some knowledge of the types and abundances of coralline algae was gained.

Having chosen the dominant corals as subjects, one must then decide what should be known about them if they are to be used as ecological indicators for the Flower Garden reef community. Differential abundances of the various species, encrusting growth, mortality, and recruitment rates are parameters considered suitable for evaluation of the coral populations. Therefore, non-destructive sampling techniques were developed and employed to generate quantitative, statistically compatible data from which to derive a baseline conception of these parameters. Continued measurement, interpretation of data, and comparison with previous results would reveal changes, or lack of changes, in coral population function. Conclusions drawn from reef monitoring efforts for this contract period follow.

INTERPRETATION OF RESULTS

Biotic Zonation

Benthic organisms inhabiting the Flower Garden Banks are stratified into distinct biotic zones (Figures III-1 and 2), the limits of which seem to be related to substratum type, light penetration, turbidity, sedimentation, and depth. High diversity living coral reefs, the *Diploria-Montastrea-Porites* Zone, occur between 16 and 36 m depth; lower diversity coral reefs, the *Stephanocoenia-Millepora* Zone, occur between 36 and 46 m. Crustose coralline algae are dominant on nodules and partly drowned reefs within the Algal-Sponge Zone between 46 and 82 m depth at the East Flower Garden, and between 46 and 88 m at the West Flower Garden. Drowned reefs below these depths (a) lack significant populations of hermatypic corals and coralline algae, (b) are typically sediment covered, and (c) are generally surrounded by finer sediments and soft-bottom biological assemblages.

The biotic and sedimentological zonation of the banks suggests that suspended sediment loads commonly found below about 75 m have an inhibitory effect on coral and coralline algae populations.

Over 30 species of algae, 250 invertebrates, and 100 fishes are known from the Flower Gardens. Most are representatives of the Caribbean reef biota, of which the Flower Garden assemblage is a part.

Coral Population Studies

During 1980, coral population ecology studies were continued at the East Flower Garden and initiated at the West Flower Garden. Comparison of population parameters from both banks leads to the following conclusions:

1. Species diversity, evenness, and richness values at the East and West Flower Gardens reefs are statistically similar.

2. Montastrea annularis has the highest levels of dominance, relative dominance, and relative density among coralline algae and corals. M. annularis was identified on all transects at both reefs.

3. Colpophyllia spp. occurs at higher levels of dominance and relative dominance at the East Flower Garden than at the West Flower Garden.

4. All other corals occur at statistically similar intraspecific levels of dominance, relative dominance, and relative density at both reefs. The similarity is generally quite strong.

5. Coralline algal dominance and abundance levels are statistically greater at the West Flower Garden than at the East Flower Garden reef.

6. The percent live coral cover averages 64% at the East Flower Garden reef and 55% at the West Flower Garden reef. The difference is statistically insignificant.

Coral Growth and Mortality

Sclerochronological analysis of cores taken from heads of the coral Montastrea annularis at the East and West Flower Garden coral reefs indicates an average accretionary growth rate for this species of 7.5 mm/year over the past 15 to 20 years. Similar analysis of one core of Diploria strigosa from the East Flower Garden indicates a growth rate of 5.1 mm/year.

Short-term seasonal measurements of encrusting growth (lateral advance of living tissue) and mortality (lateral retreat of living tissue) were made for six species at both banks (Table III-1). The most reliable data are for the dominant corals Montastrea annularis and Diploria strigosa. The data suggest that, where mortality occurs in either of these species, it progresses at rates considerably greater than the measured rates of growth for the same species; mortality/growth is about 2.5 for M. annularis and 10 for D. strigosa.

The fire coral, Millepora alcicornis, is almost certainly the fastest growing coral on the high diversity reefs at the Flower Garden Banks.

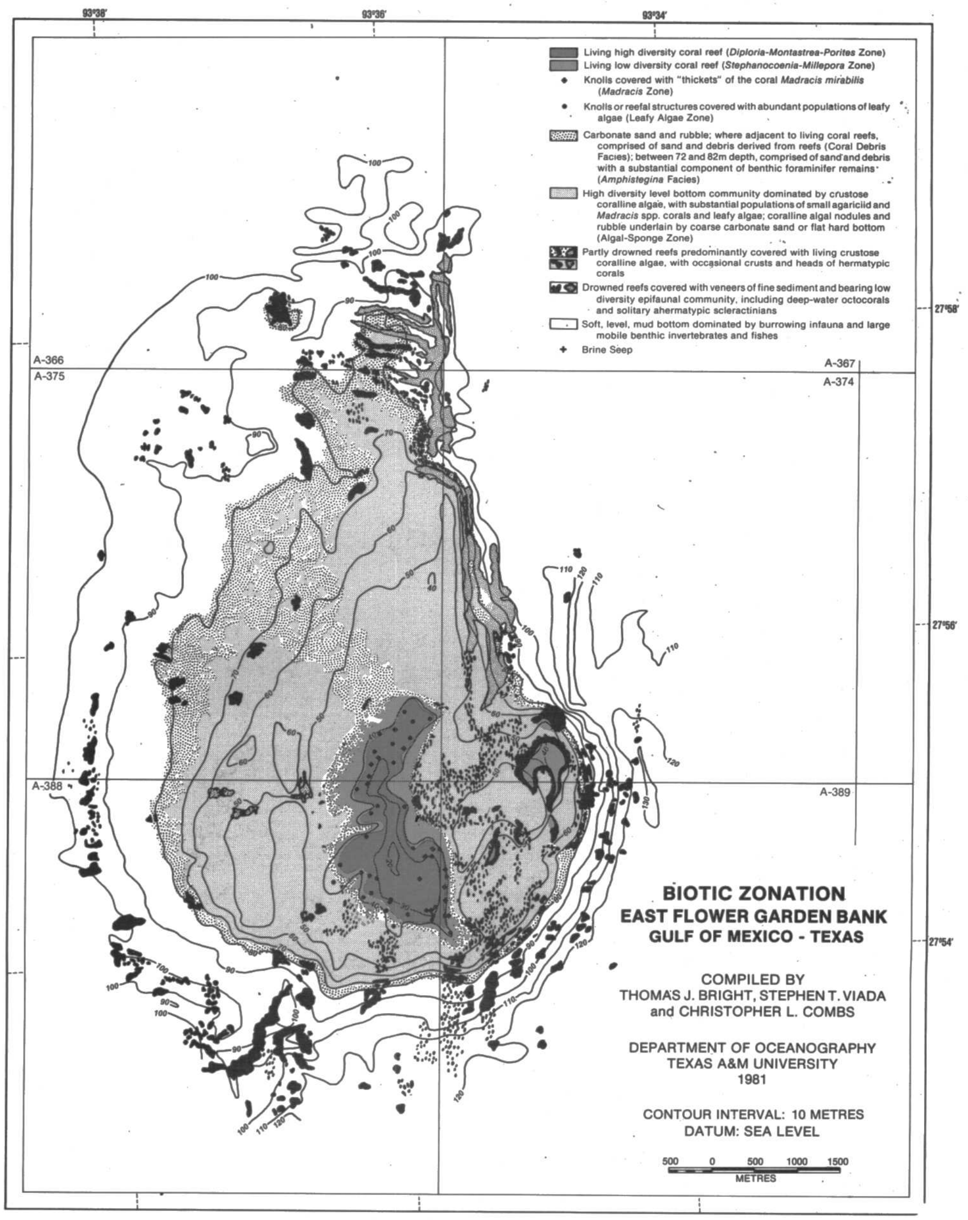

Figure III-1. Biotic zonation, East Flower Garden Bank. Note: The northwestern rim of the bank, between about 60 m and 90 m depth, is largely covered by crusts of coralline algae on hard, steeply inclined substratum. This extensive area is biologically similar to the partly-drowned reefs. It is depicted on the map by stippling somewhat finer than that for carbonate sand, but coarser than that for the other shaded zones. It is not represented or defined in the map's legend.

