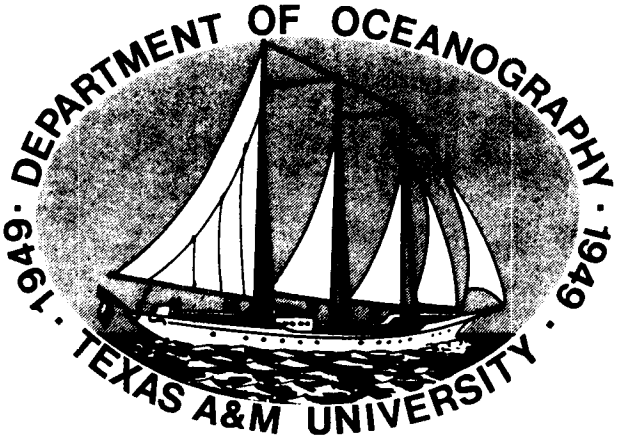

NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES STUDY

FINAL REPORT

VOLUME TWO

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

Contract No. AA551-CT8-35

Department of Oceanography
Texas A&M University
College Station, Texas

Technical Report No. 81-2-T

Research Conducted Through
the Texas A&M Research Foundation

MARCH 1981

This volume has been reviewed by the Bureau of Land Management and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Bureau, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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TABLE VII-1
SPECIFICATIONS FOR VESSELS USED ON ALL CRUISES

SPECIFICATIONS	VESSELS											
	GYRE	RED SEAL	BLACK SEAL	ROSS SEAL	PROTON/ JOYRO	BERING SEAL	MED SEAL	TANYA & JOE	ROUNSE-FELL	BERING SEAHORSE	BELLOWS	SEA INVADER
LENGTH O.A.	174'	185'	185'	176'	85'	210'	165'	80'	65'	176'	61'9"	120'
BEAM	36'	38'	88'	38'	26'	40'	38'	15'	18'	38'	20'	N.A.
DEPTH-FEET	36'	14'	14'	13'	8.7'	15'	12'	4'	N.A.	13'	5'	N.A.
HORSEPOWER	1700	2500	2500	1700	670	3640	1700	-	200	2250	N.A.	2400
NO. GENERATORS	2	2	2	2	2	2	2	2	2	2	2	2
DRAFT:LOADED/LIGHT	12'/ 5'	N.A.	N.A.	N.A.	7'/ 5.5'	8'6"/ 12'8"	N.A.	4'/ 3'	7'/ 5'	11'/ 6'	N.A.	7'/ 5'
DECK SPACE	140' x 52'	120' x 32'	120' x 32'	113' x 32'	40' x 24'	102' x 34'	122' x 28'	15' x 30'	538'*	124' x 29'	N.A.	75' x 18'
BERTHS	28	17	17	15	14	25	19	9	11	20	13	0
KNOTS	11	13-14	13-14	12-14	10	13-14	10-12	11-12	9	12	8.5	22
NO. OF CREW	10	6-9	6-9	6-9	4	7-9	5-7	2	3	7	3	4
YEAR BUILT	1973	1978	1979	1977	1964	1976	1967	1972	1941	1971	1969	1978
RADIOS	RAD-TEL & SAT	SSB VHF	SSB CAI VHF	SSB CAI VAI	SSB VHF	SSB VHF	SSB VHF	SSB VHF CB	CB VHF SSB	SSV RF201	VHF	DRAKE TRM VHF/T12000
RADARS	DECCA RM1229 SPERRY	DECCA 914 (2X)	DECCA	VHF-STR	DECCA	DECCA 916 (2Y)	DECCA	Yes	Yes	DECCA MOD202	DECCA 916	DECCA RM914C
DEPTH RECORDER	ROSS 400A	ELAL LAZ-STAT	ELAL LAZ-518G	ELAL LAZ-518G	DE-731	SINRAD EX 38D	SINRAD 519-92	Yes	Yes	Ray-theon	DE-731, 725	N.A.
LORAN	NECCO 500 MEICO 6811	MEICO A&C	MEICO A&C	MEICO A&C		SPERRY	KONEL KL151A	A	A&C	None	A&C	TI9000A
RADIO CALL LETTERS	KJCL	WYA 2362	WYA 2825	WYG 7180	WO 6701	WYM 2318	WYZ 8304		WYZ 6357	WZQ 7506	WY 6808	WYB 6699

*Outside = 538 sq. feet
lab = 100 sq. feet

CHAPTER VII

METHODS AND PROCEDURES

INTRODUCTION

Methods and procedures for analyses and sample collection for all but the Florida Middle Ground segments of the contract are presented in this chapter. Information on navigation, mapping and sub-bottom profiling, and submersible operations, which are applicable to all segments, are presented in Parts A, B, and C. Parts D, E, F, and G present methods used in the four basic areas of study: geology, biology, water and sediment dynamics, and chemical analyses. Specifications for all vessels used on this contract are given in Table VII-1.

PART A: NAVIGATION

NAVIGATION ON MAPPING CRUISES

Navigation for the first mapping cruise was accomplished using three LORAC service chains: "DE" for the Texas Outer Continental Shelf, "A" for the Louisiana Outer Continental Shelf, and "JK" for the Florida Middle Ground. The LORAC receivers were interfaced with a Decca Autocarta system consisting of a PDP 11/05 computer, TI 73ASR Data Terminal, Houston Instruments DP-3 Plotter, and a Decca Survey 10409 Left/Right Display. The Autocarta System assisted the helmsman by displaying distance off line and recording the positioning fixes and depths on magnetic tape cassettes for later processing.

LORAC calibration was performed at known platform locations near each of the survey areas. The lanecount was tracked on an analog recorder, and a closed lanecount traverse was made to and from each survey area to insure the correctness of the lanecount. Lanecount was also checked frequently at nearby platforms and at lanecount buoys especially emplaced for that purpose.

Navigation for the second mapping cruise used the same Autocarta navigation system and LORAC "DE" service chain.

NAVIGATION ON SUBMERSIBLE CRUISES

Navigation was accomplished using the same three LORAC chains used on the mapping cruises: "DE" on the Texas Outer Continental Shelf, "A" on the Louisiana Outer Continental Shelf, and "JK" on the Florida Middle Ground. Navigational services were subcontracted to Mr. Wess Hudgins, who mobilized/demobilized the LORAC equipment, guided ships to predetermined locations, arranged for the reduction and conversion of navigational data, and plotted bathymetric and transect data. (Note: charts plotted by Mr. Hudgins proved inaccurate and were later replotted by Mr. Oscar Chancey.)

LORAC positioning was also used for recording transects of the submersible, the DRV DIAPHUS. After launch, the submersible proceeded on the surface to the desired dive site and submerged. Upon reaching the bottom, it followed a predetermined course using the gyrocompass. Tracking of the submarine from the ship was accomplished by taking visual bearings and radar ranges on a two-foot diameter tether buoy attached to the submarine by a light polypropylene line. In sea conditions not favorable to radar, a 4.3 m rubber zodiac boat was sent to the position of the tether buoy to provide a larger "target" for the radar. Course corrections were conveyed to the submarine from the ship through the underwater telephone. A maneuvering board plot of the submarine positon relative to the ship was kept during each dive.

NAVIGATION ON OTHER CRUISES

Navigation on Florida Middle Ground diving cruises conducted by the University of Alabama, Dauphin Island Sea Laboratory, was supported by Loran A and C, a depth recorder, and a Helle in situ pinger.

Navigation on monitoring cruises to the East and West Flower Garden Banks, conducted by LGL Limited, Inc. and Texas A&M University Oceanography Department personnel on the M/V TONYA and JOE, was by Loran A coordinates, an in situ Helle Model 2400 pinger, and subsurface buoy.

Navigation on the various seasonal cruises to the East and West Flower Garden Banks was accomplished with the "DE" LORAC service chain, supplemented by Loran C. Lanecount checks were conducted regularly at platforms or buoys.

TABLE VII-2
DATA ON DIRECTION AND DISTANCE OF SURVEY LINES, MAPPING CRUISES

CRUISE	BANK	REGULAR SURVEY LINES		TIE LINES		SURVEY LINE DISTANCE	
		DIRECTION	SPACING	DIRECTION	NUMBER	STATUTE MILES	KILOMETRES
1st Mapping							
Leg 1	Florida Middle Ground	E-W	300 m	- -	0	230	370
Leg 2	Florida Middle Ground	E-W	300 m	N-S	8	1146	1844
	SUB-TOTAL					1376	2214
Leg 3	Alderdice	N-W	300 m	E-W	3	77	124
	Coffee Lump	N-S	300 m	E-W	3	140	225
	Diaphus	N-S	300 m	E-W	3	83	134
	Elvers	N-S	300 m	E-W	3	125	201
	Fishnet	N-S	150-300 m	E-W	3	23	37
	Geyer	N-S	300 m	E-W	3	125	201
	Jakkula	N-S	300 m	E-W	3	40	64
	Rezak-Sidner	N-S	300 m	E-W	3	121	195
1ST MAPPING CRUISE SURVEY LINES TOTAL						2110	3395
2nd Mapping							
	West Flower Garden	N-S	900 m	E-W	3	302	486

PART B: MAPPING AND SUB-BOTTOM PROFILING

FIRST MAPPING CRUISE

General

Approximately 2110 statute miles of survey data from eight Northern Gulf of Mexico banks and the Florida Middle Ground were obtained during the first mapping cruise, conducted on the M/V JOYRO (see Table VII-2). The JOYRO is a 25.9 m utility boat configured for seismic surveying and is owned and operated by Oceanonics, Inc. Navigation and calibration were as described above. Shot points (navigation fixes) were taken and recorded at 152 m (500 ft) intervals. The surveys were plotted at a scale of 1:12000. An automatic event marker was used to place shot points on all the survey records. Equipment operators in the electronics van annotated the records with line and shot point numbers.

Bathymetry

The echosounder used to obtain bathymetric data was a Raytheon DE 719B. The unit has a depth range of 132.9 m. The range was sufficient for most of the banks surveyed; but at a few of the banks where depths on portions of the bank exceeded 132.9 m, depths were taken from the 3.5 kHz high resolution sub-bottom profiler.

The echosounder transducer was mounted on the port side of the vessel, 6.1 m aft of the LORAC antenna at a depth of 3.3 m. Bar checks to 16.4 m were made regularly. The stylus rotation was set to correspond to seawater sound velocity of 1520 m/sec, and the transducer draft on the recorder was set at 3.3 m. The recorder uses dry paper 20.3 cm wide.

The echosounder was coupled with an Interspace Technology Model 412 Autotrack (digitizer), and the output of the digitizer was interfaced with the Autocarta Computer. Depth at each shot point was recorded in feet and later converted into metres by computer.

Side-Scan Sonar

A Klein Side-Scan Sonar System Model 400 was used for the survey. This consisted of a Klein Model 421 Recorder and a Model 402 Towfish. The system operates at a frequency of 105 kHz $\pm$ 10%. The recorder was set at the 150 m range giving a record of 50 lines per centimetre.

The side-scan sonar fish was towed behind the vessel from the center stern. To stream and recover the towed sonar fish, an electrically powered winch was mounted at the stern. The amount of cable payed out during a survey line varied with the depth to the bottom and the speed of the vessel.

TABLE VII-3
BENCHMARK LOCATIONS

BANK	WATER DEPTH (ft/m)	X/Y	LAT/LONG	LORAN A	LORAC R/G
Alderdice	186/	1787007	28°04'36"	3H0=3276	701.36
	56.71	-213998	91°59'36.5"	3H2=2339	902.33
Coffee Lump	192/	3638885	28°04'33"	3H0=3297	911.64
	58.54	-123783	93°55'01"	3H2=3378	673.30
Diaphus	248/	2201992.6	28°05'18.52"	3H0=3258	349.67
	75.61	-207728.3	90°42'25.92"	3H2=1655	1559.78
Elvers	202/	1495402	27°49'15"	3H0=3256	1031.79
	61.59	-304255	92°53'36"	3H2=2828	680.30
Fishnet	195/	1845491.0	28°08"40"	3H0=3283	963.48
	59.45	-189590.0	91°48'45"	3H2=2238	628.73
Florida Middle Ground	94/	249401	28°35'00.23"	3H0=2665	790.15
	28.67	-10382354	84°20'23.85"	3H1=3820	865.35
Geyer	160/	493202	27°51'17.62"	3H0=3262	1092.90
	48.78	-3080959	93°04'08.56"	3H2=2920	629.67
Jakkula	197/	1896314.1	27°58'56.63"	3H0=3260	596.37
	60.06	-248732.4	91°39'15.84"	3H2=2156	1078.23
Rezak-Sidner	164/	1664767	27°54'56"	3H0=3260	848.95
	50.00	-271701	92°22'15"	3H2=2550	806.07
West Flower Garden	21/	3675615	27°52'27"	3H2=3292.5	924.16
	6.4	52033	93°48'46.5"	3H3=3124.32	710.26

Sub-Bottom Profiling

Two systems were used for sub-bottom profiling. These were the ORE Model 310 Pipeline Transceiver, coupled with an EPC 4200 Recorder for high resolution sub-bottom profiling, and an EG&G Model 231-232 Uniboom operated at 500 joules and coupled with an EPC 4600 Recorder for somewhat deeper penetration.

The ORE Model 310 operates at selectable frequencies of 3.5, 5, 14, and 200 kHz. It was operated at 3.5 kHz for the present survey. The ORE transducer fish was deployed from a davit on the starboard side of the vessel 7.62 m aft of the LORAC antenna at a depth of 12 m.

The EG&G boomer sled was towed on the port side of the vessel 20 m aft of the LORAC antenna. The hydrophone streamer was deployed on the starboard side of the vessel with the hydrophones 23 m aft of the LORAC antenna.

The recorders were operated at a 1/4 second sweep rate.

Benchmarks

Benchmarks made of 55 gal oil drums filled with concrete were emplaced in each survey area. Table VII-3 lists the locations of these benchmarks by water depths, X-Y coordinates, latitude and longitude, Loran A, and LORAC lanecounts. The locations of the benchmarks are also indicated on the final charts.

SECOND MAPPING CRUISE

General

Operations on the second mapping cruise were limited to one bank, the West Flower Garden. The vessel used for this survey was the M/V PROTON (the JOYRO, re-named), owned and operated by Oceanonics, Inc. The PROTON is a 25.9 m utility boat equipped for seismic surveying. The Autocarta navigation system was located in the wheelhouse, and the LORAC antenna was located above the wheelhouse. All recorders were located within the deckhouse on the main deck. The 3.5 kHz towfish was towed at a depth of 1.8 m from a davit on the starboard side of the ship, 9.1 m aft of the LORAC antenna. The Uniboom sled was towed from a davit on the port side of the ship, 29 m aft of the LORAC antenna. The hydrophone array for the Uniboom system was towed from the starboard side, 44.2 m aft of the LORAC antenna. The side-scan fish was towed aft of the ship on the port side. The amount of cable used for the fish varied with water depth and is annotated on the side-scan record. The side-scan winch was located 13.7 m aft of the LORAC antenna.

Preplots, Survey Lines, and Benchmarks

Preplots of the survey area were prepared by the Autocarta system while enroute from Galveston to the West Flower Garden. The main survey lines (N-S) were spaced 274.5 m (900 ft) apart with shot points every 152 m (500 ft) along the lines. Shot points were recorded automatically by the Autocarta on all records, and every fifth shot point was annotated manually by the operator. The preplotted lines consisted of 75 shot points. However, during the survey it was found that the preplotted area was slightly to the north of the survey area. As a consequence, some of the lines were shortened at the north end and extended at the south end. The survey lines were terminated 1,000 m beyond the point where bedded rocks appeared on the Uniboom record.

The number of lines surveyed and other survey data are given in Table VII-2, above. A benchmark was emplaced at the same site as the benchmark emplaced by the FGORC survey in 1972. Data on the location of the benchmark are given in Table VII-3, above.

Bathymetry and Sub-Bottom Profiling

Bathymetric data were obtained with a Raytheon Model 731 precision depth recorder and an Inner Space Digitizer. The sidescan sonar system used was the EG&G SMS 960. High resolution sub-bottom profiles were obtained using an Edo Western Transceiver, ORE 1036 Transducer, and EPC 3200 recorder. The shallow seismic system used was the EG&G Uniboom, Del Norte amplifier/filter, and EPC 3200 recorder.

During the execution of survey line 43, a malfunction in the power supply shorted out several components in the Raytheon Model 731 depth recorder and the Inner Space Digitizer, causing both units to fail. The decision was made at that time to continue the survey and to use the 3.5 kHz record for bathymetry. The impact of this failure was the omission of digitized depth values on the post plot printouts from the Autocarta System. However, the impact was minimal as the 3.5 kHz records were excellent and were digitized at the Oceanonics, Inc. office upon completion of the cruise.

PART C: SUBMERSIBLE OPERATIONS

GENERAL

Two submersible cruises were conducted under this contract for the purpose of biological and geological reconnaissance and sampling at selected topographic features to characterize their biotic communities and surficial geology. The first submersible cruise (fall 1978) was conducted at the Florida Middle Ground and at eight topographic features in the northwestern Gulf of Mexico: Alderdice, Coffee Lump, Diaphus, Elvers, Fishnet, Geyer, Jakkula, and Rezak-Sidner Banks. The second submersible cruise (fall 1979) was limited to the East and West Flower Garden Banks. Submarine transects were selected at each bank on the basis of topography and geological sampling. Dives made using the DRV DIAPHUS are summarized in Table VII-4.

VESSELS

Ships used on submersible cruises were the R/V GYRE, owned and operated by Texas A&M University, and three Sealcraft vessels: M/V RED SEAL, M/V BLACK SEAL, and M/V ROSS SEAL. Specifications for these vessels are given in Table VII-1, above.

The submersible used in all operations was the DRV DIAPHUS, owned and operated by Texas A&M University. The DIAPHUS was built by Perry Submarine Builders, Riviera Beach, Florida, in 1974. This vessel is 6.04 m (20 ft) in length with a 365.8 m (1200 ft) depth capability. The DIAPHUS carries one pilot and one observer on a 180 manhour life support capacity. The pilot controls the progress of the submersible while looking out of a conning tower. The observer and all photographic equipment use the forward 91.4 cm hemispherical viewport.

For all sampling purposes this submersible was equipped with a four direction hydraulic manipulator arm and a wire mesh collection basket. Bottom sediment samples were taken using a small scoop type sampler constructed of 6.35 cm clear Lexan pipe.

For the dive at the brine pool location on the East Flower Garden, an additional system was added which included a temperature probe and hose attached to the manipulator arm. The hose was run through the submersible bulkhead and valved so that water samples could be collected in situ. The vacuum hose apparatus was improved on the second submersible cruise. A tubular net holder was mounted on the starboard side. The aft-end has a motor driven propeller which pulls water through the net. Forward, a hose runs to the manipulator arm, thus enabling the operator to control the nozzle placement. This vacuum collects sediment samples and certain epifaunal organisms that the manipulator does not.

TABLE VII-4
SUBMERSIBLE DIVES AND DATA COLLECTION

BANK OR STATION	DIVE					FILM		
	No.	Date	Duration	Pilot	Observer	8 mm	35 mm	Video
Coffee Lump	103	27 Sep 78	7 + 00	Green	Bright	0	2	5
	113	11 Oct 78	4 + 14	Green	Rezak	0	1	4
	114	11 Oct 78	1 + 18	Smith	Green	0	Check-out Dive	
East Flower Garden	104	28 Sep 78	2 + 40	Cooke	Lavar	0	---	---
	105	29 Sep 78	3 + 44	Cooke	Ambler	0	---	---
	106	29 Sep 78	4 + 31	Cooke	Perry-Plake	0	1	4
	107	30 Sep 78	6 + 10	Green	Bright	0	4	6
	108	1 Oct 78	6 + 03	Cooke	Norse	0	2	6
	109	2 Oct 78	5 + 12	Bottom	Bright	0	2	5
	110	5 Oct 78	3 + 48	Green	McGrail	2*	1	3
	111	6 Oct 78	3 + 37	Cooke	McGrail	2*	1	2
	112	6 Oct 78	2 + 13	Bottom	Jenkins	1*	1	2
	129	22 Oct 78	5 + 12	Green	Perry-Plake	0	3	4
	130	22 Oct 78	1 + 12	Cooke	Warsi	0	0	2
	131	23 Oct 78	3 + 44	Smith	Cooke	0	0	0
	132	23 Oct 78	1 + 48	Green	Bright	0	0	2
	133	24 Oct 78	4 + 42	Green	Rezak	0	2	7
	134	24 Oct 78	3 + 19	Smith	Cooke	0	Check-out Dive	
	1	5 Sep 79	1 + 35	Green	Hagerbaumer		Check-out Dive	
	2	8 Sep 79	3 + 37	Cooke	Rezak	0	1	1
	3	9 Sep 79	2 + 45	Bottom	McGrail		Check-out Dive	
	4	10 Sep 79	4 + 37	Cooke	McGrail	4	2	3
	6	25 Sep 79	5 + 22	Green	Bright	0	1	5
	8	27 Sep 79	6 + 13	Cooke	Powell	0	0	0
	9	16 Oct 79	7 + 17	Green	Huff	7	1.5	4
West Flower Garden	5	23 Sep 79	4 + 56	Cooke	Bright	0	1	3
	7	26 Sep 79	2 + 57	Green	Viada	0	0	2
	10	17 Oct 79	5 + 14	Bottom	Rezak	0	1	3
	11	18 Oct 79	2 + 32	Green	Horne	1	0	2
	12	18 Oct 79	3 + 15	Bottom	Barrow	4	0	3
	13	19 Oct 79	3 + 46	Green	Rezak	0	2	2
	14	20 Oct 79	3 + 46	Green	Horne	2	1	3
	15	20 Oct 79	3 + 38	Bottom	Huff	3	0	1

*16 mm

VII-4 (Continued)

BANK OR STATION	DIVE No.	Date	Duration	Pilot	Observer	FILM 8 mm	35 mm	Video
Geyer	115	12 Oct 78	8 + 37	Cooke	Bright	0	4	8
	127	21 Oct 78	2 + 02	Cooke	Titgen	0	1	3
	128	21 Oct 78	2 + 48	Green	Cooper	0	0	1
Fishnet	116	13 Oct 78	2 + 25	Green	Rezak	0	1	3
	117	13 Oct 78	3 + 52	Green	Titgen	0	2	4
Diaphus	118	16 Oct 78	2 + 51	Cooke	Wong	0	1	3
	119	16 Oct 78	3 + 49	Green	Bright	0	1	4
Sidner	120	17 Oct 78	3 + 41	Cooke	Bright	0	3	3
Alderdice	121	18 Oct 78	4 + 48	Green	Rezak	0	1	5
	122	18 Oct 78	3 + 59	Cooke	Bright	0	1	4
	123	19 Oct 78	2 + 42	Green	Rezak	0	2	4
Jakkula	124	19 Oct 78	2 + 34	Cooke	Bright	0	3	6
Rezak	125	20 Oct 78	3 + 08	Cooke	Rezak	0	1	3
Elvers	126	20 Oct 78	5 + 48	Green	Bright	0	3	6
Florida Middle Ground								
Station 151	137	7 Nov 78	3 + 23	Smith	Steinmetz	0	1	3
	138	7 Nov 78	3 + 50	Cooke	Shapiro	0	0	2
	144	11 Nov 78	4 + 20	Bright	Clark	0	2	3
Station 247	135	6 Nov 78	3 + 42	Green	Hopkins	0	1	4
	136	6 Nov 78	3 + 24	Bright	Steinmetz	0	1	5
	145	12 Nov 78	3 + 45	Green	Hopkins	0	0	5
	146	12 Nov 78	1 + 30	Green	Hudgins	0	0	2
Station 481	139	9 Nov 78	3 + 46	Smith	Meyer	0	1/2	3
	140	9 Nov 78	4 + 15	Bright	Lutz	0	0	3
Station 491	141	10 Nov 78	3 + 10	Cooke	Steinmetz	0	1/2	4
	142	10 Nov 78	3 + 51	Green	Dardeau	0	0	2
Station 493	143	11 Nov 78	3 + 40	Cooke	Adkinson	0	1	3

RECOVERY OF SUBMERSIBLE

Recovery of the submersible was made with the ship underway. A new launching platform and frame were installed, enabling the submersible to operate in rougher sea conditions. In fact, the operation is now limited more by what conditions the zodiac support boat can operate in than by the submersible.

Procedure for recovery was as follows. As the ship approached the submersible, a swimmer attached a line from the ship to the submersible. As the ship passed the submersible, the submersible was brought up to the stern of the ship until it was directly below the U-frame. The swimmer attached a large hook and line from the U-frame to the top of the submersible. The submersible was then lifted out of the water and placed in its stand under the U-frame. This method of recovery should allow for a safe recovery of the sub in three-metre seas.

PHOTOGRAPHIC EQUIPMENT

For photographic purposes, the submersible was equipped with the following cameras and lights:

1. A Benthos Model 3980 flood light was used for all photography when available light was too low for photographic use.

2. A Burns and Sawyer 175 watt spot light was used for general lighting and photography.

3. A Sony Video system was used for general documentation on all dives. This system consisted of a Model AVC 3400 television camera, a Model AV 3400 television recorder, and an 18 cm monitor. Power for the system was supplied from the main batteries of the submersible. The camera, aimed through the main viewing port, was mounted on a bracket although it was easily detached for hand held use.

4. A Bauer Royal 8 E Makro Super 8 mm movie camera was also used on most dives. This camera had a time lapse rate of 1 frame/second and was bracket mounted. The film used was Kodak Ektachrome EF 7242, film speed ASA 160.

5. Hand held 35 mm photos were taken with a Nikon FTN and 55 mm lens. The films used for this camera were Kodachrome 64, KR 135-36, film speed ASA 64, and Kodak Ektachrome, EH 135-36, film speed ASA 160.

SUBMERSIBLE STUDIES OF WATER AND SEDIMENT DYNAMICS

One component of the first submersible cruise was collection of data associated with the sedimentary processes in the bottom boundary

layer at the East Flower Garden Bank. A Martek XMS transmissometer, Plessey Model 9006 STD, and a Hydro Products Model 960 profiling current meter were attached to the submersible. In addition to bottom sampling, dye emission studies were also conducted on two of the submersible dives. On arrival at the site, the dye emittor was lowered to the bottom. The DRV DIAPHUS was launched and taken to the bottom where the dye flow in the oceanic bottom boundary layer could be observed. The vessel then anchored and the standard data collection (transmissometer profile, STD profile, current meter records, and bottom suspended sediment sampling) was begun. The anchor was raised prior to recovery of the DRV DIAPHUS.

PART D: GEOLOGY

R. Rezak, S. Gartner

SEDIMENTOLOGY

Clay Mineralogy of Bottom Sediments

Clay Mineral Analysis Procedures

Samples prepared for clay mineral analysis were dispersed overnight in deionized water. The clay fraction (< 0.002 mm) was separated from the bulk sample by treating with 1 ml of 2.5 m NH_4OH to disperse the sample before centrifuging for two minutes at 1000 rpm. The remaining suspended sediment fraction (< 0.002 mm) from this process was decanted from each centrifuge bottle and continuously collected in a one-gallon polyethylene bottle. Approximately ten to twelve centrifuge cycles were required to collect the entire clay fraction.

Two oriented clay slides, one Mg-glycerol saturated and one K-saturated, were prepared on ceramic tiles for each sample (Carroll, 1970; Gibbs, 1971; Huang et al., 1975). To minimize any experimental variation, a .035 mm clay film was prepared for each sample by placing appropriate amounts of clay suspension onto the tiles. Acid treatment to dissolve the carbonate minerals was not necessary, because the 25°C X-ray scan showed no visible masking of the clay mineral assemblage.

One set of X-ray diffractograms was obtained from each of the above two oriented clay slides. The Mg-glycerol saturated clays were subject to X-ray analysis after drying in air at 25°C. The K-saturated clays were subject to X-ray analysis after each of three steps: (1) drying in air at 25°C, (2) heating at 300°C for four hours, and (3) heating at 550°C for one hour.

X-ray analysis was carried out on a Phillips Norelco diffractometer operating at 35 Kv and 20 mA at a scanning speed of 1°2θ/min (2θ is the angle of d-spacing) and a chart speed of 11.7 cm/h (30 in/h). A 1° beam slit, with a 0.003 inch receiving slit, was used for the entire scan (2° to 35°2θ).

Mineral Identification Criteria

Illite is used as a group name here to include all clay mineral constituents of "mica-type" structure in argillaceous sediments (Grim et al., 1937). Basal reflections of illite are approximately 10, 5, and 3.3A.U. (1A.U. = angstrom = 10^{-8} cm). Illite peaks in these samples, for the most part, show extremely well crystallized reflections with relatively well developed [(002) Miller Index] resolution.

Kaolinite is difficult to differentiate from chlorite by using X-ray diffraction techniques (Johns and Grim, 1958; Griffin, 1962), because the d-spacings of the (001) crystal face of kaolinite and the (002) crystal face of chlorite are both at 7.2A.U., and kaolinite (002) and chlorite (004) coincide at 3.5A.U. However, kaolinite was identified by using both the (001) and (002), occurring at 7.15 - 7.20A.U. and 3.52 - 3.58A.U., respectively, which collapse to an amorphous state after heating at 550°C for one hour. Biscaye (1965) suggests that the 3.52-3.58A.U. reflection should be examined carefully to resolve this identification problem, but samples with the abundance of kaolinite found in this study did not need such resolution.

Chlorite identification was resolved by the following criteria:

(1) Characteristic basal reflections at 14.1 - 14.5, 4.75, and 3.54A.U. for the (001), (003), and (004), respectively. Since the (002) coincides with the (001) of kaolinite at 7.15 - 7.20A.U., the (002) of chlorite can only be used after the sample is heated at 550°C for one hour when kaolinite is in an amorphous state.

(2) The 14A.U. reflection will be intensified after being heated at 550°C (Brindley, 1961). Since chlorite occurred in such small amounts, true identification of this mineral was accomplished only after the 550°C treatment for the (001) and (002).

Smectite is a group of clay minerals characterized by a basal reflection which expands to 19.6A.U. (001) and 9.8A.U. (002) when saturated with magnesium and glycerol. The (001) reflection collapses to 10A.U. after being heated at 550°C. The large abundance of this mineral allows for simplified identification.

The non-clay minerals of the clay size fraction were identified in the following manner. Identification of calcite was primarily from the characteristic diffraction array between 2.99 - 3.05A.U. For these samples, a distinction was made between high and low magnesium calcite (2.99 - 3.01A.U. and 3.03 - 3.05A.U., respectively).

Numerous semi-quantitative estimation techniques have been proposed to determine abundances of clay minerals. These methods include the comparison of peak area, peak intensity, and chemical analyses (Johns et al., 1954; Jackson, 1956; Biscaye, 1964; Carroll, 1970; Griffin, 1971). No universal procedure has been adopted by clay mineralogists. The relative clay mineral percentages of this study were determined by measurement of the (001) peak area using a planimeter. The Mg-glycerol saturated samples were used to determine the relative amounts of illite. These separate measurements at 25°C were to differentiate the illite (001), which was overlapped by the smectite (002) on the Mg-glycerol saturated sample. The relative abundance of kaolinite was determined by the difference in the intensity of the 7.15 - 7.20A.U. reflection on the Mg-glycerol saturated diffraction patterns at two temperatures: 1) at 25°C, and 2) heated at 550°C for one hour. Because they are not affected by the treatment, the non-clay minerals of this fraction were identified from both diffractograms.

Sand Size Mineral Analysis (X-Ray Diffraction)

Samples for the greater than 0.062 mm fraction were separated from the silt and clay fraction during the clay preparation by sieving the silt through a 0.062 mm sieve after the clays were extracted. This sand size fraction was dried at 110°C, finely ground, packed randomly into aluminum holders, and analyzed by X-ray diffraction. The major minerals that made up the assemblage were identified by the following characteristic peak criteria: (1) quartz: 4.26, 3.35A.U.; (2) calcite: 2.99 to 3.05A.U. (distinction can be made for low or high magnesium calcite by the reflection position within this range); (3) aragonite: 3.40, 3.27, 2.70A.U.

Suspended Sediments

Field sampling consisted of taking thirty-litre Niskin samples at depths determined from observing inflection points on the transmissometer profiles in order to determine the location of the nepheloid layer. Seawater was transferred from the Niskin bottles to 2.5 or 5.0 l cubitainers for storage in a refrigerator until such time as they could be transferred to the laboratory.

The gravimetric procedure followed in the analysis of the water samples is similar to that of Bassin (1975). Standard 47 mm diameter Nuclepore GE-40 membrane filters, having a nominal pore size of 0.00040 mm, were pre-weighed on an Ainsworth Type 24 N precision weighing balance to an accuracy of 10^{-5} g. Filters were passed over uranyl acetate crystals before being weighed in the presence of an α-emitting ionizing source (Polonium 210), which minimizes the effects of static electricity. Weighing occurred in blocks of 28, with three of the filters serving as control filters. The controls were weighed six times each, whereas the 'use' filters were weighed twice each. The controls were treated exactly as the 'use' filters except that no seawater was filtered through. Filters were stored individually in plastic petri dishes over sodium hydroxide crystals within a desiccator.

To determine the amount of manufacturing residue present and its effect on filter gravimetry, an experiment was conducted with Nuclepore filters. Two litres of distilled, deionized water samples were filtered through each of five Nuclepore filters. The filtrate was considered particle free. The results are as follows:

Nuclepore Dissolution Experiment

Filter No.	Weight Loss (mg)	
1E	.022	
2E	.014	
3E	.023	
4E	.018	
5E	.018	Mean loss: .019 mg

Nuclepore filters averaged a loss of .019 mg. Effects of such a loss due to manufacturing residue are minimal in this study where concentrations were measured in several mg/l or hundreds of mg/l.

Corrections due to changes in humidity, temperature, and balance were reflected by weight changes of control filters. These corrections were on the order of .004 to .007 mg. In most cases, correction values, when applied to filter weights, had very little effect on concentration levels.

The filtering system itself was as follows: the cubitainers containing the water samples were placed on a holding rack and connected via Tygon tubing to Millipore in-line disc filter holders which had Nuclepore filters enclosed. A gas vacuum pump provided the suction by which water was drawn through the Nuclepore filters into four-litre collecting flasks. Water was drawn through the system until the filter became clogged or all but one litre of the water sample was filtered. These filters commonly became so clogged that particles of an order of magnitude smaller than the nominal 0.00040 mm pore size were retained (Sheldon and Sutcliffe, 1969). Volumes of filtered water samples were measured to the nearest 10 ml. Tygon vacuum tubing connected the filter holders to the collecting flasks and to the vacuum pump.

Immediately after filtration, the basal in-line filter holder, with saturated filter pad, was transferred to a 500 ml vacuum flask and rinsed three to five times with a total of 300 - 500 ml of double distilled, deionized water. The filters were allowed to drain nearly dry before the next rinsing session. Filtered effluent was tested with 0.1 N silver nitrate for indications of sea salts. After washing, the filters were stored in small plastic petri dishes over sodium hydroxide pellets in a desiccator. Five to seven days were allowed for drying and equilibration to the atmosphere of the weighing room before being reweighed. Concentration of total suspended matter in mg/l was found by determining the weight of material trapped on a filter and dividing this value by the volume of water filtered.

The clay fraction (< .002 mm) of the samples was separated from the bulk sediment by dispersing with 1.0 ml of 2.5M NH_4OH and centrifuging for two minutes at 1,000 rpm. The remaining suspended fraction (< .002 mm) was decanted from each centrifuge bottle and continuously collected until the suspension became clear. Concentrations of each sample were determined by drying and weighing 15 ml aliquots in preweighed aluminum dishes. Each sample was vacuum-sedimented onto a Selas silver filter (.00045 mm pore size and 25 mm diameter) under controlled conditions. In order to intensify the clay peaks and to prevent differential settling of particles, a controlled unit of water sample (2 ml) was introduced at approximately four-minute time intervals. The sample was then washed with deionized water to remove any residual salts and treated with four aliquots of 20% glycerol at the same four minute time intervals.

One set of five X-ray diffractograms was obtained for each sample by analyzing the sample after each of the following consecutive treatments: 1) air dried at 25°C untreated, 2) glycolation at 25°C, 3) heating at 110°C for twelve hours, 4) heating at 300°C for four hours, and 5) heating at 550°C for one hour. X-ray analysis was carried out on a Phillips-Norelco diffractometer using Cu Kα nickel-filtered radiation. The diffractometer operated at 35 Kv and 20 mA, a scanning speed of 1°2θ/min, and a chart speed of 30 in/h. A 1° beam slit, with a 0.003 inch receiving slit, was used for the entire 2θ scan (2° to 35° 2θ). The silver filters were placed on a special vacuum holder attachment to keep the sample surface flat.

Standard criteria were used to identify each of the clay minerals present. Illite was designated by the 10A.U. (001), 5A.U. (002), and 3.3A.U. (003) basal reflections, which were not affected by glycolation or heating treatment through 550°C. As stated above, kaolinite is difficult to differentiate from chlorite by using X-ray diffraction techniques (Griffin, 1962; Johns and Grim, 1958), because the d-spacings of kaolinite (001) and chlorite (002) are both at 7.2A.U., and kaolinite (002) and chlorite (004) coincide at 3.5A.U. However, kaolinite was identified by using both the (001) and (002) reflections, occurring at 7.15-7.20A.U. and 3.52-3.58A.U., respectively, which collapse to an amorphous state after heating at 550°C for one hour. As kaolinite was an obvious constituent of these samples, identification of relative abundance was made by comparing the (001) reflections (7.15-7.20A.U.) at 25°C and 550°C. Chlorite identification was resolved by characteristic basal reflections at 14.0A.U. (001), 4.75A.U. (003), and 3.54A.U. (004). The 14A.U. peak will be slightly intensified after being heated at 550°C, but identification is insured by no change in d-spacing through this heating treatment. Smectite is characterized by a basal reflection of about 12.5A.U. untreated, expanding to 19.6A.U. when saturated with glycerol at 25°C, with a gradual collapse in d-spacing, through the heating treatments described, to approximately 10A.U. at 550°C.

Total Carbonate Analysis

$CaCO_3$ percentage in the sediment was determined using a modification of the Scheibler method described by Bouma et al. (1969) Approximately 0.4 g of sample, along with 5 ml distilled water and 7 ml HCL (25%) in a small plastic beaker, is placed in a bottle and sealed. After mixing the acid and the sample by shaking them for twenty minutes, the volume of gas evolved is measured in a water-filled buret connected to the bottom by plastic tubing. Accuracy may be checked by duplicate sample analysis, allowing no greater than 10% $CaCO_3$ difference in the results.

Procedure for Grain Size Analyses of Sediment

For grain size analysis, a Coulter Counter, Model TAII, was used for the sediment fraction finer than 0.062 mm, and a Woods Hole type Rapid Sediment Analyzer (RSA) was used for the sediment fraction coarser than 0.062 mm.

The sample pre-analysis preparation procedures were as follows:

(1) Place approximately 50-60 g of sediment into a one-litre jar.

(2) Add 5 ml of hydrogen peroxide every 15 min up to a total of 30 ml.

(3) Allow to react overnight.

(4) Fill jar with distilled water and again allow to sit overnight or until the water is clear.

(5) Pour off supernatant.

(6) Add 15 ml of 40% sodium hexametaphosphate to sediment slurry.

(7) Wet sieve through a 230 mesh sieve, collecting the fine material in a one-litre column.

(8) Dry coarse fraction and sift through 230 mesh sieve again. Add the pan fraction to the fines. Weigh coarse fraction.

(9) Take a 20 ml aliquot; dry and weigh. The weight of the sample equals the weight of solids in the beaker minus .12 g (the sodium hexametaphosphate) multiplied by 50.

(10) Place the coarse fraction into a labeled envelope and save for the RSA.

(11) Use another aliquot of the sample for analysis with the Coulter Counter. Do not resuspend the dried sample.

The Coulter Counter procedures were modified from those used by the U.S.G.S. laboratory at Corpus Christi, Texas. Samples are no longer dried before analysis, as this introduces a very serious artifact into the results of the analysis (Folk, 1974).

The RSA procedures were as follows:

(1) Sieve the coarse fraction using a 10 mesh (2 mm) sieve to separate the sand from the gravel.

(2) Weigh material retained on sieve.

(3) Split the sand fraction repeatedly, using a microsplitter to obtain an appropriate size work sample (13 g, when possible).

(4) Turn on the electronics and allow to warm up to twenty minutes; then zero amplifier.

(5) Fill water column until flush with top edge of tube before calibration and each analysis. Record water temperature.

(6) Calibrate using Ottawa Sand (1Ø size).

(7) Be careful to minimize all shock waves in support and air due to walking, doors closing, etc.

(8) Spread sample evenly over the central portion of the moistened entry plate; avoid clumping grains.

(9) Turn on recorder pen and chart, using a chart speed of 10"/min.

(10) Gently close plate and start a stop watch to begin timing.

(11) Mark time of closing on chart; after 95 sec change chart speed to 2"/min or 1"/min (depending on sample).

(12) Continue monitoring chart for about five minutes until the curve reaches the baseline.

(13) Terminate analysis and label chart.

Interpretation of the RSA data consists of the following (modified from G.L. Shideler, 1976, personal communication):

(1) Mark the following three points on the pressure curve:
   (a) Introduction time (T_o) (first major pressure deflection, usually downward);
   (b) 0% inflection point;
   (c) 100% termination point (minimal pressure).

(2) Draw baseline from termination point parallel with graph paper grid.

(3) Using the size-fall time overlay, make the baseline of the overlay coincident with the drawn baseline. Vertically align the "0" time line of the overlay with the introduction time (T_o) mark on the graph paper. Tape down the graph paper and overlay.

(4) Place a Gerber scale perpendicular to the baseline at the 0% inflection point and divide it into 100 increments. Using a straight-edge, read off the cumulative percentage for each half-phi size and record on data sheet (nearest 0.5%). As the 0% size, use the size value immediately preceding the 0% inflection point. If the 4.0Ø size value occurs at less than 100%, consider it as the 100% size value. If the curve terminates prior to 4.0Ø, consider the half-phi value immediately prior to termination as the 100% size value.

Grain Size Parameters

A computer program was written by S. Helwick to combine the RSA and Coulter Counter Data, as well as the weight of gravel, and to compute the gravel/sand/silt/clay percentages, median, mean, standard deviation, skewness, and kurtosis. The statistical grain-size parameters were calculated using both the graphic method and method of moments. Calculations for the method of moments were taken from Carver, 1971. The results of the method of moments calculations are listed in Volume One, Appendix A, Tables III-1 through 5.

Graphic statistical parameters were calculated as follows:

Median Diameter - That diameter corresponding to the 50% mark on the cumulative curve. The measure determines that size in which half of the particles are coarser than the median and half are finer.

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

$$\text{Graphic Mean} = \frac{\emptyset 16 + \emptyset 50 + \emptyset 84}{3}$$

where $\emptyset = -\log_2$ (diameter in mm)
and $\emptyset 16$ = 16th percentile grain size, $\emptyset 50$ = 50th percentile, etc.

Inclusive Graphic Standard Deviation - a measure of sorting, determined by the formula

$$\text{Standard Deviation} = \frac{\emptyset 84 - \emptyset 16}{4} + \frac{\emptyset 95 - \emptyset 5}{6.6}$$

This formula includes 90% of the distribution and is considered to be the best overall measure of sorting. Folk, 1974 (p. 46) suggests the following classification scale for sorting:

Values less than		.35ø,	very well sorted
0.35	-	0.50ø,	well sorted
0.50	-	0.71ø,	moderately well sorted
0.71	-	1.00ø,	moderately sorted
1.0	-	2.0ø,	poorly sorted
2.0	-	4.0ø,	extremely poorly sorted.

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

$$SK_I = \frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$$

Graphic Kurtosis - used to determine the departure of the frequency from that of the normal probability curve. It is determined by the formula:

$$K_G = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

The value of this parameter is open to question because most sediments do not have a normal distribution curve but are bimodal or polymodal. Folk (1977, personal communication) feels that there is some value to the parameter and that it should be calculated for each analysis.

