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Chemical Contaminants in Northeast United States Marine Sediments

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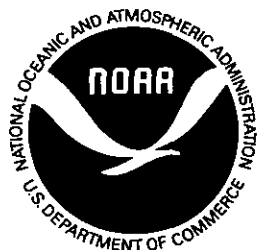
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CHEMICAL CONTAMINANTS
IN NORTHEAST UNITED STATES
MARINE SEDIMENTS

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1. Abstract

The initial (1981) segment of the NEMP area-wide sediment sampling and organic contaminant analytical program was conducted covering the Chesapeake Bay to Gulf of Maine region. Replicate samples taken from 28 stations (Figure 1) in each of two seasons were analyzed for the gross sediment quality parameters of total organic carbon (TOC), sediment grain-size distributions (GSD), and total Kjeldahl nitrogen (TKN). Additionally, five replicate cores from eight stations (Figure 1) were analyzed for their polychlorinated biphenyl (PCB), polynuclear aromatic hydrocarbon (PAH) and coprostanol (a fecal steroid) content. Statistical analyses of the concentration data were used successfully to assess changes in compound levels at each station and to assess differences between stations. Diagnostic ratios of PCB/TOC, coprostanol/total steroids, and coprostanol/PCB were used to determine whether concentration differences were due to geochemical and sedimentological phenomena or were due to real additional pollutant inputs to a given site. An organic pollutant monitoring system has thus been set in place which will allow for statistically valid monitoring of pollutant inputs to the benthos as reflected in sediment organic geochemistry.

2. Objectives

The goal of this effort was to perform analytical measurements of the polychlorinated biphenyl (PCB), polynuclear aromatic hydrocarbon (PAH) and coprostanol contents of approximately 70 sediment cores and to additionally analyze approximately 400 sediment cores for their total organic carbon (TOC), total Kjeldahl nitrogen (TKN) and grain size distribution (GSD). Samples were taken as part of a northeastern U.S. area-wide study from Chesapeake to Massachusetts Bays with more intensive sampling taking place in the New York Bight region.

PCB and PAH distributions are particularly relevant in determining pollution inputs and impacts as these components are ubiquitous contaminants of estuarine and nearshore sediment (Sayler, et al. 1978; West and Hatcher, 1980; Boehm, 1980, 1982; Windsor and Hites, 1979). Additionally these component classes include both toxic and mutagenic compounds.

The presence of coprostanol, a fecal steroid, has been used as an indicator of municipal sewage contamination (Hatcher and McGillivray, 1979; Hatcher, et al., 1977; Escalana, et al., 1980; Kanazawa and Teshisma, 1978; Boehm, 1980, 1982).

The detailed organic chemical makeup of sediments along with important support measurements of TOC, TKN and GS define geochemical pollutant sources in the northeast region and can be used to measure changes in the nature and quantity of pollutant inputs with time. TOC varies inversely with grain size while the ratio of TOC to TKN has been used to indicate the type of organic material(s) present. Grain size is an extremely important determinant in defining the habitat for

benthic organisms. The ratio of the abundance of certain organic chemicals (e.g., PAH, PCB) to TOC can also be used to define regional "geochemical provinces" (Boehm, 1981a), and to thus monitor changes in a particular province.

3. Summarization of Activities and Rationale

3.1 Sampling Activities

For the first phase of this program one hundred and thirty-three (133) sediment cores (0-10 cm) from 27 stations were taken for sediment grain size, TOC and TKN measurements. These consisted of five replicate cores at eighteen stations occupied during cruise AL81-07 (area wide survey) and five replicate cores at eight stations and three replicates at one station occupied during cruise AL81-09 (New York Bight survey). Additionally, five replicate cores taken at 8 stations located outside Chesapeake Bay, at the Philadelphia dumpsite, on the southern flank of Georges Bank, in Buzzards Bay, in Massachusetts Bay, in the "mud patch" south of Nantucket Island, and at two stations in the New York Bight region (equals 40 samples) were obtained for PCB, PAH and coprostanol analyses. The second phase of the program involved the analyses of one hundred and forty (140) sediment cores from 28 stations for grain size, TOC and TKN parameters. These cores were taken on NEMP cruise Al-82-01 in February of 1981. Ten (10) cores from two stations just seaward of the mouth of Delaware Bay taken in November 1981 were subjected to these analyses as well. Additionally ten (10) cores from the 106 Mile Deepwater Dumpsite location were analyzed. Five replicate cores from the same eight (8) stations as described above were analyzed for PCB, PAH, and coprostanol.

All samples were obtained by NOAA/NMFS personnel using a Pamatmat multiple quartz corer. Details of the sampling locations are presented in Figure 3-1 and can be found in Reid et al., 1981.

3.2 Analytical Methodology

The analytical methodologies used in this program are summarized in Table 3-1 and the detailed methods for organic chemical measurements shown in Figures 3-2 and 3-3.

4. Summarization of Findings

4.1 Sediment Character, Gross Chemistry

This section presents the absolute levels of TOC, TKN and GSD data on percent silt/clay (greater than 4 phi). Detailed TOC, TKN and GSD data are presented in Tables A-1 to A-33 in the Appendices in Section 8. The data from the five replicates from each station are given as the mean plus or minus one standard deviation, in Tables 4-1 and 4-2.

TOC and TKN values currently reported (1981 and 1982) are compared (Table 4-3) with values previously obtained from two 1980 samplings. Comparisons are generally quite good. Discrepancies most notably occur at Station 35, 16C and 17 where sampling variability is suspected. In addition, there is some problem with the location of Station 17, with different maps showing differing locations (Reid et al., 1981; White, 1981).

The ratio of organic carbon to kjeldahl nitrogen (TOC/TKN) has in the past been computed to aid in the interpretation of

TABLE 3-1
SUMMARY OF ANALYTICAL METHODS

PARAMETER	METHOD	REFERENCE	DETECTION LIMIT
Grain Size (GSD)	Sieve and pipette analysis	Folk (1974)	NAA
Total Kjeldahl Nitrogen (TKN)	Acid digestion - automated colorimetry	USGS (1979); Technicon (1976)	10 µ/g dry wt.
Total Organic Carbon (TOC)	High temperature combustion	Gibbs (1977)	0.01 mg/g dry wt.
PCB	Gas chromatography (GC); electron capture detection	Albro & Parker (1980); Boehm (1980a)	0.1 ng/g dry wt.
Coprostanol	Capillary GC - flame ionization after derivatization	Hatcher & McGillivary (1979); Boehm (1980a)	0.005 µg/g dry wt.
PNAH	Capillary GC - flame ionization after Sephadex cleanup	Ramos & Prohaska (1981); Brown et al. (1980); Boehm et al. (1981); Boehm (1980a)	1 ng/g dry wt. (individual component)

^aNot Applicable.

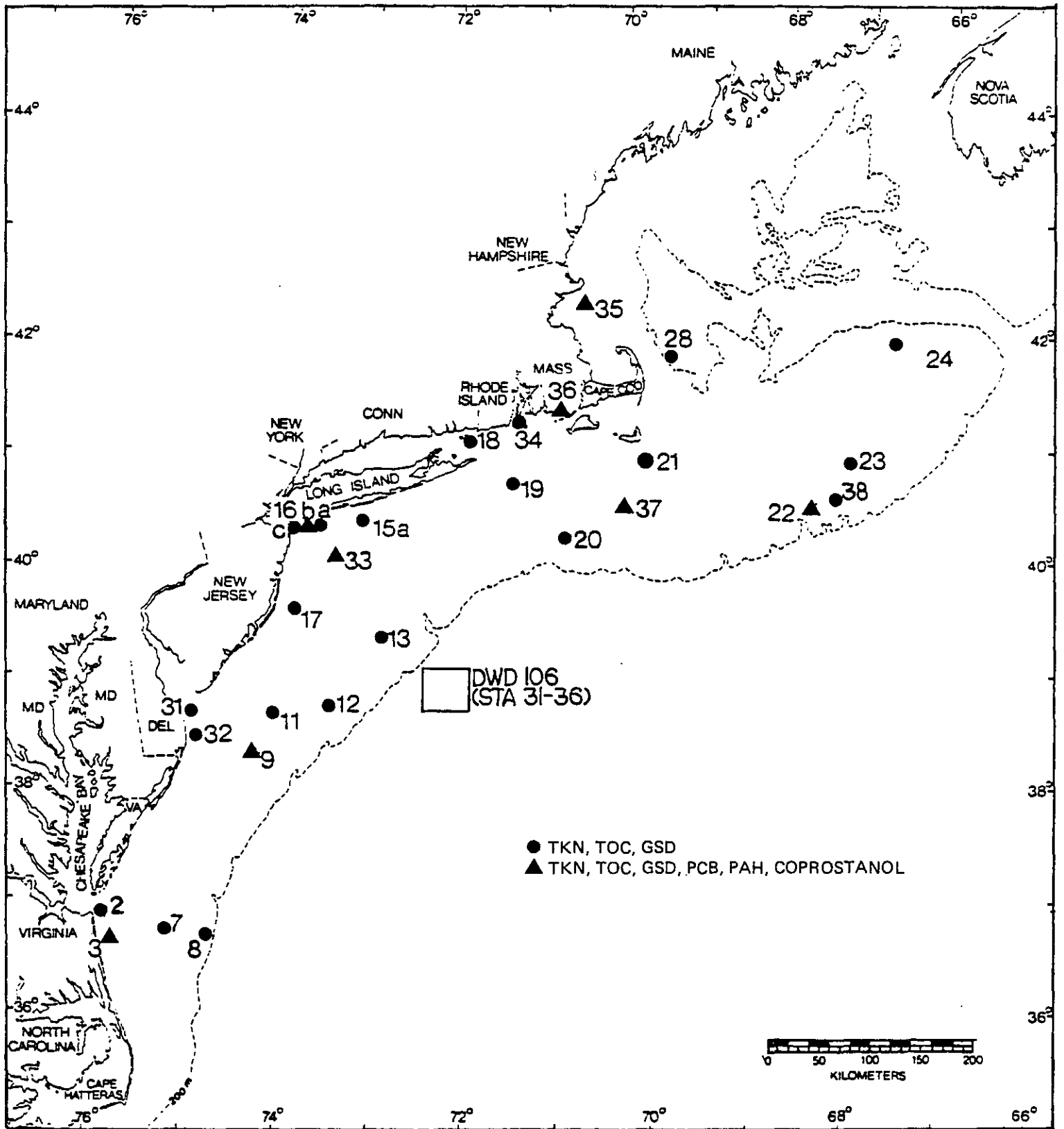


Figure 3-1. Sampling Locations for Sediments.

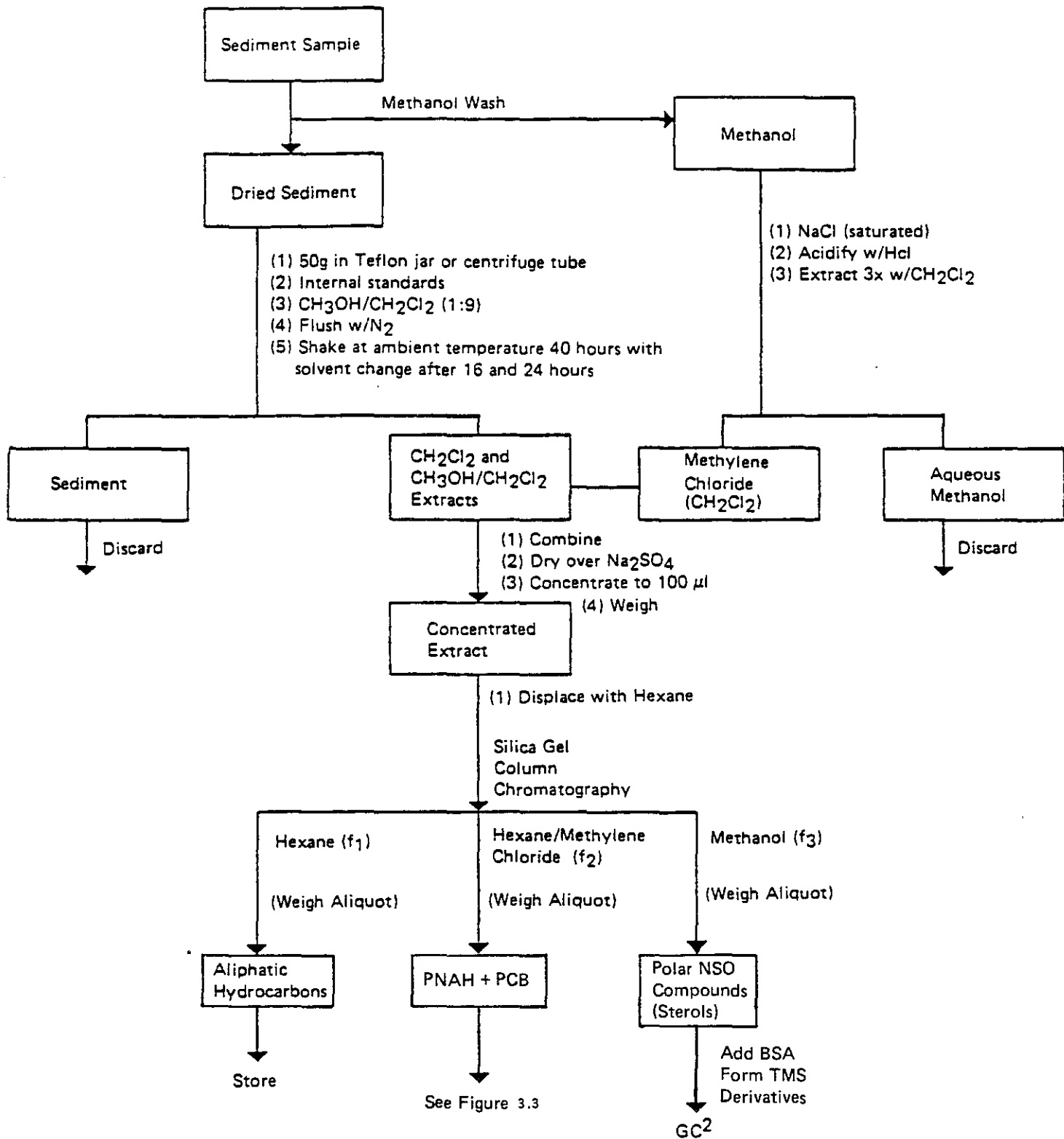


Figure 3-2. Analytical scheme for sediment samples.