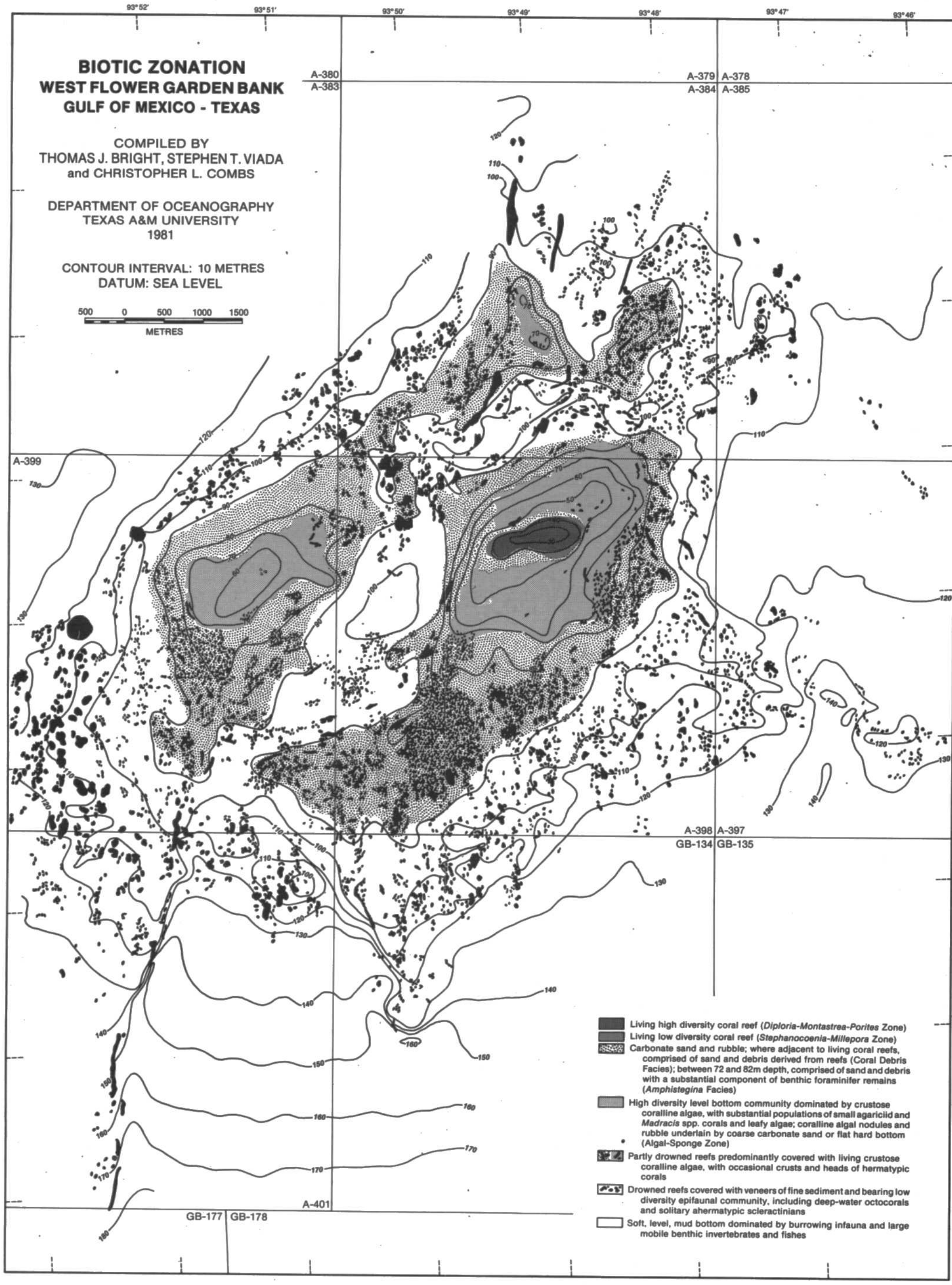

Figure III-2. Biotic zonation, West Flower Garden Bank.

TABLE III-1
AVERAGE ENCRUSTING GROWTH AND MORTALITY OF SELECTED CORALS AT THE EAST AND WEST FLOWER GARDEN REEFS

SPECIES	MILLIMETRES/ MONTH		NUMBER OF MEASUREMENTS	
	Growth	Mortality	Growth	Mortality
Montastrea annularis	0.45	1.15	26	4
Diploria strigosa	0.16	6.05	14	10
Montastrea cavernosa	0.34	0.27	15	2
Porites astreoides	0.35	2.21	4	2
Millepora alcicornis	1.97	--	8	--
Agaricia agaricites	0.60	--	5	--

Coral Recruitment and Early Growth

Experimental Design

Two recruitment sampling stations were established at the East Flower Garden reef and two at the West Flower Garden reef for the sampling period 22 September 1979 through 21 February 1981.

Short-term and long-term samples were collected from each station during each of four sampling cruises. Cruises ranged from three to five months apart. The sampling scheme was disturbed by a loss of samples resulting from heavy seas presumed associated with Hurricane Allen, 9 August 1980.

Preliminary Results

1. The shallow station at the East Flower Garden reef produced the largest corals (greatest growth) and the greatest number of corals over time (recruitment). At the West Flower Garden, the shallower station produced the smallest and fewest corals of those observed so far.

2. In terms of absolute coverage, plate bottoms collected greater numbers of corals, and corals of larger sizes. This may be due, in some measure, to the greater surface area of plate bottoms in comparison to tops and sides.

3. In terms of relative coverage, west and east sides of plates were, in general, apparently favored surfaces. These sides produced the largest mean seasonal growth values, suggesting the possibility of environmental influences on recruitment success, and on growth rates, such as possible west-east current oscillations.

4. Recruitment and growth were least during winter and early spring, and greatest during summer and early fall. Older samples tend to have more corals on undersides than on other surfaces.

RECOMMENDATIONS

It is recommended that monitoring of the Flower Garden Banks be continued. Oil and gas production are just now getting started at the Flower Garden Banks: Mobil Oil Co. installed the first production platform 1.5 miles southeast of the East Flower Garden in the spring of 1982. The present and the near future are critical periods wherein information concerning the state and function of coral communities is needed, if for nothing more than to confirm continuance of the hoped-for environmental status quo.

Possibly the biological reef monitoring program developed and initiated in the present study will continue. It was adopted as a component of the required monitoring program for the Mobil production drilling operation. The methods and station locations for the Mobil study are nearly identical to those used by us, so the data should be comparable.

Quantitative measurement of coral population abundance, encrusting growth, mortality, and recruitment should be required components of all future monitoring programs for the Flower Garden Banks. The non-destructive sampling techniques developed are easy to employ and not subject to a great deal of user bias. Analysis and interpretation of data are considerably more complex but can be easily mastered by well-trained reef ecologists, of whom there are many. While drilling for petroleum proceeds at the Flower Gardens, the coral population studies reported here should be continued, one way or another, by qualified reef ecologists.

CHAPTER IV

WATER AND SEDIMENT DYNAMICS AT THE FLOWER GARDEN BANKS

D. McGrail
Principal Investigator

GOALS

There were several goals for the investigations carried out under the category of water and sediment dynamics. The large-scale objective was to establish what the oceanographic climate of the East and West Flower Garden Banks actually is; i.e., to determine the nature of the prevailing currents, how they are modulated, and the salinities, temperatures, and sediment loads of the passing waters. The investigation was also to determine the circulation over the banks and, in particular, the possibility of sweeping sediment from the base of the banks up to the crests.

The effect of suspended sediment on coral growth is addressed by biologists (Chapter III). Any sedimentary damage to corals would be from decreased available light caused by the presence of the sediment in the water column. Inasmuch as no significant levels of detrital (non-biogenic) suspended sediment were observed shallower than about 75 m, there should be no effect at the level of the coral reef.

FIELD RESEARCH PROGRAM

In order to fulfill the objectives of this study, a three-element program of research was designed and carried out. First, long-term current meter moorings were established in the vicinity of both banks. The instruments on the moorings all measured temperature and current velocity. During the course of the deployments, new transmissometers were added to the deepest instruments on each mooring to record the relative amount of suspended sediment in the water column as a function of time.

The second element of the field work involved the use of instruments deployed from a surface ship to measure current velocity, transmissivity, conductivity, and temperature as a function of depth. An instrumented package was developed to substantially increase the number of stations that could be occupied per unit of ship time and to increase the quantity and quality of data acquired at each station. These profiles provide a measure of the spatial variation of the various parameters.

The third element of the investigation was *in situ* dye emission experimentation in the bottom boundary layer. This study was designed to analyze the structure of the flow in the boundary layer and the magnitude of the shear stresses that were applied to the bottom under known flow conditions. The boundary layer work was tied to the other elements by locating some of the experiments near the moored current meters and by taking profiles during the dye experiments.

RESULTS

The most important observations from this study are connected with the discovery that the mean flow on the outer shelf and upper slope in the vicinity of the East and West Flower Garden Banks is persistently toward the east. Previously, currents were believed to flow predominantly toward the west. This proven eastward flow occasionally attains speeds approaching 100 cm/sec in the upper portions of the water column.

A second finding is confirmation of previous evidence that bottom waters move around the banks, not up and over the banks (McGrail and Horne, 1981). Analyses of the records from mooring 2, located immediately adjacent to the East Flower Garden Bank, show that even during major storm events the vertical excursions of water particles do not exceed 10 to 15 m. The large scale sediment waves on both banks show that even under extreme flow conditions the water tends to parallel the isobaths. This tendency is also borne out by the orientation and magnitude of the variance tensors (tangent to the isobaths) computed from the records of meters on mooring 2.

The effect of winter storms or northers appears to be: a deepening of the isothermal surface layer to a depth of about 60 to 80 m; establishment of strong, four-day cross-shelf oscillations; and generation of strong inertial oscillations which last for three to five days. Hurricanes produce similar phenomena, but they probably induce somewhat less deepening of the surface mixed layer. Northers induce greater deepening because they carry cold dry air over the Gulf. This cold dry air significantly reduces the surface water temperatures through evaporation and convection, thus making the surface water dense and creating instabilities that aid in vertical mixing. Tropical storms, on the other hand, are formed of warm moist tropical air and therefore do not produce such strong density-driven mixing.

Tides at the shelf edge appear to produce very small amplitude currents most of the year. During periods of strong stratification, the amplitudes seem to vary, and phase relations between surface and bottom oscillations wander. This wandering is caused by the complex interaction of the baroclinic (internal) tide and the shelf-edge topography.