Particle Type Identification

The coarse fraction from each surface sediment sample was split until a sample of approximately 200 grains was obtained. These were then dispersed on a tray and examined using a Bausch and Lomb binocular light microscope. Two hundred grains were identified using nine compositional parameters based on relative abundance in the samples. These include: quartz, benthic foraminifers, planktonic foraminifers, echinoderms, molluscs, coral, algae, lithoclasts, and miscellaneous. The miscellaneous category included not only heavy minerals and unidentified skeletal fragments but also identifiable skeletal fragments not applicable to other categories, such as diatoms and sponge spicules.

PERSPECTIVE DIAGRAMS

In order to create a better visual image of the bank physiography, computer-produced perspective diagrams were constructed. By digitizing contour lines at irregular, closely spaced points, the interpretation of the manually drawn contour maps was preserved. These data were then converted to a form compatible with the SYMAP program.

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

The concept, overall design, and mathematical model was developed in 1963 by Howard T. Fisher (Northwestern Technological Institute). It was programmed by Mrs. O.G. Brown of the Northwestern University Computing Center. Since then changes have been accomplished by Robert A. Russel and Donald S. Shepard at the Laboratory for Computer Graphics and Spatial Analysis, Harvard University. This study used version #5.

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

SYMVU is a computer program which plots three-dimensional displays of data. It was developed by Frank J. Rens, under the direction of Howard T. Fisher, at the Laboratory for Computer Graphics and Spatial Analysis, Harvard University. The data from SYMAP was later used by SYMVU in order to obtain perspective views of the banks. Plotting was performed by using a Systems Engineering Laboratory plotter.

LONG TERM SUSPENDED SEDIMENT DISPERSAL (FOSSIL COCCOLITHS)

This section describes the laboratory methods and study techniques used in determining the distribution of redeposited coccoliths in the study of long term suspended sediment dispersal. These methods and techniques are essentially the same as in previous TAMRF-BLM contracts.

Sample Preparation

For microscopic examination, all samples were mounted on glass slides. Because of differences in the nature of the samples, bottom sediments and suspended sediments were prepared by two different techniques.

Bottom Sediments

Core top samples were prepared as follows: a small amount of sediment was suspended in 1 to 2 ml of water to which were added two drops of polyvinyl alcohol solution (PVA). This suspension was thoroughly mixed and spread onto a cover glass. The suspension was dried on a warming plate, thereby depositing a uniform layer of sediment on the cover glass. This sediment layer was held to the cover glass by a thin film of polyvinyl alcohol. The dry cover glass was mounted on a glass slide with Caedex, a synthetic resin.

Suspended Sediments

To prepare suspended sediment for microscopic examination, a 47 mm diameter Millipore filter with 0.0008 mm pore size was masked so all filtrate was deposited on a rectangular area measuring 20 mm by 28 mm. Half of a one-litre water sample was filtered onto this area. If the amount of suspended sediment was very small, the filter was again masked, this time in such a way as to expose 1/4 of the area on which the sample had been filtered previously. The remaining suspended sediment was then filtered onto this area. (The ratio of suspended sediment on the two parts of the filter is 1:5, and this allows for a relatively wide latitude of concentration in the water sample without appreciably increasing the difficulty of making counts on the filtrate.)

The filter was rinsed of salt by drawing about 50 ml of distilled water through the filter after the water sample. The filter and sediment were then dried at low temperature (100 to 110°F). The rectangular portion of the filter containing the suspended sediment was trimmed, mounted on a glass slide with immersion oil (refractive index = 1.515), and covered with a cover glass. The immersion oil rendered the filter transparent and allowed study of the suspended sediment in transmitted light.

Study Techniques

Abundances of reworked and of modern coccoliths were determined by counting the number of specimens within a given area. Counts were made at 1000X magnification in cross-polarized light. Because the indigenous modern forms were generally much more abundant than reworked Cretaceous species, especially in samples taken towards the edge of the continental shelf, the count for indigenous modern species could be made on one or two fields. In these samples a much larger area had to be scanned to get a count of the reworked Cretaceous species.

After the counts were made, the values were normalized for an equal area. The ratio of total coccoliths to reworked coccoliths was determined from these normalized values. The total coccolith number was used rather than that of indigenous modern species so that the ratio could not be less than 1, even if only reworked coccoliths were encountered, and all of the ratios are presented by numbers ranging from 1 to ∞. Samples containing no redeposited species yield a ratio of ∞; samples containing one or more redeposited specimens yielded numbers from 1 to about 65,000. These ratios represent a very large spread and cannot be visualized or represented on a map readily. Therefore, ratios were reduced to exponential values of powers of ten. Thus ratios ranging from 1 to 10 are represented by the exponent 1; ratios between 10 and 100 are represented by the exponent 2; ratios between 100 and 1,000 are represented by the exponent 3; ratios between 1,000 and 10,000 are represented by the exponent 4; and ratios greater than 10,000 (including ∞) are represented by the exponent 5. When reduced to exponential values, the ratios can be readily plotted and visualized for interpretation.

PART E: BIOLOGY

PI: T. Bright

GENERAL STUDIES OF THE GULF OF MEXICO BANKS

T. Bright

Biological reconnaissance and sampling from the submersible followed the procedures established on the previous contracts. As before, samples from biological dives were collected and put in five-gallon buckets. Once in the wet lab, they were separated for preservation and transportation. Separation consisted of isolating delicate and priority organisms into individual jars; the remaining material was sorted into five-gallon buckets in such a manner that damage would not occur during transportation. The organisms were anesthetized with $MgCl_2$ for approximately six hours and then preserved with 10% buffered formalin.

All Spondylus americanus samples were collected with the manipulator arm. They were then individually wrapped intact, labeled, and frozen for transportation. Specimens for hydrocarbon analysis were wrapped in foil and those for trace metal analysis in plastic bags. After wrapping, each specimen was bound with tie-wraps to ensure the shells would remain closed. Finally, the samples were sent to Dr. B.J. Presley for trace metal analysis and to Dr. C.S. Giam for hydrocarbon analysis.

Chemical water samples were taken from aboard the R/V GYRE using 30-litre Niskin Bottles. The O_2 determinations were performed aboard ship using the Winkler Method, and the nutrient samples were frozen for preservation and transportation. All samples were analyzed in the laboratory of Dr. James Brooks at TAMU.

EAST FLOWER GARDEN MONITORING STUDIES

T. Bright, S. Viada, C. Combs, G. Denoux

Many of the methods employed in the East Flower Garden monitoring study are experimental. This section describes experimental methods used in three studies: coral and coralline algae populations, coral and coralline algae recruitment, and coelenterate larvae and other zooplankton.

Coral and Coralline Algae Populations

Field Procedures

Two established study sites at the East Flower Garden were chosen as reference points for the study of coral and coralline algae populations: the BLM site, established by the 1977 Texas A&M University monitoring study (27°54'01.28" N, 93°34'38.27" W), and the site established by Continental Shelf Associates (Tequesta, FL) during the 1978 monitoring study (27°54'37.37" N, 93°35'55.79" W). Both sites are located within the Diploria-Montastrea-Porites zone at the East Flower Garden Bank (see Volume Three, Figure X-C-1).

Location of the BLM site during the sampling cruises was facilitated by the use of a 27 kHz Helle model 2400 pinger and 1104 battery pack (Helle Engineering, Inc., San Diego, CA). These were deployed to the reef in the vicinity of an hourglass-shaped sandflat which served as a central reference point for the site. A Helle model 6270 diver-held acoustic locator was used to find the pinger on subsequent cruises. A subsurface buoy was anchored to the bottom within the confines of the sandflat for visual confirmation of the site by divers. The subsurface buoy was secured to the reef by extending a series of short polypropylene guy lines from the buoy's concrete anchor to the surrounding reef rock, and fastening them to eyebolts which were epoxyed into the dead reef rock, or corallum. After securing a large surface float and line to the subsurface buoy, the anchored buoy array was then used to tie off the zodiac inflatable boat which transported the diver teams from the ship to the site.

The Continental Shelf Associates' site A (CSA-A) was marked with a similar subsurface float and a 54 kHz "Wet Beacon" pinger (Sound Wave Systems, Inc., Costa Mesa, CA). It was found that the life of the pinger battery was less than the time span between sequential sampling cruises, so that divers located the CSA-A site by visual recognition of the general surrounding area and the subsurface floats.

Sampling was accomplished by taking a series of 34 stratified random 10 m line transects*, using a modified form of the method described by Loya (1972). Instead of measuring the dimensions of various biotic components of the transect in situ, a camera jig apparatus was used to create photographic mosaics of the transects.

*These were analyzed as 8 m transects. See below, p. 32.

The camera jig consisted of a Nikonos III 35 mm camera with a 28 mm UW Nikkor lens (Ehrenreich Photo-Optical, Garden City, NY), and a pair of Sea and Sea YS35 strobes (Leach Photosystems, Keno, OR) for stereo lighting, positioned on a stainless steel framing device, thus producing a photographic area of 0.5 m^2. The rim of the framer was covered with a closed cell foam tubing, to minimize damage to coral tissue when the transect was photographed. A fiberglass fabric metric measuring tape was initially stretched over randomly selected areas of the hard bottom portion of the reef, to designate the boundaries of the 10 m transects. The photographs were taken along the length of the measuring tape, allowing a certain degree of overlap, such that a complete photographic mosaic of the transect area could subsequently be pieced together in the laboratory. Six random transects per cruise were taken on each site. In choosing the positions of each transect, the diver-photographer descended to the bottom in the general vicinity of the sandflats which served as central reference points for the two sites. The diver would then swim an unprescribed distance from the sandflat and lay out the measuring tape, choosing a random direction.

The collection of corals for the determination of species composition within this zone of the East Flower Garden Bank served to verify the identifications of corals measured in the transect photographs. Dives were conducted in random locations around the two study sites on the reef for collection of coral colony sections, or in some cases, individual coral polyps, for confirmation of in situ systematic determinations. The coral species collected were photographed in situ using a Nikon F 35 mm camera with a 55 Micro Nikkor lens (Ehrenreich Photo-Optical, Garden City, NY), housed within an Ikelite (Ikelite Underwater Systems, Indianapolis, IN) underwater camera case, and coupled with a Subsea Mark 150 strobe (Subsea Products, Riviera Beach, FL). Kodak "Kodacolor 100" color print film (Eastman-Kodak Co., Rochester, NY) was used for the transect and in situ coral species photographs.

Laboratory Methods for Transect Analysis

Each set of transect photographs was pieced together on a strip of heavy poster board to form a photographic mosaic of the complete transect swath covered by the camera jig framer. A line was drawn across the center of the completed mosaic, and any individual coral species and epibenthic organism (such as algae or sponge occupying dead coral reef rock that was intercepted by the line) was recorded. The length of the portion of the line overlying the organism was measured to the nearest centimetre. An individual was defined as any colony growing independently of its neighbors (i.e., whenever an empty space was recorded between two adjacent colonies [from Loya, 1978]). In cases where an individual colony was clearly separated into two or more portions by the death of the intervening parts, the separate parts were considered as one individual. The fiberglass fabric measuring tape shown in the lower edge of each photograph was used as a scale of reference when measuring the epibenthic reefal community. The photographic mosaic was analyzed under a Luxo magnifying light (Luxo Lamp Corp., Sausalito, CA) in order to facilitate species identifications.

The beginning and ending measurements of the coral, algae, or sponge colonies were recorded along with the sampling cruise number, transect number, and a coral species code. Portions of the transects which could not be clearly analyzed, as a result of distance from the camera's focal plane or a mismatch of the mosaic community, were voided from the final analysis and given a specific void designation. The data were then processed by a statistical computer program originally designed for analysis of range vegetation distributions determined by the same line intercept method.

Statistical Methods for Transect Analysis

The statistical analysis compared line transect data from the two study stations on the East Flower Garden Bank to determine coral species population relationships.

The data were analyzed to determine and record the total number of individuals of each species, the total of intercept lengths for each species, and the number of transects in which each coral species occurred. From these values, eight parameters, based on studies involving population levels and distributions of terrestrial vegetation, were calculated using a computer program. The eight parameters calculated include:

1. Species Dominance
2. Relative Dominance
3. Relative Density
4. Frequency
5. Relative Frequency
6. Species Diversity
7. Species Evenness
8. Species Richness

Since an understanding of these statistical analyses is crucial to interpreting the results of coral population studies at the East Flower Garden, the description of statistical methods is included in Volume Three, Chapter X-C, prefacing those results.

Review of Previous Linear Transect Studies

The line intercept method of sampling vegetation, used in determining coral population relationships, is based on the measurement of all plants intercepted by the vertical plane of randomly located lines of equal length (Canfield, 1941). This method uses the line transect as the sampling unit for the measurement of plant communities. The line transect is visualized as having length and vertical dimensions only. No lateral dimension, or width, is included (Weaver and Clements, 1938). Line transect methods basically involve the recording of the length of randomly spaced lines which are intercepted by plants or sessile animals. Continuous transect recording is based on the expectation that total transect length divided by total population area will equal total intercepted transect length divided by total area of living population (Loya, 1978).

Most of the invertebrate communities of coral reefs are discrete, relatively sessile (or limited in their mobility), and thus easily mapped. In this sense, coral reef invertebrate communities and terrestrial plant communities are very similar. Therefore, for our study of benthic coral reef communities, it was deemed justifiable to adopt and test concepts and techniques used by terrestrial ecologists (Canfield, 1941; Greig-Smith, 1964; Loya, 1978).

Stoddart (1969, 1972) reviewed field methods of linear transect studies of hermatypic corals with emphasis on problems of sampling design, sampling unit, and data recording. He divided coral reef linear transect studies into two categories:

(1) qualitative studies, which aim to record variation in organisms and elevation along transects in terms of species present and relative abundance, without necessarily counting or measuring;

(2) quantitative studies, which consist of either some form of continuous recording on transects, or sampling along transects.

Many of the studies falling into these two categories deal with quadrat sampling, a sampling technique which conventionally uses as the sampling area a rigid square or rectangular structure of variable size, usually one metre square (Brown, 1954). Most of the quantitative studies of vegetation or coral reefs by means of quadrat sampling record the number of genera or species present per quadrat and their relative cover (Mayor, 1924; Manton, 1935; Abe, 1937; Emery et al., 1954; Odum and Odum, 1955; Kornicker and Boyd, 1962; Storr, 1964; Kissling, 1965; Stoddart et al., 1966).

Loya and Slobodkin (1971) and Loya (1972) devised for the first time a coral reef sampling program which employed sampling along transects, wherein the transect had specified length but no width. The present sampling program was specifically designed to study the community structure of hermatypic corals, using species composition, zonation, and diversity pattern parameters within different zones of the reef.

Goreau (1959) estimated the species composition and zonation of corals in Jamaica by qualitative analysis of transects. While proceeding along the length of the transect line, divers noted both a sounding line marked off in metres and corals of different species in the range of vision. Porter (1972a,b) studied species diversity of hermatypic corals in Panama using a slightly modified transect technique. A 10 m long chain was laid across the reef parallel to the depth contour at three-inch intervals down the reef face. The number of chain links (each 1.3 cm long) covering each coral colony was then recorded.

Ott (1975) analyzed the community structure of a coral reef bank in Barbados, West Indies, using a photographic line transect method. A nylon line with one metre divisions was placed normal to the direction of the bank top and photographed at every one metre line division.

Information was therefore limited to the one metre line segments under the nylon transect line. Laxton and Stablum (1974) described a sampling design for the quantitative estimation of sedentary organisms on coral reefs. Photographs were taken every fourth metre along the transect line and analyzed for percent coverage by sedentary organisms.

Advantages of Line Transect Methods

One of the principal advantages of the line interception (transect) method is that it is a method of sampling which is based on actual measurement of the community growing on "randomly located and clearly defined sampling units" (Canfield, 1941). Use of a line not only increases the likelihood of encountering a greater number of corals, but also increases the chance of encountering a greater number of species than would be expected in the shorter more compact rectangular plot, or quadrat. McIntyre (1953) stated that use of the line transect method for estimating percent ground cover by different species in a sample area is "well established in theory and practice as giving a level of precision in the estimate for a given effort which compares very favorably with other methods." This finding proves especially true when marked aggregation of species occurs. All of the distance transect techniques are more efficient in terms of results obtained per time expended. Cottam and Curtis (1956) stated that use of linear transect techniques decreased the time expended by 90% or more, to obtain equivalent results by other techniques. Loya (1972) asserted that the application of line transects is highly efficient for information recorded per time spent underwater. Problems arising from complex bottom topography are also avoided using line transects, since a line may be placed along bottom contours; quadrat sampling is much more complicated to handle in underwater studies. Loya also stated that the amount of information derived from line transects is for many purposes as useful as that derived from quadrat sampling techniques. Laxton and Stablum (1974) concluded that apart from yielding accurate values of percentage cover of sedentary organisms on coral reefs, their photographic transect technique is rapid and inexpensive, requires a minimal time expenditure in the field, produces an exact record of the size, number of colonies and their spatial arrangement for a given instant in time, and possesses the capability of producing relative growth data when rephotographing transects periodically.

Determination of Sample Size

The sample size, which relates to transect length or the number of times a given density or frequency quadrat should be repeated, is often arbitrarily delimited (Dornbois and Ellenberg, 1974). Greig-Smith (1965) emphasized that the accuracy of the count is not a function of the area sampled, but a function of the number of enumerations, which relates to the spatial distribution of individuals. Where the individuals are spaced widely apart, far fewer are counted in the same size of plot or transect than where the individuals are close together. Variability in the spacing of individuals within the sample area necessitates a standard technique for the determination of sample size.

Gleason (1922) pointed out in his vegetation studies of Michigan aspen distributions that as the sampled area (transect length) increased, the number of unrecorded species increased to a certain point and then decreased. This concept was referred to as the "species-area curve" and has been widely used in plant ecology studies (Cain, 1938; Goodall, 1952; McIntyre, 1953; Greig-Smith, 1957; Strong, 1966). The species-area curve is a graphical representation of the relationship between species diversity and sample size. The abscissa plots sample (or transect) length, while the ordinate plots the average number of species present, i.e. species diversity. The resultant curve shows an initial increase followed by a gradual leveling off. The point on the species-area curve where the curve itself flattens strongly is taken as an indication of minimal area, or adequate sample size (Cain, 1938; Braun-Blanquet, 1951; Loya, 1978).

Variability in the spatial distributions of individuals within the sampled area does affect the results obtained with the species-area curve. According to Greig-Smith (1957), "the influence of pattern on the species-area curve has commonly been overlooked or ignored, although it is clear that if most species are markedly contagiously distributed, the number of species observed in a sample of a particular size will be less than if the species were randomly distributed, unless the sample size exceeds the maximum scale of heterogeneity of all the species present." He pointed out that for this reason, some discrepancy from the theoretical species-area curve, which is based upon random distributions of individuals, is to be expected.

Since the present work involved deep diving, it was very important to determine the smallest sample size (i.e., smallest transect length) appropriate for the purposes of this work. The species-area curve concept was employed by Loya (1972) in determining an adequate transect length in a study of community structure of hermatypic corals in the Gulf of Eilat, Red Sea. He found that a 10 m line transect was an adequate sample size for that region. Investigators in other regions found similar results (Porter, 1972a; Wallace, 1974; Loya, 1976). From these results, a transect length of 10 m was chosen for this work.

In piecing together the photographic mosaics, however, some of the original 10 m transects were effectively reduced to slightly less than 10 m. Therefore, all transects were reduced to 8 m in the analysis in order to standardize the sample size for statistical validity.

Recruitment and Early Growth of Corals and Coralline Algae

The study of recruitment and early growth of corals and coralline algae required construction of a sampling system. The system was designed for collecting quantifiable samples of newly settled coral and coralline algae and also for exploring possible long-term effects of barite on these organisms. This section describes the construction of the prototype sampling rack (Volume Three, Figure X-C-4) and procedures for sample analysis.

Construction of Settling Plates

For construction of settling plates used in the sampling rack, Portland cement (Type I) was chosen as a sampling substrate because it could be easily obtained, easily molded into any configuration, and readily mixed with barite. Additionally, because Portland cement is composed primarily of limestone, it should reasonably simulate a natural limestone substrate in the limestone-dominated environment of the Flower Garden reefs.

Portland cement used for control plates was sieved to remove lumps. Similarly, barite plates were made from sieved Portland cement mixed with unsieved barite in a ratio of 2:1 by volume. Mixes were prepared in either a stainless steel tub or a nylon tub in order to avoid possible container-related contamination. Because the composition of batches of mixed barite was assumed to vary proportionally by some small but undetermined amount, each batch was considered unique, and a record was kept of which plates were constructed from which batch. Similar records were kept on construction of control plates because several sacks of cement were expected to be used before the end of the experiment.

A square framework for mass-production of plates was constructed of 2 cm x 4 cm wooden strips evenly spaced 10 cm apart in perpendicular rows to form one hundred 10 cm x 10 cm squares (Volume Three, Figure X-C-3). The framework was laid flat on the smooth surface of a masonite sheet which had been covered with either a sheet of acetate (plates #1-#100), or with waxed paper to prevent sticking (plates #101 ff.). In order to prevent cross-contamination of the two mixes used to form plates, half of the framework was permanently designated for "control" plates and half for "barite" plates.

Plates were molded by placing mixed cement into each square in sufficient quantity to yield a plate thickness of approximately one centimetre. Basal "stems" of 1/2-inch PVC tubing cut into 15 cm lengths were pressed vertically into the center of each square; four 6 mm holes drilled laterally into one end of each PVC stem permitted cement flow-through when embedded, assuring rigid attachment of plate to stem. Small "branding iron" numerals were formed from heavy wire and were used to impress identifying numbers into the "stem-side" of each plate when the cement became semi-rigid. Both types of plates were numbered sequentially, but barite plate-numbers were prefixed with a "B".

Construction of Prototype Rack

The prototype system (Volume Three, Figure X-C-4) consisted of four parallel, removable 120 cm lengths of one-inch PVC pipe, called "rods," each supporting five control plates, arranged within a PVC "rack." Barite plates were not used here, as the primary objective was to first learn whether corals and coralline algae would settle on a cement substrate; a sample size of five plates per rod was judged sufficient. The 20 plates used in the original four rows of the prototype

rack were made from the same batch of cement in order to minimize possible variability in cement composition and were numbered sequentially. Plates were mounted 22.5 cm apart, center to center, on each rod. The four parallel rods were mounted 30 cm apart within the rack, so that the 20 sampling plates, with a combined surface area of 2000 cm^2, were arranged within a larger imaginary square measuring 1 m^2, or 10,000 cm^2. Short pins (9 cm) were used to secure each rod within the rack and were constructed using cut segments from 2 m long fiberglass bicycle flag-staffs of 6 mm diameter. Pins were secured in place using nylon tie-wraps, assuring rigidity of the rack in the event of strong bottom currents or surges. The rack was supported by height-adjustable 1-1/4 inch PVC legs embedded at their bases in molded concrete. For added security, legs were tied down using 500 lb-test braided nylon line attached to large galvanized nails driven into nearby dead coral.

Collection and Transport of Samples

Compartmentalized plywood boxes of a size sufficient to store six rods each were constructed and sealed with fiberglass resin. Boxes were intended to provide safe transport of new samplers to the field and leakproof and damage-proof return of formalin-fixed samples from the field.

Rods being changed were transported to the dive-site inside one of the boxes aboard the zodiac dive-tending skiff. Divers then transported the new rods to the bottom and returned the old rods to the surface, where they were placed inside the box and the lid closed. Aboard the ship, sampling plates attached to the rods were immediately processed by placing over each plate a small plastic bag containing borax-buffered formalin mixed 1:10 with seawater, then securing the bag with a nylon tie wrap. Rods were arranged inside each of these boxes in a small rack such that the plates hung down touching neither the box nor each other. With reasonable care, samples were returned to the lab undamaged.

Analysis of Samples

Plates were removed from rods, and stems were sawed off adjacent to the surface of each plate. Plates were stored in 70% alcohol in plastic boxes large enough to hold about 25 plates (individually wrapped in paper towels) when plates were placed surface-to-surface in two edge-standing rows. This vertical placement prevented sampling surfaces from being crushed while in storage.

Analysis of samples was conducted using a stereo dissecting microscope. To avoid double-counting of specimens, a counting grid was constructed using very fine nylon line (commercially called "invisible thread") stretched over a plastic picture frame. Dark and light colored line was used in a pattern yielding 100 squares, each 1 cm^2 in area, and each with a different pattern of colored sides from that of its neighbor on each side. The grid was overlaid just above the surface of each plate permitting detailed examination of each square

centimetre. A data-recording sheet designed to simulate the counting grid was used to record the location of each specimen on the plate according to an alphanumeric coordinate system. Specimens were measured to the nearest 0.05 mm across the basal disc, using an ocular grid in the microscope.

Coelenterate Larvae and Other Zooplankton

For the study of coelenterate larvae and other zooplankton, samples were collected with nets fitted on a buoy array. The nets used were 0.5 m wide with 0.333 mm mesh, and were equipped with General Oceanics Digital Flowmeters, Model 2030. Initially, three nets were set in an array to fish at 40, 30, and 20 m depths. The array was later fitted with two more nets, one at 10 m and one at the surface. The array was lowered over the side of an anchored vessel in about 50 m of water on the shoulder of the bank for one hour. The sample was collected as the current (usually about 0.5 knots) passed through the nets. During the winter 1979 monitoring cruise, the array was lost. An oblique sample was taken over the reef with a 0.5 m net. All samples were preserved in 5% buffered formalin.

In the laboratory, the entire sample was scanned for coelenterate larval stages. The samples were then split with a Folsom plankton splitter, according to standard procedures (McEwen et al., 1954). Aliquots were chosen so that about 500 individuals were counted. Counts were made with a Wild M-5 Stereomicroscope. Abundance estimates were standardized to 100 m^3.

PART F: WATER AND SEDIMENT DYNAMICS

D. McGrail

SAMPLING

Transmissometry data were taken through the use of a Martek 1 m folded path transmissometer and accompanying depth sensor. Salinity, temperature, and depth data were acquired through the use of a Plessey 9006 STD system. The transmissometer was coupled to a Martek data processor, and the data were recorded on cassette tape. The data processor also provided an automatic print-out of all incoming data. Salinity, temperature, and depth data were recorded from the STD on a Leeds and Northrop xy plotter. All salinity and temperature data were checked at the surface and near-bottom using Nansen bottles with reversing thermometers.

A Hydro Products profiling current meter Model 960, complete with a gasoline engine powered winch and on-deck readout, was employed to measure the water velocity from the sea surface to the bottom. In addition, the sensor unit was sometimes deployed to a particular depth to measure how velocity changed as time elapsed.

WATER COLUMN MEASUREMENTS

Water column measurements were taken in two stages. In stage one, the procedure was to first place the transmissometer in the water for calibration, then hand lower it to the bottom and raise it back to the surface. Transmissivity values and depth were logged automatically on cassette tape and a hard copy printer at one second intervals and were also hand-logged every three seconds on the way down. These data were used to determine the depth and total number of 30-litre Niskin bottles to use in stage two. In stage two, the STD was placed in the water for calibration, lowered to the bottom, raised back to the surface, and taken out. Salinity, temperature, and depth were logged by the Leeds and Northrup xy plotter. Then the profiling current meter was lowered by winch in 5 m increments until it reached the vicinity of the bottom, at which time the rate was decreased. At some stations, the current meter was then lowered to a pre-selected depth and the readout monitored by one person for the duration of the station.

LONG-TERM CURRENT MEASUREMENT

For long-term current measurements, current meter arrays were set out near the East and West Flower Garden Banks. Two types of current meters were used, the Hydro Products 550 and the Marsh-McBirney 585. The Hydro Products 550 is a Savonius Rotor meter with vane for indicating direction. Temperature, time, speed, and direction are stored on cassette tapes at six-minute increments. The Marsh-McBirney 585 is an electromagnetic current meter which records time, speed, direction, and

orientation on a cassette tape at time increments of 10-20 min. A Hydro Products temperature conductivity probe was deployed with the electromagnetic meter.

Before deployment of a current meter array, the hardware for the array was assembled and the meters checked out. Each piece of wire for use in the array was pre-cut and attached to swivels and shackles prior to going to sea. At sea the current meters, acoustic releases, and buoys were shackled into the array, and all shackles were seized immediately before deployment.

Each current meter was checked before deployment. The checkout procedure for the Hydro Products 550 current meter requires that batteries be replaced and voltage be at least 12.3 volts with the instrument off. The rotor sensor circuit was adjusted for proper symmetry. The analog-to-digital converter was adjusted and calibrated. Calibration of the temperature measurement circuit was checked. O-rings were cleaned and inspected; bad rings were replaced. New cassette tapes were installed. With the meter turned on, the tape advance was verified. At the beginning of the next sample period, the number of rotor revolutions during the sampling time was counted to verify that the instrument was making the correct speed measurement. To check compass headings, the instrument was rotated 90° after each of the next four sample periods. After sample data points were recorded, the cassette tape was removed from the instrument and read to insure that proper speed and direction were actually recorded by the Hydro Products current meter.

After this checkout, board #1 was wired for the desired sample rate, the tape was mounted, and the instrument was turned on. The time that the instrument was turned on was recorded as the start time of the tape. Before sealing the unit, the pressure case was purged with argon gas, rotor bearings were cleaned, and the rotor was blocked to prevent rotation in the air.

Checkout for the Marsh-McBirney 585 electromagnetic current meter was similar to that for the Hydro Products 550, except that speed verification is not possible (except a speed of zero in still water), nor is it possible to read the cassette tapes to verify that the correct data were actually recorded. The 585 was connected to an RS232C terminal for checkout. This allowed for a printout of data as the data were measured. Compass measurements (for the orientation of the meter) were checked by rotating the instrument through 360°. Zero speed output was obtained by placing the sensor in a container of ordinary tap water. Before deployment, 1) the batteries were charged and the voltage checked; 2) The internal time clock and sample rates were reset; and 3) the O-rings were cleaned and fresh desiccant and sacrificial anodes were emplaced and mounted on the case. The electromagnetic meter was also purged with inert gas immediately before sealing the pressure housing.

When all instruments were checked out and the ship neared the site for deployment, the array was assembled and laid out on deck.

Immediately before reaching the deployment site, the array was strung out behind the ship with only the anchor portion remaining on the ship. At the exact location where the current meter array was to be deployed, the anchor was released over the side so that the array could free fall to the bottom. Exact time and position were recorded.

Recovery of the current meter was accomplished by sending a frequency encoded acoustic signal to the acoustic release located immediately above the anchor in the array. Upon receipt of this signal, the array separated from the bottom anchor and floated to the surface. Meters, releases, and buoys were brought on deck. The meters were immediately rinsed with fresh water and cleaned. Rotors and gimbals were checked for any wear or obstructions that might influence data collection. Tapes were given a preliminary check when possible to determine that the instruments had worked satisfactorily. Cycle time and clock accuracy were verified.

After the cruise, the Hydro Products data tapes were read, using a Hydro Products data processor, and stored on computer discs. Marsh-McBirney cassettes were sent to Marsh-McBirney for transcription to 9-track tape. Since occasional errors appear in the Hydro Products cassettes, these bad data points were replaced by interpolated data from surrounding points. Records were determined to be bad, 1) if data were present in the depth or conductivity bits (there are no depth or conductivity sensors on the Hydro Products current meters), 2) if the time was incorrect, or 3) if the temperature deviated from the average temperature of the previous hour by more than 2°C. The number of these errors varied from instrument to instrument but was generally about 1%. In general, the Hydro Products meters stopped recording speed before the end of the deployment period, although the direction of the currents was still recorded. Attempts to synthesize current data for some of these missing points have been made by determining an average speed in each of 36 10° segments of direction. These average speeds were used in conjunction with direction to determine velocities where only direction was recorded. These synthesized data were reported separately from the real data.

Speed and direction from the current meter records were converted to speed and direction components (U and V) and corrected for magnetic deviation of the compass reading. For additional processing, current velocity, temperature, and time data, along with a flag indicating which data were interpolated, were sent to the TAMU main computer via a modem. Current meter data were low-pass filtered using a Butterworth filter (Stearns, 1973) with three passes, then inverted and refiltered to eliminate phase shifts. This filter removed all periods of less than thirty hours, including any tidal effects on the currents and temperature. Spectra were computed on the unfiltered and low-passed data using programs developed by Peter Oppenheimer at South Florida State, 1976. This program was a Cooley-Tukey Fast Fourier Transformer. Rotary spectra were computed on the U and V components of velocity (Gionella, 1972). Time series plots of low-passed and unfiltered current velocities were compared with plots of tides (from Galveston) and wind.

DYE EMISSION STUDIES

Submersible dye emission studies were undertaken in September 1978 for the purpose of observing boundary layer processes and eventually relating these processes to sediment transport. Fluorescent dye was passively introduced into the near-bottom flow with dye emittors. Three dye emittors were gimballed onto a stainless steel wire held taut by a steel pipe frame. The position of the dye emittors on the taut wire varied from dive to dive. They were positioned before each dive, and their height from the base of the stand was measured. The dye emittors consisted of streamlined plastic with a hole in the front of the main body to allow water to enter. Water which entered the hole mixed with dye and exited through a 1/4-inch plastic tube which extended up and behind the main body of the emittor. Aluminum fins one metre long, marked in 5 cm increments, were attached behind the plastic emittors. The purpose of the fins was to provide scale for visual recordings. Both the emittors and the fins were free to rotate 360° without interference, thus allowing them to orient themselves with the flow.

The movement of the dye was recorded with 16 mm color movies and black and white video tape. The 16 mm movie camera was used both freehand and rigidly mounted. The black and white video camera was rigidly mounted and recorded audio during the observation. Filming speed varied depending on the observer and the type of observation.

Before each dive, the dye emittor stand was lowered to the bottom from the ship. The location of the emittor stand was marked by a surface buoy tethered to the top of the stand. After the stand was in place on the bottom, the submersible was launched. The submersible maneuvered to the surface buoy marking the dye emittor stand. The submersible descended to the stand following the marker line. Once the submersible was in position, observations of the dye began. The direction of the dye was noted, along with transmissivity, salinity, and temperature. At the completion of each dive, the submersible ascended and was retrieved by the ship. The dye emittor stand was winched up to the ship and brought on board with a crane. The submersible and dye emittor stand were then prepared for the next dive.

Additional data were also obtained by the surface support ship during each dive. Current and transmissivity profiles were taken prior to each dive and as often as possible during each dive.

PART G: CHEMISTRY

PROCEDURES FOR TRACE METAL ANALYSIS

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Organisms

Sampling Procedures

All Spondylus samples were collected using the research submersible DRV DIAPHUS. During the October 1978 submersible cruise, 19 individual Spondylus were collected for analysis from the four banks sampled: East Flower Garden (15 individuals), Elvers (1 individual), Sidner (1 individual), and Jakkula (2 individuals). Of these banks, only East Flower Garden had been sampled in previous years (i.e., 1976 and 1977).

Every reasonable precaution was taken to avoid contamination during sampling. Each individual Spondylus was strapped shut with nylon cable ties before being placed in a polyethylene sample bag. This was done to minimize the potential contamination of soft parts resulting from the intrusion of materials on the exterior shell surfaces into the mantle cavity during sample storage. To avoid any release and redistribution of metals in the oyster by microbial action, all samples were frozen immediately on board ship and remained frozen during transport and storage until prepared for analyses.

Sample Preparation

Spondylus samples were thawed just prior to being prepared for freeze drying. The shell length and width of each oyster were measured. A new dissection procedure was employed so that separate organs from individual Spondylus could be analyzed for trace metal content. The following organs were separated from individual Spondylus: mantle, gill, adductor muscle, digestive gland/visceral mass and gonads (if apparent). Since only whole Spondylus were analyzed during the first two years of the TFS, one-half of each organ (except gonad) was pooled to produce a single "whole organism" sample. This pooled sample was analyzed to produce trace metal body burden data directly comparable to that observed in the earlier studies. These data are required by the contract and are reported in Volume Two, Chapter IX-A. The analysis of the remaining halves of each organ was not required and will be accomplished as time permits.

This approach will give a much more detailed view of the occurrence of selected trace metals in Spondylus. It will also allow comparison of the variability in trace metal levels among different organs and determination of whether any differences observed between pooled samples are reflected equally in all component organs or only in certain organs. These observations will be very useful in determining

which sample type (i.e. pooled or a component organ) would give the most information for the least cost in any future monitoring program in the study area.

All dissections were done in a clean room on acrylic plastic cutting boards using stainless steel scalpels, scissors, and nylon or teflon tweezers as required. At no point during the dissection were the preparer's fingers allowed to touch the tissue to be analyzed. All dissecting equipment was thoroughly rinsed with 1 N HNO_3 and deionized water between each sample. At the end of each preparation session, all equipment was thoroughly cleaned in an Na_2CO_3 solution and rinsed with 1 N HNO_3 and deionized water. The equipment was stored in polyethylene bags until the next use. The acrylic boards were soaked in 0.5 N HCl between each use.

Each piece of tissue was rinsed sparingly with filtered seawater to remove any mud or other foreign material adhering to its surface. Portions of the gut containing ingested material were also removed. The tissue was given a final light rinse with deionized water. The deionized water used for all work in this study was prepared by passing distilled water through an ultrapure, mixed bed demineralizer column (Barnstead DO809).

Each separate tissue sample was placed immediately in a tared, snap-cap vial and weighed to determine wet weight. The samples were covered with parafilm and placed in a freezer. When a sufficient number of samples had accumulated, all samples were freeze-dried for 24 to 96 h to a constant weight. After removal from the freeze dryer, the samples were reweighed to determine dry weight so that the percentage of moisture lost by each sample could be calculated. Samples were then stored in a desiccator until analyzed.

Digestion (Wet Oxidation) of Samples

Freeze-dried samples were prepared for atomic absorption spectrophotometric (AAS) analysis using a nitric (HNO_3):perchloric ($HClO_4$) acid digestion procedure. This procedure, as used in our laboratory, yielded very acceptable procedural blanks (Table VII-5). In this procedure the volume of acids used was minimized by employing an essentially closed refluxing system during the digestion process. A 1-2 g dry weight sample was placed in a spoutless, electrolytic style Pyrex beaker, to which were added 4-5 ml of 70% HNO_3 per gram of sample and 1 ml total of $HClO_4$. The beaker was covered with a 75 mm, non-ribbed Pyrex watchglass and allowed to sit overnight at room temperature. The mixture was then refluxed at low heat on a hotplate for 6 to 24 h. A bent glass rod was placed between the beaker lip and the watchglass, and the heat was increased to permit HNO_3 evaporation. At the first sign of white $HClO_4$ fumes (i.e., when most of the HNO_3 was gone), the glass rod was removed, allowing the watchglass to again rest flush on top of the beaker. The sample was allowed to reflux until the solution cleared completely. If the sample did not clear, an additional 1 ml of HNO_3 and 0.5 ml $HClO_4$ was added and the refluxing continued until clearing occurred. This step was repeated once, if necessary.

Finally, the watchglass was removed and the mixture was allowed to evaporate to near dryness. Spike recovery experiments conducted frequently during the 1976 study showed that there was no significant loss of any of the metals studied during this digestion procedure (Presley and Boothe, 1977).

Each digested sample was transferred to a tared 30 ml Oak Ridge type, screw-top polypropylene centrifuge tube by washing the beaker several times with 0.1 N HNO_3 (Baker Ultrex grade) and pouring the resultant solutions into the centrifuge tube. This transfer procedure was apparently quite complete. To determine the amount of metals remaining, randomly selected beakers were occasionally rinsed with stronger acid (1 N HNO_3) after the sample had been removed. This acid solution was then analyzed using our routine AAS procedures. Even for livers which contain relatively high levels of the trace metals studied, the residual amounts of metals in the digestion beakers were minimal (i.e., much less than 1% of the total of each element analyzed). Each sample was brought to approximately 25 ml, thereby diluting the original dry weight sample 10 to 20 times. The volume of each sample was determined by reweighing the filled sample tube and making a small correction (e.g. 1.01-1.04, pH 0.5-1) for the specific gravity of the sample solution, which was determined for each digestion. Further dilutions from the original solution were made on a weight/weight basis in 5 dram snap-cap vials using 0.1 N HNO_3.

All digestion glassware were soaked immediately after use for up to several days in a solution of "Micro" detergent and distilled water in covered polyethylene pans. The glassware were then rinsed thoroughly with deionized water and soaked in 3 N reagent grade HNO_3 in covered polyethylene or polypropylene pans until the next use. The centrifuge tubes were prepared for use by cleaning in a "Micro" solution. They were then filled with 5 N reagent grade HNO_3, heated for several days at 50°C, and stored at room temperature until used. Prior to use, the tubes were emptied, rinsed thoroughly with deionized water, and tared. The 5 dram snap-cap vials used for further dilutions were filled with 1 N reagent grade HNO_3 and allowed to sit at room temperature for several days. Prior to use they were emptied, rinsed with deionized water, and tared.

Three to five procedural blanks were included with each group of samples digested to determine the amount of each metal contributed to the samples by the digestion glassware and reagents. These blanks received the same reagents and treatment as the tissue samples. An aliquot of the 0.1 N HNO_3 used to transfer and dilute the samples was placed in a centrifuge tube and analyzed with each digestion as a diluent/tube blank. Reagent blanks were analyzed for all bottles of acid prior to their use in sample digestion. These blanks were prepared by taking $\geq$ 10 ml of acid, evaporating it to near dryness in digestion glassware, and transferring the residue to a centrifuge tube in the same manner described above. For each series of dilutions made using 5 dram vials, one or more vial blanks were prepared and analyzed.

TABLE VII-5

ACCURACY, PRECISION, AND CHARACTERISTICS OF ATOMIC ABSORPTION ANALYSES

ELEMENT	STANDARD REFERENCE MATERIAL BOVINE LIVER (NBS NO. 1577)		PRECISION[1]		MINIMUM DETECTABLE CONCENTRATION[2]	SENSIVITY[3]	AVERAGE TOTAL PROCEDURAL BLANK
	This Study (n=15)	NBS Values	This Study	NBS Values	(ppb)	(pg or ppm)	(ng)
	Concentration (ppm dry wt. ±1 S.D.)						
Cd	0.28 ± 0.03	0.27 ± 0.04	11	15	0.025	9.0	4
Cr	0.08 ± 0.02	< 0.2[4]	25	NA	1.0	25.	25
Cu	190 ± 15	193 ± 10	8	5	*	0.05	< 75
Fe	244 ± 42	270 ± 20	17	7	*	0.07	< 100
Ni	0.08 ± 0.03	< 0.2[4]	38	NA	4.0	100.	< 95
Pb	0.38 ± 0.08	0.34 ± 0.08	21	24	0.30	25.	28
Zn	130 ± 11	130 ± 10	8	8	*	0.02	< 75

*Minimum detectable concentration was generally about one half of the sensivity.

[1]Precision expressed as percent coefficient of variation; i.e. [Standard deviation (S.D.)/mean] x 100.

[2]At 10x scale expansion and approximately 1 chart unit; except Ni at 3x and 2 chart units.

[3]For Cd, Cr, Ni, Pb: average amount of metal injected giving a signal of .0044 absorbance units.
For Cu, Fe, Zn: average concentration giving a signal of .0044 absorbance units.

[4]Not certified values.

Atomic Absorption Spectroscopy (AAS) Procedures

AAS was used to determine the concentrations of seven elements (Cd, Cr, Cu, Fe, Ni, Pb, Zn) in 1978 oyster samples. Flameless AAS was used to measure Cd, Cr, Ni and Pb. These analyses were made using a Perkin-Elmer Model 306 atomic absorption spectrophotometer equipped with an HGA-2100 graphite furnace atomizer. The operating characteristics for these analyses are given in Table VII-5.

External and internal furnace purge gas flow rates were verified at specified levels of 0.9 and 0.3 l/min, respectively, at 2.76 bar delivery pressure. The injection volume was .025 ml. The furnace temperature gauge was calibrated using a clamp-on (inductive) ammeter and an optical pyrometer.