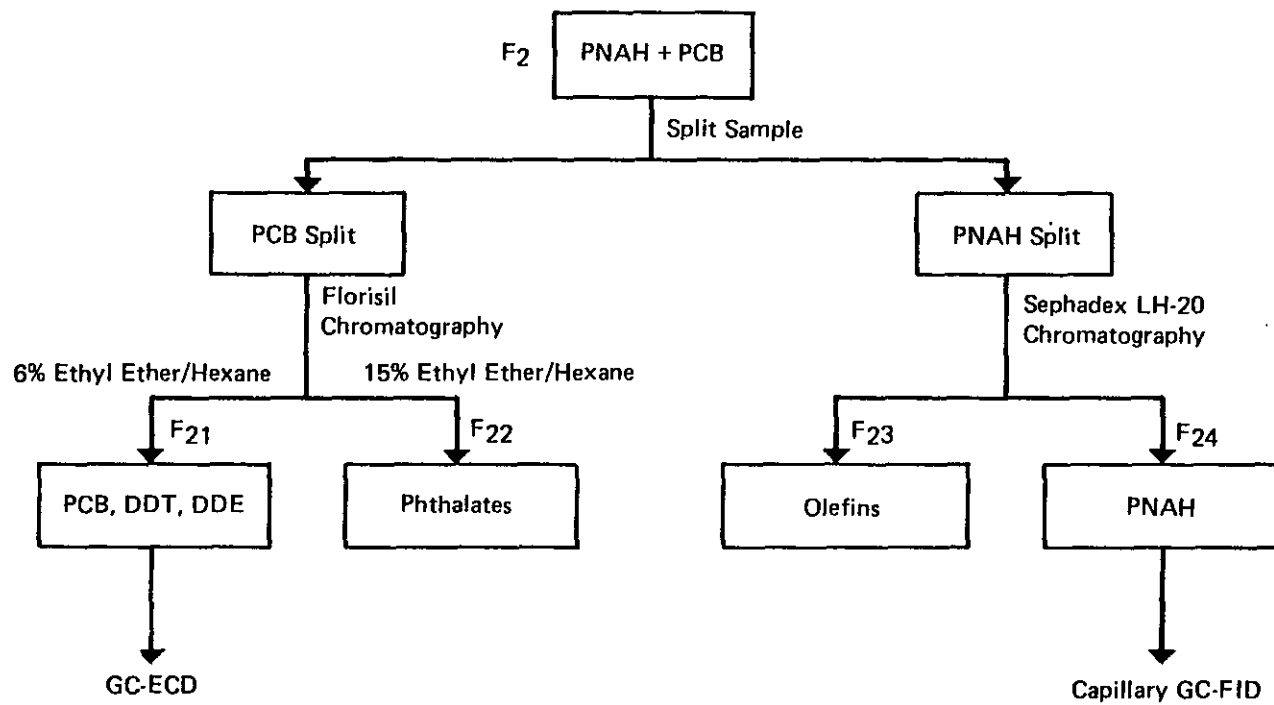


Figure 3-3. Processing of F₂ silica chromatography extract for PCB and PNAH determinations.

variable TOC and/or TKN concentrations in sediment (Freeland and Swift 1978; Milliman 1972) and to reveal possible sources of observed variability. This ratio is generally greater than 10 in coastal areas where riverine and/or anthropogenic influences are important, and 5-10 where marine organic matter (i.e., plankton, etc.) influences the sediment composition. While there is some variability in this ratio at a given station over time (Table 4-3) there is an obvious relationship between this ratio and the depositional environment at a given station. TOC/TKN values tend to be greater than 9 in areas of higher deposition (of terrigenous silt/clay, and associated pollutants) as evidenced by silt/clay percentages (Tables 4-1 and 4-2) of greater than ~1%. Thus stations 15A, 16A, 16B, 16C, and 33 in the New York Bight, 28 and 35 in Massachusetts Bay/Gulf of Maine, 18 in Long Island Sound, and 20 in the shelf deposition region off Rhode Island all exhibit high TOC/TKN ratios. Note that where grain size was found to be the same in 1981 and 1982 TOC/TKN ratios were similar, but where the sediment character was found to differ (e.g., stations 24, 31) the ratio changed. There are, however, exceptions to these "rules" (e.g., stations 17, 36). Although TOC/TKN values are generally in the range of 5-30 and perhaps can be grouped, the ratio is insensitive as a monitoring parameter both due to the variability of the ratio and its insensitivity to trace level additions of pollutants and even to large (100 ppm or so) additions of, for example, petroleum. A 100 ppm addition of oil (mostly carbon and hydrogen) to a sediment whose TOC was 5 mg/g (0.5%) and TKN was 400 mg/g would show a TOC change upwards to 5.1 mg/g (well within the range of natural variability at a given station) and a TOC/TKN change from 12.5 to 12.75.

TOC and TKN are best utilized as normalization parameters for trace level organics or metals (see section 4.2, 4.3) or as measurements which help select samples for additional (PCB, PNAH, coprostanol) analyses.

TABLE 4-1
SUMMARY OF TOC, TKN AND GS DATA (1981)

CRUISE	STATION	TOC (mg/g) (CaCO ₃ free)	TKN (ug/g dry weight)	MEAN TOC	GSD	
				MEAN TKN	% Silt/Clay (> 4 phi)	
AL81-07	3	2.3 + 1.0	276 + 110	8.3	5.79 +	2.80
AL81-07	7	1.4 + 0.4	128 + 64	10.8	0.4 +	.51
AL81-07	8	1.0 + 1.0	110 + 17	9.1	0.23 +	.07
AL81-07	9	2.0 + 1.0	249 + 71	8.0	14.8 +	2.3
AL81-07	11	1.9 + 0.3	197 + 42	9.6	3.0 +	2.6
AL81-07	12	1.4 + 1.0	214 + 76	6.7	0.9 +	1.6
AL81-09	13	1.6 + 0.6	135 + 61	11.9	6.5 +	1.5
AL81-09	15A	0.7 + 0.1	138 + 36	3.8	25.6 +	4.2
AL81-09	16A	4.6 + 2.8	183 + 97	25.1	1.62 +	.82
AL81-09	16B	23.5 + 4.7	962 + 108	24.4	17.4 +	4.8
AL81-09	16C	1.0 + 0.5	85 + 53	11.5	0.74 +	.73
AL81-09	17	1.2 + 0.3	79 + 24	15.9	.08 +	.06
AL81-07	18	4.7 + 1.3	623 + 196	7.5	18.7 +	2.2
AL81-07	19	3.7 + 0.8	461 + 112	8.0	20.3 +	6.7
AL81-07	20	14.3 + 2.3	1,685 + 340	8.5	81.3 +	2.6
AL81-07	21	0.8 + 0.8	124 + 111	6.7	0.26 +	.11
AL81-07	22	1.9 + 0.6	423 + 66	4.5	6.3 +	1.2
AL81-07	23	1.5 + 0.4	181 + 96	8.3	0.24 +	.15
AL81-07	24	0.4 + 0.4	82 + 50	4.9	.37 +	.35
AL81-07	28	13.8 + 1.6	957 + 290	14.3	96.1 +	2.1
AL81-09	31	1.6 + 0.9	211 + 29	7.6	5.5 +	2.62
AL81-09	32	1.3 + 0.7	122 + 23	10.6	0.75 +	.73
AL81-09	33	NA	NA		NA	
AL81-07	34	7.1 + 1.6	729 + 569	9.7	67.2 +	4.8
AL81-07	35	4.0 + 1.0	341 + 151	11.8	32.7 +	8.3
AL81-07	36	13.1 + 2.4	854 + 339	15.3	59.1 +	25.5
AL81-07	37	8.3 + 1.5	519 + 276	16.0	44.7 +	9.0

NA = Not analyzed

TABLE 4-2

SUMMARY OF TOC, TKN, AND GRAIN SIZE DATA (1982 AND OTHER CRUISES)

CRUISE	STATION	TOC (mg/g) (CaCO ₃ free)		TKN (ug/g dry weight)		MEAN TOC MEAN TKN		GSD % Silt/Clay (> 4 phi)		
AL 82-01	2	.5	+ .07	69.4	+ 34.6	8.8		1.91	+ .79	
	3	.6	+ .09	66.4	+ 8.1	9.2		1.84	+ 1.09	
	7	.6	+ .10	101	+ 37.8	5.6		1.21	+ .26	
	8	.6	+ .16	61.4	+ 19.6	9.3		1.57	+ .40	
	9	1.4	+ .30	200	+ 79.8	7.1		2.50	+ .69	
	11	.7	+ .13	155	+ 22.2	4.3		1.98	+ .53	
	12	1.1	+ .10	210	+ 141	5.3		3.40	+ .97	
	13	1.2	+ .20	372	+ 137	3.2		6.82	+ .27	
	15A	.6	+ .1	61.4	+ 17.0	10.0		.24	+ .14	
	16A	5.2	+ 1.2	152	+ 61.6	34.2		.72	+ .12	
	16B	25.4	+ 8.8	1000	+ 629	25.2		18.3	+ 9.4	
	16C	6.0	+ 1.2	401	+ 226	15.0		21.6	+ 15.0	
	17	.5	+ .21	58.8	+ 4.8	8.5		1.06	+ .22	
	18	6.9	+ 2.0	352	+ 153	19.6		23.2	+ 7.4	
	19	3.2	+ 0.5	346	+ 205	9.3		11.9	+ 10.0	
	20	13.9	+ 5.5	1020	+ 277	16.6				
	21		NA		NA					
	22	1.32	+ .61	145	+ 62.5	9.1				
	23	.8	+ .29	161	+ 41.4	5.0		0.89	+ .50	
	24	1.0	+ .69	31.8	+ 7.0	30.3		.24	+ .15	
	28	11.2	+ 1.2	918	+ 249	12.2		97.4	+ .91	
	31	12.7	+ 4.8	856	+ 477	14.8		21.3	+ 19.4	
	32	0.6	+ .20	34.8	+ 11.3	18.4		1.52	+ 1.16	
	33	8.4	+ 2.1	450	+ 189	18.7		20.12	+ 11.38	
	34	7.8	+ 2.6	682	+ 265	11.4		62.1	+ 4.84	
	35	5.3	+ 1.1	634	+ 161	8.4		58.0	+ 3.92	
	36	7.2	+ 1.0	1160	+ 263	6.2		82.4	+ 4.2	
	37	7.0	+ .6	745	+ 140	9.4		43.3	+ 3.8	
	38	.7	+ .2	50.6	+ 18.2	14.2		.27	+ .20	
	18NOV1981	60 (NEMP31)	6.9	+ 1.8	342	+ 69	20.2		5.5	+ .11
	18NOV1981	61 (NEMP32)	.66	+ .23	33.6	+ 4.8	19.6		.60	+ .13
	MI-RP-27-80	DWD106-31	10.0	+ 4.3	341	+ 52	29.3		75.6	
		DWD106-32	10.0	+ 2.1	513	+ 78	19.5		88.6	
		DWD106-33	9.8	+ 1.7	263	+ 162	37.3		10.5	
		DWD106-34	8.5		241		35.2		96.1	
		DWD106-35	11.6		462		25.1		80.9	
		DWD106-36	11.4	+ .85	886	+ 83	12.9		91.6	

NA = Not analyzed.

TABLE 4-3

COMPARISON OF CURRENT AND HISTORICAL TOC AND TKN DATA

STATION	TOC (mg/g)					TKN (µg/g)					TOC/TKN			
	JAN 82	AUG 81	NOV 81	JUL 80	DEC 80	JAN 82	AUG 81	NOV 81	JUL 80	DEC 80	JAN 82	AUG 81	JUL 80	AUG 80
3	0.61	2.3	-	1.4	1.6	66	276	-	260	190	9.2	8.3	5.4	8.4
7	0.56	1.4	-	0.9	1.1	101	128	-	180	100	5.5	10.9	5.0	11.0
8	0.57	1.0	-	-	1.1	61	110	-	-	60	9.3	9.1	-	18.3
9	1.4	2.0	-	-	2.5	200	249	-	-	240	7.0	8.0	-	10.4
11	1.1	1.9	-	-	1.4	155	197	-	-	110	7.1	9.6	-	12.7
12	1.2	1.4	-	-	2.3	210	214	-	-	190	5.7	6.5	-	12.1
13	1.2	1.6	-	-	-	372	135	-	-	-	3.2	11.9	-	-
15A	0.6	0.7	-	-	-	61	138	-	-	-	9.8	5.1	-	-
16A	5.2	4.6	-	3.2	1.3	152	183	-	410	130	34.2	25.1	7.8	10
16B	25.4	23.5	-	12.0	3.0	1000	962	-	1100	280	25.4	24.4	10.9	10.7
16C	6.0	1.0	-	10.0	1.1	401	85	-	1000	-	15.0	11.8	10.0	-
17	0.5	1.3	-	11.0	0.7	59	79	-	1500	-	8.5	16.5	7.3	-
18	6.9	4.7	-	6.8	5.6	352	623	-	940	620	19.6	7.5	10.4	9.0
19	3.2	3.7	-	4.1	4.7	346	461	-	590	780	9.2	8.0	6.9	4.8
20	13.9	14.3	-	-	-	1020	1685	-	-	-	13.6	20.9	-	-
21	-	0.8	-	-	-	-	124	-	-	-	-	6.5	-	-
22	1.3	1.9	-	3.5	3.5	145	423	-	530	610	9.0	4.5	8.1	5.7
23	0.81	1.5	-	1.4	-	161	181	-	230	-	5.1	8.3	6.1	-
24	1.0	0.4	-	0.5	0.4	32	82	-	20	-	31.3	5.0	20.0	-
28	11.2	13.8	-	-	13.3	918	957	-	-	2540	12.2	14.4	-	5.2
31	12.7	1.6	6.9	-	-	856	211	342	-	-	14.8	7.9	-	-
32	0.6	1.3	0.7	0.6	0.7	35	122	34	90	50	17.1	10.7	6.7	14.0
33	8.4	NA	-	1.8	8.1	450	NA	-	290	970	18.7	-	6.2	8.4
34	7.8	7.1	-	-	-	682	729	-	-	-	11.4	9.7	-	-
35	5.3	4.0	-	11.0	6.5	634	341	-	1400	980	8.4	11.7	7.9	6.6
36	17.2	13.1	-	-	-	1160	854	-	-	-	14.8	15.3	-	-
37	7.0	8.3	-	-	-	745	519	-	-	-	9.4	16.0	-	-

4.2 Polychlorinated Biphenyls

PCB concentrations in these nearshore and offshore sediments ranged from a high of 290 ± 110 ppb at Station 16B in the Christiaensen Basin of the New York Bight Apex in 1982 to $0.16 \pm .13$ ppb at station 22 (NEMP) in the shelf region of Georges Bank (Table 4-4, Figure 4.1). PCB concentrations at the center of Buzzards Bay (station 36) were variable (12.8 ± 7.7 ppb when sampled in 1981, and 44 ± 7.4 ppb in 1982), but were similar during the two samplings at station 37 within the depositional "mud patch" south of Nantucket and within the inshore Hudson Canyon (station 33) (i.e., 8-9 ppb). There was sizeable variation in the "mud patch" (station 37) values in 1981 (0.6-30 ppb) and at other stations. The median values and mean values are presented in Table 4-4. In most cases means and median values were similar. Coefficients of variation (s/\bar{x}) indicated within station variabilities of 17 to 150% (most often 50-70%) thus indicating the need for multiple sampling at each station. Analytical variability (3 sub-samples of a particular sample) ranged from 4-20%.

PCB values can be put into perspective when viewed versus other recent coastal sediment data (Table 4-5 and 4-6). We see that the absolute PCB levels for the New York Bight/Hudson Canyon samples (stations 16B and 33), .006-.29 ppm, and the other samples fall within expected ranges.