The boundary layer studies, combined with time series transmissivity (XMS) records and profiles of temperature, salinity, and depth, reveal that the nepheloid layer is much more complex than was originally assumed. The processes of erosion and local resuspension appear to be limited to the lowermost 2 or 3 m. It is only within this thin layer that one would perceive a direct correlation between current speed and the amount of sediment in the water column. Above this layer is a zone of turbulent mixing that has longer time and length scales. This larger scale turbulence smooths out the short-term changes in sediment concentrations caused by differences in bottom shear stresses. At the level of the lowest current meters with transmissometers (4 m), this decoupling is evidenced by poor coherence between velocity and XMS variance. The variance between XMS values at 4 m and 12 m above the bottom at the same location is poorly correlated, except at long periods (> 2 days). The mean XMS gradient between 4 and 12 m off the bottom is on the order of 1%/m transmissivity per metre.

All of this implies that it is only within the lowest 3 m of the bottom that local resuspension due to strong flow events contributes to significant changes in the sediment concentration. Above that level, advective processes dominate the variances in sediment loading. These advective processes include (a) stacking of boundary layers during periods of flow off the shelf and (b) creation of convergence zones produced by the intersection of downwelling shelf waters and upwelling slope waters in the bottom boundary layer.

MANAGEMENT IMPLICATIONS

It is highly unlikely that drilling muds discharged in the bottom boundary layer near the Flower Garden Banks would be resuspended to the level of the living reefs. Sediment in the nepheloid layer above 4 m appears to be transported long distances (at least tens of kilometres) by currents. By inference, lateral homogenization by large-scale mixing of sediments is also occurring. In other words, the significantly greater space scales involved in this kind of long-distance sediment transport mean that the sediment in the nepheloid layer should consist of a heterogenous mixture of particles integrated from regional sources, not material derived solely from the immediate vicinity of the banks. The exception would be in the lower metres of the nepheloid layer, which may consist mainly of locally suspended sediment.

The mean direction of the flow in the bottom boundary layer is to the east-southeast, but there are periods of rather strong onshore and offshore flow when inertial oscillations penetrate to the bottom.

CHAPTER V

CHEMICAL ANALYSES

C. Giam and P. Parker

HIGH MOLECULAR WEIGHT HYDROCARBONS IN ORGANISMS

Spondylus americanus (Atlantic thorny oysters) were collected from the East Flower Garden (10 samples) and the West Flower Garden (11 samples) Banks during October 1980. The soft tissues of 20 samples were analyzed for high molecular weight hydrocarbons (one sample lacked soft tissue).

In general, the results of the analyses were similar to results from samples taken in 1976-1978 (Giam et al., 1978a,b; 1981), i.e., relatively low total alkane content, relatively broad distribution of carbon chain lengths, and Carbon Preference Index (CPI_{14-20}) values greater than 2. The CPI_{14-20} values were consistent with hydrocarbons of biological origin. Squalene was present in most samples, but no aromatic compounds were detectable by gas chromatography/mass spectroscopy. Phytane, which is generally associated with petroleum but not biological sources, was present at very low concentrations in many of the samples. While the occurrence of phytane suggests possible very low-level contamination with petroleum, the absence of other typical petroleum indicators, such as aromatic hydrocarbons or low CPI values, does not support this finding.

HIGH MOLECULAR WEIGHT HYDROCARBONS, DELTA C-13, AND TOTAL ORGANIC CARBON IN SEDIMENTS

Sediment analysis to deduce the degree of present day ecological damage from petroleum-derived organic compounds in the marine environment involves isolating the hydrocarbon fraction from samples and identifying molecules which are the common components of petroleum. The present report deals with hydrocarbons in the molecular weight range of C-12 to C-32, consisting of saturated, unsaturated, and aromatic compounds, isolated from the sediment samples. In addition, measurements of total organic carbon (TOC) and Delta C-13 have been made as a measure of petroleum-derived carbon in sediment.

Chemical studies of the Texas Outer Continental Shelf have shown that low concentrations of petroleum-like hydrocarbons are present in the water column, sediments, and biota (Parker et al., 1979). In general, the total high molecular weight hydrocarbon (HMWH) concentration is in the range of a few parts per million, with individual components at the parts per billion level. These data served as a baseline for the present evaluation of levels of HMWH levels.

The present study analysed eight samples obtained in 1979/80 by subsampling Gray-O'Hara grab samples taken at the East and West Flower Garden Banks (four at each bank). The distribution of HMWH, total organic carbon, and Delta C-13 in these sediment samples does not display patterns consistent with major petroleum contamination. Comparison with previous data (Table V-1; see also Parker et al., 1979) indicates that although levels of petroleum-like hydrocarbons may be slowly increasing in the region, they remain near baseline concentrations as compared to other Texas shelf sediments.

TABLE V-1
COMPARISON OF RESULTS OF CHEMICAL ANALYSES OF SEDIMENTS

TYPES OF ANALYSIS	RANGE OF RESULTS BY YEAR			
	Flower Gardens Region			STOCS
	1979/80*	1978**	1977†	1976§
1. HMWH				
A. Total Saturated Concentrations (units are parts per million)	1.88 to 20.00	0.3 to 11.2	0.1 to 0.5	1.00 to 16.00
B. Average OEP Index (ratio of odd to even normal hydrocarbons)	1.86 to 2.47	0.44 to 3.32	.2 to 5.1	--
C. Average Pristane/Phytane Ratio	.95	1.11	1.43	2.17
2. TOC (in %)	0.59 - 1.36	0.68 to 1.49	1.15 to 1.39	--
3. Delta C-13 (values reported relative to PDB carbonate standard)	-18.68 to -20.94	-20.04 to -21.78	-19.52 to -21.53	--

* Parker et al., 1982.
** Parker et al., 1981.
† Parker et al., 1978.
§ Parker et al., 1979.

CHAPTER VI

GEOLOGY OF SELECTED BANKS

R. Rezak
Principal Investigator

INTRODUCTION

Seven banks were selected for geological analysis and interpretation, chiefly based on existing sub-bottom and sedimentary data. Bouma, Bright, 18 Fathom, Ewing, Parker, and MacNeil Banks are shelf-edge carbonate banks; Stetson Bank is a mid-shelf siltstone/claystone bank. All are located between 27°53'-28°09'55"N latitude and 90°59'41"-94°17'40"W longitude on the Outer Continental Shelf of the Gulf of Mexico (Figure VI-1). All but MacNeil Bank were surveyed in two previous studies (Bright and Rezak, 1978a,b).

Table VI-1 summarizes the data for these surveys, including the number of sediment stations on each bank. Although the two previous studies had no requirements for sub-bottom profiling, the profiling equipment was aboard the vessel and the data were acquired at no additional cost.

TABLE VI-1
SUMMARY OF SURVEY DATA ON SELECTED BANKS

BANK	DATE MAPPED	SURVEY LINES (km)	SEDIMENT STATIONS	SIDE-SCAN (no. of lines)	SEISMIC RECORDS 7 kHz	3.5 kHz	Boomer
Ewing	May/Jun 77	239.1	0	53	53	0	53
Parker	May/Jun 77	223.2	4	36	36	0	13
Bouma	May 77	131.9	0	24	24	0	0
18 Fathom	May 77	131.1	0	32	32	0	2
Bright	May/Jun 77	161.1	4	35	35	0	0
Stetson	Jul 76	18.9	33	16	0	16	1
MacNeil	Aug/Sep 80	233.3	0	44	0	44	36

A major problem in the interpretation of structure on a few of the banks was the fact that the length of the survey lines was limited by bathymetry rather than geologic structure. An additional 1000 m of record on each end of each line would have yielded considerable additional information on the geologic history of the structures.

Maps and other visuals prepared for the seven selected banks are listed in Table VI-2. These maps are included in Chapter VI of the final report (Rezak, 1982b).