Dry, char, and atomization temperatures and times were optimized for each metal, using selected representative samples according to the manufacturer's recommendations (Perkin-Elmer Corp., 1974). Nonresonance lines used for this optimization to estimate the magnitude of broad band molecular absorption for various sample types were 226.5 (Cd), 231.6 (Ni), 282.0 (Pb), and 352.0 (Cr) nm. Corrections for nonspecific or broad band molecular absorption were made by a deuterium arc background corrector. For Cd and Pb, sample dilutions $\geq$ 1/50 were used for quantitation, and for Cr and Ni, dilutions of $\leq$ 1/50. Chemical interference was evaluated and corrected as necessary by frequent use of the standard additions technique and check dilutions. Mixed standard metal solutions were prepared in dilute HNO_3 (Baker Ultrex grade) by diluting concentrated commercial atomic absorption standards. Samples were quantitated by peak height comparison with bracketing standards injected before and after the sample. Consideration was given to temporal variations in instrumental sensitivity, nonlinearity between bracketing standards, and gross differences in peak shape.

Analysis of Cu, Fe, and Zn was by flame AAS using a Jarrell-Ash Model 810 atomic absorption spectrophotometer. Analyses were carried out following the manufacturer's recommended procedure (Fisher Scientific Co., 1971; 1972). A summary of the operating characteristics for these analyses is given in Table VII-5.
Non-specific absorption was monitored by measuring simultaneously the absorbance of a nonresonance line and the analytical line of the element of interest. A fairly lean air-acetylene flame with flow rates of approximately 7 and 2.5 l/min, respectively, was used for all three elements. Aspiration rate was generally 5 to 6 ml/min. Chemical interference was checked by use of the standard additions technique. Mixed standards used were prepared as described above.

The accuracy and precision of AAS analysis was evaluated by analyzing a National Bureau of Standards (NBS) standard biological reference material (i.e. #1577 bovine liver) with each digestion. The results of these analyses compared to NBS certified values are given in Table VII-5. Why our average Fe concentration is consistently below the NBS value is not known. Several different batches of Fe standards

were used to determine these various concentrations during the course of this study.

Analyses of Vanadium

The determination of V in marine samples by neutron activation analysis (NAA) is degraded significantly by background activities of ^{24}Na and ^{38}Cl. The removal of these interferents is thus necessary prior to activation.

To remove Na, an aliquot of each organism digestate was diluted with an equal volume of 16 N HNO_3. The resulting solution was passed through a column of hydrated antimony pentoxide (HAP) according to the procedure of Girardi and Sabbioni (1968) as modified by Science Applications, Inc. (SAI) (Reed, 1977). Vanadium is not quantitatively eluted from this column. Corrections for incomplete recovery from the column were made on the basis of spiked replicate samples run with every group of samples. The antimony (Sb) carryover experienced by SAI is a continuing problem. However, careful manipulation of the times for irradiation, pre-counting delay, and counting has yielded detection limits of 10-20 ng V, which is adequate for the Spondylus samples. Chloride in the elutriate was removed by adding 0.2 m of concentrated H_2SO_4 and evaporating the solution in a teflon beaker to near dryness or until SO_3 fumes were observed. The teflon beaker contents were poured into a 1.5 ml irradiation polyethylene vial used by the Texas A&M University Nuclear Science Center. The vial was heat-sealed and placed in a secondary polyethylene container and heat-sealed again to prevent sample loss during analysis and handling.

Each sample was irradiated separately for one minute by a 1 MW TRIGA reactor. This process was facilitated by a pneumatic transport system which can rapidly transfer samples in and out of the reactor core. Standards prepared from commercial AAS standards were used.

After return of the sample and an appropriate delay period (usually two minutes, so that the dead time was < 30 %), the irradiated sample was placed on an ORTEC Ge(Li) detector and counted using a separate Canberra SCORPIO 1000 data acquisition and analysis system. After a two-minute counting period, the spectrum was stored on magnetic tape.

Data reduction was done using the program HEVESY (Schlueter, 1972). This program calculates peak intensities and converts them to concentration by comparison with standards. Corrections were made for varying delay times, dead times, and neutron fluxes.

One characteristic of NAA is its capability for analyzing several elements from a single irradiation. The concentrations of Al and Ca were determined concurrently with V analysis. However, the analytical conditions could not be optimized for all three elements during a single irradiation. The sensitivity for Al was good, and the Al concentration data satisfactory. However, the analysis was marginal for Ca, so these data should be considered in this light.

Sediment

Sampling Procedures

Surface sediment samples were collected from the sampling sites with a Smith-McIntyre grab. Uncontaminated sediment from the center of the grab was taken to a depth of 5 cm with a plastic scoop, placed in labeled plastic containers, and frozen until returned to the laboratory.

Laboratory Procedures

Prior to analysis, the samples were thawed and homogenized with a plastic rod. Approximately 8 g were removed and placed in 30 ml acid-washed plastic centrifuge tubes. These sediments were washed twice with 15 ml of distilled, deionized water to remove salts, with the water being discarded following centrifugation.

While still in the centrifuge tube, the samples were freeze dried to constant weight (approx. 48 h). The dried sediment was transferred from the tubes to acid-washed, plastic, snap cap vials and homogenized by shaking in a Spex Mixer/Mill.

For determination of leachable trace elements, approximately 1.4 g of dry sediment were transferred to clean 30 ml centrifuge tubes, excluding material greater than 3 mm diameter. To minimize foaming during carbonate dissolution, 15 ml 5 N redistilled nitric acid was added slowly. The tubes were capped and mixed for 30 min on a rotary shaker. Then 15 ml of distilled, deionized water were added, and the tubes were capped and shaken manually. The leachate was separated from the residual sediment by centrifugation, then poured into a clean snap cap vial and saved for analysis.

For determination of total trace element content, approximately 1 g of dry, salt-free sediment was transferred from the storage vials to clean Teflon beakers. Concentrated hydrofluoric and perchloric acids were added (6 and 2 ml, resp.) and the samples were covered with Teflon watchglasses and heated on a hot plate for 4-5 h. The watchglasses were removed and the samples were evaporated to dryness. The acid treatment was repeated, and prior to evaporation 0.5 ml of conc. H_2SO_4 was added to drive off Cl. The dry sample was dissolved with 2 ml of conc. HNO_3, to which small quantities of distilled, deionized water were gradually added while heating. The resulting solution was diluted to 25 ml with distilled, deionized water and stored in a clean snap cap vial.

Leachate and total digest solutions were analyzed for Cr, Cu, Fe, Ni, Pb, and Zn by flame atomic absorption spectrophotometry (AAS) on a Jarrel-Ash Model 810 atomic absorption spectrophotometer. Instrumental settings, as optimized from the manufacturer's recommendations, are presented in Table VII-6. Non-specific molecular background absorption was monitored by the use of a nonabsorbing line.

Cadmium was analyzed by flameless AAS on a Perkin Elmer Model 306 equipped with an HGA2100 graphite furnace and a deuterium arc background corrector. Instrumental settings are presented in Table VII-6.

Barium and vanadium were determined by neutron activation analysis of aliquots of leachate and total digest solutions. Sample irradiation, counting, and data reduction were performed at the Texas A&M Nuclear Science Center with a 1 MW TRIGA reactor, an analog-to-digital converter coupled to a Ge(Li) detector for gamma-ray spectroscopy, and a Canberra SCORPIO computer analysis system. Both elements were determined by the comparator method using standards irradiated and counted under conditions identical to those of the samples. Barium was determined by counting the ^{131}Ba 497 keV photopeak for 20 min following a 14 h irradiation and a 14 day decay period. Vanadium was determined by counting the 1433 KeV photopeak of ^{52}V for 2 min following a 30 sec irradiation and a 4 min decay period. Information on accuracy and precision was determined through analysis of USGS MAG-1 reference samples and replicates of a house sediment reference sample (Table VII-6).

TABLE VII-6
INSTRUMENTAL PARAMETERS FOR ANALYSIS OF TRACE METALS IN EAST FLOWER GARDEN SEDIMENTS BY ATOMIC ABSORPTION

FLAME	ELEMENT	WAVELENGTH (nm)	SLIT WIDTH (Å)	HGA 2100 Temp.	HGA 2100 Time
Air-C_2H_2, oxidizing	Cu	324.7	4	—	—
Air-C_2H_2, reducing	Cr	357.9	1	—	—
Air-C_2H_2, oxidizing	Fe	248.3	2	—	—
Air-C_2H_2, oxidizing	Ni	232.0	2	—	—
Air-C_2H_2, oxidizing	Pb	283.3	4	—	—
Air-C_2H_2, oxidizing	Zn	213.9	4	—	—
Flameless	Cd	228.8	0.7	Dry 85°C Char 300 Atom. 1800	60 sec 60 8

ELEMENT	NO. OF ANALYSES	MEAN CONCENTRATION[1] This Laboratory	MEAN CONCENTRATION[1] Certified Values[2]	PERCENT[3] ACCURACY	TOTAL[4] PRECISION
USGS MAG-1 Standard Marine Sediment					
Al	2	8.20 (%)	8.70 (%)	94	0.6
Ba	2	448	476	94	6.2
Cu	2	27	30	90	-
Cr	2	91	103	88	-
Fe	2	4.9 (%)	4.8 (%)	102	-
Ni	2	55	62	89	-
Pb	2	28	28	100	-
V	2	110	120	92	-
Zn	2	125	124	101	-
House Marine Sediment Standard					
Cu	4	16 ± 0.55			3.4
Cr	4	59 ± 4.0			6.8
Fe	4	3.0 ± 0.02			0.7
Ni	4	30 ± 0.30			1.0
Pb	4	24 ± 1.4			5.8
V	2	110 ± 2.1			1.9
Zn	4	80 ± 0.90			1.1

[1]Parts per million dry weight ± one standard deviation except Al and Fe in percent.

[2]Certified values were selected by Manheim et al. (1976), as being the best values available for USGS MAG-1 based on numerous determinations by various investigators.

[3]This laboratory value/certified value x 100.

[4]Total precision expressed as percent coefficient of variation: (std. dev./mean) x 100.

PROCEDURES FOR HIGH MOLECULAR WEIGHT ANALYSIS IN ORGANISMS

C. Giam, G. Neff, Y. Hrung

Materials

Solvents were Mallinckrodt Nanograde® and were used as received or redistilled when required. Silica gel (Woelm, 70-230 mesh) and Aluminum Oxide Woelm Neutral (Activity Grade 1) were activated at 200°C for at least 24 h before use. Hydrocarbon standards were obtained from Analabs, Polyscience Co., ICN K&K Laboratories, Inc., and Aldrich Chemical Company, Inc.

Instrumentation

A Hewlett-Packard 5830A gas chromatograph (GC) and a Varian 3700 equipped with dual flame ionization detectors and programmable integrators were used. They were equipped with 30 m WCOT SP-2100 glass capillary columns. Hydrogen was used as the carrier gas. The injector was at 270°C and the detector at 300°C. The column oven was temperature-programmed from 70°C to 270°C at 3°C/min.

Procedure

Background Reduction

Prior to actual sample analysis, procedure blanks and recovery studies were performed. All solvents to be used in the procedure were concentrated to the extent required by the procedure and analyzed by gas chromatography. Any solvent exhibiting any impurities in the hydrocarbon region of the spectrum was rejected or redistilled in an all-glass system. Solid reagents were purified by heating in a 325°C oven for at least 24 hours; concentrates of solvent rinses of these reagents were inspected by gas chromatography as described for solvents. Glassware and equipment were washed with "Micro" cleaning solution (International Products Corp.) and distilled water, rinsed with acetone, methanol, and hexane, and heated overnight at 325°C. After heating, they were rinsed with two portions of benzene and two of hexane. The final hexane rinse was concentrated and checked by gas chromatography. If any impurities were present, rinsing was repeated as needed to obtain an acceptable blank. Glassware checks accompanied each sample run, and procedure blanks were performed at frequent intervals. (Procedure blanks constituted approximately 10% of the total analyses.)

Extraction and Saponification of Macrofauna

The amount of tissue used was dependent on the size of the organism to be analyzed; the maximum amount used was approximately 100 g. Each sample was macerated with a Polytron® homogenizer and the wet weight determined. An aliquot of the sample was then placed in a tared beaker and dried at 60°C until a constant weight was obtained. In

this manner, the wet and dry weights of the sample were obtained. The remainder of the sample was saponified.

Saponification was conducted by refluxing the sample with 0.05 g KOH/g tissue in approximately 50 ml methanol/100 g tissue. Saponification was continued until the tissues were digested. After the completion of digestion, an equal volume of distilled and petroleum ether-extracted water was added to the mixture. The mixture was then refluxed overnight. Upon completion of hydrolysis, the mixture was diluted with an equal volume of a 5% NaCl solution. The mixture was then extracted three times with n-pentane. The volume of n-pentane used for each extraction was equivalent to the volume of methanol initially used in the saponification. The n-pentane fractions were then combined and washed with an equal volume of water. The solvent was removed from the pentane extract (for weight determination) prior to column chromatographic separation.

Column Chromatography

A weight ratio of about 100 parts alumina to one (1) part lipid sample and 200 parts silica gel to one (1) part lipid sample was used. The columns used were 20 cm long with an internal diameter of 0.9 cm. Both the silica gel and the neutral alumina were Activity I. The column was packed in hexane and rinsed with one column volume of n-pentane. At no time was the column allowed to run dry. The extract, taken up in a small volume of n-pentane, was then applied to the column and the aliphatic fraction eluted with two column volumes of n-pentane. This was followed by elution of aromatics with two column volumes of benzene. The eluates from the two fractions were then taken to near dryness and transferred to screw cap vials. The remainder of the solvent was removed with a stream of purified nitrogen, and the vials were capped with teflon-lined caps. Following column chromatography, all eluates were analyzed by gas chromatography.

Gas Chromatographic Separations

Each eluted fraction obtained from the column chromatographic separation was quantitatively dissolved in a small volume of isooctane for injection into the gas chromatograph (GC). A WCOT glass capillary column (30 m, SP-2100) was used for the analyses. The column resolved n-C_{17} from pristane and n-C_{18} from phytane with a resolution (R) of approximately unity, where

$$R = \frac{2d}{(w_1 + w_2)} \quad \text{and,}$$

w is the width of each peak at the base on one phase for both pairs of components, and

d is the distance between apices.

The column was also capable of resolution of hydrocarbons from n-C_{14} through n-C_{32}. To assist identification, the following

compounds were used as standards to match the retention times of peaks in the gas chromatogram: aliphatic hydrocarbons C_{14}-C_{32}; trimethylbenzene; 1,2,3,5-tetramethylbenzene; 1,2,3,4-tetramethylbenzene; naphthalene; 2-methylnaphthalene; 1-methylnaphthalene; 1,5-dimethylnaphthalene; 2,3-dimethylnaphthalene; 4-phenyltoluene; 3,3'-dimethylbiphenyl; 4,4'-dimethylbiphenyl; fluorene; 1-methylfluorene; phenanthrene; anthracene; 9-methylanthracene; fluoranthene; and chrysene.

Gas Chromatography-Mass Spectrometry (GC-MS)

Aliquots of extracts from 10% of the GC samples were analyzed by GC-MS. The runs were made by J. Efimenko of the Texas A&M Center for Trace Characterization. Since the concentrations of components were very low (often near the limit of detection of GC-MS), only major components found in gas chromatograms were identified.

The analyses were performed with a Hewlett-Packard 5982A dodecapole mass spectrometer interfaced to a 5980 gas chromatograph. This GC-MS system was supported with a 5933A Data System, a Tektronix 4012 CRT terminal, a Tektronix 4631 Hard Copy Unit, and a 15,000 spectra reference library stored on a single disc (Aldermaston).

Capillary columns coated with SE-30 (30 m) or SP-2100 (30 m) were used in the GC. Helium was used as the carrier gas at 1.5 cc/min. All samples were run in the splitless mode with injector flush occurring 50 seconds after injection. The temperature was held at 70°C for two minutes and then raised to 270°C at 4°C/min. The column effluent was taken directly into the ion source producing a pressure of 10^{-5} torr. The source temperature for all runs was 185°C $\pm$ 10°C. The mode of ionization was electron impact using a beam of 70 eV electrons at a current of approximately 200 μa. Mass range was scanned from 50 to 500 amu at a rate of 162 amu/sec.

The total ion chromatogram for each sample was permanently stored on auxillary discs. The spectra were background-subtracted where necessary. Major sample components which appeared in both GC and GC-MS were identified. The electron-impact spectra of individual components were permanently stored on disc for comparison with library spectra or for other uses. Individual spectra from data files were compared: 1) by computer with spectra included in the Aldermaston Library on disc using the "search" routine; 2) with reference spectra run on our instrument; and 3) with the "Eight Peak Index of Mass Spectra" (Mass Spectrometry Data Center).

PROCEDURES FOR THE ANALYSIS OF HIGH MOLECULAR WEIGHT HYDROCARBONS, DELTA C-13, AND TOTAL ORGANIC CARBON IN SEDIMENT

P. Parker, R. Scalan, J. Winters, D. Boatwright

Analysis of High Molecular Weight Hydrocarbons in Sediment

Sample Procedures

Samples were obtained by subsampling Smith-McIntyre grab samples. Approximately 400 g of sediment taken from the top 5 cm of the grab were transferred to precleaned glass or Teflon jars. The jars were labeled, immediately frozen, and stored for subsequent analyses.

Laboratory Procedures

Approximately 300 g of freshly thawed sediment were dried by filtering on a Buchner funnel, resuspending the sediment in 400 ml of anhydrous methanol by sonication, and filtering the suspension on a Buchner funnel.

The filtrates were combined, concentrated under vacuum, and saved for subsequent extraction.

The dried sediment was transferred to a large, round-bottom flask and extracted via reflux for 17 h with 300 ml of benzene-methanol azeotrope (3:2, by volume). After filtration, the sediment was extracted a second time for 4 h and filtered. The filtrates were combined, concentrated under vacuum, and added to the concentrated methanol wash. The concentrate was transferred to a separatory funnel, an equal volume of water added, and the solution extracted with hexane (3 x 30 ml) and benzene (1 x 30 ml). The extracts were combined, concentrated under vacuum to approximately 2 ml, and saponified for 6 h with 50 ml of 1N KOH in 85% methanol. This was concentrated under vacuum to approximately 10 ml, an equal volume of water added, and the solution extracted with hexane (3 x 20 ml) and benzene (1 x 20 ml). The extracts were combined, concentrated under vacuum to approximately 1 ml, and chromatographed on a slurry packed silica gel column (220 x 11 mm). Elution was accomplished with two column volumes (30 ml) each of hexane, benzene, and methanol. The hexane and benzene eluates, which contained the aliphatic and aromatic fractions, respectively, were collected and saved. The methanol eluate was set aside for future analysis. Gas chromatographic analyses were performed on a 0.25 mm (I.D.) x 27 mm OV-101 gas capillary column installed in a Perkin-Elmer Model 910 Gas Chromatograph equipped with a flame ionization detector. The operating conditions are shown in Table VII-7.

Electronic integration of peak areas was performed by a Hewlett-Packard 3352B Data System. The concentration of individual components was determined by the use of internal and external standards. The identification of individual components was determined by co-injection

with hydrocarbon standards and, for certain selected samples, by combined gas chromatography-mass spectrometry.

Analysis by combined gas chromatography-mass spectrometry was performed on a Finnigan Model 4023 Mass Spectrometer with an INCOS Data System. The gas chromatograph interfaced with this system was a Finnigan Model 9601 fitted with a 0.25 mm x 30 m SP-2100 glass capillary column. Operating conditions are shown in Table VII-7. Definitive identification was accomplished by this GC/MS/DS analysis using specific ion mass-chromatograms and mass spectra of individual components.

Analysis of Delta C-13 in Sediment

Sample Procedures

Samples were obtained by subsampling Smith-McIntyre grab samples. Approximately 400 g of sediment taken from the top 5 cm of the grab were transferred to precleaned glass or Teflon jars. The jars were labeled, immediately frozen, and stored for subsequent analyses. This represents a subsample of the high molecular weight hydrocarbon sample.

Laboratory Procedures

The method for the determination of Delta C-13 values was the same as in previous years of this study (Parker et al., 1972, 1979). The CO_2 from the total organic carbon (TOC) measurement was transferred to a sample collection bulb, vented into a Nuclide Corporation Model RMS-60 Isotope Ratio Mass Spectrometer, and its 13°C/12°C isotope ratio determined relative to the PDB standard.

Analysis of Total Organic Carbon (TOC) in Sediment

Sample Procedures

Samples were obtained by subsampling Smith-McIntyre grab samples. Approximately 400 g of sediment taken from the top 5 cm of the grab were transferred to precleaned glass or Teflon jars. The jars were labeled, immediately frozen, and stored for subsequent analyses. This represents a subsample of the high molecular weight hydrocarbon sample.

Laboratory Procedures

The method for the determination of total organic carbon (TOC) was the same as in previous years of this study (Parker et al., 1972, 1979).

Approximately 5 g of freshly thawed sediment was acidified with excess 6 N HCl and set aside for 4-6 h until all carbonate material had been destroyed. The residue was filtered, rinsed with water until neutral, and dried overnight at 60°C. Then 500 mg of the sample was burned in a LECO induction furnace and evolved CO_2 was measured manometrically.

TABLE VII-7
GC-MS STANDARD OPERATING CONDITIONS

OPERATING CONDITIONS	*GAS CHROMATOGRAPH	
	Perkin-Elmer Model 910	Finnigan Model 9601
Carrier Gas	He	He
Carrier Flow	2 ml/min	2 ml/min
Initial Time	1 min	5 min
Initial Temperature	100°C	70°C
Programmed Rate	5°C/min	5°C/min
Final Temperature	285°C	250°C
Final Time	20 min	30 min
	*MASS SPECTROMETER	
	Finnigan Model 4023	
Source Temperature	250°C	
Electron Accelerating Potential	70 volts	
Ion Accelerating Potential	1400 volts	
Mass Range Scanned	600 - 40 amu	
Scan Speed	4 sec/decade	

* The Finnigan Model 9601 gas chromatograph was interfaced with the Finnigan Model 4023 Mass Spectrometer for combined GC-MS analysis.

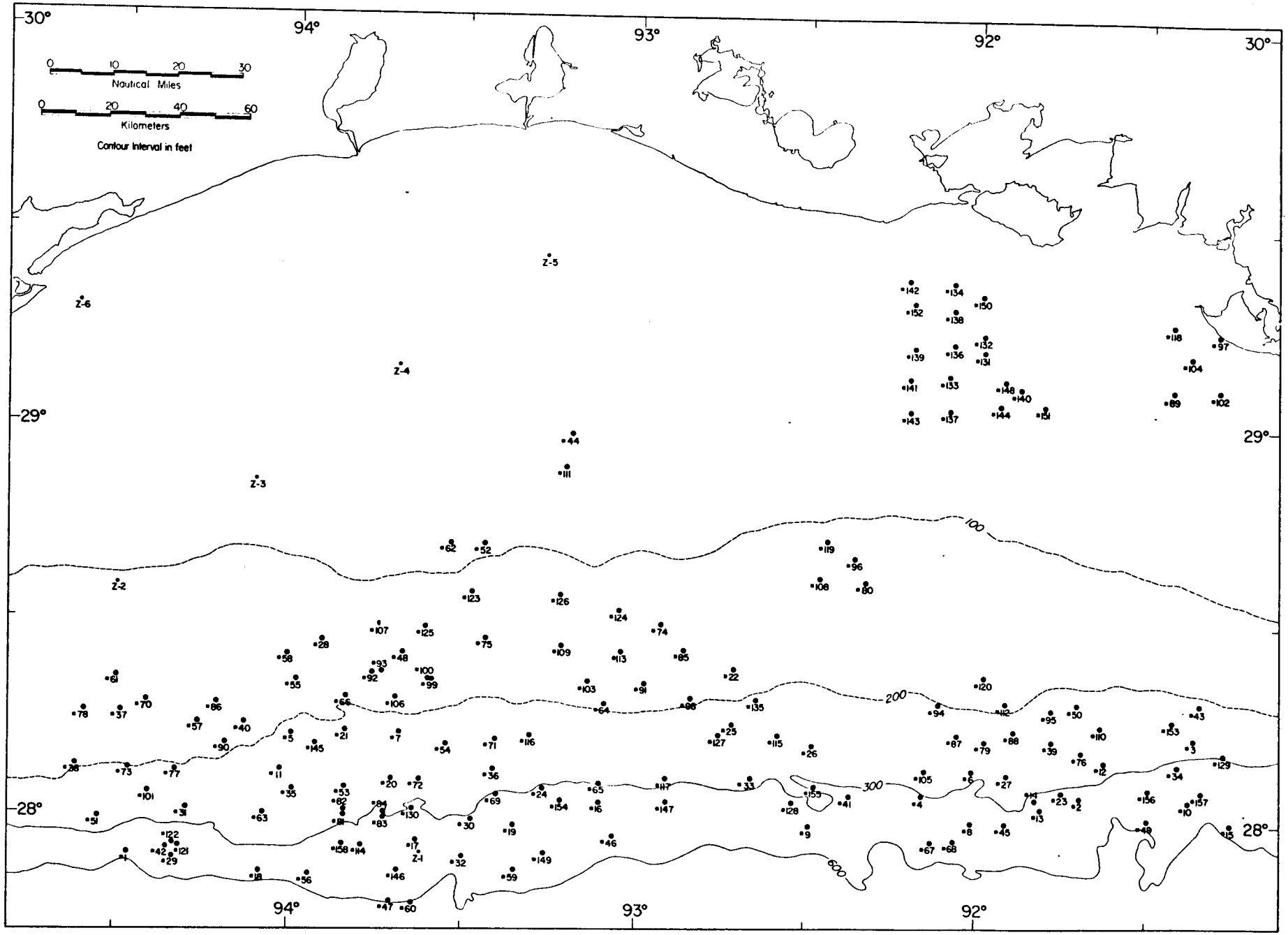

Figure VIII-1. Sample location map for surficial sediment samples (Tenneco suite + Z-transect). (See Appendix B, Tables VIII-1 and 2.)

CHAPTER VIII

LONG TERM SUSPENDED SEDIMENT DISPERSAL (FOSSIL COCCOLITHS)

S. Gartner, A. Levitan, M. Jiang

INTRODUCTION

In 1976-77 a study was undertaken as part of the South Texas Topographic Features Study to evaluate the potential usefulness of modern and fossil coccoliths as tracers for long term suspended sediment dispersal on the continental shelf in the vicinity of the topographic features which are located mainly toward the edge of the continental shelf. The results of that initial study were encouraging, and the study was subsequently expanded in 1977-78. The data base was increased substantially so that the sample spacing would be adequate to confirm and define possible significant anomalies indicated during the initial study. The final results were spectacular in that they showed that the dispersal pattern for the suspended sediment is rather different from what had been inferred from grain size distribution studies. These new results were, however, compatible with inferred current regimes in the area (for details see Gartner, in Bright and Rezak, 1978b).

The rationale and detailed justification for using a ratio of redeposited to indigenous modern coccoliths to trace suspended sediment dispersal are given in the 1978 report to the Bureau of Land Management (see Gartner, in Bright and Rezak, 1978b); therefore, only a brief summary will be given here.

Redeposited coccoliths, mainly fossil Cretaceous species, are eroded in a belt from the landward edge of the coastal plain and enter the Gulf of Mexico as suspended particles at several point sources where rivers or bays and estuaries connect with the open Gulf. Prevailing currents redistribute these particles across the continental shelf where they accumulate with other fine sediment, including the distinctly different coccoliths contributed by the modern coccolithophores living in the overlying water column. The relative abundance of redeposited fossil coccoliths, therefore, reflects the relative proportion of coccolith size (.001 mm to .01 mm) suspended sediment transported into a particular area, and a gradient in abundance would then suggest direction of dispersal or transport of suspended particles.

Techniques for sample collection and analysis are the same used in previous studies (Bright and Rezak, 1978a, pp. 136 and 148-49; Bright and Rezak, 1978b, pp. V-8 to V-10). These are described above in Chapter VII.

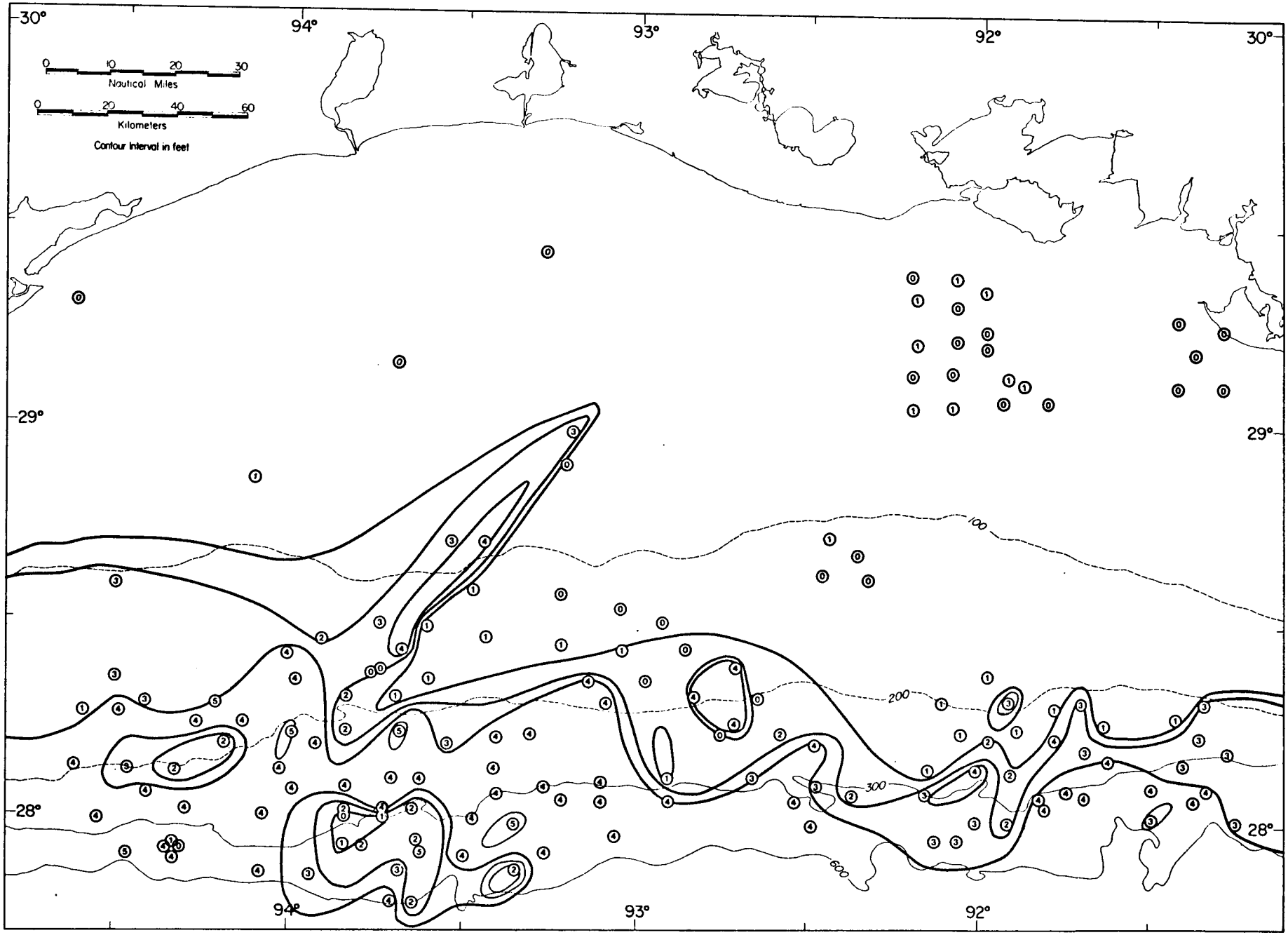

Figure VIII-2. Distribution of fossil and modern coccoliths in surficial sediment, northern Gulf of Mexico. Numbers are exponential values of the proportion of modern and fossil species (for explanation of how this number is obtained, see Study Techniques, Chapter VII).

RESULTS AND INTERPRETATION

The data from this study are reported in tabular form in Appendix B, Tables VIII-1 through 14. The data have also been plotted on maps (Figures VIII-1 through 11) so that they can be contoured for visual presentation.

Surface Sediments

Outer Continental Shelf

From a large collection of samples taken by Tenneco Oil Co., mostly on the outer part of the northern Gulf of Mexico continental shelf, a representative, more or less uniformly spaced, suite of 189 samples was selected for study and characterization of the distribution of calcareous nannofossils in surface sediments. In addition, six samples were collected in a Z-transect on the continental shelf south and east of Galveston. The locations for these samples are given in Figure VIII-1 (above). Only 158 stations are plotted because some of the 189 samples were duplicates, samples from near stations where the initial values were anomalous, or considered not representative after the initial analysis. The reduced data from the analyses (Appendix B, Tables VIII-1 and 2) are plotted and contoured on the same base map on Figure VIII-2. The greatest concentration of redeposited species (equal to the largest proportion of indigenous modern species) is represented by the number 1; the lowest concentration of redeposited species (equal to the largest proportion of indigenous modern species) is represented by the number 5.

In general the trend is that the greatest concentration of redeposited species is found in the landward direction and the proportion of indigenous modern species increases in the basinward direction, more or less with increasing water depth. Curiously, virtually no coccoliths, fossil or modern, were found in sediment inside (shoreward of) the 100 ft (31 m) isobath. Only beyond water depths of about 150 to 200 ft (46-61 m) are coccoliths consistently present.

The reason why coccoliths are nearly uniformly absent inside the 100 ft or the 150 ft isobath is not immediately obvious. It is clear that winnowing and current transport are not the causes because the fine silt- and clay-size fraction is abundantly represented in these sediments. A more probable explanation is that bottom water and/or pore water chemistry is detrimental to preservation of fine carbonate particles, since clay- and silt-size particles of all kinds are also uniformly absent from these samples.

On the outer continental shelf and in the region of the shelf break, the general trend of an increase in the proportion of indigenous modern species in the basinward direction is clearly discernible. The actual pattern is anything but simple, however, with numerous areas of anomalously high or low numbers of redeposited fossil Cretaceous species occurring over the area. Several anomalies are obviously related to the irregular topography of the area; specifically, some anomalies

seem to bear a relationship to the various banks that have been identified and mapped. Some anomalies, however, appear not to be associated with any major topographic feature, such as the prominent banks. One such anomaly, the largest feature in the distribution pattern of modern and fossil coccoliths, is located north (shoreward) of the Flower Garden Banks and is a tongue- or finger-shaped extension of a high proportion of modern indigenous species, extending from about the 200 ft (61 m) isobath northeastward to well inside the 100 ft (31 m) isobath. The cause for this anomaly is not immediately obvious, although it may indicate that in the water above the anomaly there is a subtle hydrographic boundary which has not yet been recognized. It is interesting and perhaps useful to note that if projected seaward this anomaly points out toward the continental slope between Stetson Bank and the Flower Garden Banks, passing just to the north and west of the West Flower Garden Bank.

Another feature worth noting is the small but persistent topographic irregularity of the continental shelf precisely at this anomaly. The topographic feature in question is a low ridge running just north of the Flower Gardens with a gentle slope dropping off and blending into the topography to the south and southeast, and with a low but steep drop off to the northwest (shelf side). This ridge is a subtle feature indeed and not discernible on most bathymetric maps of the Texas-Louisiana continental shelf (see e.g. Sorenson et al., 1975), although it can be clearly recognized on the much older and highly detailed bathymetric map published by the American Association of Petroleum Geologists (1970). Even on the latter map the coccolith ratio anomaly extends shoreward well beyond the limit of the ridge or the trough behind the ridge. It is reasonable to conclude, therefore, that it is not this low ridge nor the adjacent trough that controls the anomaly in the coccolith distribution but, rather, that the ridge may be related to (possibly responsible for) a local current. The effects of this current may extend upshelf a considerable distance beyond the point where the ridge and trough still have expression. Possibly the trough and/or ridge were sculpted during the latest Pleistocene exposure of the continental shelf and have since then been largely buried. Alternatively, a more complex relationship exists, one independent of late Pleistocene drainage across the shelf, but one that may possibly be related to present day currents on the shelf. It may be useful to establish whether it is the manifestation of a sink of fine grained sediment. Neither possibility can be ruled out from the data.

With regard to anomalies in coccolith proportions that are clearly associated with prominent topographic features, some interesting generalizations seem to suggest themselves. Unusually low concentrations of redeposited fossil coccoliths characterize areas north and west of topographic features. This generalization is true for Rezak-Sidner and Bouma Banks (sample spacing and the proximity of these banks to one another preclude resolving local trends individually for each bank), for Parker Bank, for Sonnier Banks, for Bright Bank, and for the Flower Garden Banks. The only bank within the study area that does not

show this pattern is Stetson Bank, but this bank is at a substantially shallower depth than the others.

There are several possible ways to interpret this pattern, although unfortunately it is not possible to say which is the correct interpretation. If one is willing to assume that the distribution pattern of modern and fossil coccoliths on the Outer Continental Shelf is due entirely to the action of currents on sediment particles, then it is reasonable to interpret the pattern as resulting from a dispersal of sediment particles from east (southeast) to west (northwest). This in turn implies long term fine sediment transport from east to west more or less parallel to the edge of the shelf. This process very probably contributed to the pattern around Parker Bank, Bouma Bank, and Sonnier Banks, but this no doubt is only part of the story.

The areas of high concentration of modern indigenous coccoliths are too large and broad to be attributable solely to current action around banks. This is particularly obvious for Bright Bank and the adjacent East Flower Garden where these high concentrations are found all around the bank, east, north, and west. If currents were the only responsible agent, then fine particulates (including the higher concentration of redeposited fossil coccoliths, which probably are relict features in the immediate vicinity of these banks) ought to be reflected as plumes extending out and away from the banks.

What, then, is the alternative?

A likely explanation is that the mere presence of the banks enhances productivity by providing a mechanism whereby nutrients are renewed to the surface by turbulence that results from currents impinging on the banks. This higher productivity ultimately contributes much of the fine biogenic particulate material, though both its presence and distribution are attributable to current action around the banks.

Selected Banks

Surficial sediment samples were collected also from the immediate vicinity, as well as from the surface, of six banks (Appendix B, Tables VIII-3 through 8). The most complete coverage is from East Flower Garden Bank, where 39 samples were taken on and around the bank. Although these samples were taken at three different times, they are nevertheless plotted on one map (Figure VIII-3). The fact that surficial sediment is sampled, the composition being the result of sedimentary processes acting over a period of time far longer than the sampling interval, justifies combining results from the three sets of samples. This rationale is borne out by the very similar results obtained from all of the stations, even though these stations may have been at significantly different locations around the bank and were indeed sampled at different times (for comparison of data see Appendix B, Table VIII-3).

When the data are reduced to exponential values and plotted on a base map of the East Flower Garden Bank (Figure VIII-3), only a very

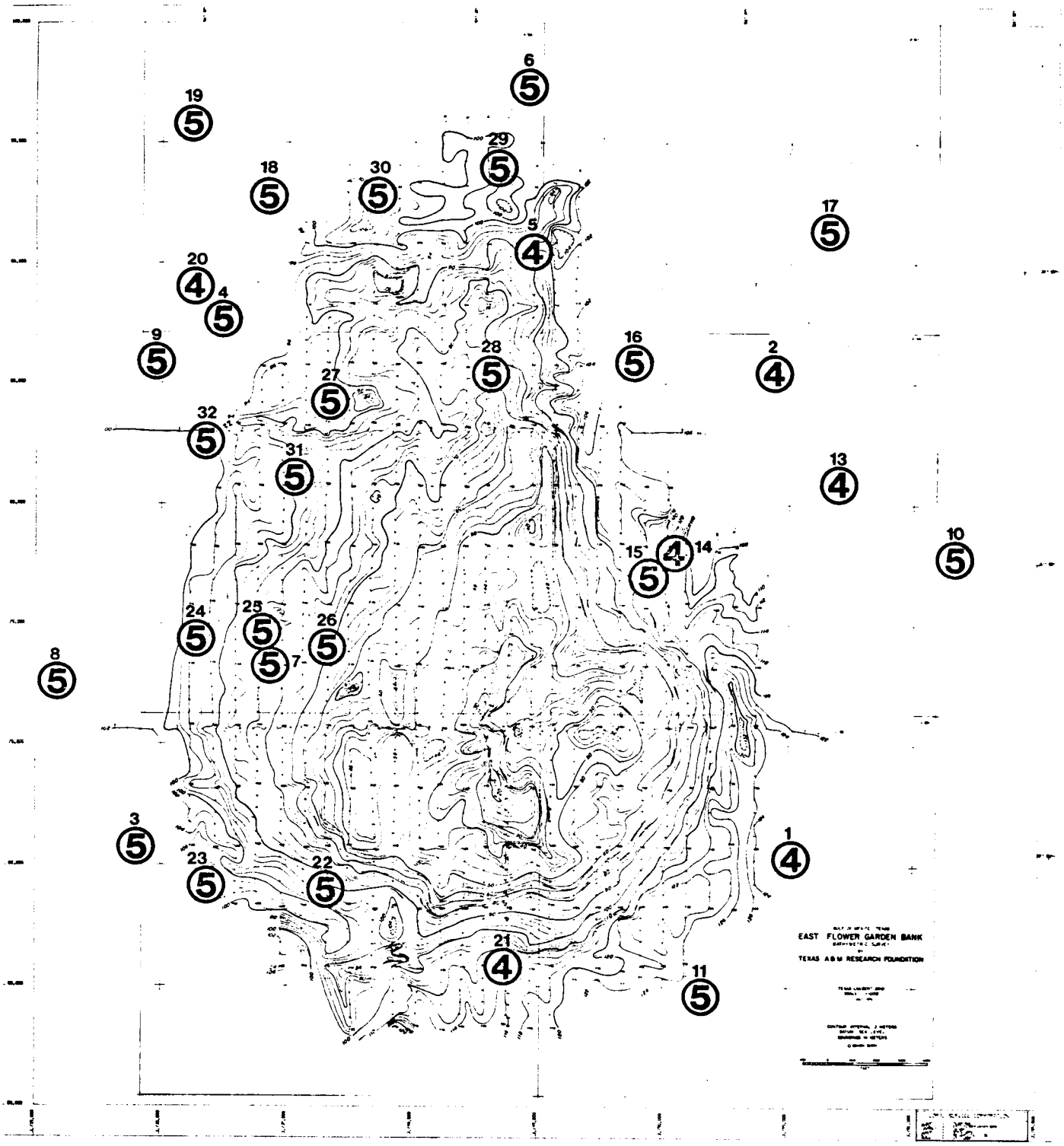

Figure VIII-3. Fossil and modern coccolith proportions in surficial sediment samples, East Flower Garden Bank, three seasons. (Only 32 of 39 samples are plotted; see Appendix B, Table VIII-3.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

weak pattern is discernible. The area surrounding the bank is dominated by an input of indigenous modern coccoliths with very few redeposited species being present. Only on the east side of the bank are redeposited species found consistently. Their occurrence makes an arcuate pattern from northeast of the bank around the east side and south of the bank. This pattern suggests either that a) deposition of fine detrital material originating from land is greater on the east and south side of the bank; or that b) surficial sediment to the south and east contains a significant proportion of relict material; or that c) the larger proportion of indigenous species to the north and west reflects high phytoplankton productivity resulting from renewal of nutrients by currents moving over the bank from the east and southeast to the west and northwest.

The data from the immediate vicinity of the bank and from on top of the bank cannot by themselves indicate which of the above three possibilities is the more likely. However, the larger pattern of surficial sediment data discussed in the previous section is most compatible with the last alternative: higher production of indigenous coccoliths northwest and north of the banks results in more intense dilution of land-derived detrital material. The ultimate cause for this higher productivity may be the interaction of the banks with prevailing deep currents of the shelf edge.

If the slightly higher proportion of redeposited species of fossil coccoliths on the east side of the bank is attributed to relict sediment (alternative b) above), then it follows that somewhat more current activity exists along the bottom on the east and southeast sides of the bank than on the west and southwest sides. From the point of view of fine sediment dispersal, both of the above explanations imply that fine silt- and clay-size particles would be least likely to be moved or resuspended on the north, northwest, and west side of the bank, whereas on the south, southeast and east side of the bank there is a greater possibility that such fine sediment particles could be moved, however feebly, by bottom currents.

Four samples were also examined from each of the five second priority banks, the samples being from the four primary stations at each bank (Figures VIII-4 through 8, and Appendix B, Tables VIII-4 through 8). Because sample 2 from Jakkula Bank contained only rubble, no fine sediment data could be obtained for that station. All of the remaining samples yielded coccolith assemblages dominated overwhelmingly by modern indigenous species, although rare redeposited species were found on every bank and in nearly every sample. Exponential values are all 4's and 5's, although there were too few sampling stations to allow inference about the distribution pattern. The consistency of the coccolith proportions does suggest, however, that the mechanism (current system) controlling the pattern is probably not greatly different on these banks from what it is on, say, the East Flower Garden Bank.

