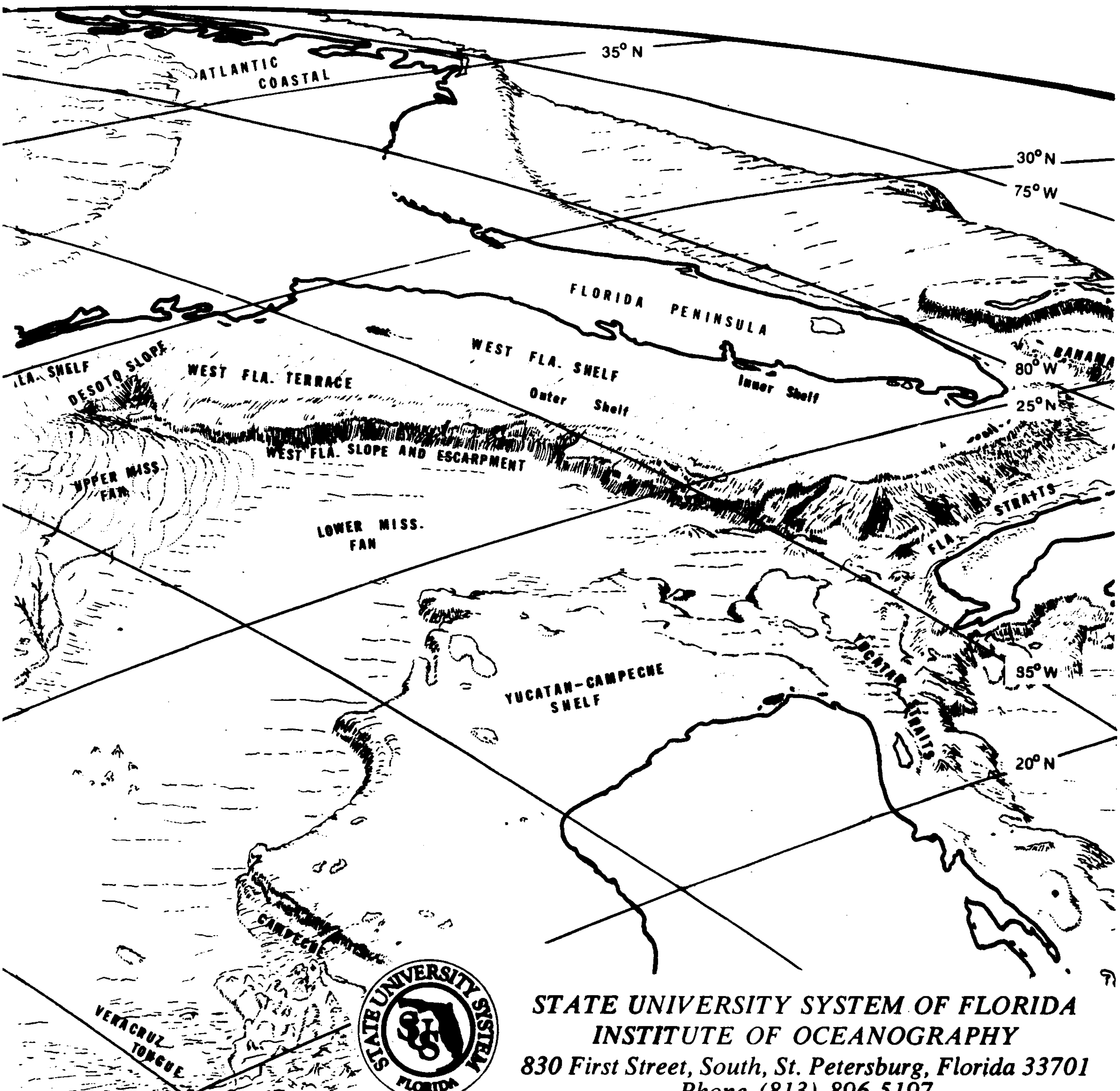
1977 - 17

BASELINE MONITORING STUDIES, MISSISSIPPI, ALABAMA, FLORIDA OUTER CONTINENTAL SHELF, 1975-1976

BLM CONTRACT NO. 08550-CT5-30

VOLUME I

EXECUTIVE SUMMARY



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16. Abstracts Benchmark studies on the Eastern Gulf of Mexico Outer Continental Shelf were conducted seasonally to establish baseline information prior to extensive oil and gas development activity. No crude oil-like hydrocarbons were found in sediments, benthic organisms, zooplankton, suspended particulates nor dissolved phases on the Florida shelf. Moreover the abundance and diversity of organisms suggested that these organisms are living in an essentially pristine and natural ecological states, and show no evidence of stress owing to influx of pollutants. Some evidence of hydrocarbon anomalies were found in samples from the Mississippi-Alabama shelf probably due to drainage from the Mississippi River. A study of tissue pathology revealed only parasites in otherwise normal benthic organisms. Major features affecting the study area were the Mississippi River, the Loop Current and hurricane Eloise. Trace metal (Cd, Cr, Cu, Fe, Ni, Pb and V) concentrations in Eastern Gulf samples were at levels expected for non-polluted areas.

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EXECUTIVE SUMMARY

A Report to the Bureau of Land Management

in fulfillment of

Contract No. 08550-CT5-30

Submitted by

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EXECUTIVE SUMMARY

In 1974 the Bureau of Land Management (BLM) as the administrative agency responsible for leasing of submerged federal lands and acting under the guidelines established by the National Environmental Policy Act of 1969, contracted with the State University System of Florida, Institute of Oceanography (SUSIO) to obtain multidisciplinary, short-term, benchmark data in the Mississippi-Alabama-Florida (MAFLA) Outer Continental Shelf (OCS) area prior to oil and gas exploration in the region. The study was conducted in six lease tract areas (Figure 1) in June-July, 1974 by a consortium of investigators having special interests and expertise in the region.

In Areas I, II, and III the results of the initial benchmark studies indicate that the crude oil-like hydrocarbons were not present in the bottom organisms or sediments. In the water column similar conditions were present in the particulate and dissolved phases and in the zooplankton. Moreover, the abundance and diversity of organisms, as well as evidence of similar populations living in the same ecological niches on the shelf in the recent past, suggested that these organisms are living in an essentially pristine and natural ecological states, and show no evidence of stress owing to influx of pollutants.

The situation was more complex in Areas IV and V. Some sediments in the former showed evidence of the presence of petroleum-type hydrocarbons, whereas others showed only the presence of biologically synthesized hydrocarbons. Area V sediments revealed indications of petroleum hydrocarbons

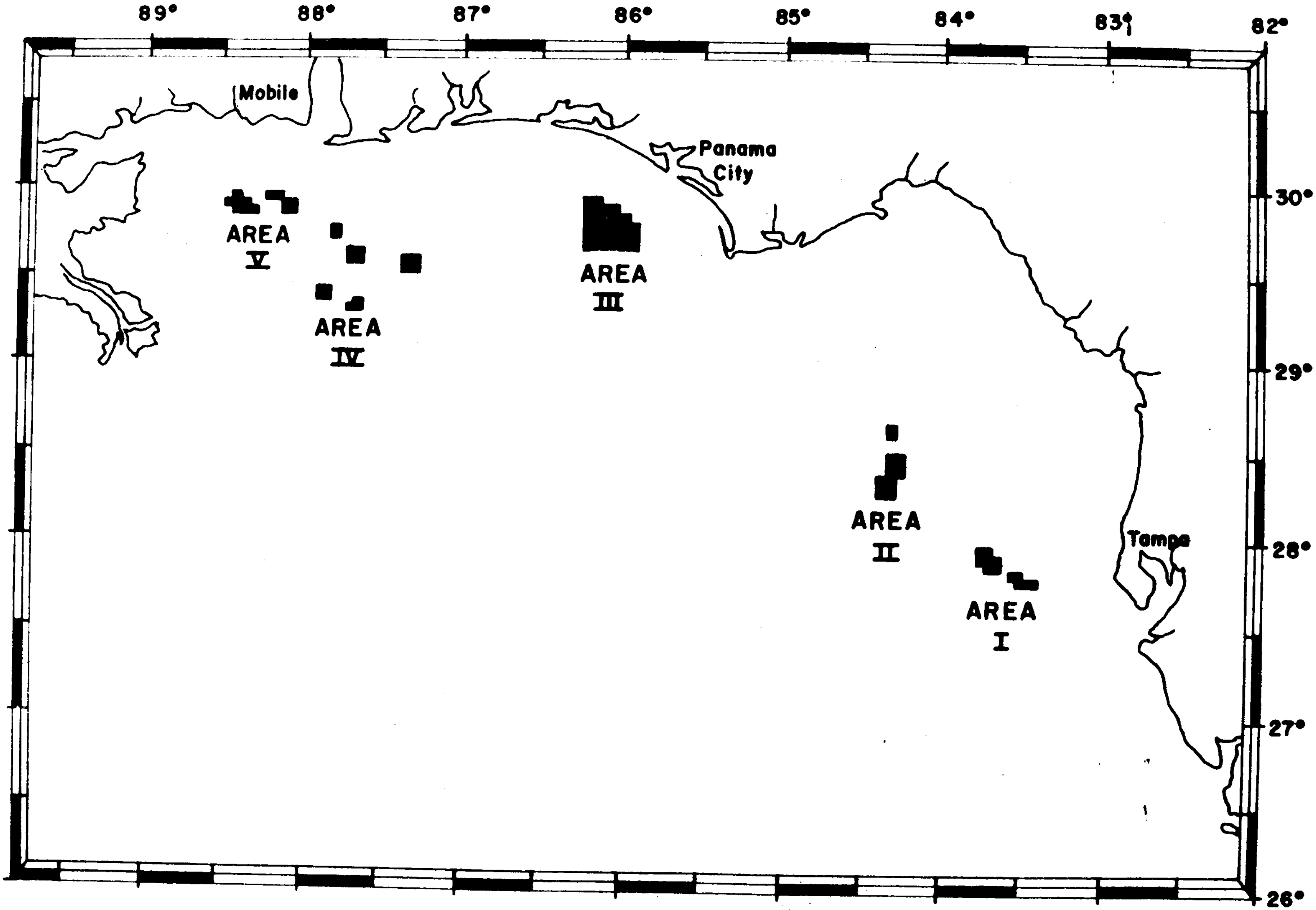

Figure 1. MAFLA benchmark study area.

in the sediments. Populations of organisms also showed similar divergent trends.

Trace metals (e.g., cadmium, chromium, copper, iron, lead, nickel and vanadium) in the sediments, organisms, water and suspended matter did not show concentrations beyond those expected for comparable non-polluted areas.

The recognized need by BLM for long-term studies to collect appropriate data necessary for sound management decisions in the MAFLA region resulted in a continuation and expansion of the 1974 study into a projected three year major study starting in 1975. In this effort the study was broadened to include the entire shelf. Prior to the preparation of the study plan for the 1975-1976 MAFLA program a special BLM study was completed. The main focus of this effort was to assemble and synthesize the historical and contemporary physical and meteorologic data pertinent to the northeast Gulf of Mexico. Within this study were recommendations on sampling locations for future biological, chemical, geological and physical oceanographic investigations. Recommendations were also included for the physical oceanographic study of the MAFLA continental shelf which was to address the meteorology, hydrography, horizontal currents, sea level, bottom pressure and river run-off. The hydrographic section contained recommendations for the location of the transects and the stations for future biological, chemical, geologic and physical oceanographic investigations.

Within the 1975-1976 program conducted by SUSIO the BLM elected to address only the shelf hydrographic section in its water column program. The recommendations for this component included a monthly occupation of approximately ten standard stations on each side of eight transect grid lines across the shelf and slope regions (Figure 2). At each of these stations a standard salinity-temperature-depth (STD) cast plus occasional water samples for dissolved oxygen and nutrients were to be taken so that the major features of the seasonal evolution of the hydrographic fields could be determined.

These recommended sampling grid transects were modified to insure that the 1975-1976 water column transects crossed through the five MAFLA lease block areas. They were further reduced to four transects in an attempt to (1) document the environmental conditions in selected hydrobiological areas on the shelf, (2) describe the motion inducing forces on the general circulation, (3) supply input to numerical models, and (4) to connect where possible with a BLM Special Study Program Concerned with the Loop Current in the Gulf of Mexico.

The rationale for this change in numbers and locations of the sampling grid were related to (1) the existence of monthly or seasonal historic data files on which one could draw for a determination of the normality of the data being generated in any one year, (2) the four run-off areas present in MAFLA, (3) marine summary and hydrobiological zones (Figure 3), (4) limitations in the scientific capacity and resources to perform the chemical analyses and supporting water column work, and (5) no attempt was to be made to collect synoptic data.

In the 1975-1976 study four water column grid transects (Figure 3) were established and occupied during June-July and September-October, 1975 and January-February, 1976. In planning the water column sampling program

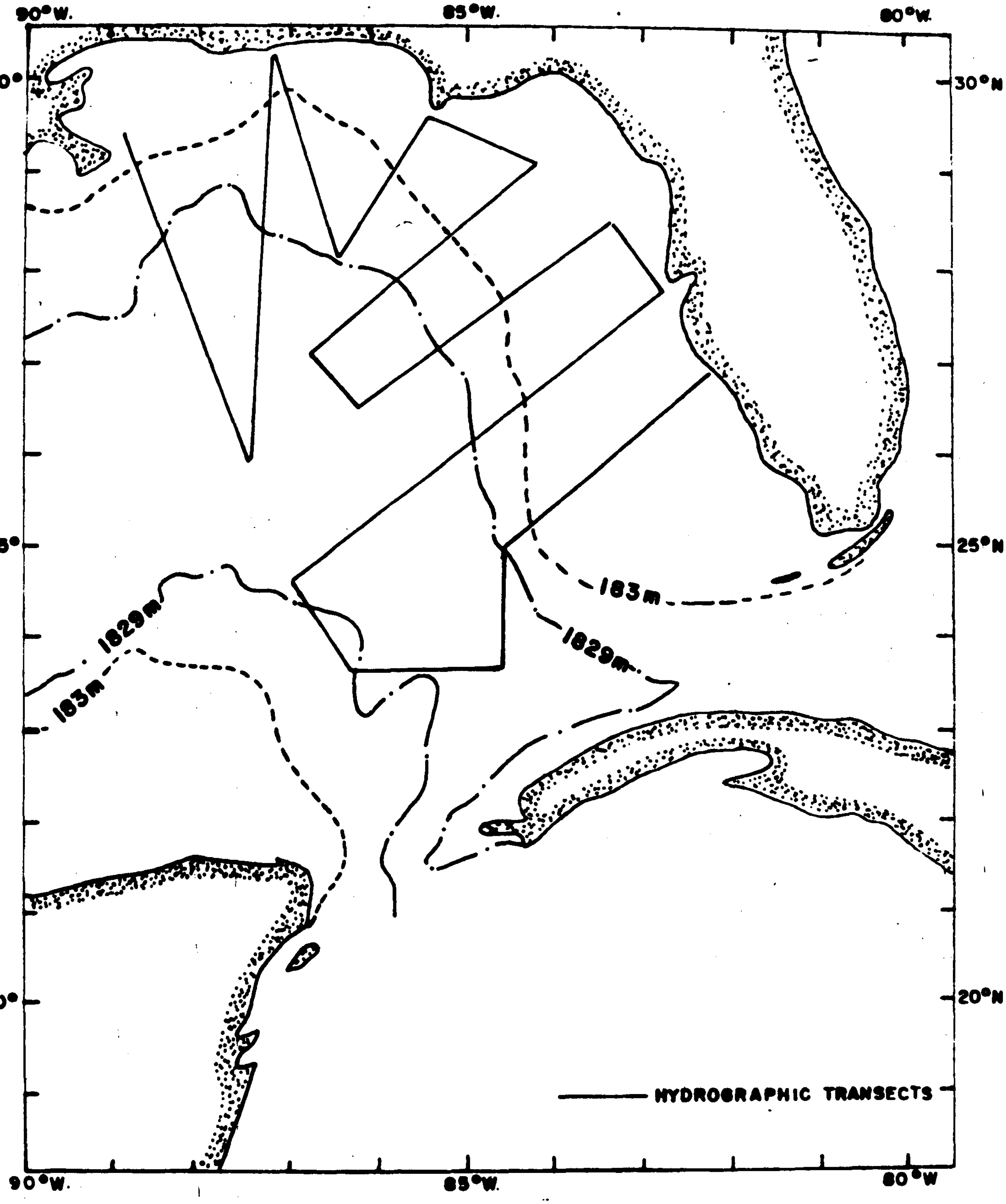

Figure 2. Recommended hydrological transects.