Statistical comparisons (Table 4-7) were made to compare PCB data from the two samplings. Note that PCB values are statistically higher at stations 9, 36, 16B during the second sampling. As the PCB/TOC ratios (see next paragraph) are also higher one concludes that the 1982 samples contained a greater proportion of PCB relative to TOC thus implying a definitive increase in PCB levels. However, our knowledge of the three

TABLE 4-4
SUMMARY OF PCB DATA

STATION	1981			1982		
	CONCENTRATION (ng/g=ppb)	$\bar{X} \pm S$	MEDIAN	CONCENTRATION (ng/g=ppb)	$\bar{X} \pm S$	MEDIAN
3	0.1			<.1		
3	0.2			0.6		
3	0.7	.32±.24	0.2	0.9	.44±.32	0.4
3	0.2			0.4		
3	0.4			0.2		
9	0.6			2.5		
9	0.4			1.6		
9	0.6	0.5±0.1	0.5	2.2	2.1±.91	2.2
9	0.4			0.8		
9	0.5			3.2		
16B(6)	182			450		
16B(6)	124			300		
16B(6)	130	144±41	130	240	290±110	300
16B(6)	93			275/300/430		
16B(6)	189			145/151/139		
22	<.1			0.4		
22	0.2			0.1		
22	0.7	0.55±.42	0.7	<0.1	.16±.13	0.1
22	0.7			<.01		
22	1.1			<.01		
33(15)	9.0			5.5		
33(15)	10.			5.0		
33(15)	11.	8.8±2.3	9.0	1.0	5.7±3.2	5.5
33(15)	9.			7.1		
33(15)	5.			9.8		
35	12.0			2.6		
35	4.0			7.7		
35	1.0	6.4±4.2	7.0	5.3	5.9±2.7	5.3
35	7.0			9.4		
35	8.0			4.7		
36	8.0			32		
36	19.0			43		
36	15.0	12.8±7.7	15.0	50	44±7.4	48
36	20.0			49		
36	2.0			48		
37	4.0			7.0		
37	3.0			1.6		
37	3.0	8.1±12.2	3.0	0.6	3.3±2.5	2.6
37	0.6			4.5		
37	30.0			2.6		

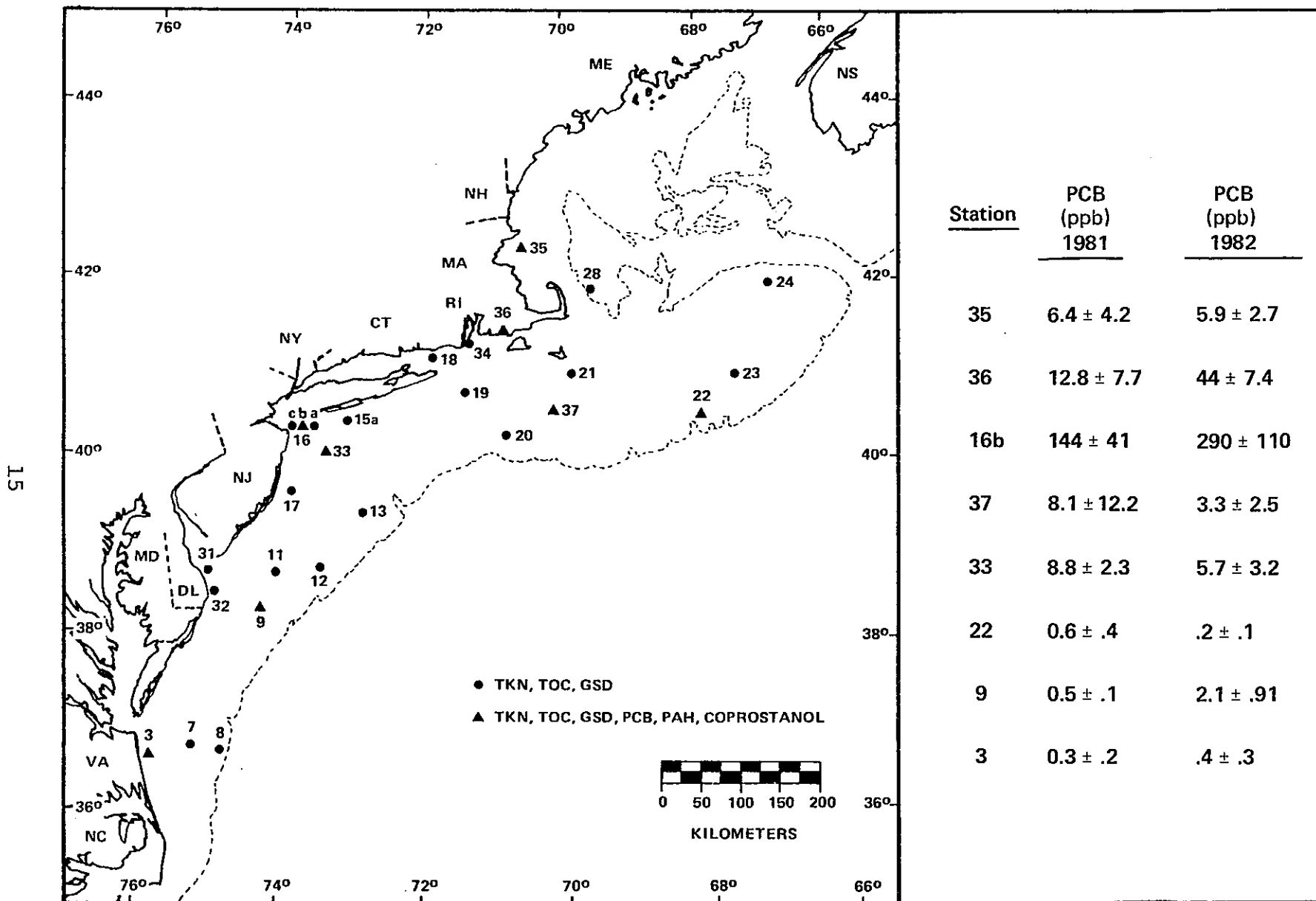


Figure 4-1. PCB concentrations in sediments.

TABLE 4-5

REPORTED PCB CONCENTRATIONS IN NEW YORK BIGHT REGION SEDIMENTS

LOCATION	CONCENTRATION (ppm)	REFERENCE
Hudson River	0.5-140	Bopp et al., 1981
Upper Bay	0.13	MacLeod et al., 1981
	0.40	Boehm 1981b
Lower Bay	0.7	MacLeod et al., 1981
Newark Bay	1.6	Boehm 1981b
Arthur Kill Region	2-3	MacLeod et al., 1981
	0.32 (dredged area)-1.1	Boehm 1981b
Raritan Bay	0.4-0.5	MacLeod et al., 1981
	0.27	Boehm 1981b
Christiaensen Basin	1.3-1.5	MacLeod et al., 1981
	0.05-0.15	Boehm, 1980
	0.1-0.3	West and Hatcher, 1980
New York Bight (non-dumpsite)	ND-.01	Boehm, 1980
	0.002-0.01	West and Hatcher, 1981
Dredge Spoils (Metropolitan N.Y.)	0.4-3.5	MacLeod et al., 1981
	3.7-6.9	Boehm and Fiest, 1980
Sewage Sludge (Metropolitan N.Y.)	3.5	Bopp et al., 1981
	6.4	West and Hatcher, 1980
Sewage Sludge Deposit (New York Bight)	0.4	Boehm, 1982
	0.06-0.2	Boehm, 1980
	1.5-2.2	West and Hatcher, 1980
Dredge Spoil Deposit (New York Bight)	0.003-.28	Boehm, 1982
	0.03	Boehm, 1980
	0.4	West and Hatcher, 1980

ND = None detected.

TABLE 4-6
REPORTED PCB CONCENTRATIONS
IN OTHER U.S. NEARSHORE AND MARINE SEDIMENTS

LOCATION	CONCENTRATION (ppm)	REFERENCE
New Bedford Harbor		
Inner Harbor	3-30	Mass. DEQE (1980, unpublished)
Outer Harbor	0.3-78	US EPA (1980, unpublished) WHOI (1980, unpublished)
Buzzards Bay	0.08-0.54	SMU (1980, unpublished)
Boston Harbor		
Sewage Solids (MDC)	20-30	(New England Aquarium, 1976)
Massachusetts Bay		
Nearshore	.015-.030	(New England Aquarium, 1976)
Offshore	.001-.020	(New England Aquarium, 1976)
Chesapeake Bay	.004-0.4	(Sayler et al., 1978)
Gulf of Mexico	.0002-.035	(US EPA, 1976)
Escambia Bay (Fla.)	ND-8	(US EPA, 1976)
Coastal California (depending on distance from Los Angeles discharges)	.5-7	(Young et al., 1977)

TABLE 4-7
WITHIN STATION COMPARISONS FOR PCB

STATION	SAMPLING		PROBABILITY OF SIMILARITY ^a	RESULT
	AL 81-07 \bar{X} (ng/g) S	AL 82-01 \bar{X} (ng/g) S		
3	.32 \pm .24	.44 \pm .32	.52	same
9	0.50 \pm .10	2.1 \pm .91	.01	differ
16B	144 \pm 41	294 \pm 113	.02	differ
22	0.56 \pm .41	.16 \pm .13	.07	same
33	8.8 \pm 2.3	5.5 \pm 3.6	.12	same
35	6.4 \pm 4.2	5.9 \pm 2.7	.84	same
36	12.8 \pm 7.7	44. \pm 7.4	<.01	differ
37	8.1 \pm 12.3	3.3 \pm 2.5	.41	same

^aUsed a two-tailed t-test on untransformed data, N=5; P>.05 indicates that values are statistically similar at the 95% level.

sites, New York Bight, Philadelphia Dumpsite, and Buzzards Bay suggests that inherent patchiness at these sites (i.e., sampling variability) may contribute to this increase at Philadelphia dumpsite rather than new PCB inputs, and that there are equal probabilities of new inputs and sampling variability accounting for observed increases at stations 16B and 36. PCB values at each station were also compared to those of the other stations within each of the two (1981, 1982) sample sets (Table 4-8).

Since the program involved analysis from only eight stations over a wide geographic area, no uniform geochemical relationships can be assumed to govern pollutant distributions in sediment. However, if one looks at the relationship of PCB to TOC (Table 4-9) we find that the "unpolluted" coastal sediments from stations 3, 9, and 22 have low (0.14×10^{-6} to 0.29×10^{-6}) PCB to TOC ratios in 1981. At the more PCB-impacted stations, a greater proportion of the TOC is PCB material. Thus, PCB/TOC ratios at stations 36 and 37 are similar to each other in 1981 while they are much higher both in the 1981 and 1982 New York Bight sample sets (6.1 and 11.4×10^{-6}). Furthermore, PCB/TOC increased at the Buzzards Bay station (36) in 1982 (6.1×10^{-6}). Thus PCB/TOC is sensitive to variations in absolute PCB inputs, and is an indicator of PCB hot-spots not attributable merely to a grain size phenomenon (i.e., TOC input). For example it is quite possible to see an increase or a decrease in PCB levels with no change in the PCB/TOC ratio.

Stations 16B and 33 have been sampled previously as part of the New York Bight Benthic survey (Boehm 1980). At that time PCB values were determined to be 55 and <0.5 ppb respectively. The values reported here are notably higher, indicative of the inherent patchiness in the system or increased levels due to PCB inputs.

TABLE 4-8

STATION COMPARISON MATRIX FOR PCB CONCENTRATIONS

STATION	STATION (1981)						
	9	16B	22	33	35	36	37
3	.16	<.01	.29	<.01	..01	.01	.19
9	-	<.01	.76	<.01	.01	.01	.20
16B	-	-	<.01	<.01	<.01	<.01	<.01
22	-	-	-	<.01	.01	<.01	.21
33	-	-	-	-	.29	.30	.12
35	-	-	-	-	-	.14	.78
36	-	-	-	-	-	-	.49
37	-	-	-	-	-	-	-

STATION	STATION (1982)						
	9	16B	22	33	35	36	37
3	.01	<.01	.11	.01	<.01	<.01	.04
9	-	<.01	<.01	.07	.02	<.01	.35
16B	-	-	<.01	<.01	<.01	<.01	<.01
22	-	-	-	.01	.01	<.01	.03
33	-	-	-	-	.83	<.01	.28
35	-	-	-	-	-	<.01	.14
36	-	-	-	-	-	-	<.01
37	-	-	-	-	-	-	-

ap>.05 indicates statistical similarity.

TABLE 4-9

KEY PARAMETER RATIOS

STATION	$\frac{\text{COPROS}}{\text{PCB}}$	$\frac{\text{COPROS}}{\text{TOTAL STEROIDS}^a}$	PCB/TOC ($\times 10^6$)
1981			
3	108 \pm 58	.02 \pm .009	0.14
9	21 \pm 4	.01 \pm .002	0.25
16B	134 \pm 66	.58 \pm .03	6.13
22	58 \pm 55	.03 \pm .01	0.29
33	7.1 \pm 3.8	.011 \pm .0	-
35	10 \pm 11	.017 \pm .005	1.6
36	3.5 \pm 1.6	.045 \pm .028	0.98
37	6.6 \pm 5.9	.010 \pm .008	0.98
1982			
3	41 \pm 36	.01 \pm 0	0.70
9	9.4 \pm 8.9	.01 \pm 0	1.5
16B	108 \pm 68	.50 \pm .04	11.4
22	85 \pm 34	.01 \pm .01	0.12
33	12 \pm 2.2	.012 \pm .004	0.68
35	8.0 \pm 5.0	.01 \pm .01	1.1
36	3.0 \pm 1.3	.014 \pm .005	6.1
37	15 \pm 21	.01 \pm .01	0.47

^aSum of five steroids: coprostanol, cholesterol, cholestanol, stigmasterol, β -sitosterol.

4.3 Coprostanol

The amounts of fecal steroid, coprostanol, in the surface sediments (Table 4-10, Figure 4.2) ranged, on the average, from 0.01 to 26.7 ppm. Only in the New York Bight station within the sewage depositional area (16B) is the coprostanol value, 17.4 ppm (1981) and 26.7 ppm (1982), reflective of gross sewage contamination. These values are similar to that determined previously for this station, 11 ppm (Boehm 1980). Similarly, the station 33 values for the three data sets are similar (1980 : .07; 1981 = .05; 1981 = .08 ppm). At all other stations other than station 36 (Buzzards Bay) in 1982, coprostanol values of 0.01 to .035 ppm are "typical" of shelf values (nd - 0.06; Boehm 1980) determined for New Jersey and Long Island Atlantic shelf values.

Statistical comparisons are presented in Tables 4-11 and 4-12 for seasonal and spatial comparisons respectively. Coprostanol values remain the same at stations 9, 35, 37, and 33 while they differ at stations 36, 16B (increase in 1982) and 3, 22 (decrease in 1982).

The importance of sewage-derived organic matter relative to non-sewage steriodal inputs can be examined using the ratio of coprostanol to total measured steroids (Table 4-9). It can be seen that only at station 16B within the New York bight and perhaps at station 36 within the Buzzards Bay are sewage-related inputs to sediments evidenced by virtue of coprostanol to total steroid ratios in the 0.05 to 0.6 range. A scale of 0 to 0.74 has previously been established (Boehm 1980) to indicate the relative importance of sewage-related compounds to marine sediments. Thus it can be seen that sewage-associated pollutants are low-level ubiquitous components of offshore marine sediments.