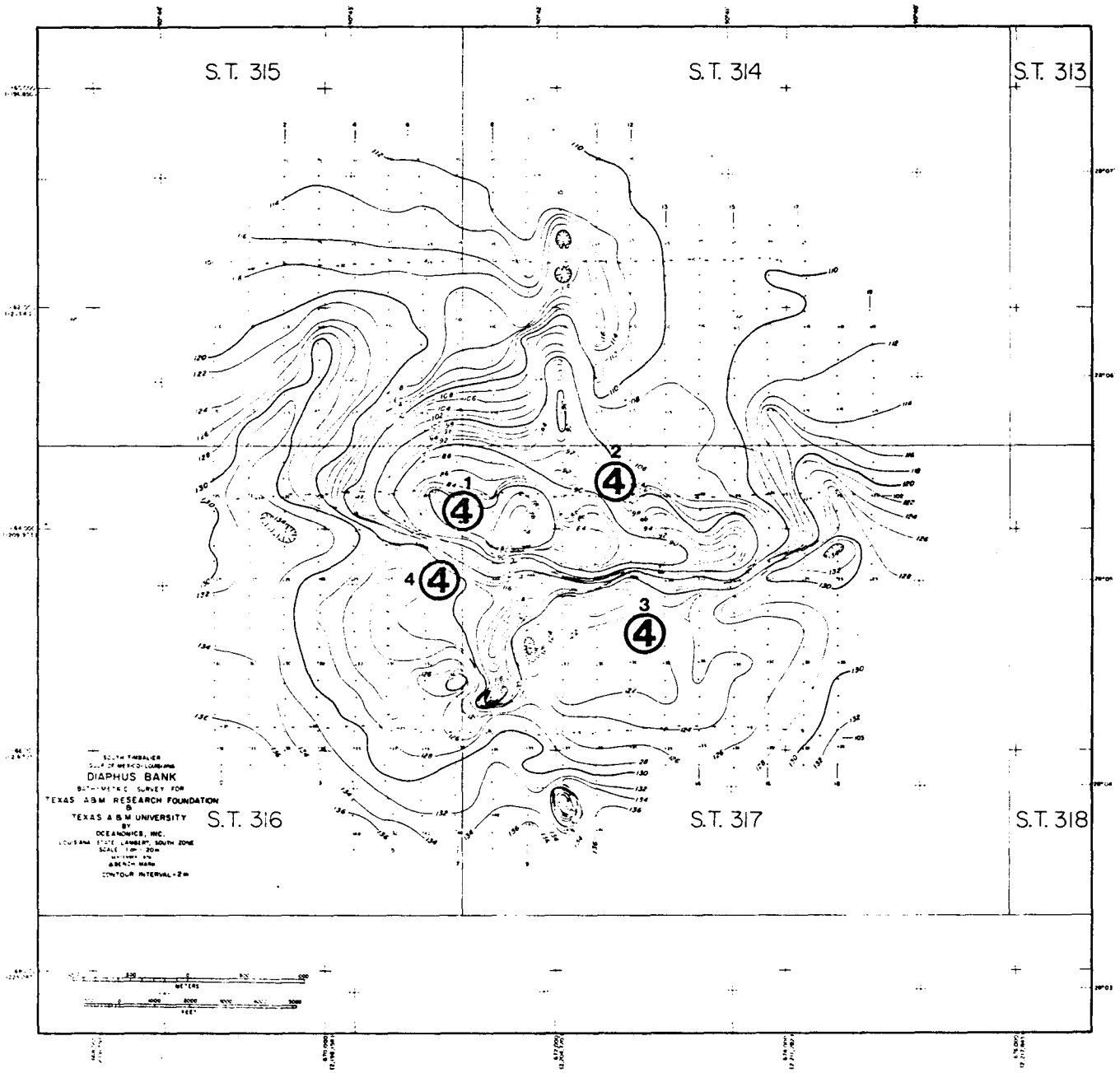

Figure VIII-4. Fossil and modern coccolith proportions in surficial sediment samples, Diaphus Bank. (See Appendix B, Table VIII-4.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

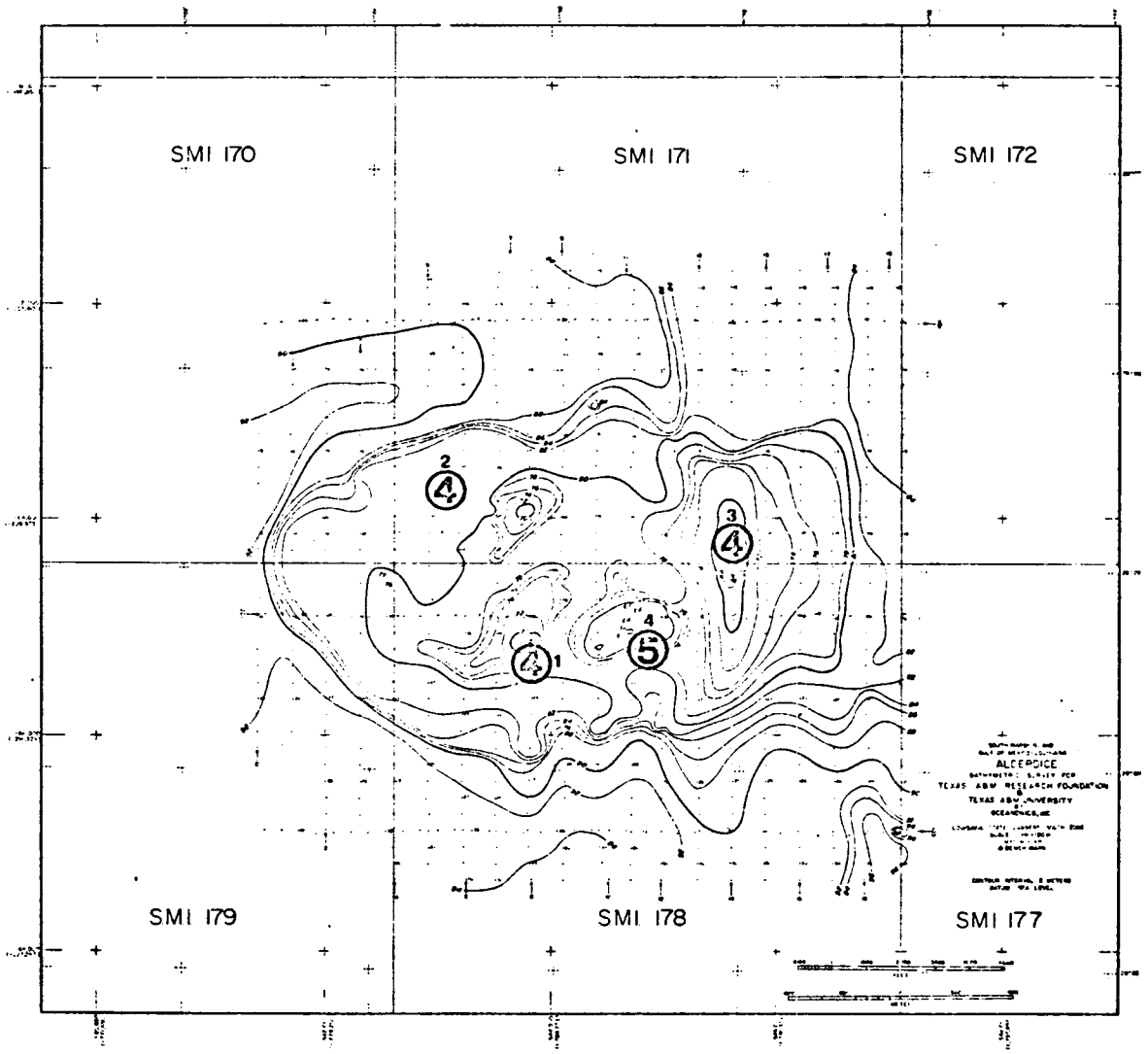

Figure VIII-5. Fossil and modern coccolith proportions in surficial sediment samples, Alderdice Bank. (See Appendix B, Table VIII-5.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

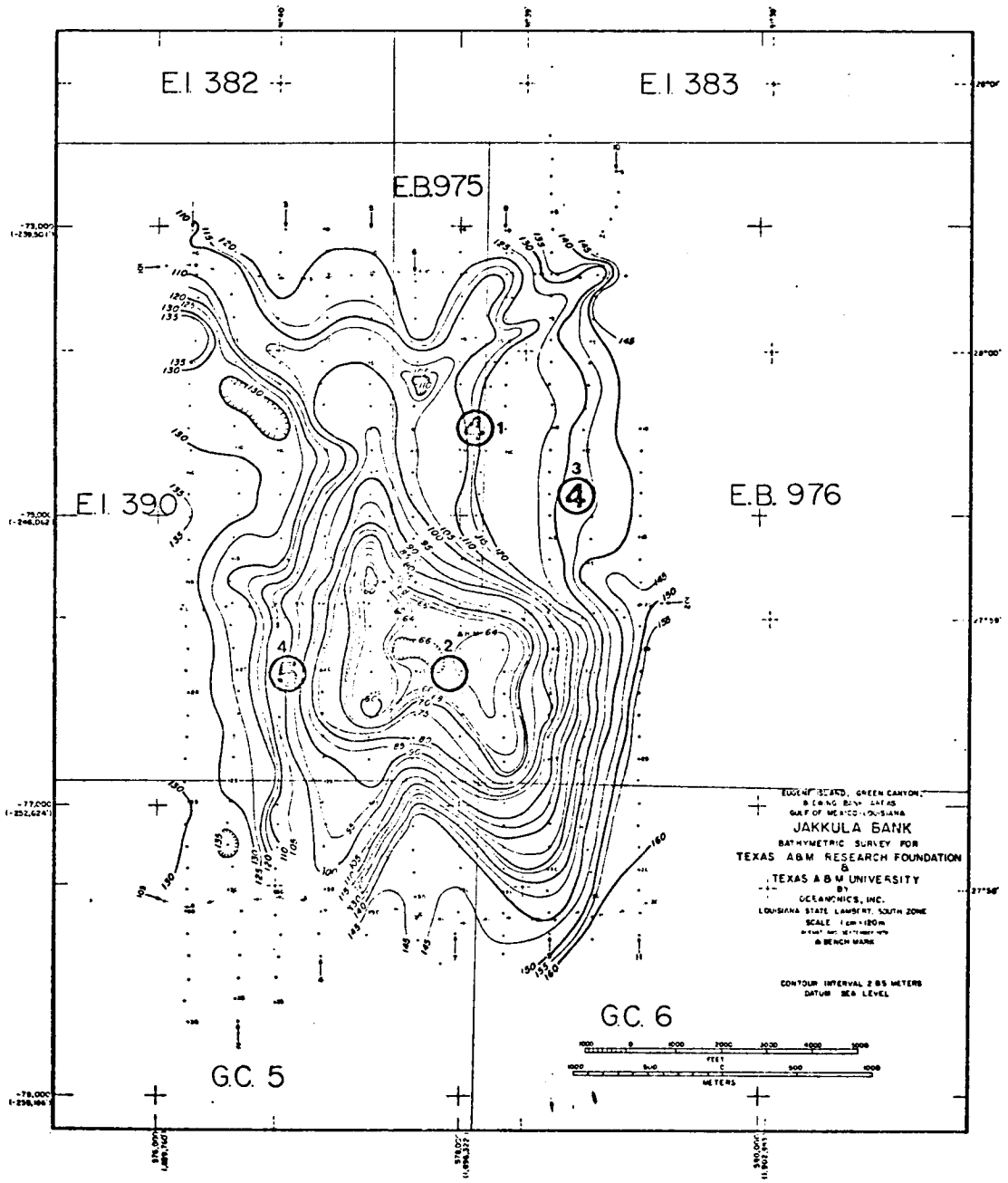

Figure VIII-6. Fossil and modern coccolith proportions in surficial sediment samples, Jakkula Bank. (Empty circle indicates that no sample was obtained at this station; see Appendix B, Table VIII-6.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

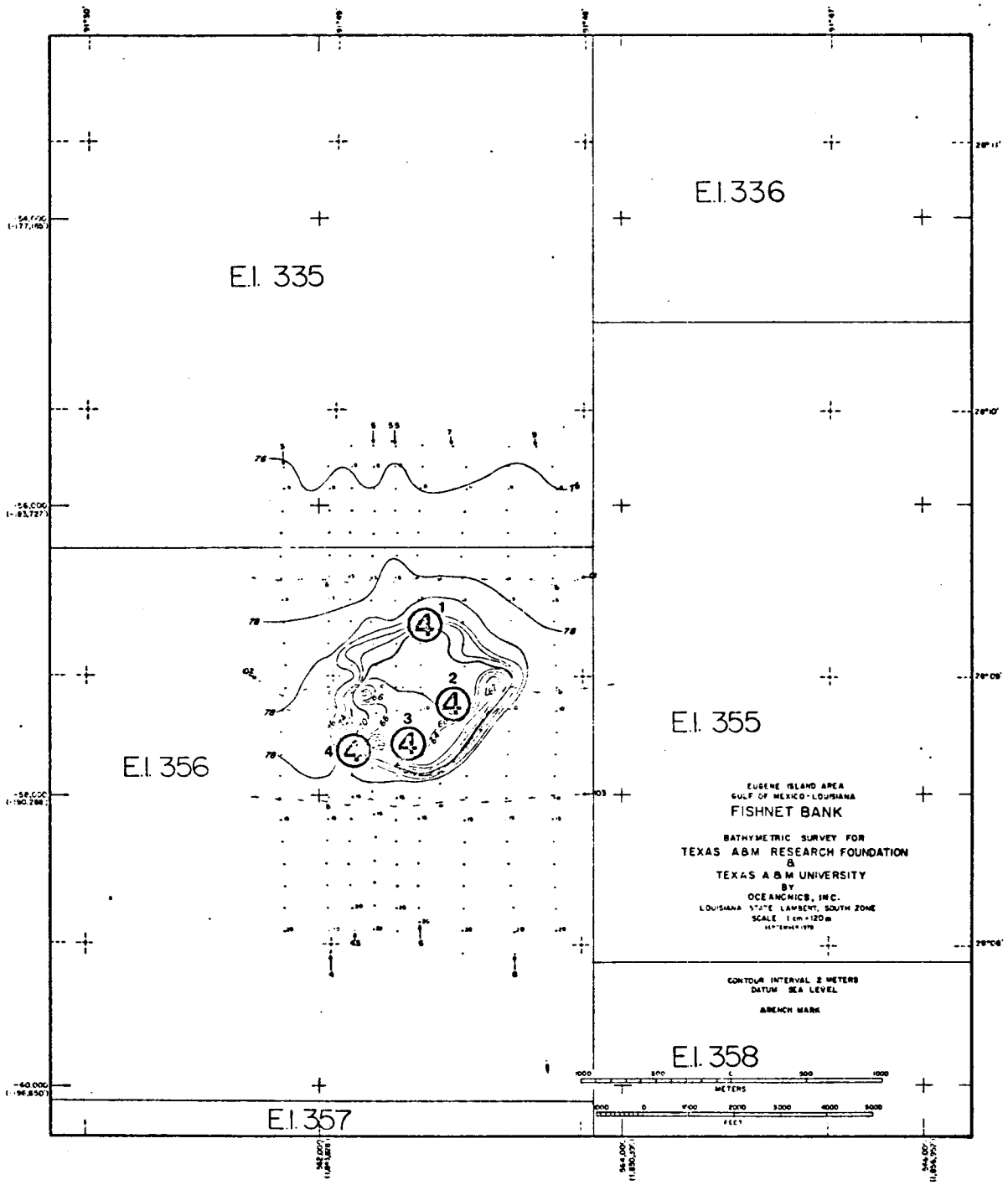

Figure VIII-7. Fossil and modern coccolith proportions in surficial sediment samples, Fishnet Bank. (See Appendix B, Table VIII-7.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

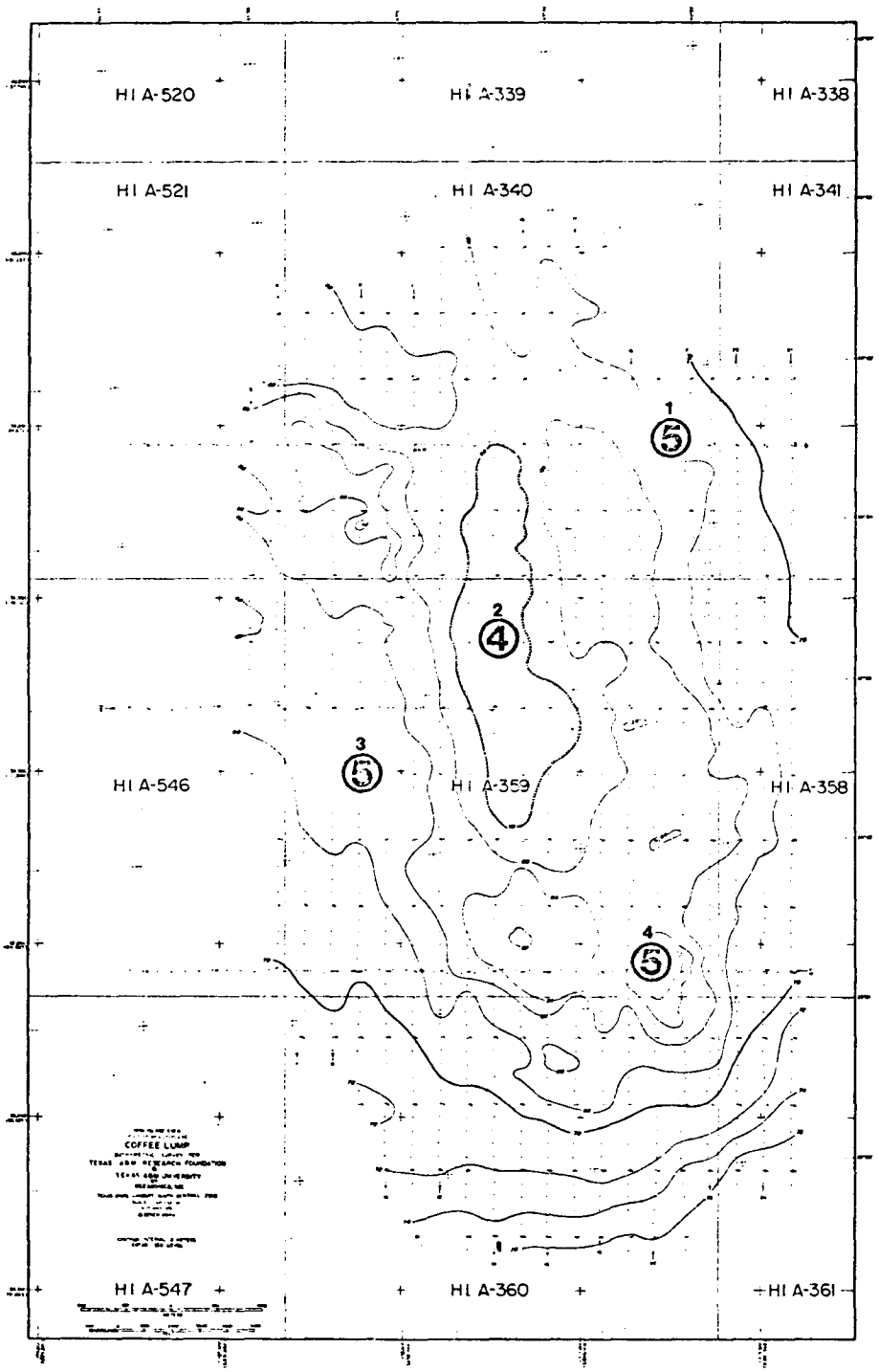

Figure VIII-8. Fossil and modern coccolith proportions in surficial sediment samples, Coffee Lump Bank. (See Appendix B, Table VIII-8.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

Near-Bottom Suspended Sediment

The proportion of modern and redeposited fossil coccoliths was determined also in suspended sediment over five of the six banks studied during the course of this project (Appendix B, Tables VIII-9 through 13).

Over the East Flower Garden Bank, near-bottom suspended sediment was sampled during three seasonal cruises, samples being taken on primary and secondary stations. The exponential values for reduced data are plotted on Figures VIII-9 through 11 (see also Appendix B, Table VIII-9). It is difficult to see a consistent pattern in these data, although that is probably of little importance. The significant point is that nearly all of the exponential values are 4's and 5's, precisely the same as the values for surficial sediment on and around the bank. This in turn suggests that the suspended sediment probably originated by resuspension of material on or near the bank rather than having been transported into the area from elsewhere. Over the course of three seasonal samplings, three stations out of thirty-four yielded exponential values smaller than 4. Two of these values are based on one specimen each and, therefore, cannot be considered significant. The remaining station yielded a value of 3 (April, station 18). The significance of this point is not obvious, but since station 18 is northwest of the bank this value might indicate derivation of the suspended sediment from a relict sediment pocket on the bank. However, this is a rather speculative conclusion, being based on one point only. Nevertheless the conclusion is consistent with the transport direction inferred from the surficial sediment data, although the anomalous value does not itself contribute to this conclusion.

Near-bottom suspended sediment was analyzed also from four of the remaining five banks. Thirteen samples, four each from Alderdice Bank, Fishnet Bank, and Coffee Lump Bank, and one from Jakkula Bank, all yielded exponential values of 4 or 5, values totally consistent with those obtained from surficial sediments on and around the banks (Appendix B, Tables VIII-10 through 13). This again indicates that the suspended sediment near the bottom on or in the vicinity of the banks very probably is derived from the bank sediment or from the surficial sediment around the banks, and that most of the suspended sediment has not been transported a long distance.

One additional suite of samples contributed data on the proportion of redeposited and indigenous coccoliths in the near-bottom suspended sediments. This suite came from the Z-transect (Appendix B, Table VIII-14). The suspended sediment from stations Z-5 and Z-6, those farthest inshore, yielded no coccoliths whatsoever, fossil or modern. The remaining four stations all yielded exponential values of 4 or 5, indicating that the near-bottom suspended sediment contains chiefly modern coccoliths with very rare or no redeposited species.

Although the redeposited coccoliths are generally more abundant in the surficial sediments than in the near-bottom suspended sediment, these discrepancies are not very large and probably can be attributed

to differential preservation. The important thing is that the general trend in surficial sediment and suspended sediment is the same.

CONCLUSIONS AND SUMMARY

Coccolith ratios from surficial sediment samples over the northern Gulf of Mexico continental shelf indicate that fine suspended sediment may possibly be subject to landward transport north of the Flower Garden Banks in an area that has a narrow belt of sharp topographic irregularity. The data also suggest that around various banks fine suspended sediment of the size of coccoliths (about .001 mm to .01 mm) may be more likely to settle out of suspension on the west and northwest sides of the banks than on the east and southeast sides of the banks.

The coccolith ratios in near-bottom suspended sediment indicate that these sediments are derived for the most part from the surficial sediment near the area where they were taken and probably have not been transported a very long distance.

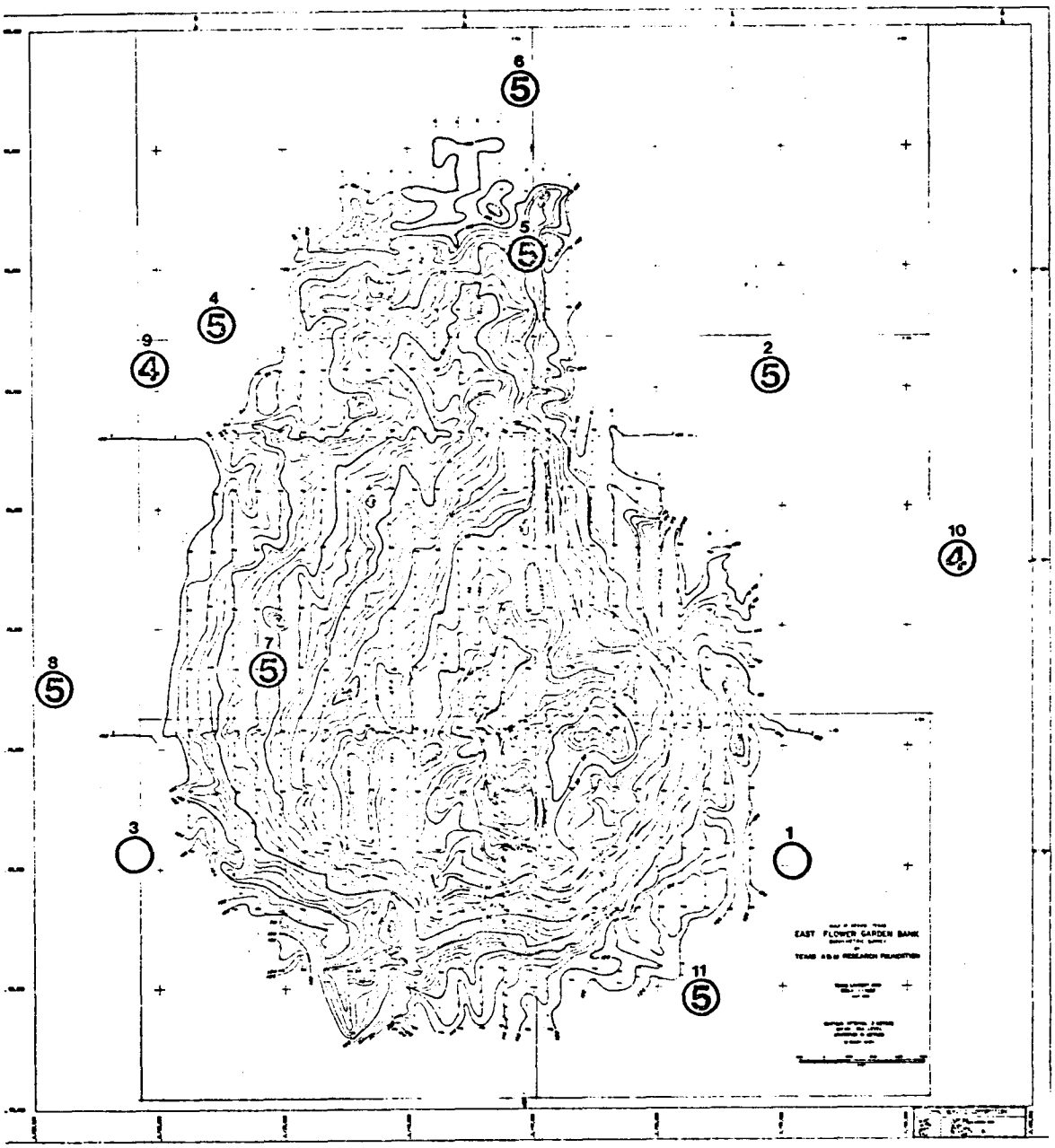

Figure VIII-9. Fossil and modern coccolith proportions in near-bottom suspended sediment at East Flower Garden Bank. First seasonal cruise, January 1979, combined with four stations from October 1978 cruise. (Empty circle indicates that no sample was obtained at this station; see Appendix B, Table VIII-9.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

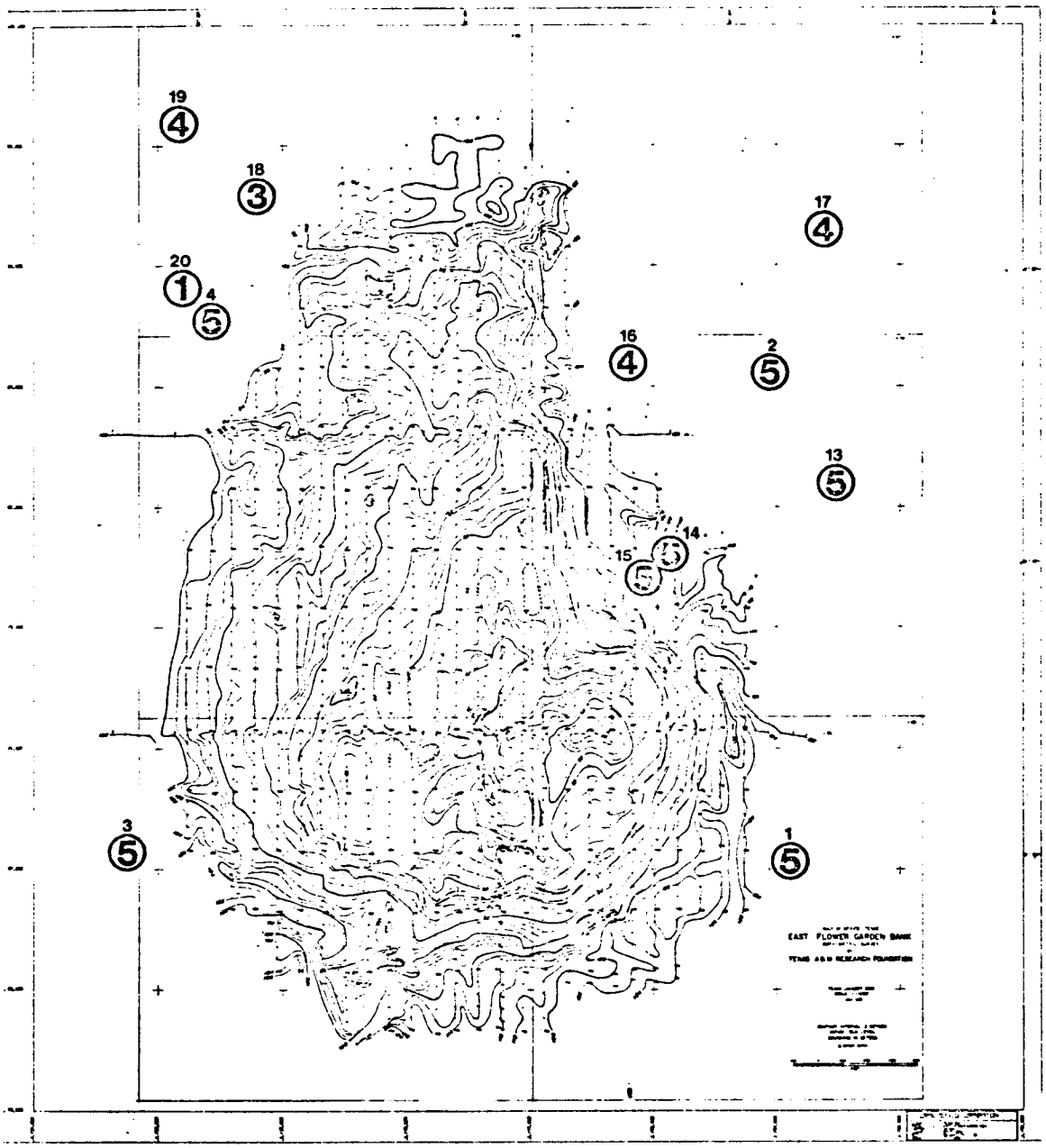

Figure VIII-10. Fossil and modern coccolith proportions in near-bottom suspended sediment at East Flower Garden Bank. Second seasonal cruise, April 1979. (See Appendix B, Table VIII-9.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

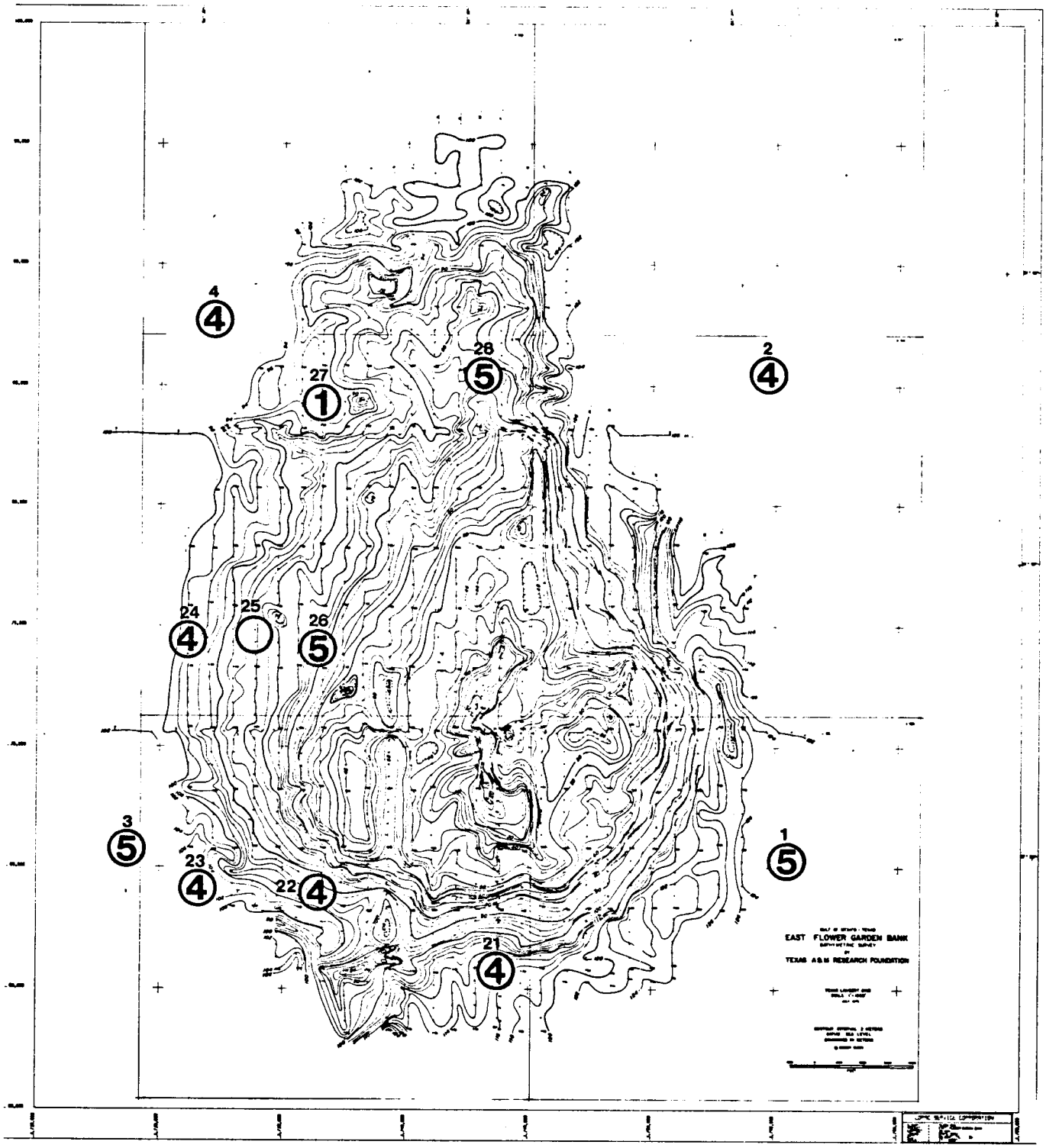

Figure VIII-11. Fossil and modern coccolith proportions in near-bottom suspended sediment at East Flower Garden Bank. Third seasonal cruise, July 1979. (Empty circle indicates insufficient data; see Appendix B, Table VIII-9.) Circled numbers are ratios reduced to exponential values; smaller numbers are station numbers.

CHAPTER IX

CHEMICAL ANALYSIS

PART A: TRACE METALS

B. Presley, P. Boothe, J. Schofield, R. Taylor

ANALYSIS OF ORGANISMS

Introduction

As part of the Bureau of Land Management's Topographic Features Study (TFS), the concentrations of selected trace elements have been determined in organisms collected from many topographic highs (i.e. fishing banks) on the Texas-Louisiana Outer Continental Shelf. These baseline trace metal data provide a basis for detecting and evaluating future changes in organismal trace element levels which could result from increased petroleum exploration and development in the vicinity of these banks.

This report presents data from the third year (1978) of the TFS trace metals project. During the first two years of this study, three species of organisms were analyzed, including two macronekton species (fish: Lutjanus campechanus, Red snapper; Rhomboplites aurorubens, Vermilion snapper) and one epifaunal species (Spondylus americanus, Atlantic thorny oyster). In 1978, however, only Spondylus were collected for trace metal analysis.

The Atlantic thorny oyster is a large (up to 15 cm in this study), spinose, sublittoral bivalve. It occurs off the United States coast from South Carolina to Texas and south to Brazil (Abbott, 1974). Spondylus was a good choice for a baseline study such as this one. Environmental research has suggested that bivalves may be valuable as sentinel organisms for indicating levels of pollutants in coastal marine waters (Goldberg et al., 1978). Spondylus not only contains easily measurable levels of all metals of interest to this study, but being a sessile, filter-feeding organism, it should be a good indicator of ambient levels of biologically available trace metals. With Spondylus, one also has a unique opportunity to observe trace element concentrations in a bivalve from an unusual marine habitat. Virtually all previous studies have dealt with metal levels in bivalves from estuarine, coastal, or nearshore areas (Kidder, 1977). The Spondylus analyzed in this study were collected in deep water (30-100 m) from topographic highs (elevated banks) located 130-370 km off the Texas-Louisiana coast. By comparing Spondylus trace metal data to similar data from very different nearshore environments, one can gain some insight into which environmental factors may be important in influencing trace element levels in bivalves.

The concentrations of ten trace elements (Al, Ca, Cd, Cr, Cu, Fe, Ni, Pb, V, and Zn) were determined in Spondylus for this study. Of the

metals selected, some are associated with potential petroleum related contamination while others represent some of the more toxic trace metals often associated with the increased activities of man. Nickel (Ni) and vanadium (V), for example, have been shown to be present in large concentrations in some oils and tars. Cadmium (Cd) and lead (Pb), two very toxic metals, are frequently observed to be above natural levels near industrial and population centers.

Methods and procedures for trace metals analyses are described in Chapter VII. Results and discussion of these analyses are presented below.

Results and Discussion

A comprehensive tabulation of raw trace metal data for the 19 Spondylus analyzed during the 1978 TFS is included in the data appendix of this volume (Appendix B, Table IX-A-1). The summary tables in this section were produced using both this tabulation and comparable metals data from the 1976 and 1977 TFS Final Reports (Presley and Boothe, 1978; Presley et al., 1978). All these data are of trace metal levels in homogenized samples of individual whole Spondylus (i.e. all soft parts except gonads).

Table IX-A-1 summarizes Spondylus trace metal data for all three years of the TFS. The trace metal levels in Spondylus collected in 1978 are generally very similar in both magnitude and variability to those observed in 1976 and 1977. The generally small number of Spondylus collected at each bank makes rigorous, quantitative evaluations of geographic (inter-bank) trends within this data set infeasible. Although some sizeable differences are apparent between banks, no consistent geographic trends emerge. The differences may well be artifacts of the small and variable sample sizes. This inference is supported by the fact that the two banks with the largest number of samples (i.e. East Flower Garden, n = 15, 1978; 18 Fathom Bank, n = 6, 1977) show no significant differences, with the possible exception of Fe.

The only bank sampled during all three years of the TFS was the East Flower Garden (EFG). Trace metal levels observed in Spondylus from this bank are summarized in Table IX-A-2. The levels observed are very similar among all three years except for the anomalously high levels of Cu and Pb in the 1976 samples. The reason for these higher levels is unclear, but they certainly do not represent any trend.

The collection of 15 Spondylus at the East Flower Garden in 1978 provided a good opportunity to investigate some potential sources of the variability observed in trace metal body burden among individual oysters. Since the 15 Spondylus were collected from the same bank over a short period of time, there was a reasonable expectation that they all received a similar exposure to trace metals in the environment. One possible source of variability would be a difference in trace metal levels as a function of the size of the oyster analyzed. This possibility was especially appropriate for the 1978 East Flower Garden

samples, since the range of whole body (all soft parts except gonads) dry weight for these Spondylus was 0.853-15.905 g. Three metals (Cr, Pb, Zn) exhibited significant correlation coefficients between body burden and dry weight. These coefficients are 0.85 ($p < .01$), -0.89 ($p < .001$), and -0.62 ($p < .05$), respectively. Iron showed a positive correlation that was almost significant. These correlations mean that between 60% and 90% of the variability observed for these metals can be explained on the basis of the size of the individual analyzed. These results have important implications for any future monitoring program involving Spondylus. Specifically, it will be necessary to adjust for the size of the individuals when attempting to detect any differences in trace metal levels among various Spondylus samples. However, when this adjustment is made, the variability in certain trace metal levels will be sufficiently reduced to permit the accurate detection of relatively small differences between samples.

Table IX-A-3 compares the concentrations of selected trace metals in TFS Spondylus with comparable data for oysters from other studies in the Gulf of Mexico. Trace element levels in Spondylus were determined as part of the BLM Mississippi-Alabama-Florida (MAFLA) study during 1974-76. These data are amazingly similar to those observed in this study. The Spondylus for the MAFLA study were also collected at offshore stations (140 km) in an area removed from any direct terrigenous influence, such as a river delta. The similarity of these data suggests that Spondylus could be used as a monitoring organism to detect changes in trace metal levels at offshore stations over essentially all of the U.S. Gulf Coast.

The concentrations of trace elements in inshore oysters analyzed as part of the mussel watch study (Table IX-A-3) are drastically different from those of Spondylus. The significantly lower level of Cd and similar levels of Pb in these estuarine oysters is especially surprising. These two metals are associated with anthropogenic pollution of coastal waters (Bruland et al., 1974). One would expect that the levels of these metals in nearshore oysters would be higher than in offshore ones.

Inshore oysters appear to be exposed to significantly higher environmental levels of Cd than are offshore ones such as Spondylus. For example, the concentration of dissolved Cd (water sample filtered prior to analysis) in Galveston Bay is about 30 pgl^{-1}, while the total Cd levels (unfiltered water sample analyzed) in surface waters in the vicinity of the East Flower Garden are < 10 pgl^{-1} (Keeney, 1980). Cadmium concentrations in sediments from areas of Spondylus sampling are generally less than those for nearshore sediments. Sediment samples collected in the vicinity of the East Flower Garden in 1978 contained an average of 0.16 ppm Cd (see below). Sediments from the Florida Middle Ground, where MAFLA Spondylus samples were collected, had a mean Cd concentration of 0.09 ppm (Trefry et al., 1979). In even unpolluted bays along the Texas coast, surficial sediment Cd levels average 0.2 ppm (Trefry and Presley, 1976). Calcium carbonate ($CaCO_3$) levels in sediments from Spondylus sampling sites are generally higher than levels found in nearshore sediments. It is possible that Cd

TABLE IX-A-1
MEAN CONCENTRATIONS OF SELECTED TRACE METALS IN WHOLE SPONDYLUS AMERICANUS
ACCORDING TO BANK SAMPLED IN 1976, 1977, and 1978

BANK SAMPLED	YEAR SAMPLED	NO. OF SAMPLES	TRACE METALS				
			Cd	Cr	Cu	Fe	Ni
			Concentration (ppm dry weight ± one standard deviation)				
ELV	1978	1	17.0	3.50	6.5	16	25
SID	1978	1	28.0	6.50	3.0	95	40
JAK	1978	2	6.0 ± 3.5	3.00 ± 1.00	2.4 ± 1.9	65 ± 40	35 ± 14.0
EFG	1978	15	24.0 ± 11.0	4.50 ± 3.00	7.0 ± 4.5	90 ± 35	50 ± 19.0
EFG	1977	1	17.0	2.50	4.0	50	30
EFG	1976	3	50.0 ± 25.0	3.00 ± 1.50	85.0 ± 35.0	50 ± 10	45 ± 3.0
BOU	1977	1	16.0	0.06	3.5	150	55
BRI	1977	1	11.0	2.50	1.4	35	25
18F	1977	6	20.0 ± 8.0	3.50 ± 1.50	7.0 ± 5.0	45 ± 15	30 ± 15.0
HOS	1976	3	24.0 ± 8.5	3.50 ± 2.00	9.0 ± 5.0	240 ± 95	30 ± 4.0
SOU	1976	3	16.0 ± 5.0	3.50 ± 3.00	3.0 ± 1.0	150 ± 35	35 ± 2.5
STE	1976	3	17.0 ± 4.0	1.20 ± 0.30	19.0 ± 6.5	160 ± 120	30 ± 10.0
28F	1976	3	35.0 ± 15.0	1.90 ± 0.45	12.0 ± 2.5	75 ± 15	65 ± 25.0

BANK SAMPLED	YEAR SAMPLED	NO. OF SAMPLES	Pb	Zn	V	Al	Ca
ELV	1978	1	1.20	100	0.85	2.0	17
SID	1978	1	1.40	75	3.50	11.0	35
JAK	1978	2	0.70 ± 0.60	100 ± 40	2.50 ± 1.60	20.0 ± 10.0	15 ± 1.4
EFG	1978	15	2.20 ± 1.70	150 ± 45	3.00 ± 0.65	30.0 ± 25.0	35 ± 11.0
EFG	1977	1	0.30	150	2.50	< 7.0	< 1,400
EFG	1976	3	6.50 ± 4.00	250 ± 85	6.50 ± 2.00	80.0 ± 30.0	3,000 ± 550.0
BOU	1977	1	0.40	200	3.00	160.0	< 1,800
BRI	1977	1	0.20	110	1.80	45.0	< 2,200
18F	1977	6	0.50 ± 0.30	140 ± 45	2.50 ± 1.90	20.0 ± 17.0	1,500 ± 350.0
HOS	1976	3	1.20 ± 0.10	110 ± 30	11.00 ± 5.00	50.0 ± 3.5	2,500 ± 400.0
SOU	1976	3	1.10 ± 0.55	85 ± 70	8.00 ± 0.80	95.0 ± 80.0	1,900 ± 750.0
STE	1976	3	2.50 ± 0.70	210 ± 55	13.00 ± 16.00	2,000.0 ± 3,500.0	5,000 ± 3,000.0
28F	1976	3	5.00 ± 2.00	180 ± 150	9.50 ± 2.50	300.0 ± 250.0	4,500 ± 3,000.0

ELV = Elvers; SID = Sidner; JAK = Jakkula; EFG = East Flower Garden; BOU = Bouma; BRI = Bright; 18F = 18 Fathom; HOS = Hospital Rock; SOU = Southern Bank; STE = Stetson Bank; 28F = 28 Fathom.