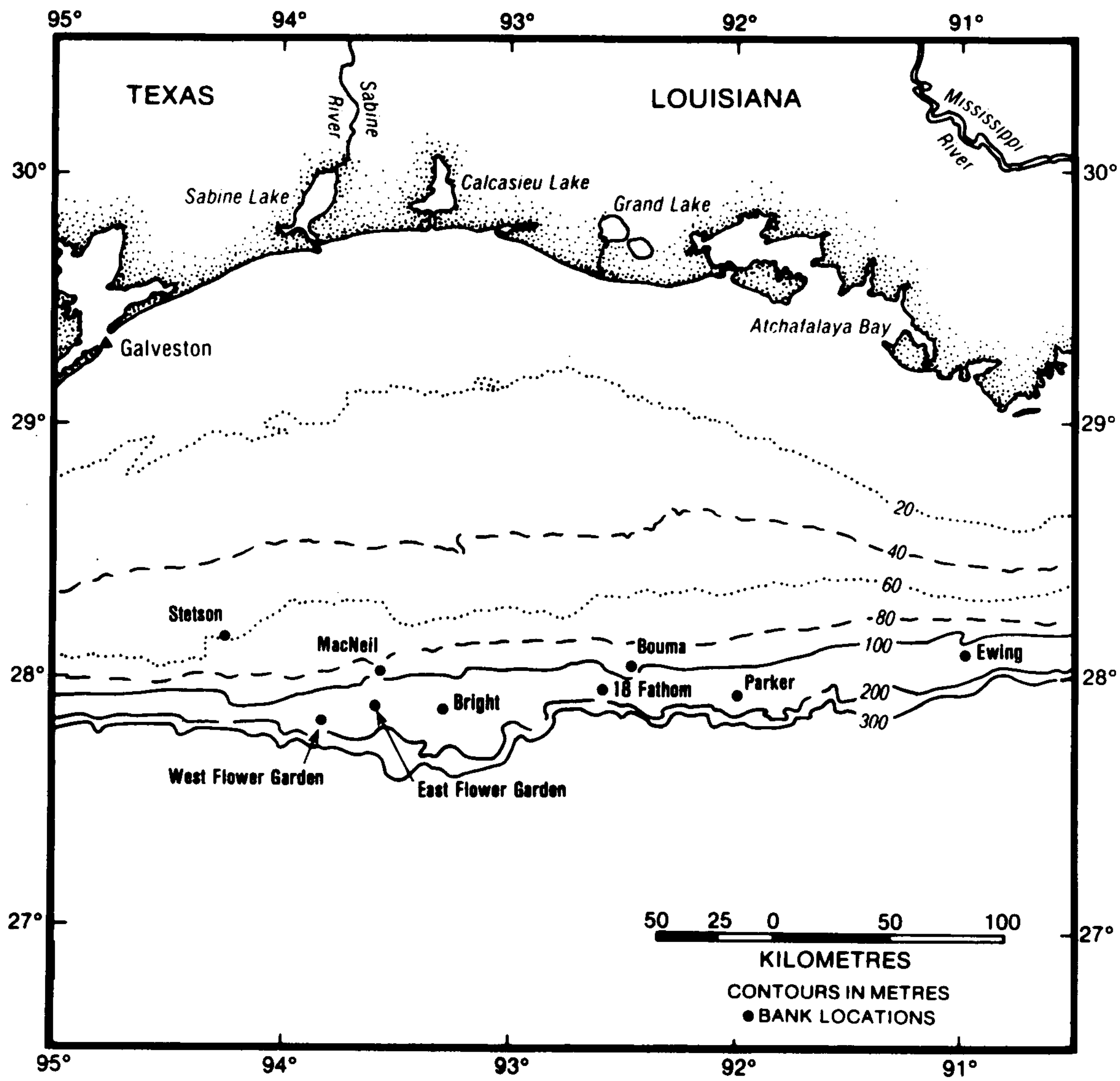

Figure VI-1. Location map for selected banks.

TABLE VI-2
SUMMARY OF VISUALS PREPARED FOR SELECTED BANKS

VISUAL	SELECTED NORTHWESTERN GULF OF MEXICO BANKS						
	Bouma	Bright	Ewing	MacNeil	Parker	Stetson	18 Fathom
Maps							
Bathymetric	X	X	X	X	X	X	X
Structure/Isopach	X	--	X	X	X	X	X
Seafloor Roughness	X	X	X	--	X	X	X
Sediment Distribution	--	--	--	--	--	X	--
Other Graphics:							
Perspective Views	X	X	X	X	X	X	X
Side-Scan Sonar	X	X	X	--	X	--	--
Boomer Profiles	--	--	X	X	X	--	X
Sub-Bottom Profiles	X	X	X	--	X	X	--
Side-Scan Sonar Mosaic	--	--	--	X	--	--	--

EWING BANK

General Description

Ewing Bank is located at 28°05'43.87"N latitude and 90°59'41.37"W longitude (Figure VI-1). It lies in Lease Blocks 337, 349, 350, and 351 of the Ship Shoal Area, South Addition (Figure VI-2) and covers an area of approximately 25 km^2.

The bank is roughly triangular in shape and is enclosed by the 80 m isobath, with gentle slopes beyond that depth into deeper water. Two prominent peaks are situated at the southern corners, and one low prominence occurs at the northern corner of the triangle. The northern prominence is very broad and rises to a depth of 74 m. The western peak rises to a depth of 56 m, with a broad area enclosed by the 60 m isobath. The eastern peak is slightly smaller, but shallower, with a minimum depth of 55 m. A saddle at a depth of 67 m lies between the two major peaks.

Structure and Physiography

Ewing Bank is a mature salt dome with a well developed crestal graben. Boomer profiles over the central portion of the bank show positive relief owing to renewed uplift of the diapir. Profiles on the eastern side of the bank display negative relief on the crestal graben, as this area has not been affected by the renewed uplift. Side-scan

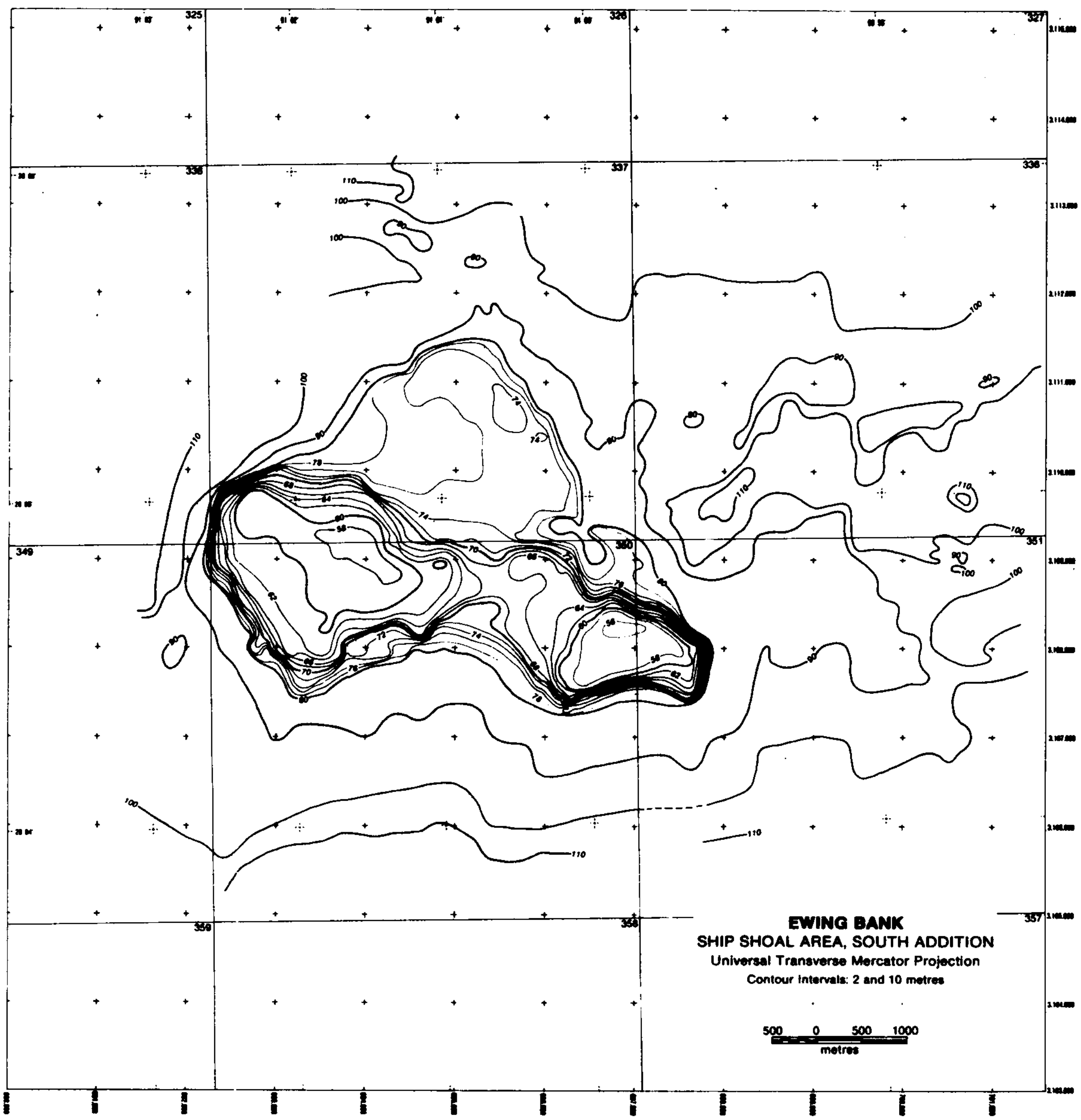

Figure VI-2. Bathymetric map of Ewing Bank.

sonar records show individual features from less than one metre up to five metres in height, with a spatial frequency ranging from five features to greater than ten features per hectare. These features appear to be reefs growing on rock outcrops on the upthrown sides of normal faults.

PARKER BANK

General Description

Parker Bank is located at 27°56'49.10"N latitude and 92°00'40.08"W longitude (Figure VI-1). The bank lies in Lease Blocks 194, 195, 202, and 203 of the South Marsh Island Area (Figure VI-3). The bank is nearly rectangular in shape and covers an area of 38.5 km^2. A deep valley trending in an east-west direction lies in the north-central part of the bank giving the bank the appearance of an asymmetrical horseshoe. The valley bifurcates at the east side of the bank, one branch going towards the northeast and the other towards the southeast.

The shallowest depth is 57 m in the east central part of the bank. Water depths surrounding the bank vary from 100 to 140 m, and the central valley reaches depths of 120 m.

Structure and Physiography

The surface expression of Parker Bank is fault-controlled. The major faults trend towards the east on either side of the axial graben; radial faults bound the northeast and southeast arms of the valley. Parker is a mature salt dome. The faulting that created the axial graben occurred during or shortly after the Pleistocene epoch.

BOUMA BANK

General Description

Bouma Bank is located at 28°03'35.73"N latitude and 92°27'51.47"W longitude (Figure VI-1). It lies in Lease Blocks 370, 371, 384, and 385 of the Vermilion Area (Figure VI-4).