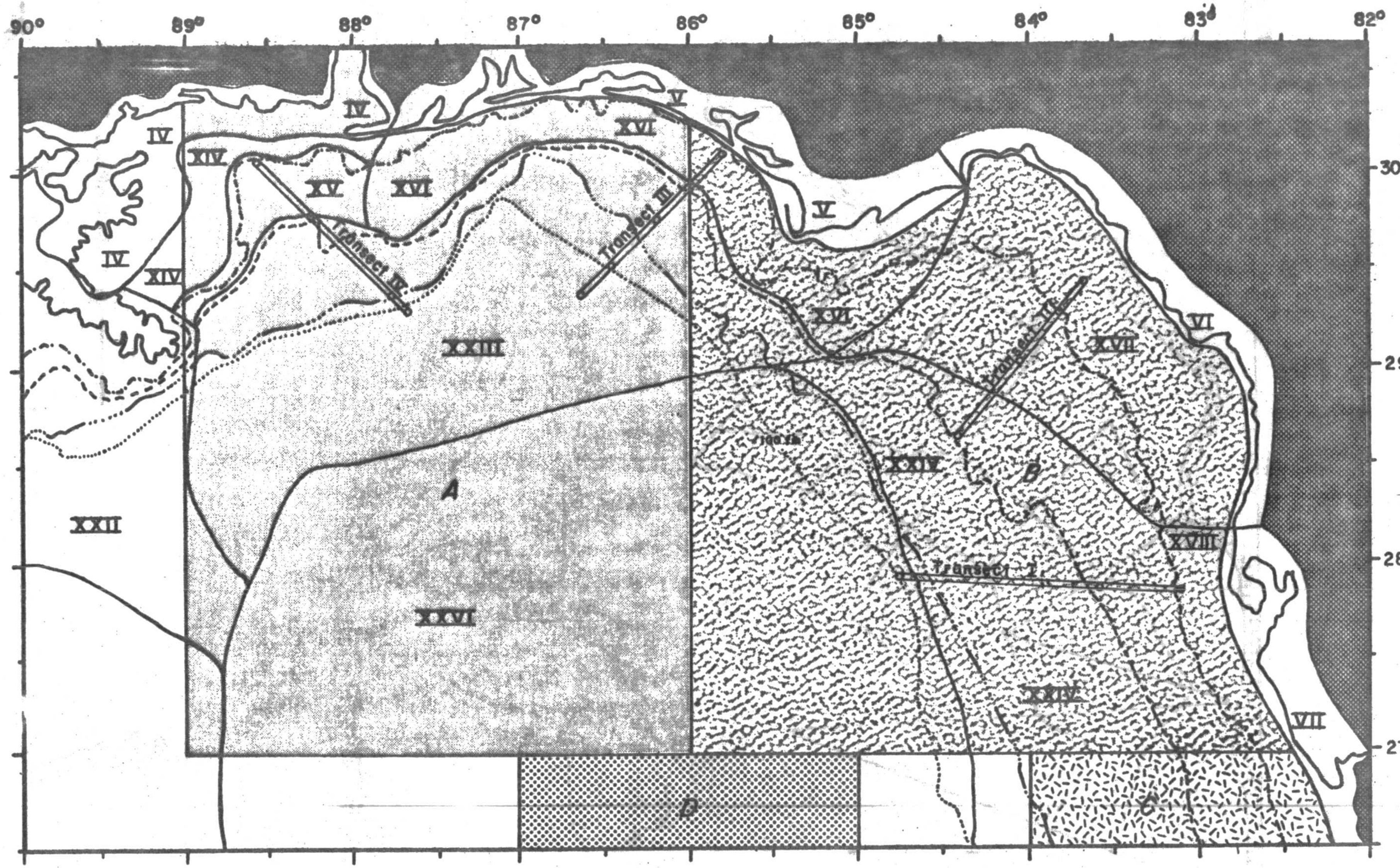

Figure 3. Delineation of boundaries of dissimilar hydro-biological zones IV-VII, XIV-XVIII, XXII-XXIV, & XXVI, eastern Gulf of Mexico in the bays, lagoons, estuaries and nearshore regions, the intermediate shelf regions and oceanic Gulf regions.

it was assumed that the major source of chemical contamination on the shelf would be associated with low salinity surface pockets resulting from drainage run-off. Measurements for chemical samples were set at ten meters since historical chemical data indicated that a sampling depth of five to ten meters would be required to reduce the possibility of contamination from the vessel, and physical data indicated that these low salinity surface pockets in the MAFLA area were usually fifteen meters deep.

The benthic sampling program was broadened to cover the same lateral extent that the water column studies covered. Six transects were established (Figure 4) across the shelf and sufficient stations were established along each of these to allow for optimal utilization of MAFLA baseline stations and also to allow for adequate coverage of the known hydrobiological zones and lease tracts.

The rationale behind the selection of these transects was based upon the need for the assessment of the benthic biotopes in the MAFLA area. Transect I was a totally new transect and on the average it is influenced by Loop Current waters 33% of the time and has a much greater assemblage of Caribbean species than the more northern transects. Transects II, IV, V and VI were selected because they cross existing lease areas and new stations were added to these transects to allow for proper assessment of the different hydrobiological zones not previously sampled. Transect III encompasses an area for which there is little benthic biological information and which is overlain by a water mass structure somewhat unique to the MAFLA area.

The total number of stations was reduced from 65 to 45 based on the similarity of the data from the 1974 study in certain lease areas. The

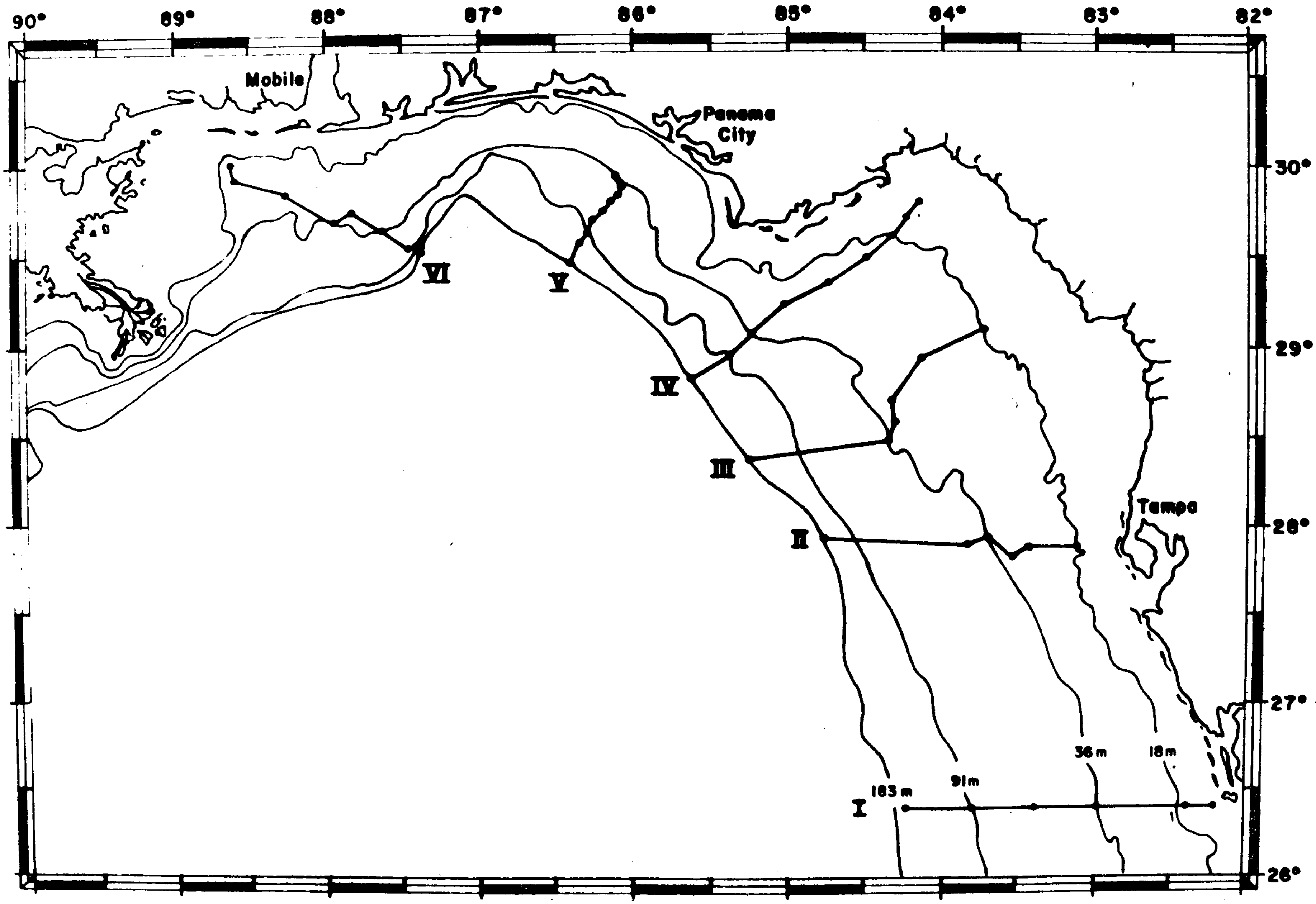

Figure 4. MAFLA box core stations, 1975-1976.

45 stations were sampled three times during the year and in the same intervals of time as in the water column effort since there appear to be three biological seasons in the MAFLA area.

The restriction of the 1974 program to the lease block areas allowed for the extensive use of divers to document the pre-drilling environment. The expansion of the program in 1975 precluded much of the use of divers since the 1974 results had shown that visibility was restricted in the waters south of Mobile, Alabama and Panama City, Florida, and Transect III was too deep for diving; trawling and dredging were conducted at three stations on each transect to supplement the box coring program.

For this, six transects (Figure 5) were established within the MAFLA area each consisting of stations located at approximately the 37, 91 and 183 m depth contour. These stations were located within the selected depth interval based on the examination of historical data which suggested that these depths were representative of biological zones.

The northernmost two transects (VI, located south of Mobile Bay and V located south of Pensacola Bay) lay partially over the steep slopes of the northern sector of the DeSoto Canyon. Transect III traversed the Florida Middle Ground area and this placed the inner station amongst scattered coral reefs. Transect I extended westward from the Fort Myers area and bordered on tropical substrate. Transects II and IV were located on gently sloping shelf bottom with no outstanding topographic features.

The Florida Middle Ground is an area of recognized biological sensitivity due to the presence of a substantial system of viable hermatypic (reef-building) corals. Special emphasis was placed on the Florida Middle Ground based on the high priority and interest expressed in this unique reef community by the U.S. Department of the Interior. Qualified diver-scientists were utilized

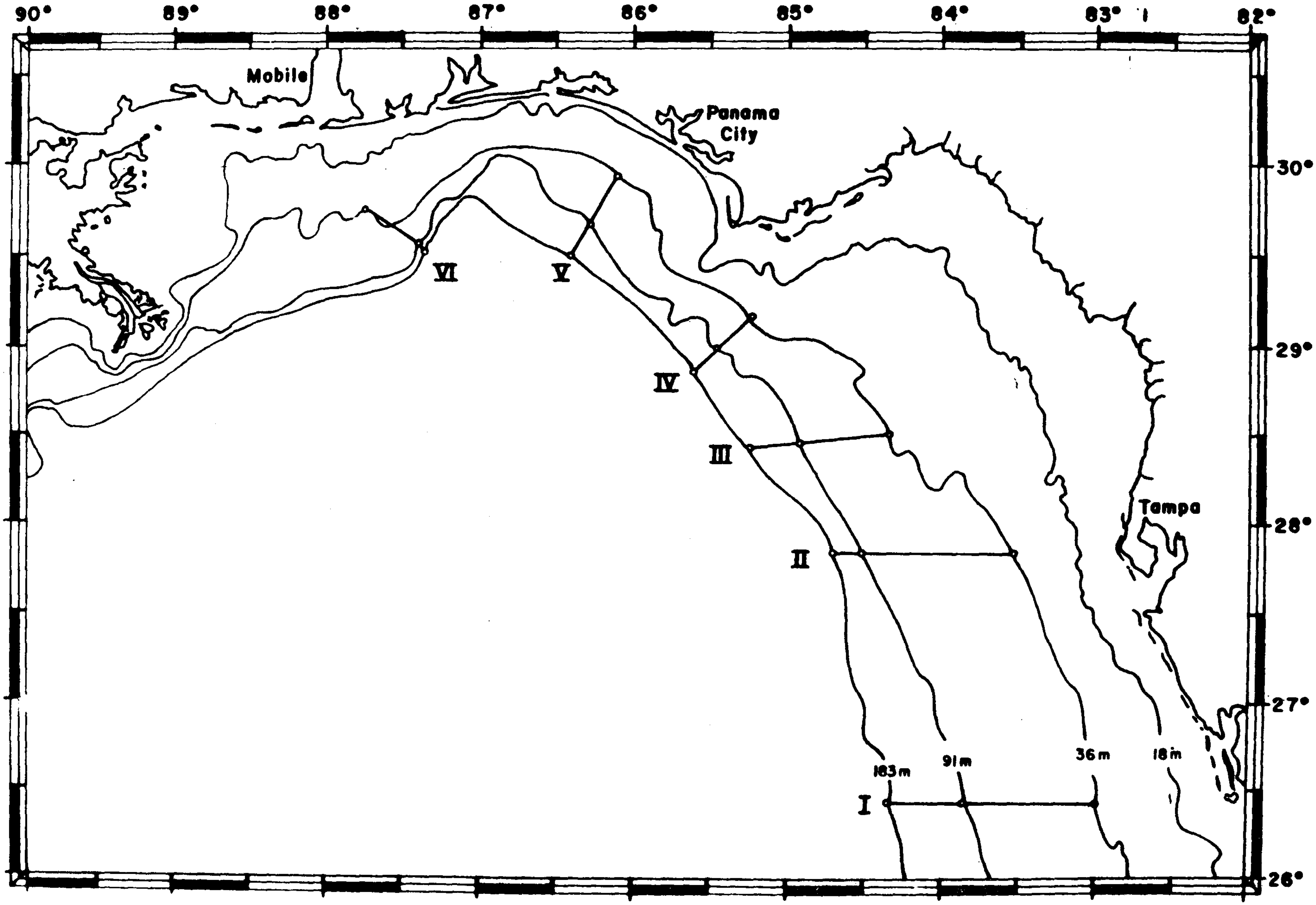

Figure 5. MAFLA dredge/trawl stations, 1975-1976.

to conduct *in situ* observations at six stations on the reef (Figure 6) and to collect the appropriate materials during each of the three sampling seasons. Two additional stations located off Clearwater, Florida were sampled for reference purposes.