TABLE IX-A-2
MEAN CONCENTRATIONS OF SELECTED TRACE METALS IN WHOLE *SPONDYLUS AMERICANUS* FROM THE EAST FLOWER GARDEN BANK IN 1976, 1977, 1978

YEAR	NUMBER OF SAMPLES	CONCENTRATION (ppm dry weight ± one standard deviation)									
		Cd	Cr	Cu	Fe	Ni	Pb	Zn	V	Al	Ca
1978	15	24 ± 11	4.5 ± 3.0	7.0 ± 4.5	90 ± 35	50 ± 19	2.2 ± 1.7	150 ± 45	3.0 ± 0.65	30 ± 25	35 ± 11
1977	1	17	2.5	4	50	30	0.3	150	2.5	< 7.0	< 1400
1976	3	50 ± 25	3.0 ± 1.5	85 ± 35	50 ± 10	45 ± 3	6.5 ± 4.0	250 ± 85	6.5 ± 2.0	80 ± 30	3000 ± 550

TABLE IX-A-3
COMPARISON OF TRACE METAL LEVELS IN OYSTERS FROM THE GULF OF MEXICO

SPECIES	LOCALITY	YEAR	NUMBER OF SAMPLES	CONCENTRATION (range of concentration) (ppm dry weight ± one standard deviation)						
				Cd	Cr	Cu	Fe	Ni	Pb	Zn
*Spondylus** *americanus*	East Flower Garden	1976 1977 1978	19	28 ± 16 (4.5-79)	4.0 ± 2.5 (1.3-13)	7.0 ± 4.5 (1.3-15)	80 ± 35 (25-150)	50 ± 18 (25-80)	2.3 ± 1.8 (0.30-6.5)	170 ± 65 (75-350)
*Spondylus*** *americanus*	Florida Middle Ground	1974 1975 1976	22	16 ± 9.5 (1.5-35)	6.5 ± 4.5 (1.8-14)	4.0 ± 2.2 (1.0-9.0)	100 ± 60 (19-250)	25 ± 16 (5.5-70)	1.0 ± 0.55 (0.14-1.8)	— --
*Crassostrea**** *virginica*	Texas Louisiana Coast	1977	14	4.5 ± 1.7 (1.8-8.6)	— —	120 ± 95 (34-410)	300 ± 150 (50-690)	2.5 ± 1.0 (1.6-5.4)	2.5 ± 0.45 (ND-3.5)	1600 ± 1700 (450-7080)
*Ostrea**** *equestris*	Florida Coast	1976	2	1.8 (1.3,2.4)	— —	120 (21,220)	— —	4.5 (1.4,7.3)	0.20 (0.1,0.3)	2000 (310,3600)

* This study.
** BLM MAFLA study (Betzer 1977, Betzer and Sims 1977, Gould and Moberg 1979).
*** EPA mussel watch study (Goldberg *et al.* 1978)

associated with such $CaCO_3$-rich sediments could be more readily available for bioaccumulation by bivalves when the sediment is ingested. However, for East Flower Garden sediments analyzed in this study, the percentage of total Cd released by a 1 N HNO_3 leach (averaged 61%) was independent of the $CaCO_3$ content of the sediment.

Why Spondylus accumulate significantly higher concentrations of Cd than do inshore oysters, while exposed to lower levels of Cd in the environment, is not certain. It is not a matter of longer exposure times. Cadmium levels in Spondylus show no correlation with size (age). Even the smallest individuals analyzed contain high Cd concentrations (> 25 ppm). Based on current data, the most likely explanation is a physiological difference between Spondylus and the nearshore oyster species studied concerning their capability to absorb and sequester Cd.

Conclusions

1. Trace metal levels in Spondylus americanus were generally similar among the three years (1976-78) of this study.

2. No consistent geographic (inter-bank) trends were apparent in the three years of Spondylus trace element data. The few such differences observed were most likely an artifact of the small and variable sample sizes.

3. Four metals (Cu, Fe, Pb, Zn) were significantly correlated with the size of Spondylus analyzed from the East Flower Garden. These relationships accounted for 60-90% of the variability in trace element levels observed among these individuals.

4. Trace metal concentrations in Spondylus from the TFS bank stations on the Texas-Louisiana Outer Continental Shelf were not significantly different from levels observed in this oyster from the Florida Middle Ground during the MAFLA Study (1974-76).

Management Implications

During the three-year period covered by the Topographic Features Study, the concentrations of ten trace metals (Al, Ca, Cd, Cr, Cu, Fe, Ni, Pb, V, Zn) have been determined in 43 individual Spondylus

americanus. These specimens were collected from eleven different banks during the period 1976-78, as follows:

1976		1977		1978	
Bank	No.	Bank	No.	Bank	No.
East Flower Garden	3	East Flower Garden	1	East Flower Garden	15
Hospital	3	Bouma	1	Elvers	1
Southern	3	Bright	1	Jakkula	2
Stetson	3	18 Fathom	6	Sidner	1
28 Fathom	3				

The small and variable number of Spondylus collected at each bank makes only qualitative comparisons possible. However, trace element levels are generally similar among all the banks and years sampled. From these data, **there is no indication of trace metal pollution at any of the banks.** The levels of several metals (Cr, Fe, Pb, Zn) are strongly correlated with the size of Spondylus analyzed. This factor must be considered when attempting to detect differences in ambient trace metal levels by comparing concentrations observed in individual oysters.

Spondylus is an excellent choice for any future trace metal monitoring study on this bank. It is a large bivalve (up to 15 cm) which contains easily measurable concentrations of all the elements studied here. Furthermore, the variability in these metal levels is among the lowest of any organism we have analyzed from the Gulf of Mexico. Not only is Spondylus available at offshore, hard bottom stations along the entire U.S. Gulf Coast, but the levels of trace elements in individuals from such widely separated locations as Florida and Texas are not significantly different. The best way to employ Spondylus in future monitoring studies would be to conduct caged experiments. Spondylus would be collected at one location and then placed in metal free cages (5-15 per cage) at control and experimental bank stations to be compared. After one month the oysters would be retrieved, analyzed and the trace metal data compared statistically.

ANALYSIS OF SEDIMENT

Introduction

This laboratory has analyzed organisms collected as part of the Topographic Features Study for the past three years but has analyzed sediment only for the past year. During the first two years of the project, sediment trace metal data were reported by the U.S. Geological Survey.

Sediment samples from the past year were all collected in an area around the East Flower Garden Bank and cannot, therefore, be used to

characterize the whole TFS area. Fortunately, enough trace metal work has been done in nearby parts of the Gulf of Mexico (e.g. Holmes, 1973; Trefry and Presley, 1976) to characterize the general area and allow recognition of anomalies in the present data.

In a baseline study such as this one, anomalies give clues to anthropogenic sources of trace metals. It is essential, then, to accumulate enough data to allow anomalies to be recognized and, if possible, explained. It is especially important to the present study to recognize trace metal introduction associated with petroleum exploration and production. Because a number of trace metals are known to be highly toxic to marine organisms, any unnatural addition of trace metals to the ocean is of concern.

Samples for the present study were collected at four sites near the East Flower Garden Bank. Samples 1 and 2 come from the flat seafloor one nautical mile east of the sharp scarp which forms the east approach to the bank (Figure IX-A-1). Samples 3 and 4 came from the western side of the bank where the slope leading away from the crest is rather gentle. Physically, samples 1 and 2 were similar, being a fine-grained sand which was about 20% $CaCO_3$. Samples 3 and 4 were quite different from 1 and 2 in that they were much coarser grained with much rubble from the reef and a very high, but variable, $CaCO_3$ content averaging 70%. Thus, the sediment on the west is mostly reef-derived whereas that on the east is not. This basic difference in sediment source might be expected to strongly influence the trace metal concentrations, but this does not appear to be the case.

Analytical procedures for sediment trace metal analysis are described in Chapter VII.

Results

Leachable and total trace element concentrations for the sediment analyzed in this study are presented in Table IX-A-4 through IX-A-7. The effectiveness of the leaching procedure must be considered in data interpretation. Effectiveness is determined by comparing leached and total levels for the eight samples which were analyzed both ways. To further emphasize this point, the percentage of the total which is removed by the 5 N HNO_3 leach used is presented in Table IX-A-8.

As would be expected, virtually all of the Ca present is removed by the 5 N HNO_3 leach, through the mechanism of $CaCO_3$ dissolution. On the other hand, the leach removed only a small fraction of the total Al, since it was unable to significantly attack the structure of the alumino-silicate component of the sediments. The remaining elements varied greatly in leachability, those with high leach removal percentages most likely being associated with either the particle surfaces or the $CaCO_3$ component of the sediment. Lead is shown to be quite effectively removed (89%), while Zn, Cu, Ni, and Cd are removed to a lesser extent (52-61%). Iron is removed to a still lesser extent (39%), as would be predicted by its frequent substitution for Al in the

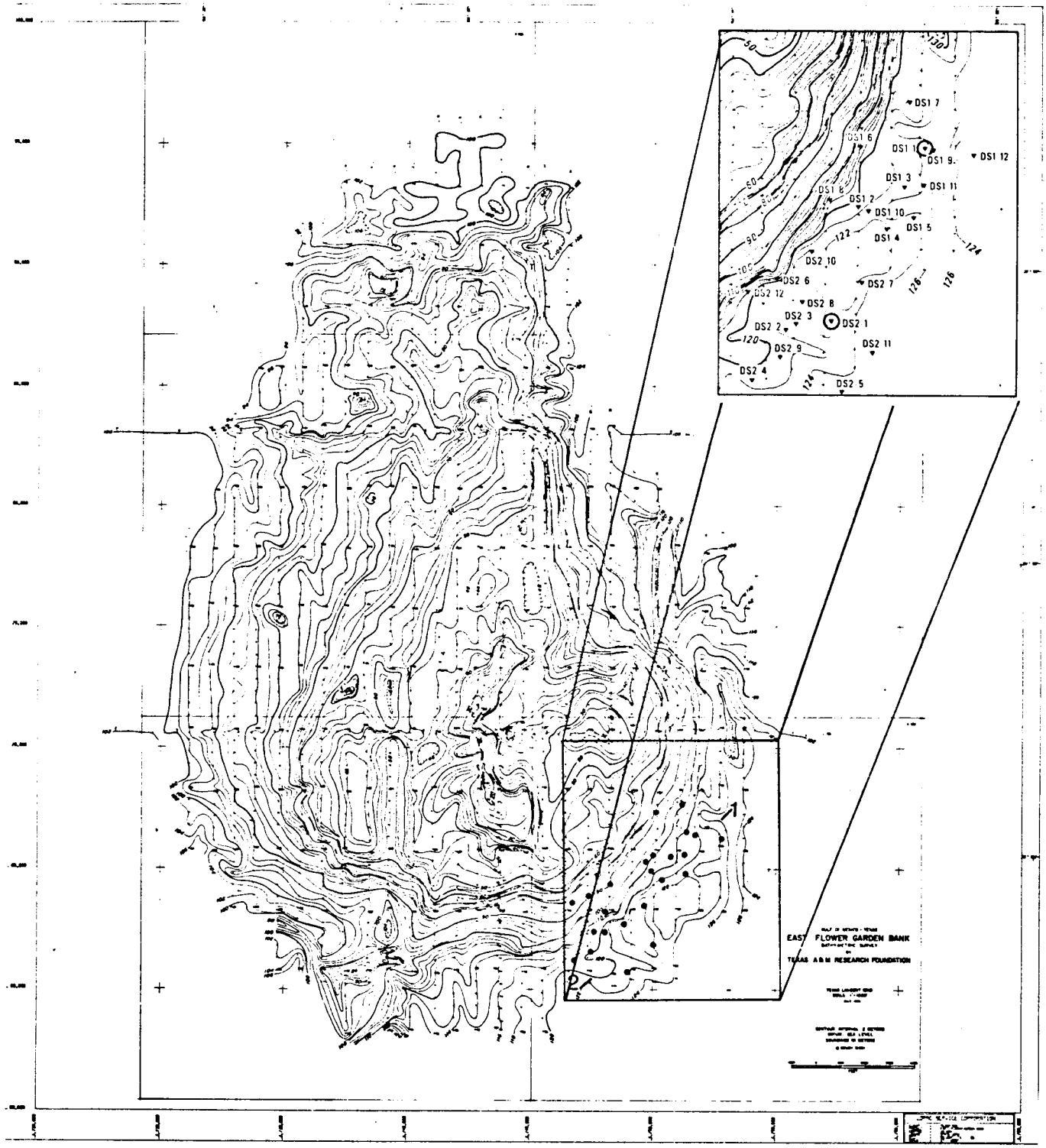

Figure IX-A-1. Sediment sampling sites at the East Flower Garden Bank, showing sampling scheme around the two drill sites, DS-1 and DS-2 (circled on inset).

TABLE IX-A-4
TRACE METAL CONCENTRATIONS IN LEACHATES OF EAST FLOWER GARDEN SEDIMENT SAMPLES FROM DRILL SITE #1

Station Number	Concentration[1]										
	Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
1	0.53	180	7.5	.08	9.5	7.5	1.2	17	21	13	50
2	0.56	140	7.2	0.08	10	8.0	1.3	18	22	16	55
3	0.55	210	7.2	0.08	11	8.5	1.3	18	25	15	55
4	0.56	240	7.1	0.08	12	8.5	1.4	19	28	16	55
5	0.51	100	8.3	0.08	9.5	7.5	1.2	18	20	11	50
6	0.49	100	11.5	0.09	8.5	6.5	1.1	16	18	14	45
7	0.52	105	8.0	0.07	8.5	7.5	1.2	16	18	15	45
8	0.54	300	8.4	0.08	11	8.0	1.3	17	29	15	55
9	0.54	150	7.6	0.07	9.5	7.5	1.2	17	21	15	50
10	0.16	-	30	0.15	4.0	2.2	0.72	7.5	11	6.5	23
11	0.53	150	7.1	0.08	9.5	7.5	1.1	17	18	14	50
12	0.53	-	6.5	0.09	8.5	7.0	1.3	18	17	17	50

[1]Al, Ca and Fe in percent salt-free dry weight. All other elements in ppm salt-free dry weight.

TABLE IX-A-5
TRACE METAL CONCENTRATIONS IN LEACHATES OF EAST FLOWER GARDEN SEDIMENT SAMPLES FROM DRILL SITE #2

Station Number	Concentration[2]										
	Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
1	0.56	130	8.1	.08	9.9	7.9	1.2	17	19	15	53
2	0.43	180	9.5	.05	11	6.9	1.0	14	21	12	49
3	0.47	370	8.9	.10	15	7.8	1.1	15	30	12	61
4	0.48	180	11	.06	9.2	6.9	1.1	15	17	13	44
5	0.55	120	7.6	.07	11	7.6	1.2	18	19	15	53
6	0.13	51	35	.19	4.7	2.0	0.39	5.8	9.6	7.5	17
7	0.47	150	12	.08	8.1	6.5	1.1	14	16	12	41
8	0.50	340	8.0	.09	16	7.8	1.2	16	26	14	56
9	0.53	300	7.9	.08	12	7.3	1.2	17	22	15	55
10	0.38	170	14	.08	8.0	5.1	0.89	12	17	11	39
11	0.51	-	7.9	.07	9.0	6.8	1.1	17	19	13	50
12	0.23	88	29	.23	6.2	3.4	0.50	9.0	10	7.9	21

[2]Al, Ca and Fe in percent salt-free dry weight. All other elements in ppm salt-free dry weight.

TABLE IX-A-6
TRACE METAL CONCENTRATIONS IN LEACHATES OF EAST FLOWER GARDEN SEDIMENT SAMPLES FROM THE CONTROL AREA

Station Number	Concentration[1]										
	Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
1 1G	0.54	-	8.2	0.09	8.9	6.8	1.1	17	16	12	49
1 2G	0.57	-	6.8	0.09	10	7.7	1.2	18	18	16	50
2 1G	0.47	106	8.8	0.08	8.0	6.0	1.0	16	16	12	43
2 2G	0.45	96	8.4	0.06	7.5	5.7	1.0	15	16	11	42
3 1G	0.16	-	33	0.16	2.8	2.0	0.43	6.6	10	7.3	15
3 2G	0.11	-	35	0.15	1.9	1.7	0.32	6.0	9.2	4.2	13
4 1G	0.15	-	33	0.15	4.0	2.1	0.61	6.7	10	7.9	21
4 2G	0.56	282	7.6	0.09	11.0	7.7	1.2	17	26	15	56

[1]Al, Ca and Fe in percent salt-free dry weight. All other elements in ppm salt-free dry weight.

TABLE IX-A-7
TRACE METAL CONCENTRATIONS IN TOTAL DIGESTS OF EAST FLOWER GARDEN SEDIMENT SAMPLES

Area	Station Number	Concentration[2]										
		Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
Drill Site 1	4	6.5	2400	8.4	0.13	76	16	3.3	34	32	110	90
Drill Site 1	8	6.2	3300	8.5	0.13	63	15	3.2	34	38	100	88
Drill Site 1	12	6.6	420	6.6	0.14	74	13	3.6	37	22	100	85
Drill Site 2	4	5.2	1400	11	0.12	66	13	2.7	29	23	81	72
Drill Site 2	8	5.8	4700	7.4	0.15	79	15	2.9	31	22	93	88
Drill Site 2	12	2.6	600	26	0.38	27	7.3	1.5	15	13	48	42
Control	2 2G	5.5	520	8.1	0.11	63	12	2.6	27	16	75	71
Control	4 2G	6.5	1900	7.0	0.14	78	16	3.3	34	28	94	98

[2]Al, Ca and Fe in percent salt-free dry weight. All other elements in ppm salt-free dry weight.

TABLE IX-A-8
FRACTION REMOVED BY ACID LEACH[3]

Area	Station Number	Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
Drill Site 1	4	.086	.097	.84	.64	.16	.55	.42	.55	.86	.15	.63
Drill Site 1	8	.086	.088	.98	.60	.17	.53	.40	.51	.75	.15	.63
Drill Site 1	12	.080	-	.98	.64	.11	.54	.36	.49	.79	.16	.60
Drill Site 2	4	.093	.13	.95	.52	.14	.54	.42	.53	.76	.16	.61
Drill Site 2	8	.087	.073	1.1	.59	.20	.54	.41	.53	1.2	.15	.63
Drill Site 2	12	.089	.14	1.1	.60	.23	.49	.33	.60	.81	.16	.50
Control	2 2G	.082	.18	1.0	.60	.12	.49	.39	.55	1.0	.15	.60
Control	4 2G	.087	.15	1.1	.67	.14	.50	.37	.52	.94	.16	.57
Mean		.086	.12	1.0	.61	.16	.52	.39	.54	.89	.16	.60

[3]Calculated by dividing concentration in the acid leach by concentration in the total digest.

alumino-silicate lattice. The leach removal effectiveness for Ba, Cr, and V lies between that of Fe and Al.

It appears that one of the strongest factors affecting trace element concentrations in the samples analyzed is the contribution of calcium carbonate to the total sediment mass. Tables IX-A-9 and IX-A-10 show that Ca, which comes mostly from $CaCO_3$, has a highly negative correlation coefficient with most metals, and inspection of the data tables indicates that those samples having high Ca content characteristically have low values for most other metals. Shell fragments and carbonate mud, which are high in Ca and low in most trace elements studied, dilute the sedimentary trace element concentrations. Such was observed to be the case for samples recovered from varying water depths and varying locations, both within the designated drill site areas and at stations away from the reef area itself.

Discussion

The effect of $CaCO_3$ dilution is partially responsible for the high correlation between Fe and trace elements, which are both in low concentrations in the $CaCO_3$. If all the sediment samples are viewed as a mixture of two end members, one of $CaCO_3$ and the other of alumino-silicate material, then by using the total sediment regression line between Fe and Ca (Figure IX-A-2), it is possible to compute the Fe content of each end member. Thus, the alumino silicate material contains approximately 3.8% Fe, while the $CaCO_3$ component contains only about 0.2% Fe.

Copper, nickel, and zinc are seen to be quite similar in their behavior. As was mentioned previously, all three elements are leached with similar effectiveness. In addition, their concentrations are highly correlated in both leached and total fractions (Tables IX-A-9 and IX-A-10), and they show similar linear relationships with Fe. The scatter diagram of Ni vs. Fe (Figure IX-A-3) illustrates the linear relationships. Based on the available data, no evidence links drilling activity at the sampling area to concentrations of these three elements in the sediment.

The low effectiveness of 5 N HNO_3 in leaching Cr may be explained by the fact that Cr^{3+} closely resembles Al^{3+} and Fe^{3+} in its chemical properties and ionic size, and thus it will behave similarly during weathering processes. Shiraki (1978) states that there are a large number of minerals where Cr^{3+} replaces other cations, especially Al^{+3}, and that Cr is more resistant to weathering than any other trace element. The strong association between Cr and weathering products results in the high positive correlations observed between Cr and the five elements Cu, Ni, V, Fe, and Al.

The total Cr concentrations found in this study are within the range of previously published values for carbonate and deep sea clays. When the effect of $CaCO_3$ dilution is considered (< 2 ppm Cr, Livingston and Thompson, 1971), there is little variation in total Cr

between the sampling sites, and, hence, no indication of drilling-caused pollution.

The behavior of Cd is strikingly different from that of the other trace elements studied in that it alone showed a positive correlation with Ca. This correlation requires that the carbonate end member have a higher Cd concentration than the alumino-silicate fraction. Although this finding is at odds with much published data from other locations (Turekian and Wedepohl, 1961), it supports an observation by Trefry et al. (1979) at an offshore, carbonate-rich station in the Eastern Gulf of Mexico. Mullin and Riley (1956) suggested that Cd may substitute for Ca in calcite, based on their equivalent valences and similar ionic radii (1.03 and 1.06A, resp.). Brehler (1978) noted that $CdCO_3$ forms a continuous series of solid solutions with $MnCO_3$, and shows limited solubility in series with $CaCO_3$. The source of the Cd for the observed enrichment in the carbonate phase is not obvious. Seawater concentrations of Cd are almost vanishingly low (a few parts per trillion according to Martin et al. [1976] and others), thus necessitating a strong concentrating mechanism if seawater is the source. Details of the concentrating phenomenon and its dependence on water depth, the presence of naturally occurring hydrocarbon emanations, etc., will have to be worked out through additional research. It seems unlikely that the Cd enrichment in the carbonate is in any way related to the activities of man, but this too needs additional confirmation.

Like Cr, V is leached to only a small extent by 5 N HNO_3. During weathering, this element either remains in the residual rock-forming and Fe-bearing minerals or becomes associated with minerals in the silt or clay fraction (Butler, 1953). This statement is supported by the high V correlation with Al and Fe observed in both leached and total samples. The lack of oil well drilling contributions of V is indicated by the low efficiency of leach removal and by the lack of increased concentrations at the drill sites compared to control sites.

Lead and barium are the only elements studied which give an indication of a drilling source. Lead shows a high leachability, which indicates that it is either associated with the carbonate phase or with particle surfaces. The former possibility is ruled out by the negative correlation with Ca (Table IX-A-9). A Pb association with Fe-Mn oxide coatings on particles has been noted in previous studies in this general geographic area (e.g. Trefry and Presley, 1976) and is suggested here by the combination of a high leach efficiency and a high correlation with Fe. However, Figure IX-A-4 shows that a number of points lie off the regression line for Pb vs Fe, perhaps indicating a source of additional Pb. Drilling activity may have been the source of the Pb excess, as indicated by the fact that five of the outliers came from the center of the two drill sites. However, a definitive case for Pb pollution cannot be made, since the sixth outlier was located on the opposite side of the East Flower Garden, in an area of no known drilling activity. This Pb anomaly definitely needs further verification due to the strong indication that it is anthropogenic.

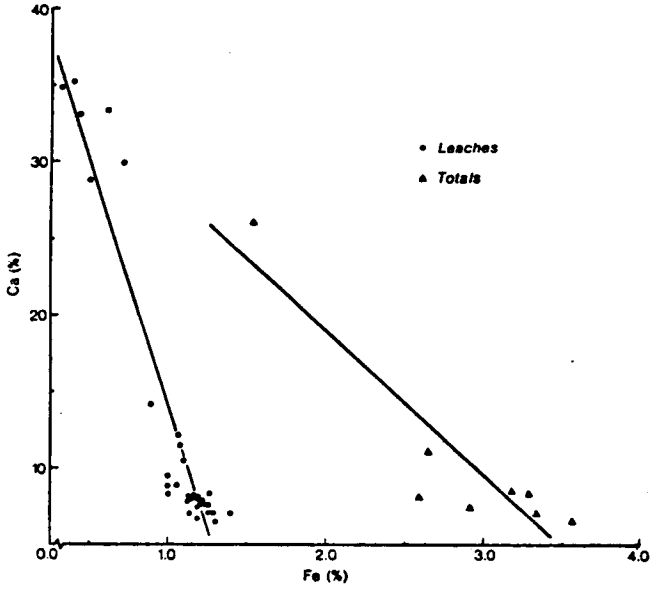

Figure IX-A-2. Ca vs. Fe plot of leachable and total concentrations in East Flower Garden sediment.

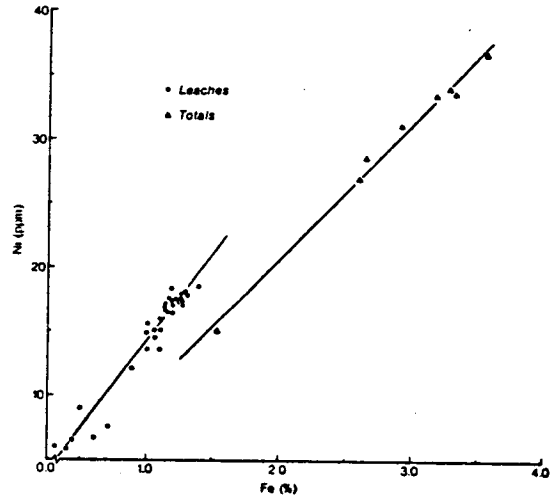

Figure IX-A-3. Fe vs. Ni plot of leachable and total concentrations in East Flower Garden sediment samples.

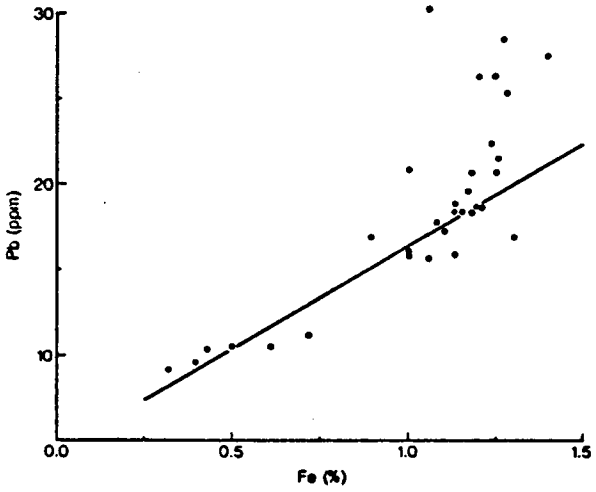

Figure IX-A-4. Pb vs. Fe plot of leachable concentration in East Flower Garden sediment.

TABLE IX-A-9
INTER-ELEMENT CORRELATION COEFFICIENTS FOR LEACHATES OF EAST FLOWER GARDEN SEDIMENT SAMPLES

Element	Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
Al	1.0000										
Ba	.3948	1.0000									
Ca	-.9816	-.4108	1.0000								
Cd	-.8327	-.2404	.8867	1.0000							
Cr	.8067	.8702	-.8162	-.6320	1.000						
Cu	.9783	.5279	-.9653	-.8105	.8791	1.000					
Fe	.9654	.4684	-.9514	-.8335	.8082	.9584	1.000				
Ni	.9930	.3716	-.9739	-.8135	.7943	.9718	.9701	1.000			
Pb	.7503	.8628	-.7514	-.6162	.9101	.8357	.7896	.7454	1.000		
V	.9300	.4182	-.8947	-.7285	.7770	.9233	.9361	.9260	.7289	1.000	
Zn	.9518	.6661	-.9560	-.8160	.9185	.9748	.9537	.9451	.8781	.9004	1.000

TABLE IX-A-10
INTER-ELEMENT CORRELATION COEFFICIENTS FOR TOTAL DIGESTS OF EAST FLOWER GARDEN SEDIMENT SAMPLES

Element	Al	Ba	Ca	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
Al	1.0000										
Ba	.3264	1.0000									
Ca	-.9629	-.3494	1.0000								
Cd	-.8878	-.2669	.9527	1.0000							
Cr	.9324	.4459	-.9468	-.8684	1.000						
Cu	.9265	.5915	-.8795	-.8099	.9216	1.000					
Fe	.9785	.2924	-.9030	-.7939	.8964	.8992	1.000				
Ni	.9835	.3423	-.9260	-.8358	.9150	.9150	.9941	1.000			
Pb	.6616	.5506	-.5231	-.5025	.5127	.7948	.6761	.6874	1.000		
V	.9541	.4427	-.8676	-.7700	.8781	.9284	.9702	.9768	.7664	1.000	
Zn	.9453	.5248	-.8979	-.7872	.9356	.9807	.9332	.9351	.7280	.9238	1.000

Leaching removes very little barium from the sediment. This fact would normally argue against a pollution source for most elements. However, the use of $BaSO_4$ in drilling mud and its low solubility in the acid leach used makes it necessary to consider Ba as a special case. Examination of the areal distribution of total Ba shows that, as in the case of Pb, the highest concentrations are found in the centers of the drill sites. However, the low number of samples analyzed for total Ba, and the fact that once again a high value was observed at a station far from the known drilling activity, preclude a definitive statement regarding the source of the Ba. It seems likely that the observed Ba enrichment is due to man's activities; the Pb and even the Cd values are suggestive of the same thing. A more extensive sampling and analysis program is needed before more definite statements can be made.

Conclusions

Concentrations of Al, Ca, Cd, Cr, Cu, Fe, Ni, V, and Zn were found to be highly variable on and near the East Flower Garden Bank. Most of this variability is due to variations in the $CaCO_3$ content of the samples, as $CaCO_3$ is very low in these metals. Cadmium levels were also variable, but were higher in $CaCO_3$-rich samples. The measured levels of the metals just listed are considered to be normal for the sediment type considered, and there is little reason to believe they have been influenced by man. On the other hand, a few samples contained Pb concentrations about 50% higher than would be expected, anda few contained Ba as much as 10 times above expected levels. The samples enriched in Pb and Ba were almost all from very near sites of exploratory oil well drilling and thus are likely to be due to the drilling.

Management Implications

Trace metal concentrations are generally low around the East Flower Garden Bank and probably around the other topographic highs. This is particularly true when the $CaCO_3$ content of the sediment is high. Under the circumstances, the sediment can be easily contaminated by relatively small additions of trace metals by man. **We found very strong evidence for such contamination with Pb and Ba at the East Flower Garden Bank.** Future activities by man at any of the fishing banks will have to be conducted in such a way as to minimize additions of trace metals to the bottom sediments.

PART B: HIGH MOLECULAR WEIGHT HYDROCARBONS IN SPONDYLUS AND MACRONEKTON

C. Giam, G. Neff, Y. Hrung

INTRODUCTION

This project was undertaken to analyze Spondylus and macronekton sampled from various topographic features of the northwestern Gulf of Mexico for high molecular weight hydrocarbons. For these studies, Spondylus americanus were obtained from the East Flower Garden and Sidner Bank during winter 1978 and from the East and West Flower Garden Banks during fall 1979. The macronekton were Pagrus sedecim (Red porgy) from Jakkula Bank, collected in winter 1978, and Lutjanus campechanus (Red snapper) from the East Flower Garden, collected in fall 1979. The samples were analyzed using the techniques outlined by BLM for hydrocarbons; these methods are detailed in Chapter VII. Interpretation of the data was based on our previous experience (Giam et al., 1978a,b; 1979) and on the report of Clark (1974). Sample inventory and results are presented in Tables IX-B-1 through 8.

RESULTS

Analytical Procedures

The analytical methods were essentially those used in the previous years of this study and yielded adequate sensitivity and accuracy Giam et al., 1978a,b). Procedure blanks were performed routinely and were $\leq$ 0.01 ppm total hydrocarbons. The limit of detection for individual aliphatic hydrocarbons was 0.001 ppm; for aromatic hydrocarbons it was 0.005 ppm. The recovery of aliphatic hydrocarbons (C_{14}-C_{32}) subjected to all steps of the procedure averaged 80%, while that for aromatic hydrocarbons averaged 75%. Gas chromatography-mass spectrometry was used to confirm the identity of the major hydrocarbon peaks in 10% of the samples. Carbon Preference Indices (CPI_{14-20} and CPI_{20-32}) (Clark, 1974) were used for the determination of odd/even preference in hydrocarbon distribution. They are calculated as follows:

$$CPI_{14-20} = 1/2 \left[\frac{\sum_{n=15}^{n=19} \text{HC odd}}{\sum_{n=16}^{n=20} \text{HC even}} + \frac{\sum_{n=15}^{n=19} \text{HC odd}}{\sum_{n=14}^{n=18} \text{HC even}} \right]$$

$$CPI_{20-32} = 1/2 \left[\frac{\sum_{n=21}^{n=31} \text{HC odd}}{\sum_{n=22}^{n=32} \text{HC even}} + \frac{\sum_{n=21}^{n=31} \text{HC odd}}{\sum_{n=20}^{n=30} \text{HC even}} \right]$$

The CPI_{20-32} is generally of the same order of magnitude for petroleum (mean 1.2) and for biological organisms (mean 1.0-1.5), but the CPI_{14-20} more accurately reflects the odd-carbon dominance of biological samples that is absent in petroleum. The CPI_{14-20} is almost always > 2 for organisms and averages 1.0 for petroleum (Clark, 1974).

Analyses of Spondylus

The results of the analyses of the 21 Spondylus samples are given in Tables IX-B-3 and 7 as percent distribution and concentration of n-paraffins, the levels of pristane and phytane, the ratios of pristane/phytane, pristane/heptadecane (C_{17}), phytane/octadecane (C_{18}), the Carbon Preference Indices (CPI_{14-20} and CPI_{20-32}), and the total concentration of alkanes. Total n-paraffin concentrations varied from 0.004 to 0.49 ppm with a mean of 0.12 ppm (standard deviation ± 0.15). Pristane was present in ten of the samples (range: 0.01-0.05 ppm), and phytane was found in two (0.02 and 0.04 ppm). Thus, the total and mean of n-alkanes had values similar to those for total paraffins (range: 0.004-0.52; mean: 0.13; standard deviation ± 0.16). The pristane/phytane ratio was only calculable in two cases (0.88 and 1.03), as was the phytane-C_{18} ratio (1.12 and 2.56). The pristane/C_{18} ratio (10 samples) ranged from 0.12 to 5.56. The CPI_{14-20} (9 samples) varied from 1.41 to 7.20. The CPI_{20-32} (5 samples) ranged from 0.51 to 1.36. Squalene was the only compound identified in the aromatic fraction.

Analyses of Macronekton

The results of the analyses of muscle, liver, and gonadal tissues from the three macronekton samples are detailed in Tables IX-B-4 and 8 as percent distribution and concentration of n-paraffins, the levels of pristane and phytane, the ratios of pristane/phytane, pristane/heptadecane (C_{17}), phytane/octadecane (C_{18}), the Carbon Preference Indices (CPIs), and total alkanes. Squalene was the only compound detected in the aromatic fraction. Due to the small number of samples (i.e. one red porgy, two red snappers), ranges and means of parameters were not calculated.

DISCUSSION

Spondylus Analysis

The analysis of the 21 Spondylus americanus samples received for this study generally yielded the limited distribution and low concentrations of hydrocarbons seen in the previous years of this study (Table IX-B-9) (Giam et al., 1978a,b). However, the two fall 1979 samples (labeled SAC and SAE, Tables IX-B-7 and 9) obtained from the East Flower Garden (southeast transect) showed a marked difference. Both had higher concentrations and a wider range of hydrocarbons, particularly in the higher end of the range, and lower CPI_{14-20} values than were found in most Spondylus from the East Flower Garden area in previous years or from other sites. A sample obtained from the East Flower Garden in 1977 also had a relatively high concentration and broad distribution of hydrocarbons, but had higher CPI values. A CPI_{14-20} value near 1 is suggestive of petroleum (Clark, 1974). Samples SAC and SAE were also the only Spondylus samples thus far found to have phytane. Phytane is generally considered to be of petroleum rather than of biological origin, and its presence suggests a petroleum source (Farrington et al., 1972). These two samples appear to have been collected closer to a drilling site than the other samples obtained for this study, and there is a possibility of some petroleum contamination. The mean of the concentration of alkanes in these two samples, however, was only slightly above the means previously seen for Spondylus (see Table IX-B-9), and this plus the absence of aromatic hydrocarbons indicates that petroleum contamination, if present, is at very low levels.

Macronekton Analysis

The three macronekton samples were pooled for analysis to avoid individual variations. The single Red porgy sample (Pagrus sedecim) (Table IX-B-4) had low concentrations of hydrocarbons in muscle and liver. The gonads had much higher concentrations and a low CPI_{14-20} value (1.07), but no phytane, so these values may be normal for the species rather than caused by petroleum hydrocarbons. In the absence of other samples of this species, it is difficult to ascertain the significance of the high gonadal concentrations, but the gonads are sites of lipid storage and frequently have high hydrocarbon concentrations (Giam et al., 1978a, 1979). The two Red snapper (Lutjanus campechanus) samples (Table IX-B-8) were within the ranges previously seen for this species (Giam et al., 1977, 1978, 1979), although the second sample from fall 1979 (sample LCB) had lower concentrations than the first (sample LCA). This was probably due to the fact that the first sample consisted of three large fish, while the second consisted of five smaller fish. Variations between sexes and between adults and juveniles were noted in our earlier studies (Giam et al., 1979). The sample LCA had a broader distribution of hydrocarbons and lower CPI_{14-20} values in muscle than found in most samples analyzed previously, but the absence of aromatic compounds indicates that if any petroleum contamination is present, it is at very low levels.

CONCLUSIONS

In hydrocarbon concentrations and distributions, the majority of the samples obtained during 1978 and 1979 were similar to samples from previous years. However, the analyses of two samples of Spondylus americanus and of a Lutjanus campechanus from the East Flower Garden Bank yielded results suggestive of slight petroleum contamination, such as a broad range of aliphatic hydrocarbons and low Carbon Preference Indices. While no firm conclusion can be drawn in the absence of other typical petroleum indicators such as aromatic hydrocarbons, this is the first time petroleum contamination has even been suggested by the hydrocarbon analyses. Thus, **these results do indicate a need for further monitoring of the area to determine if petroleum contamination is occurring.**

MANAGEMENT IMPLICATIONS

The evidence suggesting possible petroleum contamination in the two samples of Spondylus americanus from the southeast area of the East Flower Garden indicates a need for continued monitoring of this species to determine the impact of petroleum-related activities on the Flower Garden area.