The eastern half of Bouma bank is clearly defined by the almost semicircular 100 m isobath. On the west side of the bank, the slope from the 80 m isobath to deeper water is much more gradual. The major portions of the bank are enclosed by the 80 m isobath. However, even within this area, a number of major features are observed. The southernmost prominence rises from 100 m to a depth of 62 m. Immediately north of this peak lies a deep basin with a depth of 88 m. To the northwest of this area is a broad rise enclosed by the 72 m isobath. On the northwest side of this rise, a peak rises to a depth of 59 m. The gradient steepens between the 65 to 80 m isobaths towards the

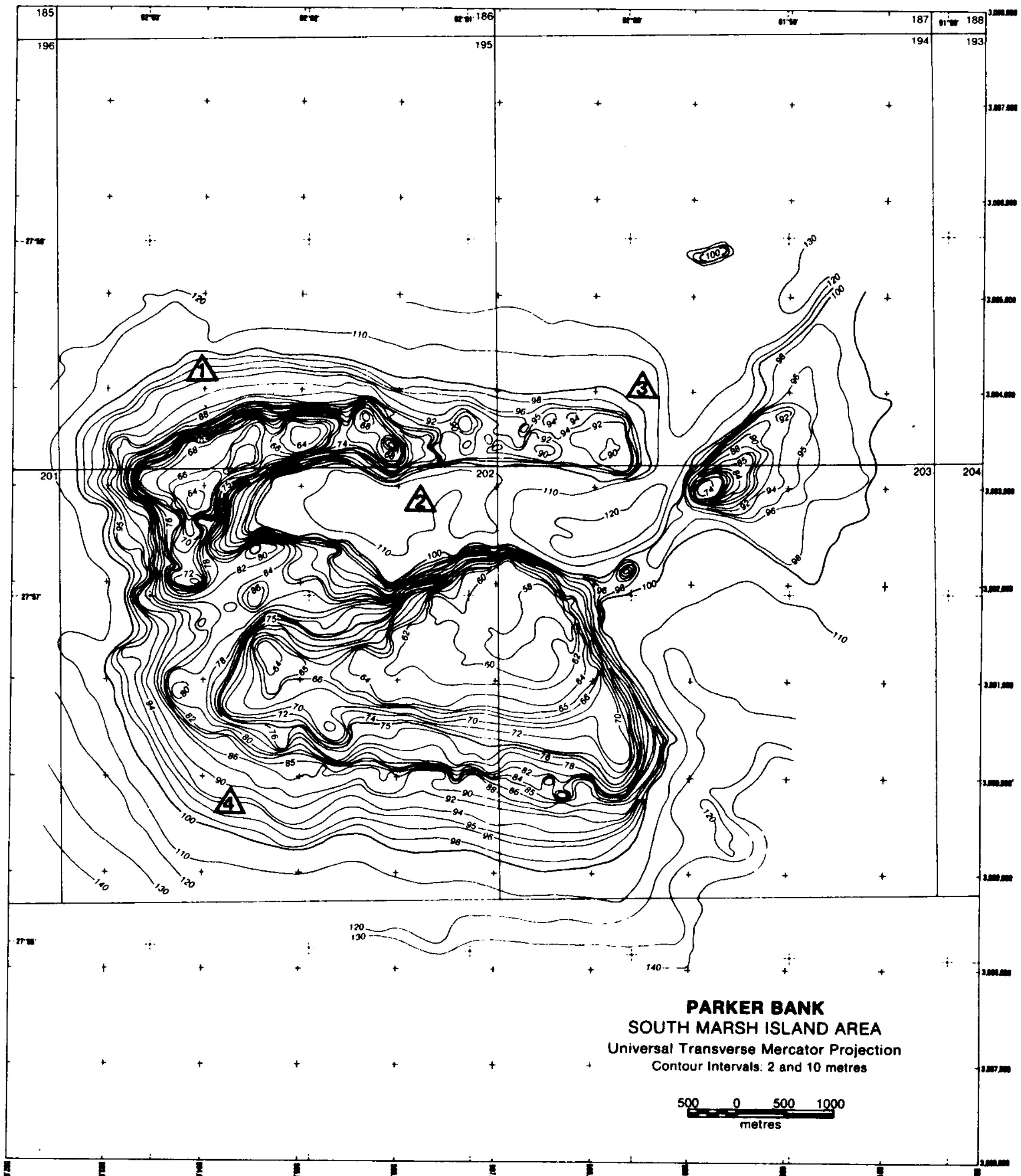

Figure VI-3. Bathymetric map of Parker Bank showing the location of sediment sample stations.

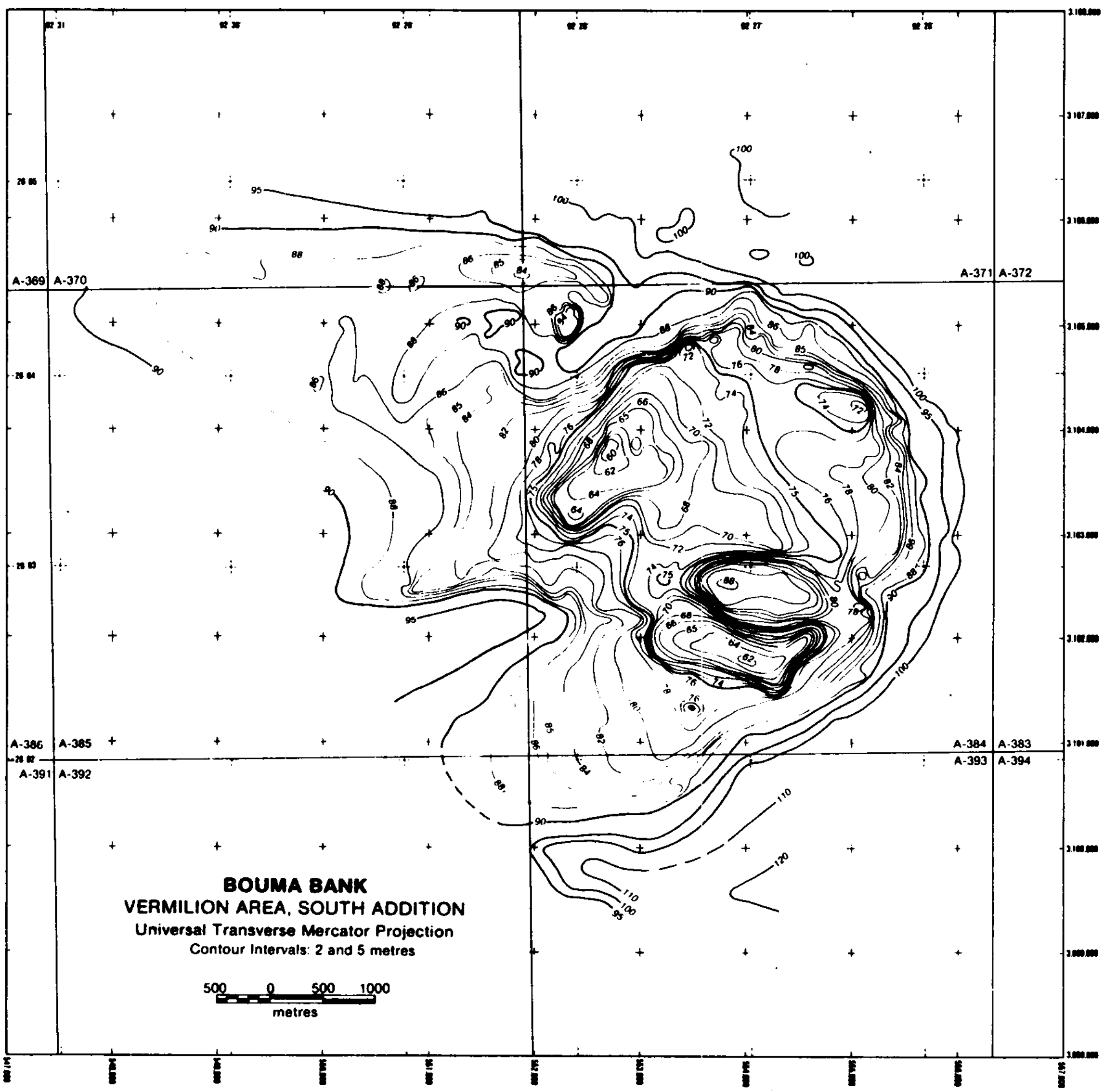

Figure VI-4. Bathymetric map of Bouma Bank.

northwest of this peak. Additional peaks at 72, 82, and 84 m are located on the north side of the bank.

Structure and Physiography

Bouma Bank is a mature salt dome that shows evidence of crestal collapse. An outcrop of siltstone was encountered at a depth of 77 m on the northern flank of the south peak during Submersible Dive No. 9 on September 29, 1977. The occurrence of siltstone without encrustations of coralline algae at that depth indicates very recent exposure due to faulting. Local features vary in size from less than one metre to greater than five metres in height, and from one to five features per hectare to more than ten features per hectare.

18 FATHOM BANK

General Description

Located at 27°57'48.47"N latitude and 92°35'45.04"W longitude (Figure VI-1), 18 Fathom Bank lies in Lease Blocks 362 and 379 of the East Cameron Area, South Addition, and Lease Blocks 389, 409, and 410 of the Vermilion Area, South Addition (Figure VI-5). The feature is a pair of northwest-southeast trending ridges separated by a valley. It covers an area of approximately 28 km^2. The bank lies close to the shelf break and has the shallowest crest (46 m) of the shelf-edge banks west of the Mississippi delta, except for the West Flower Garden Banks. The crest of the bank lies at 46 m depth with a depth of 130 m approximately one kilometre south of the crest. The maximum relief is approximately 85 m.