In addition to the monitoring aspects of the water column and sea floor programs two special projects were incorporated into the program. The first of these involved the compilation of a lithologic map of the MAFLA area which would also incorporate the available historical data on the distribution of benthic organisms. As an adjunct to this a review of the high-resolution seismic data at the University of South Florida and acquisition of 3700 km of new geophysical data were to be made. Survey lines were to cover transects established for the benthic sampling program.

After review and analysis of the geophysical data the interpretations were to be plotted at appropriate scales and integrated with the results obtained from the benthic biologists which pertained to the distribution of macrobenthos and with data from the sedimentologists. This would help delineate major provinces of surface sediment distribution, location of near-surface structural features and areas of rock outcrops, reef buildups,etc. Existing bathymetric maps, charts and profiles in the public domain were to be used as compilation bases.

The second special project involved a site-specific study which was designed to provide a pre-, during, and post-operational assessment of selected biological, chemical, and geological aspects of the environment in the immediate vicinity of an exploratory drilling rig in an area selected by the Bureau of Land Management. Originally, this site-specific study was to have been conducted in the eastern Gulf of Mexico. However, due to a lack of drilling activities in this area during the contractual period, these

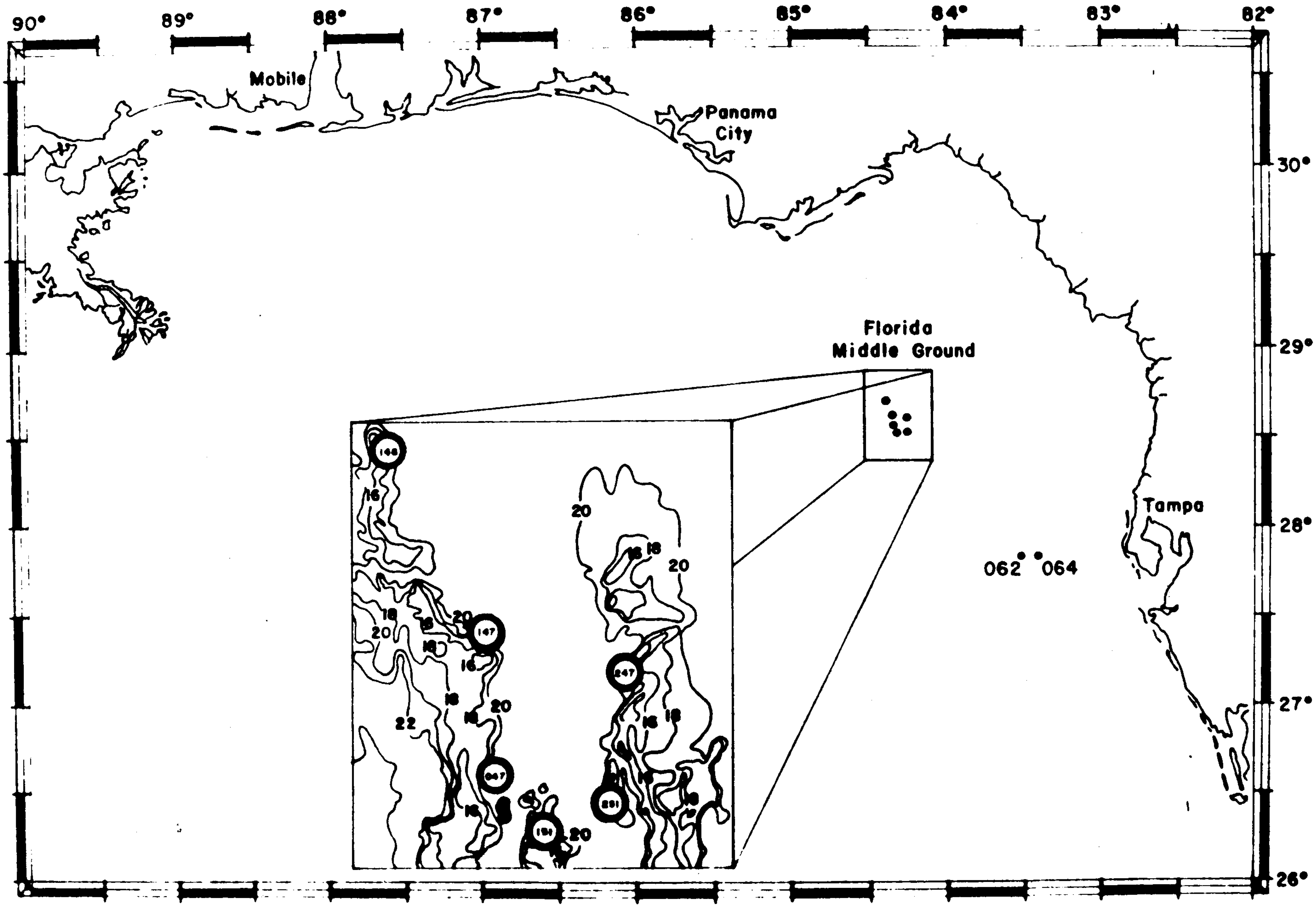

Figure 6. MAFLA dive stations, Florida Middle Ground and Clearwater sites.

efforts were relocated to the South Texas OCS region.

The need for this special study relates to the fact that numerous substances, including hydrocarbons, may be introduced into the marine environment from drilling rigs and production platforms during offshore petroleum development. For instance, from a typical well (3,000 m in depth) approximately 900,000 kg of drill cuttings alone are discharged before production commences and large volumes of drilling muds may be put over the side as well. Considerable quantities of brine (from formation waters) may also be discharged overboard, depending upon the geologic formation, and hydrocarbons may be released from minor spills and support activities (these are considered routine and unavoidable for practical reasons). In spite of the potentially large quantities of these introduced substances, there is, at the present time, little public information available on their fate and effects.

The rationale of this research is based on the supposition that offshore drilling operations have an impact on the environment in which they are conducted. The purpose of the study was to determine the spatial and temporal impacts on the immediate environment during all stages of offshore oil and gas exploration.

The actual rig monitoring survey was centered on a drilling location near the north lease line of Mustang Island (Texas), Block 792. The sampling pattern (Figure 7) was laid out in the form of a wheel with eight spokes, the drill site being the hub. One sampling point was established at the drill site and additional points at distances of 100, 500 and 1000 m from the site along each spoke, thus producing 25 sampling points (24 during the second phase).

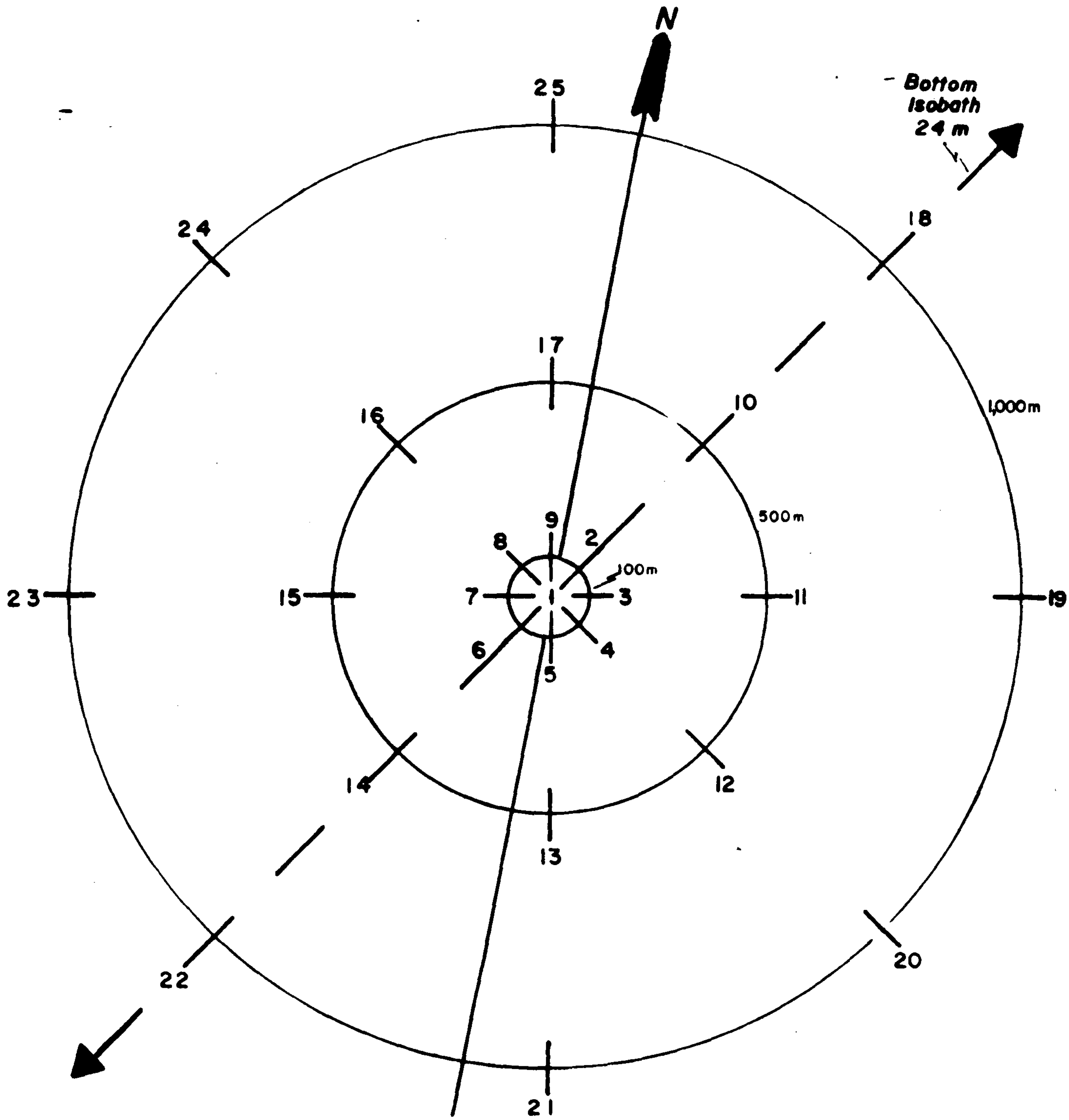

Figure 7. Station arrangement for rig monitoring.

To ensure repeatability of sampling positions not only within a season but also between seasons in the box coring, diving and rig programs high precision navigation equipment operated to ascertain the position of the ships to within ±15.2 m. LORAN A was used in the dredging and trawling and water column work.

Five research vessels were involved in the collection of these data during the 1975-1976 sampling season. The vessels, their assignments and their navigational equipment are shown in Table 1.

Table 1. Vessels, their assignments and navigational equipment used in MAFLA.

Effort	Vessel	Navigation
Benthic		
Box Coring	R/V COLUMBUS ISELIN R/V GYRE	LORAC DECCA Hi Fix
Dredging/Trawling	R/V GYRE R/V BELLOWS	LORAN A LORAN A
Diving	R/V BELLOWS	LORAC, DECCA Hi Fix
Geophysics	M/V DECCA PROFILER	DECCA Hi Fix
Rig	R/V BELLOWS R/V TURSIOPS	DECCA Hi Fix DECCA Hi Fix
Water Column	R/V TURSIOPS	LORAN A

Participation in the scientific aspects of the 1975-1976 study of the MAFLA lease tract included the following discipline studies, principal investigators, and organizations hereinafter referred to as the SUSIO Consortium as shown in Tables 2a and b:

Table 2a. Principal Investigators.

I. Sea Floor	
A. Biology	
1. Infauna	
Macromolluscs	N. J. Blake[1]
Micromolluscs	D. R. Moore[3]
Foraminifera	W. D. Bock[3]
Meiofauna	F. Maturo[7]
	M. Crezee[7]
Polychaetes	H. Kritzler[6]
	B. Vittor[9]
2. Epifauna	
Invertebrates	T. S. Hopkins[9]
Fish	S. A. Bortone[8]
	G. F. Mayer[1]
	R. L. Shipp[10]
Histopathology	N. J. Blake[1]
3. Epiflora	T. S. Hopkins[9]
B. Chemistry	
1. ATP (Sediments)	P. A. LaRock[6]
2. Trace Metals (Epifauna)	S. B. Betzer[1]
3. Trace Metals (Sediments)	B. J. Presley[11]
4. Hydrocarbons	
Epifauna	P. A. Meyers[12]
Epiflora	J. & T. Lytle[13]
Sediment	J. & T. Lytle[13]
C. Geological	
1. Standard Sediment Parameters	L. J. Doyle[1]
2. Clay Mineralogy	W. H. Huang[2]
3. Carbonate Analysis, Molluscan Lithotopes	H. R. Wanless[3]
4. X-Radiography	T. V. Mayou[2]
5. Geophysics	T. E. Pyle[1]
	V. J. Henry[4]

Table 2a - continued.

II. Water Column	
A. Physical Oceanography	M. O. Rinkel[5]
B. Transmissometry	F. T. Manheim[1]
C. Biological	
Primary Production	R. L. Iverson[6]
Zooplankton	F. J. Maturo[7]
	J. Caldwell[7]
Neuston	S. B. Collard[8]
D. Chemical	
Organic Carbon	G. A. Knauer[6]
Trace Metals (Particulate)	P. R. Betzer[1]
Trace Metals (Zooplankton)	P. R. Betzer[1]
Trace Metals (Neuston)	P. R. Betzer[1]
Hydrocarbons (Particulate and Dissolved)	J. A. Calder[6]
Hydrocarbons (Zooplankton)	J. A. Calder[6]
Hydrocarbons (Neuston)	J. A. Calder[6]
E. Geological	
Clay Mineralogy (Suspended Matter)	W. H. Huang[2]
III. Data Management	C. P. Tsokos[14]

Table 2b. Principal Investigator's Affiliation.

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   Miami, Florida 33149

4. University of Georgia
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   P.O. Box 13687
   Savannah, Georgia 31406

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   St. Petersburg, Florida 33701

6. Florida State University
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   Tallahassee, Florida 32306

Table 2b - continued.

7. University of Florida
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Gainesville, Florida 32611

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Department of Biology
University of West Florida
Pensacola, Florida 32504

9. Dauphin Island Sea Lab
P.O. Box 386 - University of Alabama
Dauphin Island, Alabama 36528

10. University of South Alabama
Mobile, Alabama 36688

11. Texas A&M University
Department of Oceanography
College Station, Texas 77843

12. University of Michigan
Dept. of Atmospheric and Oceanic Science
1213 Base Research
Ann Arbor, Michigan 48103

13. Gulf Coast Research Laboratory
P.O. Drawer AG
Ocean Springs, Mississippi 39564

14. University of South Florida
Department of Mathematics
4202 Fowler Avenue
Tampa, Florida 33620

The actual types and numbers of samples collected in the 1975-1976 MAFLA OCS program are shown in Tables 3a and b and the summarized cruise data are shown in Table 4.

Table 3a. Numbers of biological, chemical and geological samples collected in MAFLA in 1975-1976.

Sampling Method	No. of Samples	Number of Subsamples Chemical	Biological	Geological	Archives
Box core	1,452	303	2,340	765	135
Anchor dredge	5	-	5	-	-
Diver collected	639	426	205	-	-
Trawl and Capetown dredge	54*	297	178	-	-
Hydrocast**	180	225	360	45	-
Neuston tow	270	240	135	-	-
STD	112				
XBT	40				

* 1 sample = 2 dredge tows
** Does not include STD, transmissometry, or XBT casts

Table 3b. Numbers of biological, chemical and geological samples collected in the rig monitoring study.