TABLE IX-B-1
CONCENTRATION OF ALKANES[1] IN SPONDYLUS AND MACRONEKTON (FALL 1978)

STATION/TRANSECT	CODE	SPECIES	SAMPLE Wt. (g)	CONC. IN PPM (µg/g dry wt.)
East Flower Garden	SPA	Spondylus americanus	51.5	0.14
Sidner Bank	SPB	Spondylus americanus	88.5	0.07
East Flower Garden	SPC	Spondylus americanus	52.6	0.23
East Flower Garden	SPD	Spondylus americanus	6.5	0.52
East Flower Garden	SPE	Spondylus americanus	69.0	0.02
East Flower Garden	SPF	Spondylus americanus	75.1	0.03
East Flower Garden	SPG	Spondylus americanus	60.7	0.02
East Flower Garden	SPH	Spondylus americanus	36.1	0.06
Sidner Bank	SPI	Spondylus americanus	140.3	0.45
East Flower Garden	SPJ	Spondylus americanus	70.5	0.05
East Flower Garden	SPK	Spondylus americanus	101.3	0.01
East Flower Garden	SPL	Spondylus americanus	73.2	0.02
East Flower Garden	SPM	Spondylus americanus	13.4	0.19
East Flower Garden	SPN	Spondylus americanus	56.3	0.11
East Flower Garden	SPO	Spondylus americanus	74.7	0.04
Jakkula Bank	RPA-M[2]	Red porgy Pagrus sedecim	111.6	0.09
Jakkula Bank	RPA-L[2]	Pagrus sedicim	4.2	0.26
Jakkula Bank	RPA-G[2]	Pagrus sedicim	0.6	4.48

[1]Total for Alkanes includes total paraffins, pristane and phytane
[2]M = muscle; L = liver; G = gonad

TABLE IX-B-2
ORGANS AND INDIVIDUALS ANALYZED (FALL 1978)

STATION/TRANSECT	CODE	SPECIES	ORGAN USED*	# OF INDIVIDUALS
East Flower Garden	SPA	Spondylus americanus	W-S	1
Sidner Bank	SPB	Spondylus americanus	W-S	1
East Flower Garden	SPC	Spondylus americanus	W-S	1
East Flower Garden	SPD	Spondylus americanus	W-S	1
East Flower Garden	SPE	Spondylus americanus	W-S	1
East Flower Garden	SPF	Spondylus americanus	W-S	1
East Flower Garden	SPG	Spondylus americanus	W-S	1
East Flower Garden	SPH	Spondylus americanus	W-S	1
Sidner Bank	SPI	Spondylus americanus	W-S	1
East Flower Garden	SPJ	Spondylus americanus	W-S	1
East Flower Garden	SPK	Spondylus americanus	W-S	1
East Flower Garden	SPL	Spondylus americanus	W-S	1
East Flower Garden	SPM	Spondylus americanus	W-S	1
East Flower Garden	SPN	Spondylus americanus	W-S	1
East Flower Garden	SPO	Spondylus americanus	W-S	1
Jakkula Bank	RPA-M	Red porgy Pagrus sedecim	M	2
Jakkula Bank	RPA-L	Pagrus sedicim	L	2
Jakkula Bank	RPA-G	Pagrus sedicim	G	2

*W-S = whole less shell; M = muscle; L = liver; G = gonad

TABLE IX-B-3
PERCENT DISTRIBUTION OF n-PARAFFINS, CONCENTRATIONS OF n-PARAFFINS, PRISTANE, PHYTANE, AND TOTAL ALKANES AND CALCULATED RATIOS FOUND IN SPONDYLUS (FALL 1979)

PARAMETERS	STATIONS AND SAMPLE CODES					STATIONS AND SAMPLE CODES					STATIONS AND SAMPLE CODES				
	EFG SPA	SID SPB	EFG SPC	EFG SPD	EFG SPE	EFG SPF	EFG SPG	EFG SPH	SID SPI	EFG SPJ	EFG SPK	EFG SPL	EFG SPM	EFG SPN	EFG SPO
CARBON NO.															
14	-	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-
15	3.8	24.0	4.9	-	-	-	-	-	-	-	-	-	3.4	8.9	11.9
16	10.0	18.0	8.3	10.3	-	18.5	-	-	-	-	-	-	5.7	-	-
17	66.2	48.0	80.5	47.2	100	81.5	100	82.6	-	82.5	100	100	40.1	85.6	88.1
18	6.2	-	3.9	13.0	-	-	-	-	-	17.5	-	-	5.7	-	-
19	3.8	-	2.4	6.9	-	-	-	-	-	-	-	-	6.8	-	-
20	5.4	-	-	6.1	-	-	-	-	-	-	-	-	11.3	-	-
21	4.6	-	-	3.4	-	-	-	-	-	-	-	-	11.9	5.5	-
22	-	-	-	-	-	-	-	-	6.4	-	-	-	9.0	-	-
23	-	-	-	-	-	-	-	-	18.0	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	27.3	-	-	-	6.1	-	-
25	-	-	-	-	-	-	-	-	33.3	-	-	-	-	-	-
26	-	-	-	4.7	-	-	-	17.4	12.6	-	-	-	-	-	-
27	-	-	-	3.0	-	-	-	-	2.4	-	-	-	-	-	-
28	-	-	-	5.4	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Paraffins*	0.13	0.05	0.21	0.49	0.02	0.03	0.02	0.05	0.45	0.04	0.01	0.02	0.18	0.09	0.04
Pristane*	0.01	0.02	0.02	0.03	-	-	-	0.01	-	0.01	-	-	0.01	0.02	-
Phytane*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pr/Py	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pr/C_{17}	0.12	0.83	0.12	0.13	-	-	-	0.24	-	0.30	-	-	0.14	0.26	-
Py/C_{18}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CPI_{14-20}	3.99	3.29	7.20	2.08		4.41	-	-	-	4.71	-	-	3.31	-	-
CPI_{20-32}	-	-	-	0.51		-	-	-	1.16	-	-	-	0.62	-	-
Total Alkanes*	0.14	0.07	0.23	0.52	0.02	0.03	0.02	0.06	0.45	0.05	0.01	0.02	0.19	0.11	0.04

*ppm

TABLE IX-B-4
PERCENT DISTRIBUTION OF n-PARAFFINS, CONCENTRATIONS OF n-PARAFFINS, PRISTANE, PHYTANE, AND TOTAL ALKANES AND CALCULATED RATIOS FOUND IN MACRONEKTON (FALL 1978)

PARAMETERS	STATIONS AND SAMPLE CODES		
	JAK RPA-M	JAK RPA-L	JAK RPA-G
CARBON NO.			
14	-	-	-
15	-	8.6	-
16	-	8.0	11.8
17	23.3	19.6	22.6
18	-	6.8	13.4
19	-	-	6.3
20	-	-	4.0
21	-	-	4.0
22	-	11.0	6.0
23	-	14.1	7.6
24	-	20.2	10.1
25	16.3	11.7	8.9
26	14.0	-	5.3
27	16.2	-	-
28	14.0	-	-
29	16.2	-	-
30	-	-	-
31	-	-	-
32	-	-	-
Total Paraffins*	0.04	0.16	4.48
Pristane*	0.05	0.10	-
Phytane*	-	-	-
Pr/Py	-	-	-
Pr/C_{17}	5.56	3.23	-
Py/C_{18}	-	-	-
CPI_{14-20}	-	1.91	1.07
CPI_{20-32}	1.74	0.83	0.88
Total Alkanes*	0.09	0.26	4.48

*ppm

TABLE IX-B-5
CONCENTRATIONS OF ALKANES[1] IN SPONDYLUS AND MACRONEKTON
(FALL 1979)

Station	Code	Species	Sample Wt. (g)	Conc. in ppm (µg/g dry wt.)
West Flower Garden/N.E.	SAA	Spondylus americanus	126.2	0.02
West Flower Garden	SAB	Spondylus americanus	43.4	0.03
East Flower Garden/S.E.	SAC	Spondylus americanus	56.2	0.40
West Flower Garden/N.E.	SAD	Spondylus americanus	110.4	< 0.01
East Flower Garden/S.E.	SAE	Spondylus americanus	58.0	0.31
West Flower Garden/N.E.	SAF	Spondylus americanus	128.4	< 0.01
East Flower Garden	LCA-M[2]	Lutjanus campechanus	96.6	0.15
	LCA-G[2]		9.6	2.77
	LCA-G[2]		6.2	2.40
East Flower Garden	LCB-M[2]	Lutjanus campechanus	95.2	< 0.01
	LCB-L[2]		4.3	1.22
	LCB-G[2]		4.7	0.99

[1]Total alkanes includes total paraffins, pristane and phytane.
[2]M = muscle; L = liver; G = gonad

TABLE IX-B-6
ORGANS AND INDIVIDUALS ANALYZED (FALL 1979)

STATION/TRANSECT	CODE	SPECIES	ORGAN USED*	# OF INDIVIDUALS
West Flower Garden/N.E.	SAA	Spondylus americanus	W-S	1
West Flower Garden	SAB	Spondylus americanus	W-S	1
East Flower Garden/S.E.	SAC	Spondylus americanus	W-S	1
West Flower Garden/N.E.	SAD	Spondylus americanus	W-S	1
East Flower Garden/S.E.	SAE	Spondylus americanus	W-S	1
West Flower Garden/N.E.	SAF	Spondylus americanus	W-S	1
East Flower Garden	LCA-M	Lutjanus campechanus	M	3
	LCA-L		L	3
	LCA-G		G	3
East Flower Garden	LCB-M	Lutjanus campechanus	M	5
	LCB-L		L	5
	LCB-G		G	5

*W-S = whole less shell; M = muscle; L = liver; G = gonad.

TABLE IX-B-7
PERCENT DISTRIBUTION OF n-PARAFFINS; CONCENTRATIONS OF n-PARAFFINS, PRISTANE, PHYTANE, AND TOTAL ALKANES; AND CALCULATED RATIOS FOUND IN SPONDYLUS (FALL 1979)

PARAMETERS	STATIONS AND SAMPLE CODES					
	WFG/N.E. SAA	WFG SAB	EFG/S.E. SAC	WFG/N.E. SAD	EFG/S.E. SAE	WFG/N.E. SAF
CARBON NO.						
14	26.3	-	3.9	-	4.5	100.0
15	24.3	51.8	5.6	100.0	6.2	-
16	24.0	48.2	5.7	-	6.2	-
17	25.4	-	21.4	-	12.3	-
18	-	-	5.6	-	5.1	-
19	-	-	-	-	4.5	-
20	-	-	7.9	-	5.4	-
21	-	-	-	-	-	-
22	-	-	7.1	-	5.1	-
23	-	-	7.9	-	5.6	-
24	-	-	8.3	-	6.0	-
25	-	-	6.5	-	5.4	-
26	-	-	9.1	-	-	-
27	-	-	10.8	-	10.4	-
28	-	-	-	-	10.9	-
29	-	-	-	-	11.8	-
30	-	-	-	-	-	-
31	-	-	-	-	-	-
32	-	-	-	-	-	-
Total Paraffins*	0.02	0.03	0.31	0.004	0.28	0.004
Pristane*	-	-	0.05	-	0.01	-
Phytane*	-	-	0.04	-	0.02	-
Pr/Py	-	-	1.03	-	0.88	-
Pr/C_{17}	-	-	0.68	-	0.41	-
Py/C_{18}	-	-	2.56	-	1.12	-
CPI_{14-20}	1.53	-	1.59	-	1.41	-
CPI_{20-32}	-	-	0.90	-	1.36	-
Total Alkanes*	0.02	0.03	0.40	0.004	0.31	0.004

*ppm

TABLE IX-B-8
PERCENT DISTRIBUTION OF n-PARAFFINS; CONCENTRATIONS OF n-PARAFFINS, PRISTANE, PHYTANE, AND TOTAL ALKANES; AND CALCULATED RATIOS FOUND IN MACRONEKTON (FALL 1979)

PARAMETERS	STATIONS AND SAMPLE CODES					
	EFG LCA-M	EFG LCA-L	EFG LCA-G	EFG LCB-M	EFG LCB-L	EFG LCB-G
CARBON NO.						
14	3.3	18.0	2.4	-	9.5	-
15	36.7	16.8	28.7	-	78.8	-
16	3.5	10.7	2.9	-	-	-
17	0.1	15.1	13.4	-	11.7	7.0
18	3.5	2.6	4.3	-	-	-
19	3.2	3.0	4.3	-	-	-
20	3.6	2.9	4.0	-	-	-
21	2.9	6.6	3.9	-	-	-
22	3.3	2.2	3.7	-	-	-
23	3.7	3.5	4.2	-	-	16.6
24	3.8	3.3	4.0	-	-	14.2
25	4.5	2.3	4.4	-	-	17.6
26	5.3	3.0	5.4	-	-	19.6
27	7.2	3.9	7.7	-	-	25.0
28	6.9	6.0	6.9	-	-	-
29	8.6	-	-	-	-	-
30	-	-	-	-	-	-
31	-	-	-	-	-	-
32	-	-	-	-	-	-
Total Paraffins*	0.11	2.32	1.86	< 0.01	1.13	0.73
Pristane*	0.04	0.35	0.48	-	0.09	0.26
Phytane*	< 0.01	0.10	0.06	-	-	-
Pr/Py	10.34	3.74	7.94	-	-	-
Pr/C_{17}	221.56	1.00	1.93	-	0.68	5.1
Py/C_{18}	0.86	1.56	0.75	-	-	-
CPI_{14-20}	3.82	1.64	4.47	-	4.78	-
CPI_{20-32}	1.29	1.05	0.92	-	-	1.75
Total Alkanes*	0.15	2.77	2.40	< 0.01	1.22	0.99

*ppm

TABLE IX-B-9
COMPARISON OF SELECTED PARAMETERS FOR SPONDYLUS AMERICANUS AT THE EAST FLOWER GARDEN AND OTHER SAMPLING SITES FOR 1976-1979

PARAMETERS	YEAR SAMPLED							
	1976		1977		1978		1979	
Location	EFG	Other Banks*	EFG	18F	EFG	SID	EFG	WFG
Number of Samples	3	12	1	4	13	2	2	4
Total n-Paraffins	0.007	0.016	0.28	0.01	0.10	0.25	0.30	0.014
Total Alkanes	0.007	0.016	0.30	0.01	0.11	0.26	0.36	0.014
CPI_{14-20}	---	---	3.7	---	4.3	2.0	1.1	1.5

* 28 Fathom, Stetson, and Southern Banks and Hospital Rock

PART C: HIGH MOLECULAR WEIGHT HYDROCARBONS, DELTA C-13, AND TOTAL ORGANIC CARBON IN SEDIMENT

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INTRODUCTION

Since 1975 knowledge of the levels of petroleum-derived hydrocarbons in the coastal environment of Texas has advanced so that the data support the general statement that there is a very low baseline level of high molecular weight hydrocarbons (HMWH) in the Outer Continental Shelf, including the water column, sediment, and biota. This generalization is based on data obtained in the four-year BLM/STOCS program. These data are summarized in the three-volume report to BLM (Parker et al., 1976). The present report confirms this generalization and extends it to the topographic high features of the area. A simple statement of the observation is to note that the levels of individual HMWH in the study area are, with rare exceptions, at the sub-part per billion level.

By contrast, two other distinctive sub-environments of the Texas coast have been identified in terms of HMWH level. One of these is acute: the beach zone which received massive inputs of petroleum derived from the IXTOC blowout. At the present time (spring 1980), tar balls are abundant on the beach, and reefs of petroleum reside at several locations in the beach sand along the second and third bars. This very high level of oil will begin to dissipate with summer weather conditions, but it is not probable that it will reach the BLM/STOCS areas.

The third distinct coastal environment of Texas in terms of HMWH is the estuarine system. Preliminary work (Winters, personal communication) indicates that a fairly high level of aromatic HMWH persists in the sediment of Corpus Christi Bay. These levels are in the parts per million range, two to three orders of magnitude higher than the STOCS.

Given these three observations, the management goal is clear. First, keep IXTOC type events from happening because these levels of HMWH are directly toxic to many planktonic marine organisms (Parker et al., 1979). Second, devise management and operation practices which will keep the levels of HMWH in the open Gulf of Mexico well below the level found in the bays and estuaries. While the exact damage being done to bay marine life by present levels is not known, it is generally agreed that offshore life is more sensitive to any kind of stress, perhaps by an order of magnitude. This total consideration suggests that the various parts of the coastal system may be near their carrying capacity at the present time.

RESULTS AND DISCUSSION

This section presents overall results for the three kinds of analysis performed on the total set of 37 sediment samples. Specific conclusions and discussion regarding data from the East Flower Garden Bank (30 samples), West Flower Garden Bank (3 samples), and Coffee Lump (4 samples) are included in the special chapters on these banks (i.e. Volume Three, Chapter X, and Volume Four, Chapter XI).

High Molecular Weight Hydrocarbon in Sediments

The results of HMWH analyses of sediments are shown in Tables IX-C-1 through 3, Figures IX-C-1 through 7, and Appendix B, Tables IX-C-1 through 37. The general level of total HMWH is in the parts per billion range. This is taken to be a level approaching the natural background level. For example, the total saturated hydrocarbon range was from 0.3 to 11.2 ppb (µg/g). This is somewhat higher than last year's range (0.1 to 0.5 (µg/g), but it is doubtful that the increase is significant. Further studies may resolve this observation.

The ratio of odd to even straight chain hydrocarbon as expressed by the average OEP index falls in the same range as last year's BLM study (0.5 to 3.3). This finding suggests that no significant change has taken place in the study area since last year. Furthermore, the pristane/phytane ratios in this report are similar to those of last year. These data are summarized in Table IX-C-1.

Total Organic Carbon (TOC) and Delta C-13

The TOC and Delta C-13 values are reported in Table IX-C-2. The TOC levels are similar to values (ranging from 2.1 to 1.75) reported in earlier BLM/STOCS studies (Parker et al., 1979). The Delta C-13 values are slightly more negative (approx. 1 per mil) than reported last year. This shift is small and does not reflect petroleum contamination, but it may reflect particle size, such as Gearing et al. (1977) reported for sediment of the Mississippi River.

CONCLUSIONS

The distribution of HMWH, TOC, and Delta C-13 is not highly site dependent. Coffee Lump Bank showed total HMWH at a somewhat lower level than the other sites. Overall, no high to moderate levels of petroleum contamination were evident. However, drill site 2 at the East Flower Garden Bank showed slightly higher total HMWH levels than drill site 1. It was noted that the levels of light HMWH were significantly higher near drill site 2 than elsewhere in the study.

Post-IXTOC samples (labeled BLS and RS) showed no elevated HMWH levels. This is consistent with the University of Texas observations that the IXTOC oil was concentrated in the nearshore zone.

It is to be noted that this year aromatic HMWH molecules were unambiguously detected (Table IX-C-2 and 3, and Appendix B, Tables IX-C-1 through 37), which was not the case last year. The range of individual compounds was from 1.5 to 36 parts per billion. Much improved techniques account for the detection of aromatics this year as compared to none last year. While the level is very low, it should be a consideration in future studies. It would be useful to reanalyze the 1977 samples by the GLC and GC/MS techniques used in 1978-1979.

MANAGEMENT IMPLICATIONS

The study sites should be protected by requiring the most stringent clean drilling methods. This is so because the offshore is clean and the organisms there are probably much more sensitive to oil than inshore forms.

Program planning and operation can be improved as regards chemical studies by more rigorous station location and description, by use of nonbreakable sample containers, and by more carefully relating biota sampling to sediment sampling.

The data suggest that a carefully designed monitoring study will detect any significant addition of HMWH to the topographic features sites.

TABLE IX-C-1

CONCENTRATIONS OF n-ALKANES IN SEDIMENTS FROM THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES STUDY (μg/g)

PARAMETERS	SAMPLE CODE											
	DS1-1G	DS1-2G	DS1-3G	DS1-4G	DS1-5G	DS1-6G	DS1-7G	DS1-8G	DS1-9G	DS1-10G	DS1-11G	DS1-12G
Carbon No.												
12	-	-	-	-	-	-	0.0013	0.0045	-	0.0008	0.0011	-
13	-	-	-	0.0004	0.0042	0.0691	0.0013	0.0027	0.0727	0.0007	-	-
14	0.0004	-	0.0011	0.0008	0.0048	0.2165	0.0039	0.0074	0.0517	0.0012	0.0010	0.0014
15	0.0018	0.0031	0.0040	0.0016	0.0010	0.0415	0.0075	0.0080	0.0498	0.0048	0.0032	0.0035
16	0.0026	0.0096	0.0038	0.0015	0.0084	0.0338	0.0094	0.0104	0.0394	0.0052	0.0036	0.0106
17	0.0051	0.0158	0.0102	0.0032	0.0169	0.0327	0.0158	0.0124	0.0421	0.0140	0.0084	0.0099
18	0.0054	0.0190	0.0091	0.0033	0.0167	0.0454	0.0155	0.0113	0.0455	0.0182	0.0105	0.0134
19	0.0072	0.0263	0.0141	0.0055	0.0250	0.0505	0.0214	0.0158	0.0644	0.0220	0.0113	0.0184
20	0.0062	0.0196	0.0118	0.0034	0.0202	0.0293	0.0172	0.0102	0.0397	0.0217	0.0124	0.0175
21	0.0043	0.0194	0.0169	0.0056	0.0386	0.0344	0.0257	0.0173	0.0567	0.0341	0.0158	0.0259
22	0.0046	0.0162	0.0157	0.0028	0.0028	0.0246	0.0187	0.0109	0.0438	0.0287	0.0154	0.0235
23	0.0058	0.0184	0.0162	0.0038	0.0277	0.0375	0.0315	0.0180	0.0693	0.0226	0.0127	0.0262
24	0.0061	0.0145	0.0091	0.0024	0.0204	0.0326	0.0263	0.0145	0.0635	0.0173	0.0069	0.0180
25	0.0102	0.0252	0.0141	0.0051	0.0396	0.0583	0.0570	0.0355	0.1122	0.0214	0.0094	0.0319
26	0.0092	0.0146	0.0095	0.0036	0.0250	0.0506	0.0391	0.0262	0.0963	0.0149	0.0061	0.0245
27	0.0169	0.0477	0.0254	0.0055	0.0980	0.1167	0.1061	0.0537	0.2364	0.0437	0.0169	0.0362
28	0.0054	0.0080	0.0084	0.0051	0.0363	0.0747	0.0524	0.0321	0.1179	0.0179	0.0029	0.0278
29	0.0201	0.0853	0.0413	0.0095	0.1796	0.3096	0.2027	0.1401	0.4616	0.0583	0.0252	0.0611
30	0.0056	0.0335	0.0143	0.0023	0.0375	0.0890	0.0459	0.0290	0.0935	0.0099	0.0121	0.0210
31	0.0166	0.0679	0.0435	0.0037	0.1788	0.2478	0.2013	0.1122	0.3744	0.0446	0.0186	0.0636
32	0.0096	0.0244	0.0071	-	0.0221	0.1066	0.0389	0.0359	0.1056	0.0116	0.0034	0.0215
Total Alkanes	1.0236	1.1229	2.8797	0.3033	2.2614	8.9692	2.3216	1.3999	10.7076	2.2648	1.8463	1.3243
Pristane	0.0048	0.0145	0.0070	0.0024	0.0147	0.0242	0.0122	0.0101	0.0319	0.0146	0.0070	0.0082
Phytane	0.0034	0.0111	0.0040	0.0023	0.0107	0.0392	0.0085	0.0058	0.0460	0.0126	0.0049	0.0067
Pr/Ph	1.41	1.31	1.75	1.04	1.37	0.62	1.54	1.74	0.69	1.16	1.43	1.23
Pr/17	0.94	0.92	0.69	0.75	0.87	0.74	0.80	0.83	0.76	1.04	0.83	0.83
Ph/18	0.63	0.58	0.44	0.70	0.64	0.86	0.55	0.51	1.01	0.69	0.47	0.50
OEP (12-20)	1.16	1.18	1.45	1.47	1.48	0.91	1.23	1.15	1.24	1.35	0.86	1.00
OEP (21-32)	1.93	2.59	3.32	1.50	2.82	2.03	2.38	2.36	2.26	2.34	2.11	1.96

TABLE IX-C-1 (Continued)

PARAMETER	SAMPLE CODE											
	DS2-1G	DS2-2G	DS2-3G	DS2-4G	DS2-5G	DS2-6G	DS2-7G	DS2-8G	DS2-9G	DS2-10G	DS2-11G	DS2-12G
Carbon No.												
12	0.0059	0.0087	0.0585	0.0894	0.0384	0.0028	0.0337	0.0905	0.0218	-	0.0253	0.0052
13	0.0030	0.0025	0.0163	0.0259	0.0242	0.0014	0.0109	0.0127	0.0057	-	0.0122	0.0011
14	0.0172	0.0099	0.0117	0.0262	0.0337	0.0075	0.0310	0.0527	0.0223	-	0.0269	0.0064
15	0.0094	0.0053	0.0100	0.0226	0.0370	0.0032	0.0183	0.0239	0.0110	-	0.0244	0.0012
16	0.0209	0.0126	0.0120	0.0280	0.0581	0.0100	0.0380	0.0645	0.0292	-	0.0335	0.0069
17	0.0161	0.0131	0.0155	0.0345	0.0897	0.0086	0.0412	0.0643	0.0251	-	0.0596	0.0036
18	0.0181	0.0188	0.0203	0.0449	0.0817	0.0133	0.0678	0.0874	0.0372	-	0.0636	0.0070
19	0.0228	0.0253	0.0283	0.0646	0.0778	0.0126	0.0868	0.1183	0.0415	-	0.0732	0.0062
20	0.0155	0.0202	0.0184	0.0468	0.0564	0.0096	0.0642	0.0892	0.0298	-	0.0466	0.0049
21	0.0184	0.0266	0.0186	0.0480	0.0518	0.0081	0.0896	0.1064	0.0339	-	0.0547	0.0045
22	0.0135	0.0244	0.0151	0.0360	2.1290	0.1386	0.1267	0.6398	0.0282	-	1.0637	0.0424
23	0.0216	0.0382	0.0210	0.0542	0.0779	0.0097	0.1515	0.6270	0.0408	-	0.0917	0.0058
24	0.0150	0.0422	0.0201	0.0510	0.1108	0.0113	0.1462	0.1238	0.0399	-	0.1262	0.0075
25	0.0375	0.0730	0.0302	0.0990	0.1616	0.0167	0.2810	0.2599	0.0808	-	0.2092	0.0100
26	0.0246	0.0591	0.0211	0.0942	0.1564	0.0161	0.1866	0.1959	0.0694	-	0.2354	0.0136
27	0.0674	0.1178	0.0281	0.2112	0.2265	0.0268	0.3781	0.4206	0.1500	-	0.2896	0.0141
28	0.0441	0.0780	0.0282	0.2172	0.1462	0.0149	0.2396	0.2501	0.0845	-	0.1918	0.0131
29	0.1318	0.2349	0.0956	0.5471	0.3229	0.0436	0.6295	0.7134	0.2511	-	0.4126	0.0231
30	0.0263	0.0904	0.0286	0.4807	0.1031	0.0116	0.1970	0.1925	0.0640	-	0.1306	0.0071
31	0.1494	0.2606	0.0973	0.8285	0.3177	0.0257	0.8013	0.7645	0.2388	-	0.4335	0.0220
32	0.0270	0.1050	0.0167	0.5301	0.0973	0.0126	0.2334	0.1630	0.0966	-	0.1015	-
Total Alkanes	1.3928	2.4417	2.6807	7.7785	7.3144	0.8155	8.6377	11.1970	4.0896	-	7.7640	0.7021
Pristane	0.0139	0.0114	0.0141	0.0312	0.0483	0.0051	0.0278	0.0495	0.0183	-	0.0337	0.0019
Phytane	0.0082	0.0095	0.0140	0.0262	0.0347	0.0049	0.	0.0406	0.0146	-	0.0291	0.0020
Pr/Ph	1.70	1.20	1.01	1.19	1.39	1.04	0.87	1.22	1.26	-	1.25	0.97
Pr/17	0.86	0.87	0.91	0.90	0.54	0.59	0.67	0.77	0.73	-	0.57	1.89
Ph/18	0.45	0.50	0.69	0.58	0.42	0.37	0.47	0.46	0.39	-	0.46	3.5
OEP (12-20)	0.86	0.86	1.07	1.04	0.92	0.61	0.86	0.76	0.70	-	0.95	0.50
OEP (21-32)	2.34	1.76	1.98	1.60	1.19	1.40	1.84	1.65	1.60	-	1.21	0.79

TABLE IX-C-1 (Continued)

PARAMETERS	SAMPLE CODE									
	EFG-1G	EFG-2G	EFG-3G	EFG-4G	*RS-1G	*RS-2G	*RS-3G	*BLS-33	*BLS-34	*BLS-35
Carbon No.										
12	0.0104	-	-	-	0.0103	0.0018	0.0024	0.0021	0.0007	-
13	0.0026	-	0.0433	0.0240	0.0052	-	0.0009	0.0015	0.0008	-
14	0.0114	0.0090	0.0244	0.0131	0.0259	0.0100	0.0066	0.0102	0.0021	-
15	0.0073	0.0103	0.0205	0.0121	0.0125	-	0.0036	0.0055	0.0020	-
16	0.0165	0.0135	0.0149	0.0090	0.0332	0.0125	0.0084	0.0146	0.0036	0.0008
17	0.0182	0.0195	0.0144	0.0061	0.0256	0.0049	0.0083	0.0178	0.0071	0.0033
18	0.0187	0.0182	0.0189	0.0055	0.0432	0.0152	0.0144	0.0307	0.0143	0.0089
19	0.0237	0.0265	0.0226	0.0077	0.0658	0.0256	0.0212	0.0446	0.0224	0.0165
20	0.0185	0.0201	0.0156	0.0058	0.0634	0.0296	0.0188	0.0337	0.0167	0.0139
21	0.0284	0.0246	0.0162	0.0076	0.0709	0.0312	0.0245	0.0374	0.0165	0.0161
22	0.1821	0.0203	0.0127	0.0071	0.0444	0.0267	0.0239	0.0328	0.0163	0.0137
23	0.0327	0.0332	0.0195	0.0089	0.0497	0.0233	0.0293	0.0399	0.0200	0.0153
24	0.0380	0.0249	0.0162	0.0077	0.0399	0.0174	0.0269	0.0339	0.0211	0.0142
25	0.0621	0.0708	0.0439	0.0129	0.0786	0.0388	0.0421	0.0628	0.0341	0.0253
26	0.0480	0.0370	0.0331	0.0099	0.0623	0.0267	0.0391	0.0532	0.0416	0.0348
27	0.1095	0.1197	0.0608	0.0200	0.1926	0.0655	0.0871	0.1454	0.0444	0.0378
28	0.0560	0.0574	0.0451	0.0180	0.1151	0.0471	0.0493	0.0717	0.0452	0.0441
29	0.0720	0.2165	0.1253	0.0367	0.3614	0.1314	0.1768	0.2648	0.0733	0.0723
30	0.0507	0.0404	0.0342	0.0104	0.1584	0.0447	0.0404	0.0592	0.0307	0.0285
31	0.1878	0.2213	0.1397	0.0440	0.4676	0.1596	0.1650	0.2919	0.0708	0.0766
32	0.0362	0.1074	0.0773	-	0.2473	0.0431	0.0575	0.1235	0.0417	0.0330
Total Alkanes	2.5082	2.6941	9.7859	6.1883	4.5336	1.6391	2.0644	3.4595	1.2768	1.0333
Pristane	0.0133	0.0166	0.0073	0.0032	0.0250	0.0037	0.0056	0.0120	0.0049	0.0019
Phytane	0.0071	0.0113	0.0091	0.0059	0.0279	0.0064	0.0060	0.0119	0.0065	0.0037
Pr/Ph	1.87	1.47	0.80	0.54	0.90	0.58	0.93	1.01	0.75	0.51
Pr/17	0.73	0.85	0.51	0.52	0.98	0.76	0.68	0.67	0.69	0.58
Ph/18	0.38	0.62	0.48	1.07	0.65	0.42	0.42	0.39	0.45	0.42
OEP (12-20)	0.84	1.24	1.11	1.15	0.62	0.44	0.67	0.76	0.87	0.83
OEP (21-32)	1.29	2.55	1.94	1.39	1.83	2.19	2.21	2.25	1.32	1.45

*Post - IXTOC samples. RS samples taken at the West Flower Garden; BLS samples taken at the East Flower Garden.

TABLE IX-C-1 (Continued)

PARAMETERS	SAMPLE CODE									
	EFG-1G	EFG-2G	EFG-3G	EFG-4G	*RS-1G	*RS-2G	*RS-3G	*BLS-33	*BLS-34	*BLS-35
Carbon No.										
12	0.0104	-	-	-	0.0103	0.0018	0.0024	0.0021	0.0007	-
13	0.0026	-	0.0433	0.0240	0.0052	-	0.0009	0.0015	0.0008	-
14	0.0114	0.0090	0.0244	0.0131	0.0259	0.0100	0.0066	0.0102	0.0021	-
15	0.0073	0.0103	0.0205	0.0121	0.0125	-	0.0036	0.0055	0.0020	-
16	0.0165	0.0135	0.0149	0.0090	0.0332	0.0125	0.0084	0.0146	0.0036	0.0008
17	0.0182	0.0195	0.0144	0.0061	0.0256	0.0049	0.0083	0.0178	0.0071	0.0033
18	0.0187	0.0182	0.0189	0.0055	0.0432	0.0152	0.0144	0.0307	0.0143	0.0089
19	0.0237	0.0265	0.0226	0.0077	0.0658	0.0256	0.0212	0.0446	0.0224	0.0165
20	0.0185	0.0201	0.0156	0.0058	0.0634	0.0296	0.0188	0.0337	0.0167	0.0139
21	0.0284	0.0246	0.0162	0.0076	0.0709	0.0312	0.0245	0.0374	0.0165	0.0161
22	0.1821	0.0203	0.0127	0.0071	0.0444	0.0267	0.0239	0.0328	0.0163	0.0137
23	0.0327	0.0332	0.0195	0.0089	0.0497	0.0233	0.0293	0.0399	0.0200	0.0153
24	0.0380	0.0249	0.0162	0.0077	0.0399	0.0174	0.0269	0.0339	0.0211	0.0142
25	0.0621	0.0708	0.0439	0.0129	0.0786	0.0388	0.0421	0.0628	0.0341	0.0253
26	0.0480	0.0370	0.0331	0.0099	0.0623	0.0267	0.0391	0.0532	0.0416	0.0348
27	0.1095	0.1197	0.0608	0.0200	0.1926	0.0655	0.0871	0.1454	0.0444	0.0378
28	0.0560	0.0574	0.0451	0.0180	0.1151	0.0471	0.0493	0.0717	0.0452	0.0441
29	0.0720	0.2165	0.1253	0.0367	0.3614	0.1314	0.1768	0.2648	0.0733	0.0723
30	0.0507	0.0404	0.0342	0.0104	0.1584	0.0447	0.0404	0.0592	0.0307	0.0285
31	0.1878	0.2213	0.1397	0.0440	0.4676	0.1596	0.1650	0.2919	0.0708	0.0766
32	0.0362	0.1074	0.0773	-	0.2473	0.0431	0.0575	0.1235	0.0417	0.0330
Total Alkanes	2.5082	2.6941	9.7859	6.1883	4.5336	1.6391	2.0644	3.4595	1.2768	1.0333
Pristane	.0133	0.0166	0.0073	0.0032	0.0250	0.0037	0.0056	0.0120	0.0049	0.0019
Phytane	0.0071	0.0113	0.0091	0.0059	0.0279	0.0064	0.0060	0.0119	0.0065	0.0037
Pr/Ph	1.87	1.47	0.80	0.54	0.90	0.58	0.93	1.01	0.75	0.51
Pr/17	0.73	0.85	0.51	0.52	0.98	0.76	0.68	0.67	0.69	0.58
Ph/18	0.38	0.62	0.48	1.07	0.65	0.42	0.42	0.39	0.45	0.42
OEP (12-20)	0.84	1.24	1.11	1.15	0.62	0.44	0.67	0.76	0.87	0.83
OEP (21-32)	1.29	2.55	1.94	1.39	1.83	2.19	2.21	2.25	1.32	1.45

*Post - IXTOC samples. RS samples taken at the West Flower Garden; BLS samples taken at the East Flower Garden.

TABLE IX-C-2
TOTAL ORGANIC CARBON AND DELTA C-13 VALUES IN SEDIMENTS FROM NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES STUDY
(Drill Sites 1 and 2, East Flower Garden Bank)

SAMPLE	TOC*	Delta C-13**	SAMPLE	TOC*	Delta C-13**
DS1-1G	1.35	-20.89	EFG-1G	1.27	-21.34
DS1-2G	1.49	-21.32	EFG-2G	1.32	-21.33
DS1-3G	1.18	-20.47	EFG-3G	1.10	-21.44
DS1-4G	1.15	-21.23	EFG-4G	0.94	-20.79
DS1-5G	1.33	-20.74			
DS1-6G	1.33	-21.22	COF-1	0.22	-21.46
DS1-7G	1.14	-21.21	COF-2	0.38	-21.00
DS1-8G	1.13	-21.50	COF-3	0.54	-21.25
DS1-9G	0.68	-21.78	COF-4	0.13	-22.53
DS1-10G	1.35	-20.85			
DS1-11G	1.18	-20.04	†BLS-33b	1.00	-21.26
DS1-12G	1.28	-20.10	†BLS-34b	1.26	-20.67
			†BLS-35b	1.46	-21.51
DS2-1G	1.04	-20.95			
DS2-2G	0.87	-20.96	††RS-1b	0.99	-21.73
DS2-3G	0.97	-21.73	††RS-2b	0.58	-21.03
DS2-4G	1.20	-20.69	††RS-3b	1.36	-21.35
DS2-5G	1.28	-21.40			
DS2-6G	1.13	-21.39			
DS2-7G	1.00	-21.48			
DS2-8G	1.08	-21.40			
DS2-9G	1.21	-21.27			
DS2-10G	-	-			
DS2-11F	0.97	-21.35			
DS2-12G	1.11	-21.35			

* TOC is percent Total Organic Carbon on a carbonate free basis.
** Delta C-13 values reported relative to PDB carbonate standard.
† East Flower Garden Bank - post-IXTOC samples.
†† West Flower Garden Bank - post-IXTOC samples.

TABLE IX-C-3
PEAK IDENTIFICATION IN BENZENE ELUATES

Peak No.	Compounds	M.W.
1	Naphthalene	128
2	Methylnaphthalenes	142
3	Dibenzothiophene	184
4	Phenanthrene	178
5	Fluoranthene	202
6	Pyrene	202
7	Benz[a]anthracenes	228
8	Chrysene	228
9	Benz[*]fluoranthenes	252
10	Benz[e]pyrene	252
11	Benz[a]pyrene	252
12	Perylene	252

*Exact isomers are not known.

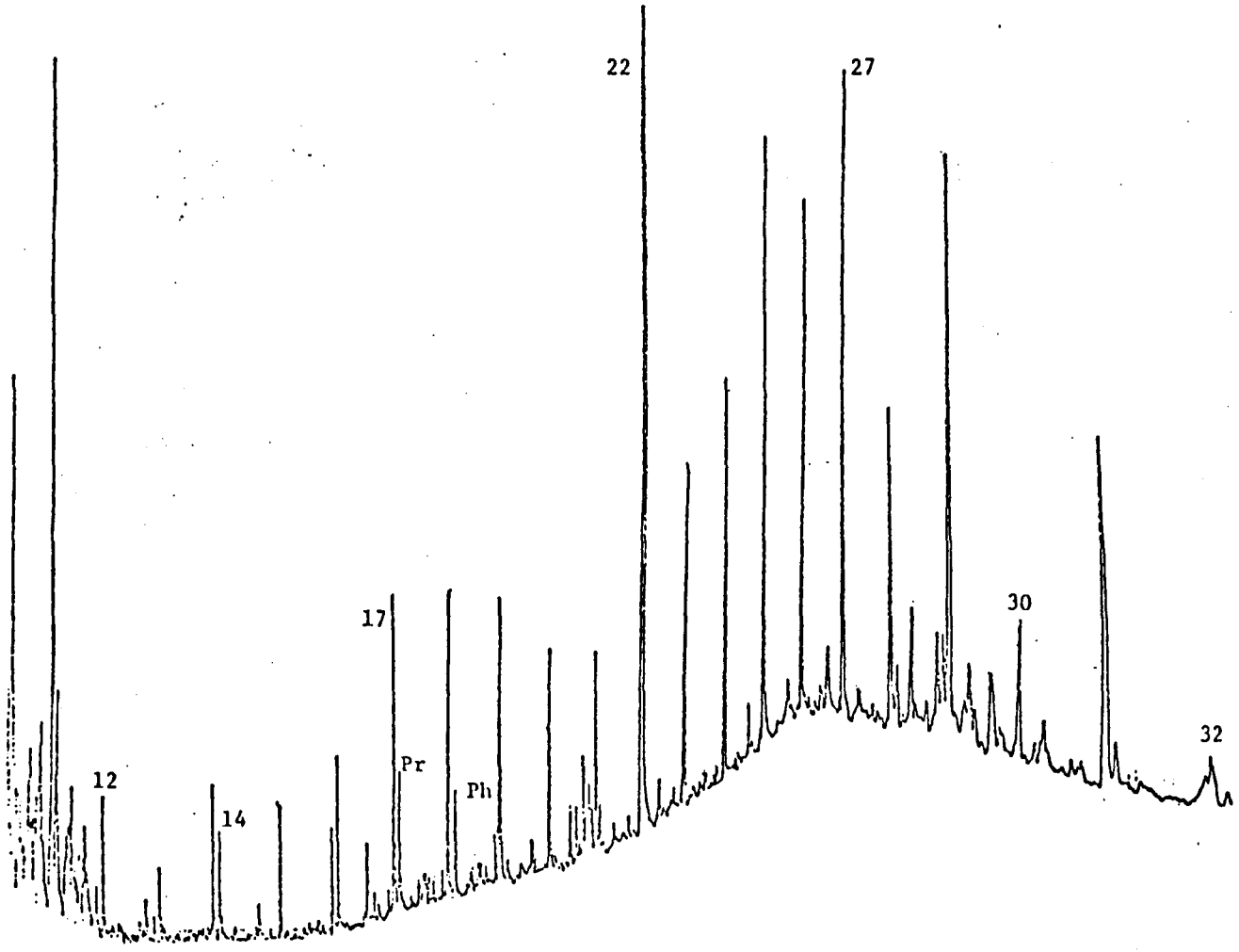

Figure IX-C-1. Gas chromatogram of DS2-11G hexane eluate. Numbers indicate carbon numbers of normal alkanes; Pr = pristane; Ph = phytane.

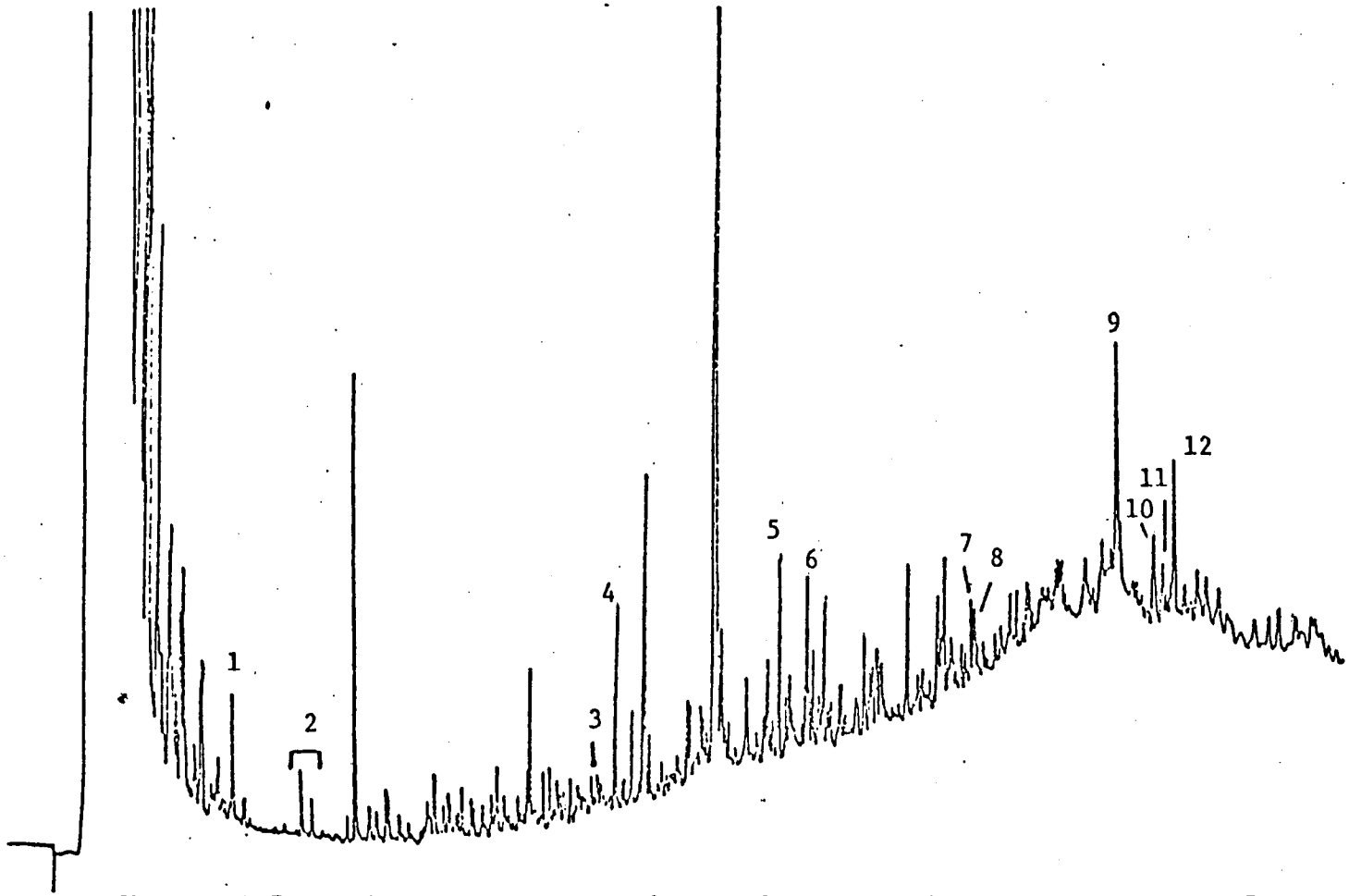

Figure IX-C-2. Gas chromatogram of DS2-7G benzene eluate. See Table IX-C-3 for peak identifications.