TABLE 4-10
SUMMARY OF COPROSTANOL DATA

STATION	1981			1982		
	CONCENTRATION ($\mu\text{g/g}=\text{ppm}$)	$\bar{X}+S$	MEDIAN	CONCENTRATION ($\mu\text{g/g}=\text{ppm}$)	$\bar{X}+S$	MEDIAN
3	.010			<.01		
3	.039			<.01		
3	.048	.028 \pm .015	.026	<.01	<.01	
3	.026			<.01		
3	.019			<.01		
9	.01			.02		
9	.01			.01		
9	.01	.01 \pm .002	.01	.01	.014 \pm .005	.015
9	.01			.02		
9	.012			.01		
16B(6)	14.4			28.6		
16B(6)	13.6			22.6		
16B(6)	26.9	17.4 \pm 5.7	14.4	22.0	26.7 \pm 4.5	28.6
16B(6)	18.7			27.1		
16B(6)	13.4			33.0		
22	.015			.01		
22	.028			.01		
22	.014	.024 \pm .009	.027	<.01	.01	
22	.027			.01		
22	.036			<.01		
33(15)	.054			.06		
33(15)	.039			.07		
33(15)	.062	.050 \pm .01	.058	.07	.08 \pm .02	.07
33(15)	.058			.11		
33(15)	.068			.11		
35	.032			.04		
35	.038			.03		
35	.025	.033 \pm .007	.038	.02	.04 \pm .02	.04
35	.042			.06		
35	.027			.05		
36	.035			.14		
36	.025			.18		
36	.064	.035 \pm .019	.035	.06	.13 \pm .04	.13
36	.040			.12		
36	.013			.13		
37	.017			<.01		
37	.009			.03		
37	.015	.02 \pm .015	.015	.03	.02 \pm .01	.01
37	.012			<.01		
37	.047			<.01		

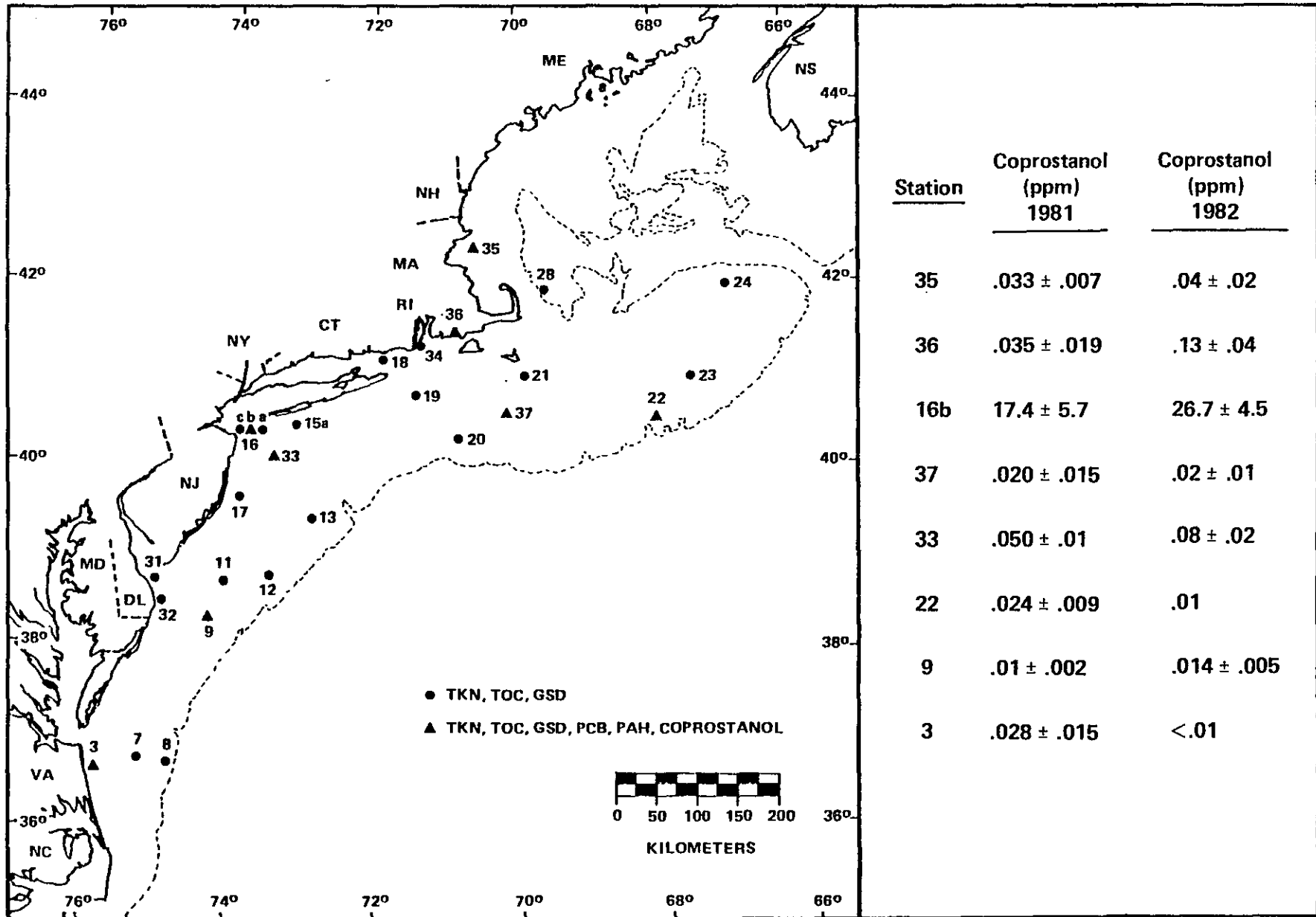


Figure 4-2. Coprostanol concentrations in sediments.

TABLE 4-11

WITHIN STATION COMPARISONS OF COPROSTANOL CONCENTRATIONS

STATION	SAMPLING				PROBABILITY OF SIMILARITY ^a	RESULT
	1981		1982			
	\bar{X} (ng/g)	S	\bar{X} (ng/g)	S		
3	.03 \pm .016		.010 \pm <.001		.02	b
9	.01 \pm <.001		.014 \pm .005		.14	same
16B	17.4 \pm 5.7		26.7 \pm 4.5		.02	differ
22	.026 \pm .011		.010 \pm <.001		.01	b
33	.056 \pm .011		.084 \pm .024		.05	same
35	.034 \pm .005		.040 \pm .016		.45	same
36	.036 \pm .018		.13 \pm .043		<.01	differ
37	.022 \pm .016		.018 \pm .011		.66	same

^aThe statistical analyses were done using a two-tailed t-test on untransformed data. N=5; P>.05 indicates statistical similarity at the 95% level.

^bThese comparisons were statistically different but in both cases all values from one sampling were at or below the detection limit.

TABLE 4-12

STATION COMPARISON MATRIX FOR COPROSTANOL CONCENTRATIONS^a

STATION	STATION (1981)						
	9	16B	22	33	35	36	37
3	.02	<.01	.66	.02	.61	.59	.46
9	-	<.01	.01	<.01	<.01	.01	.14
16B	-	-	<.01	<.01	<.01	<.01	.01
22	-	-	-	<.01	.20	.33	.67
33	-	-	-	-	.01	.07	.01
35	-	-	-	-	-	.82	.16
36	-	-	-	-	-	-	.24
37	-	-	-	-	-	-	-

STATION	STATION (1982)						
	9	16B	22	33	35	36	37
3	.14	<.01	1.0	<.01	<.01	<.01	<.01
9	-	<.01	.14	<.01	<.01	<.01	.49
16B	-	-	<.01	<.01	<.01	<.01	<.01
22	-	-	-	<.01	<.01	<.01	.14
33	-	-	-	-	<.01	.10	<.01
35	-	-	-	-	-	<.01	.03
36	-	-	-	-	-	-	<.01
37	-	-	-	-	-	-	-

^ap>.05 indicates statistical similarity.

4.4 Relation of PCB to Coprostanol

Another potentially useful parameter is that of the ratio of coprostanol to PCB. Although PCB are abundant in sewage sludges, PCB inputs are of course not limited to sewage-related sources. Coprostanol to PCB ratios near the sewage dumpsite in the New York Bight have been determined to be 150-200 (Boehm 1980). A value found in sediments within this range can therefore be interpreted as meaning that most PCB found in the sediments are sewage related. Theoretically this ratio approaches zero as "pure" PCB inputs (sewage-free) are approached. Interestingly, consistently elevated ratios are observed (Table 4-9) for station 16B, due to its location adjacent to the sewage dumpsite, but also for Station 3 off-shore Chesapeake Bay, and for the Georges Bank station (22) indicating that PCB inputs to sediments from these stations have a significant sewage-related source. Some of the PCB observed at the other stations (9, 35, 37, and 33) show a small but significant sewage influence (copros/PCB = 5-20). Most interestingly, and quite indicative of the power of this ratio as a diagnostic geochemical tool is the fact that at station 36 the ratio is low (3-4) while the PCB levels are high. This implies a non-sewage source for PCB which we know in Buzzards Bay to be related largely to industrial rather than sewage-mediated inputs. The trends in the coprostanol/PCB ratio can be statistically evaluated (Tables 4-13 and 4-14) for seasonal and spatial trends. Note that increases in PCB levels without concomitant coprostanol increases occur at stations 3, 9, and 33.

4.5 Polynuclear Aromatic Hydrocarbons (PAH)

PAH compounds are ubiquitous constituents of marine sediments from the continental shelves of the world's oceans

TABLE 4-13

WITHIN STATION COMPARISONS OF COPROSTANOL/PCB RATIO

STATION	SAMPLING				PROBABILITY OF SIMILARITY ^a	RESULT
	1981 \bar{X} (ng/g)	S	1982 \bar{X} (ng/g)	S		
3	114 \pm 61		41 \pm 36		.05	differ
9	21 \pm 4		9.4 \pm 8.9		.03	differ
16B	134 \pm 66		108 \pm 68		.44	same
22	89 \pm 81		85 \pm 34		.45	same
33	7.1 \pm 4.0		13 \pm 2.2		.04	differ
35	10 \pm 11		8.0 \pm 5.0		.73	same
36	3.5 \pm 1.6		3.0 \pm 1.3		.69	same
37	6.6 \pm 5.9		15 \pm 21		.06	same

^ap>0.05 indicates statistical similarity.

TABLE 4-14

STATION COMPARISON MATRIX FOR COPROS/PCB RATIO^a

STATION	STATION (1981)						
	9	16B	22	33	35	36	37
3	<.01	.56	.24	<.01	.02	<.01	.03
9	-	<.01	.10	<.01	.06	.01	.05
16B	-	-	.18	<.01	.02	<.01	.03
22	-	-	-	<.01	.03	.01	.04
33	-	-	-	-	.70	.08	.36
35	-	-	-	-	-	.18	.57
36	-	-	-	-	-	-	.48
37	-	-	-	-	-	-	-

STATION	STATION (1982)						
	9	16B	22	33	35	36	37
3	.03	.05	.11	.39	.02	.01	.08
9	-	.01	.01	.06	.93	.08	.39
16B	-	-	.48	.01	.01	.01	.06
22	-	-	-	.03	.01	.01	.06
33	-	-	-	-	.05	.01	.11
35	-	-	-	-	-	.07	.36
36	-	-	-	-	-	-	.50
37	-	-	-	-	-	-	-

^ap>.05 indicates statistical similarity.

(Windsor and Hites, 1979). PAH were detected in nearly all sediments from the study area, the exception being station 9 near the Philadelphia dumpsite in 1981. The station 9 collection from 1982 did contain detectable levels primarily of fluoranthene and pyrene (Table 4-15). Concentrations range from 1.0 ppb at station 22 on Georges Bank to 31,000 ppb in New York Bight (Table 4-15, Figure 4.3). Interestingly the "mud patch" depositional site (37) contained moderate PAH levels (100-150 ppb) indicating that this represents a true pollutant depositional area. Massachusetts Bay (35) contained roughly a part per million of total PAH (.650-1.22 ppm).

Trends in PAH data are quite dissimilar from those of PCB indicating that transport routes and sources for these two pollutant classes differ. For example, while PCB levels were seen to increase between 1981 and 1982 at station 16B, the PAH levels decreased. While PAH increased at stations 35 and 22, the PCB levels remained the same at 35 and decreased at 22. However, PAH (and PCB) levels remained the same at stations 3, 33, and 37.

Sources of PAH compounds to the sediments are generally discerned from the following criteria: Petroleum sources are indicated by a high amount of alkylated (C_1 , C_2 , C_3 , C_4) naphthalenes, phenanthrenes, fluorenes, and dibenzothiophenes relative to the parent (unsubstituted) compounds (i.e., C_0) (Youngblood and Blumer, 1975); combustion sources are indicated by an equal or larger amount of C_0 compounds relative to C_1 and C_2 plus large relative quantities of the larger PAH compounds (fluoranthene and pyrene [4 rings], benzofluoranthene and the benzopyrenes [5 rings]). The percentage of total PAH attributable to petroleum can be approximated according to Table 4-16. PAH sources to all but the heavily impacted New York Bight station (16B) are primarily (90-95%) of a

TABLE 4-15

SUMMARY OF PAH DATA (ng/g dry weight)
(Mean of 5 replicate determinations)

	SAMPLING CRUISE	STATIONS									
		3	9	22	35	36	37	16Ba	16B (1980) ^b	33a	(1980) ^b
(1) Total naphthalenes (C ₀ -C ₄) ^{c,d}	81-07	nd	nd	nd	2.8	<1	nd	6,575	790	10	12
	82-01	nd	nd	1.0	nd	nd	7.0	1,790		nd	
(2) Total dibenzothiopenes (C ₀ -C ₃) ^{c,e}	81-07	nd	nd	nd	1.4	nd	nd	169	830	<1	15
	82-01	nd	nd	1.0	5.0	5.0	nd	105		2.0	
Phenanthrene (C ₀) ^c	81-07	7.7	nd	nd	60	6.8	12	1,290	820	110	16
	82-01	1.0	1.0	3.0	127	49	15	640		35	
(3) Total phenanthrenes (C ₀ -C ₄) ^c	81-07	7.7	nd	nd	120	9.8	22	12,900	3,430	130	47
	82-01	1.0	1.0	3.0	170	68	19	1,160		63	
Fluoranthene (C ₀) ^c	81-07	3.0	nd	1.0	105	20	23	1,640	1,100	72	28
	82-01	.0	6.0	4.0	232	87	37	700		65	
Pyrene (C ₀) ^c	81-07	1.0	nd	nd	96	38	14	1,370	1,200	55	25
	82-01	8.0	19	nd	233	187	34	640		161	
(4) Total fluoranthenes and pyrenes (C ₀ -C ₁) ^c	81-07	4.0	nd	nd	270	58	43	3,810	-	140	-
	82-01	9.0	25	4.0	540	300	72	1,810		250	
Benzanthracene	81-07	nd ^c	nd	nd	43	2.0	3.3	660	800	18	15
	82-01	nd	nd	nd	71	21	6.0	270		17	
Chrysene	81-07	nd	nd	nd	61	7.3	8.5	840	600	32	20
	82-01	nd	nd	nd	108	43	11	530		35	
(5) Total benzanthracenes and chrysenes (C ₀ -C ₁) ^c	81-07	nd	nd	nd	136	9.3	20	2,390	-	87	-
	82-01	nd	nd	nd	250	81	24	1,240		90	
Benz(a)pyrene (252)	81-07	nd	nd	nd	32	3.3	2.5	670	720	26	18
	82-01	nd	nd	nd	81	31	8	310		32	
Benzo(a)fluoranthenes (252)	81-07	nd	nd	nd	39	4.3	9.5	1,300	1,300	45	90
	82-01	nd	nd	nd	67	28	9	350		32	
Benzo(e)pyrene (252)	81-07	nd	nd	nd	33	3.3	11	1,010	590	40	22
	82-01	nd	nd	7	74	30	9	360		32	
Perylene (252)	81-07	nd	nd	nd	12	<1	5	380	180	15	10
	82-01	nd	nd	nd	24	13	4	99		23	
(6) Im/e 252	81-07	nd	nd	nd	116	10	29	3,360	2,790	126	140
	82-01	nd	nd	7	250	102	30	1,120		120	
ΣPAH (1-6)	81-07	11.7	nd	1.0	646	177	114	30,730	9,500	493	300
	82-01	10.0	26	16	1,220	560	150	7,220		490	

^aFrom Boehm, 1980.