Sampling Method	No. of Samples	Number of Subsamples Chemical	Biological	Geological	Archives
Diver collected	518	164	74	148	222
Trawl	74	256	148	-	-
Hydrocarbon "Sniffer"	86	86	-	-	-

Table 4. Summary of cruises, MAFLA OCS.

Box Core

Cruise No.	Vessel	Dates	Stations Occupied
BLM 10	COLUMBUS ISELIN	27 May-10 June '75	34 of 45
BLM 14	GYRE	22 July-25 July '75	9 more
BLM 17	BELLOWS	30 July-31 July '75	2 remaining
BLM 21	COLUMBUS ISELIN	12 Sept-29 Sept '75	45 of 45
BLM 29	GYRE	15 Jan-8 Feb '76	45 of 45

Dive

Cruise No.	Vessel	Dates	Stations Occupied
BLM 11	BELLOWS	2 June-2 July '75	8 of 8
BLM 19	BELLOWS	2 Sept-6 Oct '75	8 of 8
BLM 32	BELLOWS	4 Feb-22 Feb '76	8 of 8
BLM 34	BELLOWS	3 Mar-12 Mar '76	

Dredge/Trawl

Cruise No.	Vessel	Dates	Stations Occupied
BLM 13	GYRE	18 July-21 July '75	6 of 18
BLM 15	BELLOWS	23 July-28 July '75	12 remaining
BLM 22	GYRE	18 Oct-23 Oct '75	18 of 18
BLM 30	GYRE	8 Feb-9 Feb '76	6* of 18
BLM 33	BELLOWS	24 Feb-29 Feb '76	12 remaining
BLM 35	TURSIOPS	3 Mar-4 Mar '76	Complete BLM 30

* Sampling not completed on two stations

Table 4 - continued.

Water Column	Cruise No.	Vessel	Dates	Stations Occupied
	BLM 12	TURSIOPS	18 June-17 July '75	15 of 15
	BLM 20	TURSIOPS	6 Sept-3 Oct '75	15 of 15
	BLM 28	TURSIOPS	6 Jan-11 Feb '76	15 of 15
Geophysical				
	BLM 16	DECCA PROFILER	25 July-17 Aug '75	3700 km geophysical cruise
Rig Monitoring				
	BLM 24/25	BELLOWS	20 Nov-6 Dec '75	25 - Phase I
	BLM 26/27/31	BELLOWS	2 Jan-24 Jan '76	24 - Phase II
	BLM 36	TURSIOPS	25 Mar-3 Apr '76	25 - Phase III

The data derived from the 1975-1976 study are large and extensive. For ease of presentation of these and for the convenience of the reader the remaining sections of this summary have been broken into sea floor and water column.

Sea Floor

The Mississippi River Delta System forms a continental margin province which dominates the north central portion of the Gulf of Mexico. East of the Delta lies a second province known by the acronym MAFLA. The eastern part of the MAFLA margin is dominated by the Florida platform, an accumulation of over 4,572 m of carbonate sediment ranging in age from Jurassic to Recent. West of Cape San Blas (southeast of Panama City, Florida), carbonates become intercalated with increasing amounts of clastics. Across the northern extension of the Florida Escarpment the sedimentary basement rocks change from dominantly carbonates on the east to Cenozoic clastics on the west. The Florida Escarpment trend therefore represents a major sedimentary boundary between the Gulf Coast Geosyncline and the Florida carbonate platform.

Bathymetrically the major relief features present in the shelf are the relict spur-like ridges at the shelf break and on the outer shelf and the Florida Middle Ground reef complex. One unusual type of bathymetric anomaly was present in the peninsular shelf. These are the elongate notches and offsets in the shelf which are oriented in an east-west direction and which trend normal to the bathymetry. All had the same directional orientation and some, especially those at 28°30'N (approximately Tarpon Springs, Florida) are reflected far west as offsets in the face of the Florida Escarpment. The origin of these "notches" is unknown.

Pinnacles and linear coral-algal ridges are common on the outer shelf and at the shelf break. The most well developed pinnacles were observed around the margins of the DeSoto Canyon and on the outer peninsular shelf between 27°N and 28°N. Landward of the shelf break on the peninsular shelf the only large skeletal buildup is the Florida Middle Ground reef complex.

Most of the sediment of the Mississippi River is delivered directly to the shelf edge or is transported to the west. As a result the MAFLA continental margin is covered by a sand sheet which is predominantly quartz west of Cape San Blas and carbonate east of Cape San Blas.

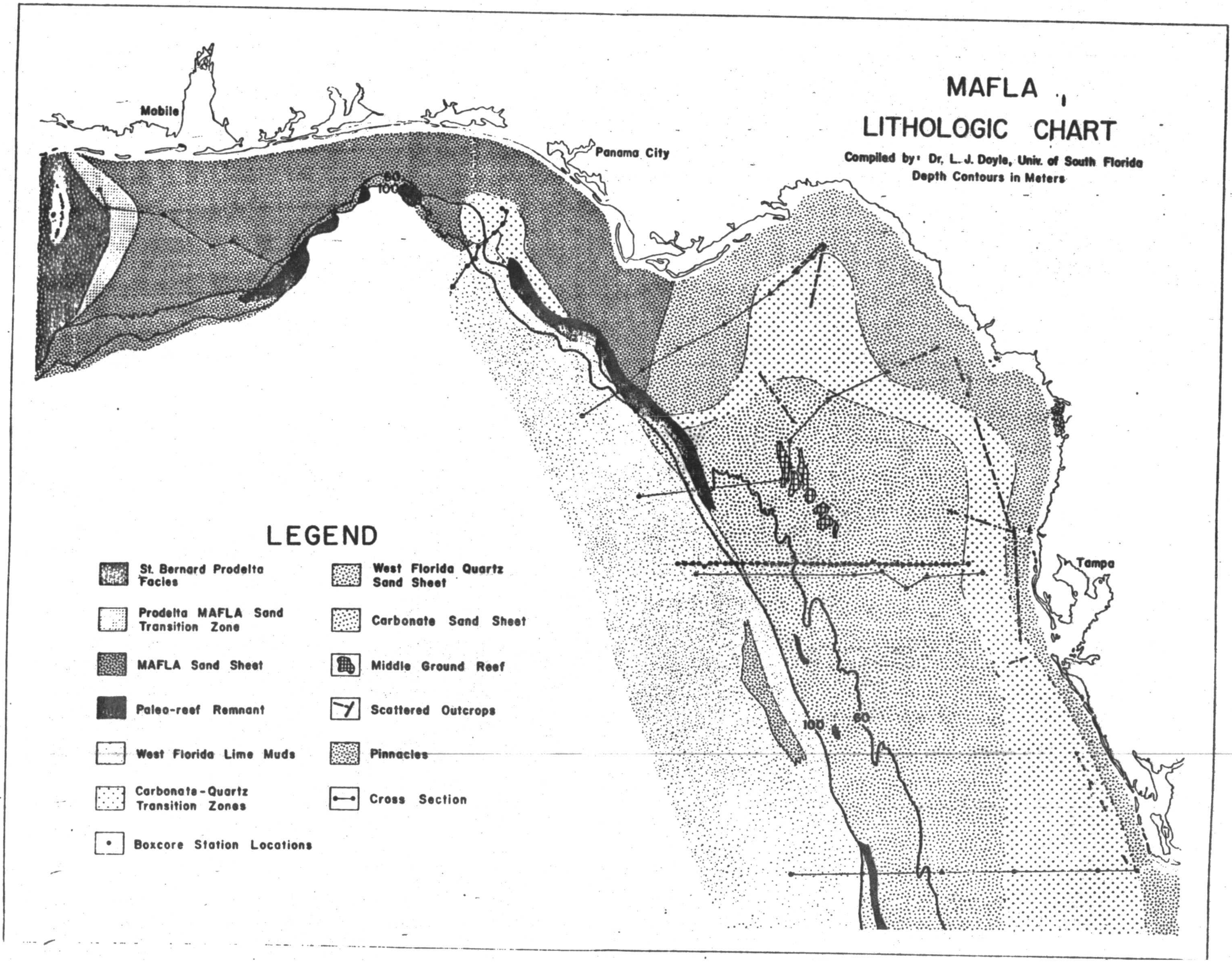
Excepting mineralogy, the MAFLA sand sheet is much like that of the continental shelf of the southeastern U.S. Atlantic margin. Rivers which empty into the MAFLA region carry little sediment and virtually none of this is sand sized. Furthermore, most of the fine sediments delivered to the coast are trapped in estuaries, bays and lagoons.

Although these (estuaries, bays and lagoons) have been rather thoroughly investigated, few studies of the continental shelf of the MAFLA area have been undertaken and these have not been thoroughly integrated.

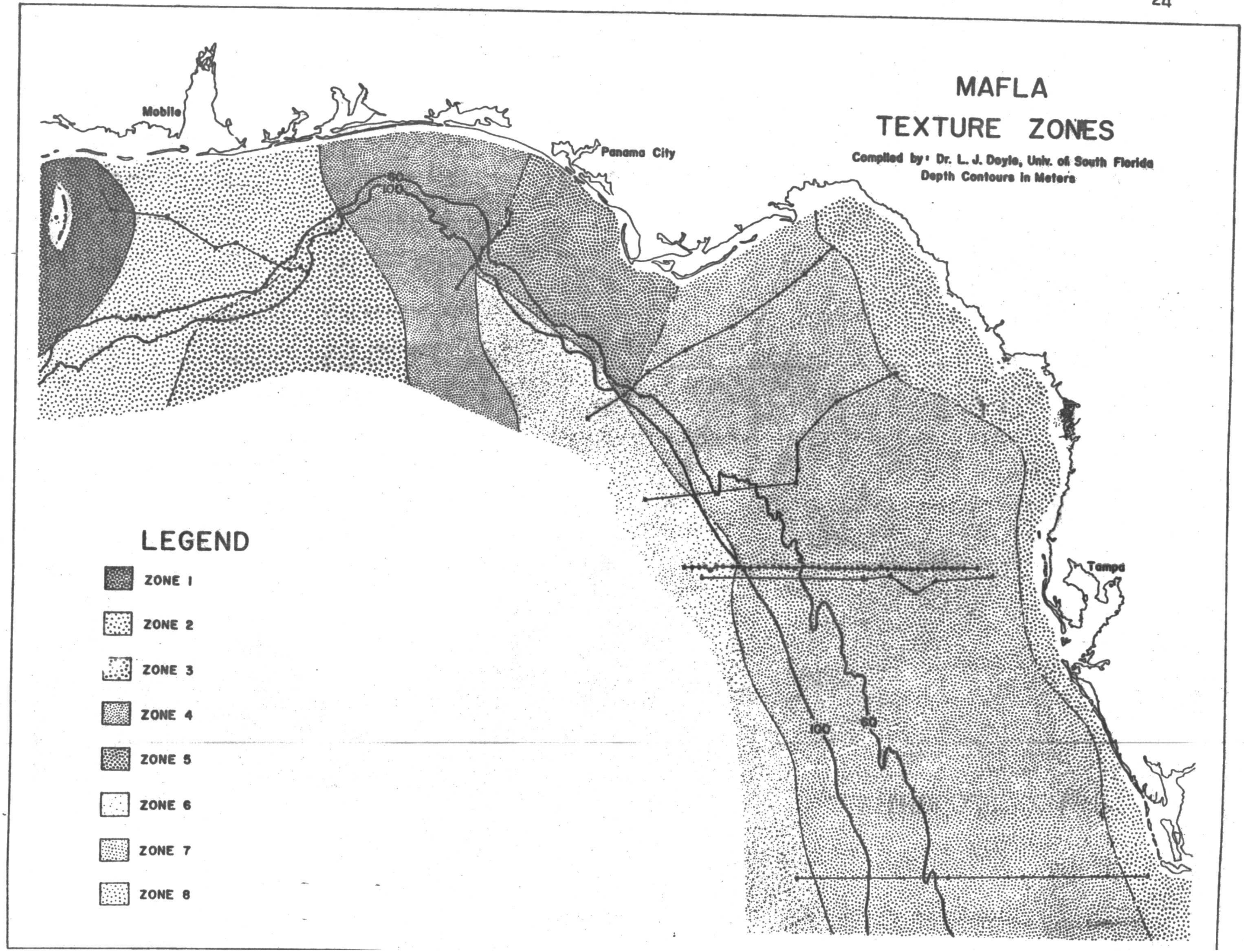
The results of this study are summarized in Figures 8a and 8b. Based on these data and especially those shown in Figure 8b, the MAFLA continental shelf and upper slope can be divided into eight separate sediment zones on the basis of selected particle size ratios, the amount of carbonate present and the mineralogy. It is immediately apparent that the effect of the Mississippi River upon the characteristics of the sediment in the region diminishes from west to east and is not detectable in the shelf sediments east of Cape San Blas.

Zone I is composed of fine grained pro-delta sediments characterized by a smectite dominated clay mineral suite while the sediments of Zone II are composed primarily of quartz sand with the clay fraction still dominated by smectite. Zones III and IV are the steep western and gentler eastern flanks of the DeSoto Canyon. The former is made up of carbonate sands; the latter of lime muds typical of the upper west Florida continental slope.

Zone V is the transition from the DeSoto Canyon to the clastic shelf of the northwest Florida margin. East of Cape San Blas the transition to the Florida carbonate platform begins. Kaolinite becomes the predominant clay mineral and carbonates increase at the eastern edge of the shelf. Zone VI represents the upper continental slope of the Florida platform and Zone VII is the thin carbonate sand sheet covering most of the west Florida



MAFLA
LITHOLOGIC CHART
Compiled by: Dr. L. J. Doyle, Univ. of South Florida
Depth Contours in Meters
Mobile
Panama City
Tampa
60
100
100
60
LEGEND
St. Bernard Prodelta Facies
Prodelta MAFLA Sand Transition Zone
MAFLA Sand Sheet
Paleo-reef Remnant
West Florida Lime Muds
Carbonate-Quartz Transition Zones
Boxcore Station Locations
West Florida Quartz Sand Sheet
Carbonate Sand Sheet
Middle Ground Reef
Scattered Outcrops
Pinnacles
Cross Section


MAFLA
TEXTURE ZONES
Compiled by: Dr. L. J. Doyle, Univ. of South Florida
Depth Contours in Meters
Mobile
Panama City
Tampa
60
100
100
60
LEGEND
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8

shelf. Zone VIII is the quartz band of the inner shelf and coastal zone.

Geologic hazards are present on the west Florida platform and consist of karst (a porous limestone region containing sinkholes and deep fissures) and unstable slopes. Four major karst trends were mapped; two of these are believed to indicate concentrations of dolines (a closed depression in an area of karst topography that is formed either by solution of surface limestone or by collapse of underlying caves) and these were confined to the Big Bend region. The other two karst trends appeared to be "karren" (a general term for solutional furrows or channels formed on the surface of limestone) surfaces and their relationship to breaks in slope suggest that they may have resulted from locally high fluxes of ground water during previous regressions.

Unstable bottom was noted on the upper peninsula slope at two localities as indicated in Figure 9. Unstable slopes also exist around the upper slope in the vicinity of the DeSoto Canyon. This condition was more common on the steeper western side where much slumping, especially to the south, was evident.

Faults were numerous in the area between Horn Island and Pensacola from nearshore to the shelf break. Also a few small faults exist on the shelf offshore from Panama City, extending from about midshelf to nearshore.

Unidentified structures, appearing to result from salt plug intrusion, are found in the area immediately south of Mobile Bay, Alabama. A buried erosion surface, well developed on both the Mississippi-Alabama and Florida panhandle shelf, is present.