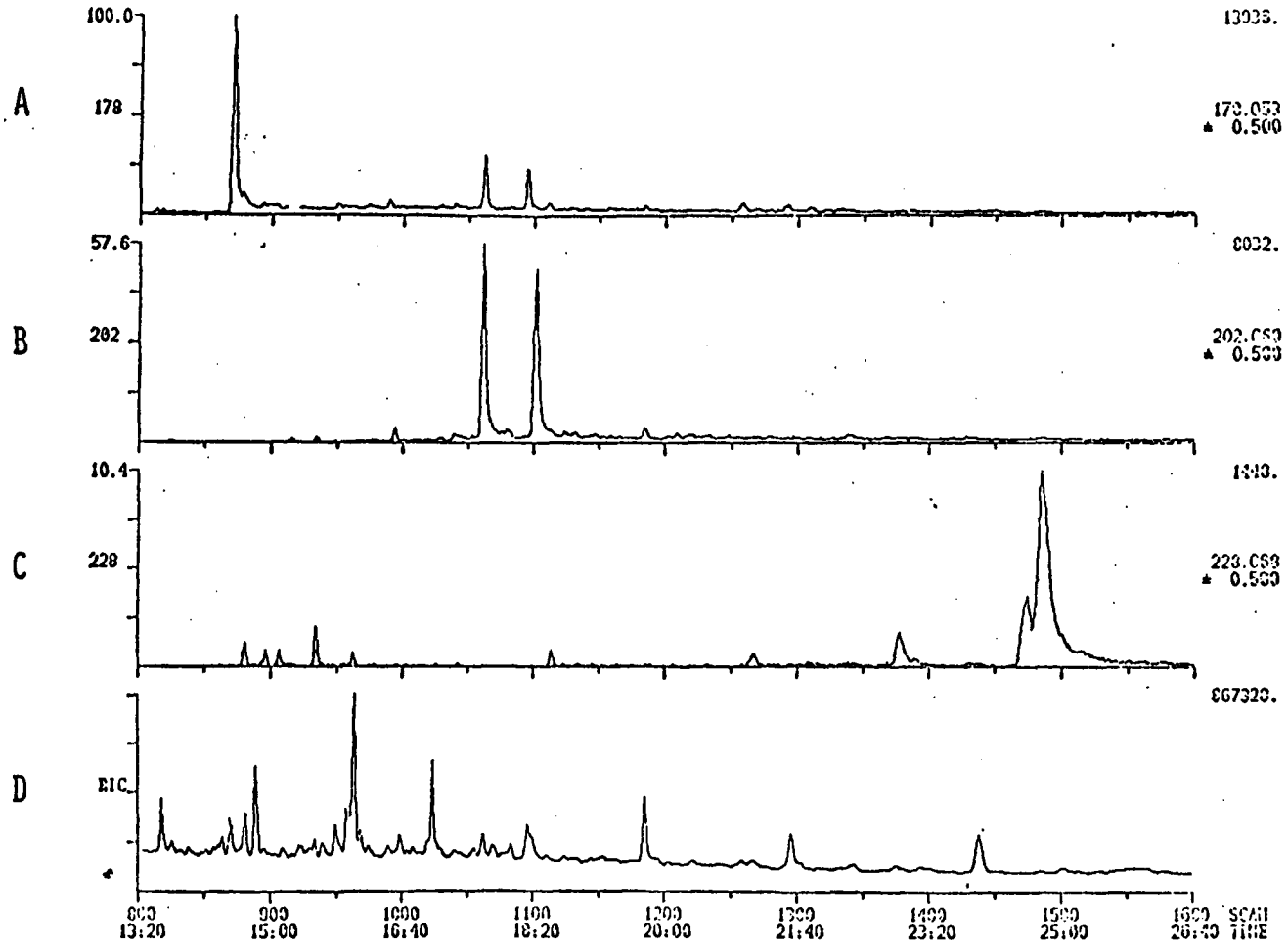

Figure IX-C-3. Mass chromatograms of polycyclic aromatic hydrocarbons from sample DS2-7G. A) Phenanthrene (M/E = 178); B) Fluoranthene and Pyrene (M/E = 202); C) Benz[a]Anthracene and Chrysene (M/E = 228); D) Reconstructed gas chromatograph showing polycyclic aromatic hydrocarbon range.

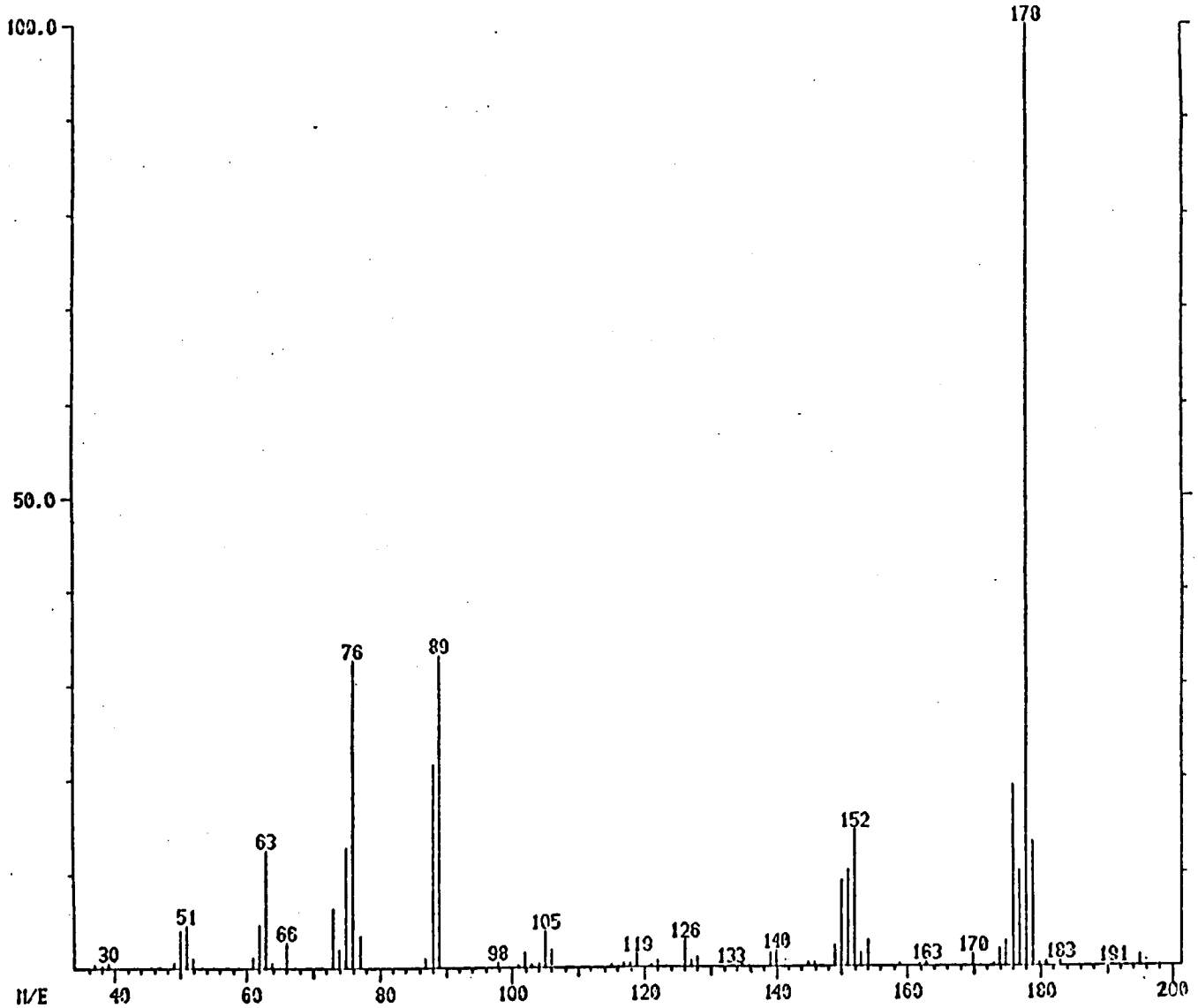

Figure IX-C-4. Mass spectrum of phenanthrene (M/E = 178) from sample DS2-7G.

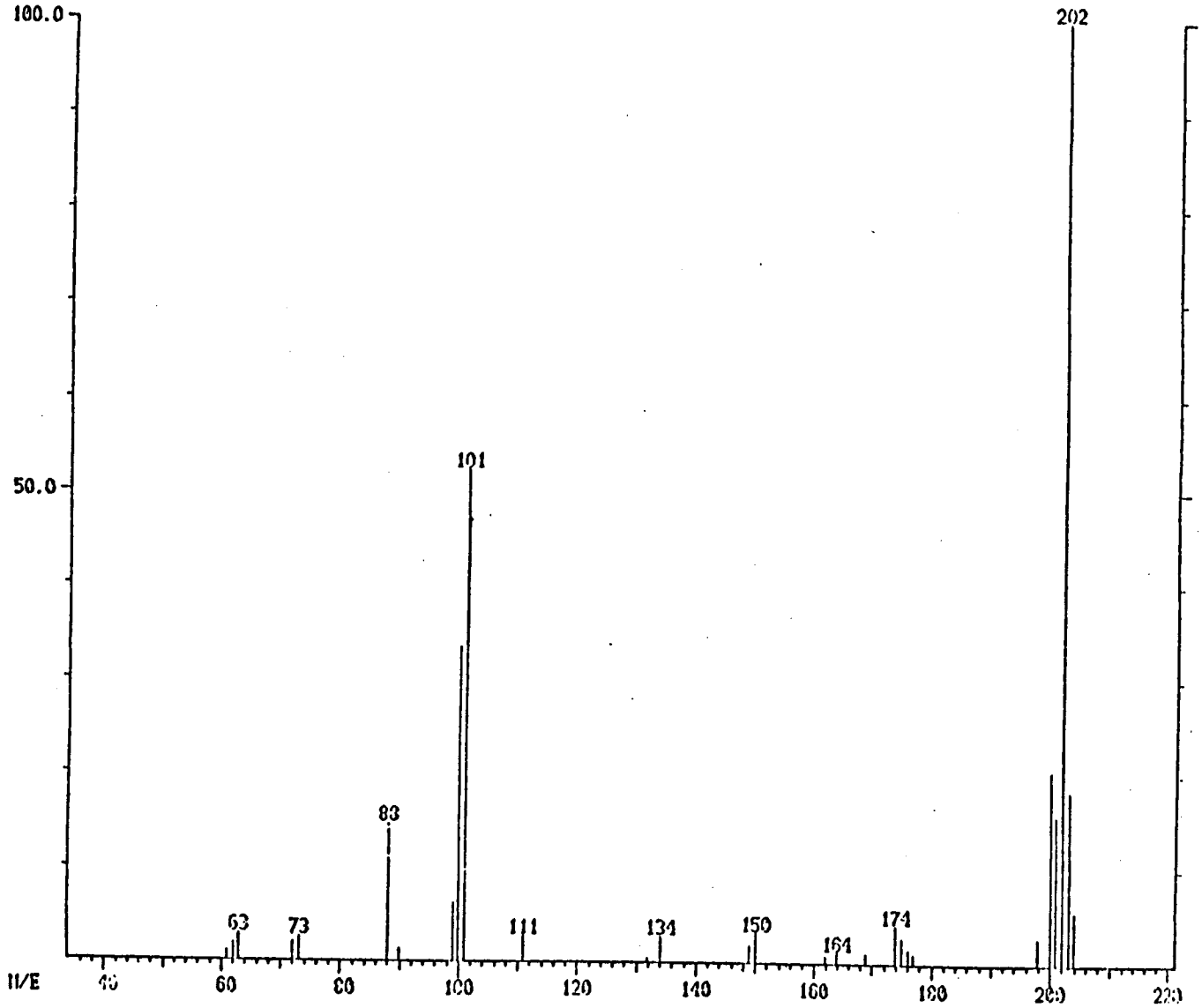

Figure IX-C-5. Mass spectrum of fluoranthene (M/E = 202) from sample DS2-7G.

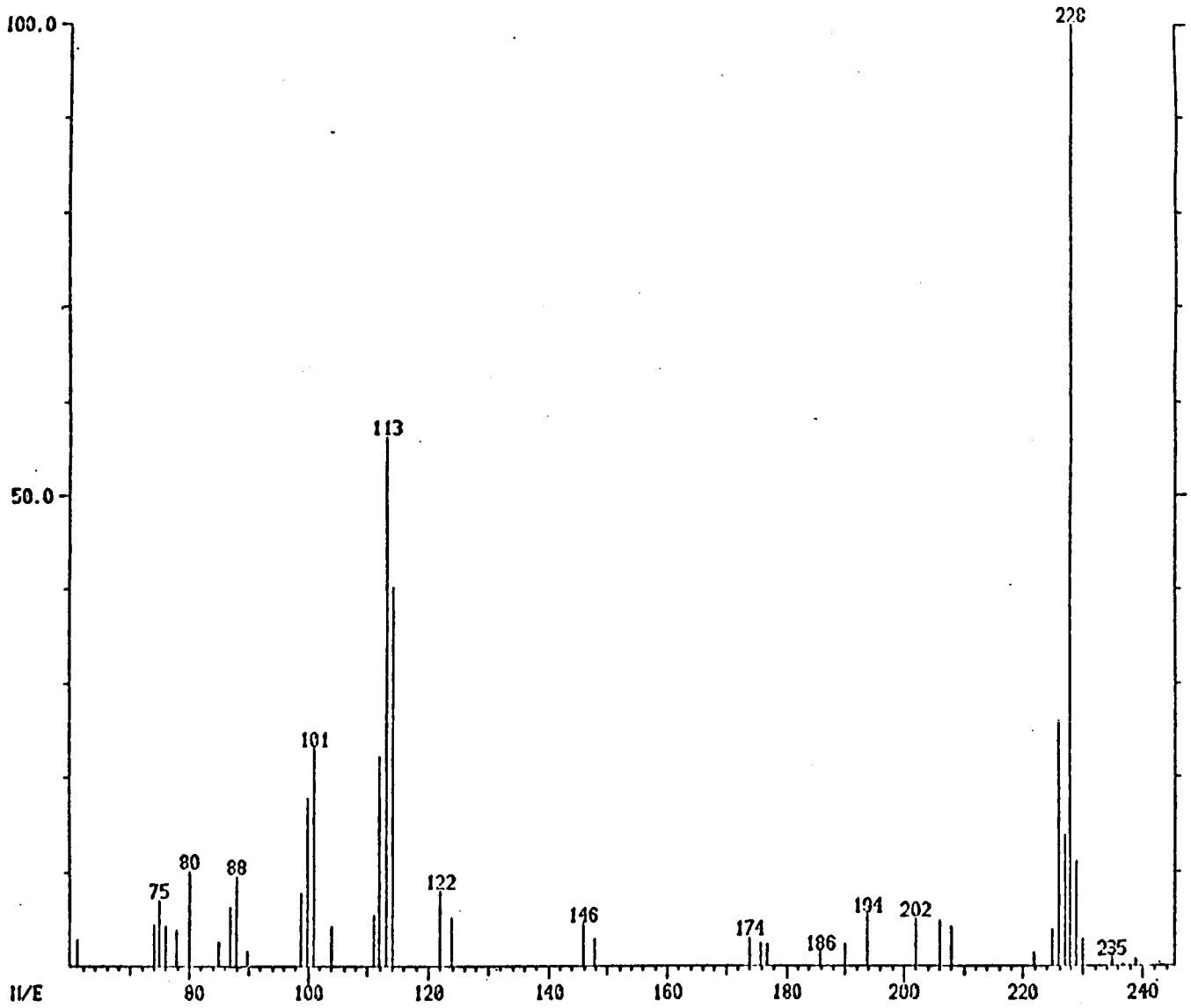

Figure IX-C-6. Mass spectrum of chrysene (M/E = 228) from sample DS2-7G.

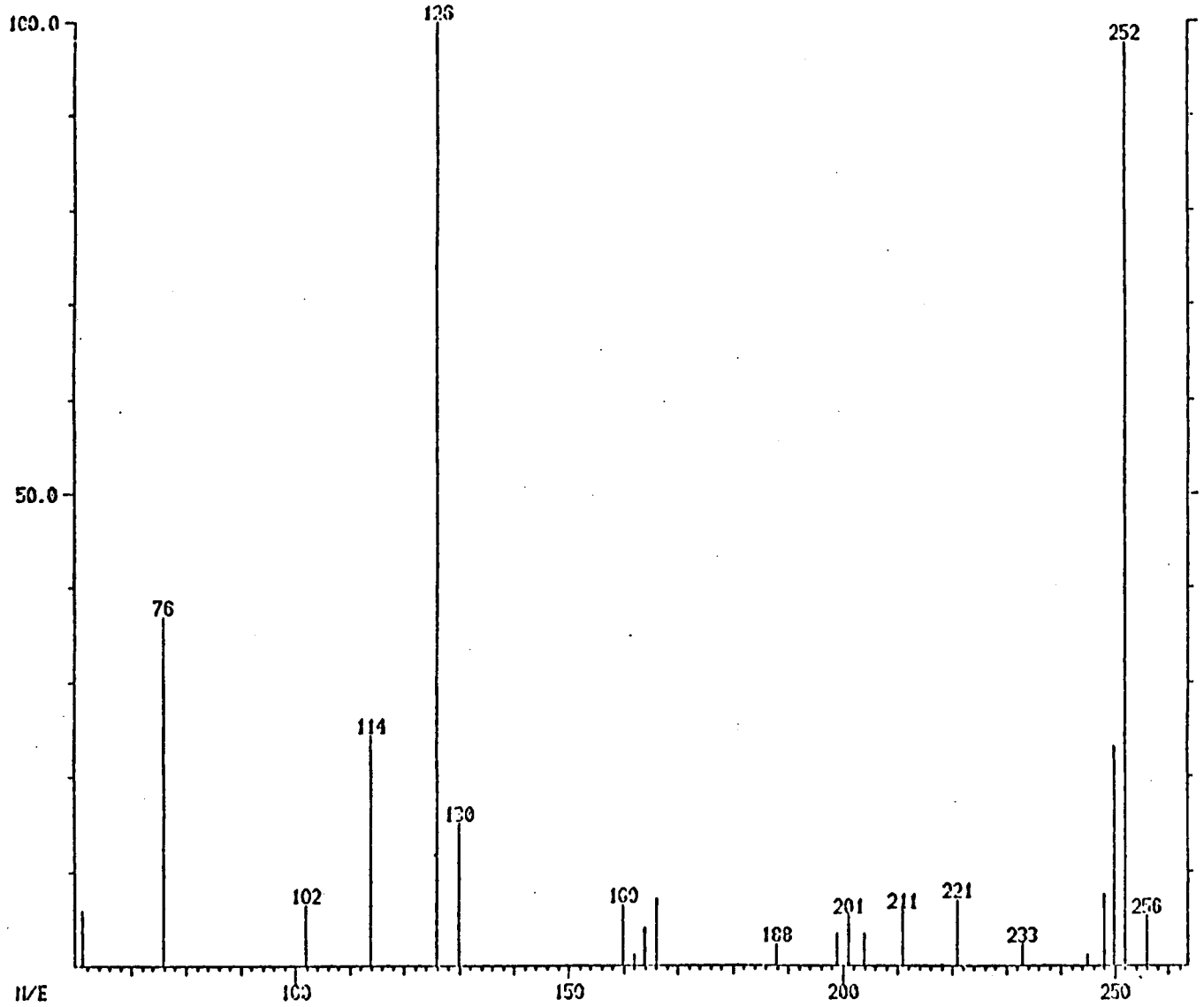

Figure IX-C-7. Mass spectrum of perylene (M/E = 252) from sample DS-7G.

APPENDIX B

RAW DATA TABLES

TABLE VIII-1
SAMPLE DATA - SURFICIAL SEDIMENT SAMPLES (TENNECO)

SAMPLE			COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS			EXPONENTIAL
Area	Line	Station	Reworked	Total	Reworked	Total(mm)	Reworked	Total	RATIO	VALUE
47	BB	6	3	383	26.8	0.17	3	60379	20126	5
31	B	13	4	277	27.9	0.34	4	22730	5683	4
C-2	I	13	21	328	18.3	1.19	21	5044	240	3
36	F	2	11	227	15.1	0.34	11	10081	916	3
44	A	12	3	246	27.0	0.17	3	39071	13024	5
27	B	1	4	280	27.7	0.51	4	15208	3802	4
42	C	20	2	323	27.2	0.34	2	25840	12920	5
27	B	19	20	271	17.3	0.85	20	5516	276	3
38	N	1	6	398	28.0	0.34	6	32776	5463	4
13	B	16	11	281	27.3	0.17	11	45125	4102	4
44	E	1	1	298	27.4	0.85	1	9606	9606	4
32	M	10	12	261	27.3	0.51	12	13971	1164	4
30	C	11	8	244	26.8	0.34	8	19233	2404	4
30	A	11	15	375	27.7	0.34	15	30551	2037	4
13	I	25	37	288	26.3	0.85	37	8911	241	3
39	F	15	11	370	28.0	0.34	11	30471	2770	4
54	G	22	118	237	28.2	1.19	118	5616	48	2
45	B	21	19	218	28.2	0.17	19	36162	1903	4
40	B	1	2	326	28.4	0.34	2	27231	13615	5
54	B	1	8	387	27.8	0.51	8	21095	2637	4
42	C	1	4	203	26.1	17.04	4	311	78	2
25	L	1	9	240	27.7	0.68	9	9776	1086	4
30	C	1	10	412	27.8	0.68	10	16844	1684	4
C-4	C	15	11	367	28.9	0.34	11	31195	2836	4
25	F	17	13	219	19.5	0.17	13	25121	1932	4
38	C	19	17	393	28.2	0.34	17	32596	1917	4
35	A	7	7	207	28.2	43.97	7	133	19	2
43	A	15	4	60	28.8	42.61	4	41	10	2
47	A	19	10	366	27.1	0.34	10	29172	2917	4
21	E	8	10	329	26.8	0.34	10	25933	2593	4
47	J	15	9	350	27.1	0.34	9	27897	3100	4
21	K	1	8	441	27.2	0.34	8	35280	4410	4
25	C	36	20	224	26.1	0.34	20	17195	860	3
28	G	9	38	217	28.1	1.19	38	5124	135	3
44	I	1	20	376	29.0	0.17	20	64141	3207	4
20	H	15	12	341	28.7	0.51	12	19190	1599	4
49	F	11	7	467	29.1	0.51	7	26646	3807	4
48	A	1	8	412	28.0	0.34	8	33929	4241	4
33	J	12	15	211	27.0	5.11	15	1115	74	2
46	H	13	13	371	29.1	0.34	13	31753	2443	4
38	N	19	11	230	26.7	6.48	11	948	86	2
47	C	14	21	551	28.4	0.17	21	92049	4383	4
C-2	J	1	11	223	35.9	2.39	11	3350	305	3
C-6	B	1	8	222	28.1	3.75	8	1664	208	3
27	H	19	155	330	28.8	0.68	155	13976	90	2
22	B	11	13	361	27.5	0.34	13	29199	2246	4
54	C	44	15	501	27.1	0.17	15	79865	5324	4
50	F	10	4	254	28.2	0.68	4	10534	2633	4
29	C	12	29	273	28.8	0.85	29	9250	319	3
32	C	1	40	235	28.3	0.68	40	9780	245	3

TABLE VIII-1 (Continued)

SAMPLE			COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS			EXPONENTIAL
Area	Line	Station	Reworked	Total	Reworked	Total(mm)	Reworked	Total	RATIO	VALUE
48	K	1	12	287	28.3	0.17	12	47777	3981	4
C-5	H	1	4	265	26.7	0.85	4	8324	2081	4
53	K	1	5	314	27.7	0.85	5	10233	2047	4
20	A	1	5	252	37.1	2.39	5	3912	782	3
43	F	1	6	343	29.5	0.51	6	19840	3307	4
45	K	21	14	249	26.2	1.70	14	3838	274	3
46	C	1	5	291	27.9	1.53	5	5306	1061	4
43	A	1	5	438	28.8	0.68	5	18551	3710	4
40	G	1	31	252	18.6	1.53	31	3064	99	2
54	G	44	26	234	27.2	2.56	26	2486	96	2
49	J	1	3	260	25.8	4.09	3	1640	547	3
C-5	B	2	8	271	28.1	1.87	8	4072	509	3
45	B	2	5	572	27.8	0.51	5	31180	6236	4
18	A	11	6	299	27.6	0.51	6	16181	2697	4
39	C	15	7	313	27.8	0.68	7	12796	1828	4
51	K	1	6	212	27.2	23.01	6	251	41	2
36	N	5	38	248	38.1	1.36	38	6948	183	3
36	N	13	10	323	29.4	1.70	10	5586	559	3
21	C	18	3	358	23.9	0.34	3	25165	8388	4
49	J	15	5	299	27.7	1.87	5	4429	886	3
19	A	1	7	316	27.5	0.85	7	10224	1461	4
54	G	1	4	401	28.4	0.68	4	16748	4187	4
52	C	1	0	0	-	18.41	0	0	-	0
52	D	1	10	228	28.6	5.79	10	1126	113	3
18	R	1	0	0	-	20.79	0	0	-	0
18	R	2	0	0	-	40.05	0	0	-	0
C-8	H	18	4	3	26.7	26.93	4	3	1	1
C-8	G	18	0	0	27.5	38.18	0	0	-	0
32	I	12	37	229	29.2	1.70	37	3933	106	3
32	I	13	6	53	26.3	51.47	6	27	5	1
52	C	17	0	0	27.9	30.51	0	0	-	0
52	D	17	13	236	29.0	6.31	13	1085	83	2
49	B	1	2	3	27.3	30.68	2	3	1	1
49	B	2	12	37	28.9	54.20	12	20	2	1
C-3	C	25	3	205	27.0	48.23	3	115	38	2
C-3	C	24	13	47	28.8	40.39	13	34	3	1
34	I	9	0	0	-	21.82	0	0	-	0
53	P	1	0	0	-	28.29	0	0	-	0
53	O	1	16	300	28.6	8.35	16	1028	64	2
53	P	15	10	108	28.5	74.65	10	41	4	1
53	O	15	22	590	29.7	0.51	22	34359	1562	4
18	R	15	0	0	-	35.11	0	0	-	0
18	R	14	0	0	-	41.58	0	0	-	0
46	H	1	9	37	27.8	68.17	9	15	1	1
46	H	2	0	302	26.2	0.17	0	46544		5
26	G	2	4	10	27.8	56.07	4	5	1	1
26	G	3	5	31	28.4	63.91	5	14	3	1
33	C	11	0	0	-	42.44	0	0	-	0
33	C	10	24	154	28.3	43.29	24	101	4	1
C-7	B	24	0	0	-	32.38	0	0	-	0
46	C	13	0	3	28.6	37.84	0	0	-	0

TABLE VIII-1 (Continued)

SAMPLE			COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS			EXPONENTIAL
Area	Line	Station	Reworked	Total	Reworked	Total(mm)	Reworked	Total	RATIO	VALUE
46	C	12	68	276	29.0	2.56	68	3127	46	2
18	I	15	0	0	-	38.35	0	0	-	0
18	I	14	0	0	-	30.34	0	0	-	0
50	A	18	0	0	-	36.64	0	0	-	0
50	B	18	0	0	28.4	37.15	0	0	-	0
37	C	1	14	30	18.3	72.43	14	8	1	1
37	C	2	140	336	27.7	29.14	140	319	2	1
33	J	1	11	76	17.7	42.44	11	32	3	1
34	G	1	0	0	-	34.60	0	0	-	0
C-7	J	4	0	0	-	35.79	0	0	-	0
25	C	1	0	0	-	37.84	0	0	-	0
25	C	2	20	755	27.7	0.34	20	61510	3076	4
50	K	19	0	0	-	32.55	0	0	-	0
50	J	19	5	10	27.7	40.22	5	7	1	1
47	J	1	2	15	26.8	51.13	2	8	4	1
47	J	2	17	535	18.2	0.17	17	57276	3369	4
C-7	J	24	0	0	-	48.40	0	0	-	0
18	A	1	0	0	-	46.53	0	0	-	0
18	A	2	14	433	27.9	0.68	14	17766	1269	4
C-7	E	12	0	0	-	42.10	0	0	-	0
26	A	15	3	8	28.0	43.46	3	5	2	1
26	A	14	9	21	28.0	42.61	9	14	2	1
42	EE	19	4	10	26.2	49.60	4	5	1	1
42	EE	18	10	26	27.8	36.98	10	20	2	1
50	A	2	3	5	27.1	49.94	3	3	1	1
50	B	1	5	301	29.5	2.56	5	3469	694	3
34	A	13	0	0	-	43.63	0	0	-	0
41	J	1	12	55	27.6	63.40	12	24	2	1
41	J	2	11	38	28.4	44.65	11	24	2	1
32	I	1	13	52	26.8	68.68	13	20	2	1
32	I	2	3	5	27.8	38.52	3	4	1	1
C-6	A	13	0	0	-	31.87	0	0	-	0
C-3	G	10	29	205	26.5	65.62	29	83	3	1
C-3	G	11	20	278	17.8	1.19	20	4158	208	3
18	I	1	0	0	26.5	46.87	0	0	-	0
18	I	3	2	3	27.6	43.29	2	2	1	1
53	D	1	3	18	29.3	71.75	3	7	2	1
53	D	8	208	244	14.1	1.53	208	2249	11	2
25	L	29	11	240	26.1	47.89	11	131	12	2
19	G	1	0	0	-	48.91	0	0	-	0
19	G	2	15	650	27.6	0.34	15	52765	3518	4
23	E	1	4	66	26.9	53.86	4	33	8	1
23	E	3	40	214	29.3	39.37	40	159	4	1
C-7	B	1	0	0	28.1	43.63	0	0	-	0
34	B	1	2	11	28.2	55.39	2	6	3	1
C-3	C	1	3	13	28.6	51.13	3	7	2	1
47	D	19	0	0	-	35.28	0	0	-	0
47	D	17	94	239	17.2	34.09	94	121	1	1
C-8	F	1	0	0	25.8	48.06	0	0	-	0
C-8	F	2	48	137	28.7	40.22	48	98	2	1
41	D	23	0	0	-	39.20	0	0	-	0
41	D	22	0	0	-	41.76	0	0	-	0

TABLE VIII-1 (Continued)

SAMPLE			COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS			EXPONENTIAL
Area	Line	Station	Reworked	Total	Reworked	Total(mm)	Reworked	Total	RATIO	VALUE
50	K	1	12	82	27.5	63.40	12	36	3	1
50	J	1	1	12	28.3	55.73	1	6	6	1
41	A	1	0	0	-	47.04	0	0	-	0
41	B	1	0	0	-	35.28	0	0	-	0
25	C	17	0	0	-	37.32	0	0	-	0
38	I	1	33	594	28.0	0.34	33	48918	1482	4
13	H	1	28	294	28.1	0.34	28	24298	868	3
54	F	11	30	230	28.8	13.80	30	480	16	2
24	N	21	0	0	-	39.20	0	0	-	0
24	N	15	0	0	-	38.01	0	0	-	0
24	H	35	0	0	-	38.18	0	0	-	0
24	I	2	2	5	28.6	38.01	2	4	2	1
25	L	15	0	0	-	37.32	0	0	-	0
24	I	24	0	0	-	37.15	0	0	-	0
24	H	48	19	74	29.4	40.05	19	54	3	1
24	I	12	0	0	23.2	40.73	0	0	-	0
24	B	25	5	14	28.7	39.54	5	10	2	1
24	U	13	1	5	28.8	41.76	1	3	3	1
24	A	36	0	0	-	36.64	0	0	-	0
24	A	1	0	0	-	39.20	0	0	-	0
24	A	48	56	203	28.0	45.16	56	126	2	1
24	Q	19	0	0	-	34.60	0	0	-	0
44	E	17	17	636	27.5	0.51	17	34294	2017	4
54	D	33	141	271	28.8	0.51	141	15304	109	3
23	E	9	30	635	27.9	0.34	30	52107	1737	4
24	R	10	69	181	28.4	43.80	69	117	2	1
40	D	12	28	683	28.0	0.34	28	56247	2009	4
24	N	1	2	11	26.9	42.95	2	7	4	1
43	A	14	9	245	27.6	34.09	9	198	22	2
24	Y	19	0	0	-	36.81	0	0	-	0
24	B	9	1	6	29.4	42.27	1	4	4	1
24	D	12	69	1219	28.7	0.34	69	102898	1491	1
C-2	E	7	3	7	37.6	38.35	3	7	2	1
39	F	1	20	356	29.0	0.34	20	30365	1518	4
38	I	11	37	297	28.8	0.51	37	16772	453	3
29	C	1	40	477	28.9	0.34	40	40545	1014	4

TABLE VIII-2
SAMPLE DATA - Z-TRANSECT GRAB SAMPLES, JULY 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
Z-1	0	323	26.3	0.51	0	16657	-	5
Z-2	1	301	27.3	12.07	1	681	681	5
Z-3	1	2	-	-	-	-	-	1
Z-4	0	0	-	-	-	-	-	0

TABLE VIII-3
SAMPLE DATA - EAST FLOWER GARDEN BANK GRAB SAMPLES

CRUISE	SAMPLE	MONTH	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
			Reworked	Total	Reworked	Total(mm)	Reworked	Total		
78G9*	EFG1	OCT	1	382	27.3	0.17	1	61345	61345	5
78G9*	EFG2B	OCT	1	521	25.3	0.17	1	77537	77537	5
78G9*	EFG3	OCT	(SAMPLE NOT AVAILABLE)							
78G9*	EFG4	OCT	(SAMPLE NOT AVAILABLE)							
79BS1	EFG5	JAN	9	373	29.1	0.17	9	63849	7094	4
79BS1	EFG6	JAN	6	398	28.3	0.17	6	66255	11043	5
79BS1	EFG7	JAN	3	728	29.3	0.17	3	125473	41824	5
79BS1	EFG8	JAN	3	433	29.0	0.17	3	73865	24622	5
79BS1	EFG9	JAN	0	326	29.4	0.17	0	56378		5
79BS1	EFG10	JAN	1	326	23.2	0.17	1	44489	44489	5
79BS1	EFG11	JAN	5	352	29.2	0.17	5	60461	12092	5
79BS1	EFG12	JAN	2	361	28.5	0.17	2	60521	30261	5
79MS1	EFG1-2G	APR	6	535	28.6	0.34	6	45003	7501	4
79MS1**	EFG2-1G	APR	4	332	29.5	0.34	4	28806	7202	4
79MS1**	EFG2-2G	APR	3	319	25.8	0.34	3	24206	8069	4
79MS1**	EFG3-1G	APR	1	456	27.3	0.34	1	36614	36614	5
79MS1**	EFG3-2G	APR	3	531	26.3	0.34	3	41074	13691	5
79MS1**	EFG4-1G	APR	2	561	28.9	0.34	2	47685	23843	5
79MS1**	EFG4-2G	APR	9	461	28.2	0.17	9	76472	8497	4
79MS1	EFG13	APR	6	349	28.7	0.17	6	58919	9820	4
79MS1	EFG14	APR	8	356	28.9	0.17	8	60520	7565	4
79MS1	EFG15	APR	6	538	27.2	0.17	6	86080	14347	5
79MS1	EFG16	APR	2	360	22.3	0.17	2	47224	23612	5
79MS1	EFG17	APR	4	442	28.9	0.17	4	75140	18785	5
79MS1	EFG18	APR	7	498	29.2	0.17	7	85539	12220	5
79MS1	EFG19	APR	5	339	28.8	0.17	5	57431	11486	5
79MS1	EFG20	APR	10	503	29.2	0.17	10	86398	8640	4
79BS	EFG21	JUL	11	389	27.0	0.17	11	61782	5617	4
79BS	EFG22	JUL	3	544	27.6	0.17	3	88320	29440	5
79BS	EFG23	JUL	4	619	28.3	0.17	4	103045	25761	5
79BS	EFG24	JUL	5	589	28.0	0.17	5	97012	10402	5
79BS	EFG25	JUL	6	642	29.2	0.17	6	110273	18379	5
79BS	EFG26	JUL	2	546	27.4	0.51	2	29334	14667	5
79BS	EFG27	JUL	4	330	28.7	0.17	4	55712	13828	5
79BS	EFG28	JUL	3	325	26.0	0.17	3	49706	16569	5
79BS	EFG29	JUL	5	493	28.9	0.17	5	84810	16762	5
79BS	EFG30	JUL	6	567	28.7	0.17	6	95723	15954	5
79BS	EFG31	JUL	4	545	28.8	0.17	4	92329	23082	5
79BS	EFG32	JUL	2	472	29.1	0.17	2	80795	40398	5

* Incomplete suite duplicated later; these are not plotted on map.
**3 sets of duplicate samples; each pair was plotted as one point.

TABLE VIII-4
SAMPLE DATA - DIAPHUS BANK GRAB SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	8	383	28.1	0.34	8	31654	3957	4
2	14	337	24.8	0.51	14	16387	5462	4
3	3	283	28.1	0.85	3	9356	3119	4
4	10	352	29.2	0.51	10	20154	2015	4

TABLE VIII-5
SAMPLE DATA - ALDERDICE BANK GRAB SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	7	385	27.7	0.17	7	62732	8962	4
2	13	440	27.3	0.51	13	23553	1812	4
3	9	455	28.8	0.51	9	25694	2855	4
4	5	401	28.1	0.17	5	66283	13257	5

TABLE VIII-6
SAMPLE DATA - JAKKULA BANK GRAB SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	12	417	29.5	0.51	12	24124	2010	4
2	(MISSING)							
3	9	425	28.0	0.34	9	35000	3889	4
4	6	408	27.9	0.17	6	66960	11160	5

TABLE VIII-7
SAMPLE DATA - FISHNET BANK GRAB SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	13	517	28.8	0.68	13	21896	1684	4
2	11	432	28.8	0.34	11	36593	3327	4
3	13	562	28.3	0.34	13	46778	3598	4
4	8	472	28.6	0.34	8	39704	4963	4

TABLE VIII-8
SAMPLE DATA - COFFEE LUMP BANK GRAB SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	6	488	25.1	0.17	6	72052	12009	5
2	8	513	28.1	0.34	8	42398	5300	4
3	6	409	28.9	0.17	6	69530	11588	5
4	3	361	24.4	0.17	3	51814	17271	5

TABLE VIII-9

SAMPLE DATA - EAST FLOWER GARDEN BANK SUSPENDED SEDIMENT SAMPLES

CRUISE	SAMPLE	MONTH	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
			Reworked	Total	Reworked	Total(mm)	Reworked	Total		
78G9	EFG1	OCT	(SAMPLE NOT AVAILABLE)							
78G9	EFG2B	OCT	0	100	23.3	36.98	0	63	-	5
78G9	EFG3	OCT	(SAMPLE NOT AVAILABLE)							
78G9	EFG4	OCT	0	212	23.7	24.88	0	202	-	5
79BS1	EFG5	JAN	0	284	22.7	5.97	0	1080	-	5
79BS1	EFG6	JAN	0	228	23.4	2.05	0	2603	-	5
79BS1	EFG7	JAN	0	269	23.8	1.70	0	3766	-	5
79BS1	EFG8	JAN	0	240	22.7	1.87	0	2913	-	5
79BS1	EFG9	JAN	1	276	22.8	0.68	1	9254	9254	4
79BS1	EFG10	JAN	1	306	23.0	0.85	1	8280	8280	4
79BS1	EFG11	JAN	0	262	23.4	2.05	0	2991	-	5
79BS1	EFG12	JAN	0	214	22.5	2.39	0	2015	-	5
79MS1	EFG1	APR	0	258	22.7	0.34	0	17225	-	5
79MS1	EFG2	APR	0	304	11.0	0.34	0	9835	-	5
79MS1	EFG3	APR	0	189	11.1	0.34	0	6170	-	5
79MS1	EFG4	APR	0	200	9.4	1.19	0	1580	-	5
79MS1	EFG13	APR	0	278	10.2	0.34	0	8340	-	5
79MS1	EFG14	APR	0	209	11.3	0.68	0	3473	-	5
79MS1	EFG15	APR	0	247	11.3	1.19	0	2345	-	5
79MS1	EFG16	APR	1	166	11.5	0.34	1	5615	5615	4
79MS1	EFG17	APR	2	200	11.9	0.17	2	14000	7000	4
79MS1	EFG18	APR	2	166	11.1	6.31	2	292	146	3
79MS1	EFG19	APR	1	232	11.1	0.51	1	5049	5049	4
79MS1	EFG20	APR	1	0	10.9	-	-	-	-	1
79BS2	EFG1	JUL	0	346	10.9	3.06	0	1297	-	5
79BS2	EFG2	JUL	1	367	11.4	0.85	1	4922	4922	4
79BS2	EFG3	JUL	0	148	16.1	7.65	0	311	-	5
79BS2	EFG4	JUL	1	323	12.0	2.21	1	1754	1754	4
79BS2	EFG21	JUL	2	359	11.0	1.36	2	2904	1452	4
79BS2	EFG22	JUL	1	393	11.7	1.19	1	3864	3864	4
79BS2	EFG23	JUL	1	357	11.1	2.89	1	1371	1371	4
79BS2	EFG24	JUL	1	337	11.4	3.06	1	1255	1255	4
79BS2	EFG25	JUL	1	61	12.1	11.22	1	66	66	1
79BS2	EFG26	JUL	0	335	11.1	2.89	0	1287	-	5
79BS2	EFG27	JUL	0	0	11.0	10.20	0	0	-	0
79BS2	EFG28	JUL	0	340	11.3	3.57	0	1076	-	5

TABLE VIII-10
SAMPLE DATA - ALDERDICE BANK SUSPENDED SEDIMENT SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	0	333	11.3	2.21	0	1703	-	5
2	2	385	11.1	0.85	2	5028	2514	4
3	3	472	11.0	0.51	3	10180	3393	4
4	2	319	10.9	2.21	2	1573	787	3

TABLE VIII-11
SAMPLE DATA - FISHNET BANK SUSPENDED SEDIMENT SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	0	246	16.0	3.40	0	1158	-	5
2	3	335	11.0	1.19	3	3097	1032	4
3	3	314	12.3	1.02	3	3786	1262	4
4	7	455	11.3	0.68	7	7561	1080	4

TABLE VIII-12
SAMPLE DATA - COFFEE LUMP BANK SUSPENDED SEDIMENT SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	2	461	11.1	0.68	2	7525	3763	4
2	3	371	11.9	0.85	3	5194	1731	4
3	4	376	11.2	0.85	4	4953	1238	4
4	0	339	12.9	2.72	0	1608	-	5

TABLE VIII-13
SAMPLE DATA - JAKKULA BANK SUSPENDED SEDIMENT SAMPLES, JUNE 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
1	1	346	11.5	1.19	1	3344	3344	4
2	(SAMPLE NOT AVAILABLE)							
3	(SAMPLE NOT AVAILABLE)							
4	(SAMPLE NOT AVAILABLE)							

TABLE VIII-14
SAMPLE DATA - Z-TRANSECT SUSPENDED SEDIMENT SAMPLES, JULY 1979

SAMPLE	COUNTS OF SPECIMENS		COUNTING DISTANCE		NORMALIZED COUNTS		RATIO	EXPONENTIAL VALUE
	Reworked	Total	Reworked	Total(mm)	Reworked	Total		
Z-1	0	277	10.3	0.85	0	3357	-	5
Z-2	1	354	11.2	0.34	1	11661	11661	5
Z-3	2	191	10.8	0.68	2	3034	1517	4
Z-4	0	92	10.4	8.84	0	108	-	5
Z-5	0	0	-	-	-	-	-	0
Z-6	0	0	-	-	-	-	-	0

TABLE IX-A-1
TABULATION OF RAW TRACE METAL DATA FROM INDIVIDUAL SPONDYLUS AMERICANUS
COLLECTED DURING THE 1978 TOPOGRAPHIC FEATURES STUDY

BANK	COLLECTION DATE	DRY WEIGHT (g)	CONCENTRATION (ppm dry weight)					
			Cd	Cr	Cu	Fe	Ni	Pb
Sidner	10-17-78	10.125	28	6.5	3.0	95	40	1.4
Jakkula	10-17-78	10.812	8.5	2.1	3.5	95	45	1.1
Jakkula	10-17-78	15.554	3.5	3.5	1.0	35	25	0.30
Elvers	10-20-78	11.063	17	3.5	6.5	16	25	1.2
EFG	10-22-78	0.853	24	1.3	6.0	25	65	3.5
EFG	9-30-78	1.542	24	1.9	9.5	80	45	6.5
EFG	10-23-78	1.731	38	3.0	7.0	130	65	4.0
EFG	10-22-78	2.370	32	2.5	14	65	80	4.5
EFG	10-22-78	4.061	20	1.9	8.5	55	45	2.5
EFG	10-23-78	4.764	43	2.5	15	85	80	2.5
EFG	10-23-89	5.136	29	3.0	2.4	80	45	1.1
EFG	10- 2-78	6.118	13	3.5	2.4	110	35	0.75
EFG	10-22-78	8.112	18	4.0	4.5	140	50	1.2
EFG	10-23-78	8.145	26	4.0	13.	75	35	1.6
EFG	10-23-78	8.431	4.5	4.5	1.3	95	35	0.75
EFG		8.866	19	6.0	6.0	150	75	1.3
EFG	10-22-78	9.728	29	13.	3.0	130	65	0.85
EFG	10-23-78	13.799	10	6.0	1.4	85	25	0.50
EFG	10-22-78	15.905	35	7.0	12	40	25	1.2

			Zn	V	Al	Ca	% Water
Sidner	10-17-78	10.125	75	3.5	11	35	85.5
Jakkula	10-17-78	10.812	130	3.5	40	16	82.6
Jakkula	10-17-78	15.554	70	1.2	< 2	14	83.4
Elvers	10-20-78	11.063	100	0.85	2.0	17	82.5
EFG	10-22-78	0.853	210	1.4	21	45	88.8
EFG	9-30-78	1.542	190	3.0	75	55	88.9
EFG	10-23-78	1.731	170	2.5	55	30	86.8
EFG	10-22-78	2.370	190	2.5	21	40	87.9
EFG	10-22-78	4.061	140	4.0	11	35	86.2
EFG	10-23-78	4.764	190	2.5	10	9	85.6
EFG	10-23-89	5.136	180	3.5	11	24	84.6
EFG	10- 2-78	6.118	180	2.5	55	21	86.4
EFG	10-22-78	8.112	210	3.0	60	30	84.8
EFG	10-23-78	8.145	95	3.0	17	35	84.4
EFG	10-23-78	8.431	90	3.0	13	24	85.0
EFG		8.866	160	3.5	65	40	84.6
EFG	10-22-78	9.728	100	3.5	--	40	86.8
EFG	10-23-78	13.799	75	3.0	8.5	30	82.8
EFG	10-22-78	15.905	110	1.9	11	40	82.0

EFG = East Flower Garden Bank.