^bC₀, C₁, C₂, C₃, C₄ = number of alkyl substituents on aromatic molecule.

^cwhere detected <1% naphthalene; ~20% methyl naphthalenes; ~40% (dimethyl + ethyl naphthalenes); ~40% trimethylnaphthalenes; C₄ naphthalenes not quantified.

^dnd = <1.0 ng/g.

^ewhere detected ~10% dibenzothiophene; ~20% methyl DBT; ~30% dimethyl DBT; ~40% trimethyl DBT.

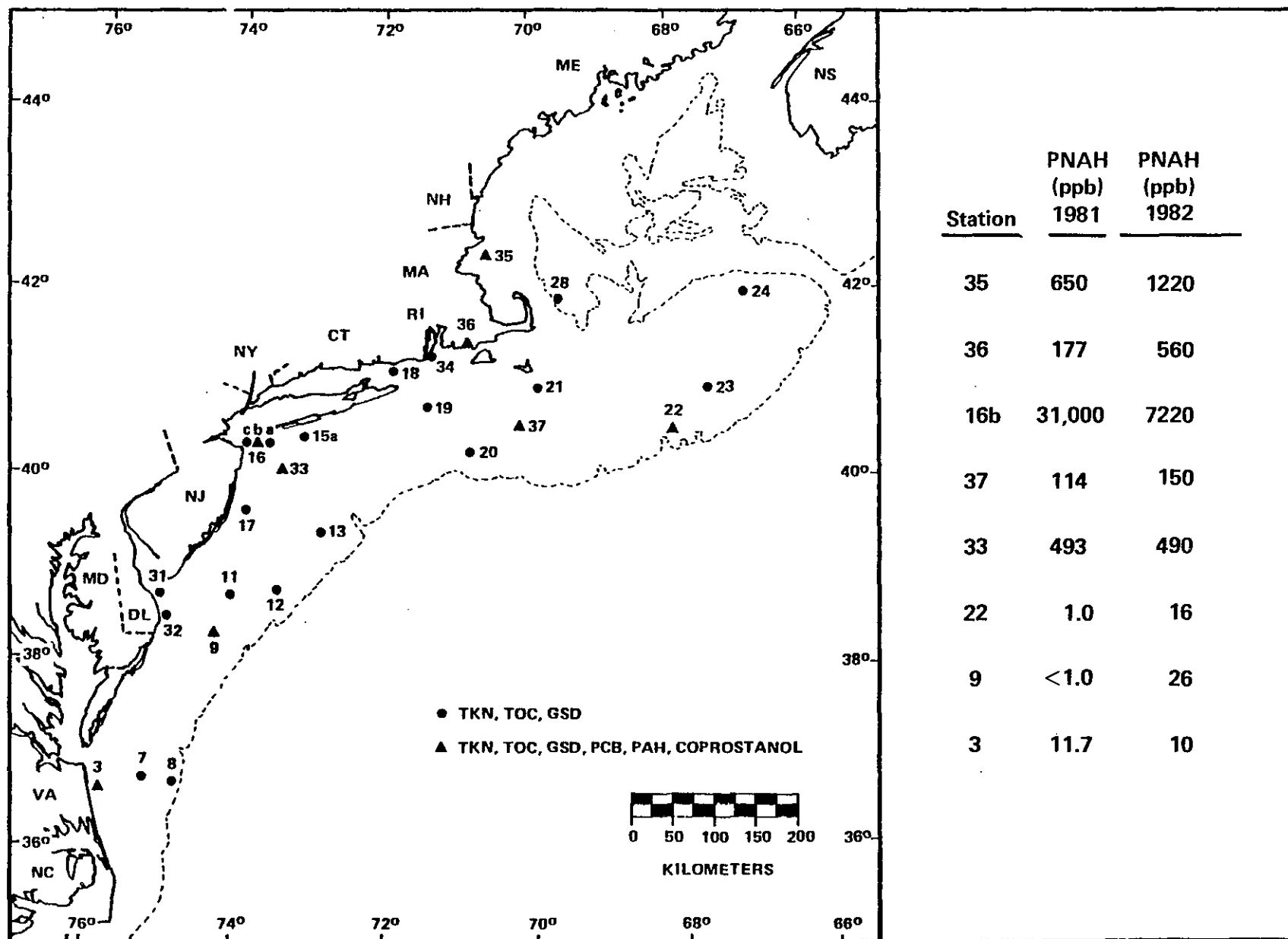


Figure 4-3. PNAH concentrations in sediments.

combustion origin with 3-5 ring aromatics dominant. PAH sources to station 16B are a mixture of petroleum (35-50%) and combustion-derived material. Note that when one compares 1980 and 1981 determined PAH concentrations (Table 4-15) the increase at Station 16B is primarily in the naphthalene and dibenzothiophene compound series, indicating a petroleum-related increase. However, in spite of quantitative differences at some of the stations (e.g., 9,22,35,16B) the contributions of the main source classes (Table 4-16) remain relatively constant.

What significance do the PAH values have? In general as aromatic compounds get larger by either increased ring size or methyl substitution up through the alkyl-phenanthrenes and fluoranthene, they become more toxic. Beyond this molecular size the molecules become less soluble in water and hence less readily available in the sense of resulting in acute toxicity. However, many of the five-ringed compounds are carcinogenic (see Table 4-17) once introduced to the animal via uptake routes other than through the water soluble fraction (i.e., sediment uptake, or uptake of contaminated food). Thus the PAH compounds are both acute toxicants and carcinogens depending on molecular size.

5. Summary of Interpretation of Findings

The PCB, coprostanol, and PAH data sets along with the TOC measurements represent a highly useful set of geochemical data with which to assess pollutant inputs to marine sediments. Although the stations are widely separated several important trends are noted in the data.

There appears to be a strong direct relationship between TOC and TKN levels which is revealed in the TOC/TKN ratio in

TABLE 4-16

SOURCES OF PNAH COMPOUNDS OBSERVED IN STUDY AREA SEDIMENTS

STATION	PERCENT PETROLEUM PNAH ^a	
	1981	1982
3	0	0
9	0	0
16B	50	35
22	0	0
33	6	7
34	5	5
36	2	4
37	4	8

^aThat percentage of total PNAH ascribed to petroleum rather than to other (e.g., fossil fuel combustion particulates) PNAH inputs:

$$= \frac{\Sigma \text{naphthalenes} + \Sigma \text{dibenzothiophenes} + 1/2 \Sigma \text{phenanthrenes}}{\Sigma \text{PNAH}} \times 100$$

TABLE 4-17

RELATIVE CARCINOGENICITY OF PAH TO LABORATORY MAMMALS

COMPOUND	CARCINO- GENICITY ^a	COMPOUND	CARCINO- GENICITY ^a
Anthracene	-	Aceanthrylene	-
Phenanthrene	-	Benz(j)aceanthrylene = cholanthrene	++
Benz(a)anthracene	+	3-Methycholanthrene	++++
7,12-Dimethylbenz(a)- anthracene	++++	Naphtacene	-
Dibenz(aj)anthracene	+	Pyrene	-
Dibenz(ah)anthracene	+++	Benzo(a)pyrene	+++
Dibenz(ac)anthracene	+	Benzo(e)pyrene	-
Benzo(a)phenanthrene	+++	Dibenzo(al)pyrene	<u>+</u>
Fluorene	-	Dibenzo(ah)pyrene	+++
Benzo(a)fluorene	-	Dibenzo(ah)pyrene	+++
Benzo(b)fluorene	-	Dibenzo(cd,jk)pyrene	-
Benzo(c)fluorene	-	Indeno(1,2,3-cd)pyrene	+
Dibenzo(ag)fluorene	+	Chrysene	<u>+</u>
Dibenzo(ah)fluorene	<u>+</u>	Dibenzo(b,def)chrysene	++
Dibenzo(ac)fluorene	<u>+</u>	Dibenzo(def,p)chrysene	+
Fluoranthene	-	Dibenzo(def,mno)chrysene = anthanthrene	-
Benzo(b)fluoranthene	++	Perylene	-
Benzo(j)fluoranthene	++	Benzo(ghi)perylene	-
Benzo(k)fluoranthene	-	Coronene	-
Benzo(mno)fluoranthene	-		

^a - not carcinogenic

+ uncertain or weakly carcinogenic

+ carcinogenic

++, +++, ++++ strongly carcinogenic.

Source: NAS, 1972.

Tables 4-1 through 4-3. Terrigenous organic matter tends to have high values (>10). TOC/TKN ratios decrease with distance from shore or from anthropogenic input reflecting inputs of marine TKN material. Thus it can be seen from the tables that there is a gradation in this ratio with high values (>10) indicative of terrigenous and anthropogenic inputs characteristic of the impacted stations of New York Bight, Massachusetts Bay, Buzzards Bay, and the depositional areas south of Nantucket and in the Gulf of Maine.

As increased TOC/TKN ratios are indicative of direct dumping or of silt/clay depositions, it is not surprising to find highest PCB, coprostanol and PAH levels at those stations with highest silt/clay content (33, 16B, 37, 36, 35). Of particular importance are the parameter ratios of coprostanol/total steroids, coprostanol/PCB, and PCB/TOC which indicate several important facts. The PCB at stations 35, 36, 37, and 16B are more abundant than if they were "normally" deposited by geochemical mechanisms, thus implying local inputs of contaminants. These observations are consistent with our knowledge of inputs of contaminants to urbanized regions (Stations 16B, 33, 36, 35) but are quite new for the offshore depositional areas (e.g., Station 37). Presumably other offshore depositional areas having high TOC or silt/clay contents (e.g., Stations 28, 20) would reflect these elevated PCB levels as well.

The source of PCB is nicely revealed in the coprostanol to PCB ratio (Table 4-10). At Station 3, although levels of PCB and coprostanol are low, this ratio (100-150) indicates that most of the PCB is sewage related. Similarly, elevated ratios at Stations 9 and 22 reveal low level sewage impacts, not obvious through single parameter (e.g., PCB alone) measurements. In contrast, elevated levels in Buzzards Bay (36) are shown not to be related to sewage but to industrial inputs.

Similar trends are revealed in the PAH data, with those sediments of higher silt/clay content higher in PAH. However, while most of the PAH material in the offshore samples and in the Massachusetts and Buzzards Bay samples is closely related to combustion sources (urban air fallout and runoff), the New York Bight samples are heavily laden with petroleum aromatics. If it is assumed that naphthalenes, dibenzothiophenes and one half of the total phenanthrenes less phenanthrene itself are from petroleum, while the other PAH constituents are combustion related, then about 40% of PAH in New York Bight (16B) sediments are from petroleum. This decreases to ~10% further offshore (33). In contrast, less than 10% of offshore PAH, and ~10% of PNAH in the bays are due to petroleum-type inputs. Note that in the 1980 survey only about 20% of the PAH at Station 16B was petroleum related. Trends in PCB and PAH data indicate that their distributions, although related to the fineness of the sediment, are decoupled, indicating differing sources for these two compound classes.

Statistical differences in PCB and coprostanol levels are noted for several of the stations (16B, 36) which may be attributable to increases in pollutant levels. The significant within-station variability suggests that the analysis of sample replicates is crucial in being able to compare pollutant changes with time.

Thus combinations of TOC, TKN, GSD, and organic parameter measurements provide powerful quantitative and compositional tools for monitoring pollutant histories and changes in offshore benthic environments.

6. Inventory of Data Acquired

Table 6-1 presents a list of those samples analyzed and the nature of the analyses performed on each sample. The location of the sampling stations is shown in Figure 3-1.

7. Statement of Problems

No significant problems have been encountered on this project.

8. Data Appendices

TOC and TKN data for individual replicates are presented in Table A-1. PCB and coprostanol replicate data are presented in Table A-2. GSD data for replicates at each station are found in Tables A-3 through A-34.

TABLE 6-1

SUMMARY OF SEDIMENT SAMPLE SETS ANALYZED (1981-1982)

STATION	TOC	TKN	GS	PCB	PAH	COPROSTANOL
2 ^a	X	X	X			
3	X	X	X	X	X	X
7	X	X	X			
8	X	X	X			
9	X	X	X	X	X	X
11	X	X	X			
12	X	X	X			
13	X	X	X			
15A	X	X	X			
16A	X	X	X			
16B	X	X	X	X	X	X
16C	X	X	X			
17	X	X	X			
18	X	X	X			
19	X	X	X			
20	X	X	X			
21	X	X	X			
22	X	X	X	X	X	X
23	X	X	X			
24	X	X	X			
28	X	X	X			
31 ^b	X	X	X			
32 ^b	X	X	X			
33	X	X	X	X	X	X
34	X	X	X			
35	X	X	X	X	X	X
36	X	X	X	X	X	X
37	X	X	X	X	X	X
38 ^a	X	X	X			
DWD 106 ^{c,a}	X	X	X			

^a1982 set only.

^bAdditional set from November 1981 analyzed.

^cTen samples analyzed from 6 stations within the site.

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APPENDIX A

TABLE A-1

TKN AND TOC RESULTS

SAMPLE ^a (STATION-REPLICATE)	TKN (µg/g dry)		TOC (mg/g dry)	
	AL81-07	AL82-01	AL81-07	AL82-01
2-1	NA	<30	NA	0.5
2-2	NA	68	NA	0.38
2-3	NA	72	NA	0.56
2-4	NA	47	NA	0.48
2-5	NA	120	NA	0.45
3-1	105	76	3.8	0.58
3-2	284	38	0.91	0.52
3-3	365	85	2.05	0.58
3-4	378	62	2.14	0.62
3-5	243	71	2.46	0.77
7-1	247	137	1.93	0.47
7-2	36	146	1.57	0.64
7-3	156/150	89	0.96	0.48
7-4	143	68	1.27	0.70
7-5	79	67	1.14	0.52
8-1	129	64	2.68	0.30
8-2	106	33	0.44	0.54
8-3	126	52	1.42	0.54
8-4	100	77	0.30	0.74
8-5	88	81	0.24	0.70
9-1	208	286	1.21	0.96
9-2	156	275	1.06	1.73
9-3	325	179	2.13	1.58
9-4	247	165/165	1.78	1.56
9-5	312	96	3.62	1.28
11-1	224	172	2.27	1.20
11-2	263	135	1.96	1.28
11-3	211	135	1.83	1.00
11-4	171	148	1.61	1.52
11-5	158	184	1.75	1.40
12-1	263	147	0.50	1.20
12-2	250	144	1.72	1.12
12-3	84	205	0.25	0.96
12-4	211	100	2.13	1.14
12-5	250	453	2.48	1.20

^aNote that results for a particular individual replicate should not be compared from one season to another. It is only valid to compare mean of replicates from a particular station from one season to the other mean of replicates from that season or to compare station means from two seasons.