An important aspect of the entire MAFLA region is the extreme textural

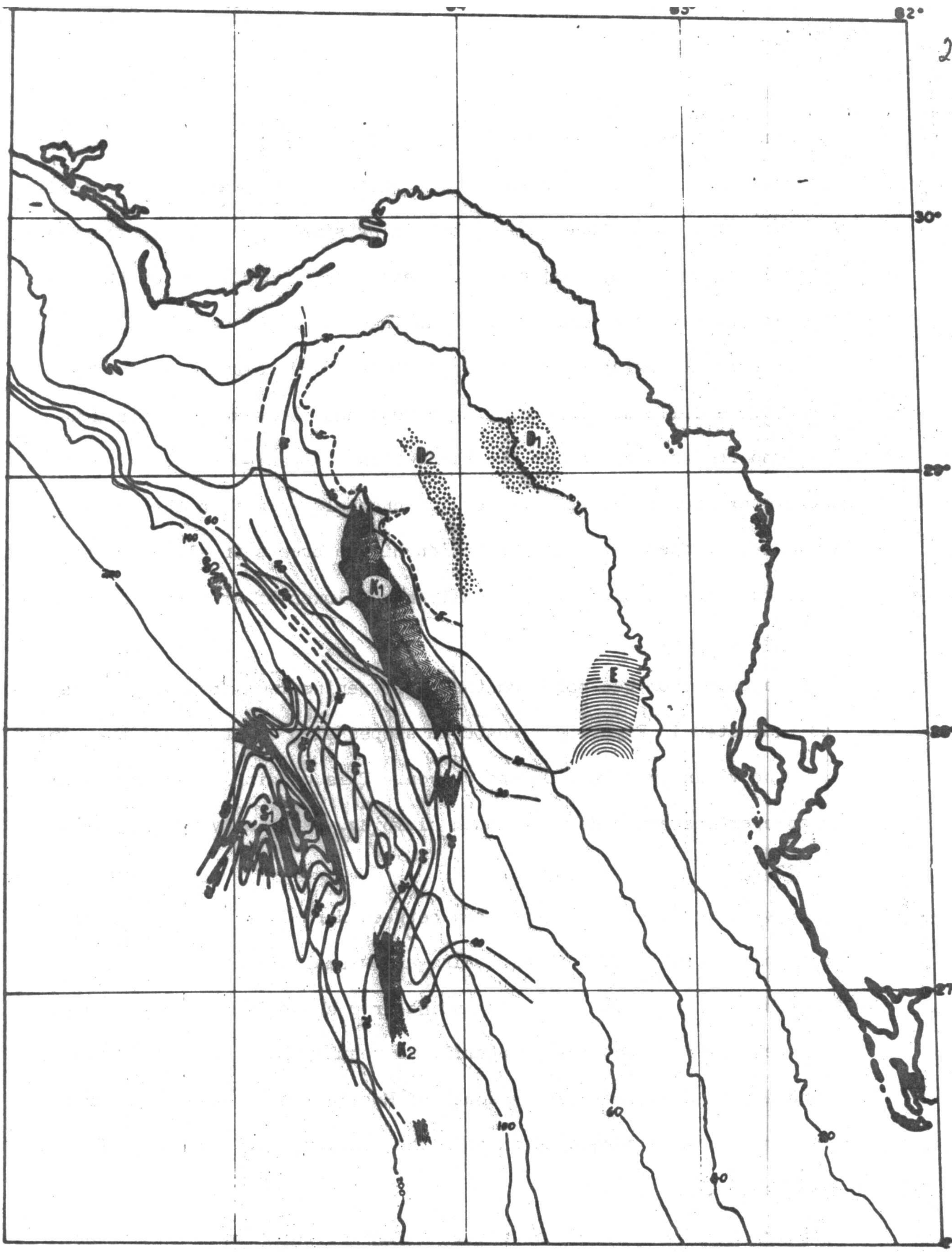


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Figure 9. Various subsurface structures located on the peninsula Florida shelf. D_1 and D_2: areas of doline karst features; K_1 and K_2: karren karst trends; S_1 and S_2: slope instability evidenced by creep or slumping; E: major filled valley complex; "raw time": thickness of past Miocene strate given in 10 msec contour intervals.

variability landward of the shelf break. This was confirmed both by discrete sampling at the box core sites and especially in the geophysics program. This has important pertinent implications to the explanation of the observed inter and intra seasonal variability which were noted in the infaunal populations of the sediments.

For example, the densities of infaunal taxa show a partial, but by no means definitive, dependence on sediment grain size and this relationship was most apparent for the microbial population. Surprisingly, the species associations could not be attributed to substrate characteristics, not even for the corals which one might expect to be substrate dependent. Rather, many of these associations were more depth-related than either to the textural or geographic variability.

Depth was found to be the major factor influencing the species affinities and dominant species assemblages of both infaunal and epifaunal taxa. Variations in these between differing depth zones along the same transect were usually greater than variations between the same depth zones of different transects. This generality held even at the extremes (Transect I compared to Transect VI).

Four epifaunal assemblages were determined for the MAFLA study region each of which was depth delineated. These assemblages are: (1) Middle Shelf, 30-60 m assemblage; (2) North Middle Shelf, 30-60 m high relief assemblage; (3) Middle Shelf, 60-140 m assemblage; and (4) Deep Shelf, 140-200 m assemblage. Assemblages (1), (3) and (4) show temperate affinities. The Florida Middle Ground (North Middle Shelf, 30-60 m high relief assemblage) shows strong tropical affinities. The Florida Middle Ground is a unique faunal and floral entity, not only within the MAFLA study region but also within the Gulf of Mexico and it is proposed that the biotic community of the Florida Middle Ground is partially maintained by the periodic influx of Loop Current water and this is indicative of a slow recruitment rate for this sensitive community.

The infaunal and epifaunal groups in the MAFLA region were abundant and diverse. Table 5 shows the number of species represented by living specimens for the major benthic taxa taken during the 1975-1976 program.

Table 5. Number of species represented by live specimens for major benthic taxa occurring in the MAFLA study region.

Taxa	Number of Species
INFAUNA (from box core samples)	
Foraminifera	219
Mollusca	305
Polychaete Annelids	616
EPIBIOTA (from trawl/dredge and diving samples)	
Porifera	48+
Octocorallia	25
Scleractinia	30
Molluscs	236
Polychaete Annelids	100+
Decapod Crustaceans	~190
Echinoderms	65+
Demersal Fish	204
Algae	194

In addition to the above biological relationships the benthic biology of the area west of Cape San Blas is further characterized by a low species diversity, species and specimen abundance and biomass. This is attributable to the finer grained sediments and higher sedimentation rates in this region. Another reason may be the relatively high freshwater loadings of the northwestern zone via the northwest drainage basin. Indications of environmental stress conditions in the northwest zone, particularly benthic Transect VI which is the most proximal to the Mississippi Delta and Mobile Bay, are supported by the notably higher microbial biomasses in this region of the MAFLA study region and the occurrence in relatively high densities of several foraminiferal species which are known indicators of environmental stress. The trace metal and hydrocarbon results of this study indicate that this "depauperate," stressed condition is not, at present, due to anthropogenic influences. The area east and south of Cape San Blas is characterized by a high species diversity, species and specimen abundance and biomass. This high level of diversity which approaches 80% or more of the maximum potential diversity attributable to this region indicates that this biotic community exists under relatively stable conditions. This is indicative of the sensitivity of the MAFLA area (and especially that region east and south of Cape San Blas) to perturbations.

Superimposed on the above characterization is the unique faunal and floral biota of the Florida Middle Ground. The sensitivity of this area to natural perturbations was demonstrated as a result of the passage of Hurricane ELOISE in September, 1975. The effects of this storm on the Florida Middle Ground resulted in the complete elimination of some species and the fragmentation of many macro algae. For example, _Halymenia_ plants were torn or reduced to only a holdfast with a small residual stipe and blade fragment. However, the cumulative effects of later winter storms were even more severe. Sandy areas became churned into deep sand ripples and extensive _Caulerpa_ communities were destroyed. Despite all of this devastation it is evident from three seasons of observations (1974, 1975, 1976) that the plant populations recovered each year.

Trace metal concentrations in the sediments were also variable no doubt primarily in response to the changes in both chemistry and mineralogy implied by the grain size, calcium carbonate and iron variations. Past experience has shown that high metal concentrations are found with fine-grained materials, organic matter and iron and manganese hydrous oxides, whereas low concentrations are observed when sediments contain appreciable amounts of quartz, carbonate and coarse-grained material.

With the type of sediment trace metal data collected in this study it was convenient to normalize the observed metal concentrations to a single index which encompasses the more important concentration factors. Being at percent levels in the sediment and being relatively unreactive in oxic water, iron provides this index and is considered to act as a fairly good mineralogical indicator. It is also anticipated that iron levels are not as sensitive to non-induced changes which might affect the trace (ppm level) levels.

Figures 10a and b show metal to iron scatter plots for chromium versus iron and vanadium versus iron in the MAFLA sediments. In both instances there is a strong linear correlation of the metals with iron. The same relationship was observed between copper-, nickel-, chromium-, and iron. The plots provide a prediction interval for evaluating future sediment analyses and show no present day evidence of pollution. Any input of trace metals to the area from man's activities would result in data points which deviate from linearity in the positive y-direction on the scatter plots assuming that anthropogenic iron additions are not high

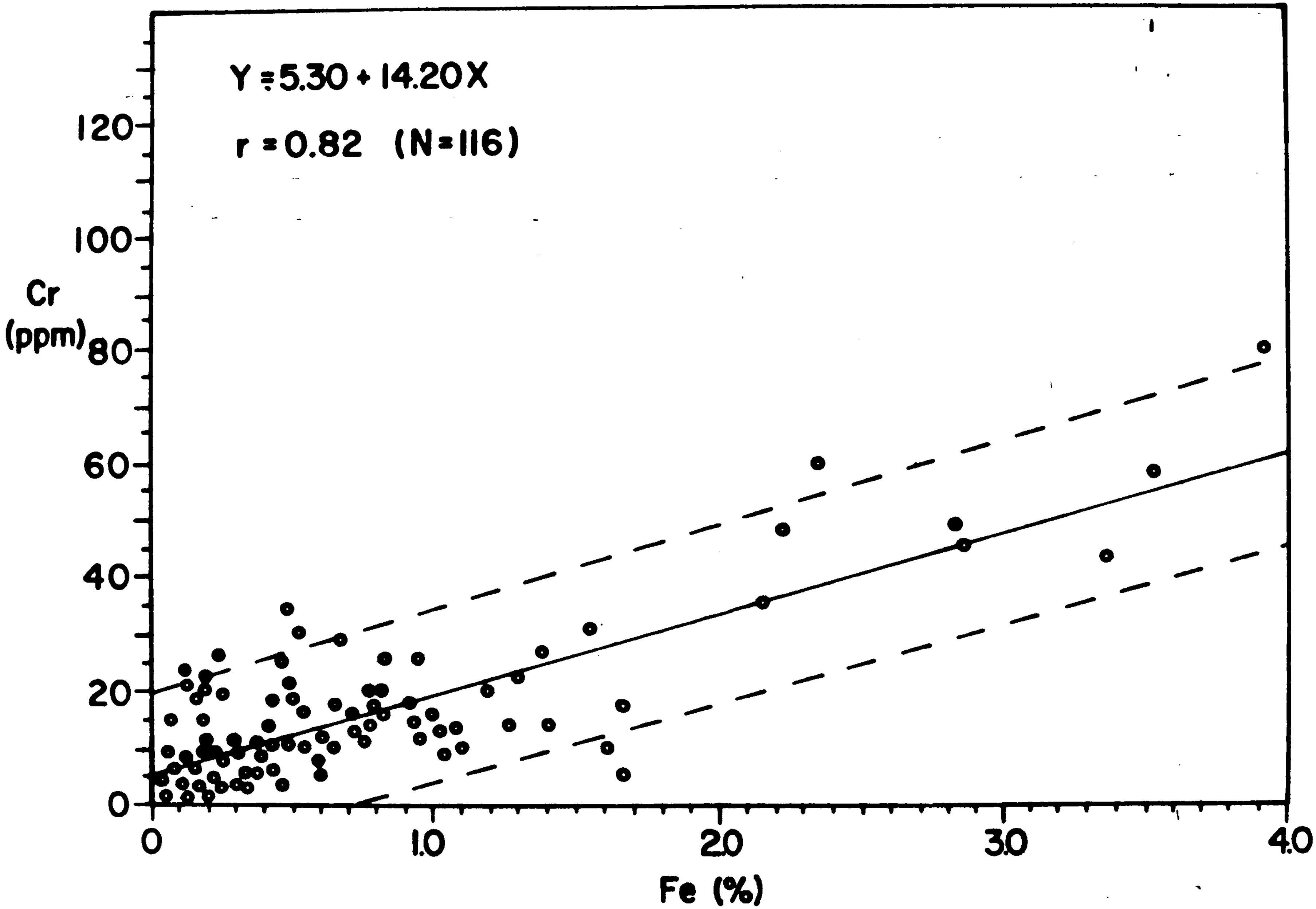


Figure 10a. Chromium versus iron scatter plot for MAFLA shelf sediments with 95% prediction interval.

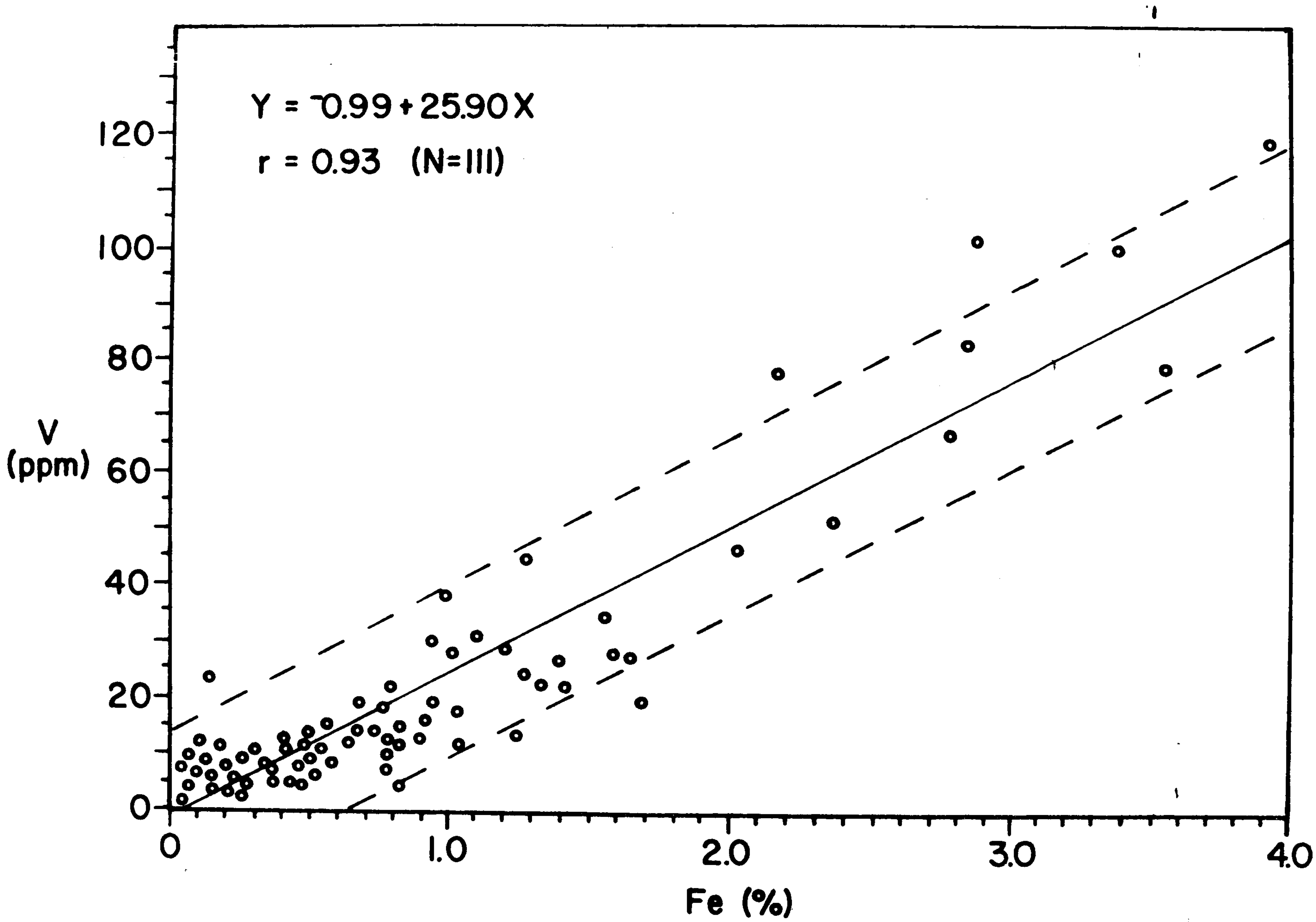


Figure 10b. Vanadium versus iron scatter plot for MAFLA shelf sediments with 95% prediction interval

enough to influence the normal sediment iron content.