Structure and Physiography

The bank appears to be underlain by a northwest-southeast oriented ridge of salt. Dissolution of salt at the crest of the ridge has created an axial graben. The side-scan sonar records show large areas containing features ranging in size from less than one metre to over five metres in height, and a spatial frequency of from five to ten features per hectare.

BRIGHT BANK

General Description

Bright Bank is located at 27°53'N latitude and 93°18'W longitude (Figure VI-1) in Lease Blocks 650, 656, and 657 of the West Cameron Area, South Addition (Figure VI-6). It lies near the shelf edge and is about 10 n.m. east of 28 Fathom Bank. The bank is rhomboid in shape and covers an area of approximately 36.5 km^2. The surrounding water depths range from 100 m to the west to 120 m to the southeast. Depths increase generally towards the south. The crest of Bright Bank lies at

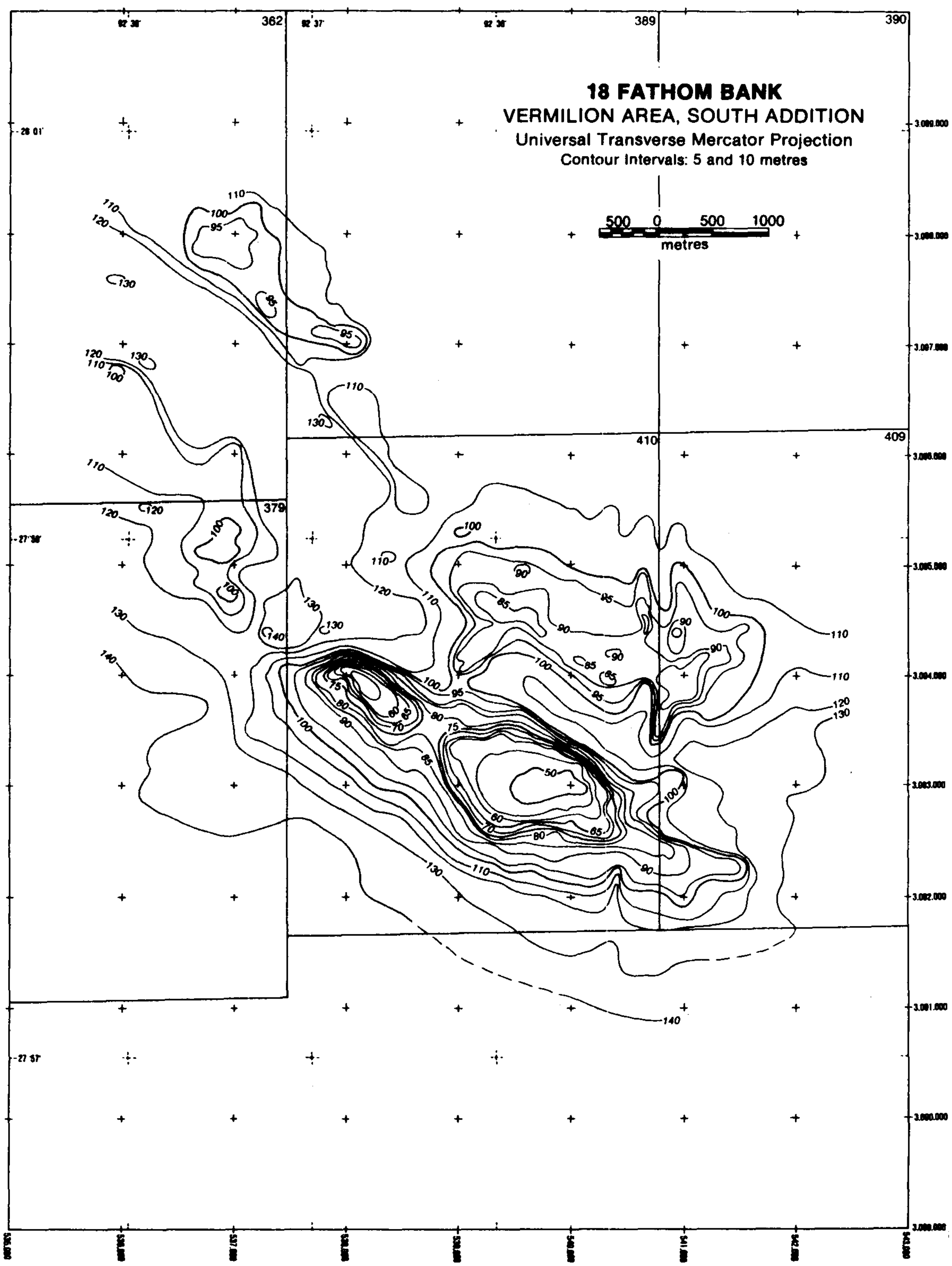

Figure VI-5. Bathymetric map of 18 Fathom Bank.

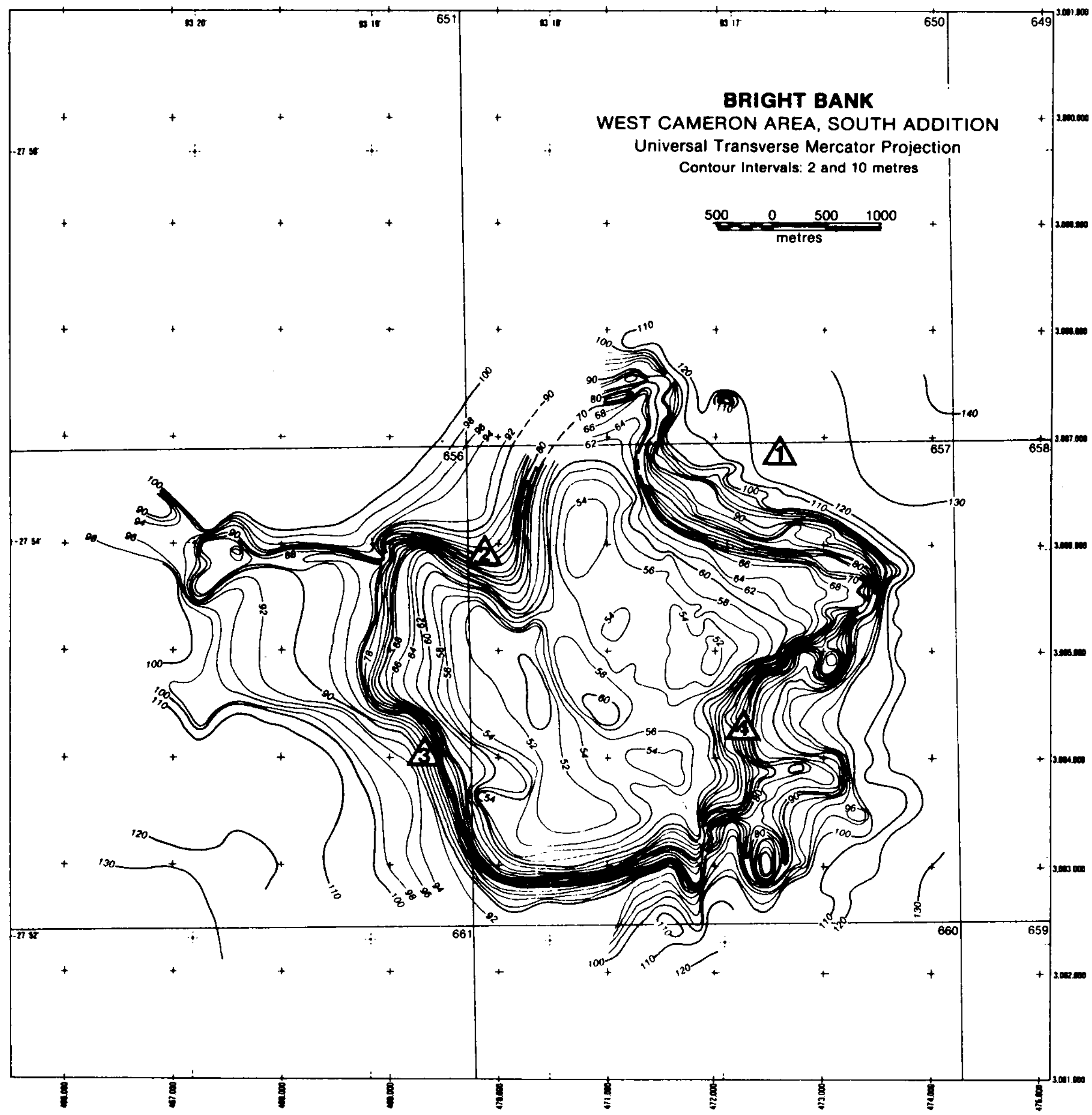

Figure VI-6. Bathymetric map of Bright Bank showing the location of sediment sample stations.

50 to 55 m depth. The total relief on the bank ranges from 50 to 65 m.

Structure and Physiography

Although 35 7 kHz sub-bottom profiles were taken at Bright Bank, the very poor reflectivity of the sub-bottom sediments prevented the preparation of a structure map for this bank. Natural gas seeps were observed during the submersible transect, and the poor quality of the sub-bottom profiles may be due to the presence of gas charged sediments.