TABLE A-1 (CONT.)

SAMPLE ^a (STATION-REPLICATE)	TKN ($\mu\text{g/g}$ dry)		TOC (mg/g dry)	
	AL81-07	AL82-01	AL81-07	AL82-01
13-1*	119	290	1.34	1.40
13-2	84	311	2.27	1.28
13-3	203	616	1.16	1.19
13-4	-	321	-	0.84
13-5	-	222	-	1.20
15A-1*	174	46	0.75	0.67
15A-2	118	41	0.60	0.68
15A-3	140	62	0.94	0.70
15A-4	164	56	0.67	0.51
15A-5	88	88	0.68	0.49
16A-1*	289	240	5.75	6.65
16A-2	33	116	4.47	4.95
16A-3	197	85	2.44	5.60
16A-4	237	132	1.83	3.40
16A-5	158	187	3.69	5.20
16B-1*	942	447	28.7	10.4
16B-2	1,014	567	19.5	12.9
16B-3	1,100	2,044	20.3	15.3
16B-4	1,110	1,000	28.5	49.0
16B-5	843	965	20.6	39.0
16C-1*	33	149	0.39	6.20
16C-2	158	277	1.36	4.40
16C-3	89	755	1.34	5.40
16C-4	108	400	1.28	7.60
16C-5	36	424	0.65	6.40
17-1*	95	65/65	1.31	0.29
17-2	94	54	1.22	0.58
17-3	84	60	1.56	0.82
17-4	<25	54	0.63	0.41
17-1	43	61	1.16	0.53
18-1	314	290	2.89	9.00
18-2	729	311	5.48	8.40
18-3	614	616	3.74	7.50
18-4	614	321	5.12	5.80
18-5	843	222	6.20	4.00
19-1	493	433	5.04	3.10
19-2	275	604	3.68	2.60
19-3	580	88	3.36	3.75
19-4	418	411	3.03	3.60
19-5	418	194/196	3.29	2.90

*These stations from Cruise 81-09.

TABLE A-1 (CONT.)

SAMPLE ^a (STATION-REPLICATE)	TKN ($\mu\text{g/g}$ dry)		TOC (mg/g dry)	
	AL81-07	AL82-01	AL81-07	AL82-01
20-1	1830/1808	914	14.4	5.30
20-2	1,255	1,014	11.2	18.3
20-3	1,809	1,330	13.2	13.5
20-4	2,104	1,230	15.5	19.1
20-5	1,426	625	17.2	13.2
21-1	286	NA	1.47	NA
21-2	121	NA	1.76	NA
21-3	<20	NA	0.63	NA
21-4	45	NA	0.23	NA
21-1	169	NA	0.27	NA
22-1	366	155	1.22	1.31
22-2	394	243/270	1.55	1.04
22-3	423	162	2.47	2.35
22-4	394	107	2.48	1.17
22-5	535	107	1.83	0.74
23-1	143	123	1.48	0.64
23-2	34	154	2.03	0.88
23-3	208	204	1.19	0.80
23-4	247	213	1.09	0.58
23-5	273	131	1.49	0.60
24-1	169	21	0.01	0.39
24-2	44	39	0.92	0.86
24-3	57	37	0.45	0.89
24-4	62	30	0.01	2.15
24-5	75	32	0.45	0.57
25-1	810	NA	12.1	NA
25-2	902	NA	15.5	NA
25-3	610	NA	12.2	NA
25-4	1,190	NA	14.5	NA
25-5	1,310	NA	14.6	NA
28-1	NA	552	NA	12.0
28-2	NA	803	NA	10.0
28-3	NA	1,047	NA	12.1
28-4	NA	990	NA	9.80
28-5	NA	1,199	NA	12.0
31-1	240	925	2.65	9.40
31-2	195	1,041	1.26	18.6
31-3	169	164	0.82	17.2
31-4	195	1,172/1425	0.81	9.6
31-5	230	414	2.66	8.8

TABLE A-1 (CONT.)

SAMPLE ^a (STATION-REPLICATE)	TKN ($\mu\text{g/g}$ dry)		TOC (mg/g dry)	
	AL81-09	AL82-01	AL81-07	AL82-01
31(60-1)*	NA	285	NA	7.80
31(60-2)	NA	365	NA	4.30
31(60-3)	NA	369	NA	8.40
31(60-4)	NA	431	NA	8.15
31(60-5)	NA	292/257	NA	5.65
32-1	117	22	1.90	0.98
32-2	158	28	2.23	0.63
32-3	103	52	0.61	0.62
32-4	130	36	0.83	0.44
32-5	-	36	-	0.54
32(61-1)*	NA	36	NA	5.00
32(61-2)	NA	38	NA	5.40
32(61-3)	NA	30	NA	4.60
32(61-4)	NA	37	NA	10.0
32(61-5)	NA	<27	NA	7.80
33-1	110/110	388	NA	10.8
33-2	NA	413	NA	6.95
33-3	NA	191	NA	10.4
33-4	NA	682	NA	8.10
33-5	NA	577	NA	6.00
34-1	692	295	5.27	6.40
34-2	1,423	508	7.16	5.90
34-3	231	893	8.02	8.60
34-4	1,173	779	9.16	12.0
34-5	123	914	5.92	5.90
35-1	379	753	3.21	5.45
35-2	103	504	5.19	4.98
35-3	466	670	2.81	6.40
35-4	466	812/805	4.08	6.22
35-5	293	432	4.78	3.65
36-1	1,100	1,190	9.41	8.20
36-2	1,160	1,000	15.6	6.85
36-3	343	1,400	14.5	6.40
36-4	986	1,420	12.5	6.20
36-5	709	806	13.6	8.35

NA - not analyzed

*Samples are from 18 Nov 1981 (not 81-09 cruise).

TABLE A-1 (CONT.)

SAMPLE ^a (STATION-REPLICATE)	TKN ($\mu\text{g/g}$ dry)		TOC (mg/g dry)	
	AL81-09	AL82-01	AL81-07	AL82-01
37-1	667	653	7.80	6.40
37-2	122	968	9.30	-
37-3	413	798	7.10	7.60
37-4	857	668	7.00	6.55
37-5	540	636	10.4	7.55
38-1	NA	33	NA	0.55
38-2	NA	42	NA	0.59
38-3	NA	50	NA	0.58
38-4	NA	47	NA	0.83
38-5	NA	81	NA	1.00

SAMPLE	DATE	TKN ($\mu\text{g/g}$)	TOC (mg/g)
31 (12) 1 of 2*	7/11/80	304	12.9
31 (12) 2 of 2*	7/11/80	360/394	7.10
32 (18) 1 of 2*	7/9/82	568	11.5
32 (18) 2 of 2*	7/9/80	458	8.50
33 (15) 1 of 2*	7/9/80	377	11.0
33 (13) 2 of 2*	7/9/80	148	8.60
34 (14) 1 of 2*	7/10/80	241	8.50
35 (11) 1 of 1*	7/10/80	462	11.6
36 (19) 1 of 1*	7/8/80	945	12.0
36 (18) 2 of 2*	7/12/80	827	10.8

*All samples in this series taken from 106 dumpsite.
Cruise MI-RP-27-80.

TABLE A-2

PCB AND COPROSTANOL LEVELS IN SEDIMENTS

STATION- REPLICATE	PCB (ng/g)		COPROSTANOL (µg/g)	
	AL81-07	AL82-01	AL81-07	AL82-01
3-1	0.1	<.1	0.01	<.01
3-2	0.2	0.6	0.04	<.01
3-3	0.7	0.9	0.05	<.01
3-4	0.2	0.4	0.03	<.01
3-5	0.4	0.2	0.02	<.01
9-1	0.6	2.5	0.01	.02
9-2	0.4	1.6	0.01	.01
9-3	0.6	2.2	0.01	.01
9-4	0.4	0.8	0.01	.02
9-5	0.5	3.2	0.01	.01
16B-1	182	450	14.4	28.6
16B-2	124	300	13.6	22.6
16B-3	130	240	26.9	22.0
16B-4	93	275/300/430	18.7	23.4/28.2/29.6
16B-5	189	145/151/139	13.4	31.8/27.6/39.6
22-1	<0.1	0.4	0.02	.01
22-2	0.2	0.1	0.03	.01
22-3	0.7	<0.1	0.01	<.01
22-4	0.7	<0.1	0.03	.01
22-4	1.1	<0.1	0.04	<.01
33-1	9	5.5	0.05	.06
33-2	10	5.0	0.04	.07
33-3	11	0.1	0.06	.07
33-4	9	7.1	0.06	.11
33-5	5	9.8	0.07	.11
35-1	12	2.6	0.03	.04
35-2	4.0	7.7	0.04	.03
35-3	1.0	5.3	0.03	.02
35-4	7.0	9.4	0.04	.06
35-5	8.0	4.7	0.03	.05
36-1	8.0	32	0.04	.14
36-2	19	43	0.03	.18
36-3	15	50	0.06	.06
36-4	20	49	0.04	.12
36-5	2.0	48	0.01	.13
37-1	4.0	7.0	0.02	<.01
37-2	3.0	1.6	0.01	.03
37-3	3.0	0.6	0.02	.03
37-4	0.6	4.5	0.01	<.01
37-5	30	2.6	0.05	<.01

TABLE A-3
GRAIN SIZE DETERMINATION (WT %)
STATION 2

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2		0.74			
-1	0.55	0.61	0.66		
0	2.92	0.57	0.81	1.25	0.03
1	27.02	2.52	4.06	22.87	0.72
2	56.46	15.21	49.68	65.90	22.46
3	10.59	36.42	32.60	6.84	49.33
4	1.64	41.25	9.78	1.79	25.12
5					
6					
7	0.82	2.68	2.40	1.34	2.33
8					
9					
10					
>11					

TABLE A-4
GRAIN SIZE DETERMINATION (WT %)
STATION 3

AL81-07 REPLICATE NUMBER					
ø	1	2	3	4	5
-4					
-3					
-2		0.12		0.45	0.44
-1	0.52	1.18	0.62	1.48	0.68
0	1.48	0.59	0.65	1.89	0.72
1	2.36	1.65	2.44	4.58	1.90
2	22.47	6.36	49.74	15.29	15.12
3	63.93	62.64	35.83	58.25	62.24
4	4.51	19.56	3.21	16.73	11.40
5		2.79	4.30		2.65
6		2.48	2.65		2.35
7		1.03	0.54		0.98
8	4.75	0.85		1.32	0.91
9		0.75			0.61
10					
>11					

AL82-01 REPLICATE NUMBER					
ø	1	2	3	4	5
-4					
-3					
-2		0.46	0.14		
-1	0.11	0.11	0.12	0.16	0.30
0	0.05	0.57	0.28	0.48	0.45
1	0.38	0.98	2.01	1.04	1.34
2	22.75	16.25	51.53	18.88	9.93
3	71.82	74.80	42.06	71.47	83.98
4	2.89	5.32	1.61	4.73	3.77
5					
6					
7	2.00	1.50	2.25	3.23	0.24
8					
9					
10					
>11					

TABLE A-5

GRAIN SIZE DETERMINATION (WT %)
STATION 7

AL81-07 REPLICATE NUMBER					
ϕ	1	2	3	4	5
-6					
-5	1.52				
-4	-				
-3	-			0.20	
-2	0.28		0.33	0.06	0.06
-1	0.32	0.20	1.20	0.62	0.95
0	1.76	0.42	2.65	1.54	0.61
1	37.93	1.54	24.47	23.01	8.32
2	52.93	85.40	60.35	58.74	78.34
3	4.68	10.93	10.20	13.77	11.36
4	0.42	1.41	0.52	0.76	0.68
5	] 0.15	] 0.10	] 0.27	] 1.30	] 0.18
6					
7					
8					
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
ϕ	1	2	3	4	5
0					
-4					
-3					
-2				0.99	0.19
-1			0.99	0.02	0.35
0	0.44	0.13	0.18	0.56	0.73
1	0.76	0.88	0.86	14.48	24.69
2	79.53	64.16	26.37	72.85	65.89
3	16.53	32.88	60.45	8.36	6.72
4	1.35	0.63	0.60	1.95	0.31
5	] 1.38	] 1.31	] 1.46	] 0.80	] 1.11
6					
7					
8					
9					
10					
>11					

TABLE A-6

GRAIN SIZE DETERMINATION (WT %)
STATION 8

AL81-07 REPLICATE NUMBER					
ϕ	1	2	3	4	5
-6		4.10			4.11
-5		-			2.01
-4		-			-
-3		-			-
-2		0.46	0.12	0.29	0.16
-1	1.95	2.35	1.66	2.62	2.51
0	6.04	6.88	7.74	10.28	9.00
1	49.57	43.91	49.97	66.38	43.27
2	36.86	35.41	35.33	16.04	29.29
3	4.73	6.24	4.77	4.05	9.18
4	0.53	0.40	0.29	0.07	0.21
5	] -0.31	] -0.23	] -0.12	] -0.26	] -0.25
6					
7					
8					
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
ϕ	1	2	3	4	5
-4					
-3					
-2	0.78	0.23	0.64	0.25	0.40
-1	3.34	1.49	1.61	3.10	2.90
0	11.80	4.23	4.22	5.78	7.33
1	29.07	23.16	44.76	30.70	29.65
2	47.36	62.60	44.05	48.51	46.71
3	4.96	6.06	2.68	10.28	11.50
4	0.64	0.62	0.19	0.23	0.21
5	] -2.05	] -1.59	] -1.85	] -1.05	] -1.30
6					
7					
8					
9					
10					
>11					

TABLE A-7
GRAIN SIZE DETERMINATION (WT %)
STATION 9

AL81-07 REPLICATE NUMBER					
ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2	10.02	0.66	0.45	6.05	0.04
-1	4.87	0.61	1.43	0.15	0.14
0	4.35	1.39	2.21	1.18	0.96
1	15.03	19.79	18.04	16.04	14.04
2	27.84	45.40	42.66	37.27	46.48
3	18.35	15.65	19.05	24.03	25.43
4	1.20	1.45	1.38	1.73	0.82
5	6.73	4.79	7.82	5.78	6.72
6	8.29	3.86	3.92	5.22	0.85
7	2.13	3.47	2.87	2.66	4.14
8	1.16	2.91	0.17		0.38
9	0.04	0.02			
10					
>11					

AL82-01 REPLICATE NUMBER					
ø	1	2	3	4	5
-4					
-3					
-2	7.36	4.79	2.40	1.24	3.82
-1	4.39	6.92	27.51	2.86	2.02
0	7.25	8.57	1.67	2.73	1.91
1	17.21	20.61	8.01	11.21	13.38
2	32.83	19.31	21.54	40.02	33.40
3	27.6	34.79	35.64	35.21	38.12
4	1.06	1.50	1.22	5.00	4.84
5					
6					
7					
8	] -2.73	] -3.51	] -2.02	] -1.73	] -2.51
9					
10					
>11					