From the hydrocarbon aspect the sediments of the MAFLA area are essentially free of contamination. The major exceptions to this were all of the sediments sampled along Transect VI (south of Mobile, Alabama) and all of the deep water stations sampled along each transect. All of these stations are characterized by abundant high molecular weight n-alkanes of terrestrial distribution and lesser amounts of low molecular weight n-alkanes with a fairly uniform distribution typical of weathered petroleum.

No discernible changes in either the amounts or composition of hydrocarbons in the epifaunal samples were detected between stations nor between sampling periods (nor were any non-biogenic hydrocarbons found). All organisms appeared to be basically pristine and the natural hydrocarbon distributions appeared to be relatively simple with a small number of major components dominating. These components are different for different genera and phyla.

In the algae, however, 15 out of the 36 samples analyzed contained hydrocarbons indicative of petroleum contamination. There was no correlation of this contamination with the presence of petroleum residues in nearby sediments or the species of algae. It was noted that the frequency of this contamination decreased steadily from summer through winter and this is indicative of circulation related contamination.

Trace metal concentrations in the epifauna were within the range reported by other investigators. Corals, contrary to the other groups, were uniform in their trace metal concentrations and this was true not only among the various groups but between the individuals within a species.

Among the other groups the variation in metal content was high and this was true among the species within a phylum. This was most evident in the sponges where the variation was several orders of magnitude. In spite of this large variation, geographical trends in metal content were indicated for the sponges and echinoderms.

The pre-drilling conditions at the rig site suggest an initially stressed environment. The prime evidence is derived from the presence of stress indicator species throughout the area prior to drilling. The organism, <u>Ammonia beccarii</u> (a foraminifera) is a well known indicator of stress and has been well studied. With increasing stress on an environment, from whatever source, this species will increase in abundance as the normal fauna finds it more difficult to survive. At the rig site this organism completely dominated every sample composing 55-88% of the living fauna. This, in itself, is indicative of the stress present in this environment before drilling operations.

It should also be noted that in normal shelf environments in a 24 m water depth (the sampling depth), a rather diverse benthonic foraminiferal fauna usually exists, generally supporting a population of 25-60 species with abundance dependent to some extent on the grain size of the sediment (the coarser the sediment the lower the diversity and abundance and vice versa). Adult individuals usually attain close to maximum size for the major dominant species. At all of the sampling sites (pre-, during and post drilling), over 90% of the sediment was less than 63 μm in size yet the species diversity was still very low. It was also noted that only a few specimens attained a size greater than 125 μm. Smallness has long been associated with stressed environments and this coupled with the low species diversity and the dominance of a stress indicator species rather conclusively indicates that this environment was stressed before the drilling operations began.

At the oil rig site the significant changes observed in the environment could not, in toto, be attributed to drilling operations. Environmental effects attributable to the drilling activities were a change in the clay mineralogy of the sediment (illite increased and kaolinite decreased). Significant changes in the levels of sand, silt, clay and calcium carbonate occurred. Sand, clay and calcium carbonate levels increased in the during phase while silt levels showed a significant decrease. Comparison of the during and after drilling levels shows that the clay and calcium carbonate levels had decreased and the silt levels had increased. The after drilling levels of sand still remained high. In the during drilling phase drill cuttings were noted at only four - 100 m periphery stations and one - 500 m periphery station. Drill cuttings were still observable at these same five stations but were noticeably less abundant.

Comparisons of the hydrocarbon and trace metal content of the sediments between the three drilling phases indicated that no significant changes had occurred. For example, Table 6 shows the averaged (for all stations) gravimetric, aliphatic and aromatic hydrocarbon levels before, during and after drilling. Comparisons of before, during and after drilling values for individual stations showed that these variations were random and not associated with drilling activities or station location. Further examination of the hydrocarbons in the sediments (by gas chromatography)

Table 6. Averaged (for all stations) gravimetric, aliphatic and aromatic hydrocarbon levels of rig sediments before, during and after drilling.

		Aliphatics, ppm	Aromatics, ppm
Before			
	$\bar{X}\pm1$ S.D.	18.2±9.1	9.0±5.0
	Range	4.8-39.9	2.1-19.6
During			
	$\bar{X}\pm1$ S.D.	17.9±7.3	7.0±5.6
	Range	8.9-39.2	0.8-27.8
After			
	$\bar{X}\pm1$ S.D.	20.6±5.5	9.2±2.3
	Range	6.3-30.9	3.8-13.2

showed that the basic characteristics of the gas chromatograms were the same in the before, during and after samples and there was evidence of past oil pollution in the area.

The hydrocarbon content of the epifauna collected in the area during all phases of operations showed that two samples collected in the after phase of drilling were contaminated and possibly two from the during phase. The contaminant was tentatively identified as No. 2 fuel oil and presumably these samples were contaminated when the net came through the surface film.

Only two species of epifauna were analyzed for hydrocarbon content in all three drilling phases. The two shrimplike species were *Penaeus setiferus* and *Trachypenaeus similis* which are highly motile, nektonic forms. The *T. similis* samples analyzed from the after drilling phase were significantly higher in aromatic hydrocarbons than those from the pre- and during drilling phase.

Sediment and epifaunal organisms were also analyzed for cadmium, chromium, copper, iron, lead, nickel and vanadium. Barium was also determined in the sediment samples. No differences were noted in the distribution of these trace metals (except iron and barium) that could be attributed to the drilling activities. Iron concentrations in the muscle tissue of P. setiferus was also higher in the during phase than in either the pre- or post drilling phase. Similar findings between the during and post levels of iron in T. similis and Squilla chydae were made. No explanation is available to explain these data. Whether they were storm related, rig related or even typical of seasonal changes cannot be stated.

The barium data showed a marked increase in both the during and after drilling phases. Since barium (barium sulfate) is commonly used in drilling muds this finding is not unexpected. The amounts found were a function of both distance from the rig and currents in the area. During drilling the barium levels increased markedly near the rig (as much as eight-fold at some stations). The distribution of barium demonstrates the influence of the local currents (Figures 11a, b and c). Barium levels also increased significantly but to a much smaller extent throughout the sampling area. Approximately three months after drilling had stopped the barium levels had returned to pre-rig levels in much of the area although a "core" of high levels still existed near the former drill site.

It should also be noted that light hydrocarbon sniffer analyses conducted around the rig indicated no significant change in the level of

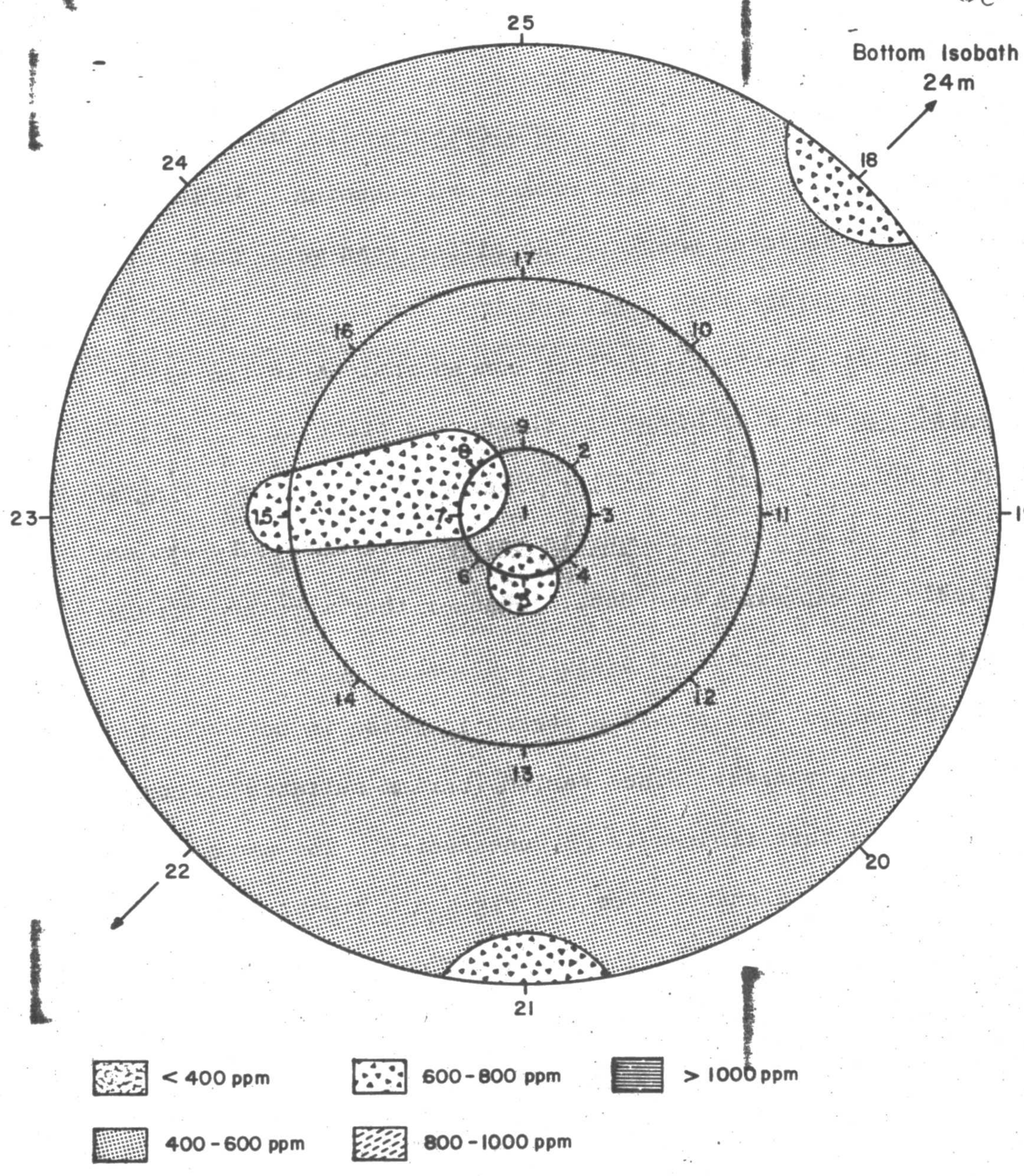


Figure 11a. Distribution of barium (pre-drilling).

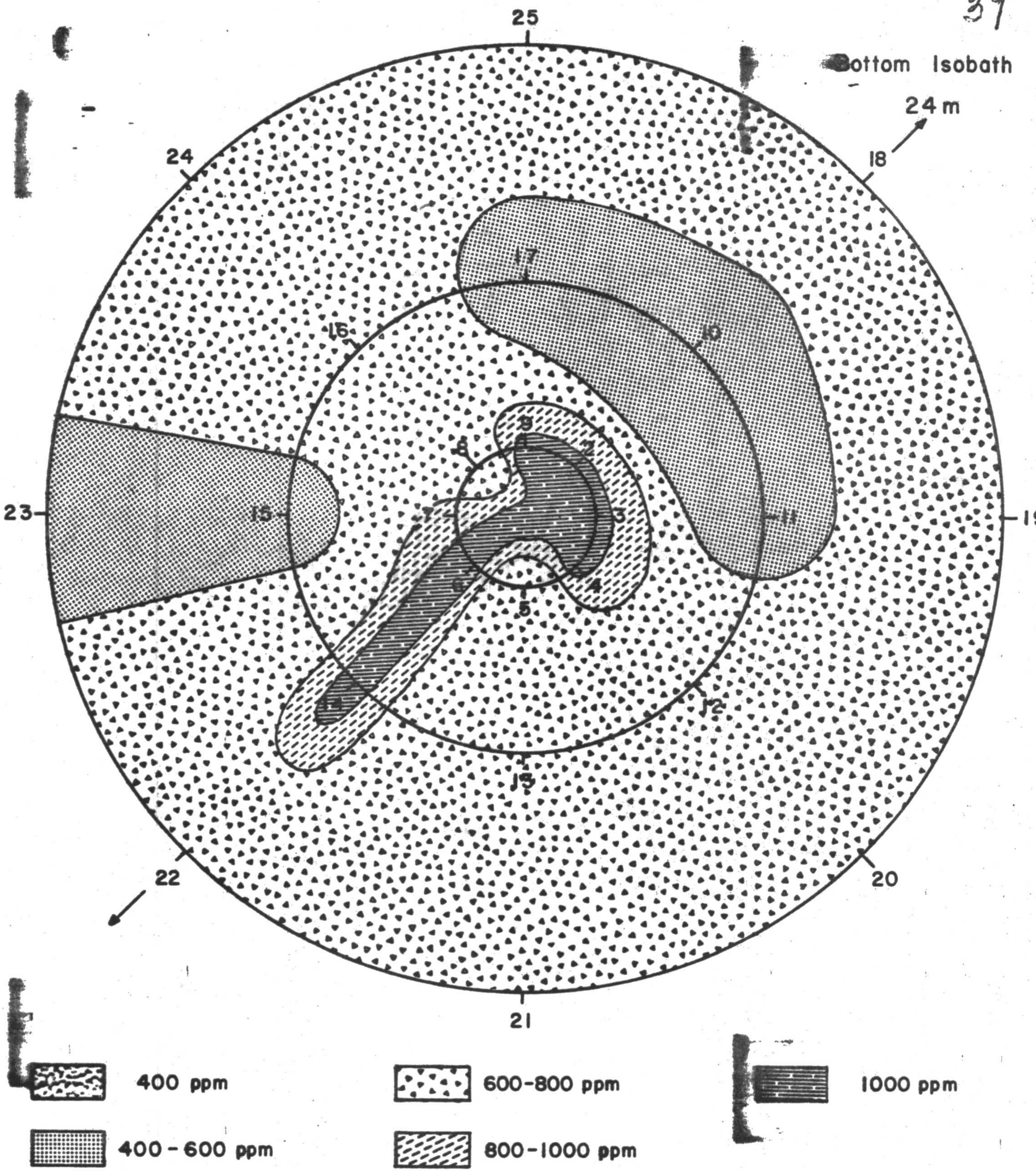


Figure 11b. Distribution of barium (during drilling).