TABLE IX-C-1
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-1G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
10.64	1.699	-	-
17.05	1.100	-	-
19.64	6.276	-	-
20.81	.694	0.0003	Phenanthrene
22.12	2.109	-	-
24.71	1.219	-	-
25.94	1.149	-	-
26.32	2.859	-	-
26.73	1.159	-	-
27.19	3.360	0.0014	Fluoranthene
27.63	1.055	-	-
27.87	1.184	-	-
28.26	2.619	0.0010	Pyrene
28.52	1.779	-	-
28.98	1.817	-	-
30.25	1.013	-	-
30.58	1.459	-	-
30.83	1.246	-	-
32.97	1.251	-	-
33.53	1.756	-	-
33.76	2.908	-	-
34.14	1.400	-	-
34.49	1.211	-	-
34.97	2.212	-	-
36.08	1.476	-	-
36.33	1.292	-	-
36.67	1.143	-	-
37.14	2.489	-	-
37.31	1.044	-	-
37.54	1.052	-	-
37.69	2.127	-	-
37.79	1.035	-	-
37.95	1.200	-	-
38.42	1.877	-	-
40.28	1.059	-	-
40.83	7.513	0.0117	Benzl *]Fluoranthene
41.00	2.092	-	-
41.59	1.017	-	-
42.50	2.443	0.0013	Perylene
44.42	1.435	-	-
45.79	1.413	-	-
49.41	1.415	-	-
52.42	1.887	-	-
52.76	1.474	-	-
53.56	2.054	-	-
56.24	1.498	-	-

Total Benzene Eluate 0.1031 g/g
*Exact isomers are not known.

TABLE IX-C-2
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-2G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
17.45	1.715	-	-
19.09	1.459	-	-
19.30	1.273	-	-
20.49	2.169	0.0041	Phenanthrene
21.53	1.723	-	-
21.74	1.286	-	-
23.19	1.188	-	-
23.72	3.860	-	-
23.89	1.256	-	-
24.19	4.920	-	-
25.44	1.905	-	-
26.23	1.649	-	-
26.69	2.232	0.0038	Fluoranthene
27.11	1.546	-	-
27.74	2.408	0.0038	Pyrene
27.97	1.509	-	-
28.26	1.016	-	-
29.98	1.119	-	-
32.10	1.270	-	-
32.86	1.765	-	-
33.10	1.842	-	-
34.12	.731	0.0045	Benz a]Anthracene
34.28	1.322	0.0031	Chrysene
36.38	1.998	-	-
36.91	1.167	-	-
37.14	1.104	-	-
37.57	1.606	-	-
39.73	3.742	0.0237	Benz *]Fluoranthene
41.19	1.300	0.0092	Benz e]Pyrene
42.01	2.259	0.0050	Perylene
43.67	1.576	-	-
49.91	1.995	-	-
50.70	2.866	-	-
52.19	1.019	-	-
52.68	1.666	-	-
53.01	1.922	-	-
55.29	4.953	-	-
56.34	2.025	-	-

Total Benzene Eluate 0.4218 g/g
*Exact isomers are not known.

TABLE IX-C-3
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-3G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
14.02	.546	-	-
27.84	.611	0.0027	Phenanthrene
35.95	16.352	-	-
38.70	2.616	-	-
40.13	1.794	-	-
41.42	1.259	-	-
45.06	1.100	-	-
53.68	1.177	-	-
58.46	.625	0.0032	Benz[a]Anthracene
58.49	.420	0.0022	Chrysene
63.90	1.464	-	-
66.96	1.575	-	-
70.38	1.119	0.0050	Benz[*]Fluoranthene
72.63	.555	0.0033	Benz[a]Pyrene
73.96	2.157	0.0103	Perylene
74.86	1.644	-	-
82.32	1.805	-	-
83.83	3.607	-	-
84.38	4.613	-	-
84.70	1.738	-	-
85.26	3.533	-	-
85.71	1.812	-	-
86.35	1.123	-	-
86.97	1.414	-	-
87.96	1.673	-	-
88.21	2.529	-	-
88.47	1.863	-	-
88.89	1.477	-	-
89.20	1.421	-	-
89.50	1.649	-	-
89.82	1.307	-	-
90.30	3.160	-	-
90.84	1.192	-	-
91.04	2.541	-	-
92.62	3.582	-	-
96.00	1.760	-	-
102.75	3.658	-	-

Total Benzene Eluate 0.9218 g/g
*Exact isomers are not known.

TABLE IX-C-4
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-4G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
8.35	-	0.0006	2-Methylnaphthalene
8.79	-	0.0005	1-Methylnaphthalene
20.44	1.999	0.0030	Phenanthrene
21.05	2.461	-	-
21.47	1.285	-	-
22.40	1.263	-	-
23.66	4.151	-	-
23.83	3.450	-	-
24.08	2.088	-	-
24.14	3.300	-	-
25.37	1.018	-	-
26.18	1.185	-	-
26.64	1.691	0.0023	Fluoranthene
27.06	1.171	-	-
27.69	2.075	0.0026	Pyrene
28.37	1.478	-	-
33.05	1.170	-	-
34.23	.940	0.0046	Benz[a]Anthracene
35.84	1.522	-	-
36.34	1.046	-	-
36.72	1.682	-	-
36.84	1.323	-	-
37.10	1.467	-	-
37.52	1.619	-	-
37.91	1.608	-	-
38.47	2.567	-	-
39.11	1.249	-	-
39.70	3.273	0.0166	Benz[*]Fluoranthene
41.19	1.179	0.0063	Benz[e]Pyrene
42.82	2.515	-	-
43.73	1.190	-	-
46.81	1.224	-	-
47.95	1.220	-	-
48.16	1.435	-	-
49.33	1.442	-	-
49.97	2.410	-	-
50.80	1.972	-	-
51.30	1.777	-	-
55.40	13.392	-	-
56.74	10.597	-	-

Total Benzene Eluate 0.3382 g/g
*Exact isomers are not known.

TABLE IX-C-5
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-5G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
8.47	.705	0.0008	2-Methylnaphthalene
8.83	.634	0.0007	1-Methylnaphthalene
10.50	5.352	-	-
19.29	1.348	-	-
20.48	2.286	0.0029	Phenanthrene
21.10	2.615	-	-
21.51	1.275	-	-
23.17	1.166	-	-
23.71	3.354	-	-
24.13	8.754	-	-
25.42	1.425	-	-
26.68	1.103	0.0025	Fluoranthene
27.10	1.024	-	-
27.73	2.534	0.0027	Pyrene
27.96	1.095	-	-
29.98	1.044	-	-
32.84	1.227	-	-
33.09	1.700	-	-
34.27	1.478	-	-
35.90	1.326	-	-
36.38	2.271	-	-
36.90	2.131	-	-
37.13	1.656	-	-
37.46	1.279	-	-
37.56	1.698	-	-
37.87	1.340	-	-
38.49	2.187	-	-
38.81	1.262	-	-
39.42	1.165	-	-
39.74	5.120	0.0215	Benz[*]Fluoranthene
39.89	2.045	-	-
41.20	2.170	0.0032	Perylene
42.84	2.245	-	-
43.28	1.507	-	-
49.32	1.295	-	-
49.94	2.074	-	-
50.75	3.710	-	-
52.27	1.655	-	-
53.07	1.689	-	-
55.34	5.353	-	-
56.82	1.070	-	-

Total Benzene Eluate 0.2804 g/g
*Exact isomers are not known.

TABLE IX-C-6
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-6G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
6.28	1.108	0.0016	2-Methylnaphthalene
6.67	.727	0.0010	1-Methylnaphthalene
8.32	3.700	-	-
18.27	.977	0.0016	Phenanthrene
18.90	4.746	-	-
19.32	2.940	-	-
19.89	2.212	-	-
21.69	9.169	-	-
21.91	6.491	-	-
24.04	1.560	-	-
24.35	1.010	-	-
24.47	.971	0.0014	Fluoranthene
25.53	1.144	0.0015	Pyrene
26.17	1.027	-	-
28.14	1.274	-	-
37.49	1.464	0.0078	Benz[*]Fluoranthene
38.93	.519	0.0031	Benz[e]Pyrene
39.76	1.906	0.0035	Perylene
46.93	1.573	-	-
47.49	1.203	-	-
48.51	1.238	-	-
52.80	2.536	-	-
54.99	1.268	-	-
56.13	1.084	-	-

Total Benzene Eluate 0.3545 g/g
*Exact isomers are not known.

TABLE IX-C-7
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-7G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.32	1.344	-	-
3.33	1.532	-	-
3.81	1.004	-	-
5.71	.691	.0016	Naphthalene
8.34	.380	.0009	2-Methylnaphthalene
8.70	.288	.0005	1-Methylnaphthalene
10.38	2.164	-	-
19.45	.266	.0017	Dibenzothiophene
20.34	1.064	.0028	Phenanthrene
21.39	2.032	-	-
24.07	13.184	-	-
24.30	1.153	-	-
26.53	1.091	.0026	Fluoranthene
27.58	1.306	.0029	Pyrene
33.98	.417	.0035	Benz[a]Anthracene
34.12	.576	.0019	Chrysene
39.54	2.317	.0201	Benz[*]Fluoranthene
40.97	.967	.0093	Benz[e]Pyrene
41.33	.591	.0058	Benz[a]Pyrene
41.78	1.748	.0054	Perylene
42.67	1.100	-	-
43.02	1.059	-	-
48.97	2.058	-	-
49.55	1.196	-	-
54.82	2.285	-	-
56.95	1.733	-	-
58.16	1.970	-	-

Total Benzene Eluate 0.5847 g/g
*Exact isomers are not known.

TABLE IX-C-8
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-8G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.37	1.093	-	-
3.48	1.630	-	-
3.86	1.581	-	-
3.98	1.456	-	-
4.70	1.202	-	-
5.96	1.139	0.0021	Naphthalene
8.67	.649	0.0012	2-Methylnaphthalene
9.07	.463	0.0008	1-Methylnaphthalene
10.76	1.318	-	-
20.94	1.324	0.0027	Phenanthrene
22.03	2.398	-	-
24.76	21.276	-	-
25.02	1.282	-	-
27.29	1.437	0.0026	Fluoranthene
28.36	1.267	0.0027	Pyrene
29.06	1.243	-	-
32.43	1.155	-	-
33.61	1.252	-	-
33.83	1.334	-	-
35.04	.516	0.0034	Benz[a]Anthracene
36.08	1.365	-	-
36.44	1.522	-	-
36.72	1.068	-	-
37.16	1.270	-	-
39.51	1.062	-	-
40.81	2.610	0.0176	Benz[*]Fluoranthene
42.47	.826	0.0062	Benz[e]Pyrene
43.39	2.477	0.0059	Perylene
52.11	1.808	-	-
52.55	1.111	-	-
53.39	1.112	-	-
56.01	1.081	-	-
58.59	2.950	-	-

Total Benzene Eluate 0.4503 g/g
*Exact isomers are not known.

TABLE IX-C-9
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-9G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
8.22	.417	0.0009	2-Methylnaphthalene
8.64	.375	0.0008	1-Methylnaphthalene
17.03	1.392	-	-
19.56	1.297	-	-
20.54	1.582	0.0037	Phenanthrene
21.67	1.709	-	-
22.73	1.240	-	-
23.43	1.025	-	-
24.11	1.645	-	-
24.34	2.358	-	-
24.45	1.370	-	-
24.64	1.035	-	-
25.67	1.705	-	-
26.78	1.002	-	-
26.89	1.749	0.0036	Fluoranthene
27.98	1.537	0.0030	Pyrene
28.22	1.096	-	-
28.66	1.006	-	-
30.28	1.098	-	-
33.49	1.258	-	-
34.65	.856	0.0024	Chrysene
36.77	1.853	-	-
37.36	1.247	-	-
37.60	1.187	-	-
38.27	1.069	-	-
39.25	1.048	-	-
40.44	2.902	-	-
42.03	1.133	-	-
43.85	1.185	-	-
44.17	1.201	-	-
48.38	1.049	-	-
51.60	4.330	-	-
52.08	1.037	-	-
52.96	1.936	-	-
55.42	1.025	-	-
57.81	3.695	-	-

Total Benzene Eluate 0.5154 g/g

TABLE IX-C-10
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-10G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
13.70	.461	-	-
27.58	.575	0.0050	Phenanthrene
35.87	9.267	-	-
38.51	1.577	-	-
39.77	1.079	-	-
40.75	.382	0.0044	Fluoranthene
41.20	1.127	-	-
43.23	.651	0.0075	Pyrene
53.60	1.000	-	-
58.25	.495	0.0062	Benz a]Anthracene
58.48	.430	0.0054	Chrysene
63.76	1.079	-	-
66.79	1.269	-	-
72.62	.563	0.0080	Benz a]Pyrene
73.95	1.942	0.0224	Perylene
82.27	1.282	-	-
83.88	2.605	-	-
84.44	4.767	-	-
85.30	2.126	-	-
85.71	1.680	-	-
86.36	1.148	-	-
88.00	1.755	-	-
88.28	1.871	-	-
88.57	1.440	-	-
89.00	1.618	-	-
89.26	1.011	-	-
89.70	2.660	-	-
90.42	2.495	-	-
91.08	2.442	-	-
92.63	3.073	-	-
94.59	1.143	-	-
96.10	2.643	-	-
103.13	5.133	-	-
109.74	1.445	-	-

Total Benzene Eluate 1.7824 g/g

TABLE IX-C-11
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-11G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
13.53	.516	-	-
27.51	.940	0.0078	Phenanthrene
35.83	9.026	-	-
38.48	1.400	-	-
39.74	1.671	-	-
41.17	1.283	0.0115	Fluoranthene
43.20	.587	0.0065	Pyrene
44.75	.913	-	-
53.61	1.019	-	-
58.25	.470	0.0056	Benz[a]Anthracene
58.51	.389	0.0047	Chrysene
63.77	1.051	-	-
70.26	.972	0.0101	Benz[*]Fluoranthene
73.89	1.624	0.0180	Benz[e]Pyrene
74.77	1.066	0.0118	Perylene
83.82	1.973	-	-
84.36	3.182	-	-
85.26	1.572	-	-
88.19	1.767	-	-
90.33	1.704	-	-
91.03	2.120	-	-
91.89	1.577	-	-
92.55	2.939	-	-
94.96	1.670	-	-
96.01	1.832	-	-

Total Benzene Eluate 2.1353 g/g
*Exact isomers are not known.

TABLE IX-C-12
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA
SAMPLE: DS1-12G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
13.83	.415	-	-
27.63	.216	0.0010	Phenanthrene
35.78	6.028	-	-
38.39	1.480	-	-
39.65	1.077	-	-
41.09	1.216	0.0051	Fluoranthene
43.15	.601	0.0031	Pyrene
44.65	1.360	-	-
50.06	1.205	-	-
53.41	1.315	-	-
63.63	1.382	-	-
66.67	1.431	-	-
70.12	1.344	0.0065	Benz[*]Fluoranthene
72.48	.732	0.0067	Benz[e]Pyrene
73.72	2.542	0.0131	Benz[a]Pyrene
74.64	1.824	0.0095	Perylene
82.06	1.565	-	-
83.62	1.613	-	-
84.21	3.676	-	-
87.78	1.181	-	-
88.01	1.441	-	-
89.02	1.833	-	-
89.43	4.062	-	-
90.14	1.934	-	-
90.91	1.249	-	-
91.02	1.067	-	-
91.55	1.704	-	-
92.44	3.359	-	-
93.90	1.072	-	-
94.81	1.530	-	-
95.75	2.527	-	-
102.65	4.936	-	-
105.06	1.101	-	-

Total Benzene Eluate 1.0005 g/g
*Exact isomers are not known.

TABLE IX-C-13
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-1G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.65	.630	0.0025	Naphthalene
8.30	.649	0.0026	2-Methylnaphthalene
8.69	.361	0.0015	1-Methylnaphthalene
10.34	4.618	-	-
20.32	1.068	0.0048	Phenanthrene
23.74	2.673	-	-
23.97	7.002	-	-
26.07	1.074	-	-
26.50	1.210	0.0049	Fluoranthene
27.55	1.483	0.0056	Pyrene
28.02	1.008	-	-
28.23	1.136	-	-
32.91	1.132	-	-
36.12	1.461	-	-
38.49	1.541	-	-
39.75	1.792	0.0271	Benz[*]Fluoranthene
41.36	.554	0.0088	Benz[e]Pyrene
42.27	3.121	0.0165	Perylene
42.71	1.226	-	-
43.80	1.030	-	-
47.61	1.458	-	-
50.74	1.740	-	-
51.14	1.028	-	-
57.07	2.556	-	-
59.20	1.283	-	-

Total Benzene Eluate 1.0250 g/g
*Exact isomers are not known.

TABLE IX-C-14
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-2G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.79	1.221	0.0036	Naphthalene
8.43	1.077	0.0032	2-Methylnaphthalene
8.82	.612	0.0018	1-Methylnaphthalene
10.47	6.001	-	-
20.44	.703	0.0023	Phenanthrene
21.49	1.298	-	-
23.87	3.047	-	-
24.08	1.592	-	-
26.63	.615	0.0018	Fluoranthene
27.74	.696	0.0019	Pyrene
28.35	1.396	-	-
34.10	.843	0.0091	Benz[a]Anthracene
37.02	1.369	-	-
37.60	3.875	-	-
38.48	1.740	-	-
39.69	1.296	0.0144	Benz[*]Fluoranthene
41.95	5.157	0.0201	Perylene
44.06	1.455	-	-
46.06	1.344	-	-
46.53	1.932	-	-
49.23	2.229	-	-
49.79	2.945	-	-
55.13	2.321	-	-
57.31	4.496	-	-
58.54	1.399	-	-

Total Benzene Eluate 0.7416 g/g
*Exact isomers are not known.

TABLE IX-C-15
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-3G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.28	1.912	-	-
3.39	5.216	-	-
3.56	1.595	-	-
3.78	3.516	-	-
3.88	4.381	-	-
4.34	2.598	-	-
4.53	1.070	-	-
4.60	3.722	-	-
4.96	1.047	-	-
5.26	2.387	-	-
5.85	3.814	0.0150	Naphthalene
8.56	2.437	0.0096	2-Methylnaphthalene
8.96	1.205	0.0048	1-Methylnaphthalene
20.78	.698	0.0031	Phenanthrene
24.26	1.276	-	-
24.48	1.219	-	-
24.58	.628	-	-
26.64	1.226	-	-
27.07	.484	0.0019	Fluoranthene
28.14	.406	0.0015	Pyrene
36.80	1.196	-	-
37.61	1.037	-	-
42.89	2.859	0.0148	Perylene
44.22	1.166	-	-
51.05	1.227	-	-
57.31	2.096	-	-
59.49	1.203	-	-

Total Benzene Eluate 0.9856 g/g

TABLE IX-C-16
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-4G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.19	2.415	-	-
3.30	4.572	-	-
3.48	1.307	-	-
3.68	3.602	-	-
3.79	3.736	-	-
4.24	2.820	-	-
4.49	4.354	-	-
4.84	1.063	-	-
5.15	2.014	-	-
5.73	3.414	0.0166	Naphthalene
8.40	2.182	0.0106	2-Methylnaphthalene
8.79	1.131	0.0055	1-Methylnaphthalene
10.47	5.702	-	-
20.58	.798	0.0044	Phenanthrene
21.65	1.057	-	-
24.06	2.132	-	-
24.28	1.411	-	-
24.38	1.916	-	-
26.45	1.289	-	-
26.86	.670	0.0033	Fluoranthene
27.93	1.116	0.0051	Pyrene
34.41	1.275	0.0224	Benzo[a]Anthracene
36.57	1.239	-	-
40.12	1.013	-	-
42.52	4.628	0.0295	Perylene
50.41	1.167	-	-
50.89	1.241	-	-
56.57	1.893	-	-
58.73	1.488	-	-

Total Benzene Eluate 1.2127 g/g

TABLE IX-C-17
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-5G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
2.06	3.079	-	-
2.40	3.243	-	-
2.46	6.240	-	-
2.86	7.950	-	-
3.41	4.076	-	-
3.75	4.587	-	-
3.89	7.080	-	-
4.27	2.860	-	-
4.54	14.003	-	-
4.94	1.983	-	-
5.22	6.539	-	-
5.41	1.419	-	-
5.80	6.663	0.2331	Naphthalene
6.26	1.051	-	-
8.47	.968	0.0339	2-Methylnaphthalene
8.86	.585	0.0204	1-Methylnaphthalene
20.65	.272	0.0107	Phenanthrene
31.01	1.299	-	-
31.28	1.022	-	-
31.92	1.032	-	-
32.08	1.894	-	-

Total Benzene Eluate 8.7474 g/g

TABLE IX-C-18
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-6G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
2.33	1.461	-	-
2.72	1.379	-	-
3.25	1.941	-	-
3.61	2.465	-	-
3.73	2.925	-	-
4.10	2.647	-	-
4.40	8.254	-	-
4.74	1.775	-	-
4.87	2.296	-	-
4.96	1.756	-	-
5.04	3.150	-	-
5.22	2.314	-	-
5.34	1.529	-	-
5.51	1.075	-	-
5.60	5.386	0.0208	Naphthalene
8.21	1.189	0.0046	2-Methylnaphthalene
8.59	.676	0.0026	1-Methylnaphthalene
10.22	6.744	-	-
18.80	12.809	-	-
20.17	.439	0.0019	Phenanthrene
23.90	2.071	-	-
26.72	.279	0.0011	Fluoranthene
27.59	.269	0.0010	Pyrene
30.54	1.129	-	-
34.54	7.202	-	-

Total Benzene Eluate 0.9662 g/g

TABLE IX-C-19
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-7G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.32	1.345	-	-
3.59	1.388	-	-
3.71	1.190	-	-
4.39	1.246	-	-
5.61	.729	0.0077	Naphthalene
8.26	.427	0.0045	2-Methylnaphthalene
8.50	.325	0.0034	1-Methylnaphthalene
10.30	7.937	-	-
13.38	1.247	-	-
15.88	1.095	-	-
18.57	1.180	-	-
19.52	1.003	-	-
20.46	.577	0.0069	Phenanthrene
21.93	1.395	-	-
24.35	4.864	-	-
26.49	2.439	-	-
26.80	.669	0.0071	Fluoranthene
27.22	1.069	-	-
27.89	.819	0.0081	Pyrene
28.11	1.131	-	-
30.69	2.561	-	-
31.94	1.251	-	-
32.65	1.683	-	-
34.52	2.120	0.0309	Chrysene
36.32	1.785	-	-
36.61	1.944	-	-
37.44	1.038	-	-
37.91	1.050	-	-
38.11	2.337	-	-
39.02	1.425	-	-
40.09	.608	0.0241	Benz[*]Fluoranthene
40.23	.778	0.0309	Benz[*]Fluoranthene
41.18	.492	0.0218	Benz[e]Pyrene
41.76	.635	0.0282	Benz[a]Pyrene
42.23	1.393	0.0194	Perylene
42.66	2.106	-	-
43.74	3.707	-	-

Total Benzene Eluate 2.6457 g/g
*Exact isomers are not known.

TABLE IX-C-20
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-8G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
2.12	1.012	-	-
2.31	9.477	-	-
2.70	5.880	-	-
3.23	2.564	-	-
3.59	3.819	-	-
3.70	3.849	-	-
4.08	1.886	-	-
4.31	3.026	-	-
4.38	4.919	-	-
4.93	1.413	-	-
5.01	1.994	-	-
5.58	3.426	0.0430	Naphthalene
8.18	.792	0.0099	2-Methylnaphthalene
8.56	.410	0.0052	1-Methylnaphthalene
10.20	1.356	-	-
18.76	4.961	-	-
20.11	.369	0.0052	Phenanthrene
23.86	1.008	-	-
25.36	1.459	-	-
26.29	.337	0.0042	Fluoranthene
27.35	.419	0.0049	Pyrene
34.50	2.797	-	-
43.29	4.357	-	-
53.72	6.531	-	-

Total Benzene Eluate 3.138 g/g

TABLE IX-C-21
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-9G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.18	2.900	-	-
3.28	5.339	-	-
3.45	1.241	-	-
3.63	5.733	-	-
3.76	6.293	-	-
4.14	3.539	-	-
4.38	4.400	-	-
4.44	6.179	-	-
4.79	2.022	-	-
4.91	2.001	-	-
5.00	2.063	-	-
5.09	2.840	-	-
5.27	1.988	-	-
5.39	1.206	-	-
5.66	4.236	0.0402	Naphthalene
8.31	.760	0.0072	2-Methylnaphthalene
8.70	.412	0.0039	1-Methylnaphthalene
10.37	3.544	-	-
11.56	1.025	-	-
19.12	6.193	-	-
20.51	.381	0.0041	Phenanthrene
26.80	.354	0.0034	Fluoranthene
27.88	.408	0.0036	Pyrene
35.18	3.655	-	-
37.74	1.266	-	-
38.66	1.729	-	-
38.89	1.136	-	-
42.47	.667	0.0083	Perylene
47.40	1.148	-	-

Total Benzene Eluate 2.3717 g/g

TABLE IX-C-22
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-11G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
18.13	3.792	-	-
20.15	.929	0.0053	Phenanthrene
20.64	1.753	-	-
21.49	1.474	-	-
23.43	1.540	-	-
23.79	1.162	-	-
23.91	1.167	-	-
25.08	1.480	-	-
25.96	1.985	-	-
26.32	.571	0.0029	Fluoranthene
27.38	.609	0.0029	Pyrene
28.05	1.021	-	-
29.46	1.424	-	-
30.05	1.516	-	-
30.33	1.280	-	-
30.56	1.874	-	-
30.68	1.709	-	-
31.29	1.191	-	-
31.53	1.257	-	-
31.91	1.863	-	-
33.81	1.210	-	-
37.28	1.107	-	-
39.27	1.024	-	-
41.44	1.460	-	-
45.74	1.445	-	-
46.23	2.634	-	-
48.29	1.180	-	-
53.84	1.796	-	-

Total Benzene Eluate 1.2715 g/g

TABLE IX-C-23
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: DS2-12G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
18.26	1.329	-	-
19.12	1.131	-	-
21.14	1.033	-	-
21.47	1.553	-	-
22.18	1.706	-	-
23.17	1.207	-	-
23.37	1.069	-	-
23.75	1.030	-	-
23.87	2.480	-	-
24.86	1.106	-	-
25.91	1.604	-	-
27.49	1.167	-	-
28.06	1.662	-	-
29.98	1.073	-	-
31.21	1.767	-	-
32.98	1.717	-	-
33.73	1.095	-	-
35.67	12.134	-	-
36.96	1.640	-	-
37.19	1.410	-	-
38.59	1.061	-	-
40.76	3.391	-	-
45.42	2.407	-	-
53.28	1.830	-	-
58.00	4.676	-	-
58.55	4.637	-	-
59.36	5.629	-	-
59.69	1.623	-	-

Total Benzene Eluate 0.2103 g/g

TABLE IX-C-24
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: EFG-1G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.24	1.938	-	-
3.34	5.059	-	-
3.51	1.167	-	-
3.71	7.256	-	-
3.82	7.415	-	-
3.94	1.616	-	-
4.20	3.643	-	-
4.44	5.711	-	-
4.51	8.886	-	-
4.85	1.952	-	-
4.98	1.797	-	-
5.06	2.639	-	-
5.15	3.475	-	-
5.34	1.636	-	-
5.46	1.116	-	-
5.72	5.823	0.0147	Naphthalene
8.37	1.291	0.0033	2-Methylnaphthalene
8.76	.719	0.0018	1-Methylnaphthalene
10.42	2.169	-	-
19.20	8.440	-	-
20.59	1.099	0.0031	Phenanthrene
24.29	2.244	-	-
26.52	1.189	-	-
26.86	1.164	-	-
27.93	1.105	-	-
35.17	4.736	-	-
40.05	1.228	0.0115	Benz[*]Fluoranthene
41.90	4.145	0.0437	Benz[a]Pyrene
42.40	.923	0.0030	Perylene

Total Benzene Eluate 0.6290 g/g
*Exact isomers are not known.

TABLE IX-C-25
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: EFG-2G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.12	1.953	-	-
3.22	2.754	-	-
3.59	2.186	-	-
3.69	1.732	-	-
4.36	1.374	-	-
5.56	1.286	0.0032	Naphthalene
8.15	.654	0.0016	2-Methylnaphthalene
8.53	.467	0.0011	1-Methylnaphthalene
10.16	34.473	-	-
20.08	.887	0.0024	Phenanthrene
21.12	1.070	-	-
23.80	6.344	-	-
25.03	1.206	-	-
26.24	.887	0.0022	Fluoranthene
26.63	1.103	-	-
27.30	.976	0.0022	Pyrene
27.50	1.089	-	-
27.94	1.157	-	-
33.70	.691	0.0061	Benz[a]Anthracene
33.86	.354	0.0012	Chrysene
36.97	1.109	-	-
39.16	1.356	0.0125	Benz[*]Fluoranthene
40.53	.607	0.0062	Benz[e]Pyrene
41.32	.590	0.0019	Perylene
48.11	1.916	-	-
48.65	1.184	-	-
53.65	2.096	-	-

Total Benzene Eluate 0.6126 g/g
*Exact isomers are not known.

TABLE IX-C-26
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: EFG-3G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
2.27	6.347	-	-
2.34	7.526	-	-
2.66	2.569	-	-
2.72	2.874	-	-
3.10	1.447	-	-
3.19	3.030	-	-
3.25	1.909	-	-
3.58	3.243	-	-
3.67	5.166	-	-
4.06	1.525	-	-
4.35	5.326	-	-
4.82	2.079	-	-
5.00	2.712	-	-
5.19	1.099	-	-
5.57	3.604	0.0172	Naphthalene
6.02	1.327	-	-
8.18	2.916	0.0140	2-Methylnaphthalene
8.57	1.519	0.0073	1-Methylnaphthalene
10.20	5.580	-	-
20.14	.323	0.0017	Phenanthrene

Total Benzene Eluate 1.1986 g/g

TABLE IX-C-27
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA
SAMPLE: EFG-4G Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
3.06	3.008	-	-
3.28	2.277	-	-
3.43	6.794	-	-
3.60	1.355	-	-
3.80	0.070	-	-
3.92	8.568	-	-
4.04	1.008	-	-
4.31	2.754	-	-
4.56	5.302	-	-
4.63	7.433	-	-
4.98	1.623	-	-
5.11	1.287	-	-
5.20	2.237	-	-
5.29	3.608	-	-
5.48	1.618	-	-
5.86	6.626	0.0530	Naphthalene
6.08	1.065	-	-
6.32	2.002	-	-
8.56	3.115	0.0249	2-Methylnaphthalene
8.95	1.494	0.0210	1-Methylnaphthalene
10.64	9.668	-	-
20.84	.248	0.0022	Phenanthrene

Total Benzene Eluate 1.9996 g/g

TABLE IX-C-28
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA
SAMPLE: BLS-33 Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.72	.909	0.0041	Naphthalene
8.34	.782	0.0035	2-Methylnaphthalene
10.36	3.139	-	-
12.04	1.008	-	-
16.08	1.007	-	-
18.76	1.002	-	-
19.76	.857	0.0101	Dibenzothiophene
20.50	1.076	0.0054	Phenanthrene
21.57	1.733	-	-
22.08	1.057	-	-
24.00	5.956	-	-
24.31	1.644	-	-
24.41	1.990	-	-
24.50	2.027	-	-
26.57	1.940	-	-
26.81	.906	0.0041	Fluoranthene
27.92	1.462	0.0061	Pyrene
28.75	1.270	-	-
30.72	1.793	-	-
32.68	1.082	-	-
34.52	2.135	0.0131	Chrysene
36.63	3.612	-	-
37.78	1.266	-	-
38.08	1.927	-	-
40.20	1.148	0.0193	Benz *]Fluoranthene
41.86	1.397	0.0258	Benz e]Pyrene
42.09	1.689	0.0312	Benz a]Pyrene
42.60	2.907	0.0171	Perylene
42.89	1.196	-	-
44.75	2.419	-	-
47.05	1.533	-	-
47.24	1.211	-	-
47.45	6.039	-	-
47.84	1.878	-	-
48.11	1.379	-	-
50.11	1.288	-	-
51.73	1.364	-	-
55.38	2.545	-	-
56.32	1.982	-	-
56.74	3.292	-	-

Total Benzene Eluate 1.1197 g/g
*Exact isomers are not known.

TABLE IX-C-29
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: BLS-34 Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.96	.191	0.0012	Naphthalene
20.46	.265	0.0019	Phenanthrene
22.61	2.692	-	-
26.79	.201	0.0012	Fluoranthene
27.89	.342	0.0020	Pyrene
32.56	1.019	-	-
33.95	3.878	-	-
34.89	1.449	-	-
36.50	4.996	-	-
38.48	7.490	-	-
42.35	27.154	-	-
42.84	3.788	-	-
56.84	1.315	-	-
57.64	5.888	-	-
58.29	1.436	-	-
58.47	2.981	-	-
59.13	1.198	-	-
59.68	2.842	-	-

Total Benzene Eluate 1.5910 g/g

TABLE IX-C-30
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: BLS-35 Benzene SITE: EFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.36	.390	0.0010	Naphthalene
10.05	11.746	-	-
20.01	.328	0.0010	Phenanthrene
22.13	1.835	-	-
35.63	6.660	-	-
36.82	1.122	-	-
38.51	1.089	-	-
40.72	44.057	-	-
45.27	1.380	-	-
53.11	1.428	-	-
54.30	1.354	-	-

Total Benzene Eluate 0.6546 g/g

TABLE IX-C-31
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: COF-1 Benzene SITE: COF

Retention Time (minutes)	Area %	Concentration (g/g)	Name
2.02	3.279	-	-
2.24	1.033	-	-
2.43	4.678	-	-
2.81	1.610	-	-
3.33	2.148	-	-
4.20	1.101	-	-
5.69	1.286	0.0018	Naphthalene
8.40	.643	0.0009	2-Methylnaphthalene
8.80	.413	0.0006	1-Methylnaphthalene
10.29	12.853	-	-
11.50	1.653	-	-
14.13	1.365	-	-
15.65	1.033	-	-
16.70	1.796	-	-
18.28	1.947	-	-
20.41	.715	0.0011	Phenanthrene
21.24	10.671	-	-
21.56	1.949	-	-
23.49	2.498	-	-
23.86	1.383	-	-
24.14	3.439	-	-
26.02	1.835	-	-
26.44	.949	0.0013	Fluoranthene
27.47	1.098	0.0015	Pyrene
30.10	1.548	-	-
33.85	1.122	0.0056	Benz[a]Anthracene
37.18	1.369	-	-
37.32	1.824	-	-
38.17	1.045	-	-
39.35	1.083	-	-
41.52	1.635	0.0030	Perylene
43.54	1.069	-	-
45.35	2.282	-	-
45.77	3.814	-	-
46.13	2.658	-	-
47.37	2.039	-	-
47.76	1.260	-	-
47.99	1.383	-	-
49.33	1.269	-	-
51.91	2.827	-	-
53.62	1.220	-	-
55.58	2.247	-	-

Total Benzene Eluate 0.3472 g/g

TABLE IX-C-32
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: COF-2 Benzene SITE: COF

Retention Time (minutes)	Area %	Concentration (g/g)	Name
9.57	1.520	-	-
18.48	1.224	-	-
20.54	4.304	-	-
20.85	1.345	-	-
22.27	1.115	-	-
22.78	2.301	-	-
22.92	1.555	-	-
23.14	1.500	-	-
23.26	5.189	-	-
23.44	5.256	-	-
24.08	1.219	-	-
25.30	2.812	-	-
25.69	1.215	-	-
26.08	1.011	0.0045	Fluoranthene
27.01	3.537	-	-
27.39	1.242	0.0052	Pyrene
27.47	1.492	-	-
29.39	2.058	-	-
29.51	1.719	-	-
30.99	2.349	-	-
31.31	2.148	-	-
32.76	1.286	-	-
33.14	2.025	-	-
34.91	1.335	-	-
35.11	1.008	-	-
35.26	1.233	-	-
35.95	1.251	-	-
36.08	1.686	-	-
36.57	1.041	-	-
36.70	1.752	-	-
38.94	2.147	0.0357	Benz[*]Fluoranthene
40.52	.981	0.0182	Benz[e]Pyrene
41.44	4.082	0.0238	Perylene
45.87	1.629	-	-
46.57	3.252	-	-
46.98	2.404	-	-
48.75	2.233	-	-
50.12	2.223	-	-
51.97	1.617	-	-
53.57	7.995	-	-

Total Benzene Eluate 0.1108 g/g
*Exact isomers are not known.

TABLE IX-C-33
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA

SAMPLE: COF-3 Benzene SITE: COF

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.62	.505	0.0012	Naphthalene
8.15	.281	0.0007	2-Methylnaphthalene
8.50	.	0.0002	1-Methylnaphthalene
10.12	19.889	-	-
16.25	2.164	-	-
16.51	1.302	-	-
18.11	1.106	-	-
18.97	1.572	-	-
20.53	.379	0.0005	Phenanthrene
21.33	2.210	-	-
23.05	1.090	-	-
23.60	2.701	-	-
23.71	2.265	-	-
25.79	1.792	-	-
26.31	1.402	-	-
26.96	1.272	0.0031	Fluoranthene
27.38	1.270	-	-
27.96	.340	0.0008	Pyrene
33.61	1.114	-	-
37.07	1.365	-	-
41.13	1.463	-	-
43.01	1.418	-	-
45.31	2.806	-	-
47.74	1.379	-	-
53.18	2.581	-	-
55.36	2.242	-	-

Total Benzene Eluate 0.6003 g/g

TABLE IX-C-34
CONCENTRATION AND RETENTION TIME OF AROMATIC HYDROCARBONS IN SEDIMENTS OF THE NORTHERN GULF OF MEXICO TOPOGRAPHIC FEATURES AREA

SAMPLE: COF-4 Benzene SITE: COF

Retention Time (minutes)	Area %	Concentration (g/g)	Name
16.75	1.104	-	-
18.35	1.163	-	-
19.21	1.446	-	-
20.16	.948	0.0006	Phenanthrene
21.22	2.717	-	-
21.56	1.830	-	-
23.46	1.314	-	-
23.84	1.361	-	-
23.96	2.667	-	-
26.00	2.981	-	-
26.51	2.288	-	-
26.57	3.000	0.0016	Fluoranthene
26.72	1.778	-	-
27.58	2.586	0.0013	Pyrene
28.16	1.532	-	-
30.07	1.937	-	-
31.40	1.121	-	-
31.99	1.047	-	-
33.40	1.251	-	-
33.82	1.197	-	-
35.26	1.198	-	-
35.57	1.297	-	-
35.84	2.370	-	-
37.03	1.648	-	-
37.28	1.752	-	-
40.91	21.709	-	-
42.96	1.338	-	-
43.29	2.857	-	-
45.19	1.398	-	-
45.60	2.462	-	-
53.57	1.113	-	-
58.44	1.036	-	-
63.00	1.168	-	-
63.88	1.126	-	-
65.01	1.561	-	-

Total Benzene Eluate 0.1340 g/g

TABLE IX-C-35
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: RS-1G Benzene SITE: WFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
19.01	1.432	-	-
19.81	1.225	0.0063	Phenanthrene
20.85	1.612	-	-
22.49	1.373	-	-
23.63	1.149	-	-
25.13	1.426	-	-
25.72	1.199	-	-
25.97	.802	0.0037	Fluoranthene
27.05	.860	0.0037	Pyrene
27.21	1.026	-	-
29.18	1.137	-	-
29.76	1.391	-	-
32.73	1.098	-	-
33.48	1.234	-	-
35.51	3.867	-	-
36.32	1.120	-	-
36.71	1.579	-	-
36.93	1.550	-	-
37.75	1.355	-	-
38.86	1.888	0.0327	Benz[*]Fluoranthene
40.19	.664	0.0176	Benz[e]Pyrene
40.70	1.224	0.0233	Benz[a]Pyrene
40.97	2.456	0.0148	Perylene
41.77	1.050	-	-
41.99	1.325	-	-
46.04	1.531	-	-
47.56	2.011	-	-
52.88	3.430	-	-
55.06	1.526	-	-
56.15	1.500	-	-

Total Benzene Eluate 1.1538 g/g
*Exact isomers are not known.

TABLE IX-C-36
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: RS-2G Benzene SITE: WFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.46	.461	0.0010	Naphthalene
8.10	.356	0.0007	2-Methylnaphthalene
8.47	.143	0.0003	1-Methylnaphthalene
10.01	10.107	-	-
18.09	1.748	-	-
18.24	1.129	-	-
19.16	1.129	-	-
19.92	1.774	0.0041	Phenanthrene
26.08	1.267	0.0026	Fluoranthene
26.45	1.005	-	-
27.15	1.123	0.0022	Pyrene
33.58	1.161	0.0087	Benz[a]Anthracene
33.69	.510	0.0015	Chrysene
38.94	1.863	0.0145	Benz[*]Fluoranthene
40.51	2.516	0.0215	Benz[a]Pyrene
41.03	3.707	0.0101	Perylene
41.37	1.443	-	-
41.80	1.424	-	-
43.95	1.490	-	-
44.63	1.276	-	-
47.55	2.094	-	-
48.18	1.123	-	-
49.26	1.032	-	-
50.62	1.263	-	-
51.18	1.075	-	-
52.78	3.370	-	-
54.97	1.793	-	-

Total Benzene Eluate 0.5190 g/g
*Exact isomers are not known.

TABLE IX-C-37
CONCENTRATION AND RETENTION TIME OF
AROMATIC HYDROCARBONS IN SEDIMENTS
OF THE NORTHERN GULF OF MEXICO
TOPOGRAPHIC FEATURES AREA
SAMPLE: RS-3G Benzene SITE: WFG

Retention Time (minutes)	Area %	Concentration (g/g)	Name
5.61	.299	0.0012	Naphthalene
8.30	.206	0.0008	2-Methylnaphthalene
8.72	.104	0.0004	1-Methylnaphthalene
10.37	1.116	-	-
19.74	.694	0.0076	Dibenzothiophene
20.58	.485	0.0023	Phenanthrene
21.65	2.489	-	-
26.67	.810	0.0034	Fluoranthene
28.04	.707	0.0027	Pyrene
30.83	1.099	-	-
34.66	1.308	0.0075	Chrysene
36.76	2.147	-	-
37.98	2.442	-	-
38.27	1.835	-	-
42.19	1.872	-	-
42.51	25.464	-	-
42.74	1.162	-	-
42.93	1.852	-	-
45.20	2.926	-	-
47.55	1.283	-	-
48.06	2.892	-	-
51.62	1.199	-	-
57.38	2.420	-	-

Total Benzene Eluate 1.0373 g/g

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.