TABLE A-8

GRAIN SIZE DETERMINATION (WT %)
STATION 11

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3	1.30				
-2	-	0.77		0.17	
-1	0.59	0.80	0.04	0.29	0.35
0	0.39	0.70	0.50	0.23	0.63
1	0.36	0.66	1.22	0.87	0.91
2	15.53	12.46	37.89	17.83	7.71
3	78.26	75.09	57.80	76.62	86.42
4	1.22	1.89	1.22	1.22	2.45
5	]	5.23]]]
6	]	2.34]]]
7	]	0.07]]]
8	] 1.85		] 1.32	] 2.75	] 1.52
9]]]]
10]]]]
>11]]]]

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2	0.32	0.47		0.21	1.22
-1	0.24	0.74	0.13	0.14	1.22
0	0.81	0.97	0.07	0.28	1.71
1	0.97	1.81	1.05	1.09	1.95
2	21.45	30.96	35.54	18.22	5.85
3	70.33	61.48	59.50	75.19	77.32
4	3.88	2.08	2.29	2.58	8.05
5]]]]]
6]]]]]
7]]]]]
8	] 1.99	] 1.50	] 1.43	] 2.28	] 2.68
9]]]]]
10]]]]]
>11]]]]]

TABLE A-9
GRAIN SIZE DETERMINATION (WT %)
STATION 12

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4				2.70	0.96
-3				-	-
-2	2.87	0.43	4.27	3.10	0.84
-1	3.89	3.05	4.66	1.83	1.70
0	5.70	2.85	2.71	2.30	3.43
1	43.94	14.01	31.09	14.81	30.38
2	36.86	69.66	49.92	53.42	44.21
3	5.64	8.67	6.15	21.09	13.34
4	0.97	1.17	1.05	0.60	1.31
5					
6					
7					
8	] 0.14	] 0.16	] 0.16	] 0.16	] 3.83
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2	0.77	0.27	2.05	3.95	0.07
-1	1.13	1.67	1.47	0.97	1.45
0	1.72	3.06	3.26	1.73	1.49
1	8.37	8.38	6.92	4.93	5.73
2	52.28	46.33	55.56	46.53	53.57
3	31.15	35.20	27.86	39.52	34.10
4	0.24	0.59		0.11	0.52
5					
6					
7					
8	] 4.34	] 4.49	] 2.87	] 2.25	] 3.06
9					
10					
>11					

TABLE A-10

GRAIN SIZE DETERMINATION (WT %)
STATION 13

AL81-09 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5	5.03	25.07	7.12		
-4	-	-	-		
-3	-	-	1.03		
-2	1.02	0.37	2.24		
-1	2.10	1.56	2.97		
0	2.30	2.54	2.61		
1	11.86	6.82	9.16		
2	58.74	34.33	48.54		
3	10.44	20.39	20.13		
4	0.74	1.93	1.32		
5	4.14	1.30			
6	3.07	2.64			
7	0.56	1.05			
8		1.01			
9		0.63			
10		0.11			
>11		0.25			

} 4.88

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2	0.52	2.47	0.77	0.43	0.08
-1	0.52	1.01	0.23	1.84	1.66
0	1.82	1.54	0.93	2.60	1.78
1	11.73	8.21	11.23	8.40	9.18
2	48.23	53.82	57.22	59.95	62.93
3	25.29	27.16	17.81	19.35	19.31
4	4.43	0.10	0.39	0.54	0.30
5	2.93	3.07	4.99	1.67	2.28
6	2.78	1.05	4.14	3.11	1.28
7	1.65	0.65	2.29	1.51	0.68
8	0.10	0.81		0.49	0.52
9		0.11		0.10	
10					
>11					

TABLE A-11

GRAIN SIZE DETERMINATION (WT %)
STATION 15A

AL81-09 REPLICATE NUMBER					
ϕ	1	2	3	4	5
-6					
-5	5.03	25.07	7.12		
-4	-	-	-		
-3	-	-	1.03		
-2	1.02	0.37	2.24		
-1	2.10	1.56	2.97		
0	2.30	2.54	2.61		
1	11.86	6.82	9.16		
2	58.74	34.33	48.54		
3	10.44	20.39	20.13		
4	0.74	1.93	1.32		
5	4.14	1.30			
6	3.07	2.64			
7	0.56	1.05			
8		1.01			
9		0.63			
10		0.11			
>11		0.25			

} 4.88

AL82-01 REPLICATE NUMBER					
ϕ	1	2	3	4	5
-4					
-3					
-2	0.52	2.47	0.77	0.43	0.08
-1	0.52	1.01	0.23	1.84	1.66
0	1.82	1.54	0.93	2.60	1.78
1	11.73	8.21	11.23	8.40	9.18
2	48.23	53.82	57.22	59.95	62.93
3	25.29	27.16	17.81	19.35	19.31
4	4.43	0.10	0.39	0.54	0.30
5	2.93	3.07	4.99	1.67	2.28
6	2.78	1.05	4.14	3.11	1.28
7	1.65	0.65	2.29	1.51	0.68
8	0.10	0.81		0.49	0.52
9		0.11		0.10	
10					
>11					

TABLE A-12

GRAIN SIZE DETERMINATION (WT %)
STATION 16A

AL81-09 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2	0.96	1.25		0.83	1.38
-1	1.09	0.72	0.50	0.55	1.68
0	1.50	1.06	1.48	1.10	3.62
1	26.38	8.63	14.02	13.20	47.79
2	57.99	65.14	71.32	72.64	37.85
3	8.40	19.00	11.02	10.02	5.37
4	1.23	1.70	0.95	0.82	0.84
5					
6					
7					
8	] 2.46	] 2.49	] 0.72	] 0.98	] 1.46
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2		0.04	0.54		
-1	0.14	0.63	0.37	0.19	0.11
0	0.13	.61	0.55	0.29	0.45
1	2.70	75.36	4.74	3.32	4.61
2	56.82	54.57	46.32	41.99	52.89
3	37.25	35.55	42.36	47.61	38.30
4	2.39	2.59	4.22	5.86	1.79
5					
6					
7	] 0.29	] 0.11	] 0.33	] 0.46	] 0.17
8					
9					
10	] 0.28	] 0.55	] 0.56	] 0.28	] 0.60
>11					

TABLE A-13

GRAIN SIZE DETERMINATION (WT %)
STATION 16B

AL81-09 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					1.73
-4					-
-3					2.60
-2					2.60
-1				2.46	0.63
0	4.12	3.38		0.90	1.06
1	3.05	1.91	3.99	2.35	5.97
2	17.17	3.50	2.90	5.30	34.04
3	48.14	52.66	51.27	49.62	31.43
4	11.04	19.94	25.91	14.81	8.46
5	7.01	6.93	6.63	4.63	6.52
6	6.14	9.39	6.86	11.31	4.96
7	2.72	0.52	2.28	2.54	
8	0.62	1.55	0.07	6.07	
9		0.23			
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1	0.10	0.19		0.23	0.47
0	0.71	0.87	1.38	0.77	1.19
1	1.90	2.93	3.80	2.48	2.29
2	2.90	5.05	5.84	6.96	9.58
3	51.02	43.56	13.40	34.29	35.43
4	35.19	33.32	47.04	42.47	23.26
5	3.40	4.27	11.00	5.45	5.49
6	0.69	1.75	8.61	4.27	10.97
7	1.89	2.91	3.51	1.95	6.43
8	1.18	2.98	3.07	1.14	2.89
9	0.67	1.45	1.40		1.99
10	0.25	0.71	0.95		
>11	0.10				

TABLE A-14
GRAIN SIZE DETERMINATION (WT %)
STATION 16C

AL81-09 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3				0.58	
-2		0.38	0.46	4.00	
-1		0.64	0.99	12.19	0.48
0	1.09	1.23	3.67	27.13	0.70
1	13.65	9.13	41.86	31.05	4.30
2	60.67	75.32	43.22	11.43	69.38
3	22.17	12.53	8.61	12.14	23.34
4	2.37	0.77	0.33	1.28	1.60
5					
6					
7					
8	0.47	1.96	0.85	0.20	0.20
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2	0.51	0.73		3.05	
-1	0.92	3.23		0.62	0.11
0	1.24	3.01	0.75	1.20	0.45
1	5.74	5.65	2.05	3.54	2.68
2	27.25	9.98	9.89	6.78	19.73
3	44.16	25.61	47.68	42.18	56.22
4	8.55	5.72	13.53	20.09	9.33
5	2.31	4.93	7.92	3.57	4.75
6	3.35	18.18	11.16	3.34	3.92
7	2.45	13.15	4.38	2.34	1.68
8	2.20	6.03	2.64	1.79	1.13
9	1.01	3.01		0.78	
10	0.25	0.77		0.47	
>11	0.04			0.25	

TABLE A-15
GRAIN SIZE DETERMINATION (WT %)
STATION 17

AL81-09 REPLICATE NUMBER					
φ	1	2	3	4	5
-6					
-5					11.59
-4	0.55		1.54	0.78	-
-3	0.73	2.77	1.61	1.31	-
-2	2.52	10.18	6.90	4.35	1.29
-1	7.37	13.76	10.37	9.64	6.62
0	12.60	11.91	8.32	9.08	9.00
1	48.65	37.89	39.16	43.10	32.05
2	23.34	19.93	28.64	28.11	36.50
3	2.81	3.05	3.37	3.51	2.91
4	0.92	0.36	-	-	-
5					
6					
7					
8	0.01	0.15	0.09	0.11	0.04
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
φ	1	2	3	4	5
-4					
-3					
-2	1.32	2.50		5.79	2.83
-1	4.31	2.11	0.20	0.20	1.93
0	10.92	5.28	1.79	7.02	4.97
1	33.04	24.24	21.43	27.15	22.43
2	43.50	53.43	61.18	45.19	56.26
3	5.54	10.99	14.11	7.16	9.47
4	0.22	0.51	0.53	0.16	0.47
5					
6					
7	0.12	0.47	0.16	0.73	0.20
8					
9					
10	1.04	0.47	0.60	0.60	0.94
>11					

TABLE A-16

GRAIN SIZE DETERMINATION (WT %)
STATION 18

AL81-09 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2				0.27	0.26
-1	0.87	1.09	0.79	0.81	0.39
0	2.62	1.09	1.39	1.35	1.32
1	9.28	1.57	2.24	2.03	5.03
2	7.09	31.95	4.72	20.29	4.95
3	51.96	42.07	50.51	53.67	51.96
4	8.77	3.44	19.08	2.84	20.33
5	10.61	3.52	10.57	9.84	6.03
6	7.30	9.48	3.88	5.11	6.27
7	1.49	2.86	2.76	3.79	1.88
8		2.03	3.53		1.09
9		0.89	0.51		
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1	0.59	0.60	0.49		0.47
0	2.84	5.55	2.28	1.79	2.13
1	4.25	12.30	5.54	5.77	4.02
2	8.04	8.93	8.96	8.79	4.37
3	50.70	41.65	52.78	47.13	35.46
4	13.24	12.30	10.59	15.11	17.38
5	11.51	10.04	12.04	7.28	20.00
6	6.39	6.51	4.26	7.06	0.93
7	2.26	1.58	1.64	3.91	9.48
8	0.19	0.55	1.43	3.15	5.77
9					
10					
>11					

TABLE A-17
GRAIN SIZE DETERMINATION (WT %)
STATION 19

AL81-09 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2		0.09			
-1	0.03	0.15	0.37		0.87
0	2.80	1.96	3.26	1.56	4.03
1	9.79	12.73	5.42	3.68	5.68
2	54.70	62.83	56.19	63.77	43.85
3	12.00	9.03	10.76	11.73	18.67
4	0.65	2.18	5.83	1.38	3.61
5	10.24	4.94	13.24	9.79	10.56
6	2.68	2.45	3.67	1.83	4.94
7	0.73	1.33	0.45	1.79	2.60
8	2.19	1.81	0.63	3.52	3.07
9	4.18	0.35	0.15	0.61	0.91
10		0.14	0.03	0.33	0.54
>11					0.49

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2			0.20		
-1	0.16	0.78	0.65	0.55	0.32
0	1.62	2.18	6.45	2.58	1.83
1	14.51	16.00	53.64	9.42	9.71
2	43.11	45.99	31.98	37.35	42.89
3	26.26	30.92	4.28	23.17	26.76
4	0.32	2.80	0.54	2.28	1.19
5	7.84			8.18	11.22
6	3.31			9.99	5.19
7	1.75	1.33	2.26	4.23	0.03
8	1.12			2.25	0.85
9					
10					
>11					

TABLE A-18

GRAIN SIZE DETERMINATION (WT %)
STATION 20

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					0.49
-3					-
-2	2.25				-
-1	0.29	0.26	0.23	0.53	-
0	0.40	0.86	0.67	0.61	0.78
1	1.12	1.90	1.51	1.32	1.89
2	3.18	5.81	4.18	5.75	3.24
3	3.28	6.04	4.28	6.14	4.61
4	6.87	6.53	6.29	5.27	6.09
5	21.42	33.05	32.82	28.76	22.55
6	32.28	31.90	30.26	37.86	38.86
7	19.41	3.56	17.86	13.76	21.89
8	9.50	9.57	1.90		0.40
9		0.48			
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2		1.93		0.77	0.23
-1	1.13	0.55	1.47	0.73	2.58
0	0.45	0.59	1.03	1.45	3.26
1	1.81	2.95	2.94	3.20	4.41
2	5.71	5.16	5.85	4.90	8.31
3	5.90	6.08	5.25	4.95	5.27
4	2.50	3.68	4.70	5.05	4.81
5	53.14	34.68	53.78	34.52	43.60
6	17.10	28.09	8.09	33.95	13.54
7	11.54	12.22	7.63	7.98	4.52
8	0.72	4.07	1.05	2.49	4.47
9			5.01		3.93
10			3.19		1.08
>11					

TABLE A-19
GRAIN SIZE DETERMINATION (WT %)
STATION 21

Ø	AL81-07 REPLICATE NUMBER				
	1	2	3	4	5
-6					
-5					
-4		19.95	21.03		3.38
-3	5.90	2.86	4.16		10.10
-2	5.36	0.50	2.82		11.00
-1	7.85	2.36	3.81	0.24	10.26
0	7.59	2.91	7.82	8.30	11.97
1	29.96	30.91	45.32	85.98	38.81
2	34.87	34.49	12.53	5.08	11.28
3	7.01	5.12	2.02	0.12	2.95
4	1.19	0.58	0.10	0.09	0.11
5					
6	] 0.27	] 0.32	] 0.40	] 0.19	] 0.13
7					
8					
9					
10					
>11					

No 1982 Samples analyzed

TABLE A-20

GRAIN SIZE DETERMINATION (WT %)
STATION 22

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2			6.04		
-1	0.45	0.57	8.64	0.30	2.52
0	1.20	0.36	3.66	0.61	1.60
1	1.84	1.43	3.55	0.81	1.92
2	3.38	2.96	10.38	1.92	4.72
3	72.93	75.09	55.37	58.35	66.13
4	14.45	14.73	6.39	32.38	17.21
5	1.07	] 4.37	1.28	1.36	1.53
6	2.35		2.61	1.81	2.38
7	1.52		0.83	1.29	0.96
8	0.42		0.54	1.04	0.67
9	0.39		0.58	0.16	0.37
10			0.13		
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-2					0.91
-1		0.48			0.84
0	0.49	0.72	0.58	0.97	0.56
1	1.13	1.53	1.23	1.95	1.27
2	9.25	13.24	13.21	18.55	5.02
3	50.73	66.51	50.43	51.20	66.92
4	29.78	11.99	27.09	22.86	17.11
5	2.38	1.08	1.23		1.21
6	2.84	2.30	2.50		2.33
7	1.77	1.45	1.28	4.47	1.69
8	0.96	0.21	1.11		1.00
9	0.63	0.15	0.78		0.77
10	0.03	0.33	0.54		0.38
>11					