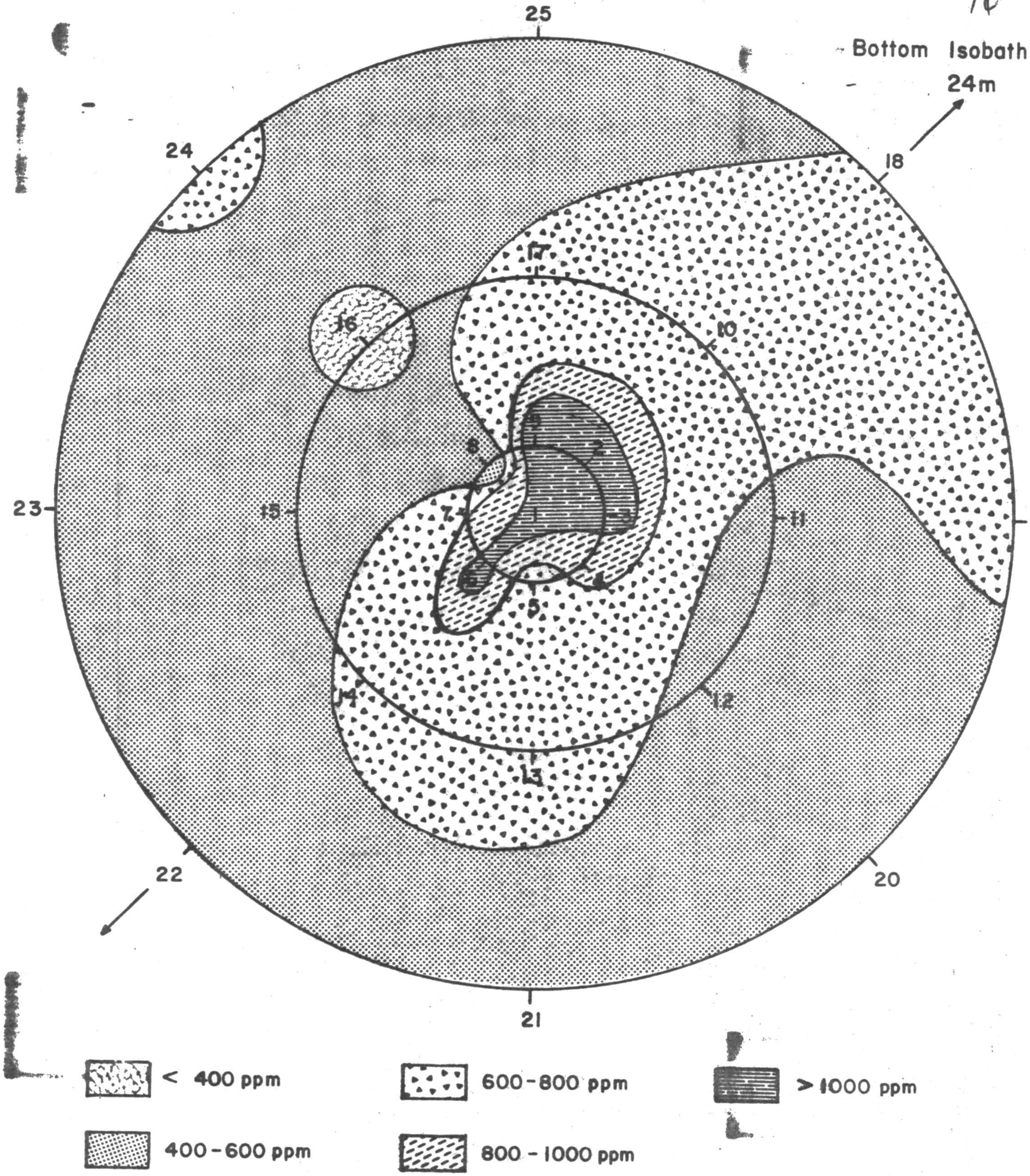


Figure 11c. Distribution of barium (post-drilling).

these materials as a result of drilling.

One change that was apparent in the benthic biota occurred in the foraminifera. As indicated previously the presence in the area of indicator species of foraminifera indicate that the area was stressed prior to drilling. All of the four major dominant species present in the area are considered to be indicators of stress.

Drilling activities further increased the stress on the foraminifera. Total and live specimen abundances of samples collected during drilling activities were significantly less than those in pre-drilling samples. Although the greatest effect on specimen abundances occurred along (and obviously within) the 100 m periphery the adverse effects were demonstrated as far as the 1000 m periphery. Post drilling samples displayed a partial recovery when compared to the pre-drilling conditions.

Histopathologically none of the specimens showed any evidence of pathology (excluding parasites which were observed in a few of the individuals) in either the pre-, during or after samples. These observations are not surprising since the shrimp probably move in and out of the area and the same population was not repeatedly sampled.

Water Column

Factors affecting the movement (transport) of the waters within the MAFLA area are atmospheric disturbances, tides, river run-off and the Loop Current. Each of these factors, except perhaps the tides, can have a large and seasonal variation.

The degree to which the Loop Current extends to the north in the Gulf of Mexico is largely dependent upon the volume of water being transported through the Yucatan Straits. Its location in the eastern Gulf of Mexico varies seasonally and in form it may be present as a continuous flow or a broken off eddy. Either one of these can affect the patterns of circulation on the shelf. From the aspect of pollutant transport this is significant since the Loop Current, by its very presence on the shelf, can transport materials emanating from the Mississippi River and other Louisiana, Mississippi, Alabama river run-off systems to the east and south across the pristine areas of the west Florida shelf.

Historically, the Loop Current is present in the MAFLA area in the summer and fall approximately 50% of the time and rarely appears in the winter. In 1975-1976 the Loop Current eddy water (in the summer) was present at the outer stations of water column Transects IV and III at a depth of approximately 100 m and on Transect I water from this current was present as a mid-water intrusion extending inwards over the shelf to approximately 75 m of depth. It should be noted that under these conditions materials spilled in the lease tracts on water column Transects IV, III and II would be transported by this current across the shelf and south to the Florida Straits.

In the fall the presence of an eddy from the Loop Current forced water to flow onto the shelf in the vicinity of Transect III and to exit the shelf near Transect II. The Loop Current was not present in the study area in the winter and was located some distance to the south of Transect I.

The winter of 1975 was unique in that the season was particularly intense with many cold and warm fronts moving through the area. The location of these fronts (and more importantly the warm fronts which follow them) resulted in a vertically well-mixed water column across the entire MAFLA area. The depth of this mixed layer was deeper than usual and resulted in a considerable resuspension of the bottom materials. Transport of these resuspended materials would be off the shelf to the deep basin.

Hurricane ELOISE is another example of atmospheric disturbances. This rapidly moving storm occurred in September, 1975 and greatly complicated the seasonal studies. These complications were present on benthic Transects V (the storm passed over this region) and VI. Both of these transects were sampled after the storm. The after effects of the hurricane were also visible as a highly turbid near bottom layer on water column Transect II and on the Florida Middle Ground where a large amount of biological devastation occurred. For the record it should also be noted that the cumulative effects of the winter storms equalled and at times exceeded the effects of Hurricane ELOISE.

Transmissometry data collected in the summer and early fall of 1975 indicated that most areas except those in the vicinity of the Mississippi Delta contain clear waters having upwards of 80% light transmission in the upper portion of the water column. A few meters from bottom more turbid layers characterized the inshore waters. In January and February, 1976 the shelf waters were turbid over long periods reflecting the repeated resuspensions of fine fractions of the bottom sediments as a result of storms and the waters were vertically well mixed to a considerable degree.

Turbidity distributions were frequently closely related to water mass structures and movements. A notable example was provided by Hurricane ELOISE on the Florida Middle Ground a few days after the occurrence of the storm. Sharply defined turbid boluses of near bottom water were related to temperature, salinity and density anomalies and were interpreted as contour currents which were enhanced by the forcing function of the storm. As indicated above these resuspended materials will move either to the south and into the Straits of Florida or to the west into the deep Gulf depending on the season of occurrence.

The resuspension and consequent redistribution of bottom materials has added significance from the aspect of pollutant additions. For example, as a result of current and potential Outer Continental Shelf activities concern has been expressed regarding the effect of added trace metals to the marine environment. The sources of these metals may be in any (or all) of the following: formation waters, drilling muds, oil, the drilling rig (its metals and coatings), sacrificial anodes, service craft and sewage. Barium, cadmium, chromium, copper and lead are drilling mud additives, iron is a component of oil and the drilling mud and nickel and vanadium are components of crude oils. Although the biological significance of barium is not clear, measurements of the metal are useful in monitoring the local movements of drilling muds lost to the marine environment. Cadmium is considered to be a toxic trace metal and can be concentrated by certain marine organisms. Copper and lead are used in paints on the drilling rigs. The prime use of iron is as an aid in data interpretation.

The concentration of these trace metals (except barium) have been determined in the suspended matter, the neuston and the zooplankton on a seasonal basis. The design of the 1975-1976 program allowed for the suspended material to be determined at the ten meter level only and thus little can be said about the metal composition of the near bottom resuspended materials (although when the water column was well mixed as occurred in some areas the ten meter sample probably reflected this resuspended matter).

Two forms of the trace metals were determined in the suspended matter. The first of these was determined as a result of a weak acid leach of the suspended materials and are generally considered to represent the "biologically available" fraction of the total element concentration in the samples. The remainder of the sample is referred to as the refractory fraction. Tables 7a, b, c, d, e, f and g show the mean and observed range of concentrations of cadmium, chromium, copper, iron, lead, nickel and vanadium respectively in suspended particulate matter, zooplankton and neuston on each transect for each season during 1975-1976. In almost all instances the concentrations of both fractions were low and the observed variations reflected the proximity of the stations from which they collected to such input areas as the Mississippi River discharge and the Mississippi-Alabama river run-off. The composition of the refractory trace metals in the winter on the shelf south of Alabama and Mississippi primarily reflects shelf sediment composition and this lends further support for the intensity of winter storms to be of sufficient magnitude to resuspend and transport bottom materials.

With the exception of cadmium the average trace metal content of the neuston as compared to that of zooplankton appeared to be regionally distinguishable. In the area east and south of Cape San Blas the average trace metal content of the neuston is generally higher than that observed in the zooplankton in both the fall and winter. On Transect IV the average trace metal content of the neuston was generally less than that found in

Table 7a. Mean and range of cadmium concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

Season	Transect		SPM ($\mu g/\ell \times 10^{-3}$) Weak Acid Soluble	SPM ($\mu g/\ell \times 10^{-3}$) Refractory	Organisms (ppm) Zooplankton	Organisms (ppm) Neuston
Summer	I	$\bar{X}$	0.87	0.6	8.3	*
		range	0.3-1.6	0.2-1.4	4.36-13.66	*
	II	$\bar{X}$	1.2	0.3	7.5	*
		range	0.9-1.8	0.2-0.5	6.95-8.33	*
	III	$\bar{X}$	7.9	0.8	6.9	*
		range	3.0-16.9	0.6-1.0	4.96-11.85	*
	IV	$\bar{X}$	10.4	3.7	5.6	*
		range	4.8-20.8	0.3-12.5	4.20-10.96	*
Fall	I	$\bar{X}$	3.7	1.7	7.7	3.9
		range	1.5-6.7	1.0-2.7	2.09-17.95	1.81-10.40
	II	$\bar{X}$	2.5	1.1	4.46	2.5
		range	1.8-3.1	0.6-1.9	2.60-10.70	1.19-4.52
	III	$\bar{X}$	2.2	1.6	9.6	6.1
		range	0.9-3.5	0.7-3.8	2.83-12.70	0.31-26.85
	IV	$\bar{X}$	4.9	3.7	13.0	2.1
		range	1.0-10.9	0.2-11.9	2.65-23.99	0.35-5.42
Winter	I	$\bar{X}$	1.3	0.9	8.1	4.1
		range	0.8-2.2	0.2-2.2	6.78-9.57	1.66-6.61
	II	$\bar{X}$	1.7	2.6	4.8	4.8
		range	1.0-3.0	0.2-6.3	3.12-6.16	2.56-7.03
	III	$\bar{X}$	1.9	1.9	6.9	4.9
		range	1.6-3.1	0.2-6.9	4.66-8.21	1.85-6.77
	IV	$\bar{X}$	2.8	<0.2	3.9	2.72
		range	1.9-3.4	-	2.69-6.12	1.60-6.81

* Not Determined

Table 7b. Mean and range of chromium concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

	Transect		SPM (μg/ℓ x 10^{-3}) Weak Acid Soluble	Refractory	Organisms (ppm) Zooplankton	Neuston
Summer	I	$\bar{X}$	N.D.	3.3	0.6	*
		range		1.7-4.5	0.21-0.91	*
	II	$\bar{X}$	N.D.	5.0	0.5	*
		range		3.6-6.8	0.25-0.84	*
	III	$\bar{X}$	N.D.	4.9	0.5	*
		range		3.0-6.3	0.06-1.06	*
	IV	$\bar{X}$	N.D.	11.3	1.2	*
		range		2.6-22.3	0.28-3.23	*
Fall	I	$\bar{X}$	N.D.	5.9	0.2	1.0
		range		3.3-8.6	0.16-0.37	0.02-4.61
	II	$\bar{X}$	N.D.	6.8	0.4	0.8
		range		4.6-10.7	0.30-1.05	0.28-1.91
	III	$\bar{X}$	N.D.	18.8	1.3	0.8
		range		4.1-52.4	0.17-3.81	0.04-2.13
	IV	$\bar{X}$	N.D.	16.0	1.8	0.5
				8.2-25.5	0.21-5.46	0.11-0.84
Winter	I	$\bar{X}$	D.	13.3	0.9	1.5
		range		3.2-19.2	0.19-1.59	0.18-3.11
	II	$\bar{X}$	D.	14.0	0.3	1.1
		range		4.7-22.7	N.D.-0.54	0.18-6.08
	III	$\bar{X}$	D.	9.3	1.2	1.5
		range		2.6-12.9	0.33-2.79	0.15-3.44
	IV	$\bar{X}$	D.	32.7	1.0	1.0
		range		18.5-43.5	0.32-1.98	0.05-4.34

* Not Determined
N.D. Not Detectable
D. Detectable at only one or two stations

Table 7c. Mean and range of copper concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

Season	Transect		SPM ($\mu g/\ell \times 10^{-3}$) Weak Acid Soluble	Refractory	Organisms (ppm) Zooplankton	Neuston
Summer	I	$\bar{X}$	7.00	1.2	15.92	*
		range	4.8-9.1	1.2-1.3	8.07-28.98	
	II	$\bar{X}$	16.75	3.6	14.1	*
		range	7.5-30.7	1.8-4.8	9.40-26.34	
	III	$\bar{X}$	22.8	34.5	12.5	*
		range	15.7-33.7	18.5-48.0	8.09-15.86	
	IV	$\bar{X}$	26.0	28.7	18.03	*
		range	17.2-44.1	14.4-55.7	9.55-31.95	
Fall	I	$\bar{X}$	1.70	1.6	15.2	22.0
		range	0.8-3.0	1.2-1.9	9.78-21.66	8.60-49.74
	II	$\bar{X}$	3.86	1.8	15.1	20.3
		range	<0.5-12.6	1.2-3.2	12.15-21.88	6.89-51.13
	III	$\bar{X}$	2.63	1.2	17.2	25.4
		range	<0.5-4.8	-	12.44-23.44	17.11-57.90
	IV	$\bar{X}$	3.05	10.4	41.9	23.8
		range	0.5-9.2	1.2-38.1	16.71-88.01	11.80-38.3
Winter	I	$\bar{X}$	0.70	1.2	13.1	12.0
		range	<0.5-1.1	-	10.54-14.54	7.16-20.77
	II	$\bar{X}$	0.78	1.2	19.0	9.5
		range	<0.5-1.6	-	12.48-33.26	6.41-13.44
	III	$\bar{X}$	0.68	18.0	15.9	11.8
		range	<0.5-1.20	1.2-68.4	12.47-18.16	6.51-16.28
	IV	$\bar{X}$	<0.5	1.2	17.7	12.5
		range	-	-	11.89-24.09	6.73-23.0