Because of the limited sub-bottom data, the structure of the bank must be interpreted from the bathymetry. The steep slopes surrounding Bright Bank are most probably the expression of a peripheral fault. The lineations on the west, north, and east sides of the bank are the results of radial faulting. The trough that lies to the southeast of the reentrant in the northwest corner of Lease Block 657 is probably the northwestern part of a central graben.

The crest of the bank at between 50 and 55 m is a broad surface of very low relief. Observations from the submersible reveal scattered outcrops of Pleistocene reef rock over this surface. Relief on the reef rock is estimated to be between 45 and 60 cm. The rock is jointed and the joints have been enlarged by solution. Large areas of coarse sand, coral, and algal nodules lie between the joint blocks.

The side-scan sonar records show individual features ranging in height from one to five metres, and spatial frequency ranging up to over ten features per hectare.

MACNEIL BANK

Introduction

MacNeil Bank was mapped 29 August-5 September 1980. Oceanonics, Inc. conducted the survey using the M/V JUNE BOLLINGER, a leased 39.6 m vessel. The survey was conducted using LORAC service chain "DE." The LORAC receivers were interfaced with a Decca Autocarta System. LORAC calibration was performed at known platform locations within the survey area. Survey equipment included a Raytheon DE 719B echosounder, an ORE Model 310 sub-bottom profiler operated at 3.5 kHz, an EG&G Model 231-232 Uniboom operated at 500 joules, and an EG&G SMS 960 side-scan sonar.

A benchmark made of a 55-gallon oil drum filled with concrete was emplaced at the crest of the shallowest peak.

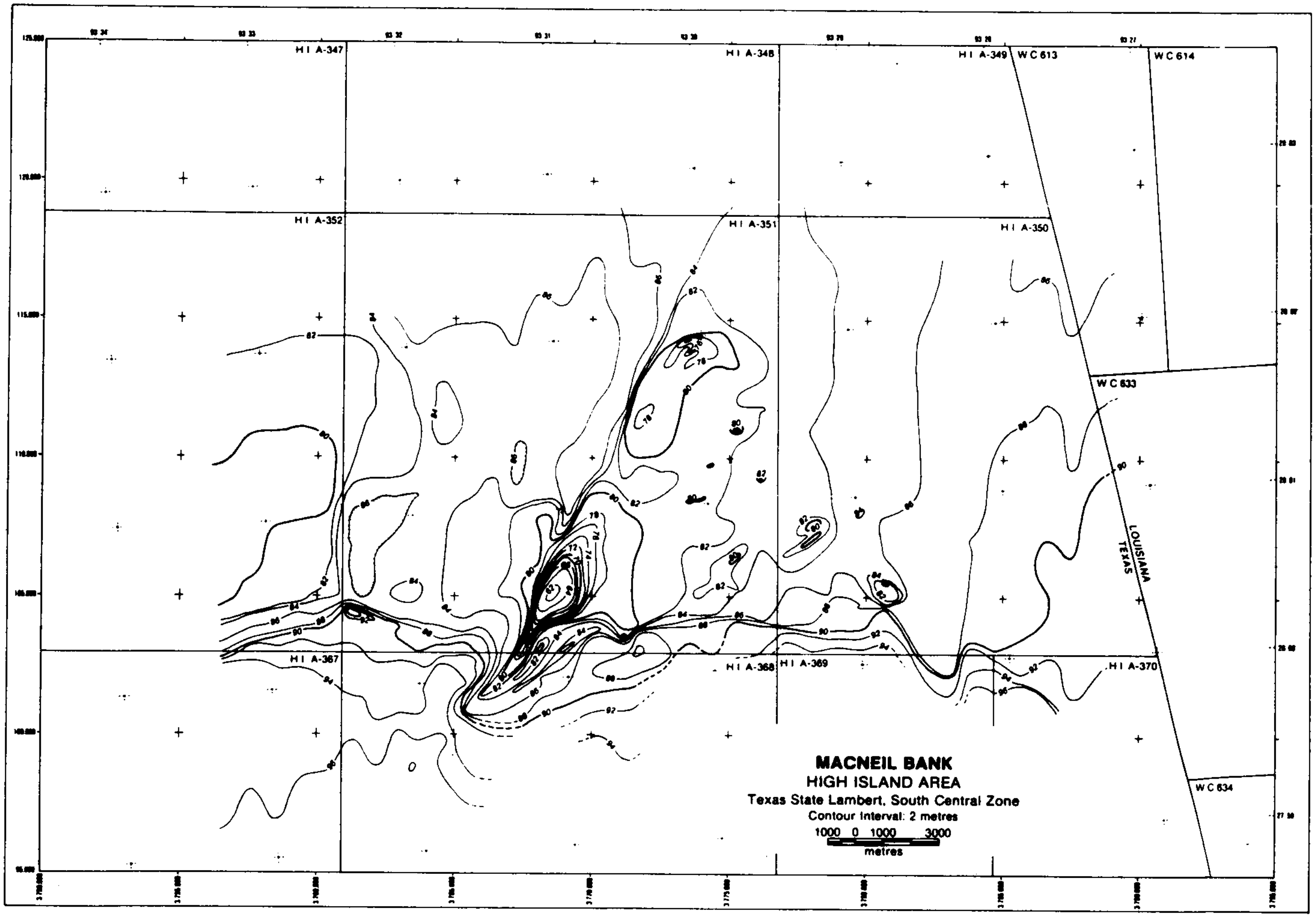

Figure VI-7. Bathymetric map of MacNeil Bank.

General Description

MacNeil Bank is located at 28°00'25"N latitude and 93°31'W longitude (Figure VI-1), in Lease Blocks A-351 and A-368 of the High Island Area, Southeast Addition (Figure VI-7). It is situated approximately 10 km northeast of the East Flower Garden Bank.

The bank is ovoid in shape and is constricted on its southwestern extremity. Completely enclosed by the 80 m isobath, the bank lies on the edge of a four to six metre high, south-facing escarpment. The area mapped is considerably larger than the bank owing to uncertainty about its position prior to the survey. It is a small bank with an area of approximately 4 km^2. The western and southeastern slopes are the steepest, with more gentle slopes towards the northeast and north.

Structure and Physiography

The structure and physiography of MacNeil Bank are interpreted on the basis of boomer seismic profiles and a side-scan sonar mosaic (Rezak, 1982b, Plate 2). Nothing is known of the nature of the seafloor at MacNeil Bank as no submersible work was conducted there. BLM Visual Graphic No. 3 shows the sediment in Lease Blocks A-350 and A-351 to be silty clays.

The main structure of the bank is a tilted fault block, with the major fault trending northeast-southwest. The western boundary of the bank is along this fault. Numerous discontinuous faults, subparallel to the major fault, lie on either side of it. One of these minor faults forms the eastern boundary of the bank. Several east-west trending faults lie along the southern boundary of Lease Blocks A-350, A-351, and A-352 and coincide with the low, south-facing escarpment.

The entire survey area appears to have a thin veneer of sediments covering well lithified sedimentary formations similar to those seen at Coffee Lump, Stetson, and Claypile Banks. These sedimentary units are generally flat-lying except where they have been deformed by faulting. The very sharp and regular lineations on the upthrown side of the major fault are bedrock outcrops that have little or no cover of reef rock.

A large field of sand waves with steep sides toward the northeast lies in Lease Block A-352 and in the northeast quarter of Lease Block A-353. The intensity of the reflections is lower than that in the gravel waves at the West Flower Garden Bank, where the waves are composed of algal nodules. The MacNeil waves are most probably sand size sediment.

To the east of the main fault in Lease Block A-351 and the western half of Lease Block A-350, numerous irregular mottles are displayed on the side-scan sonar mosaic. The mottles vary from less than 5 m to over 200 m in diameter. These are most probably outcrops of bedrock that have been encrusted by thick deposits of coralgal limestone. Numerous anchor scars are present in the area to the east of the main fault. A major pipeline crosses the map area near the northeast corner of Lease Block A-350.

The structure at MacNeil bank supports the hypothesis that structures inherited from the Jurassic basement are important in the formation of salt diapirs. The diapir at MacNeil Bank occurs at the intersection of two fault systems, which creates a zone of weakness along which the salt has risen.

Hazards

The numerous faults that displace the seafloor at MacNeil Bank indicate that this area has a potential for tectonic activity. Sporadic movement along these faults should be expected. Gas seeps were observed on the 3.5 kHz and the Uniboom records, generally associated with the two major faults. The records show large areas of hazy and chaotic reflections that may be due to the presence of gas in the sediments.

Because of the numerous faults that displace the seafloor, no structures should be emplaced until a detailed minisparker survey is conducted over the proposed site. Permanent structures should be located at least 152 m (500 ft) away from any surface or subsurface fault.

STETSON BANK

General Description

Stetson Bank is located at 28°09'55"N latitude and 94°17'40"W longitude (Figure VI-1) in Lease Block A-502 of the High Island Area, South Addition. It is a small bank covering only about 3 km^2. The bank is oval shaped and oriented in a northeast-southwest direction (Figure VI-8). The crest of the bank lies at a depth of 32 m; however, a pinnacle near the west side of the crest rises to a depth of 20 m. Surrounding depths are 64 m to the north and 62 m to the south. Total relief on the bank is approximately 40 m. Because of its small size, Stetson was mapped at a scale of 1:3000.