TABLE A-21

GRAIN SIZE DETERMINATION (WT %)
STATION 23

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3				1.17	
-2	0.04			-	
-1	0.77			-	0.20
0	1.22	0.32	2.31	6.64	0.34
1	15.39	7.88	3.85	7.22	3.98
2	67.42	74.89	34.41	62.71	26.13
3	15.00	16.72	57.83	21.71	67.99
4	0.06	0.07	1.22	0.37	0.95
5]]]]]
6					
7					
8					
9					
10	0.10	0.12	0.40	0.17	0.41
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1	0.78		0.35		0.56
0	1.55	0.18	0.39	0.31	0.25
1	5.57	10.08	6.10	5.54	7.37
2	51.22	54.47	54.34	56.78	44.21
3	38.98	32.28	37.29	33.22	44.09
4	1.45	1.89	1.17	2.81	2.19
5]]]]]
6					
7					
8					
9					
10	0.35	1.09	0.35	1.34	1.33
>11					

TABLE A-22

GRAIN SIZE DETERMINATION (WT %)
STATION 24

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5	6.73				
-4	3.84			0.27	
-3	12.45			7.92	
-2	3.94			7.58	0.65
-1	1.88	2.75	1.84	14.22	2.22
0	1.78	2.17	3.72	11.31	38.56
1	17.80	13.69	40.44	19.55	54.26
2	46.30	77.06	51.51	37.06	3.45
3	4.85	2.75	1.41	1.62	0.28
4	0.37	0.69	0.52	0.29	0.43
5					
6					
7					
8	0.07	0.90	0.56	0.17	0.15
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3		5.67			3.56
-2	7.94	9.94	7.59	10.21	8.84
-1	13.03	7.76	13.23	12.29	11.22
0	9.64	3.45	15.83	5.07	5.42
1	33.50	9.61	24.85	6.74	7.91
2	34.27	61.44	37.20	63.55	60.43
3	1.19	1.93	1.66	1.74	2.26
4				0.35	
5					
6					
7					
8	0.43	0.20	0.14	0.06	0.36
9					
10					
>11					

TABLE A-23

GRAIN SIZE DETERMINATION (WT %)
STATION 28

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2		0.03			
-1	0.34	0.14	0.13	0.11	0.01
0	0.44	0.20	0.02	0.27	0.06
1	0.51	0.46	0.22	0.72	0.38
2	0.30	0.46	0.25	0.61	1.66
3	1.12	1.43	0.25	0.64	0.84
4	0.57	0.80	1.01	0.95	0.45
5	43.31	58.05	24.27	66.96	44.57
6	25.17	17.83	70.02	13.79	31.65
7	14.78	10.30	3.83	8.27	7.12
8	4.81	8.72		3.55	4.31
9	5.71	1.58			5.14
10	2.93				3.81
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1					
0	3.93	2.64	2.75	1.37	2.52
1					
2					
3					
4					
5	40.87	53.88	33.99	43.39	41.69
6	42.12	29.03	45.89	39.98	27.24
7	10.22	14.45	16.94	14.38	11.37
8	2.87		0.43	0.13	4.62
9				0.76	7.58
10					4.97
>11					

TABLE A-24

GRAIN SIZE DETERMINATION (WT %)
STATION 31

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					1.99
-3			0.49		-
-2	1.76	0.32	1.51	0.89	0.93
-1	0.48	2.03	4.00	2.65	1.60
0	9.53	10.72	13.90	11.78	8.34
1	22.90	50.01	48.47	57.97	42.19
2	30.22	26.28	23.53	21.55	31.74
3	17.57	3.65	3.02	2.38	3.86
4	10.20	0.78	1.23	0.59	1.01
5	2.65	0.96			3.34
6	3.34	2.23			2.14
7	0.24	1.10			0.16
8	0.91	0.49	3.36	2.19	2.71
9	0.13	1.08			
10	0.07	0.21			
>11		0.13			

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2	0.23	0.45	0.23	0.98	0.07
-1	4.05	3.77	1.98	7.49	1.75
0	7.13	10.33	10.79	5.57	12.75
1	31.41	35.57	62.82	8.23	30.96
2	31.95	24.58	16.70	10.40	32.31
3	6.97	6.44	2.66	8.18	5.24
4	2.22	3.05	1.67	4.57	2.22
5	8.64	4.57		25.79	5.94
6	5.40	7.17		18.04	4.39
7	1.58	2.17	3.15	8.49	2.51
8	0.42	1.01		1.98	0.86
9		1.19		0.28	0.97
10					
>11					

TABLE A-25
GRAIN SIZE DETERMINATION (WT %)
STATION 32

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					0.37
-3	0.35		4.37		0.77
-2	0.15		-	4.49	-
-1	2.84	2.27	3.99	7.21	9.50
0	4.78	6.78	16.83	20.85	18.48
1	37.73	60.58	45.12	43.65	52.53
2	15.28	26.66	25.16	20.08	15.22
3	38.88	3.71	3.68	2.20	1.72
4	-	-	-	-	-
5					
6					
7					
8	0	0	0.84	1.51	1.41
9					
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2	0.83	5.58	2.88	5.84	3.28
-1	3.73	6.81	6.10	10.54	7.55
0	23.54	10.92	8.81	13.48	15.61
1	64.66	52.60	45.12	57.17	56.99
2	4.90	17.77	31.00	10.97	14.21
3	0.58	2.28	3.50	0.86	1.19
4	0.44	0.53	1.24	0.35	0.57
5					
6					
7					
8	1.34	3.51	1.35	0.78	0.61
9					
10					
>11					

TABLE A-26

GRAIN SIZE DETERMINATION (WT %)
STATION 33

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1	.07	.22	.10	.10	.03
0	.25	.16	.13	.42	.17
1	1.47	.88	.75	1.06	.61
2	28.37	22.56	34.23	33.94	25.87
3	25.65	23.75	29.02	31.33	33.89
4	28.01	28.37	18.58	21.20	24.78
5	4.18	5.27	3.17	2.59	3.19
6	1.96	2.89	1.04	1.41	2.36
7	2.27	3.78	3.66	0.92	0.41
8	1.50	1.60	1.52	1.53	2.88
9	0.85	2.71	1.54	0.99	0.96
10	1.86	2.65	2.05	1.58	2.17
>11	3.58	5.16	4.70	2.92	2.68

TABLE A-27

GRAIN SIZE DETERMINATION (WT %)
STATION 34

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2					
-1	0.16	0.09	0.22	0.08	0.01
0	0.29	0.55	0.41	0.20	0.03
1	0.74	0.77	0.44	0.25	0.04
2	0.98	0.51	0.37	0.28	33.04
3	2.37	1.32	1.51	1.69	0.22
4	32.38	25.94	29.00	24.97	5.22
5	30.28	28.95	24.25	37.53	25.64
6	19.54	21.57	21.53	30.00	12.05
7	11.58	19.30	15.26	3.96	21.79
8	1.67	1.00	5.08	1.04	1.93
9			1.93		
10					
>11					

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1					
0	0.04		.02		
1	0.18	0.13	.09	.08	.10
2	0.72	0.41	.24	.23	.19
3	1.92	1.33	.25	.57	.48
4	38.67	40.40	39.89	33.07	30.74
5	26.75	20.70	23.22	27.89	22.98
6	8.50	11.78	9.20	12.84	12.57
7	5.77	4.00	6.25	5.13	8.42
8	4.89	6.13	6.88	7.45	7.96
9	2.58	3.24	1.79	2.67	3.91
10	1.72	2.10	3.31	.84	2.33
>11	8.26	9.79	8.86	9.23	10.33

TABLE A-28

GRAIN SIZE DETERMINATION (WT %)
STATION 35

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2		0.35	0.05	0.26	
-1	0.23	0.53	0.01	0.72	
0	0.87	0.18	0.67	1.06	2.27
1	1.52	1.93	1.19	1.79	3.89
2	1.52	3.22	1.97	4.21	5.44
3	8.27	23.33	15.16	17.58	14.31
4	46.69	48.59	52.41	33.29	42.86
5	20.01	9.48	12.13	14.99	20.62
6	12.41	9.70	6.57	25.09	3.76
7	2.85	1.59	3.08	1.01	0.99
8	5.63	1.10	1.26		4.02
9			1.26		1.84
10			2.22		
>11			2.02		

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1		0.21			
0	0.20	0.91	0.05	0.04	0.72
1	1.16	2.43	0.67	0.31	1.08
2	3.63	4.54	2.31	1.46	1.66
3	20.27	5.92	11.55	19.05	7.01
4	12.05	32.64	28.06	23.74	28.35
5	28.19	23.01	20.96	35.77	24.44
6	26.09	15.22	17.44	14.20	23.29
7	4.55	9.74	9.65	5.43	10.49
8	2.10	5.38	9.32		2.96
9	1.31				
10	0.44				
>11					

TABLE A-29
GRAIN SIZE DETERMINATION (WT %)
STATION 36

AL81-07 REPLICATE NUMBER					
Ø	1	2	3	4	5
-6					
-5					
-4					
-3					
-2	0.12	0.49		0.16	1.81
-1	0.52	0.83		0.39	0.73
0	0.68	0.69	0.65	0.95	1.87
1	0.55	0.99	4.21	4.89	19.47
2	0.46	11.56	7.77	8.32	31.67
3	1.20	8.35	11.67	18.50	21.66
4	8.13	1.24	16.29	16.30	6.05
5	39.40	51.72	24.00	18.79	7.99
6	18.15	23.03	21.95	10.34	3.44
7	15.34	1.10	12.03	8.21	1.52
8	7.46		1.43	2.97	1.80
9	6.61			5.10	4.88
10	1.27			3.27	2.05
>11	0.11			1.81	

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					
-1				0.05	
0		0.12	0.06	0.00	
1	0.19	0.36	0.43	0.22	0.20
2	0.32	0.72	0.55	0.55	0.59
3	2.48	3.54	5.17	5.44	8.07
4	9.41	9.46	12.43	14.56	13.29
5	37.68	63.53	44.81	49.19	57.21
6	29.23	22.26	29.80	28.74	19.59
7	13.18		5.44	1.25	1.05
8	7.51		1.31		
9					
10					
>11					

TABLE A-30

GRAIN SIZE DETERMINATION (WT %)
STATION 37

AL81-07 REPLICATE NUMBER					
φ	1	2	3	4	5
-6					
-5					
-4					
-3					
-2	0.40		0.19		
-1	0.34	0.42	0.62	0.50	
0	0.40	0.71	0.80	0.94	
1	0.50	1.10	1.14	1.38	1.06
2	0.80	1.66	6.24	1.05	1.28
3	10.41	8.42	24.88	25.49	39.21
4	45.12	47.52	22.05	31.38	19.01
5	18.16	16.26	18.58	18.88	22.68
6	11.57	17.74	11.14	20.38	16.75
7	12.30	4.31	2.23		
8	17.74	1.20	3.53		
9	1.20	0.64	4.99		
10			3.61		
>11					

AL82-01 REPLICATE NUMBER					
φ	1	2	3	4	5
-4					
-3					
-2					
-1					
0		.01			.01
1	.03	.04	.06	.05	.04
2	.08	.07	.12	.08	.10
3	.45	3.05	3.49	0.69	.53
4	56.34	55.46	58.19	51.17	54.12
5	13.58	12.08	12.98	16.39	17.20
6	6.67	7.90	5.83	6.19	7.87
7	7.35	6.90	6.19	4.95	4.47
8	2.89	4.48	0.30	5.15	3.17
9	3.17	2.68	2.40	4.91	2.46
10	5.56	3.14	7.67	5.16	7.28
>11	3.87	4.97	2.78	5.25	2.74

TABLE A-31

GRAIN SIZE DETERMINATION (WT. %)
STATION 38

AL82-01 REPLICATE NUMBER					
Ø	1	2	3	4	5
-4					
-3					
-2					3.50
-1	0.33	0.18	0.05	0.24	1.45
0	7.69	5.84	4.32	2.21	9.66
1	35.85	37.84	34.77	30.79	33.64
2	51.54	51.97	56.20	62.00	49.09
3	3.58	3.36	3.84	4.02	2.04
4	0.48	0.44	0.57	0.56	0.62
5]]]]]
6]]]]]
7	]- 0.20	]- 0.10	]- 0.21	]- 0.18	]- 0
8]]]]]
9]]]]]
10	]- 0.34	]- 0.27	]- 0.04		
>11]]]		

TABLE A-32

GRAIN SIZE DETERMINATION (WT %)
STATION 60
(NEMP 31; Nov. 1981)

ϕ	REPLICATE NUMBER				
	1	2	3	4	5
-4					
-3					
-2	1.23	1.59	.62	1.43	1.52
-1	4.78	6.26	4.75	8.20	8.21
0	18.86	15.82	9.62	10.33	19.74
1	28.66	23.91	23.58	24.36	26.08
2	34.18	34.22	40.84	38.54	30.87
3	5.10	6.58	10.10	8.08	5.89
4	2.17	4.59	4.09	4.09	3.67
5	0.86	1.12	1.02	.81	.69
6	.21	.47	.51	.41	.31
7	.40	.56	.21	.27	.34
8	.96	1.24	1.19	.85	.66
9	.25	.34	.50	.27	.36
10	.37	1.03	.58	.44	.25
≥ 11	1.96	2.26	2.40	1.94	1.41

TABLE A-33

GRAIN SIZE DETERMINATION (WT %)
STATION 61
 (NEMP 32; Nov. 1981)

ϕ	REPLICATE NUMBER				
	1	2	3	4	5
-4					
-3					
-2	6.87	7.92	.56	.91	.25
-1	5.21	4.57	1.76	3.09	4.05
0	17.60	7.05	3.82	13.86	13.50
1	36.96	26.15	24.02	38.06	48.26
2	30.69	48.42	58.17	40.95	31.56
3	1.85	5.02	10.45	2.41	1.90
4	.17	.25	.46	.22	.07
5	] 0.17	] 0.18	] 0.14	] 0.51	] 0.42
6					
7					
8	] 0.48	] 0.44	] 0.62	] 0.51	] 0.42
9					
10					
≥11					

TABLE A-34

GRAIN SIZE DETERMINATION (DWD-106; MI-RP-27-80)

Ø	STATION NUMBER					
	31(12)	32(18)	33(15)	34(14)	35(11)	36(19)
-4						
-3						
-2						
-1						
0	.15	.09			.53	.29
1	1.93	.09			1.32	.29
2	10.85	2.71			2.64	.88
3	8.32	3.61	40.71		6.84	1.76
4	3.05	4.81	48.74	4.44	7.93	4.09
5	53.21	52.14	6.04	42.96	39.02	44.44
6	15.18	19.60	2.96	24.34	15.16	23.26
7	3.75	10.80	0.74	20.65	13.61	21.66
8	2.50	2.67	0.81	7.90	9.54	1.28
9	.89	1.87		0.21	3.37	1.44
10	.18	1.61				
>11						

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