* Not Determined

Table 7d. Mean and range of iron concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

Season	Transect		SPM (μg/ℓ) Weak Acid Soluble	SPM (μg/ℓ) Refractory	Organisms (ppm) Zooplankton	Organisms (ppm) Neuston
Summer	I	$\overline{X}$	70	390	94	*
		range	18-173	190-660	61-116	*
	II	$\overline{X}$	54	310	99	*
		range	28-95	230-440	51-151	*
	III	$\overline{X}$	82	310	91	*
		range	31-188	150-530	54-161	*
	IV	$\overline{X}$	427	1,140	254	*
		range	66-1,091	380-3,070	86-553	*
Fall	I	$\overline{X}$	13	190	61	142
		range	<1-29	40-300	55-69	47.6-415
	II	$\overline{X}$	23	600	101	359
		range	2-57	180-1,580	62-192	123-1,460
	III	$\overline{X}$	16	210	78	1,027
		range	1-60	70-320	52-144	94-3,130
	IV	$\overline{X}$	14	290	116	760
		range	1-27	110-560	49-237	29.2-2,920
Winter	I	$\overline{X}$	163	2,040	182	489
		range	8-350	150-3,340	53-381	42.6-1,249
	II	$\overline{X}$	175	2,350	108	166
		range	38-326	340-4,570	60-173	62.7-602
	III	$\overline{X}$	243	1,440	615	223
		range	19-698	90-2,440	100-1,892	50.7-465.8
	IV	$\overline{X}$	2,810	9,190	679	282
		range	295-6,120	2,940-18,400	N.D.-1,542	55.9-657.7

* Not Determined
N.D. Not Detectable

Table 7e. Mean and range of lead concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

			SPM ($\mu g/\ell \times 10^{-3}$)		Organisms (ppm)	
Transect			Weak Acid Soluble	Refractory	Zooplankton	Neuston
Summer	I	$\bar{X}$	11.1	1.9	1.6	*
		range	3.4-20.0	0.4-3.0	0.72-2.17	*
	II	$\bar{X}$	11.2	5.4	2.0	*
		range	5.8-15.0	1.2-9.3	1.24-3.63	*
	III	$\bar{X}$	13.4	9.3	1.8	*
		range	6.8-16.0	5.5-14.9	0.40-3.28	*
	IV	$\bar{X}$	51.6	11.2	2.1	*
		range	6.5-96.9	5.0-25.0	0.98-3.03	*
Fall	I	$\bar{X}$	4.2	11.9	0.6	3.7
		range	2.8-5.2	6.9-19.3	0.25-0.86	0.16-12.3
	II	$\bar{X}$	8.1	9.9	2.4	2.4
		range	4.4-18.9	8.3-11.3	1.17-4.22	0.94-7.47
	III	$\bar{X}$	4.5	9.2	1.3	3.8
		range	2.0-7.7	7.1-11.2	0.69-2.09	0.45-12.3
	IV	$\bar{X}$	10.6	33.1	5.0	1.4
		range	4.1-21.8	12.6-77.1	0.66-13.37	0.99-2.92
Winter	I	$\bar{X}$	18.4	8.6	2.5	1.8
		range	2.7-39.9	6.2-12.6	0.67-3.44	0.12-4.45
	II	$\bar{X}$	12.1	8.8	0.7	2.6
		range	1.4-23.5	7.2-9.9	0.16-1.78	0.04-14.46
	III	$\bar{X}$	3.6	18.6	5.5	6.9
		range	<1.3-6.9	4.4-50.5	0.69-12.49	0.30-36.41
	IV	$\bar{X}$	11.4	21.6	0.8	3.8
		range	7.1-15.3	12.9-26.6	0.16-1.17	0.15-19.04

* Not Determined

Table 7f. Mean and range of nickel concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

			SPM ($\mu g/\ell \times 10^{-3}$)		Organisms (ppm)	
Transect			Weak Acid Soluble	Refractory	Zooplankton	Neuston
Summer	I	$\bar{X}$	N.D.	N.D.	2.2	*
		range			1.18-3.80	
	II	$\bar{X}$	N.D.	N.D.	1.6	*
		range			1.40-1.86	
	III	$\bar{X}$	N.D.	N.D.	2.2	*
		range			0.88-3.59	
	IV	$\bar{X}$	N.D.	N.D.	2.4	*
		range			1.47-3.79	
Fall	I	$\bar{X}$	N.D.	N.D.	4.0	3.8
		range			3.15-5.27	0.77-9.47
	II	$\bar{X}$	D.	N.D.	1.5	3.4
		range			0.91-2.14	1.77-5.59
	III	$\bar{X}$	D.	N.D.	5.8	5.0
		range			0.98-9.74	1.34-9.25
	IV	$\bar{X}$	D.	N.D.	4.4	5.0
		range			1.23-9.75	1.05-11.25
Winter	I	$\bar{X}$	N.D.	N.D.	2.5	5.4
		range			1.68-3.76	1.74-14.90
	II	$\bar{X}$	N.D.	N.D.	1.2	1.6
		range			0.90-1.32	1.02-2.64
	III	$\bar{X}$	N.D.	N.D.	3.6	3.1
		range			2.10-5.49	0.92-6.76
	IV	X	N.D.	N.D.	2.4	2.1
		range			1.54-3.54	1.03-5.91

* Not Determined
N.D. Not Detectable
D. Detectable at only one or two stations

Table 7g. Mean and range of vanadium concentrations in suspended particulate matter, zooplankton and neuston along each transect for each season.

Transect			SPM (μg/ℓ x 10^{-3}) Weak Acid Soluble	Refractory	Organisms (ppm) Zooplankton	Neuston
Summer	I	$\bar{X}$	*	N.D.	9.2	*
		range			5.65-13.02	
	II	$\bar{X}$	*	N.D.	7.4	*
		range			3.95-12.22	
	III	$\bar{X}$	*	N.D.	1.4	*
		range			1.01-2.17	
	IV	$\bar{X}$	*	N.D.	9.8	*
		range			4.59-15.32	
Fall	I	$\bar{X}$	*	N.D.	2.7	2.1
		range			0.80-5.66	0.71-7.00
	II	$\bar{X}$	*	N.D.	1.9	2.7
		range			N.D.-5.40	1.14-6.13
	III	$\bar{X}$	*	N.D.	1.8	3.5
		range			0.19-4.75	0.41-11.40
	IV	$\bar{X}$	*	N.D.	9.3	2.8
		range			0.92-34.32	0.37-10.20
Winter	I	$\bar{X}$	*	N.D.	1.7	2.0
		range			0.99-2.35	0.70-3.92
	II	$\bar{X}$	*	N.D.	1.9	7.3
		range			1.21-2.88	0.54-34.56
	III	$\bar{X}$	*	N.D.	6.0	1.6
		range			1.77-15.22	0.47-2.66
	IV	$\bar{X}$	*	N.D.	9.7	3.6
		range			3.04-25.41	0.46-10.81

* Not Determined
N.D. Not Detectable

the zooplankton in both seasons while on Transect III the average copper, iron and lead content was higher than that found in zooplankton in the fall and less in the winter. The average cadmium content of the neuston was, with one exception, always less than that of the zooplankton. On Transect II in the winter the average cadmium content of both groups was equal.

Hydrocarbons are also released into the marine environment as a result of drilling activities. At the present time tar balls are ubiquitous in the surface waters of the eastern Gulf of Mexico and weathered petroleum is present in both the dissolved and particulate phases of the water column. This was especially true near Tampa Bay, Florida and near the Mississippi Sound. Hydrocarbons dissolved in the water, the suspended hydrocarbons and in the zooplankton fell into geographically coherent patterns and no recent petroleum contamination was evident in any of these samples (although almost every neuston sample was contaminated by tar balls). In all sample types hydrocarbons were lowest during the fall sampling period.

In addition to the measurements of the particulate and dissolved hydrocarbons in the water column measurements were also made of the particulate and dissolved organic carbon. Although the precise chemical composition and ecological significance of these sea water constituents remains poorly understood, knowledge of their origin, quantity and distribution is important because they are known to influence chemical and biological processes occurring in the sea.

The general <u>in situ</u> processes controlling the production and distribution of the particulate and dissolved organic carbon are reasonably well understood and function similarly throughout the world's oceans. However, in marine areas adjacent to land masses, such as over the Continental Shelf, these processes become more complex as both man made and natural terrestrial influence enter into consideration.

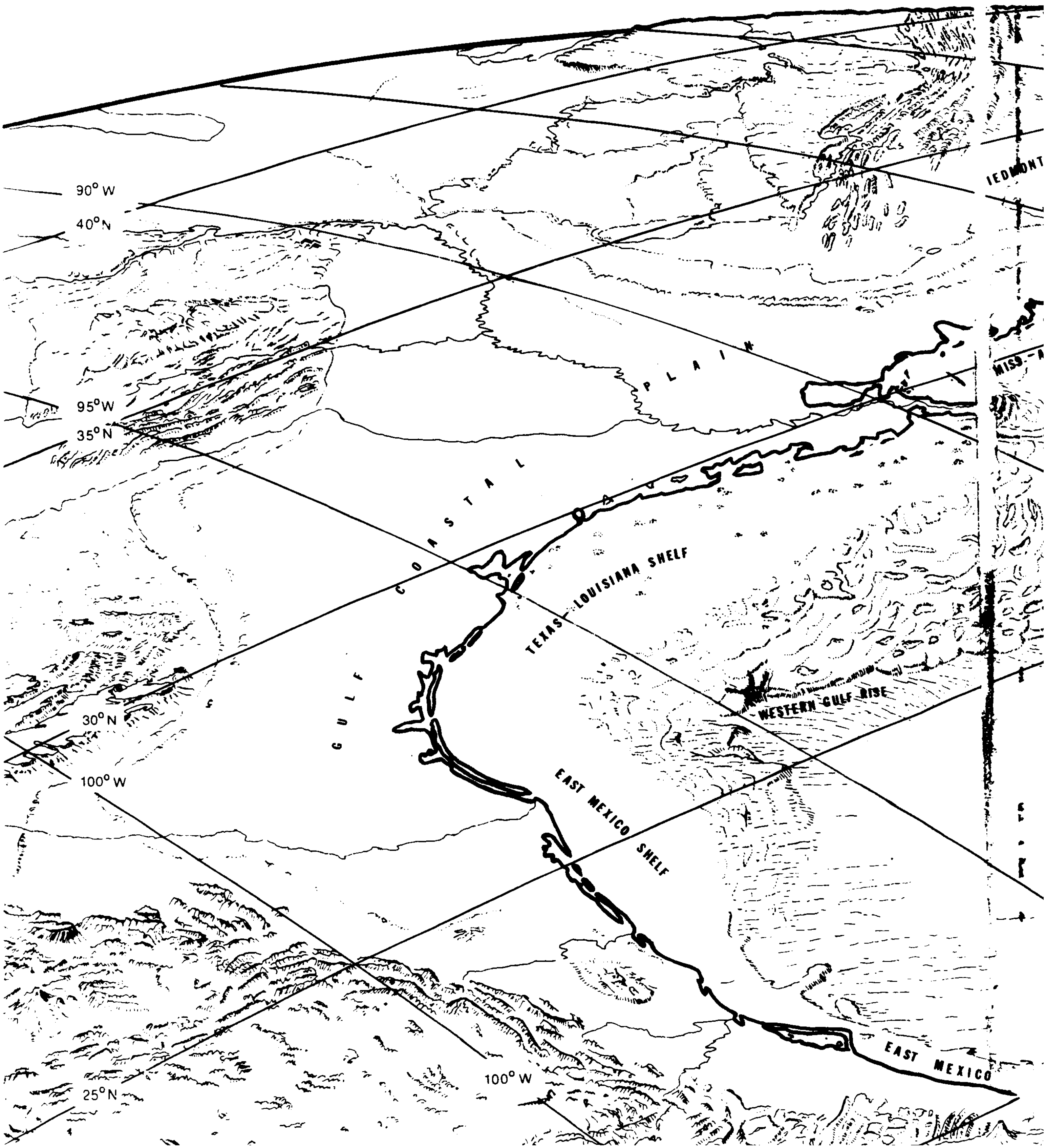
Both of these fractions fluctuated seasonally over the shelf. When different regions of the shelf were considered (e.g., inshore, intermediate and offshore), the amounts of particulate organic carbon were found to be more variable and followed localized seasonal patterns while the distribution of the dissolved organic carbon was more uniform. Levels of particulate organic carbon were closely related to the amount of phytoplankton present (as estimated by chlorophyll a) and zooplankton in the summer and fall throughout the MAFLA region although the relationships were strongest near shore. Measured quantities of dissolved organic carbon were related to the amount of dissolved hydrocarbons present.

Chlorophyll a measurements, as previously indicated, are generally used in biologically related studies to indicate the quantity of phytoplankton population in a given volume of water. Spatial and temporal changes in these concentrations are useful in interpreting observed changes in other parameters. Higher concentrations of the pigment were generally present in the bottom waters and this is in part a function of phytoplankton dependence upon light for photosynthesis. The higher concentration in the deeper portions of the water column is also typical of tropical and subtropical waters and is in agreement with other data. The lateral distribution of the pigment generally is related to the circulation patterns on the shelf. Particulate iron concentrations were also related to the amount of chlorophyll a present and this follows since the metal is involved in the biosynthesis of this pigment.

As implied in the above relationships between particulate organic carbon - chlorophyll a and zooplankton the distribution of the latter partially follows that of the phytoplankton and particulate organic matter. There was a general pattern of decreasing density of zooplankton and this is to be expected since the inshore areas are generally considered to be more productive in terms of supporting a larger standing crop of zooplankton. The neuston (those organisms living in or dependent upon the surface film of the water) appear to exhibit spatial and temporal patterns of heterogeneity but these are poorly understood at present. It was biologically significant that crustaceans, especially copepods, dominated the collections. Fish were not a major component of the neuston.

It was also noted that the greater the number of tar balls present at any one station the less the number of neustonic invertebrate phyla captured. Whether this is due to (1) wind rafting of pollutants and surface organisms, (2) the avoidance of the tar balls by the neuston or (3) sampling error is not clear. If these organisms were actively avoiding the surface layer contaminated with tar balls then oil dispersal within the surface layer may have a detrimental effect on the neustonic community.

In summation then, the overall results of the first year's seasonal study indicate that with few exceptions the MAFLA region is a pristine, ecologically rich and highly diverse environment. This is true not only from the biological aspect but also in the chemical and geological components of the region. Further, the MAFLA region appears to be a relatively unknown scientific entity as evidenced by the discovery of myriads of new biological species and species range extensions, the redefining of geological zones and biological-bathymetric and sediment relationships.



90° W
40° N
IEDMONT
95° W
35° N
PLAIN
COASTAL
GULF
MISS - A
TEXAS - LOUISIANA SHELF
WESTERN GULF RISE
30° N
100° W
EAST MEXICO SHELF
EAST MEXICO
100° W
25° N