Structure and Physiography

The structure of Stetson Bank is almost impossible to determine from the 3.5 kHz records due to the poor reflectivity of the strata. Submersible observations of the bank reveal the cause of the poor reflectivity to be the nearly vertical orientation of the bedding.

Stetson appears to be a simple, small fault block that may be related to a much larger structure in the subsurface. There is a relatively flat, eastward sloping surface at the crest of the bank. The

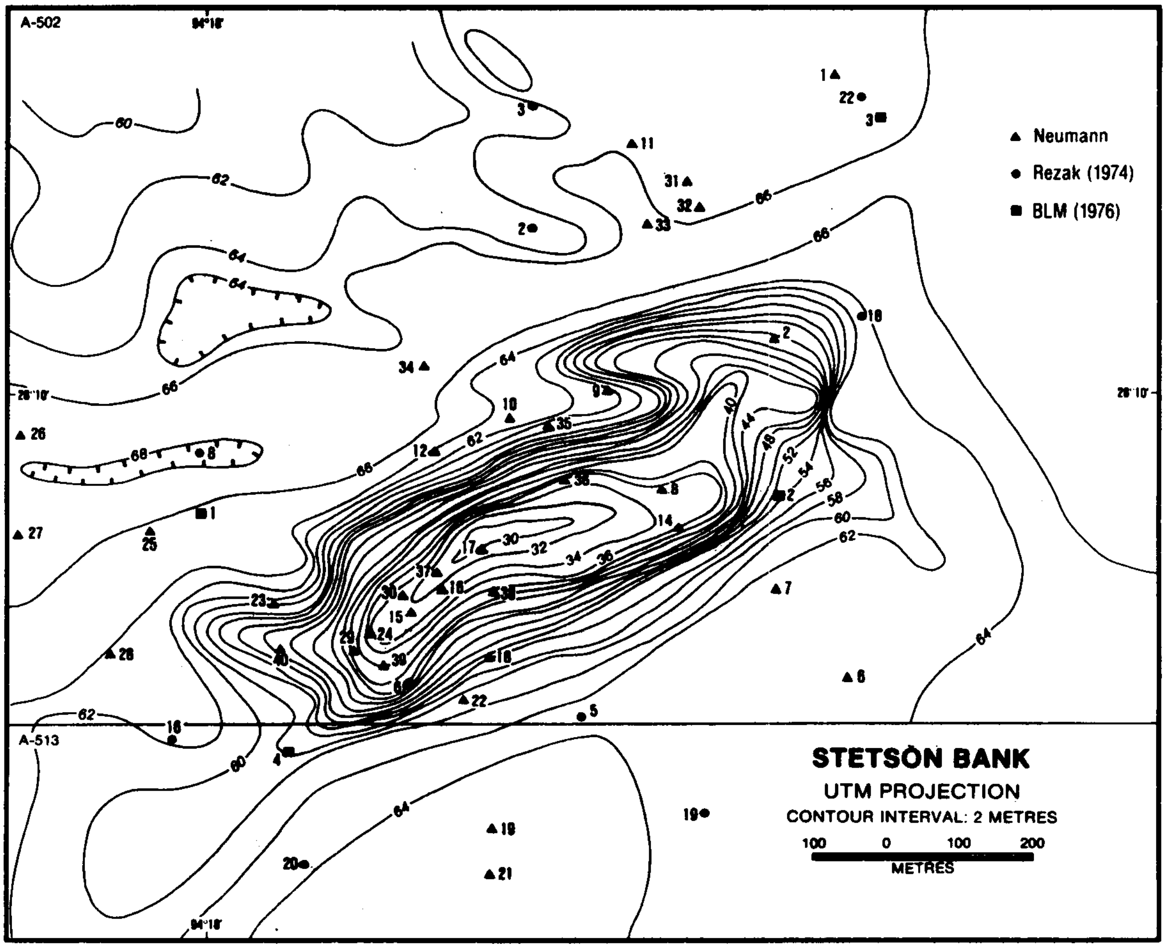

Figure VI-8. Bathymetric map of Stetson Bank showing the location of sediment sample stations.

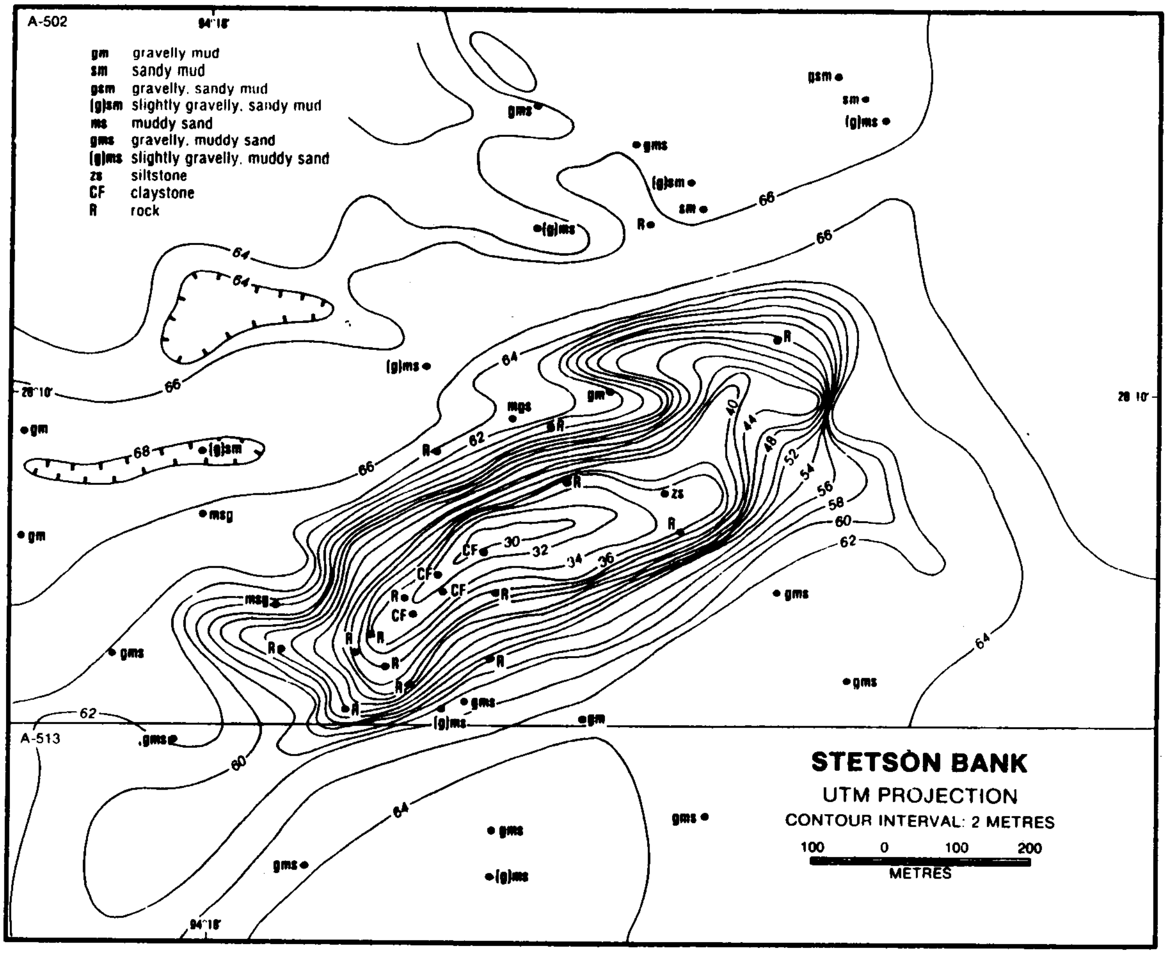

Figure VI-9. Distribution of sediment types at Stetson Bank.

average depth of this surface is about 22 m. Submersible observations show the surface of this terrace to consist of steeply dipping claystones and siltstones. The obvious interpretation is that this is an erosional terrace that has been tilted due to continued movement on the western boundary fault since sea level stood at approximately 17 m (approximately 6000 years ago).

Side-scan sonar records and direct observations of the bottom during 1974 using the DRV DIAPHUS reveal the bank to consist of steeply dipping claystones and siltstones. The strike of the beds varies from N22°E to N50°E, and the dips vary from 78° towards the southeast to nearly vertical. The claystones are extensively bored by molluscs and sponges but appear to be more resistant to submarine erosion than the siltstones. The claystones form ridges, with valleys underlain by siltstones between them. The ridges are nearly parallel to the long dimensions of the bank and stand 3 to 4 m above the adjacent siltstones.

Sedimentology

Three sets of sediment samples have been collected at Stetson Bank since 1957 (see Figure VI-8). The sediment analyses for 33 stations are presented in Appendix C of Rezak (1982b). The sediments range from gravelly sands to sandy muds, with the amount of gravel increasing towards the bank (Figure VI-9).

CONCLUSIONS AND RECOMMENDATIONS

Most of the banks described in this chapter are mature salt domes with evidence of numerous faults that displace the seafloor. Sporadic movement along these faults should be expected. Evidence for the presence of gas charged sediments is seen in the form of hazy and chaotic reflectors on seismic records and reflections from bubble trains in the water column on some of the banks.

No structures should be emplaced on or in close proximity to these banks until a detailed minisparker and high resolution sub-bottom survey is conducted over the proposed site.

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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.